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BECK

INTEGRATING EDUCATION WITH CONSUMER BEHAVIOUR RELEVANT TO ENERGY EFFICIENCY AND CLIMATE CHANGE AT THE UNIVERSITIES OF RUSSIA, SRI LANKA AND BANGLADESH

WP2 - TEACHING (LEARNING) MATERIALS: MULTI-CRITERIA OPTIMISATION AND DECISION SUPPORT SYSTEMS

VGTU

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Contents

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Chapter 1. Introduction to Intelligent Decision Support Systems

Abstract The first chapter presents definitions and descriptions of intelligent decision support systems (IDSSs) and analyzes the technology and AI methods, which serve as bases of the IDSS. Scholars have offered various definitions of IDSS. Every one of them accents that an intelligent decision support system is a DSS, which makes extensive use of artificial intelligence techniques. Artificial intelligence techniques can be utilized in all the components of IDSSs, such as in the data base, knowledge base, model base, user interface and the rest. Therefore this chapter deliberates the intelligent databases, hardware (sensors, iris camera hardware, hardware for fingerprint biometric identification, etc.) and computer human interfaces (gesture, intelligent user, motion tracking, voice and natural-language interfaces) in intelligent decision support systems.

1.1 Introduction

The first to offer a definition of an Intelligent decision support system was Holsapple (1977); Holsapple and Whinston 1987. The title of the dissertation by Holsapple (1977) was "Framework for a Generalized Intelligent Decision Support System". The development of Intelligent decision support systems (IDSSs), by this or by some other name, began from the early years of the 1990s (Jelassi 1986; Teng et al. 1988; Murphy and Stohr 1986; Slowinski and Stefanowski 1992; Pomerol et al. 1995; Matsatsinis and Siskos 1999). IDSS, which reflected an environment demanding increasingly more complicated and faster decision-making, continued improving over time and gained additional capabilities.

Currently IDSS provides decision support via text analytics and mining based DSSs; ambient intelligence and the internet of things-based DSSs; biometrics-based DSSs; recommender, advisory and expert systems, data mining, data analytics, neural networks, remote sensing and their integration with decision support systems and other IDSSs. These other IDSSs include GA-based DSS, fuzzy sets DSS, rough sets-based DSS, intelligent agent-assisted DSS, process mining integration to decision support, adaptive DSS, computer vision based DSS, sensory DSS and robotic DSS. The changes in the definitions of IDSS describe this transformation from its earliest days to the present time. These are provided in-brief next.

Turban and Watkins (1986) referred to decision support systems with inbuilt expert systems technology as intelligent decision support systems.

Intelligent Decision support systems are interactive computer-based systems that use data, expert knowledge and models for supporting DMs [decision-makers] in organisations to solve semi-structured problems by incorporating artificial intelligence techniques (Sarma 1994).

Intelligent DSSs (IDSSs), incorporating knowledge-based methodology, are designed to aid the decision-making process through a set of recommendations reflecting domain expertise (Wang 1997).

A typical IDSS consists of five main components, database system, model base system, knowledge-based system, user interface and kernel/inference engine (Matsatsinis and Siskos 1999).

IDSS is needed and is economically feasible for generic problems that require repetitive decisions. Intelligent decision support systems (DSSs) are interactive computer-based systems that use data, expert knowledge and models for supporting DMs in organizations to solve semi structured problems by incorporating artificial intelligence techniques (Turban and Aronson 2001).

Intelligent Decision support systems (DSSs) use expert systems technology to enhance the capabilities of decision makers (DMs) in understanding a decision problem and selecting a sound alternative. Because of the people-centred focus of such technologies, it is important not only to assess their technical aspects and overall performance but also to seek the views of potential users (Papamichail and French 2005).

Intelligent DSSs (IDSSs), incorporating knowledge-based methodology, are designed to aid the decision-making process through a set of recommendations reflecting domain expertise. IDSSs are able to provide services to users and they try to satisfy the user's requirements through interaction, cooperation, and negotiation. IDSSs also offer tremendous potential in support of well-defined tasks such as data conversion, information filtering, and data mining, as well as supporting ill-structured tasks in dynamic cooperation (Gao et al. 2007).

Intelligent decision support systems aim to provide decision makers with timely, useful and valid information based on some pre-coded domain knowledge (Burstein and Carlsson 2008).

IDSS add artificial intelligence functions to traditional DSS with the aim of guiding users through some of the decision making phases and tasks or supplying new capabilities. This notion has been applied in various ways (Phillips-Wren et al. 2009).

The term of intelligent decision support systems (IDSS) describes DSS that make extensive use of artificial intelligence (AI) techniques. Along with knowledge-based decision analysis models and methods, IDSS incorporate well databases, model bases and intellectual resources of individuals or groups to support effective decision making (Wan and Lei 2009).

Decision support systems (DSS), as a kind of interactive computer-based information systems, help decision makers utilize data and models to solve mostly semi-structured or un-structured decision problems in practice. Intelligent DSS, along with knowledge-based decision analysis models and methods, incorporate well databases, model bases and intellectual resources of individuals or groups to improve the quality of complex decisions. In the recent years, multi-criteria DSS, group DSS, and web-based customer recommender systems have had unimaginable developments and improvements in dealing with complex, uncertain, and un-structured decision problems under the support of computational intelligent technologies (Lu et al. 2010).

The term of intelligent decision support systems (IDSS) describes DSS that make extensive use of artificial intelligence (AI) techniques. Some research in AI, focused on enabling systems to respond to novelty and uncertainty in more flexible ways has been successfully used in IDSS. For example, data mining in AI that searches for hidden patterns in a database has been used in a range of decision support applications. The data mining process involves identifying an appropriate data set to mine or sift through to identify relations and rules for IDSS. Data mining tools include techniques like case-based reasoning, clustering analysis, classification, association rule mining, and data visualization. Data mining increases the “intelligence” of DSS and becomes an important component in designing IDSS (Yang et al. 2012).

Computational intelligence and knowledge-based methods, as well as new analytical intelligence techniques, have become necessary components in current advanced DSS. With the ever-increasing distributed decision situations and related computing systems, new web-based intelligent techniques such as semantic web, ontology, cloud computing, and service-oriented systems have been considered and applied today as key technologies for the development of a new generation of intelligent decision support systems (Zhang, Xu and Li 2012).

Quintero et al. (2005) analyze the relationship of a decision maker with IDSS. An IDSS, as its name implies, is used to support decision-making and is not intended to replace the decision maker. In fact, an intelligent decision support system works under the assumption that the decision maker is familiar with the problem to be solved and the data required for its solution. The IDSS itself simply supports the examination of alternatives. Hopefully, performance can be improved through a “what if” analysis since the computer-based IDSS speeds up such analysis and related calculations. The typical approach to decision-making follows these procedures: specify the objective or problem, obtain data, generate alternatives, evaluate alternatives, select an alternative, implement the selected alternative and obtain feedback on the implemented alternative. The IDSS bring together human judgment and computerized information providing support to decision makers primarily in the analysis of poorly or unstructured situations. The decision makers can either be an individual or a group, a useful capability to address multi-disciplinary problems (Quintero et al. 2005).

Text and data analytics, text, data and process mining, expert and advisory systems, neural networks, intelligent software agents, natural language processing, voice recognition, speech understanding, language translation, robotics and sensory systems, computer vision, fuzzy logic, rough sets, case based reasoning and genetic algorithms become important components in designing IDSS.

It is really quite complicated to analyze all these classes of IDSS in two chapters. Therefore only a brief analysis appears.

1.2 Development of Intelligent Decision Support Systems: Based on Artificial Intelligence Methods with Special Emphasis on Technology

Decision support systems (DSSs) need to “evolve” over time for many reasons, including changing user needs, technologies and problem understanding. There has been a limited amount of research on “evolution” of DSS, mostly aimed at individual characteristics or components of DSS. Those components include the technology on which the DSS is based, database (database schema and metadata), user interface, application and knowledge built into the system (O'Leary 2008). Phillips-Wren et al. (2009) and Turban et al. (2007) express similar thoughts about developing intelligent decision support systems, several of which are next presented.

Intelligent decision support system (IDSS) adds artificial intelligence (AI) functions to traditional DSS with the aim of guiding users through some of the decision making phases and tasks or supplying new capabilities. This notion has been applied in various ways. An IDSS has a data base, knowledge base, and model base, some or all of which will utilize AI methods (Phillips-Wren et al. 2009). Intelligent DSSs are support systems that contain some degree of human knowledge and intelligence in one or more components, such as in the interface, database, and model management components (Turban et al. 2007). The next presentations are on latest trend in developing IDSSs, a brief deliberation on the technology on which a DSS is based, user interface (see Section 1.3) and intelligent database (see Section 1.4).

AI technologies extend from the word technology which stems from the Greek word technos, which means "art" and "skill." A sophisticated technology is then a cumulative building of learned and well-refined skills and processes. In the AI area, these processes have manifested themselves in a number of well-recognized and maturing areas including Neural Networks, Expert Systems, Automatic Speech Recognition, Genetic Algorithms, Intelligent Agents, Natural Language Processing, Robotics, Logic Programming, and Fuzzy Logic (Saunders 2000). Decision support systems over time have become increasingly sophisticated, making use of models from a variety of disciplines ranging from artificial intelligence, operations research, and management science (Gupta et al. 2006).

DSS technology also has undergone substantial evolution over the years and will continue to do so. For example, a focus on decisions is likely first to be concerned with what has happened and structuring the problem. This may take any of several forms, including a database query, where the user tries to understand what the problem is and what is the source of the problem. As they begin to understand the nature of the problem, the system and what they do is likely to change. Once there is a strong concept as to what the problem is and what data is necessary to understand it, a second step is likely to focus on monitoring the particular problem area. Reports may be created as part of managing the problem area. Finally, in the third step, rather than just monitoring and reacting to problems, users are likely to want to anticipate problems, forecasting data to facilitate that prediction process (O'Leary

2008). Possibilities for completing the third step are described in this book. The second chapter presents text analytics and mining based DSS, integration of data analytics, data mining and DSSs. These chapter sections submit forecasting and prediction opportunities by applying the aforementioned technologies.

Further, the technology associated with DSS systems have gone from dumb terminals linked to main frames, to stand alone work stations and personal computers to locally networked computers to computers networked across the Internet. As emerging technologies, such as grid computing increase in importance, they may be integrated into our view of DSS. Further, this view can be extended beyond PCs to alternative technologies, such as mobile computing devices, including mobile phones. The next stage is likely to be an environment of wearable and embedded computing (O'Leary 2008). Furthermore it might be noticed that IDSSs are also being applied for other types of the most modern hardware. For example smart devices, sensors and such are being applied for ambient, Intelligence-based DSSs. Meanwhile various types of sensors, iris camera hardware, hardware for fingerprint biometric identification and other biometric hardware are being used in Biometrics-based DSSs. Various kinds of remote sensing hardware when integrating remote sensing into a DSSs.

DSS user interfaces have evolved over time. As DSS migrates to mobile computing environments, user interfaces will continue to evolve. For example, mobile computing environments, such as phones or other devices provide smaller screens and have different keyboard and other human computer interfaces (O'Leary 2008). Some examples of the latest types of computer human interfaces (gesture, intelligent user, motion tracking and voice and natural-language interfaces) are also provided in this book (see Section 1.3).

Researchers from different time periods have analyzed artificial intelligence approaches, concepts, techniques and division into “foundational” and “application” areas. This is analyzed next while focusing extra attention on AI methods on which a DSS is based.

Hopgood (2005) defines Artificial intelligence, as a concept of mimicking human intelligence in a computer. AI consists of many branches, such as, expert systems, artificial neural networks, genetic algorithms and fuzzy logic and various hybrid systems, which are combinations of two or more of the branches mentioned previously (Medsker 1996). In the opinion of Chrisley (2008), although the last half-century or so has seen the introduction of various new approaches to artificial intelligence, including connectionism/neural networks, dynamical systems engineering, embodied/situated robotics, and artificial life, the term “artificial intelligence” is often used more narrowly, to refer to approaches that emphasize symbolic computation (Chrisley 2008).

Turban et al. (2005) describe artificial intelligence concepts: Expert systems (Human knowledge stored on machine for use in problem-solving), Natural language processing (Allows a user to use native language instead of English), Speech recognition (Computer understanding a spoken language), Speech understanding Sensory systems (Vision, tactile and signal processing systems), Robotics (Sensory systems combine with programmable electromechanical device to perform manual labor), Vision and scene recognition (Computer intelligence applied to digital information from machine), Neural computing (Mathematical models simulating functional human brain), Intelligent computer-aided instruction (Machines used to tutor humans: Intelligent tutoring systems), Language translation (Programs that translate sentences from one language to another without human interaction), Computer vision and scene recognition, Fuzzy logic, Genetic algorithms (Computers simulate natural evolution to identify patterns in sets of data) and Intelligent agents (Computer programs that automatically conduct tasks).

The widely used term artificial intelligence refers, in the field of process engineering, to programs and systems that utilise intelligent implementation techniques, such as rule-based expert systems, fuzzy logic and neural networks, to extend the power of computers beyond the strictly mathematical and statistical functions (Järvensivu et al. 2001). Attonaty et al. (1999) present potential opportunities provided by the new techniques offered by artificial intelligence, such as automatic machine learning and multi-agent modeling. García-Cascales et al. (2007) analyze alternative techniques within artificial intelligence, such as fuzzy logic and soft computing, the possibility theory, distributed artificial intelligence (intelligent agents), neural networks, adaptive systems and many hybrid techniques (neuro-fuzzy networks, expert agents, etc.). For example, Şişman-Yılmaz et al. (2004) propose a temporal neuro-fuzzy system which is designed to provide an environment that keeps temporal relationships between the variables and to forecast the future behavior of data by using fuzzy rules. The system takes the multivariate data and the number of lags needed to construct the unfolded model in order to describe a variable and predicts the future behavior. Computer simulations are performed by using real multivariate data and a benchmark problem (Şişman-Yılmaz et al. 2004).

Artificial intelligence can be roughly divided into "foundational" and "application" areas. Foundational areas include knowledge representation, automated reasoning, probabilistic models, and machine learning. Application areas include planning, vision, robotics, speech, natural language processing, and multi-agent systems. An interface layer for AI must provide the former, and serve the latter (Domingos and Lowd 2009). Additionally fundamental (theoretical) Artificial Intelligence encompasses mathematical, logical, statistical, psychological, linguistic, cognitive, philosophical, biological and other aspects.

Artificial intelligence is applied in practice in numerous areas further described. Knowledge representation systems are an important component of many artificial intelligence applications, such as planners, robots, natural language processors, and game-playing systems (Doan et al. 2012). Artificial intelligence applications such as industrial robotics, military surveillance, and hazardous environment clean-up require situation understanding based on partial, uncertain, and ambiguous or erroneous evidence (Levitt 1986). McCarthy (2007) deliberates various AI applications (game playing, speech recognition, understanding natural language, computer vision, expert systems, heuristic classification, etc.). Chablo (1994) discusses the potential applications within telecommunications of the whole range of artificial intelligence technologies (i.e., expert systems, natural language understanding, speech recognition and understanding, machine translation, visual recognition and analysis, and robotics). Jothiprakash and Magar (2012) analyze applications of artificial intelligent in adaptive systems.

The typical issues for applying AI methods that other authors mention include pattern recognition (handwriting, speech and face recognitions), image processing, natural language processing, translation, artificial life, semantic web, remote sensing, robotics (behavior-based robotics, cognitive, cybernetics, evolutionary robotics), intelligent control, applied data mining, natural language processing, voice technology, artificial intuition, noisy text analytics, question answering and text mining.

Artificial intelligence - complete systems developed today, are commonly used for solving different artificial intelligence problems. A problem is a typical image recognition or speech recognition, but it can also be language processing, as well as, other complex systems dealing with general problem solving. However, no artificial intelligence-complete system, which models the human brain or behavior, can exist without looking at the totality of the whole situation and, and hence, incorporating an artificial intelligence-computerized sensory systems into a totality that constitute a combination of senses (Håkansson 2013).

DSS, IT, and AI can all be used to enhance knowledge management and its knowledge conversion processes: i.e., tacit to tacit knowledge sharing, tacit to explicit knowledge conversion, explicit knowledge leveraging, and explicit to tacit knowledge conversion. The purpose of including artificial intelligence is to amplify the cognitive capabilities of the decision maker in converting tacit knowledge into explicit knowledge, integrating this explicit knowledge by analyzing it to detect new patterns and relations, and understanding the new knowledge by providing analogs and explanations. AI technologies are often able to find important facts, patterns, relations and/or other types of new knowledge that would not have been found using standard analysis techniques such as regression analysis (Nemati et al. 2002).

1.3 Intelligent User Interface

First, definitions of intelligent user interfaces are presented in this section, and then some specific examples regarding their applications are described.

The term intelligent user interface describes a broad class of system types that apply artificial intelligence techniques to every aspect of human-system interaction (Wood et al. 2004). The term intelligent user interface typically implies the notion of dynamically enhancing the interaction with a single implemented artefact to suit different usage patterns, user groups, or contexts of use (Akoumianakis et al. 2000). Intelligent user interface is a subfield of Human-Computer Interaction. Term “intelligent user interface” is used to denote a particular type of interface as well as the research field. Other often mentioned synonyms are adaptive interfaces, multimodal interfaces, or intelligent interface technology. The first two are actually two subtypes of intelligent interfaces whereas the latter is used as a synonym for IUIs as a research field (Ehlert 2003). Intelligent user interfaces are human-machine interfaces that aim to improve the efficiency, effectiveness, and naturalness of human machine interaction by representing, reasoning, and acting on models of the user, domain, application, discourse, context, and media and device (Hartmann 2010).

Research in intelligent user interfaces focuses on interfaces that require intelligent techniques to bring them to fruition. These include natural language techniques in interfaces, example and programming based interfaces, personalization and recommender systems, learning approaches and Bayesian models for interfaces, multimodal input and output in interfaces, interfaces that are off the desktop, planning and reasoning in interfaces, new techniques for recognizing gestures and attention, interfaces for intelligent learning systems, interfaces and techniques for ubiquitous and affective computing and novel interfaces (Paris and Sidner 2007). The intelligent user interfaces of this type are described next.

Buyers in online auctions write feedback comments to the sellers from whom they have bought the items. Other bidders read them to determine which item to bid for (Hijikata et al. 2007). In this research, Hijikata et al. (2007) present the technique and its evaluation in a new interface for online auctions, looking at the ease of decision-making and the effectiveness of the interactive presentation of the summaries. First, Hijikata et al. (2007) examine feedback comments in online auctions. From the results of the examination, Hijikata et al. (2007) propose a method called social summarization method. It uses social relationships in online auctions for summarizing feedback comments. This method extracts feedback comments which the buyers seemed to have written from their heart. Hijikata et al. (2007) implement a system based on above method and evaluate its effectiveness.

Pu and Chen (2007) present design principles and algorithms for constructing interfaces to recommender systems to enhance trust into the systems' recommendations. Pu and Chen (2007) build a trust model for recommender agents with a focus on the agent's trustworthiness as derived from the user's perception of its competence and especially its ability to explain the recommended results. The new interface, called the organization interface where results are grouped according to their tradeoff properties, is shown to be significantly more effective in building user trust than the traditional approach. Users perceive it more capable and efficient in assisting them to make decisions, and they are more likely to return to the interface. Pu and Chen (2007) therefore recommend designers to build trust-inspiring interfaces due to their high likelihood to increase users' intention to save cognitive effort and the intention to return to the recommender system.

Context-aware interfaces use everything they can. This is particularly relevant to mobile phones. When you're using a phone, you're either in some "place" (café, restaurant, store) where you do rather specific activities, or you're moving between places. If the phone can figure out what that place is, it can also provide services that you want there, or that complement services that that place provides (e.g., song previews in a music store, comparison pricing in a supermarket, stats or replays at a baseball game). When you're between places, the phone can use other pieces of context to figure out what services to offer or it can wait for you to ask (Canny 2006).

Traditional human to computer communication is mostly limited to keyboards and pointing devices such as mice, touch pads, and track balls. This type of communication can be limiting to users since it does not enable them to realize their full expressive potential which normally also includes speech, facial expressions, and body gestures (Chaitanya 2013). Interfaces of this type are described next.

Sun and Chai (2007) investigate natural language processing, the role of discourse processing and its implication on query expansion for a sequence of questions. Sun and Chai (2007) view is that a question sequence is not random, but rather follows a coherent manner to serve some information goals. Therefore, this sequence of questions can be considered as a mini discourse with some characteristics of discourse cohesion. Understanding such a discourse will help question answering (QA) systems better interpret questions and retrieve answers. Thus, Sun and Chai (2007) examine three models driven by Centering Theory for discourse processing: a reference model that resolves pronoun references for each question, a forward model that makes use of the forward looking centers from previous questions, and a transition model that takes into account the transition state between adjacent questions. Sun and Chai (2007) provide a systematic evaluation of these models and discusses their potentials and limitations in processing coherent context questions (Sun and Chai 2007).

Conati and Merten (2007) describe research on using real-time eye-tracking data for on-line assessment of user meta-cognitive behavior during interaction with an environment for exploration-based learning. Conati and Merten (2007) contribute to user modeling and intelligent interfaces research by extending existing research on eye-tracking in HCI to on-line capturing of high-level user mental states for real-time interaction tailoring. Conati and Merten (2007) describe the empirical work done the user meta-cognitive behaviors to be modeled. Conati and Merten (2007) then illustrate the probabilistic user model designed to capture these behaviors with the help of on-line information on user attention patterns derived from eye-tracking data. Next, Conati and Merten (2007) describe the evaluation of this model, showing that gaze-tracking data can significantly improve model performance compared to lower level, time-based evidence. Finally, Conati and Merten (2007) discuss work they have done on using pupil dilation information, also gathered through eye-tracking data, to further improve model accuracy.

Kim et al. (2014) propose a wearable hybrid interface where eye movements and mental concentration directly influence the control of a quadcopter in three-dimensional space. This noninvasive and low-cost interface addresses limitations of previous work by supporting users to complete their complicated tasks in a constrained environment in which only visual feedback is provided. The combination of the two inputs augments the number of control commands to enable the flying robot to travel in eight different directions within the physical environment. Five human subjects participated in the experiments to test the feasibility of the hybrid interface. A front view camera on the hull of the quadcopter provided the only visual feedback to each remote subject on a laptop display. Based on the visual feedback, the subjects used the interface to navigate along pre-set target locations in the air. The flight performance was evaluated by comparing with a keyboard-based interface (Kim et al. 2014).

With the recent increase in the number of three-dimensional (3D) applications, the need for interfaces to these applications has increased. Although the eye tracking method has been widely used as an interaction interface for hand-disabled persons, this approach cannot be used for depth directional navigation (Lee et al. 2010). To solve this problem, Lee et al. (2010) propose a new brain computer interface (BCI) method in which the BCI and eye tracking are combined to analyze depth navigation, including selection and two-dimensional (2D) gaze direction, respectively. The proposed method is novel in the following five ways compared to previous works. First, a device to measure both the gaze direction and an electroencephalogram (EEG) pattern is proposed with the sensors needed to measure the EEG attached to a head-mounted eye tracking device. Second, the reliability of the BCI interface is verified by demonstrating that there is no difference between the real and the imaginary movements for the same work in terms of the EEG power spectrum. Third, depth control for the 3D interaction interface is implemented by an imaginary arm reaching movement. Fourth, a selection method is implemented by an imaginary hand grabbing movement. Finally, for the independent operation of gazing and the BCI, a mode selection method is proposed that measures a user's concentration by analyzing the pupil accommodation speed, which is not affected by the operation of gazing and the BCI.

Lieberman and Espinosa (2007) present Roadie, a user interface agent that provides intelligent context-sensitive help and assistance for a network of consumer devices. Using a commonsense database, the system maps user goals and device functionality. Thereafter, an artificial intelligence partial order planner provides two forms of aid to the user. It offers mixed-initiative help with executing multi-step procedures, and when something goes wrong, assistance in determining the source of the problem (Lieberman and Espinosa 2007).

In-vehicle music retrieval systems are becoming more and more popular. Previous studies have shown that they pose a real hazard to drivers when the interface is a tactile one which requires multiple entries and a combination of manual control and visual feedback. Voice interfaces exist as an alternative. Such interfaces can require either multiple or single conversational turns. In this study, each of 17 participants between the ages of 18 and 30 years old was asked to use three different music retrieval systems (one with a multiple entry touch interface, the iPod™, one with a multiple turn voice interface, interface B, and one with a single turn voice interface, interface C) while driving through a virtual world. Measures of secondary task performance, eye behavior, vehicle control, and workload were recorded. The multiple turn voice interface (B) significantly increased both the time it took drivers to complete the task and the workload (Garay-Vega et al. 2010).

Human beings perceive their surroundings based on sensory information from diverse channels. However, for human–computer interaction, we mostly restrict the user on visual perception (Foehrenbach et al. 2009). Foehrenbach et al. (2009) developed a gesture tracking system which uses six infrared cameras to track the markers placed on users to gather movement data. The system also uses a large scale display with a resolution of 4640 x 1920 pixels and a data-glove which was used for tracking finger movements.

A dilemma, caused by data variation, exists in research into signer-independent sign language recognition. An effective way to solve this dilemma, and thereby help push the research forward, is to understand sign language from the perspectives of human kinetics and linguistics (Jiang et al. 2008). Jiang et al. (2008) developed a Vision Based Interface system called Sign Language Recognition (SLR) that attempted to decode sign language gestures by electronically tracking the hand shape, orientation, position, movement and facial expressions because they are all important inputs for decoding sign language.

Gesture-based computing moves the control of computers from a mouse and keyboard to the motions of the body via new input devices. Depicted in science fiction movies for years, gesture-based computing is now more grounded in reality thanks to the recent arrival of interface technologies such as Kinect, SixthSense, and Tamper, which make interactions with computational devices far more intuitive and embodied. Publishers are beginning to explore richly visual interfaces that include multimedia and collaborative elements (Johnson et al. 2011).

Thanks in part to the Nintendo Wii, the Apple iPhone and the iPad, many people now have some immediate experience with gesture-based computing as a means for interacting with a computer. The proliferation of games and devices that incorporate easy and intuitive gestural interactions will certainly continue, bringing with it a new era of user interface design that moves well beyond the keyboard and mouse. While the full realization of the potential of gesture-based computing remains several years away, especially in education, its significance cannot be underestimated, especially for a new generation of students accustomed to touching, tapping, swiping, jumping, and moving as a means of engaging with information. At MIT, researchers are developing inexpensive gesture-based interfaces that track the entire hand. Elliptic Labs recently announced a dock that will let users interact with their iPad through gestures. Gestural interfaces can allow users to easily perform precise manipulations that can be difficult with a mouse, as the video editing system Tamper makes plain (Johnson et al. 2011).

Recent advances in 3D depth cameras such as Microsoft Kinect sensors have created many opportunities for multimedia computing. Kinect was built to revolutionize the way people play games and how they experience entertainment. With Kinect, people are able to interact with the games with their body in a natural way. The key enabling technology is human body language understanding; the computer must first understand what a user is doing before it can respond. The Kinect sensor incorporates several advanced sensing hardware. Most notably, it contains a depth sensor, a color camera, and a four-microphone array that provide full-body 3D motion capture, facial recognition, and voice recognition capabilities. In skeletal tracking, a human body is represented by a number of joints representing body parts such as head, neck, shoulders, and arms. Each joint is represented by its 3D coordinates (Zhang 2012).

Motion capture of the human body has being performed for decades with a growing number of technologies, aims and application fields; but only recent optical markerless technologies based on silhouette recognition and depth sensors which have been developed for videogames control interface have brought motion capture to a broad diffusion. Actually, nowadays there are low cost hardware and software suitable for a wide range of applications that may vary from entertainment domain (e.g., videogames, virtual characters in movies) to the biomechanical and biomedical domain (e.g., gait analysis or orthopedic rehabilitation) and to a huge number of industrial sectors (Regazzoni et al. 2014).

Frati and Prattichizzo (2011) developed a system which uses the Microsoft Kinect to track body and hand gestures. They used the Kinect with an OpenNI platform and OpenCV to track the body movements. The hand tracking algorithm uses depth image and processes to compute a virtual bounding box around the hand which is being tracked, feature detection to extract the positions and trajectories of the finger tips and tracking of other important zones of the hand like the base and wrists. This gesture recognition system is combined with a wearable haptic glove. The haptic feedback is provided to a user's fingers while they are interacting with the virtual world (Frati and Prattichizzo 2011).

Kumar and Sekmen (2008) describe an adaptive system that enables a mobile robot to learn its users' preferences and capabilities so that it can offer a dynamic and efficient GUI for each user rather than a standard GUI for all users. The system predicts future actions of the users by generating models based on the users' previous interactions with the robot. The system was implemented and evaluated on a Pioneer 3-AT mobile robot. About 20 participants who were assessed on spatial ability directed the robot in simple spatial navigation tasks to evaluate effectiveness of the adaptive interface. The results showed that although spatial reasoning ability plays an important role in mobile robot navigation, it is less important in the robot control with adaptive interfaces compared to that of the non-adaptive (Kumar and Sekmen 2008).

Kaklauskas and Krutinis et al. (2013) developed the Housing Health and Safety Decision Support System with Augmented Reality (HUSSAR) including a context-aware interface. The user of the smartphone mobile device is provided with the current locale of the user and the adjacent house, while the user is viewing first-hand the information on environmental pollution and the qualitative and quantitative characteristics describing the building. A user can also take the recommended HUSSAR and go for a virtual walk together through a house, calculate the market value of it and get suggestions on how to increase its healthiness and security and how to decrease pollution and noise (Kaklauskas and Krutinis et al. 2013).

Kaklauskas et al. (2006, 2007) developed the Intelligent Tutoring System (ITS) including a context-aware interface. The ITS, based on the Student Model, can form a supplemental system with context-aware keywords (with a lesser significance that the search being performed now) and include it with the main keywords search system in real time, as a search is being conducted. This permits effectively forming a supplemental, context-aware keywords system based on the Student Model, because students generally do not conduct a random search but one that usually fits a certain framework (preparing for a specific exam, looking at a previously taken exam with its evaluation grades, a student's favorite subjects and the like).

Context-aware interface can form a supplemental system with context-aware keywords (with a lesser significance that the search being performed now) and include it with the main keywords search system in real time, as a search is being conducted. This permits effectively forming a supplemental, context-aware keywords system based on the user model, because users generally do not conduct a random search but one that usually fits a certain framework (preparing for a specific task, looking at a previously taken assignment, a user's favorite subjects and the like).

Here the multimodal biometrics method is used (blood pressure, heart, rate, skin temperature and conductance, temperature, pupil diameter and blink rate, etc.) as a multimodal input interface for an intelligent tutoring system. Chapters 5-7 present the description of part of this system. One of the main reasons for developing this multimodal input interface is to perceive patterns in the student's learning and form conditions for that student's studies to be more effective. The developed IDSS determines the correlation between a student's stress level, learning productivity and interest in learning and that user's biometric parameters (systolic blood pressure, diastolic blood pressure, heart rate, skin humidity, temperature and conductance, temperature, pupil diameter and blink rate, etc.).

First, the IDSS collects information about a student's biometric parameters and accumulates them in the User's Biometric Database. Then the Interdependency Analysis Model starts analyzing these data and makes a real-time determination of their correlation with a student's model, stress, learning productivity and interest in learning. The IDSS automatically establishes a student's learning productivity, stress and interest in learning, based on the determined relationships. Then later, upon completion of the learning phase, the IDSS determines the correlations between a student's learning productivity, interest in learning and that student's physiological parameters. Once the IDSS has learned to find out a particular user's learning productivity and interest in learning from the variations in his/her biometrical parameters, then IDSS can select learning materials taking into account a student's learning productivity and the degree to which the learning is interesting. The IDSS learning process is always ongoing. More and more accurate dependencies are gained between the student's model, stress, learning productivity and interest in learning and that student's biometric parameters (systolic blood pressure, diastolic blood pressure, heart rate, skin humidity, temperature and conductance, temperature, pupil diameter and blink rate, etc.). This permits selecting learning materials more and more accurately by taking into account a student's model, learning productivity and the degree to which the student finds the learning interesting. For example, when the learning capacity of a studying student falls sharply in the evening, the system provides easier study materials and recommendations for increasing the productivity of the studying. Once a student's stress level exceeds a certain limit, recommendations are submitted for lessening stress. In this instance, the developed multimodal input interface for the intelligent tutoring system is able to intuit the patterns of the student's learning and provide the student with a summary about that student's learning capacity, interest and stress level along with a short explanation about why one or another item of the learning material is being provided.

1.4 Integration of Artificial Intelligent and DBMS Technologies

The integration of artificial intelligence (AI) and database management systems (DBMS) technologies promises to play a significant role in shaping the future of computing. AI/DB integration is crucial not only for next generation computing but also for the continued development of DBMS technology. The motivations driving the integration of these two technologies include the need for (a) access to large amounts of shared data for knowledge processing, (b) efficient management of data as well as knowledge, and (c) intelligent processing of data (Nihalani et al. 2009). One of the major types of integrations of AI and DBMS technologies in decision making support systems (DSSs) are intelligent databases. Current intelligent databases using artificial intelligence (data mining, etc.) components can discover relevant patterns in the data, assist users in performing searches and knowledge representation. Furthermore intelligent databases are able to manage and merge data, text, charts, images and multimedia. Examples of such intelligent databases are submitted next.

An "intelligent database" is one in which the ocean of data is collected, distilled, and classified in a comprehensive and systematic way. An intelligent database of infectious diseases was envisioned as a map of the knowledge domain of the most important infectious diseases in the world. The content of an intelligent database would include the following categories of infections: arthropod-borne, bioterrorism, childhood, community-acquired, food borne, gastroenteritis, localized, sapronoses, sexually-transmitted, and zoonoses (Brown 2008). In Brown's (2008) opinion, an intelligent database is an effective tool for developing and updating a decision-support system. Such a system could help medical practitioners to access information and improve the diagnosis of infectious diseases.

In the last decades, significant progress in the world of Intelligent Databases and Information Systems has been observed. An important part of these achievements is largely due to the use of concepts from Fuzzy Logic and Fuzzy Set Theory. Together with the Fuzzy Relational Database Model, the most often studied, we can find remarkable works in many other data models such as object-oriented, object-relational, spatio-temporal and multidimensional ones. Moreover, a number of proposals have appeared with the aim of building soft computing applications in a very wide range of areas relying on the use of these soft extensions of data modelling techniques (Marín and Pons 2008). Thus, Marín and Pons (2008) state, without fear of exaggerating, that the fuzzy databases area has done its part in the challenge of getting the computer closer to the human being by increasing capabilities towards a more flexible and intelligent behavior.

Bostan-Korpeoglu and Yazici (2007) propose a fuzzy Petri net model for intelligent databases to represent knowledge and the behavior of an intelligent object-oriented database environment, which integrates fuzzy, active and deductive rules with database objects. The techniques and solutions provided in this study can be used in various complex systems, such as weather forecasting applications, environmental information systems and defense applications. For example, in the weather forecasting application, there exist huge amounts of data related to the atmospheric elements, such as pressure, temperature, humidity, coming from sensors connected to weather stations. Since a couple of changes taking place at the same time are the indications of some forthcoming events, the system needs to perform deductions in order to determine the possible results of these changes in the environment. For example, high temperature, low pressure and high humidity in a certain location and time may trigger heavy rain, which can be represented as a fuzzy rule in the fuzzy Petri net model for intelligent databases. A particular value change on an atmospheric element often triggers multiple fuzzy rules, which should be executed concurrently and require a fuzzy inference mechanism. In addition there could be state changes in the application environment, such as seasonal changes. In winter, we expect weather events like snow, freeze, etc., while in spring we expect rain, hail or shower. The application should be intelligent enough to handle these state changes, i.e., give more importance to some rules or prune some others according to the state. There may also be user queries which require deductions. These queries may be on the current values of the elements of the application domain. For example, in a weather forecasting application, we can have a query like, “Which cities are very hot?”. We may also want to know the future trends of the elements of the application domain. For example, we may ask queries like, “What is the expected temperature change in Paris within 12 hours?” or “What is the expected weather event in Paris these days?” (Bostan-Korpeoglu and Yazici 2007).

Shen et al. (2013) present an Experience Mining System (ExMS) for effectively extracting previous urbanization practice experiences. ExMS is built based on the theories of experience representation, storage and mining. Its major components include a Sustainable Urbanization Practices Database (SUPD), a Refinery process, and a Mine-sweeper. ExMS can facilitate decision-makers in the selection of strategies and solutions when addressing urbanization practice challenges. Unlike a reporting system, a DSS performs sophisticated analyses on the data mined, involving statistical and mathematical processing. These processes are driven by an Intelligent Database Engine (IDE). In the Refinery process, an IDE undertakes a DSS process by examining given problems and helping the user to relate the problems to the experiences or solutions in the context of previous practices. IDE takes a problem as an input, and its output is a single or a set of existing practice cases with solutions relevant to the problem input. IDE also produces a list of indicators by which the performance of using the mined experiences to the identified problem practice can be assessed. IDE is a mechanism of ‘memory-based reasoning’, namely, a way of reasoning from existing examples (Shen et al. 2013).

Building management usually involves the participation of a manager who, faced with a number of problems and issues, has to make decisions which require vast knowledge, analytical skills as well as speed and self-discipline. On this account, there are tools which support the manager's activities helping to gather data, knowledge, make technical diagnostics or make decisions (Gajzler 2013). Gajzler (2013) presents a review of these tools, in particular an individual repair advisory system. One of the examples presenting the system is based on an intelligent data base and artificial neural networks system of approximate technical diagnosis of engineering objects. Based on input signals, which take into account, among others, a type of construction, its age, estimated degree of degradation of construction elements and technical equipment, the system qualifies an object to specific activities (current overhaul, major overhaul, a close-down) (Gajzler 2013). Artificial neural networks were used in this module as a classifying tool. The implementation of automatic knowledge acquisition based on data and text mining techniques is being a subject of works (Gajzler 2010)

Lee et al. (2014) present an intelligent data management induced resource allocation system which aims at providing effective and timely decision making for resource allocation. This sophisticated system is comprised of product materials, people, information, control and supporting function for the effectiveness in production. The said system incorporates a Database Management System and fuzzy logic to analyze data for intelligent decision making, and Radio Frequency Identification for result verification.

Doukas et al. (2007) present an intelligent decision support model using rule sets based on a typical building energy management system. The decision support model’s infrastructure is based on the characteristics of a typical BEMS logic. The current model includes the following components (Doukas et al. 2007):

- Indoor sensors: Sensors that measure or record temperature, relative humidity, air quality, movement and luminance in the building areas.
- Outdoor sensors: Sensors for the outdoor conditions such as temperature, relative humidity and luminance, which are essential for the efficient model’s operation.
- Controllers: This component category contains switches, diaphragms, valves, actuators etc.
- Decision unit: A real time decision support unit is included.
- Database: It includes the database for the building energy characteristics and the knowledge database, where all essential information is recorded.

Abel et al. (2004) describe the *PetroGrapher* system, an intelligent database application to support petrographic analysis, interpretation of oil reservoir rocks, and management of relevant data using resources from both knowledge-based system technology and database technology. In this project, the visual tacit knowledge applied in petrographic analysis was rendered explicit through the collection of cases (rock descriptions), which were then used in the development of a domain ontology organized in a partonomy. Expert-level basic features, which we call "visual chunks", were identified. The cases were further compared against the ontology to elucidate the relations between features in descriptions of rocks, visual chunks and expert interpretations (Abel et al. 2004).

DSSs are becoming increasingly more critical to the daily operation of organizations. Data warehousing, an integral part of this, provides an infrastructure that enables businesses to extract, cleanse, and store vast amounts of data. The basic purpose of a data warehouse is to empower the knowledge workers with information that allows them to make decisions based on a solid foundation of fact (Nemati et al. 2002). For an effective knowledge warehouse to become a reality, different types of knowledge (i.e., both tacit and explicit knowledge) and different forms of knowledge (e.g., text streams, binary large objects, production rules, mathematical models, and what-if cases) need to be captured, codified, and cataloged. In addition, this codified knowledge must contain knowledge about itself (meta-knowledge) and must be analyzed to create new knowledge (Nemati et al. 2002).

Barranco et al. (2008) propose an indexing technique for fuzzy numerical data which increases the performance of query processing when the query involves an atomic possibility measured flexible condition. The proposal is based on a classical indexing mechanism for numerical crisp data, B+-tree, which is implemented in most commercial database management systems (DBMS). This makes the proposed technique a good candidate for integration in a fuzzy DBMS when it is developed as an extension of a crisp DBMS. The efficiency of the proposal is contrasted with another indexing method for similar data and queries, G-tree, which is specifically designed to index multidimensional data. Results show that the proposal performance is similar to and more stable than the measured for G-tree when used for indexing fuzzy numbers (Barranco et al. 2008).

Morales et al. (2008) present a system to build, debug and test rules (GDB) in a Fuzzy Relational Deductive Database System (FRDDS) in a visual way avoiding the associated syntax which could be quite complex for a non-expert user. The rules will be used to compute a Measure of Quality (MoQ) of the scientific data. The MoQ will be defined and assigned taking into account the knowledge of the engineers who built the instrument and the formal documentation. Together with this MoQ, the tool will provide a semantic explanation about how the measure has been assigned. With GDB is possible to work with imprecise data, to store knowledge using rules and also to deduce new information. The MoQ and the explanation will provide to the scientists and engineers a better understanding about the instrument behavior and, therefore, about physical phenomena under study (Morales et al. 2008).

A suite of "*desirable features*" for Environmental Decision Support Systems (EDSS) is proposed by identifying the general attributes of environmental systems which are of importance to modelling and simulation, and the different categories of users of EDSSs. In the EDSSs object oriented databases can be queried to answer to such questions as "find all processes influencing zooplankton growth, when water temperature is below 25°C " (Rizzoli and Young 1997).

As in a data warehouse environment where data mining techniques can be used to discover untapped patterns of data that enable the creation of new information, by extension then, use of technologies such as data warehousing, data mining and other artificial intelligence (AI) technologies can enhance the knowledge creation, storage, dissemination and management processes (Alavi and Joachimsthaler 1992).

The author of this book, in conjunction with M. Seniut and G. Kaklauskas, describe the developed intelligent databases, which utilize an intelligent database engine, in Chapters 3-7 herein. The intelligent database engine consists of three main parts: 1) text analytics; 2) determination of the interdependencies between stress level, work (learning) capacity and interest in the work (learning) of the users under research and their physiological indicators and 3) merge and submissions of various forms of data, information and knowledge. The first and third composite parts of an intelligent database engine are used in the system that Chapter 3 describes. Meanwhile all three of the composite parts of an intelligent database engine are used in the systems described in Chapters 4-7. These three composite parts are briefly described next.

The intelligent databases that the author developed in joint with M. Seniut by utilizing text analytics perform the search for the required text. A brief description of the Intelligent Database, which is a composite part of Resilience Management IDSS, is submitted as an example. The Intelligent Database covers the inputting of a bag of concepts space (see Figure 1.1); the selecting, processing and indexing information in accordance with the inputted bag of concepts space; formulating the results of the retrieval and finally showing them to the user.

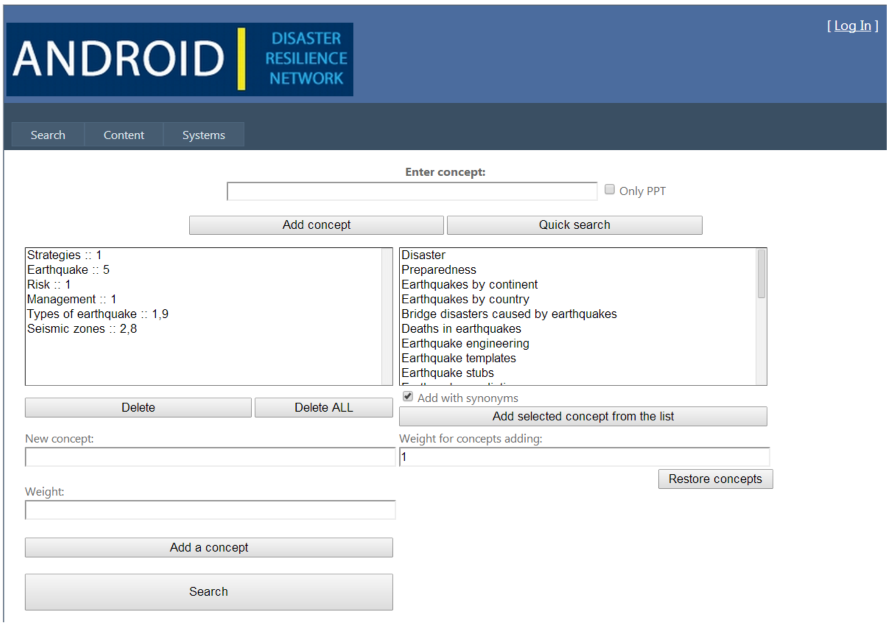


Fig. 1.1. User window of the Intelligent Database

Further, after selecting, processing and indexing documents, it covers the selecting out of composite parts (chapters/sections/paragraphs) of the documents under analysis and, after that, performing the multi-criteria analysis of the composite parts. This is followed by the designing of alternative variants of the selected information and performing a multi-criteria analysis of the summarized integrated alternatives of the text by which the retrieval results are then formulated. Intelligent Database permits selecting the maximally rational text in the coverage that the user desires. The following factors determine a rational text (Figure 1.2, 1.3 and Table 1.1):

- Citation index of papers (Scopus, ScienceDirect, Google Scholar);
- Citation of authors (Scopus, ScienceDirect, Google Scholar, etc.);
- Top 25 papers;
- Impact factor of journals;
- Popularity of a text (citation index, number of readers, time spent reading);
- Reputation of the documents;
- Supporting phrases;
- Document name and contents;
- Density of keywords.

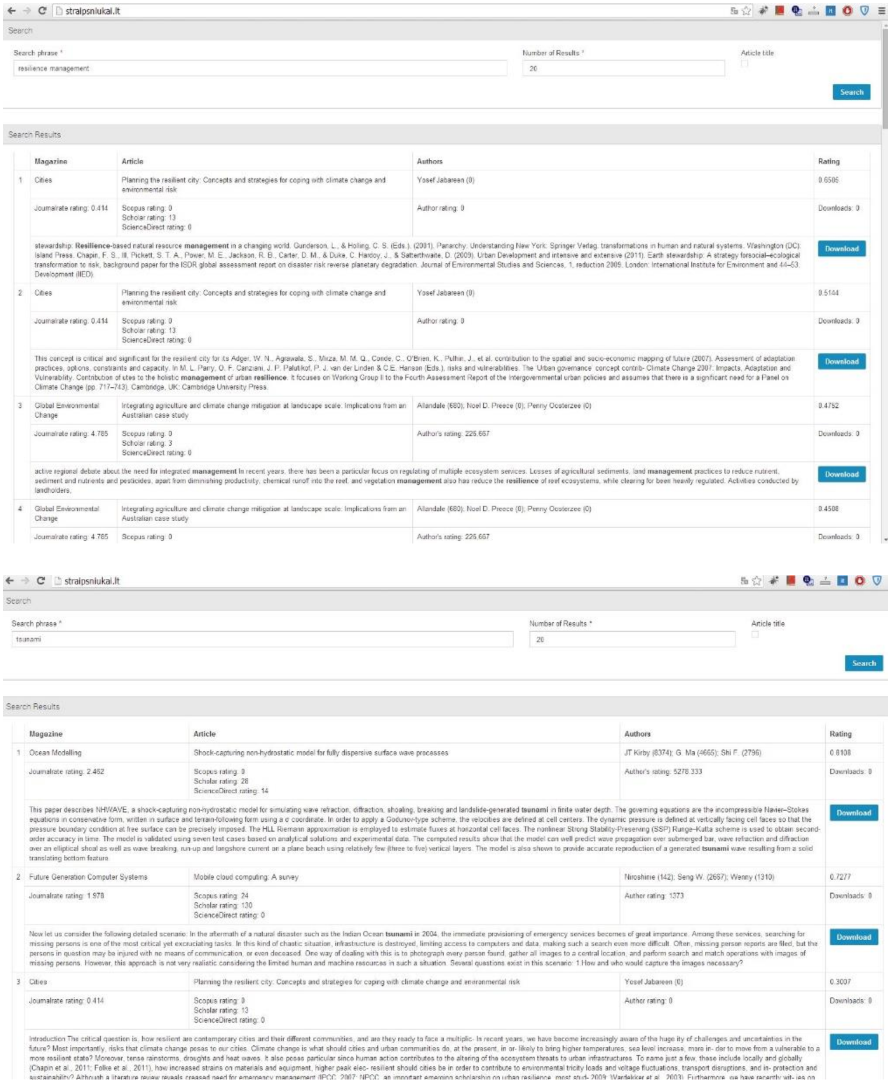


Fig. 1.2. User window of the Intelligent Database for the analysis of the citation index of papers (Scopus, ScienceDirect, Google Scholar), citation of authors and impact factor of journals

IDSS users might find it interesting to learn, why one or another paragraph or section is included in a newly-compiled text. The intelligent database serves this purpose by compiling a table that provides quantitative parameters for analyzing a text and their final evaluations regarding the priorities of the paragraphs included in the overall text (see Table 1.1).

Table 1.1 Fragment of quantitative parameters explaining selection of the most rational paragraphs

The following factors determine a rational text:	**Paragraph 1**	**Paragraph 2**	**Paragraph 3**	**Paragraph 4**
Citation of papers:				
Citation of papers (ScienceDirect)	9	4	1	0
Citation of papers (Google Scholar)	16	6	1	0
Top 25 papers	-	-	-	**+(2)**
Impact factor of journals	0,983	0,983	0,983	1,59
Density of keywords (% of a text):				
energy	-	7,54716981132075	-	14,7239263803681
buildings	6,33802816901409	5,66037735849056	6,38297872340425	16,5644171779141
Citation of authors:				
Ning Gu H index	13	0	0	0
Ning Gu Google citations	599	0	0	0
Vishal Singh H index	5	0	0	0
Vishal Singh Google citations	190	0	0	0

The designing of alternative variants provides the user with an opportunity to supplement and/or correct the already inputted bag of concepts space, modifies the weights and then repeats the search. In other words, the user is provided an opportunity to intervene in the occurring retrieval by using Intelligent Database and to redirect it; thus the retrieval takes into account the user-selected priorities and the existing situation. The Intelligent Database can select the desired number of pages in accordance to the assigned keywords and their significances (for example, 5, 39 and 246 pages). Additionally a user can assign a number of minutes for reading the information of interest. Intelligent Database also performs this function (see Figure 4). The Intelligent Database was developed as a Web application using Microsoft Visual Studio 2010, C# as the main programming language and the MS SQL Server 2012 as a database platform. An example of the fragment of the rational text analytics result is presented in Figure 1.3.

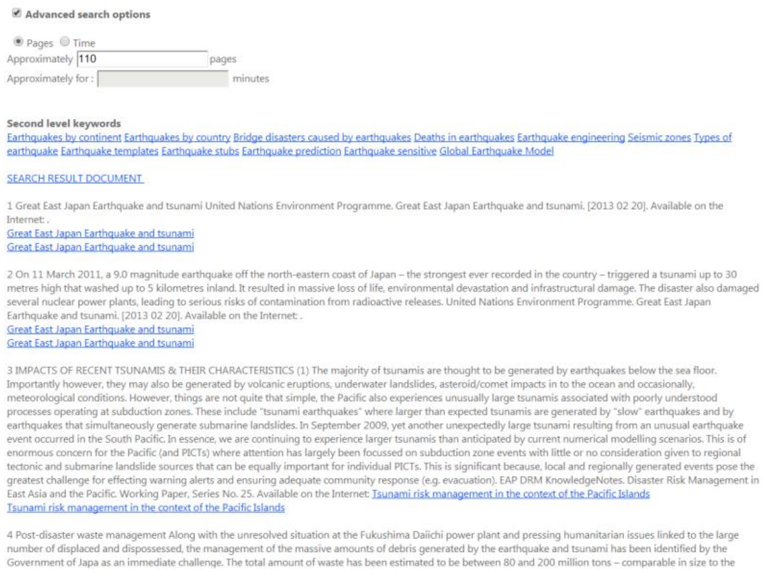


Fig. 1.3. User window of Intelligent Database results — a fragment

The interdependencies between the stress level, work capacity and interest in the work of the persons under research and their physiological indicators are determined for the intelligent databases (see Chapters 3-7), which the author developed in joint with colleagues (E. K. Zavadskas, M. Seniut, G. Dzemyda, V. Gribniak, V. Stankevic, C. Simkevičius, T. Stankevic, S. Ivanikovas, V. Raudonis, L. Bartkiene, I. Jackute, G. Kaklauskas, A. Matuliauskaite, R. Paliskiene, S. Rimkuviene, J. Rute, L. Zemeckyte, A. Vlasenko). The methods used for this purpose were ordered logit (regression model for ordinal dependent variables [see Figure 1.4]) and Anova (analysis of variance).

The intelligent databases for intelligent decision support systems developed by the author of this book (see Chapters 3-7) along with colleagues (Kaklauskas et al. 2010, 2011, 2012, 2013a, b) are able to merge in various forms the existing information, data and knowledge. Figure 1.5 is an example relevant to merged information, data and knowledge (chart, picture, table, diagram, data, text, image, multimedia), which were connected by the Recommender System to Analyze Student's Academic Performance.

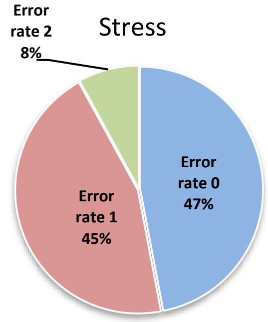
Systolic blood pressure, diastolic blood presure, heart rate and skin humidity determine stress level. Dependency is established on the basis of 406 measures.

Model 1: Ordered Logit. using observations 1-406
Dependent variable: **Stress**
Standard errors based on Hessian

	Coefficient	*Std. Error*	*z*	*p-value*	
Systolic blood pressure	0.047065	0.0152366	3.0890	0.00201	***
Diastolic blood pressure	0.0325195	0.0170768	1.9043	0.05687	*
Heart rate	0.0393941	0.0169009	2.3309	0.01976	**
Skin humidity	-0.000543943	6.12089e-05	-8.8867	<0.00001	***
cut1	4.86987	1.67169	2.9131	0.00358	***
cut2	8.60486	1.65257	5.2070	<0.00001	***
cut3	10.7249	1.68577	6.3620	<0.00001	***
cut4	12.3938	1.71818	7.2133	<0.00001	***
cut5	13.4958	1.74411	7.7379	<0.00001	***
cut6	15.5062	1.86977	8.2931	<0.00001	***

Mean dependent var	3.115764	S.D. dependent var	1.074461
Log-likelihood	-510.7746	Akaike criterion	1041.549
Schwarz criterion	1081.613	Hannan-Quinn	1057.405

Recognition level of 47% and recognition level of 92% with 1 point of error in the stress scale



Diastolic blood presure determines work productivity level. Dependency is established on the basis of 107 measures.

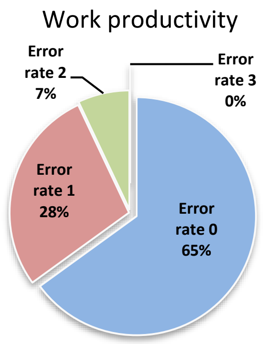
Model 6: Ordered Logit. using observations 1-107
Dependent variable: Work productivity
Standard errors based on Hessian

	Coefficient	*Std. Error*	*z*	*p-value*	
Diastolic blood pressure	-0.105247	0.0359095	-2.9309	0.00338	***
cut1	-11.1222	2.88884	-3.8501	0.00012	***
cut2	-9.7258	2.85058	-3.4119	0.00065	***
cut3	-6.43938	2.72606	-2.3622	0.01817	**
cut4	-4.00244	2.76961	-1.4451	0.14842	

Mean dependent var	7.943925	S.D. dependent var	0.762713
Log-likelihood	-109.9123	Akaike criterion	229.8246
Schwarz criterion	243.1887	Hannan-Quinn	235.2422

Number of cases 'correctly predicted' = 69 (64.5%)
Likelihood ratio test: Chi-square(1) = 42.5526 [0.0000]

Recognition level of 65% and recognition level of 93% with 1 point of error in the working productivity scale



Diastolic blood presure determines interest in work level. Dependency is established on the basis of 107 measures.

Model 3: Ordered Logit. using observations 1-107
Dependent variable: **Interest in work**
Standard errors based on Hessian

	Coefficient	*Std. Error*	*z*	*p-value*	
Diastolic blood pressure	-0.111951	0.0337495	-3.3171	0.00091	***
cut1	-11.6515	2.7258	-4.2745	0.00002	***
cut2	-10.5828	2.68257	-3.9450	0.00008	***
cut3	-8.88518	2.63448	-3.3727	0.00074	***
cut4	-6.13945	2.57219	-2.3869	0.01699	**
cut5	-4.53628	2.63539	-1.7213	0.08520	*

Mean dependent var	7.457944	S.D. dependent var	1.002642
Log-likelihood	-137.6785	Akaike criterion	287.3570
Schwarz criterion	303.3940	Hannan-Quinn	293.8582

Number of cases 'correctly predicted' = 52 (48.6%)
Likelihood ratio test: Chi-square(1) = 45.2593 [0.0000]

Recognition level of 48% and recognition level of 85% with 1 point of error in the interest in work scale

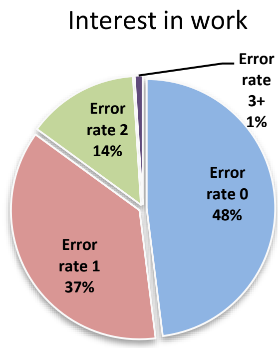
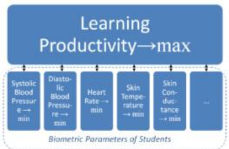


Fig.1.4. Interdependencies between stress, work productivity and interest in work among persons under research and their physiological indicators, as determined by the Ordered logit method in intelligent databases — a fragment

General theory of the topic under discussion — a fragment

Interrelations between physiological parameters and learning productivity among students (Fig. 5.1)



Interdependence linking physiological parameters of students to their learning productivity

	Skin humidity	Heart rate	Blood pressure
Arithmetic calculations	↑ Kobayashi et al. (2003) ↑ Kamei et al. (1998)		
Mental stress (Stroop task, mental arithmetic task)	↑ Fechir et al. (2009)	↑ Fechir et al. (2009)	↑ Fechir et al. (2009)
Mental stress (provoked by a standard arithmetic challenge)		↑ Harris et al. (2000)	↑ Harris et al. (2000)
Arithmetic stress		↑ Vuksanovic and Gal (2007)	↑ Vuksanovic and Gal (2007)
Mental stress		↑ Murata et al. (1999)	
Mental arithmetic		↑ Sloan et al. (1991) ↑ Turner et al. (1987) ↑ Szabo et al. (1994) ↑ Tanida et al. (2004)	↑ Sloan et al. (1991)
Arithmetic and combined arithmetic-with-cycling tasks		↑ Furedy et al. (1996)	

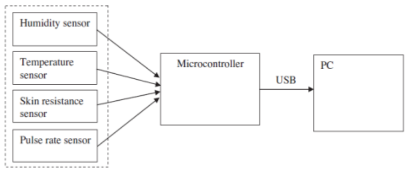
Interdependency diagrams – fragment (see Table 5.2)

Psychological parameters under measurement	Data on students' state of being at the time of self-assessment				
	Personal mood	Productivity	Interest in learning	Stress	...
Physiological computer mouse: - temperature - humidity - skin conductance - touch intensity - heart rate ...	**Interdependency diagrams determined and outlined**				

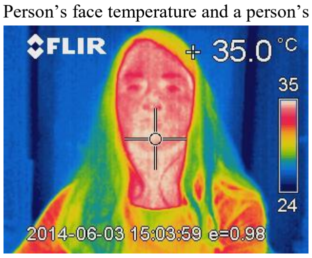
Composite parts of the system — a fragment

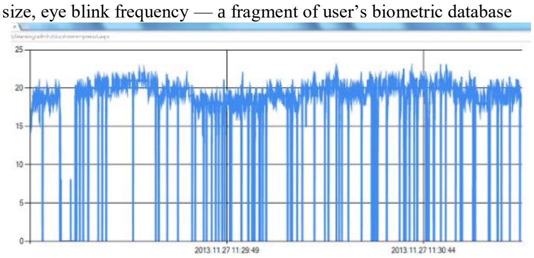
Physiological computer mouse developed by the author herein and colleagues

Physiological finger diagram



Person's face temperature and a person's pupil size, eye blink frequency — a fragment of user's biometric database





e-Self-assessment window of the launched system for students - fragment (see Fig. 5.9)

A system of criteria to evaluate the efficiency of alternative recommendations

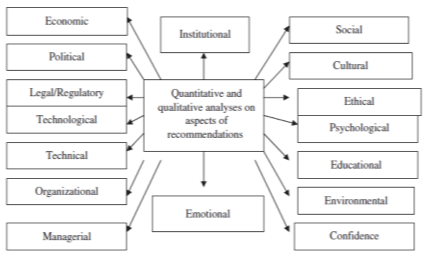
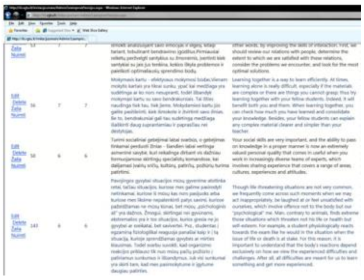


Fig. 1.5. Merged information, data and knowledge (chart, picture, table, diagram, data, text, images, multimedia), which were connected by the Recommender System to Analyze Student's Academic Performance

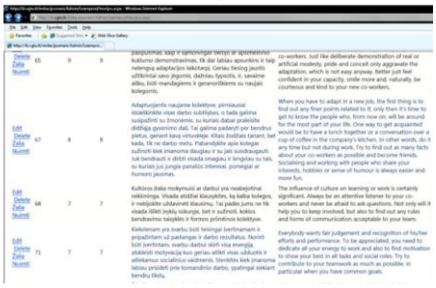
Fig. 1.5. Continuation

Motivational (a) and social learning (b) tables — a fragment (see Fig. 5.10)

a)



b)



Dependency calculations of the capiticty of a student for learning on the upper and lower part of blood pressure and the finger‘s skin resistor (applying the Logit method)

Model 4: Ordered Logit, using observations 1-239
Dependent variable: Nasumas
Standard errors based on Hessian

	Coefficient	*Std. Error*	*z*	*p-value*	
Cistol	-0,0353077	0,014637	-2,4122	0,01586	**
Diastol	-0,0323491	0,0186151	-1,7378	0,08225	*
Varza	-0,0169673	0,00699581	-2,4253	0,01529	**
cut1	-12,5652	2,12317	-5,9181	<0,00001	***
cut2	-10,7385	1,91078	-5,6199	<0,00001	***
cut3	-10,3151	1,89362	-5,4473	<0,00001	***
cut4	-9,44882	1,869	-5,0555	<0,00001	***
cut5	-7,96987	1,83267	-4,3488	0,00001	***
cut6	-7,48714	1,82378	-4,1053	0,00004	***
cut7	-6,54656	1,81009	-3,6167	0,00030	***
cut8	-3,55802	1,81059	-1,9651	0,04940	**

Mean dependent var	7,673640	S.D. dependent var	1,599033
Log-likelihood	-386,5558	Akaike criterion	795,1115
Schwarz criterion	833,3526	Hannan-Quinn	810,5216

Number of cases 'correctly predicted' = 100 (41,8%)
Likelihood ratio test: Chi-square(3) = 99,2634 [0,0000]

Dependency calculations of the interest a student has for learning on his/her pulse and finger‘s skin dampness (applying the Logit method)

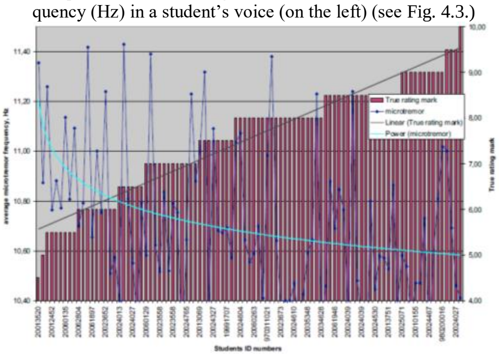
Model 4: Ordered Logit, using observations 1-145
Dependent variable: Idomum
Standard errors based on Hessian

	Coefficient	*Std. Error*	*z*	*p-value*	
Pulsas	0,0891878	0,0276295	3,2280	0,00125	***
Dregme	-0,000237342	0,000112998	-2,1004	0,03569	**
cut1	1,76084	2,02748	0,8685	0,38513	
cut2	4,13503	1,92178	2,1517	0,03142	**
cut3	5,69198	1,93274	2,9450	0,00323	***
cut4	7,11188	1,9689	3,6121	0,00030	***
cut5	8,93817	2,02491	4,4141	0,00001	***
cut6	11,3217	2,24159	5,0508	<0,00001	***

Mean dependent var	5,848276	S.D. dependent var	1,162678
Log-likelihood	-219,4048	Akaike criterion	454,8095
Schwarz criterion	478,6234	Hannan-Quinn	464,4859

Number of cases 'correctly predicted' = 59 (40,7%)
Likelihood ratio test: Chi-square(2) = 64,0449 [0,0000]

Correlation between emotional stress and examination mark in the e-test: x-axis – student Ids; y-axis – examination marks of students on a 10-point scale (on the right) and the average microtremor frequency (Hz) in a student’s voice (on the left) (see Fig. 4.3.)



Recommendations for best learning productivity as per motivational, educational persistence and social learning theories -fragment (see Fig. 5.3.)

Intelligent databases develop knowledge representation by utilizing various artificial intelligent technologies including symbolic rules, conceptual graphs, fuzzy logic, Bayesian networks, neural networks and case-based reasoning (Simic and Devedzic 2003; Hwang 2003; Josephina and Nkambou 2002; Prentzas et al. 2002;

Zhendong 2001; Magoulas et al. 2001). Knowledge representation is most often applied in intelligent tutoring systems (Hwang 2003; Josephina and Nkambou 2002; Zhendong 2001).

The second chapter presents the latest IDSSs, such as text analytics and mining based DSSs; ambient intelligence and the internet of things-based DSSs; biometrics-based DSSs, etc.

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Chapter 2. Intelligent Decision Support Systems

Abstract The second chapter presents the latest IDSSs, such as text analytics and mining based DSSs; ambient intelligence and the internet of things-based DSSs; biometrics-based DSSs; recommender, advisory and expert systems; data mining, data analytics, neural networks, remote sensing and their integration with decision support systems and other IDSSs. These other IDSSs include GA-based DSS; fuzzy sets DSS; rough sets-based DSS; intelligent agent-assisted DSS; process mining integration to decision support, adaptive DSS; computer vision based DSS; sensory DSS and robotic DSS. In addition to acquainting these IDSSs, author introduce practical examples where they have been effectively applied.

2.1 Recommender, Advisory and Expert Systems and their Integration with Decision Support Systems

The two terms — recommender systems and advisory systems — are very often used as synonyms in literature. These along with expert systems and their interconnectedness with decision making are described next. The recommender system (Wang et al. 2009; Chen et al. 2011; Lee et al. 2007), advisory system (Halim et al. 2014; Lee et al. 2008; Hejlesen et al. 1997) and expert system (Dagnino et al. 2013; Zagonari et al. 2013; Chi et al. 2008) are integrated with decision support systems (DSSs). Several such examples are provided at the end of the chapter's section.

Recommender Systems are software tools and techniques providing suggestions for items to be of use to a user. The suggestions provided are aimed at supporting their users in various decision-making processes, such as what items to buy, what music to listen, or what news to read. Recommender systems have proven to be valuable means for online users to cope with the information overload. Development of recommender systems is a multi-disciplinary effort which involves experts from various fields such as Artificial intelligence, Human Computer Interaction, Information Technology, Data Mining, Statistics, Adaptive User Interfaces, Decision Support Systems, Marketing, or Consumer Behavior (Ricci et al. 2011).

A variety of techniques have been proposed as the basis for recommender systems (Burke 2002, 2007; Ricci et al. 2011):

- Collaborative: The system generates recommendations using only information about rating profiles for different users. Collaborative systems locate peer users with a rating history similar to the current user and generate recommendations using this neighborhood.
- Content-based: The system generates recommendations from two sources — the features associated with products and the ratings that a user has given them.

- Demographic: A demographic recommender provides recommendations based on a demographic profile of the user.
- Knowledge-based: A knowledge-based recommender suggests products based on inferences about a user's needs and preferences.
- Community-based: This type of system recommends items based on the preferences of the users friends. This technique follows the epigram, "Tell me who your friends are, and I will tell you who you are".
- Hybrid recommender systems: These RSs are based on the combination of the above mentioned techniques.

Each of these techniques has known shortcomings, such as the well known cold-start problem for collaborative and content-based systems (what to do with new users with few ratings) and the knowledge engineering bottleneck in knowledge-based approaches. A hybrid recommender system is one that combines multiple techniques together to achieve some synergy between them. For example, a collaborative system and a knowledge-based system might be combined so that the knowledge-based component can compensate for the cold-start problem, providing recommendations to new users whose profiles are too small to give the collaborative technique any traction, and the collaborative component can work its statistical magic by finding peer users who share unexpected niches in the preference space that no knowledge engineer could have predicted (Burke 2007).

In general, there are recommendation techniques that are knowledge poor, i.e., they use very simple and basic data, such as user ratings/evaluations for items. Other techniques are much more knowledge dependent, e.g., using ontological descriptions of the users or the items, or constraints, or social relations and activities of the users. In any case, as a general classification, data used by RSs refers to three kinds of objects: items, users, and transactions, i.e., relations between users and items (Ricci et al. 2011).

Some DSSs may recommend that a particular alternative be picked and explain the rationale underlying that advice (Holsapple 2008). Knowledge-driven DSSs can suggest or recommend actions to managers. These DSSs are person-computer systems with specialized problem-solving expertise (Power 2012a). At the information search stage, intelligent search approaches and intelligent DSSs can sift through the massive amount of information available on the Web to make recommendations that match a customer's taste, personality, budget, previous choice patterns, or choices made by the customer's cohorts (those who share similar profiles, behaviors, and life styles) (Turban et al. 2007).

Since recommendations are usually personalized, different users or user groups receive diverse suggestions. In addition there are also non-personalized recommendations. These are much simpler to generate and are normally featured in magazines or newspapers. Typical examples include the top ten selections of books, CDs etc. While they may be useful and effective in certain situations, these types of non-personalized recommendations are not typically addressed by RS research. In their simplest form, personalized recommendations are offered as ranked lists of items.

In performing this ranking, RSs try to predict what the most suitable products or services are, based on the user's preferences and constraints. In order to complete such a computational task, RSs collect from users their preferences, which are either explicitly expressed, e.g., as ratings for products, or are inferred by interpreting user actions. For instance, a RS may consider the navigation to a particular product page as an implicit sign of preference for the items shown on that page (Ricci et al. 2011).

Advisory systems provide the advices and assist for solving problems that are normally solved by human experts. They can be classified as a type of expert systems (ElAlfi and ElAlami 2009). Both advisory systems and expert systems provide expertise to support decision making in a myriad of domains. Expert systems are used to solve problems in well defined, narrowly focused problem domains, whereas advisory systems are designed to support decision making in more unstructured situations which have no single correct answer (Beemer and Gregg 2008).

Both advisory systems and expert systems are problem-solving packages that mimic a human expert in a special area. These systems are constructed by eliciting knowledge from human experts and coding it into a form that can be used by a computer in the evaluation of alternative solutions to problems within that domain of expertise. Advisory systems do not make decisions but rather help guide the decision maker in the decision-making process, while leaving the final decision-making authority up to the human user (Turban and Aronson 2001).

Advisory systems do not make decisions but rather help guide the decision maker in the decision-making process, while leaving the final decision-making authority up to the human user. The human decision maker works in collaboration with the advisory system to identify problems that need to be addressed and to iteratively evaluative the possible solutions to unstructured decisions. Advisory systems help to synthesize knowledge and expertise related to a specific problem situation for the user; however, the ultimate decision-making power and responsibility lies with the user – not the system (Beemer and Gregg 2008).

Advisory systems are designed to support decision making in more unstructured situations, which have no single correct answer. In unstructured situations cooperative advisory systems that provide reasonable answers to a wide range of problems are more valuable and desirable than expert systems that produce correct answers to a very limited number of questions (Gregg and Walczak 2006).

Beemer and Gregg (2008) distinguish between advisory systems which utilize the case-based reasoning methodology and traditional expert systems that use rule-based reasoning. Case-based reasoning is a knowledge-based methodology which allows a problem to be solved based on past experiences (Aamodt and Plaza 1994). Case-based reasoning seeks cases similar to the current one and analyses which decision or classification was taken in order to reuse it in the present solution (Pla et al. 2013). CBR Systems solve problems by using knowledge gained from solving similar problem in the past. Major activities of such systems include retrieval relevant previous cases, adapting and combining them to solve new problems, and recording failures do that they can be avoided in the future. Applications of CRB techniques include story understanding, explanations-based reasoning, adaptive

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planning, learning and architectural design (Paek et al. 1996). Case-based reasoning is one of the emerging paradigms for designing intelligent systems. It shows significant promise for improving the effectiveness of complex and unstructured decision making. It solves new problems by adopting previously successful solutions to analogous problems (Chang et al. 2006).

In response to the organizational need of intelligent decision support, expert systems were developed by coupling artificial intelligence (AI) and knowledge management techniques. Expert systems are designed to encapsulate the knowledge of experts and to apply it in evaluating and determining solutions to well-structured problems. Unlike expert systems, the suggestions made by advisory systems do not always represent the final answer to the problem. Instead, they represent advice used by the decision maker as a part of the iterative problem solving process (Beemer and Gregg 2008). Beemer and Gregg (2008) highlight the major differences between advisory and expert systems such as the decisions they are each designed for (unstructured versus structured), the AI methodologies that each uses (case-based versus rule-based), the role they each play in the decision-making process (decision support versus decision maker).

Further several examples are provided regarding the integration of the recommender system (Wang et al. 2009), advisory system (Lee et al. 2008; Hejlesen et al. 1997) and expert system (Dagnino et al. 2013) with decision support systems.

Wang et al. (2009) developed a recommender system by focusing on the on-line decision support module with respect to customers' characteristics and supplier's profits. For effective decision support, a mathematical model is developed so that the right product can be recommended to the right person with the best profit for the company.

The design of instrumentation and control (I&C) systems for nuclear power plants (NPPs) is rapidly moving towards fully digital I&C systems and is trending towards the introduction of modern computer techniques into the design of advanced main control rooms (MCRs) of NPPs. In the design of advanced MCRs, human–machine interfaces have improved and various types of decision support systems have been developed. It is important to design highly reliable decision support systems in order to adapt them in actual NPPs. In addition, to evaluate decision support systems in order to validate their efficiency is as important as to design highly reliable decision support systems. In this research, an operation advisory system based on the human cognitive process is evaluated in order to estimate its effect. The Bayesian belief network model is used in the evaluation of the target system, and a model is constructed based on human reliability analysis event trees. In the evaluation results, a target system based on the operator's cognitive process showed better performance compared to independent decision support systems (Lee et al. 2008).

Hejlesen et al. (1997) give a description of the Diabetes Advisory System (DIAS), and the evaluation results obtained so far. DIAS is a decision support system for the management of insulin dependent diabetes. The core of the system is a compartment model of the human carbohydrate metabolism implemented as a causal probabilistic network (CPN or Bayesian network), which gives it the ability to handle the uncertainty, for example, in blood glucose measurements or physiological variations in glucose metabolism. The evaluation results suggest that, at least in our hands, DIAS can generate advice that is safe and of a quality that is at least comparable to what is available from experienced clinicians (Hejlesen et al. 1997).

With the aim of supporting decision makers to manage contamination in freshwater environments, an innovative expert decision support system (EDSS) was developed. The EDSS was applied in a sediment quality assessment along the Bormida River (NW, Italy) which has been heavily contaminated by an upstream industrial site for more than a century. Sampling sites were classified by means of comparing chemical concentrations with effect-based target values (threshold and probable effect concentrations). The level of each contaminant and the combined toxic pressure were used to rank sites into three categories: (i) uncontaminated (8 sites), (ii) mildly contaminated (4) and (iii) heavily contaminated (19). Finally, potential human risk was assessed in selected stations (11 sites) by integrating genotoxicity biomarkers (GTI index falling in the range 0.00–0.53). General conclusions drawn from the EDSS data include: (i) in sites classified as heavily contaminated, only a few exhibited some significant, yet limited, effects on biodiversity; (ii) restrictions in re-using sediments from heavily contaminated sites found little support in ecotoxicological data; (iii) in the majority of the sites classified as mildly contaminated, tested organisms exhibited low response levels and (iv) preliminary results on genotoxicity biomarkers indicate possible negative consequences for humans if exposed to river sediments from target areas (Dagnino et al. 2013).

2.2 Text Analytics and Mining based DSSs

A brief review of decision support via text analytics and mining definitions and technologies appears in the beginning of this chapter. Specific instances of applying text analytics and mining in IDSS will be provided later.

The types of statements that are emphasized by many scientists and practitioners in their discussions on the interrelationship between text mining and text analytics are akin to the following. “The application of text mining techniques to solve business problems is called text analytics.” “Text mining, which is sometimes referred to text analytics —” “Text analytics are also known as text mining.” “Text mining is roughly equivalent to text analytics” “Text Analytics is also known as Text Mining” “Text mining, also referred to as text data mining, roughly equivalent to text analytics —” “The application of text mining techniques to solve business problems is called text analytics.”

Rao and Dey (2011) hold the opinion that text mining is an interdisciplinary field that brings together concepts from statistics, machine learning, information retrieval, data mining, linguistics and natural language processing. In many ways text mining is similar to data mining, and indeed regarded by some as an extension of the same. The main point of departure from the parent discipline of data mining is in the type of data that needs to be analyzed. Whereas data mining deals with mostly numeric structured data, text, the theme of text mining, is regarded as "unstructured" data. Though the task of text mining based DSS would seem to be more challenging than that of mining of structured data, the existence of vast amounts of information in electronically available text has led to intense research in text mining techniques, and many of the challenges have been overcome (Rao and Dey 2011).

With an exponential growth in the amount of unstructured data, text mining is becoming a part of mainstream decision support technology rather than a luxury. As text-mining tools mature, they become better integrated in existing decision support processes and systems. The acceptance of text mining is growing at an accelerating pace. In combination with sound structured data analysis and reporting techniques, text mining becomes a strong competitive advantage for early adopters of this new decision support technology (Froelich and Ananyan 2008).

Traditional literature analyses are often time and resource intensive. Text analytics overcomes these challenges by applying automated means to extract and discover knowledge in unstructured data sources. Unquestionably, text mining is of significant value to researchers (Delen and Crossland 2008).

Text analytics is a promising method for literature mining. It leverages existing IS tools and databases to search, explore, and make sense of large complex sets of structured and unstructured information (Basole et al. 2013). Basole et al. (2013) study illustrate the applicability of text analytics to a specific topic domain in the organizational and management sciences, but can be easily extended to other topics and fields.

In Feldman and Sanger (2007) opinion, text mining includes several disciplines such as, kaip natural language processing, information retrieval, information extraction, data mining, and computational linguistics. Text mining is based on a combination of technologies from information retrieval, information extraction, natural language processing, and statistics (Froelich and Ananyan 2008).

Text mining can be broadly defined as a knowledge-intensive process in which a user interacts with a document collection over time by using a suite of analysis tools. In a manner analogous to data mining, text mining seeks to extract useful information from data sources through the identification and exploration of interesting patterns. In the case of text mining, however, the data sources are document collections, and interesting patterns are found not among formalized database records but in the unstructured textual data in the documents in these collections (Feldman and Sanger 2007).

Text-mining systems are comprised of databases, linguistic parsing toolkits, dictionaries of terms and relations such as WordNet or MeSH, and a variety of rule based or probabilistic algorithms. These systems are semi-automatic, involving the application of both machine learning techniques and manual configuration of dictionaries such as lists of words to exclude, names of geographical locations, and syntactic rules. Text processing typically begins with tokenization, where words are extracted and stored in a structured format. In the next stage, tools augment information about the words, such as whether a word is a noun or a verb, or what does the word sound like, or what is the word's root form. With this information, tools focus on looking for entities such as names of people, organizations, dates, and locations. Systems also focus on looking at phrases and sequences of words, or how words are associated with one another based on the statistical analysis of how often words occur within a certain proximity of each other. Together these pieces of information represent key features of text that are used as input to classification systems which assign documents into predefined categories, or clustering systems which group together similar documents. The extracted information is stored so that it can be queried or used in a report or deployed into an operational environment such as a spam filter or a search engine or a stock trading application (Froelich and Ananyan 2008).

Because data mining assumes that data have already been stored in a structured format, much of its preprocessing focus falls on two critical tasks: Scrubbing and normalizing data and creating extensive numbers of table joins. In contrast, for text mining systems, preprocessing operations center on the identification and extraction of representative features for natural language documents. These preprocessing operations are responsible for transforming unstructured data stored in document collections into a more explicitly structured intermediate format, which is a concern that is not relevant for most data mining systems (Feldman and Sanger 2007).

Text mining can help an organization derive potentially valuable business insights from text-based content such as word documents, email and postings on social media streams like Facebook, Twitter and LinkedIn. Mining unstructured data with natural language processing, statistical modeling and machine learning techniques can be challenging, however, because natural language text is often inconsistent. It contains ambiguities caused by inconsistent syntax and semantics, including slang, language specific to vertical industries and age groups, double entendres and sarcasm (Text mining 2014).

Moreover, because of the centrality of natural language text to its mission, text mining also draws on advances made in other computer science disciplines concerned with the handling of natural language. Perhaps most notably, text mining exploits techniques and methodologies from the areas of information retrieval, information extraction, and corpus-based computational linguistics (Feldman and Sanger 2007).

Text analytics software can help by transposing words and phrases in unstructured data into numerical values which can then be linked with structured data in a database and analyzed with traditional data mining techniques. With an iterative approach, an organization can successfully use text analytics to gain insight into content-specific values such as sentiment, emotion, intensity and relevance. Because text analytics technology is still considered to be an emerging technology, however, results and depth of analysis can vary wildly from vendor to vendor (Text mining 2014).

Froelich and Ananyan (2008) deliberate various decision support via text mining technologies (tokenization, morphological analysis, quality improvement using string similarity, part of speech tagging, collocation analysis, named entity recognition, word association, summarization and concept analysis, classification, clustering, dictionaries). Several decision support via text mining technologies are presented next in-brief (Froelich and Ananyan 2008):

- Word Association. Word association involves the identification and representation of a relationship between any two words or phrases or entities. This type of association in product returns is a keymetric in identifying what influences customer purchase decisions. Analyzing word association can lead to a better understanding of key relationships in text.
- Summarization and Concept Analysis. Document summarization refers to the automated delivery of a concise representation of the contents of a document. Keyword extraction, or concept extraction, is the process of finding the best keywords or phrases which represent a set of documents. Keywords are typically conflated morphologically (inflected forms are merged) and ranked according to some measure of importance such as statistical significance, frequency, or term document frequency, or by the document count. The list of words is filtered by comparing words against a dictionary of words to ignore. A thesaurus may be supplied to provide synonyms that can be used to re-weight terms based on the term frequency and the net frequency of all the term's synonyms. Keyword extraction is one of the final outputs found in most text-mining applications. Along with keywords, summaries can be provided with search results to facilitate better and faster information retrieval. This task is dependent upon accurate weighting of concepts within the text.
- Classification. Document classification is the training of a classification model to assign documents to known categories. The first step is feature extraction, which is equivalent to finding the words or phrases that best represent a document, analogous to tokenization and summarization. Next, depending on the algorithm, specific keywords, frequencies, and other information are used to split the data or group the data according to mathematical or logical rules. The categories can be hierarchical to show a higher level of organization in the topics.
- Clustering. Text clustering places documents into groups based on a measure of similarity. Common algorithms include nearest neighbor and expectation maximization. Divisive clustering algorithms work from the top down, splitting a cluster into smaller clusters. Agglomerative clustering algorithms work from the bottom up, grouping together clusters into hierarchies. This process is similar to building a dendrogram, a tree-like graph of a hierarchy. Unlike text classification, clustering algorithms are not aware of the desired set of categories. The output of the clustering can be used, like keyword extraction or summarization, to obtain the gist of a set of documents at a glance.
- Semantic Analysis. Semantic analysis is the culmination of basic linguistic and statistical processing techniques to perform a deeper analysis of text. Application

domains such as competitive intelligence rely on the ability to identify names of people or places in documents in order to identify correlations and trends.

Various scientific examinations are being performed in the area of decision support via text analytics and mining, and decision support systems are being developed (Chan and Franklin 2011; Abrahams et al. 2012; Gerber 2014; He 2013; Khare and Chougule 2012; Rao and Dey 2011; Rexer et al. 2012; Toivonen et al. 2006; León et al. 2011; Froelich and Ananyan 2008; Cao et al. 2011; Li and Wu 2010; Jiao et al. 2007; Holton 2009). The examinations first mentioned are described in brief henceforth.

Although most quantitative financial data are analyzed using traditional statistical, artificial intelligence or data mining techniques, the abundance of online electronic financial news articles has opened up new possibilities for intelligent systems that can extract and organize relevant knowledge automatically in a usable format. Most information extraction systems require a hand-built dictionary of templates and thus need continual modification to accommodate new patterns that are observed in the text (Chan and Franklin 2011). Chan and Franklin (2011) propose a novel, text-based decision support system (DSS) that (i) extracts event sequences from shallow text patterns and (ii) predicts the likelihood of the occurrence of events using a classifier-based inference engine.

Abrahams et al. (2012) employ text mining on a popular social medium used by vehicle enthusiasts: online discussion forums. Abrahams et al. (2012) find that sentiment analysis, a conventional technique for consumer complaint detection, is insufficient for finding, categorizing, and prioritizing vehicle defects discussed in online forums and describe and evaluate a new process and decision support system for automotive defect identification and prioritization. The Abrahams et al. (2012) findings provide managerial insights into how social media analytics can improve automotive quality management.

Twitter is used extensively in the United States as well as globally, creating many opportunities to augment decision support systems with Twitter-driven predictive analytics. Twitter is an ideal data source for decision support: its users, who number in the millions, publicly discuss events, emotions, and innumerable other topics; its content is authored and distributed in real time at no charge; and individual messages (also known as tweets) are often tagged with precise spatial and temporal coordinates (Gerber 2014). Gerber (2014) presents research investigating the use of spatiotemporally tagged tweets for crime prediction. Gerber (2014) uses Twitter-specific linguistic analysis and statistical topic modeling to automatically identify discussion topics across a major city in the United States. Gerber (2014) then incorporates these topics into a crime prediction model and show that, for 19 of the 25 crime types studied, the addition of Twitter data improves crime prediction performance versus a standard approach based on kernel density estimation. Gerber (2014) identifies a number of performance bottlenecks that could impact the use of Twitter in an actual decision support system (Gerber 2014).

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After text collection is ready, different text mining algorithms such as text categorization, text clustering, concept/entity extraction, production of granular taxonomies, sentiment analysis, document summarization, entity relation modelling can be applied to identify key terms, concepts, categories, their frequencies of occurrence and case clusters from the text collection. During this step, CBR developers can use one or more specific text analytics and mining tools such as SPSS Clementine, NVivo 9 and Leximancer to facilitate the text analysis and mining process (He 2013).

Khare and Chougule (2012) present a decision support system 'Domain Aware Text & Association Mining (DATAM)' which has been developed to improve after-sales service and repairs for the automotive domain. A novel approach that compares textual and non-textual data for anomaly detection is proposed. It combines association and ontology based text mining. Association mining has been employed to identify the repairs performed in the field for a given symptom, whereas, text mining is used to infer repairs from the textual instructions mentioned in service documents for the same symptom. These in turn are compared and contrasted to identify the anomalous cases. The developed approach has been applied to automotive field data. Using the top 20 most frequent symptoms, observed in a mid-sized sedan built and sold in North America, it is demonstrated that DATAM can identify all the anomalous symptom – repair code combinations (with a false positive rate of 0.04). This knowledge, in the form of anomalies, can subsequently be used to improve the service/trouble-shooting procedure and identify technician training needs (Khare and Chougule 2012).

Rao and Dey (2011) developed text mining based DSS, which integrate unstructured textual data with predictive analytics to provide an environment for arriving at well-informed citizen-centric decisions in the context of e-governance.

In general, it is probably true that the majority of data analysis activities performed in support of solving some business or other problem involve simple tabulation and cross-tabulation of quantities. This is also true for text mining (or "text analytics"). Computing simple frequency tables or averages of terms can provide very useful information about the nature of the documents, the general sentiments or topics discussed in the documents and the trends or relationships with other variables. Simple text mining operations involve simple indexing and tabulation operations (Rexer et al. 2012).

The problem of the amount of available information has changed from scarcity to abundance. It is also common that a great amount of information appears both in numerical and symbolic form. Better tools for utilizing both quantitative and qualitative information are strongly needed (Toivonen et al. 2006). To help meet that need Toivonen et al. (2006) have developed decision support system for effective value creation management in a company and applied two methods, the self-organizing map (SOM) and text mining and focused them on the logistical decision making of companies.

In this research, an integrated expert system (IES) for the analysis and classification of all the available useful information of the customer is presented. Customer classification identifies the presence of non-technical losses (NTLs) and the problem type. This IES include several modules: text mining module for analysis of inspector commentaries and extraction of additional information on the customer, data mining module to draw up the rules that determine the customer estimate consumption and the Rule Based Expert System module to analyze each customer using the results of the text and data mining modules. IES is used as a Decision support system (DSS), as it contains another module which provides a report with additional information about the customer and a summarized result that the inspectors can use to reach a decision (León et al. 2011).

Froelich and Ananyan (2008) accented that not only companies, governments and individuals are able to make use of decision support via text mining competitive advantage but numerous industries can benefit from text mining including insurance, finance, consumer products, manufacturing, healthcare, life sciences, hospitality, retail, transportation, information technology, government, and education as well. Froelich and Ananyan (2008) also provide several decision support via text mining examples as follows:

- Spam Filtering. Traditional spam filters rely on probability to classify the e-mail as spam based on the presence of keywords. A statistical algorithm such as Naïve Bayes, Support Vector Machines or a decision tree is used to learn how specific keywords cause an e-mail to belong to the spam category.
- Market Research and Survey Analysis. Text mining can assist market researchers through analysis of open-ended survey responses, news articles, press releases, blogs, call center notes, and e-mails. Information about companies, products, major concerns, consumer expectation and other insight can be generated.
- Patent Research. Patents can be classified into a hierarchy of business terminology to assist in finding patents of interest. An analyst could use the set of online patent documents to develop a trend graph of the rise and fall of certain keywords or concepts over the decades to show overall trends in technology. A corporation looking to invest in a specific technology could assess whether prior patents exist. Similarly, a corporation could use its own technology patents as a guide and use text mining to identify similar patents based on frequencies of keywords to determine if infringement has occurred. A business could setup email alerts that monitor all new patent applications for the presence of keywords.
- Competitive Intelligence. Competitive intelligence applications use text mining to extract facts from web pages, industry journals, and newsgroups. Companies can compare themselves against competitors by looking at the density of specific marketing keywords to assess which company is likely to grab prospects from search engines. Companies can monitor competitors to avoid being late in introducing a new product or technology. Other results that can be found through text mining include identifying the direction of innovators, licensing opportunities, patent infringements, and trending and forecasting specific market ideas. Pricing information can be collated to provide a detailed picture of the market and assist in determining the proper cost structure.

- Brand Monitoring. Filters can be configured to monitor occurrences of specific brand keywords. Blogs and press releases can be classified as containing positive or negative comments about a brand. Typographical analysis of the domain name can identify similar domain names to monitor. Information extraction tools can highlight names of brand perpetrators in text and flag these for follow up.
- Job Search. Employers are receiving larger amounts of less specific applications, which have increased the time it takes to review the applications. Job seekers have a larger number of job descriptions to peruse. Both parties can benefit by incorporating text-mining software. Employers can use filters based on key-words to highlight specific applications or discard others. Employers can use the Internet as an additional source of information about an applicant and fill in missing data or look for associations between applications and whether those applicants have published desirable content on the web.

2.3 Data Mining as an Important Component of Intelligent Decision Support Systems

Data mining is applied often enough in fields such as decision support system, analytics, predictive analytics, data analysis, data warehouse, business intelligence, exploratory data analysis and web mining. The beginning of this section will present a short analysis on how data mining can enlarge the opportunities for intelligent decision support systems and their interdependencies as well as the technologies being used. This section will close by providing practical examples for the use of data mining in intelligent decision support systems and by describing what sorts of additional data mining opportunities could be applied in the future while developing IDSS.

Decision support systems (DSS) are a specific class of computerized information system that support business and organizational decision making activities. On the other hand, data mining extends the possibilities for decision support by discovering patterns and relationships hidden in the data and therefore enabling an inductive approach to data analysis (Khademolqorani and Hamadani 2013).

Data mining processes data from different perspectives into useful knowledge, and becomes an important component in designing intelligent decision support systems (IDSS) (Yang et al. 2012).

It has been estimated that the amount of stored information doubles every twenty months. Data mining is a term coined to describe the process of sifting through large databases for interesting patterns and relationships. Given the recent growth of the field, it is not surprising that a wide variety of data mining methods is now available to the researchers and practitioners. No one method is superior to others for all cases (Maimon and Rokach 2010).

Frameworks that bridge the gap between data mining analysis and predictions to actions and decisions in decision support are required to ensure better integration of the two methodologies (Khan et al. 2008). Khan et al. (2008) discuss the use of data mining technologies in the creation of DSS and allied systems for human use. One of the primary implementations of data mining technologies in interpreting business and scientific data is model-driven DSS. DSS can cater to multiple audiences as producers, suppliers, and customers share the same data and information through collaborative planning, forecasting, and replenishment processes (Khan et al. 2008).

Data mining is frequently applied to any form of large-scale data or information processing (collection, extraction, warehousing, analysis, and statistics) as well as any application of decision support system (Data mining 2012).

Data mining is the process of discovering valid, novel, and potentially useful patterns (i.e., knowledge nuggets) in very large data sets by use of a variety of advanced analytical techniques (Fayyad et al. 1996). If the data is textual in nature, then this discovery process is often called text mining (Demirkan and Delen 2013).

There are many methods of Data mining used for different purposes and goals. It is useful to distinguish between two main types of Data mining: verification-oriented (the system verifies the user's hypothesis) and discovery-oriented (the system finds new rules and patterns autonomously). Discovery methods are those that automatically identify patterns in the data. The discovery method branch consists of prediction methods versus description methods. Descriptive methods are oriented to data interpretation, which focuses on understanding (by visualization for example) the way the underlying data relates to its parts (Maimon and Rokach 2010).

The process of data mining converts information to knowledge by using tools from the disciplines of computational statistics, database technologies, machine learning, signal processing, nonlinear dynamics, process modeling, simulation, and allied disciplines. Data mining allows business problems to be analyzed from diverse perspectives, including dimensionality reduction, correlation and co-occurrence, clustering and classification, regression and forecasting, anomaly detection, and change analysis. The predictive insights generated from data mining can be further utilized through real-time analysis and decision sciences, as well as through human-driven analysis based on management by exceptions or objectives, to generate actionable knowledge. The tools that enable the transformation of raw data to actionable predictive insights are collectively referred to as decision support tools (Khan et al. 2008).

Some research in AI, focused on enabling systems to respond to novelty and uncertainty in more flexible ways has been successfully used in IDSS. For example, data mining in AI that searches for hidden patterns in a database has been used in a range of decision support applications. The data mining process involves identifying an appropriate data set to mine or sift through to identify relations and rules for IDSS. Data mining tools include techniques like case-based reasoning, clustering analysis, classification, association rule mining, and data visualization. Data mining increases the "intelligence" of DSS and becomes an important component in designing IDSS (Yang et al. 2012).

The process of knowledge discovery in databases (KDD) is consisting of nine steps (Maimon and Rokach 2010):

1. Developing an understanding of the application domain. The people who are in charge of a KDD project need to understand and define the goals of the end-user and the environment in which the knowledge discovery process will take place.
2. Selecting and creating a data set on which discovery will be performed. Having defined the goals, the data that will be used for the knowledge discovery should be determined. This includes finding out what data is available, obtaining additional necessary data, and then integrating all the data for the knowledge discovery into one data set, including the attributes that will be considered for the process.
3. Preprocessing and cleansing. In this stage, data reliability is enhanced. It includes data clearing, such as handling missing values and removal of noise or outliers.
4. Data transformation. In this stage, the generation of better data for the data mining is prepared and developed. Methods here include dimension reduction (such as feature selection and extraction, and record sampling), and attribute transformation (such as discretization of numerical attributes and functional transformation).
5. Choosing the appropriate Data mining task. We are now ready to decide on which type of Data mining to use, for example, classification, regression, or clustering. This mostly depends on the KDD goals, and also on the previous steps. There are two major goals in Data mining: prediction and description. Prediction is often referred to as supervised Data mining, while descriptive Data mining includes the unsupervised and visualization aspects of Data mining. Most data mining techniques are based on inductive learning, where a model is constructed explicitly or implicitly by generalizing from a sufficient number of training examples.
6. Choosing the Data mining algorithm. Having the strategy, we now decide on the tactics. This stage includes selecting the specific method to be used for searching patterns (including multiple inducers). For example, in considering precision versus understandability, the former is better with neural networks, while the latter is better with decision trees. Thus, this approach attempts to understand the conditions under which a Data mining algorithm is most appropriate. Each algorithm has parameters and tactics of learning (such as ten-fold cross-validation or another division for training and testing).
7. Employing the Data mining algorithm. Finally the implementation of the Data mining algorithm is reached. In this step we might need to employ the algorithm several times until a satisfied result is obtained, for instance by tuning the algorithm's control parameters, such as the minimum number of instances in a single leaf of a decision tree.
8. Evaluation. In this stage we evaluate and interpret the mined patterns (rules, reliability etc.), with respect to the goals defined in the first step.
9. Using the discovered knowledge. We are now ready to incorporate the knowledge into another system for further action. There are many challenges in this step, such as losing the "laboratory conditions" under which we have operated. For instance, the knowledge was discovered from a certain static snapshot

(usually sample) of the data, but now the data becomes dynamic. Data structures may change (certain attributes become unavailable), and the data domain may be modified (such as, an attribute may have a value that was not assumed before).

Data mining is applied in various areas of human activity as IDSS is being developed. Brief descriptions of several of them follow.

The use of automated data mining techniques to support pre-established DSS tasks is one implementation of emerging technologies. The ability to merge information from various sources and blend different points of view to create one-number forecasts is a key first step towards enterprise-scale strategic, operational and tactical planning (Khan et al. 2008).

The objective of this research is to provide decision support to assembly line planners when they perform assembly time estimations. There is a lack of consistency in the assembly time analysis performed by planners. The decision support system that was developed in this research is based on mapping controlled language assembly work instructions to Methods-Time Measurement (MTM) tables. Automated analysis of historical work instructions and their related time study analysis were performed by employing knowledge discovery and data mining (KDD) algorithms through the Waikato Environment for Knowledge Analysis (WEKA) interface. As a result of this automated analysis, forty-six mapping rules were created that related work instructions to MTM tables and the data backbone for the decision support system that was created. Analyzing big historical data is crucial while creating decision support systems. KDD provides a sustainable method of analyzing big data (Renu et al. 2013).

Liu (2009) develops a decision support tool for liability authentications of two-vehicle crashes based on generated self-organizing feature maps (SOM) and data mining (DM) models. Factors critical to liability attributions commonly identified theoretically and practically were first selected. Both SOM and DM models were then generated for frontal, side, and rear collisions of two-vehicle crashes. Appropriateness of all generated models was evaluated and confirmed. Finally, a decision support tool was developed using active server pages. Although with small data size, the decision support system was considered capable of giving reasonably good liability attributions and references on given cases (Liu 2009).

El-Sappagh and El-Masri (2014) propose an open and distributed clinical decision support system architecture. This technical architecture takes advantage of Electronic Health Record (EHR), data mining techniques, clinical databases, domain expert knowledge bases, available technologies and standards to provide decision-making support for healthcare professionals. The architecture will work extremely well in distributed EHR environments in which each hospital has its own local EHR, and it satisfies the compatibility, interoperability and scalability objectives of an EHR. The system will also have a set of distributed knowledge bases. Each knowledge base will be specialized in a specific domain (i.e., heart disease), and the model achieves cooperation, integration and interoperability between these knowledge bases. Moreover, the model ensures that all knowledge bases are up-to-date by connecting data mining engines to each local knowledge base. These data mining engines continuously mine EHR databases to extract the most recent knowledge, to standardize it and to add it to the knowledge bases. This framework is expected to improve the quality of healthcare, reducing medical errors and guaranteeing the safety of patients by helping clinicians to make correct, accurate, knowledgeable and timely decisions (El-Sappagh and El-Masri 2014).

Kisilevich et al. (2013) present a GIS-based decision support system that can both, estimate objective hotel room rates using essential hotel and locational characteristics and predict temporal room rate prices. Information about objective hotel room rates allows for an objective comparison and provides the basis for a realistic computation of the contract's profitability. The temporal prediction of room rates can be used for monitoring past hotel room rates and for adjusting the price of the future contract. This research makes three major contributions (Kisilevich et al. 2013). First, Kisilevich et al. (2013) present a GIS-based decision support system, the first of its kind, for hotel brokers. Second, the DSS can be applied to virtually any part of the world, which makes it a very attractive business tool in real-life situations. Third, it integrates a widely used data mining framework that provides access to dozens of ready to run algorithms to be used by a domain expert and it offers the possibility of adding new algorithms once they are developed (Kisilevich et al. 2013).

Decision support systems (DSSs) perform complex computations to provide suggestions regarding decision-making and problem solving. Quite often, the DSS solutions are not fully accepted by users because DSSs work as a black box so that the users cannot fully understand where the results came from and how they were derived. Explanations of the generated DSSs solutions are expected to mitigate this situation. In this research, two machine-learning techniques, called rough set analysis (RSA) and dependency network analysis (DNA), are proposed for mining DSS solutions. The mining results are provided to the users as explanations for those solutions. Two parts of research results are described. First, a framework applying RSA and DNA for generating explanations for DSS solutions is presented. This framework is generic and applicable to many other DSSs. Second, as a proof-of-concept, the applications of RSA and DNA techniques are demonstrated through a case study of mining patterns from input-output pairs of ReleasePlanner™, a specific DSS for product release planning (Du and Ruhe 2014). Du and Ruhe (2014) evaluation indicates that the explanations generated by RSA and DNA improve the overall user acceptance of results provided by this specific DSS.

Data envelopment analysis (DEA) has proven to be a useful tool for assessing efficiency or productivity of organizations, which is of vital practical importance in managerial decision making. DEA provides a significant amount of information from which analysts and managers derive insights and guidelines to promote their existing performances. The main objective of this research is to develop a general decision support system (DSS) framework to analyze the results of basic DEA models. The research formally shows how the results of DEA models should be structured so that these solutions can be examined and interpreted by analysts through information visualization and data mining techniques effectively (Akçay et al. 2012).

Decision-making for the debris-flow management involves multiple decision-makers often with concerning geomorphological and hydraulic conditions. Spatial decision support systems can be developed to improve our understanding of the relations among the natural and socio-economic variables to the occurrence/non-occurrence samples of debris-flow. Accordingly, the goal of this study is to development a debris-flow decision support system to manage and monitor the debris-flows in Nan-Tou County, Taiwan. The present study, more specifically, combines a spatial decision support system with an advanced Data mining technique to investigate the debris-flow problem. In the first stage, the spatial decision support system integrates remote sensing, and aerial photos as three different resources to generate our spatial database. Each of the geomorphological and hydraulic attributes is obtained automatically through our spatial database. Then, a Data mining classifier (hybrid model of decision tree + support vector machine) will be used to analyze and resolve the classification of occurrence of debris-flow (Wan and Lei 2009).

Rupnik and Kukar (2007) introduce decision support system called Data Mining Decision Support System (DMDSS), which is based on data mining. DMDSS enables integration of data mining into decision processes by enabling repeated creation of data mining models. In DMDSS, data mining models are created by data mining experts and exploited by business users. DMDSS supports two roles: data mining expert and business user. Each of the roles has the access to the forms and their functionalities according to the production stage of the process model. DMDSS enables the use of the following data mining methods: classification, clustering and association rules. Depending on the nature of the area of analysis the DMDSS enables the use of one or more data mining methods within the area of analysis. DMDSS is a data mining based decision support system which supports decision processes based on the knowledge acquired from data mining models: rules, patterns and relationships. It is a passive DSS, because it supports decision processes through new knowledge acquired without producing explicit decision suggestions or solutions. The mission of DMDSS is to offer an easy-to-use tool which enables business users to exploit data mining models with only a basic level of understanding of the data mining concepts, which enables them to interpret the models correctly. The process model of DMDSS defines the roles of business user and data mining expert, where phases that demand expertise in data mining are performed by data mining expert and are hidden from business user. Business users only exploit data mining models, which are created by data mining expert (Rupnik and Kukar 2007).

Maimon and Rokach (2010) see several trends for future research and implementation, including (Maimon and Rokach 2010):

- Mining complex objects of arbitrary type – Expanding Data mining inference to include also data from pictures, voice, video, audio, etc. This will require adapting and developing new methods (for example, for comparing pictures using clustering and compression analysis).
- Temporal aspects - many data mining methods assume that discovered patterns are static. However, in practice patterns in the database evolve over time. This poses two important challenges. The first challenge is to detect when concept drift occurs. The second challenge is to keep the patterns up-to-date without inducing the patterns from scratch, etc.

2.4 Integration of Data Analytics and Decision Support Systems

Lately data analytics has been becoming more and more popular. However, data analytics are rarely used as composite parts of IDSS. This section contains a short description of the integration of data analytics and decision support systems.

Predictive analytics is the branch of data mining concerned with forecasting probabilities. The technique uses variables that can be measured to predict the future behavior of a person or other entity. Multiple predictors are combined into a predictive model. In predictive modeling, data is collected to create a statistical model, which is tweaked as additional data becomes available (Matlis 2006).

Kwon et al. (2014) define big data analytics as technologies (e.g., database and data mining tools) and techniques (e.g., analytical methods) that a company can employ to analyze large scale, complex data for various applications intended to augment firm performance in various dimensions.

In recent years, numerous machine learning techniques (Multilayer Perceptron, Neural networks, k-nearest neighbours, Radial basis functions, Geospatial predictive modelling, Support vector machines, Naïve Bayes), open source predictive analytic tools (KNIME, Orange, RapidMiner, Weka, R) and commercial predictive analytic tools (BIRT Analytics, IBM SPSS Statistics, IBM SPSS Modeler, KXEN Modeler, Pervasive, SAS, STATISTICA, TIBCO) have been used for predictive analytics.

Analytics refers to quantitative and statistical analysis of data. Analytic capabilities are important in both data-driven and model-driven DSS. Analysis using quantitative and statistical tools is the focus of ad hoc and routine special studies. Various sources identify three categories of analytics: 1) reporting, 2) prescriptive, and 3) predictive. Reporting summarizes data using descriptive statistics. Prescriptive analysis uses data to inform a recommendation for action. Prediction involves causal or correlational analysis. Analytics refers to a broad set of information systems and capabilities that are generally decision support applications (Power 2012a).

Analytics software encompasses three main technologies: 1) database management, 2) mathematical and statistical analysis and models, and 3) data visualization and display. Reporting analytics focuses on generating reports and visualizations from organizational data stores. That task is the main purpose of business intelligence (BI) software. In general, data-driven DSS and business intelligence are considered reporting or data analytic applications. Prescriptive analytics manipulate large data sets to make recommendations. Predictive analytics are based upon quantitative and statistical models and this category of analytics includes model-driven DSS. Analytics includes a broad spectrum of computer-based analyses used to support fact-based decisions (Power 2012a).

Analytics may be part of a data-driven or a model-driven DSS. Predictive analytics is about using models for predicting behavior or results. Predictive analytics can help managers make choices and develop competitive actions. Many banks use analytics and model-driven DSS when making credit and lending decisions. Model-driven DSS may assist in forecasting product demand, aid in employee scheduling, develop pro forma financial statements or assist in choosing plant or warehouse locations. Model-driven DSS are developed for various purposes using a variety of quantitative and statistical techniques. Model-driven decision support provides managers with models and analysis capabilities to use during the process of making a decision. The range and scope of model-driven DSS is very large (Power 2012b).

Two characteristics differentiate a model-driven DSS from the computer support used for a decision analytic: (1) a model in a model-driven DSS is made accessible to a non-technical specialist such as a manager through an easy to use interface, and (2) a specific DSS is intended for some repeated use in the same or a similar decision situation. The general types of quantitative models used in model-driven DSS include algebraic and differential equation models, various decision analysis tools including analytical hierarchy process, decision matrix and decision tree, multi-attribute and multi-criteria models, forecasting models, network and optimization models, Monte Carlo and discrete event simulation models, and quantitative behavioral models for multi-agent simulations (Power and Sharda 2007).

Data analytics are being developed in various areas of human activity. However, they are rarely integrated with decision support systems. Several of such rare examples are briefly described below.

Although the necessity of large-scale data analysis for product design is now being recognized broadly, only a few researchers have attempted to analyze large-scale data in the context of product and design analytics (Ma et al. 2014). Ma et al. (2014) propose Demand Trend Mining (DTM) as one of the analysis tools for large-scale data in order to capture the trend of demand as a function of design attributes.

Electronic Health Record (EHR) system contain large volumes of patient data that could be used for Comparative Effectiveness Research (CER), but the data contained in EHR system are typically accessible only in formats that are not conducive to rapid synthesis and interpretation of therapeutic outcomes. In the time-pressured clinical setting, clinicians faced with large amounts of patient data in formats that are not readily interpretable often feel ‘information overload’. Decision support tools that enable rapid access at the point of care to aggregate data on the most effective therapeutic outcomes derived from CER would greatly aid the clinical decision-making process and individualize patient care (Mane et al. 2012). Mane et al. (2012) highlight the role that visual analytics can play in CER-based clinical decision support. Mane et al. (2012) developed a 'VisualDecisionLinc' (VDL) tool prototype that uses visual analytics to provide summarized CER-derived data views to facilitate rapid interpretation of large amounts of data. Mane et al. (2012) highlight the flexibility that visual analytics offers to gain an overview of therapeutic options and outcomes and if needed, to instantly customize the evidence to the needs of the patient or clinician.

Souza (2014) describes the application of advanced analytics techniques to supply chain management. The applications are categorized in terms of descriptive, predictive, and prescriptive analytics and along the supply chain operations reference (SCOR) model domains plan, source, make, deliver, and return. Descriptive analytics applications center on the use of data from global positioning systems (GPSs), radio frequency identification (RFID) chips, and data-visualization tools to provide managers with real-time information regarding location and quantities of goods in the supply chain. Predictive analytics centers on demand forecasting at strategic, tactical, and operational levels, all of which drive the planning process in supply chains in terms of network design, capacity planning, production planning, and inventory management. Finally, prescriptive analytics focuses on the use of mathematical optimization and simulation techniques to provide decision-support tools built upon descriptive and predictive analytics models (Souza 2014).

MERRA Analytic Services (MERRA/AS) enables MapReduce analytics over NASA's Modern-Era Retrospective Analysis for Research and Applications (MERRA) data collection. The MERRA reanalysis integrates observational data with numerical models to produce a global temporally and spatially consistent synthesis of 26 key climate variables. It represents a type of data product that is of growing importance to scientists doing climate change research and a wide range of decision support applications. MERRA/AS brings together the following generative elements in a full, end-to-end demonstration of CAaaS capabilities: (1) high-performance, data proximal analytics, (2) scalable data management, (3) software appliance virtualization, (4) adaptive analytics, and (5) a domain-harmonized API (Schnase et al. 2014).

2.5 Artificial Neural Networks in Decision Support Systems and Biometrics

The special focus in this section is on the integration of decision support systems, neural networks and biometrics.

Artificial Neural Network (ANN) enables modeling complex nonlinear relations and providing decision support. ANN is inspired by the structure of biological neural networks, and it starts by assigning random weights to included variables and then adjusting these weights in a feed-forward, back-propagation style to minimize the difference between the actual and predicted outputs. The neurons in the hidden layer transfer the weighted input data to the output using nonlinear transfer function (Xu et al. 2013, Bishop 1995). Neural networks (NNs) are defined as massively parallel processors, which tend to preserve the experimental knowledge and enable their further use. They simulate the human brain with the intent to collect the empirical evidence during the learning process, and inter-neural connections (synapses) are used to store the knowledge (Hájek 2011, Haykin 1999).

Delen and Sharda (2008) introduce the concepts of neural networks and present an overview of the applications of neural networks in decision support systems (DSS). Neural networks can be viewed as supporting at least two types of DSS: data driven and model-driven. First, neural networks can be employed as data analysis tools for forecasting and prediction based on historical data in a data-driven DSS. Second, neural networks also can be viewed as a class of quantitative models to be used in a model-driven DSS (Delen and Sharda 2008). DSS employing a neural network are being developed in various areas of human activity (Sidiropoulos et al. 2012; Tsadiras et al. 2013; Arsene et al. 2012; Azadeh et al. 2012; Delen and Sharda 2008; Mendyk et al. 2013; Abpeykar and Ghatee 2014). Next there is a short description of several DSS that were first mentioned as employing a neural network.

A new strategy is introduced by Sidiropoulos et al. (2012) for designing and developing of an efficient dynamic Decision Support System (DSS) for supporting rare cancers decision making. The proposed DSS operates on a Graphics Processing Unit (GPU) and it is capable of adjusting its design in real time based on user-defined clinical questions in contrast to standard CPU implementations that are limited by processing and memory constrains. The core of the proposed DSS was a Probabilistic Neural Network classifier and was evaluated on 140 rare brain cancer cases, regarding its ability to predict tumors' malignancy, using a panel of 20 morphological and textural features Generalization was estimated using an external 10-fold cross-validation.

An Artificial Neural Network (ANN) based decision support system is developed by Tsadiras et al. (2013) to assist production line designers in making decisions concerning the Buffer Allocation Problem in reliable production lines. Arsene et al. (2012) present an efficient and effective decision support system (DSS) for operational monitoring and control of water distribution systems based on a three layer General Fuzzy Min–Max Neural Network (GFMMNN) and graph theory.

Developing decision support system can overcome the issues with personnel attributes and specifications. Personnel specifications have greatest impact on total efficiency. They can enhance total efficiency of critical personnel attributes (Azadeh et al. 2012). Azadeh et al. (2012) present an intelligent integrated decision support system for forecasting and optimization of complex personnel efficiency. DSS assesses the impact of personnel efficiency by data envelopment analysis (DEA), artificial neural network (ANN), rough set theory (RST), and K-Means clustering algorithm.

Quteishat, Lim, Tweedale and Jain (2009) propose a neural network (NN)-based multi-agent classifier system (MACS) using the trust, negotiation, and communication (TNC) reasoning model. The main contribution of this work is that a novel trust measurement method, based on the recognition and rejection rates, is proposed. Besides, an auctioning procedure, based on the sealed bid, first price method, is adapted for the negotiation phase. Two agent teams are formed; each consists of three NN learning agents. The first is a fuzzy min–max (FMM) NN agent team and the second is a fuzzy ARTMAP (FAM) NN agent team. Modifications to the FMM and FAM models are also proposed so that they can be used for trust measurement in the TNC model. To assess the effectiveness of the proposed model and the bond (based on trust), five benchmark data sets are tested (Quteishat, Lim, Tweedale and Jain 2009).

Tran, Abraham and Jain (2004) suggests a decision support system for tactical air combat environment where not much prior information is available about the decision regions. Tran, Abraham and Jain (2004) proposed a combination of unsupervised learning for clustering the data (to develop decision regions) and a feed forward neural network to classify the decision regions accurately. The clustered data is used as the inputs to the multi-layered feed forward neural network, which is trained using several higher order learning paradigms. The decision support system not only requires being intelligent but also should incorporate human machine interaction and consider human as the integral part of the system. The Decision support systems using hybrid neurocomputing (CWA) is a system design technique to provide corporation between the human and computing system. CWA is suitable to analyze complex systems that has high-level of cognitive input from human operators, which contributes to the strong success during unpredictable situations and assist hard decision-making. The decision support system should have high level of automation and information integration with a role of operation shift to high task level that involves problem solving, hard decision making, conceptual understanding, planning and workload management (Tran, Abraham and Jain 2004).

Applications in theory and in practice involve the integration of various types of neural networks (Feedforward neural network, Radial basis function network, Kohonen self-organizing network, Learning Vector Quantization, Recurrent neural network, Modular neural networks, Physical neural network and other types of networks) and biometrics (DNA Matching, Ear, Eyes [iris and retina], Face, Fingerprint, Finger Geometry, Gait, Odour, Signature, Typing, Vein and Voice [Speaker Verification/Authentication and Speaker Identification]). For example, artificial neural networks (i. e., systems that learn from data) have been used in different biometric applications involving pattern classification and identification (of a human [Dinkar and Sambyal 2012, Melin et al. 2012], of driver [Wu and Ye 2009], of finger-vein patterns [Wu and Liu 2011], of iris recognition [Sibai et al. 2011], of human action [Youssef and Asari 2013], of gait [Zeng and Wang 2012], of the face [Connolly et al. 2013; Kuo et al. 2011; Choi et al. 2012; Banerjee and Datta 2013; Lin and Lin 2013; Müller et al. 2013], of the hand [Michael et al. 2008], of the skin [Zaidan et al. 2014], by keystroke [Uzun and Bicakci 2012] and by gesture, speech, handwritten text recognition and the like). Various biometric systems are being developed in such a manner (face recognition, fingerprint identification, hand geometry biometrics, retina scan, iris scan, signature, voice analysis, palm vein authentication and others). This is accomplished by the application of different types of neural networks. The aforementioned scientific researches are next described in brief.

Dinkar and Sambyal (2012) present new insights and experimental results for the use of ears as a non-invasive biometric for human identification. To determine the uniqueness of the external ear pattern two methods were employed: The Weighted Scoring System and Pattern Recognition by Neural networks. A total of 10 external ear features classified into 37 sub-features for both right and left ears of 400 Indians of Goan origin were studied after acquiring standardized side profile digital photographs. These features were then converted to numeric scores by the 'Weighted Scoring System' which were then compared to ascertain the uniqueness of ear pattern in same and different individuals. The digital analysis of visually similar ear images by Neural networks revealed a recognition rate of 94% with an Equal Error Rate at threshold value of 0.225 (Dinkar and Sambyal 2012).

Sibai et al. (2011) present a simple methodology for pre-processing iris images and the design and training of a feedforward artificial neural network for iris recognition.

Melin et al. (2012) propose a new approach to genetic optimization of modular neural networks with fuzzy response integration. The architecture of the modular neural network and the structure of the fuzzy system (for response integration) are designed using genetic algorithms. The proposed methodology is applied to the case of human recognition based on three biometric measures, namely iris, ear, and voice (Melin et al. 2012).

Youssef and Asari (2013) consider developing a taxonomic shape driven algorithm to solve the problem of human action recognition and develop a new feature extraction technique using hull convexity defects. To test and validate this approach, Youssef and Asari (2013) use silhouettes of subjects performing ten actions from a commonly used video database by action recognition researchers. Testing and training of the nine test subjects is performed using a leave one out methodology. Classification utilizes both PCA and minimally encoded neural networks (Youssef and Asari 2013).

Recognition of temporal/dynamical patterns is among the most difficult pattern recognition tasks. Human gait recognition is a typical difficulty in the area of dynamical pattern recognition. It classifies and identifies individuals by their time-varying gait signature data (Zeng and Wang 2012). Zeng and Wang (2012) present a new model-based approach for human gait recognition via the aforementioned method, specifically for recognizing people by gait. The approach consists of two phases: a training (learning) phase and a test (recognition) phase. In the training phase, side silhouette lower limb joint angles and angular velocities are selected as gait features. Locally-accurate identification of the gait system dynamics is achieved by using radial basis function neural networks through deterministic learning (Zeng and Wang 2012).

A driver identification system using finger-vein technology and an artificial neural network is presented by Wu and Ye (2009). The principle of the proposed system is based on the function of near infra-red finger-vein patterns for biometric authentication. Finger-vein patterns are required by transmitting near infra-red through a finger and capturing the image with an infra-red CCD camera. The algorithm of the proposed system consists of a combination of feature extraction using Radon transform and classification using the neural network technique. The Radon transform can concentrate the information of an image in a few high-valued coefficients in the transformed domain. The neural networks are used to develop the training and testing modules. The artificial neural network techniques using radial basis function network and probabilistic neural network are proposed to develop a driver identification system (Wu and Ye 2009).

Due to a limited control over changing operational conditions and personal physiology, systems used for video-based face recognition are confronted with complex and changing pattern recognition environments. Although a limited amount of reference data is initially available during enrollment, new samples often become available over time, through re-enrollment, post analysis and labeling of operational data, etc. (Connolly et al. 2013).

Kuo et al. (2011) propose an improved photometric stereo scheme based on improved kernel-independent component analysis method to reconstruct 3D human faces. Next, Kuo et al. (2011) fetch the information of 3D faces for facial face recognition. For reconstruction, Kuo et al. (2011) obtain the correct normal vector's sequence to form the surface, and use a method for enforcing integrability to reconstruct 3D objects. Kuo et al. (2011) test the algorithm on a number of real images captured from the Yale Face Database B, and use three kinds of methods to fetch characteristic values. Those methods are called contour-based, circle-based, and feature-based methods. Then, a three-layer, feed-forward neural network trained by a back-propagation algorithm is used to realize a classifier. All the experimental results were compared to those of the existing human face reconstruction and recognition approaches tested on the same images (Kuo et al. 2011).

Michael et al. (2008) propose to use a low-resolution web camera to capture the user's hand at a distance for recognition. The users do not need to touch any device for their palm print to be acquired. A novel hand tracking and palm print region of interest extraction technique are used to track and capture the user's palm in real-time video stream. The discriminative palm print features are extracted based on a new method that applies local binary pattern texture descriptor on the palm print directional gradient responses. Experiments show promising result using the proposed method. Performance can be further improved when a modified probabilistic neural network is used for feature matching. Verification can be performed in less than one second in the proposed system (Michael et al. 2008).

Due to the rapid growth of social network services such as Facebook and Twitter, incorporation of face recognition in these large-scale web services is attracting much attention in both academia and industry. The major problem in such applications is to deal efficiently with the growing number of samples as well as local appearance variations caused by diverse environments for the millions of users over time (Choi et al. 2012). Choi et al. (2012) focus on developing an incremental face recognition method for Twitter application. Particularly, a data-independent feature extraction method is proposed via binarization of a Gabor filter. Subsequently, the dimension of the Gabor representation is reduced considering various orientations at different grid positions. Finally, an incremental neural network is applied to learn the reduced Gabor features. Choi et al. (2012) apply the proposed method to a novel application which notifies new photograph uploading to related users without having their ID being identified.

Skin colour is considered to be a useful and discriminating spatial feature for many skin detection-related applications, but it is not sufficiently robust to address complex image environments because of light-changing conditions, skin-like colours and reflective glass or water. These factors can create major difficulties in face pixel-based skin detectors when the colour feature is used (Zaidan et al. 2014). Thus, Zaidan et al. (2014) propose a multi-agent learning method that combines the Bayesian method with a grouping histogram technique and the back-propagation neural network with a segment adjacent-nested technique based on the YCbCr and RGB colour spaces, respectively, to improve skin detection performance (Zaidan et al. 2014).

Banerjee and Datta (2013) propose an improved strategy for face recognition using correlation filter under varying lighting conditions and occlusion where spatial domain preprocessing is carried out by two convolution kernels. The first convolution kernel is a contour kernel for emphasizing high frequency components of face image and the other kernel is a smoothing kernel used for minimization of noise those may arise due to preprocessing. The convolution kernels are obtained by training a generalized regression neural network using enhanced face features (Banerjee and Datta 2013).

Human face recognition has been generally researched for the last three decades. Face recognition with thermal image has begun to attract significant attention gradually since illumination of environment would not affect the recognition performance. However, the recognition performance of traditional thermal face recognizer is still insufficient in practical application (Lin and Lin 2013). Lin and Lin (2013) present a novel thermal face recognizer employing not only thermal features but also critical facial geometric features which would not be influenced by hair style to improve the recognition performance. A three-layer back-propagation feedforward neural network is applied as the classifier. Traditional thermal face recognizers only use the indirect information of the topography of blood vessels like thermogram as features. To overcome this limitation, the proposed thermal face recognizer can use not only the indirect information but also the direct information of the topography of blood vessels which is unique for every human. Moreover, the recognition performance of the proposed thermal features would not decrease even if the hair of frontal bone varies, the eye blinks or the nose breathes. Experimental results show that the proposed features are significantly more effective than traditional thermal features and the recognition performance of thermal face recognizer is improved (Lin and Lin 2013).

Keystroke Dynamics, which is a biometric characteristic that depends on typing style of users, could be a viable alternative or a complementary technique for user authentication if tolerable error rates are achieved. Most of the earlier studies on Keystroke Dynamics were conducted with irreproducible evaluation conditions therefore comparing their experimental results are difficult, if not impossible. One of the few exceptions is the work done by Killourhy and Maxion, which made a dataset publicly available, developed a repeatable evaluation procedure and evaluated the performance of different methods using the same methodology. In their study, the error rate of neural networks was found to be one of the worst-performing (Uzun and Bicakci 2012). Uzun and Bicakci (2012) have a second look at the performance of neural networks using the evaluation procedure and dataset same as in Killourhy and Maxion's work. Uzun and Bicakci (2012) find that performance of artificial neural networks can outperform all other methods by using negative examples.

Autonomous learning is demonstrated by living beings that learn visual invariances during their visual experience. Standard neural network models do not show this sort of learning (Müller et al. 2013). On the example of face recognition in different situations Müller et al. (2013) propose a learning process that separates learning of the invariance proper from learning new instances of individuals. The invariance is learned by a set of examples called model, which contains instances of all situations. New instances are compared with these on the basis of rank lists, which allow generalization across situations. The result is also implemented as a spike-time-based neural network, which is shown to be robust against disturbances. The learning capability is demonstrated by recognition experiments on a set of standard face databases (Müller et al. 2013).

Wu and Liu (2011) present a personal identification system using finger-vein patterns with component analysis and neural network technology. In the proposed system, the finger-vein patterns are captured by a device that can transmit near infrared through the finger and record the patterns for signal analysis. The proposed biometric system for verification consists of a combination of feature extraction using principal component analysis and pattern classification using back-propagation network and adaptive neuro-fuzzy inference system (Wu and Liu 2011).

2.6 Integration of Remote Sensing into a Decision Support Systems

Recently a more active integration into decision support systems (DSSs) is occurring involving active remote sensing (when a signal is first emitted from aircraft or satellites) and passive remote sensing (photography, infrared, charge-coupled devices, radiometers). There are several characteristic example of such an integration (Meyer et al. 2014; Eckman and Stackhouse 2012; Lu et al. 2014; Bonazountas et al. 2007; Qi and Altinakar 2011; Wu et al. 2009; Powell et al. 2008), which are presented next.

Remote sensing plays a critical role in operational volcano monitoring due to the often remote locations of volcanic systems and the large spatial extent of potential eruption pre-cursor signals. Despite the all-weather capabilities of radar remote sensing and its high performance in monitoring of change, the contribution of radar data to operational monitoring activities has been limited in the past (Meyer et al. 2014). Meyer et al. (2014) present new data processing and data integration techniques that mitigate some of these limitations and allow for a meaningful integration of radar data into operational volcano monitoring decision support systems. For a demonstration, Meyer et al. (2014) present an integration of the processing system with an operational volcano monitoring system that was developed for use by the Alaska Volcano Observatory.

Earth observations are playing an increasingly significant role in informing decision making in the energy sector. In renewable energy applications, space-based observations now routinely augment sparse ground-based observations used as input for renewable energy resource assessment applications (Eckman and Stackhouse 2012). Eckman and Stackhouse (2012) describe a coordinated program of demonstration projects conducted by Global Earth Observation System of Systems (GEOSS) member agencies and partners to utilize Earth observations to enhance energy management end-user decision support systems.

Building information is one of the key elements for a range of urban planning and management practices. In this study, an investigation was performed to classify buildings delineated from light detection and ranging (LiDAR) remote sensing data into three types: single-family houses, multiple-family houses, and non-residential buildings. Four kinds of spatial attributes describing the shape, location, and surrounding environment of buildings were calculated and subsequently employed in the classification. The shape attributes, such as width, footprint area, and perimeter, were most useful for identifying building types. Environmental landscape attributes surrounding buildings, such as the number of road and parking lot pixels, also contributed to obtaining building type information. Combining shape and environmental landscape attributes was necessary to obtain accurate and consistent classification results (Lu et al. 2014).

Southern Europe is exposed to anthropogenic and natural forest fires. These result in loss of lives, goods and infrastructure, but also deteriorate the natural environment and degrade ecosystems. The early detection and combating of such catastrophes requires the use of a decision support system (DSS) for emergency management (Bonazountas et al. 2007). Bonazountas et al. (2007) present the results of scientific research aiming to the development of a DSS for managing forest fires. The system integrates GIS technologies under the same data environment and utilises a common user interface to produce an integrated computer system based on semi-automatic satellite image processing (fuel maps), socio-economic risk modelling and probabilistic models that would serve as a useful tool for forest fire prevention, planning and management (Bonazountas et al. 2007).

A new decision support system has been developed for integrated flood management within the framework of ArcGIS based on realistic two dimensional flood simulations. This system has the ability to interact with and use classified Remote sensing (RS) image layers and other GIS feature layers like zoning layer, survey database and census block boundaries for flood damage calculations and loss of life estimations. The analysis of a dam break flood management strategy for Sinclair Dam in Georgia, USA is chosen as a case study to demonstrate the capabilities of the decision support system. The test results compared with HEC-FDA software indicate that this new system provides a very versatile and reliable environment for estimating various flood damage, and may greatly enhance decision making process for future design of the flood proofing facilities (Qi and Altinakar 2011).

Wu et al. (2009) propose an intelligent decision support system based on sensor and computer networks that incorporate various component techniques for sensor deployment, data routing, distributed computing, and information fusion.

Floodplain wetlands rely on catchment flows to maintain the flooding cycles critical to their ecological integrity. The development of water resources has significantly altered the flow patterns in many river systems. Recent research into water requirements for wetland systems shows that duration, frequency, depth, timing and extent of flooding are the most important influences on ecological communities. Modelling these systems is hampered by a lack of data and inappropriate model structures. Remote sensing using AVHRR satellite data were shown to be an effective option for assessing flood dynamics. This study demonstrates that a conceptually based, semi-distributed water balance approach can provide the basis for an effective decision support system for water management (Powell et al. 2008).

2.7 Biometrics-based Decision Support Systems

Several types of biometrics-based decision support systems (DSSs) are analyzed in this section: Speech Recognition and Understanding DSS, Voice Recognition DSS, Adaptive Biometric DSS and other biometrics-based DSSs.

2.7.1 Voice Recognition Decision Support Systems

The term voice recognition describes the identity of a speaker (for security purpose) and assists the translation of speech more easily (the system helps to implement the speech recognition process by establishing the specific voice of a particular person and by relying on historical experience).

Voice recognition is the ability of a computer to know the voice of a person speaking into it, so that only voices that the computer knows can use the system (Macmillan Dictionary). Ability of an electronic security device is to recognize the voice (which is unique as a fingerprint) of a particular person. In contrast, speech recognition is the ability to recognize spoken words only and not the individual voice characteristics (Business Dictionary). Despite the inherent technological challenges, voice recognition technology's most popular applications will likely provide access to secure data over telephone lines. Voice recognition has already been used to replace number entry on certain Sprint systems. This kind of voice recognition is related to (yet different from) speech recognition. While speech recognition technology interprets what the speaker says, speaker recognition technology verifies the speaker's identity (Phillips et al. 2000).

The terms "voice recognition" and "voice biometrics" are often used as synonyms (Anzar et al. 2014; Warman 2013; Rashid 2008; Face and voice... 2013; Banks turn to... 2014; Ortega-Garcia et al. 2002). Barclays Bank successfully applies voice biometrics technology in the place of a pin code. Software called "Nuance FreeSpeech" uses voice biometrics technology to compare the customer's voice to their unique voiceprint on file, and silently signals to the Barclays representative when the customer's identity has been verified. Since its introduction, Barclays says more than 84 per cent of its customers have enrolled in the Nuance voice biometrics solution, with 95 per cent of those customers successfully verified upon their first use of the system (Warman 2013). Several Voice Recognition Decision Support Systems (Dinh et al. 2006; Browne 1991; Drake 1988) have also been developed. These integrate voice recognition with decision support systems.

2.7.2 Speech Recognition and Understanding Decision Support Systems

Recently, data-driven speech technologies have been widely used to build speech user interfaces. However, developing and managing data-driven spoken dialog systems are laborious and time consuming tasks. Spoken dialog systems have many components and their development and management involves numerous tasks such as preparing the corpus, training, testing and integrating each component for system development and management. In addition, data annotation for natural language understanding and speech recognition is quite burdensome (Jung et al. 2008). Speech understanding is the processing of speech that involves the mapping of the acoustic signal, usually derived from some form of a speech recognition system to some form of abstract meaning of the speech (Dictionary of Computing). It has been quite a considerable time, since speech user interfaces have been designed for decision support (Martin 1989, Jones et al. 1989, Shiffman et al 1995). These and other studies suggest that such speech-understanding systems can help interested groups to make timely and effective decisions. For example, Conlon et al. (1994) describe a natural language processing based group decision support system. The system consists of database, model base, application programs and natural language interface system. This system is designed to both route questions to appropriate subsystems and translate these questions into the computer language controlling these subsystems (Conlon et al. 1994). Speech biometric and speech recognition are interrelated concepts. Speech biometric is being used to identify a person by that person's speech (by applying speech recognition and understanding technologies) by recognizing the intonation in the voice.

2.7.3 Adaptive Biometrics-based Decision Support Systems

An adaptive biometric system aims to auto-update the templates or model to the intra-class variation of the operational data (Rattani 2010). Self-update is the most commonly adopted biometric template update technique in which the system adapts itself to the confidently classified samples (Rattani et al. 2013). Scientists from different countries are working in the area of adaptive biometric systems (Huang et al. 2013; Pagano et al. 2014; De Marsico et al. 2012; Guerra-Casanova et al. 2011; Kaklauskas et al. 2013). Several studies by the aforementioned authors are next described in brief.

If fusion rules cannot adapt to the changes of environment and individual users, multimodal systems may perform worse than unimodal systems when one or more modalities encounter data degeneration (Huang et al. 2013). Huang et al. (2013) develop a robust face and ear based multimodal biometric system using Sparse Representation, which integrates the face and ear at feature level, and can effectively adjust the fusion rule based on reliability difference between the modalities.

Recognizing faces corresponding to target individuals remains a challenging problem in video surveillance. Face recognition (FR) systems are exposed to videos captured under various operating conditions, and, since data distributions change over time. Although these models may be adapted when new reference videos become available, incremental learning with faces captured under different conditions may lead to knowledge corruption (Pagano et al. 2014). Pagano et al. (2014) present an adaptive multi-classifier system (AMCS) for video-to-video FR in changing surveillance environments. During enrolment, faces captured in reference videos are employed to design an individual-specific classifier. During operations, a tracker allows to regroup facial captures for individuals in the scene, and accumulate the predictions per track for robust spatiotemporal FR. Given a new reference video, the corresponding facial model is adapted according to the type of concept change. If a gradual pattern of change is detected, the individual-specific classifier(s) are adapted through incremental learning. To preserve knowledge, another classifier is learned and combined with the individual's previously-trained classifier(s) if an abrupt change is detected. For proof-of-concept, the performance of a particular implementation of this AMCS is assessed using videos from the Faces in Action dataset. By adapting facial models according to changes detected in new reference videos, this AMCS allows to sustain a high level of accuracy comparable to the same system that is always updated using a learn-and-combine approach, while reducing time and memory complexity (Pagano et al. 2014).

The lack of communication and of dynamic adaptation to working settings often hinder stable performances of subsystems of present multibiometric architectures. The calibration phase often uses a specific training set, so that (sub)systems are tuned with respect to well determined conditions (De Marsico et al. 2012). De Marsico et al. (2012) investigate the modular construction of systems according to CABALA (Collaborative Architectures based on Biometric Adaptable Layers and Activities) approach. Different levels of flexibility and collaboration are supported. The computation of system reliability (SRR), for each single response of each single subsystem, allows to address temporary decrease of accuracy due to adverse conditions (light, dirty sensors, etc.), by possibly refusing a poorly reliable response or by asking for a new recognition operation (De Marsico et al. 2012).

Guerra-Casanova et al. (2011) focus on the evaluation of a biometric technique based on the performance of an identifying gesture by holding a telephone with an embedded accelerometer in his/her hand. The acceleration signals obtained when users perform gestures are analyzed following a mathematical method based on global sequence alignment. A temporal study of the technique is presented leading to the need to update the template to adapt the manner in which users modify how they perform their identifying gesture over time. Six updating schemes have been assessed within a database of 22 users repeating their identifying gesture in 20 sessions over 4 months, concluding that the more often the template is updated the better and more stable performance the technique presents (Guerra-Casanova et al. 2011).

Kaklauskas et al. (2013) developed a Recommender System to Analyze Student's Academic Performance. One of the main goals in the research was to demonstrate that the interest in learning affects learning productivity, while physiological parameters demonstrate such changes, and this provide another source of data for substantiating the impact of emotional states on learning. The Recommender System can auto-update a student's academic performance model with operational biometrical data. A low bias profile Logistic regression learning algorithm works well at the adaptive stage, when the Recommender System has accumulated enough training data. Other researchers (Poitras and Lajoie 2014; Andersen et al. 2012; Zhang 2004) have also been developing various adaptive systems by applying the logistic regression (logit regression) probabilistic statistical classification model. Then, after having completed the adaptive phase, the Recommender System determines the correlation between a student's learning productivity, interest in learning and the physiological parameters of that student. Then the Recommender System can select learning materials by taking into account a student's learning productivity and the degree to which the learning seems interesting.

2.7.4 Other Biometrics-based Decision Support Systems

There are also other biometrics-based decision support systems (DSSs) in addition to the three types listed above. These are next described in brief.

Patient empowerment might be one key to reduce the pressure on health care systems challenged by the expected demographic changes. Knowledge based systems can, in combination with automated sensor measurements, improve the patients' ability to review their state of health and make informed decisions (Gietzelt et al. 2012). Gietzelt et al. (2012) introduce ARDEN2BYTECODE for this purpose. It is a newly developed, open source compiler for service-oriented decision support systems based on the OSGi (Open Services Gateway Initiative) platform.

To cope with the increasing number of aging population, a type of care which can help prevent or postpone entry into institutional care is preferable. Activity recognition can be used for home-based care in order to help elderly people to remain at home as long as possible (Chernbumroong et al. 2014). Chernbumroong et al. (2014) propose a practical multi-sensor activity recognition system for home-based care utilizing on-body sensors. Seven types of sensors are investigated on their contributions toward activity classification. Chernbumroong et al. (2014) collected a real data set through the experiments participated by a group of elderly people. Seven classification models are developed to explore contribution of each sensor. Chernbumroong et al. (2014) conduct a comparison study of four feature selection techniques using the developed DSS models and the collected data.

Brahnam et al. (2007) propose that a machine assessment system of neonatal expressions of pain be developed to assist clinicians in diagnosing pain. The facial expressions of 26 neonates (age 18–72 h) were photographed experiencing the acute pain of a heel lance and three nonpain stressors. Four algorithms were evaluated on out-of-sample observations: PCA, LDA, SVMs and NNSOA. NNSOA provided the best classification rate of pain versus nonpain (90.20%), followed by SVM with linear kernel (82.35%). Brahnam et al. (2007) believe these results indicate a high potential for developing a decision support system for diagnosing neonatal pain from images of neonatal facial displays.

Petrushin (2002) presents agents for emotion recognition in speech and their application to a real world problem. The agents can recognize five emotional states—unemotional, happiness, anger, sadness, and fear—with good accuracy, and be adapted to a particular environment depending on parameters of speech signal and the number of target emotions. A practical application has been developed using an agent that is able to analyze telephone quality speech signal and to distinguish between two emotional states—"agitation" and "calm". This agent has been used as a part of a decision support system for prioritizing voice messages and assigning a proper human agent to respond the message at a call center (Petrushin 2002).

According to Gavrilova and Monwar (2013), the best way to develop a biometric security system is to design it as a decision-support system, which can provide information to the system operator empowering him to make an intelligent and correct decision.

2.8 Ambient Intelligence and the Internet of a Things-based Decision Support Systems

The concepts of ambient intelligence and the Internet of Things and their link to decision support systems are briefly deliberated. Ambient intelligence discusses electronic environments, which are sensitive and responsive to people's daily activities. According to Aarts et al. (2001), the ambient intelligence paradigm is characterized by systems and technologies that are embedded, context aware, personalized, adaptive and anticipatory. In the opinion held by Höller et al. 2014), the Internet of Things refers to the interconnection of uniquely identifiable embedded computing-like devices within the existing Internet infrastructure. Typically, Internet of Things is expected to offer advanced connectivity of devices, systems, and services that goes beyond machine-to-machine communications and covers a variety of protocols, domains, and applications (Höller et al. 2014). Ambient intelligence is not part of the original concept of the Internet of Things. Ambient intelligence does not necessarily require Internet structures, either. However, there is a shift in research to integrate the concepts of the Internet of Things and ambient intelligence (Uckelmann et al. 2011).

There are identical concepts, such as "pervasive computing", "ambient intelligence" and "the Internet of things". In practice, the differences between these terms is of rather an academic nature: common to all is the goal of assisting people as well as a continuous optimisation and promotion of economic and social processes by numerous microprocessors and sensors integrated into the environment (Friedewald and Raabe 2011).

The topic of smart environments, also called ambient intelligence, has been gaining interest recently. The term ambient intelligence refers to the embedding of sensors and actuators within a room or environment that react automatically to the users within that environment. The sensors are hidden from the user so they become part of the environment and should not require the user to explicitly interact with the devices. These sensors could be in the form of thermometers, microphones, cameras, motion sensors, or any device that can provide information to an automated control system regarding the state of the environment (Torunski et al. 2012). Ambient intelligence is described as a model of interaction in which people are surrounded by intelligent devices, aware of their own presence, context sensitive and able to adapt to the user's needs through embedded technology (Bajo et al. 2010).

The main goal of Ambient intelligence is the development of systems aimed at adapting the surrounding environmental conditions so that they can match the users' needs, whether those are consciously expressed or not, while at the same time satisfying other system-driven goals, such as the minimization of global energy consumption (De Paola et al. 2012).

Gasson and Warwick (2007) claim that a variety of technologies (Bluetooth low energy, RFID, implant, sensors, software agents, affective computing, nanotechnology, biometrics) can be used to enable effective Ambient intelligence environments. Objects in the Internet of Things will not only be devices with sensory capabilities, but also provide actuation capabilities (e.g., bulbs or locks controlled over the Internet) (Ersue et al. 2014). Next are brief write-ups to serve as practical examples of ambient intelligence-based and sensors-based decision support systems that have been developed (Chernbumroong et al. 2014; Droit et al. 2008; Filip 2008; El-Hachem et al. 2012; Dunkel et al. 2011; Rodger 2014; Fricoteaux et al. 2014; Edoura-Gaena et al. 2006; Howells et al. 1999; Paraskevopoulos and Singels 2014; Wu et al. 2009; Kaupp et al. 2010; Qi et al. 2014; Ansola et al. 2012).

Most traditional street lighting systems do not have the function of autonomous control. Inspired by social animals and insects, an autonomous control system for street lighting is presented in this research. All the lamp nodes compose a wireless sensor network (WSN) based lamp group in which there are a lamp leader, a succeeding leader, and some lamp members. All the lamp members communicate with the lamp leader by forming a tree topology. The lamp member collects ambient illumination using a light sensor periodically. When finding the illumination is under the preset threshold, the lamp member will send a turning-on vote to the lamp leader. The lamp leader counts the number of votes received from the members. When the number of the votes is larger than the preset threshold, the lamp leader will send a turning-on command to all the lamp members. Just like the succession behavior in social animals, the succeeding leader in the proposed Group decision making based autonomous control system for street lighting can automatically take the place of the current lamp leader when it is disabled. A failure message can be sent to the remote street lighting maintenance center by a GPRS network. Leader switching and group decision making tests have been carried out for validating these proposed methods. The experimental results show that the proposed Group decision making based autonomous control system for street lighting can automatically response to ambient light changes. The method of group decision making improves the anti-interference capability and the intelligence level of the lighting control system (Zhang et al. 2013).

Chernbumroong et al. (2014) develop a practical, multi-sensor activity recognition system for home-based care. The DSS can be used to generate a monthly activity graph which shows the amount of each activity carried out in different months. This can be used to see the trend and detect changes in activities and support the decision whether to contact the person to come to the hospital and to which department or a home visit or whether further activity data should be requested from the patient. For example, if the graph shows the decline in walking over several months, this could suggest that there is a problem with ambulating. This would help reduce the number of hospital visits, improve hospital resources utilization, and increase earlier detection rate. The DSS can be used to support the decision on the type of carer that is required for different patients. For example, if an activity record shows no decline or changes in activity pattern, a carer may not be needed. If the activity record suggests that the person may have problem with feeding, the carer who can provide assistance with feeding or cooking should be sent. The activity database can be used as part of the other clinical decision support systems to give more information to support the illness diagnostic or disease symptom. For example, if the activity record shows that the patient has very little sleep per day, it could influence the decision of the specific sleeping disorder (Chernbumroong et al. 2014).

Droit et al. (2008) aim to contribute to the design of decision support for the physical access security systems. Droit et al. (2008) address the problem of extracting information helpful for early detection of physiological and psycho-emotional data linked to situational awareness. Face images in visible and infrared bands acquired by the Biometric-Based Decision Support Assistance in Physical Access Control System constitute the input of the module for hyper-spectral face analysis and synthesis. The corresponding 3D models, one for video images and one for infrared, are generated by fitting the generic model onto images. The texture maps representing the hemoglobin and melanin content of the facial skin, as well as the temperature distribution, constitutes the output of the face analysis and modeling module. This information is used for evaluating the physiological and psycho-emotional states of a person (Droit et al. 2008).

The technical and social systems of the present day are ever large, complex and complicated objects. Their models are characterized by numerous state and control variables, time delays, and different time constants. Also they show constraints in their information infrastructure and risk sensitivity aspects. Such systems are called *large-scale complex systems* (LSS). Hierarchical approach which has been for several decades one of the most utilized methodologies for controlling large-scale systems has evolved in recent years toward more collaborative schemes. When human intervention is necessary, *decision support systems* (DSSs) can represent a solution. A DSS is an adaptive and evolving information system meant to implement several of the functions of a human support team that would otherwise be needed to help the decision-maker to overcome his/her limits and constraints he/she may face when approaching decision problems that count in the organization. This research aims at reviewing several aspects concerning the utilization and technology of DSS in the context of LSS control. Particular emphasis is put on real-time DSS and *multi-participant (group) DSS* which support collaborative work. Several advanced solutions such as mixed knowledge systems, that combine numerical methods with AI-based tools, and the prospects of using *Ambient intelligence* concepts in DSS construction are described (Filip 2008).

Amid the extremely active Semantic Web community and the Social Web's exceptionally rising popularity, experts believe that an amplified fusion between the two webs will give rise to the next huge advancement in Web intelligence. Such advances can particularly be translated into ambient and ubiquitous systems and applications (El-Hachem et al. 2012). El-Hachem et al. (2012) delve into the recent advances in knowledge representation, semantic web, natural language processing and online social networking data and concepts, to propose an inclusive platform and framework defining ambient recommender and decision support systems that aim at facilitating cross-sectional analysis of the domain of childhood obesity and generating both generic and customized preventive recommendations.

Decision support systems for traffic management systems have to cope with a high volume of events continuously generated by sensors (Dunkel et al. 2011). Dunkel et al. (2011) propose a reference architecture for event-driven traffic management systems, which enables the analysis and processing of complex event streams in real-time and is therefore well-suited for decision support in sensor-based traffic control systems.

Rodger (2014) address the problem of predicting demand for natural gas for the purpose of realizing energy cost savings. Daily monitoring of a rooftop unit wireless sensor system provided feedback for a decision support system that supplied the demand for the required number of million cubic feet of natural gas used to control heating, ventilation, and air conditioning systems (Rodger 2014).

Modern training through virtual environments is widely used in transport in order to provide a high level of precision and more and more complex situations. These virtual environments provide training scenarios with automatic and repetitive feedback to the trainees. Experienced learners receive too many aids and novice learners receive too few (Fricoteaux et al. 2014). Fricoteaux et al. (2014) have designed and evaluated a fluvial-navigation virtual training system which includes a GULLIVER (decision-making system based on user observation for an adaptive training in informed virtual environments) module to determine the most appropriate level of feedback to display for learner guiding. GULLIVER is based on a decision-making module integrating uncertain data coming from observation of the learner by the system. An evidential network with conditional belief functions is used by the system for making decisions. Several sensors and a predictive model are used to collect data in real time. Metaphors of visualization are displayed to the user in an immersive virtual reality platform as well as audio feedback. GULLIVER was evaluated on 60 novice participants. The experiment was based on a navigation case repetition (Fricoteaux et al. 2014).

A pilot Decision support system to control the aeration of sponge finger batters was developed on the basis of knowledge extraction and formalization, to help the operators to control the aeration of sponge finger batters. This system reproduces the operator's control strategies by integrating the product's sensory properties and by taking into account various operations of the entire process, which influence product quality. The system inputs are 10 sensory measurements and 4 instrumental measurements used by the operators on the production line to characterize the batter and the sponge fingers. Sensory measurements were previously formalized using the "sensory indicators" formalism. The system outputs are the appropriate corrective actions. These actions are selected with a set of 47 "if–then" type rules which represent the formalization of the strategies developed by operators for the feedback control of aeration. The Decision support system to control the aeration of sponge finger batters was implemented with CLIPS, an expert systems shell, and was evaluated by comparing its outputs to the corrective actions proposed by an expert operator. Matching was obtained in 21 cases out of the 27 tested (Edoura-Gaena et al. 2006).

In the defence area, especially that of aerospace systems, extensive use has been made of the expertise of software and system houses in developing validation methodologies (VORTEX), real time (MUSE) and multi-agent (D-MUSE) software and together with Universities, a knowledge acquisition toolkit (PC PACK). In the UK at DERA Farnborough within the Airborne Decision Support Group, Air Sector, these software and tools have been developed and applied to problems in building Decision Support Systems for Maritime Air applications. The demanding aircrew tasks are characterised by the need for assimilation and interpretation of multi-sensor data to devise tactical responses in real time based on prevailing tactical doctrine and aircrew experience. The applications include Decision Support for Anti-Submarine Warfare (ASW), Anti-Surface Warfare (ASuW), Airborne Early Warning (AEW) together with ASW/ASuW and the proposed AEW technology demonstrators (Howells et al. 1999).

Various technologies exist to support scientific irrigation scheduling, each with its own strengths and weaknesses. Weather-based crop models are good at estimating evapotranspiration and future irrigation needs over large areas, while electronic soil water sensors are able to provide good estimates of soil water status at a given point. Synergy may be obtained by combining these technologies to enhance their usefulness for irrigation management. The objective of this study was to incorporate real-time field records of soil water status into a weather based sugarcane simulation system and to evaluate its use for supporting irrigation scheduling in 15 sugarcane fields in South Africa. The integrated system provides enhanced support for irrigation water management for sugarcane production (Paraskevopoulos and Singels 2014).

Wu et al. (2009) propose an intelligent decision support system for homeland security defense based on sensor and computer networks that incorporates various component techniques for sensor deployment, data routing, distributed computing, and information fusion. The integrated system is deployed in a distributed environment composed of both wireless sensor networks for data collection and wired computer networks for data processing in support of homeland security defense. Wu et al. (2009) present the system framework and formulate the analytical problems and develop approximate or exact solutions for the subtasks: (i) sensor deployment strategy based on a two-dimensional genetic algorithm to achieve maximum coverage with cost constraints; (ii) data routing scheme to achieve maximum signal strength with minimum path loss, high energy efficiency, and effective fault tolerance; (iii) network mapping method to assign computing modules to network nodes for high-performance distributed data processing; and (iv) binary decision fusion rule that derive threshold bounds to improve system hit rate and false alarm rate. The extensive results demonstrate that these component solutions imbue the integrated system with the desirable and useful quality of intelligence in decision making (Wu et al. 2009).

Humans and robots need to exchange information if the objective is to achieve a task collaboratively. Two questions are considered in this research: what and when to communicate (Kaupp et al. 2010). To answer these questions, Kaupp et al. 2010) developed a human–robot communication framework which makes use of common probabilistic robotics representations. The data stored in the representation determines what to communicate, and probabilistic inference mechanisms determine when to communicate. One application domain of the framework is collaborative human–robot decision making: robots use decision theory to select actions based on perceptual information gathered from their sensors and human operators. Robots decide when to query operators using Value-Of-Information theory, i.e. humans are only queried if the expected benefit of their observation exceeds the cost of obtaining it. This can be seen as a mechanism for adjustable autonomy whereby adjustments are triggered at run-time based on the uncertainty in the robots' beliefs related to their task. This semi-autonomous decision making system is demonstrated using a navigation task and evaluated by a user study. Participants navigated a robot in simulation using the proposed decision making system and via classical teleoperation (Kaupp et al. 2010).

Temperature monitoring, shelf-life visibility and Least Shelf-life First Out (LSFO) stock strategy are important contents in perishable food cold chain logistics for both cold chain managers and workers in order to reduce quality and economic losses (Qi et al. 2014). Qi et al. (2014) describe a wireless sensor network (WSN) based integrated Cold Chain Shelf Life Decision Support System (C^2SLDS) designed for perishable food product cold chain management. The system is implemented based on the WSN and time temperature indicator (TTI) features. Compared with traditional cold chain management methods used before, the C^2SLDS not only bridges the information gap which exists between different cold chain phase enterprises and provide a seamless information flow along the whole chain but also enables cold chain enterprises to predict perishable food's shelf-life and helps make a smart LSFO strategy to reduce the quality and economic loss. LSFO strategy decision support system in cold chain logistics test and evaluation shows that the infield radio transmission is reliable and the whole system meets most of the users' requirements raised in system analysis (Qi et al. 2014).

Ansola et al. (2012) develop a Distributed decision support system for airport ground handling management in order to allocate resources in an airport, even when disturbances occur by combining artificial intelligent techniques with visibility technologies. Ansola et al. (2012) propose the combined use of Multi-agent systems (MAS) along with Wireless Sensor Networks (WSN) to provide the required information on the status of the resources and the environment. The MAS is based on a double layer of decision-taking levels and on a Markov reward function whereas the WSN is based on a Zigbee network of Radio Frequency Identification (RFID) readers with active tags as end nodes, which are carried by the physical resources.

The proposed Distributed decision support system for airport ground handling management using WSN and MAS has been tested at Ciudad Real Central Airport in Spain (Ansola et al. 2012).

2.9 Other Intelligent Decision Support Systems

2.9.1 GA-based Decision Support Systems

Decision support systems can be improved by integrating a genetic algorithm to generate useful solutions for resolving optimization, search and other problems (Leu et al. 2000; Wang et al. 2007a, b; Kuncheva and Jain 1999). For example, a computational optimization technique, genetic algorithms, was employed by Leu et al. (2000) to overcome drawbacks of traditional construction resource leveling algorithms. The proposed algorithm can effectively provide the optimal or near-optimal combination of multiple construction resources, as well as starting and finishing dates of activities subjected to the objective of resource leveling. Furthermore, a prototype of a decision support system for construction resource leveling was also developed. Construction planners can interact with the system to carry out ad hoc analysis through “what-if” queries (Leu et al. 2000). DSS in joint with integrated, genetic algorithms can experience behavioral changes and adapt over time in order to provide improved decision support based on previous experience. In this sort of instance, various GA-based decision support systems are developed as a genetic algorithm is being integrated (Ko and Wang 2010, Juan et al. 2009).

2.9.2 Fuzzy Sets IDSS

Under uncertain and imprecise conditions, fuzzy sets are used with multicriteria decision-making to provide techniques for modelling preferences, evaluating alternatives, aggregating preferences, selecting best alternatives, and ranking or sorting alternatives into categories. MCDM and fuzzy measurement assist in the representation of domain knowledge for modelling decision problems during the Intelligence and Design stages, whereas intelligent features of analogical reasoning, learning, and memory are facilitated by the case-based reasoning component during analysis for making choices and implementing selected strategies (Burstein and Carlsson 2008). Prototypes of fuzzy IDSS have been applied to solving decision-making problems, such as evaluation of services, partnership selection in virtual enterprises, outsourcing of IT services, risk analysis and evaluation of offers in telecommunication markets (Mikhailov et al. 2010, 2011).

2.9.3 Rough Sets

Rough sets can be used to enable decision support systems to perform better in uncertain conditions. Pawlak et al. (Pawlak and Skowron 2007; Pawlak 2002a, b) develop a decision support system for multiple criteria classification problems based on rough sets and dominance relation (4eMka2). 4eMka2 is an implementation of the new approach in multiple criteria decision support, combining advantages of rough sets and dominance relation. The purpose of this system is resolving of multi-criteria sorting problems. System can be used in many different areas e.g. finances, medicine, geology, pharmacology and many other connected with analysis of vast data sets. The main difference between this system and the ones that are already in use is that it bases on rough set theory combined with dominance relation, which is quite new approach in multi-criteria decision support. The main function of the system is extraction of the classification rules from a set of already classified examples. These rules could be used to make partition of new data sets. Rules are presented in very convenient and comprehensible manner as a set of "if ... then..." sentences. Another advantage of the system is dealing with inconsistent and incomplete data. This is possible due to use of rough set with dominance relation (Pawlak and Skowron 2007; Pawlak 2002a, b).

2.9.4 Intelligent Agent-assisted Decision Support Systems

Multi-agent systems have gained much interest of researchers over the last decade. This is evidenced by the widespread application of multi-agent systems to different domains including e-commerce, healthcare, military support, decision support, knowledge management, as well as control systems (Quteishat et al. 2009).

The term agent means different things to different authors; many definitions are not explicitly enunciated. A general list of those software agent attributes frequently mentioned or implied in literature definitions is as follows: An autonomous software agent is a software implementation of a task in a specified domain on behalf or in lieu of an individual or other agent. The implementation will contain homeostatic goal(s), persistence, and reactivity to the degree that the implementation (1) will persist long enough to carry out the goal(s), and (2) will react sufficiently within its domain to allow goal(s) to be met and to know that fact. The potential contributions of software agents to DSS have been described as enormous, and DSS implementations that utilize agent-like programs and agent communities have appeared in numerous journals (Hess et al. 2008). Intelligent agents that are integrated into DSS (Dong and Srinivasan 2013; Gao and Xu 2009; Gao et al. 2009; Favorskaya et al. 2014; Urlings et al. 2006) can perform complex cognitive tasks (knowledge sharing, machine learning, data mining, automated inference, human–machine teaming, image inpainting, etc.) without the intervention of any decision-maker.

Holsapple and Whinston (1996) and Hess et al. (2008) hold the opinion that there are various autonomous agents, which can increase the value added by DSS:

- Data-monitoring. Goes to (and stays at) supplier's site. Saves user from having to monitor supplier's prices. Only reports promising prices. This agent enhances the DSS in two fundamental ways: by automating the retrieval of information and by improving the quality of that information (in the sense that the database is updated immediately for changes in vendor prices). This latter benefit implies that additional DSS can now be built possessing real-time, on-line data capabilities.
- Data-gathering. Goes to directory sites; locates potential suppliers of parts, relieving a user from the task and only reports promising suppliers. In an enhanced system, the agent could communicate with other agents and get additional leads on promising directory sites or suppliers. This agent provides a benefit to the DSS user by automating the retrieval of information not typically stored in corporate databases.
- Modeling. The modeling agent provides enhancements to the DSS (1) by providing access to a computational tool, (2) by automatically resolving the model when any relevant data changes, (3) by providing a level of abstraction between the different languages of the DSS and the modeling application and (4) by reporting to the user only those changes in the optimal mix of products within the DSS that are deemed significant.
- Domain-manager agent. Agent provides interoperability by integrating heterogeneous, distributed agents. The agent communicates with all other agents operating on behalf of, or in, the domain the user need not keep track of these other agents.
- Preference-learning. The agent observes and records the user's disposition to follow the modeling agent's recommendations; in an enhanced system, the agent could invoke machine learning to determine the user's preferences. This agent watches the user and provides the benefit of learning his or her style or tendencies. (Holsapple and Whinston 1996; Hess, Rees and Rakes 2008).

More and more agent-based decision support systems are developed by integrating autonomous software agents into decision support systems. The next brief description of Intelligent agent-assisted decision support systems serves as examples. Dong and Srinivasan (2013) develop an Agent-enabled service-oriented decision support system. López-Ortega and Rosales (2011) develop an Agent-based decision support system that employs fuzzy clustering to group individual evaluations and the AHP to reach a final decision. Phillips-Wren, Forgionne (2006) present a new decision support system enabled by the analytic hierarchy process and intelligent software agents that can be used by researchers and practitioners in technical fields to aid information retrieval and improve search results from a controlled vocabulary.

Criminal elements in today's technology-driven society are using every means available at their disposal to launder the proceeds from their illegal activities. In response, international anti-money laundering (AML) efforts are being made. The events of September 11, 2001, highlighted the need for more sophisticated AML and anti-terrorist financing programs across the industry and nation. In the wake of this, regulators are focusing on the role that technology can play in compliance with laws and ultimately in law enforcement. Banks will have to employ or enhance AML tools and technology to satisfy rising regulatory expectations. While many AML solutions have been in place for some time within the banks, they are faced with the challenge of adapting to the ever-changing risks and methods related to money laundering (Gao and Xu 2009). In order to provide support for AML decisions, Gao and Xu (2009) have formulated an AML conceptual model. Based on this model, a novel and open multi-agent AML system prototype has been designed and developed. Intelligent agents with their properties of autonomy, reactivity, and proactivity are well suited for dynamic, ill-structured, and complex ML prevention controls. The advanced architecture is able to provide more adaptive, intelligent, and flexible solution for AML (Gao and Xu 2009).

Colin and Jain (2006) consider the problem of having an agent respond appropriately to dynamically changing environments. Colin and Jain (2006) work within the Beliefs–Desires–Intentions paradigm and show how an agent may use concepts suggested by Artificial Immune Systems to dynamically change its intentions in response to a dynamically changing environment. Colin and Jain (2006) illustrate these ideas with teams of agents who must either compete or cooperate in the context of simple artificial games in order to fulfil their specific desires.

2.9.5 Process Mining Integration to Decision Support

Business process mining takes logs to discover process, control, data, organizational, and social structures (Van der Aalst et al. 2007). Business process mining can be seen as business process intelligence, business activity monitoring, business process management, business process analysis, automated business process discovery and workflow mining (Turner et al. 2012).

Process mining stands for a set of techniques to analyze business process models and logs (Accorsi and Stocker 2012). Process mining is a process management technique that allows for the analysis of business processes based on event logs. The basic idea is to extract knowledge from event logs recorded by an information system. Process mining aims at improving this by providing techniques and tools for discovering process, control, data, organizational, and social structures from event logs (Van der Aalst 2011). Process mining provides methods for reconstructing process models from logs (process discovery), checking the conformance of an existing or reconstructed model and logs (conformance checking), and enhancing process models based on the results of analysis (process enhancement) (Accorsi and Stocker 2012).

Process mining techniques allow for the analysis of business processes based on event logs. For example, the audit trails of a workflow management system, the transaction logs of an enterprise resource planning system, and the electronic patient records in a hospital can be used to discover models describing processes, organizations, and products. Moreover, such event logs can also be used to compare event logs with some a-priori model to see whether the observed reality conforms to some prescriptive or descriptive model (Van der Aalst 2008).

Although many researchers are developing new and more powerful process mining techniques and software vendors are incorporating these in their software, few of the more advanced process mining techniques have been tested on real-life processes (Van der Aalst et al. 2007). Using a variety of process mining techniques, Van der Aalst et al. (2007) analyzed the processing of invoices sent by the various subcontractors and suppliers from three different perspectives: (1) the process perspective, (2) the organizational perspective and (3) the case perspective.

Unlike many other decision support systems, the focus is on the analysis of the current situation rather than evaluating redesigns or proposing improvements. The outcome of process mining is a better understanding of the process and accurate models that can safely be used for decision support because they reflect reality. To link process mining to decision support, we distinguish between four types of decisions when it comes to operational (i.e., workflow-like) processes (Van der Aalst 2008):

- Design-time decisions, i.e., decision made during the initial modeling of a process. These decisions are recorded in models and specifications which are used to realize information systems. For example, at design time, it may be decided that one activity has to wait for the completion of another because of data dependencies.
- Configuration-time decisions, i.e., decisions related to the customization of a process/system for a specific organizational setting. For example, the designers of the SAP R/3 system developed their system based on a set of reference processes describing the different scenarios in which the ERP system can be used. However, to become operational, the SAP system needs to be configured for a specific organizational setting. In this configuration process, all kinds of decisions are made. For example, most organizations switch off functionality and select the desired mode of operation (such as a particular way of invoicing).
- Control-time decisions, i.e. e., decisions to manage processes while they are running. Depending on the context, decisions regarding the use of capacity, the selection of paths, prioritization, etc. are taken. These decisions are at the level of the process and not at the level of an individual process instance but change over time depending on the context. For example, based on an unusual demand volume in the weeks before Christmas, it is decided not to accept rush orders, and capacity from other processes is relocated to the bottlenecks.
- Run-time decisions, i.e. e., decisions made for individual process instances (cases in workflow terminology). These are the decisions typically depicted in

process models. For example, based on the value of an order, a particular path through the process is selected. A run-time decision typically depends on the properties of a particular case.

2.9.6 Adaptive Decision Support Systems

Developments of adaptive decision support systems (Chuang and Yadav 1998; Chen et al. 2012; Johnson et al. 2011; Holm et al. 2014) have been ongoing for some time.

Knowledge plays an important role in knowledge-based decision support systems (DSSs). This is especially salient in dynamic environments where knowledge-based adaptive DSS operate. The role played by these DSS necessitates maintaining knowledge current since stale knowledge could lead to poor decision support (Shaw and Piramuthu 2008). Shaw and Piramuthu (2008) present a generic adaptive DSS framework with learning capabilities that continually monitors itself for possible deficit in the knowledge base, expired or stale knowledge already present in the knowledge base, and availability of new knowledge from the environment. The knowledge base is updated through incremental learning. Ideally speaking, an adaptive DSS must be able to support decision-making while being adaptive to changes in both the user preferences and the environment. The dynamics of change can have different sources, including the problem environment; user preference, including changes in performance criteria, as well as whether to be proactive or reactive to decision-making situations later in time (Shaw and Piramuthu 2008).

Dynamics in the problem environment could manifest in several forms including those that are expected and unexpected in the normal course of the system's lifetime. Examples of expected dynamics include the arrival of jobs in a manufacturing shop floor and the arrival of new knowledge in systems used for intelligent tutoring. Examples of unexpected dynamics include the arrival of "hot jobs" in a shop floor and the use of intelligent tutoring systems designed for students without learning disabilities by students with learning disabilities. Dynamics in the system could also be influenced by changes in performance criteria. Examples of changes in performance criteria include a change of emphasis from unit price to quality in a supply chain and from concentrating on thoroughly learning a few concepts to shallow learning of several concepts (Shaw and Piramuthu 2008).

It is hard to envision a real-world application in a dynamic environment where knowledge remains static. Stale knowledge is thus a major problem in any static knowledge-based system. The proposed framework alleviates problems associated with stale knowledge through continuous monitoring of system performance as well as availability of updated and/or new knowledge. The source of knowledge can be both external and internal. Oftentimes, it is desirable to have almost instantaneous access to necessary set of examples for learning purposes to facilitate faster learning and thus minimizing the effects of stale knowledge on system performance. The simulation component aids in quickly generating examples to any desired system parameter specification. Without the simulation component, this would not be possible given the resource constraints under which most real-world systems operate in a dynamic environment. The performance evaluation component plays a vital role in vigilantly monitoring the state of the knowledge base and quickly reacting to any observed deficits in knowledge (Shaw and Piramuthu 2008).

Next, one of the aforementioned systems will be described in brief as an example (Holm et al. 2014). Today's operators on factory shop-floors are often not stationed, dealing with a single or few tasks but have increasing responsibilities demanding enhanced skills and knowledge in a production environment where any disturbance must be settled with adequate actions without delay to keep optimum output. To be able to respond to these demands, the operators need dynamic, distributed and adaptive decision support in real-time, helping them to distinguish decision options and maximizing productivity despite incoming stochastic events. The minimum of time and option for operators to consider appropriate action both during normal production and when facing unexpected or unscheduled events point out the need of adaptive decision support for operators. When initiating this research project the question from the industry partner was the following: In what ways is it possible to support operators in making decisions for optimal productivity? By targeting this problem this research introduces a novel framework for an adaptive decision-support system enabled by event-driven function blocks and based on decision logics. The proposed decision support systems' ability to adapt to the actual conditions on the shop-floor is validated through a case study, and its capability is compared to the voice message system installed on-site (Holm et al. 2014).

2.9.7 Computer Vision based DSS

Computer vision is a field that includes methods for acquiring, processing, analyzing, and understanding images and, in general, high-dimensional data from the real world in order to produce numerical or symbolic information, e.g., in the forms of decisions (Klette 2014). This technology serves as the basis for developing computer vision based DSS (Gordan et al. 2008, Kumar et al. 2013, Segev 2010). Computer vision includes methods for acquiring, processing, analysing, and understanding images or image sequences from the real world in order to produce information, e.g., in the forms of decisions. It is the combination of Image Processing and Statistical Pattern Recognition. Biometrics deals with the recognition of persons based on physiological characteristics, such as face, fingerprint, vascular pattern or iris, and behavioural traits, such as gait or speech. It combines Computer Vision with knowledge of human physiology and behavior (Spreeuwers 2011, Boom, Spreeuwers and Veldhuis 2011). This is why computer vision and biometrics technologies are being more and more integrated lately.

2.9.8 Sensory Decision Support Systems

Sensory systems (vision, tactile, and signal processing systems), which analyze human vision, hearing, touch, taste, smell and vestibular senses, are being used as a composite part of DSS (Xiaoqiang et al. 2012; Liu et al. 2011). The term "Sensory Processing" refers to our ability to take in information through our senses (touch, movement, smell, taste, sight, hearing, balance), organize and interpret that information and make a meaningful response (SPD Australia 2014). The human eye is one of most remarkable sensory systems (Li and Jain 2009). Sensory systems are being integrated into DSS (Chernbumroong et al. 2014; Xiaoqiang et al. 2012; Liu et al. 2011; Edoura-Gaena et al. 2006; Perrot et al. 2004). One such instance is presented further. Chernbumroong et al. (2014) how the proposed multi-sensor activity recognition can be used to enhance the sensor support system (DSS) for health care. The proposed method is used for classifying the complex sensor data into activities to generate a database of activity records over times. The data management is used for manage databases from several sources. The operations that the data management carries out include organize, search, query, add, update, and delete databases. It also connects to the user interface management to provide interface for the users to perform operations with the databases. Besides the activity database, other databases related to health care information such as medical records, hospital resources, carer records, and independence assessments are connected with the data management so that the DSS can cooperate with several sources to make reliable sensors. The activity database can be used as part of the other clinical sensor support systems to give more information to support the illness diagnostic or disease symptom. For example, if the activity record shows that the patient has very little sleep per day, it could influence the sensor of the specific sleeping disorder (Chernbumroong et al. 2014).

2.9.9 Robotic Decision Support Systems

Robotics is the branch of mechanical engineering, electrical engineering and computer science that deals with the design, construction, operation, and application of robots (Oxford Dictionaries 2014). One of the trends in the development of robotics is human-robot interaction involving communications with people through speech, gestures, and facial expressions by applying biometric technologies. Various DSS are being developed (Weiss and Yung 2009; Mouaddib 2008; Johannsen 2007; Nieten and Fishwick 2007; Pernalete et al. 2007; Heikkilä et al. 2013; Patel and Kamrani 1996). These systems are being integrated with robot technologies. Sensory systems are also combined in robots with a programmable, electromechanical device to perform manual labor.

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Chapter 3. Passive House Model for Quantitative and Qualitative Analyses and its Intelligent System

Abstract The Passive House, along with models of its composite parts, has been developed globally. Simulation tools analyze its energy use, comfort, micro-climate, quality of life and esthetics as well as its technical, economic, legal/regulatory, educational and innovative aspects. Meanwhile the social, cultural, ethical, psychological, emotional, religious and ethnic aspects operating over the course of the existence of a Passive House are given minimal attention or are ignored entirely. However, all the aspects mentioned must be analyzed in an integrated manner during the time a Passive House is in existence. The author of this chapter along with colleagues implemented this goal while they participated in two Intelligent Energy Europe programs, the NorthPass and the IDES-EDU projects. The Passive House model for quantitative and qualitative analyses and its intelligent system was developed during the time of these projects. The model and intelligent system are briefly described in this chapter, which ends with a case study.

3.1 Introduction

Various models of a Passive House or its composite parts are being developed globally at the micro, meso and macro levels. Such models include the ground heat exchanger (Badescu 2007a), heating system (Badescu 2007b), heating model of the active solar heating system (Badescu 2006), earth-contact building structures (Kumar et al. 2007), a regression model of energy efficiency (Tzikopoulos et al. 2005), a computational fluid dynamics model (Karlsson and Moshfegh 2006) and others. Furthermore scientists and practitioners from various countries are developing simulation tools for a Passive House and its composite parts. Such simulation tools include dynamic simulation software (Thiers and Peuportier 2008), computer-aided design tool for passive solar systems (Yakubu 1996), simulation software for zero energy building design (Wang and Gwilliam 2009), design of low energy buildings (Chlela et al. 2009), optimization tools BEopt and EGUSA (Parker 2009) and others. The aforementioned models and simulation tools for Passive Houses and their composite parts analyze their energetic, technical, technological, economic, legal/regulatory, innovative and microclimatic aspects. However, the social, cultural, ethical, psychological, emotional, religious and ethnic aspects of the Passive House during the process of its existence are generally paid no attention at all. It is necessary to analyze the life cycle of the Passive House comprehensively on the basis of the aforementioned system of criteria to achieve an integrated examination of a Passive House life cycle. The author of this book in conjunction with colleagues (J. Rute, E. K. Zavadskas, A. Daniunas, V. Pruskus) developed the Passive House model for quantitative and qualitative analyses and its intelligent system while participating in two Intelligent Energy Europe Program projects: "Promotion of the Passive House Concept to the North European Building Market" (NorthPass) and "Master and Post Graduate education and training in multidisciplinary teams implementing EPBD and beyond" (IDES-EDU). The developed intelligent system additionally provides opportunities for designing hundreds of thousands of Passive House alternatives, selecting the most effective ones and establishing the market value of each alternative. The structure of this Chapter is as follows: Section 3.2, which follows this introduction, describes the Passive House model for quantitative and qualitative analyses. Section 3.3 analyses the Passive House intelligent, design system. Section 3.4 contains a case study.

3.2 Passive House Model for Quantitative and Qualitative Analyses and Illustration of Its Several Stages

3.2.1 Passive House Model for Quantitative and Qualitative Analyses

The Passive House model for quantitative and qualitative analyses was developed with the goal of integrating the energetic, technical, technological, economic, legal/regulatory, innovative, microclimatic, social, cultural, ethical, psychological, religious, ethnic and other aspects of the process over the life of the Passive House. This six-stage model is presented in brief heretofore (see Fig. 3.1).
Stage I. Comparative description of the Passive House in developed countries and in Lithuania (by economic, legal/regulatory, technical, technological, organizational, managerial, quality of life, thermic, indoor quality, social, cultural, political, ethical, psycho-logical and other aspects):

- Determining a system of criteria characterizing the efficiency of a Passive House by employing relevant literature and expert methods.
- Describing, per this system of criteria, the present state of the Passive House in developed countries and in Lithuania in conceptual (textual, graphical, numerical and such) and quantitative forms.

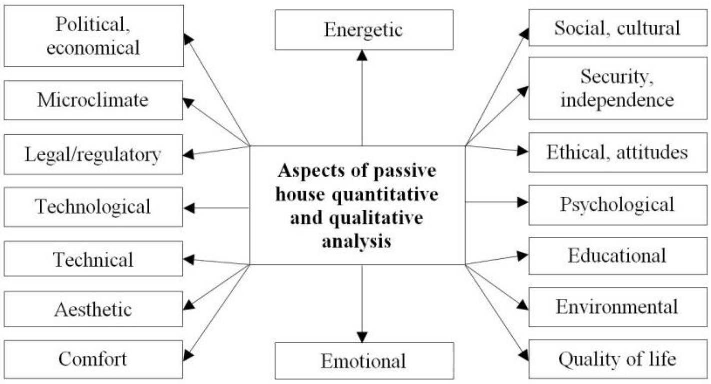


Fig. 3.1. Passive House quantitative and qualitative analyses aspects

Stage II. Comparison and contrast of the Passive House in developed countries and in Lithuania:

- Identifying the global development trends (general regularities) of the Passive House.
- Identifying the differences in Passive Houses between developed countries and Lithuania.
- Determining the pluses and minuses of these differences for Lithuania.
- Determining the best practice for the Passive House in Lithuania as per actual conditions.
- Estimating the deviation between the knowledge stakeholders have of worldwide best practices and their practice-in-use.

Stage III. Development of certain general recommendations on how to improve the knowledge levels of stakeholders. Stage IV. Submission of certain recommendations to stake-holders including several particular alternatives for each general recommendation proposed. Stage V. A multiple criteria analysis of the composite parts of a Passive House and selection of the most efficient life cycle for the project – henceforth interlinking the received compatible and rational composite parts of a Passive House into a full Passive House project. Stage VI. Transformational learning and the redesign of mental and practical behavior. A partial description of the two stages follow to illustrate the above-presented Model. These are Stage I – Passive House socio-cultural aspects, self-expression values, environmentalism and global warming and the Passive House and Stage II – Lithuania's low energy dwelling weaknesses.

3.2.2 Passive House Socio-cultural Aspects

Innovative construction of a Passive House serves the development and induction of new technologies in practice thereby laying the groundwork for economic growth. Furthermore, by offering innovative construction products, materials and services to a user, the user's viewpoint is broadened thus enhancing his/her good taste, and a need for a better quality of life forms. Nevertheless, a good deal of resistance and quite a few phobias that various socio-cultural factors stipulate are encountered at this point.

Ordinary people rely on cognitive shortcuts or heuristics to make sense of issues about which they have low levels of knowledge (Scheufele 2006), just as they do with many other political and scientific matters. These heuristics can include pre-dispositional aspects, such as ideological beliefs or value systems (Kahan et al. 2008), as well as short-term frames of reference that the media or other sources of information provide (Scheufele and Lewenstein 2005). Recent research suggests that "religious filters" are an important heuristic for scientific issues in general (Ho et al. 2008).

Representatives of different cultures have ambiguous views toward the Passive House. A great many socio-cultural factors influence such outlooks. The most important are social, cultural, ethnic, ethical, psychological, political, security, independence, attitudes, public support, religious/spiritual and environmental factors and trustworthiness. These are further presented in brief.

Social factors associate with people's income, social status, gen-der and other similar matters in life. A sufficient income lays the groundwork for the selection of an innovative Passive House when looking for more comfort, for a better quality home. The opposite is also true – a limited amount of funds forces selection of a traditional, more conservative home, because risk-taking is undesirable. The level of the quality of life in Lithuania is not high by EU standards. Thus it is no surprise that Lithuanians are not especially interested in decisions regarding innovative Passive Houses.

Some USA organizations have measured public levels of concern using various permutations of this question: How serious of a problem/threat is global warming? In a 1998 Mellman Group national poll, 70% of voters said global warming was a "very serious" or "somewhat serious" threat. By 2001 Time/CNN found that 76% thought global warming was a "very serious" or "somewhat serious" problem (Leiserowitz 2005). According to Dessai et al. (2004), lay public perceptions and interpretations of a dangerous climate change, however, are "based on psychological, social, moral, institutional and cultural processes". Public risk perceptions are influenced not only by scientific and technical descriptions of danger but also by a variety of psychological and social factors, including personal experience, affect and emotion, imagery, trust, values and worldviews (Slovic 2000).

A religious filter is more than a simple correlation between religiosity and attitudes toward science: it refers to a link between benefit perceptions and attitudes that varies depending on respondents' levels of religiosity (Brossard et al. 2009). Leiserowitz (2005) argues that religiosity is part of a package of cultural and social values that is often correlated with levels of skepticism about technological and environmental risks. According to Leiserowitz (2005), public attitudes about environmental and technological risks significantly correlate with a package of larger cultural attributes that include religiosity. Furthermore public risk perceptions are critical components of the sociopolitical context within which policymakers operate. Public opinion can fundamentally compel or constrain political, economic and social action to address particular risks. For example, public support or opposition to climate policies (e.g., treaties, regulations, taxes, subsidies) will be greatly influenced by public perceptions of the risks and dangers inherent in climate change (Leiserowitz 2005).

The book "The Protestant Ethic and The Spirit of Capitalism" is Weber's first brush with the concept of rationalization. His idea of modern capitalism as growing out of the religious pursuit of wealth meant a change to a rational means of existence, wealth. In essence then, Weber's "Spirit of Capitalism" is effectively and more broadly a Spirit of Rationalization. The Protestant work ethic is a concept in sociology, economics and history, attributable to the work of Max Weber. It is based upon the notion that the Calvinist emphasis on the necessity for hard work as a component of a person's calling and worldly success. It is argued that Protestants beginning with Martin Luther had reconceptualized worldly work as a duty which benefits both the individual and the society as a whole. Thus, the Catholic idea of good works was transformed into an obligation to work diligently as a sign of grace. Whereas Catholicism teaches that good works are required of Catholics to be saved (Wiki). Religious and cultural beliefs influence the outlook on the Passive House. People from highly religious countries, such as Lithuania, Poland or Ireland, are less likely to select a Passive House. Meanwhile people from countries where religion is less meaningful, such as Belgium, the Netherlands and Scandinavian countries, make more favorable decisions regarding Passive Houses.

Developers, builders and their supply chains are in a position to drive innovation and economies of scale in energy efficiency and distributed energy technologies. The use of new approaches can have a demonstrator effect, not only to the house building industry but to tackling carbon emissions in existing homes and communities too. The zero carbon homes policy is designed to promote leadership in this important area. Potentially this process of innovation can help to bring about wider innovation in the house building industry too – transforming design, improving quality and changing the house building process through, for example, modern methods of construction (Department for Communities… 2008).

Ethnic factors associate with the mentalities, comprehension of the priorities of material and spiritual values and the demands made for residential housing with consideration for long-standing national traditions of the various ethnic groups living within a country. The injustices and foreign occupations that Lithuania suffered over the course of history have made Lithuanians wary of innovations (including the newness of the Passive House); however, at the same time, they are flexible coupled with conservative practicality (Cultural Tradition… 2008).

Psychological factors associate with the features, inclinations and pleasures relevant to the psychological behavior of singular individuals and their groups that influence their life styles and their demands for residential housing. On their own accord, these aspects indicate the readiness of individuals to use modern construction materials and technologies as well as to accept the applicable risks. Lithuanians lived a long time within the enclosed sphere of the Soviet Union; thus they had no means to learn about and employ the latest technologies in construction and the standards of comfort in housing, such as those that the West deemed acceptable. This long-term isolation from the Western world contributed to the temperate view Lithuanians take regarding the innovations of the Passive House. However, this view has been changing, since Lithuania joined the EU and new opportunities opened up. Caution is more and more often aligned with the endeavor to achieve a better life style, which the application of new technologies in housing construction can assure.

Many academic debates about how citizens form attitudes about scientific issues boil down to a conflict between ideals and realities. There have been decades of research in social psychology, political science and risk communication suggesting that knowledge plays a marginal role, at best, in shaping people's opinions and attitudes about science and technology. In fact many researchers have suggested that the way the media present an issue and people's value systems and predispositions play a much greater role in shaping citizens' attitudes toward new technologies. For example some critics of nanotechnology have referred to it as the "asbestos of tomorrow" alluding to the potential unknown and long-term risks connected with nanoparticles. This metaphor is a highly effective way of using asbestos to evoke an existing interpretive schema that many people share. More importantly the asbestos frame is difficult to counter since it refers to risks that will not be within awareness until decades down the road. However, if scientists want to have their views heard in public debates, they need to understand and use the tools that are available and appropriate for communicating effectively with different audiences (Scheufele 2006).

Although the aforementioned factors are important for every member of a sociocultural community, each individual will ascribe his/her own priorities to them. On one hand, this indicates the level of the economic and social achievements of a community and the receptivity of its members for Passive House innovations. On the other hand, the forms of untraditional activities and the methods and means for implementing decisions can cause phobias.

Innovation rarely comes from expected places. Thus low-carbon solutions can be expected to emerge from all parts of the economy – not just the established "energy" or "environment" sectors, both of which can be hidebound by traditional ways of thinking. The "disrupters" we studied included a leadership coach, a design student, a building services manager and a hill farmer. Environmentalists alone would not save the world. And real progress can be made when a series of innovations link together and set off a chain reaction. We need to think of innovation as "tipping points" and create policy that supports them. Where innovation is locked out of current systems, the government could create space for experimentation in low-carbon innovation zones. Local and regional decision-makers could pledge carbon cuts and set a framework to achieve them. In return they could be given greater autonomy and scope for regulatory experimentation and a larger share of funding to find ways to involve local households, communities, businesses and the public sector in carbon reduction. In effect this would be a sort of low-carbon devolution creating the right conditions for radical change (Willis 2007).

The various components of the Passive House approach can be classified under the following basic elements. The first three (superinsulation, heat recovery and passive solar gain) are crucial to the Passive House concept. To fully minimize environmental impacts, however, the other two are necessary (electrical efficiency) or expedient (meeting remaining energy demand with renewables) (Emerson et al. 2010). In most cases, low energy consumption is not enough for owner-occupiers or tenants to move into a Passive House. Such benefits are, e.g., as follows: prestige, wellness, comfort, environmental friendliness (Nation Ranking 2011; Schnieder and Hermelink 2006). Compared to its neighbors, Lithuania's position in the Environmental Performance Index and the Environment Index is rather bad. The situation could be improved with more intense Passive House development (see Table 3.1).

Table 3.1 Environmental performance and other indices (Eurostat (Emerson et al. 2010; Nation Ranking 2011))

		LT	Den	Sw	Fin
1	Environmental Performance Index (2010)	37	32	4	12
2	Quality of Life Index (2011)	30	11	3	7
3	Health Index (2011)	34	25	10	21
4	Education Index (2011)	25	18	23	1
5	Wealth Index (2011)	44	16	6	19
6	Environment Index (2011)	33	28	4	10
7	Economy Index (2011)	75	25	17	31
8	Technology Index (2011)	33	43	11	19

According to Canadian Passive House Institute (Canadian Passive… 2011), Passive House is the world's most ambitious and scientifically verified route to truly sustainable buildings, achieving 80–90% energy savings over conventional construction through radical conservation. Sustainable development is also important for the quality of life for the buildings' users. Modern technologies and innovative solutions used in the construction industry can significantly affect the com-fort of apartments and offices, and thus the health of the occupants (Zelazna and Pawłowski 2011). Regarding high-tech sectors national averages, 17 out of the 32 observed countries registered values higher than the EU-27 aver-age (3.7%) with over 5.0% in Denmark, Finland and Sweden. On the other range of the scale, the lowest national shares of high-tech sectors in total employment below 2.5% were registered in Greece, Cyprus, Latvia, Lithuania, Portugal, Romania and Turkey. Six European countries (Estonia, Cyprus, Latvia, Lithuania, Luxembourg and Malta) and Iceland are classified at NUTS level 1 (Science, Technology… 2011). Apparently, modern technologies and innovative solutions are not widely used in Lithuania, which evidently might have an effect on the comfort of apartments and offices, and thus the health of the occupants in Passive House. It is a very important issue to Lithuania, the position of which in the Quality of Life Index and the Health Index is worse than that of other compared countries (see Table 3.1).

Complaints about the indoor environment indicate that certain health complaints are more prevalent with heat recovery ventilation systems. The occupancy level of dwellings is an indicator of health risk exposure as well (Hasselaar 2006). During a 3 week period different measurements in three of the first Passive Houses projects in Netherlands were undertaken to define indoor air quality and thermal comfort. Results showed that in some cases ventilation was completely insufficient. Energy saving and sustainability is very important but not at the risk of endangering health of the occupants (Zeiler and Boxem 2009). Smaller and well occupied Passive Houses are more at risk, with different indicators of potential health hazards (Hasselaar 2008). The situation with the average useful floor area per person is rather bad in Lithuania (24.9 m^2/person), while Denmark enjoys 51.4 m_2/person, Sweden 45.2 m^2/person and Finland 38.9 m^2/person. These trends seem to show that Lithuania will develop smaller and well occupied Passive Houses with potentially more health hazards. These are paramount issues to Lithuania, which globally ranks 34th in the Health Index (see Table 3.1), while Denmark (25th), Sweden (10th) and Finland (21st) enjoy impressive achievements in the area of health.

The Passive House standard can make a considerable contribution to overcoming the economic crisis. Above all, using this highly efficient standard will strengthen the regional economy. Local investments and generated turnovers will cause a boom independently from the global economic situation but with a sustainable effect on the worldwide climate (Energy Union 2010). These are important issues to Lithuania, which suffered from the crisis a great deal. In 2009 Lithuania's Real GDP Growth Rate (percentage change on previous year) dropped by as many as 14.8%.

As far as Lithuania, its construction processes and materials are concerned, different types of Passive House will be determined by certain historical conditions. The types of Passive House depended on different ethnic landscapes and regional traditions.

In Europe, a Passive House represents a level of superior com-fort. The quiet interior environment features warm walls, fresh air, no drafts, reduced levels of dust and a surprising amount of natural light. Over 10,000 Passive House Standard buildings have been constructed as of 2007 (US Housing and… 2009).

In 1989 and 1990 there were many discussion in Lithuania how to achieve Lithuania's independence: should the priority be economic or political independence.

Now the same discussion continues. Opponents argue that Lithuania joining the energy networks of Western and Northern Europe might mean more expensive electricity. In terms of energy, Lithuania in effect remains part of the USSR system. Lithuania seeks to become full member of Europe in terms of its values (energy, too), but is not so in terms of energy. This idea is foremost in construction of the LitPol Link and NordBalt interconnections. These interconnections would reinforce Lithuania's energy independence and would facilitate better resistance to a range of influences, which is a huge priceless value cherished by Lithuania's Government. EU has already made a decision to turn the European energy sector into a single network without any areas bereft of energy security, as Lithuania is now. Admittedly, some interconnections (LitPol Link and NordBalt), which are a means to eliminate such areas, may not pay off in the short term and must therefore be supported by EU funds.

The prices of energy resources used to be low in Lithuania. They were extremely low during the entire Soviet period. Then the gas prices were also very low up until 2005: just $80 per thousand cubic meters, almost five times less than now. Experts believe the situation contributed to the attitude that from economic point of view, rather than political, nothing really needed to be done.

Lithuania, now paying about $400 per thousand cubic meters, struggles to negotiate with "Gazprom" at least the same gas prices as those paid by its neighbors Estonia and Latvia. Estonia pays $309 per thousand cubic meters, but it has an interconnection with Finland; Latvia pays $310, but it has gas storage facilities owned by Russia. But Lithuania is penalized for political reasons, because it embarked on implementing the EU gas directive on separation of transmission system operators, rather than for the failure to fulfill its obligations and buy the entire negotiated amount of gas. Estonia and Latvia managed to secure an exemption, but the past Seimas, Lithuania's parliament, assumed obligation to fulfill the directive.

Lithuanian experts believe that lower energy bills will help improve Lithuania's energy independence and security. In autumn 2012, a new unit of Lithuanian Power Plant will start working in Elektrėnai: rather as an attempt to ensure country's energy security and reliable supply than to achieve any economic goals. Its electricity cost is forecasted to exceed that of imported power. The new unit will replace older less efficient units and, in winter, will be more efficient than urban combined heat and power plants.

The time span for full transition from traditional buildings to construction of energy-efficient buildings is generally rather long. Painless reorganization of the entire construction industry to adopt the newest technologies takes, for instance, about 12–20 years. The shift of mindsets and attitudes of participants in this process is equally important. Attempts to persuade construction firms proved to be particularly difficult, because construction of Passive Houses is both more costly and more complex, while civil engineers need excellent training.

The number of Passive Houses under construction varies constantly. During crisis people feel not too secure financially and revert to saving, which, in turn, led to plummeting demand for new Passive Houses. Demand fluctuations also much depend on state funding.

Public support to development of Passive Houses often is deter-mined by the price. In countries where the price of 1 kW-h of electricity is relatively high, the interest in Passive Houses is very high. But just as oil prices start falling, the doubts return. German consumers already get monthly bills with about 3% attributed to energy from renewable sources. Germans pay for such energy D10 billion per year. But since Germany has access to tons of cheap gas from Russia, public reaction is not at all times favorable. Each new law in effect transforms into a new item in the bill, thus people need motivation, and the government needs to find the best pace for transition to renewable sources. Otherwise voters may shift to other options at the next elections.

The production cost of energy from renewable sources is high; the state supports such production by subsidies and tries to improve its efficiency. As of 1 January 2012, producers of renewable energy, for instance, must take part in auctions of such renewable energy sources.

3.2.3 Self-expression Values, Environmentalism, Global Warming and the Passive House

The World Values Surveys were designed to measure all major areas of human concern, from religion to politics to economics and social life. It turns out that two dimensions of values dominate the picture: (1) Traditional vs. Secular-rational and (2) Survival vs. Self-expression. These two dimensions explain more than 70% of the cross-cultural variance on scores of more specific values. Survival values involve a priority of security over liberty, distrust in outsiders and a weak sense of happiness. Self-expression values imply the opposite on all these accounts (Inglehart and Welzel 2005).

3.2.3.1 Self-expression Values and Environmentalism

Scholars and practitioners from various countries (Inglehart 1995; Martinez-Alier 1995; Guha and Martínez-Alier 1997; Inglehart 1997; Brechin 1999; Guha 2000; Martinez-Alier 2000; Davey 2009) analyzed the interrelationship between environmentalism and post-materialist values, such as self-expression and quality of life. The connectedness of several of these is further described in brief.

There are two distinct environmental movements – the materialist and the post-materialist movements. Post-materialist environmental movements focus on “quality of life” values and conservation of wilderness and natural areas. Materialist environ-mental movements, known as “the environmentalism of the poor”, are focused on the defense of environmental resources, which are needed for survival and livelihood or are a reaction against the increased impact of pollution and environmental degradation that create health risks. Post-materialist environmental movements are more often situated in industrialized, developed countries, and the materialist environmental movements are mainly located in the third world (Guha and Martínez-Alier 1997). One such example is a campaign in the US that began in the 1980s against local pollution and toxic waste problems. The campaign highlighted the disproportionate number of toxic waste areas located in regions inhabited by poor people who happened to be "Afro, Hispanic or Native American". The issue highlighted the unfair burden placed on the poorest and the dis-enfranchised members of society (Martinez-Alier 2000).

In many respects, South Africans still regard the environment as a "luxury good" to be conserved when, and only when, other social and economic needs have been met. As a result many of the country‘s poorest people, who depend on direct water abstraction, wild harvesting of fuel and food and fodder, subsistence agriculture and soil fertility, are trapped in a cycle of ecological degradation and poverty precipitated by the very development process that was intended to assist them (Martinez-Alier 1995). Environmentalism of the poor was often overlooked, because it was seen to be more motivated by social issues and survival than concerned with the environment (Davey 2009). In addition Inglehart (1995; 1997) suggests strong positive correlations between wealth and concern with environmentalism.

Franzen and Meyer (2010) review some theoretical approaches that try to explain individual as well as cross-national differences in environmental attitudes. Particularly Franzen and Meyer (2010) discuss Inglehart's theory of post-materialism, Dunlap and Mertig's globalization explanation and the prosperity hypothesis. Secondly Franzen and Meyer (2010) test these hypotheses by applying multilevel analysis to the International Social Survey Programme (ISSP) data from the years 1993 and 2000. The results support, above all, the prosperity hypothesis. Individuals with higher relative income within countries display higher levels of environmental concern than their compatriots and, additionally, more concern is reported in wealthier countries than in poorer nations. The results indicate that environmental concern is also closely associated with postmaterialistic attitudes and various socio-demographic variables (Franzen and Meyer 2010).

3.2.3.2 Passive House, Global Warming, Zero Carbon Emissions and Self-expression Values

Three critical issues that our world faces today are energy conservation, global warming and the need for more quality housing. The solutions to these issues, however, do not always seem to fall neatly in line: How can we decrease carbon dioxide emissions and reduce energy use in existing homes whilst simultaneously dealing with increased energy demand and emissions due to the growing overall number of homes? Housing must boast dramatic reductions in energy consumption and zero carbon emission for a desirable environment to form, which will live up to Passive House standards (Buildings and the Passive… 2010).

The circumstances under which societies adapt their cultural values to cold, temperate or hot climates must include the avail-ability of money to cope with climate. In a country-level study, collective income, household income and economic growth were conceptualized as moderators of the climate-culture link, because money is primarily used to satisfy homeostatic needs for thermal comfort, nutrition and health. The results demonstrate that members of societies in more demanding climates endorse survival values at the expense of self-expression values to the extent that they are poorer (n = 74 nations). Household incomes in these lower-income societies are lower (n = 66 nations), and such societies face more economic recessions (n = 38 nations). In addition to theoretical implications, the findings have practical implications for the cultural consequences of global warming and the effective-ness of financing for human development (Van de Vliert 2008). A 104-nation study first demonstrates that cultural self-expression, individualism and democracy languish in poor countries with colder-than-temperate winters, but flourish in rich countries with such winters (Van de Vliert and Tol 2011).

Currently Lithuania conveys survival values according to the criterion of "self-expression values" as per World Values Surveys (see Fig. 3.2). It can be claimed, on the basis of the aforementioned studies, that such a situation does not foster the development of the Passive House in Lithuania. The existing state of affairs in Lithuania substantiates this claim. Only two Passive Houses of single-family residency have been constructed at this time in Lithuania. How-ever, now the situation has shifted slightly toward self-expression values.

The shift from survival values (Fig. 3.2, bottom part) to self-expression values (upper part) is very slow in Lithuania. We shall make an EU-level relative analysis of this process by looking at the residential construction and building maintenance costs in four countries (Lithuania, Denmark, Sweden and Finland) between 1995 and 2008. We shall focus on the following indicators:

- Construction Cost Index, residential buildings (2005 = 100%).
- Comparative price level indices for housing costs (gross rent, fuel and power) (EU-27 = 100%).
- Share of households that perceive housing costs without financial burden (%) (2005/2008).
- Low income households by tenure and households receiving housing allowances (2008).
- Housing consumption as share of total (culture, food, clothing, etc.) household consumption (%) (2000/2007).

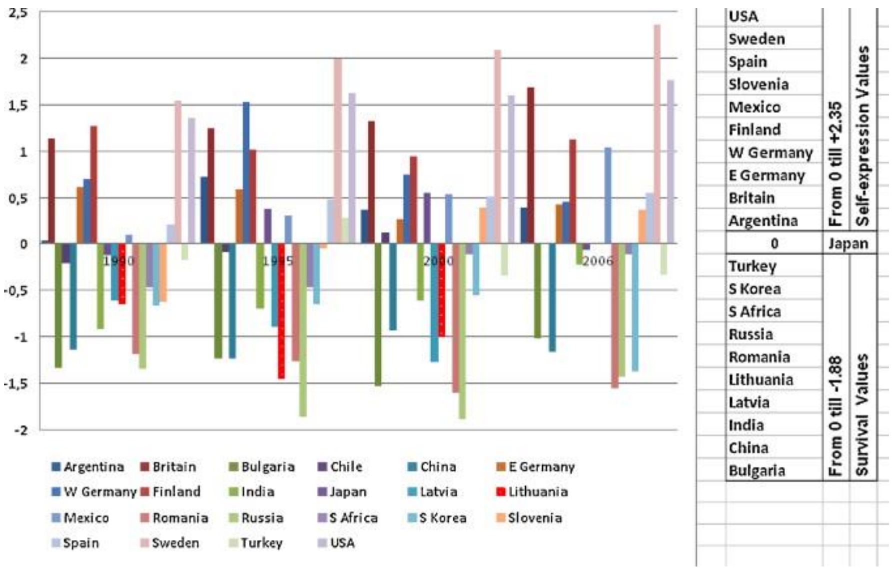


Fig. 3.2. The shift from survival values (bottom part) to self-expression values (upper part) indicate slightly better conditions for developing the Passive House in Lithuania (−0.64 in 1990, −1.45 in 1995, −1 in 2000 and 0 in 2006; in red color with dots) (World Values Surveys). Self-expression values are scaled from 0 to 2.5 scale, with a 2.5 score on the scale indicate the achieving of the highest self-expression values. Survival values are scored on a 0 till −2 scale, with a −2 score on the scale indicate the achieving of the lowest survival values

Table 3.2 presents the EU-level relative analysis of residential construction costs in four countries (Lithuania, Denmark, Sweden and Finland) between 1995 and 2008. Between 1995 and 2008 the Construction Cost Index (residential buildings, 2005 = 100%) in the countries considered here increased from 37.8% (in Finland) to 124.2% (in Lithuania). In the same period the changes of GDP per capita in Purchasing Power Standards (EU-27 = 100%) varied greatly in these countries: increased in Lithuania (73.9%) and Finland (8.4%), but dropped in Denmark (8.9%) and Sweden (4.3%). Since all countries started from very unequal economic situations in 1995, it seems logical. In 1995 GDP per capita at current prices was D1400 in Lithuania, D19,600 in Finland, D26,600 in Denmark, and D22,000 in Sweden, but the relative growth rate of this indicator was considerably higher in Lithuania and by 2008 the GDP per capita at current prices there had reached D9600, while it amounted D42,400 in Denmark, D34,700 in Finland, and D35,400 in Sweden. It seems therefore plausible to say that over the 13-year period the increase of the relative construction cost at EU level (in light of the changes of the Construction Cost Index and GDP per capita in Purchasing Power Standards) in Lithuania (124.2–73.9% = 50.3%) and Finland (37.8–8.4% = 29.4%) was lower than in Denmark (48.3% to −8.9% = 57.2%) and Sweden (63.6% to −4.3)% = 67.9%). It means that Lithuania, in terms of the residential construction costs and compared to Scandinavian countries, experienced a slow shift from survival values to self-expression values (relative drop of construction costs leaves more resources for self-expression). Such events facilitate development of Passive Houses in Lithuania.

Table 3.2 EU-level relative analysis of residential construction costs in four countries (Lithuania, Denmark, Sweden and Finland) between 1995 and 2008 (Eurostat)

Indices	Lithuania	Denmark	Sweden	Finland
1. Construction Cost Index, residential buildings (2005 = 100%):				
– Years 1995 and 2008	62.8/140.8	77.5/114.9	71.4/116.8	82.9/114.2
– Increase, %, between 1995 and 2008	+124.2%	+48.3%	+63.6%	+37.8%
2. GDP per capita in Purchasing Power Standards (EU-27 = 100%):				
– Years 1995 and 2008	35.6/61.9	131.8/120.1	125.4/120	107.7/116.8
– Increase, %, between 1995 and 2008	+73.9%	−8.9%	−4.3%	+8.4%
Between 1995 and 2008 a relative EU-level increase of the Construction Cost Index was recorded (Construction Cost Index − GDP per capita in Purchasing Power Standards)	50.3%	57.2%	67.9%	29.4%

Table 3.3 shows the EU-level relative analysis of price level indices for housing costs (gross rent, fuel and power; EU-27 = 100%) in four countries (Lithuania, Denmark, Sweden and Finland) between 2000 and 2008. Table 3.3 shows that the highest increase of Comparative Price Level indices for housing costs over the analyzed 9-year period (between 2000 and 2008) was in Lithuania (46%), followed by Denmark (12%) and Finland (2.5%), while Sweden recorded a drop of 17.8%. Meanwhile, Lithuania's GDP per capita in Purchasing Power Standards increased over the same period by as many as 57.5%, while it dropped in Denmark (8.7%), Sweden (5.3%) and Finland (0.3%). It seems therefore plausible to state that over the 9-year period the EU-level Comparative Price Level indices for housing costs (in view of the changes of the GDP per Capita in Purchasing Power Standards) relatively dropped in Lithuania (46–57.5% = –11.5%) and Sweden (−17.8% to −5.3% = –12.5%), but relatively increased in Denmark (12% to −8.7% = 20.7%) and Finland (2.5% to −0.3% = 2.8%). It means that over the 9-year period residential buildings maintenance costs dropped in Lithuania (compared to Scandinavian and EU countries), leaving more resources for self-expression values; which from a certain viewpoint encourages Passive House development in Lithuania.

Table 3.3 EU-level relative analysis of price level indices for housing costs (gross rent, fuel and power; EU-27 = 100%) in four countries (Lithuania, Denmark, Sweden and Finland) between 2000 and 2008 (Eurostat)

Indices	Lithuania	Denmark	Sweden	Finland

Comparative price level indices for housing costs (gross rent, fuel and power) (EU-27 = 100%):				
– Years 2000 and 2008	31.1/45.3	140.0/157.4	136.2/112.0	130.1/133.3
– Increase, %, between 2000 and 2008	+46%	+12%	−17.8%	+2.5%
GDP per capita in Purchasing Power Standards (EU-27 = 100%):				
– Years 2000 and 2008	39.3/61.9	131.6/120.1	126.7/120	117.1/116.8
– Increase, %, between 2000 and 2008	+57.5%	−8.7%	−5.3%	−0.3%
Between 2000 and 2008 a relative EU-level change of the housing costs was recorded (Comparative price level indices for housing costs − GDP per capita in Purchasing Power Standards)	Relatively decrease, 11.5%	Relatively increase, 20.7%	Relatively decrease, 12.5%	Relatively increase, 2.8%

Analyses of other similar indicators lead to equivalent conclusions (see Table 3.4).

Table 3.4 Other similar indicators (Eurostat)

Indices	Lithuania	Denmark	Sweden	Finland
Share of households that perceive housing costs without financial burden (%) (years 2005 and 2008)	14.9/16.5	73.2/69.6	50.4/52.7	24.1/23.1
Low income households by tenure and households receiving housing allowances (2008)	19	12	11	13
Housing consumption as share of total (culture, food, clothing, etc.) household consumption (%) (years 2000 and 2007)	17.0/13.6	26.6	27.8	24.7/24.7

Household consumption habits vary substantially among the EU Member States. Factors such as culture, income, weather, household composition, economic structure and degree of urbanization can all influence habits in each country (Eurostat).

3.2.4 Low Energy Dwelling Weaknesses in Lithuania

The following low energy dwelling weaknesses in Lithuania were established during the time of the project, “Promotion of the Passive House Concept to the North European Building Market” (NorthPass):

- Lithuania’s Law on Construction and its Technical Construction Regulations are not tailored for Passive Houses. Passive Houses were designed on the basis of the Finish, Swedish and German experiences.

- Administrative and public procurement procedures are too slow. In particular the process of obtaining decisions, permits, certificates and such from public authorities is too time-consuming causing it to be too slow for the commencement of large-scale public projects.
- The Energy Performance of Passive Houses Directive is not yet fully concerned with relevant, already existing standards and norms for Passive Houses in Lithuania.
- There is no certification of low energy design and construction experts yet. Certification of low energy products is insufficient. There is minimal information on assessed low energy houses found to have a reasonable energy and indoor climate performance.
- There is a shortage of feedback from previously known explicit and tacit information and from new low energy houses. There is a belief that building low energy houses is more expensive than the usual construction. Thus on-site problems cannot always be solved.
- A tenants' association does not always have the necessary competence. Real estate management organizations are often uninvolved. Too many prejudices from the energy saving measures from the eighties exist. Workmanship for thermal insulation has too low a status. Workers can be prejudiced regarding new methods. There are too few contractors, developers and property managers who are indoor climate and energy experts.
- The Passive House and low energy design theory is not sufficiently introduced in Lithuanian bachelor and master degree study programs.
- Users lack knowledge to be able to assess the pluses of a low energy Passive House (comfort, low noise, economic efficiency). As a result, the low energy, Passive House remains unknown and demand fails to grow.
- The media fail to deliver sufficient information to stimulate interest in passive homes and to motivate professionals and decision makers.
- Scientists lack knowledge about the needs of users and contractors. Therefore it becomes complicated for architects, designers and contractors to stay up-to-date about new energy saving products, materials and systems.
- Education faces a fragmentation problem. Each player (owner, user, developer, architect, designer, consultant, contractor, manufacturer, user, real estate and facilities manager) generally has highly narrow knowledge, in his/her own field alone.
- There are too few financials incentives (calls for projects, subsidies, energy labels and such) for developing lifelong learning about Passive Houses (web portal, seminars and workshops, technical publications presenting the codes, case studies).
- Since the market for Passive Houses is limited, prices for them continue increasing. Large scale production is currently inapplicable; therefore nonproductive efforts of all types are impossible to reduce, including labor and construction costs, and the rate of production cannot be increased to reduce the time for construction.

- Different stakeholders design a Passive House integrating its full lifecycle insufficiently.
- The price of equipment (e.g., recuperators) and structural solutions (e.g., windows) is quite high considering the salaries and the amount of energy saved. Savings, in relation to investments, are low.
- There are no land tax reductions, and land is not sold at a lower price for the construction of Passive Houses. The plot ratio is not higher in case of passive construction.
- Fees are not designed to reward designers and architects of Passive Houses that have low maintenance and low lifecycle costs. There are no available subsidies for research development on the energy consumption and on the most rational energy sources to be used for a Passive House under consideration.
- The level of the VAT level is too high on an entire list of equipment types that can increase energy efficiency in the domestic sector (efficient boilers, insulation and energy meters and such). There are no tax credit schemes in place to provide real estate owners who purchase energy saving or energy renewing equipment with an income tax refund. Furthermore there are no specific loans in place that would grant interest rate reductions in whole or in part. Banks are not accustomed to funding energy savings when issuing loans for a specific Passive House.
- The more energy costs increase, the greater the demand for Passive Houses will be.

Stakeholders only agree on one key aspect. The cases of other countries teach a lesson – only the state can put in motion the construction of energy efficient and environment-friendly houses. The range of incentives is huge, from tax benefits to easy credit terms or even a substantial discount for fuels for a certain period (Technology, Pasyvus… 2008).

3.3 The Intelligent Passive House Design System

Upon analyzing the simulation tools for a Passive House or its composite parts (Yakubu 1996; Thiers and Peuportier 2008; Chlela et al. 2009; Parker 2009; Wang and Gwilliam 2009), an Intelligent Passive House Design (IPHD) System was developed to design the most efficient versions of a Passive House. The IPHD System consists of a developed intelligent database, database management system, model-base, model-base management system and context-aware interface (Fig. 3.3).

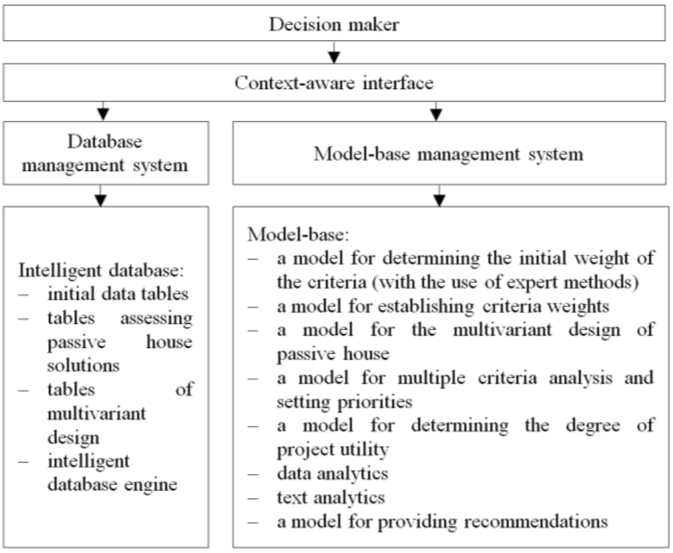


Fig. 3.3. IPHD System and its composite parts

The following tables comprise the IPHD System intelligent database:

- Initial data tables that contain general facts about a Passive House
- Tables assessing Passive House solutions that contain quantitative and conceptual information about alternative Passive House solutions relating to Passive House enclosures, engineering systems, utilities, space planning and the like
- Tables of multivariant design that provide quantitative and conceptual information on the interconnection of the elements to be designed, their compatibility and possible combinations as well as data on a complex multivariant design of a Passive House
- Intelligent database engine (see Section 1.4)

The database management system was used to design the structure of an intelligent database and perform its completion, storage, editing, navigation, searching, browsing and other functions.

The tables assessing Passive House solutions contain the available variants and their quantitative and conceptual descriptions. A quantitative description of the alternatives deals with the systems and subsystems of criteria fully defining the variants as well as the units of measurement and values and initial weights. A conceptual description defines the alternatives available in a commonly used language giving the reasons and providing grounds for choosing a particular criterion, calculation its value, significance and the like.

The above tables are used as a basis for working out decision-making matrices. These matrices, along with the use of a model-base and models, make it possible to perform a multivariant design and multiple criteria evaluation of alternative Passive House projects resulting in the selection of most beneficial variants.

The available alternatives should be analyzed to design and realise an effective Passive House project. A computer-aided multivariant design requires the availability of the tables containing the data on the interconnections of the elements to be constructed and the solutions, as well as their compatibilities, possible combinations and multivariant design.

Since the objectives and financial situations of IPHD System users often vary, the initial design data and, consequently, the results obtained will also be different. Therefore the objectives and the financial situation of the clients are expressed quantitatively and provided as the initial data for calculations. These data should be related to the other information contained in the tables. Possible Passive House variants are being developed as per the above tables of multivariant Passive House designs. As many as up to 100,000 alternative Passive House projects may be obtained using the multivariant design method that this author develops. These project versions are checked for their capacity to meet various requirements. Those that cannot satisfy the requirements raised are excluded from further consideration. Designing a number of Passive House variants causes the problem of the significance compatibility of the criteria. In this case, when a complex evaluation of the alternatives is performed, the value of a criterion weight is dependent on the overall criteria being assessed, as well as on their values and initial weights.

A model-base of a decision support system should include mod-els enabling a decision maker to do a comprehensive analysis of the variants available and make a proper choice, because the efficiency of a Passive House variant is often determined by taking into account economic, esthetic, technical, comfort, legal/regulatory, social and other aspects. The following model-base models are meant to perform this function:

- a model for determining the initial weights of the criteria (with the use of expert methods)
- a model for establishing criteria weights
- a model for the multivariant design of a Passive House
- a model for multiple criteria analysis and setting priorities
- a model for determining the degree of project utility
- data analytics (TANAGRA data mining software and KNIME Analytics Platform)
- text analytics (see Section 1.4)
- a model for providing recommendations

The methods developed by this author herein provide the bases for the development of these models as follows (Kaklauskas et al. 2005; 2006):

- A method for the complex determination of criteria weights that takes into account their quantitative and qualitative characteristics, which allows calculating and coordinating the weights of the quantitative and qualitative criteria according to the above characteristics.

- A multiple criteria method for a complex and proportional evaluation of alternatives to enable a student to obtain a reduced criterion for determining the complex (overall) efficiency of an alternative – this generalized criterion is directly proportional to the relative effect of the values and weights of the criteria considered on the efficiency of the alternatives.
- A method to define the utility degree and market value of an alternative by which the utility degree and the market value of the alternatives being estimated are directly proportional to the system of criteria that adequately describes them and the values and weights of such criteria.
- A method for the multiple criteria, multi-variant design of the life cycle of an alternative.

These developed models provide the bases for the ability of an IPHD System to generate up to 100,000 Passive House alternative versions, perform their multiple criteria analysis, determine their utility degrees and select the most beneficial variant, all without further human intervention.

A management system of the IPHD model-base provides a user with a model-base that permits modifying the available models, eliminating those which are no longer needed and adding some new models linked with the existing ones.

The greater the number of alternative versions that are investigated before making a final decision, the greater is the possibility of achieving a more rational end result. The derived information and the IPHD System form the bases making it possible to per-form a multiple criteria analysis of the composite parts of Passive House projects (walls, windows, roofs, floors, volumetric planning, engineering systems and the like) and to select the most efficient versions. Thereafter the received compatible and rational composite parts of a Passive House are joined into projects. The most efficient projects can be selected after performing a multiple criteria analysis of projects generated in such a manner. The strengths and weaknesses of the investigated projects are also analyzed. Facts regarding why and to what degree one version is better than another are also established. Conceptual and quantitative information serve as the bases for accomplishing all this.

TANAGRA is a free data mining software for academic and research purposes. It proposes several data mining methods from exploratory data analysis, statistical learning, machine learning and databases area. TANAGRA contains some supervised learning but also other paradigms such as clustering, factorial analysis, parametric and nonparametric statistics, association rule, feature selection and construction algorithms (Rakotomalala 2005).

KNIME Analytics Platform (see https://www.knime.org/) is a modern data analytics platform that allows user to perform sophisticated statistics and data mining on user‘s data to discover the potential hidden in user data, mine for fresh insights, analyze trends, predict potential results and new futures. Its visual workbench combines data access, data transformation, initial investigation, predictive analytics and visualization.

Context-aware interface can form a supplemental system with context-aware keywords (with a lesser significance that the search being performed now) and include it with the main keywords search system in real time, as a search is being conducted. This permits effectively forming a supplemental, context-aware keywords system based on the user model, because users generally do not conduct a random search but one that usually fits a certain framework (preparing for a specific task, looking at a previously taken assignment, a user's favorite subjects and the like).

3.4 Case Study

A description of working with the IPHD System and its operation and functions are presented next.

Initially a client who wants to construct a Passive House deals with the selection of the best alternatives of windows, roofs, walls, solar collectors, wind generators, geothermic boilers, gas boilers and such. All these procedures are based both on explicit and tacit knowledge. Smart windows are presented in Fig. 3.4 as an example of the graphical database.

Fig. 3.4. Fragment of the smart windows graphical database

Alvarez et al. (2010) note that nanomaterials will likely have a greater impact on the construction industry than any other sec-tor of the economy, after biomedical and electronics applications. They cite dozens of potential applications. For example nanomaterials can strengthen both steel and concrete, keep dirt from sticking to windows, kill bacteria on hospital walls, make materials fire-resistant, drastically improve the efficiency of solar panels, boost the efficiency of indoor lighting and even allow bridges and buildings to "feel" the cracks, corrosion and stress that will eventually cause structural failures (Alvarez et al. 2010).

Smart windows automatically change tint according to their temperature when using nanotechnology. The idea is simple enough: when it gets hot, the windows darken to block incoming solar radiation and, when it is cold, they are clear to allow the free heat in – all without electricity. The windows use "an organic, nontoxic polymer which changes its molecular structure in response to temperature". Smart windows can cut a building's energy use by 30–40% each year. That adds up to a potential, simple payback of 6 years for the product (Smashcrab.org 2010).

Compiled information provided by manufacturers, experts and users comprise the initial quantitative and qualitative database (criteria system, values and weights of criteria) of smart windows, roofs, walls, solar collector, wind generators, geothermic boilers, gas boilers and such.

The mouse is clicked on the items "Description of the alternatives" and "Windows". Then the system provides the user with the initial data necessary for the analysis (Table 3.5). The main data on the compared variants are presented in the form of a decision-making matrix: its columns express the discussed alternative variants of windows, and the rows present quantitative information describing the discussed alternatives in detail. In this particular case, nine windows variants are described in detail by 15 criteria for further analysis.

Table 3.5 Initial data of the windows multiple criteria analysis

Qualitative and quantitative description of the alternatives

Criteria describing the alternatives	*	Measuring units	Weight	Megrame 1 var.	Megrame 2 var.	Megrame 3 var.	Fakro FTP-V U3	Fakro FTU-V U3	Fakro PPP-V U3	Fakro FTP-V U5	Baltijos langai	Optiwin
Price	-	Lt	0,6	1085	1100	1201	1216	1411	2594	2042	960	1510
Mechanical strength and stiffness	+	points	0,0275	1	1	1	1	1	1	1	1	1
Reliability	+	Cycles	0,0291	20000	20000	20000	10000	10000	10000	10000	10000	10000
Thermal transmission coefficient of profile	-	W/m2K	0,0284	1,2	1,1	1,1	1,4	1,4	1,5	0,97	0,88	1
Thermal transmission coefficient of double glazing unit	-	W/m2K	0,0322	1	1,2	0,9	1	1	1	1	0,73	0,72
Emission ability of low emissive glass coating e	-	points	0,023	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4
Parameter of air sound isolation Rw	+	dB	0,0259	30	32	32	32	33	32	30	34	31
Air leakage, when pressure difference Dp = 50 Pa	-	(m3/m2h)	0,0246	0,5	0,55	0,6	0,3	0,25	0,42	0,5	0,4	0,35
Guarantee period	+	years	0,0302	5	5	5	10	10	10	10	5	5
Durability	+	years	0,0309	60	50	50	50	50	50	50	60	60
Light transmission of double glazing unit	+	%	0,022	74	68	68	75	78	78	72	74	75
Pay back period		years	0,0262	1	1	1	1	1	1	1	1	1
Duration of works	-	days	0,0225	14	14	14	10	10	10	10	14	10
Quantity of windows with two opening positions (horizontal and vertical) (in percent of the area of all windows)	+	%	0,0215	100	100	100	50	50	50	50	100	100
Quantity of windows with closing infiltration air vent or the third opening position (in percent of the area of all windows)	+	%	0,0258	100	100	100	80	80	80	80	100	100

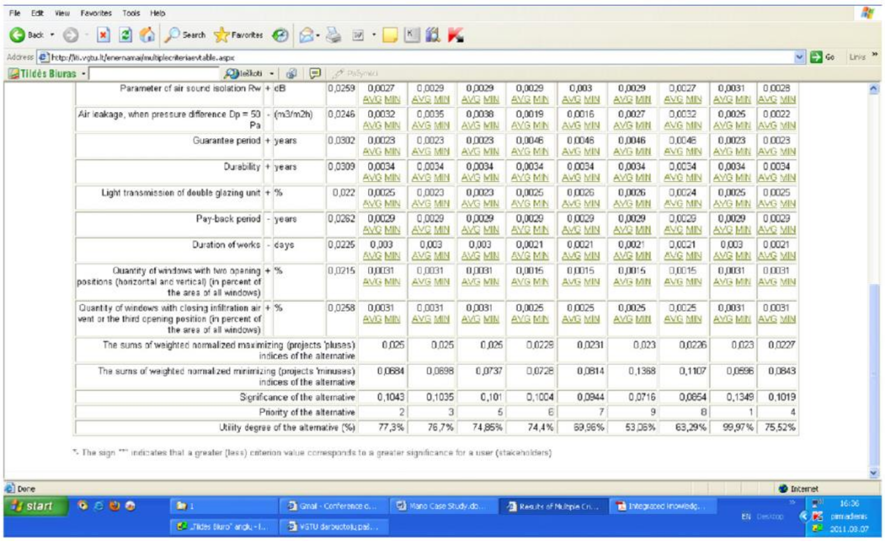
* The sign "*" indicates that a greater (less) criterion value corresponds to a greater significance for a user (stakeholders)

Table 3.5 presents the criteria system, criteria measuring units and values and weights, which describe the discussed window alternatives in detail. A user may view or specify all the alternatives, their criteria and their values and weights. A mouse-click on the title of each discussed variant (criterion) opens a new window on the web-browser, which presents detailed conceptual (textual, photographic) data of the selected variant (criterion).

The relation of various types of weights shows the number of times a particular criteria has a greater/lesser influence on the complex of the effectiveness of alternatives.

A mouse-click on the menu item “Results of multiple criteria evaluation of the alternatives” makes the system perform the multiple criteria analysis of windows. The calculations determine the utility degree and priorities of the variants (see Table 3.6).

Table 3.6 Fragment of the windows multiple criteria analysis



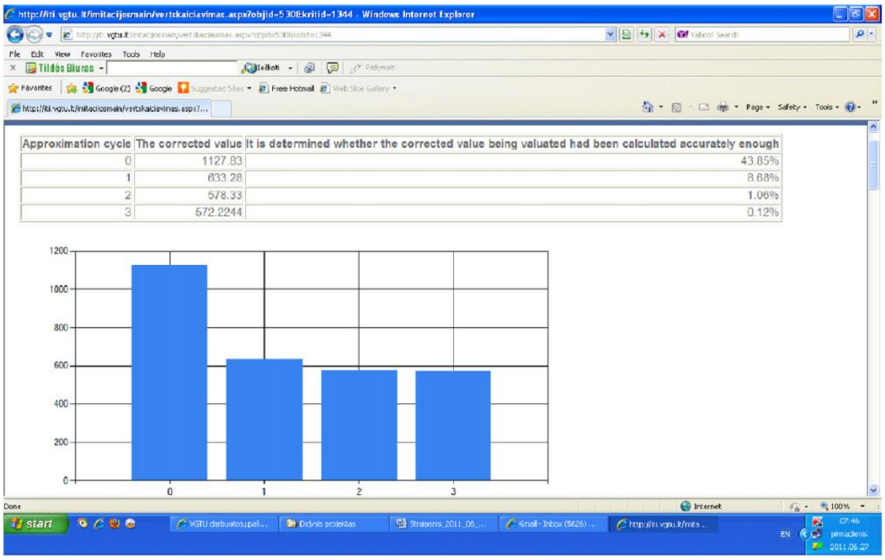
Parameter of air sound isolation Rw	+	dB	0,0259	0,0027 AVG MIN	0,0029 AVG MIN	0,0029 AVG MIN	0,0029 AVG MIN	0,003 AVG MIN	0,0029 AVG MIN	0,0027 AVG MIN	0,0031 AVG MIN	0,0028 AVG MIN
Air leakage, when pressure difference Dp = 50 Pa	-	(m3/m2h)	0,0246	0,0032 AVG MIN	0,0035 AVG MIN	0,0038 AVG MIN	0,0019 AVG MIN	0,0016 AVG MIN	0,0027 AVG MIN	0,0032 AVG MIN	0,0025 AVG MIN	0,0022 AVG MIN
Guarantee period	+	years	0,0302	0,0023 AVG MIN	0,0023 AVG MIN	0,0023 AVG MIN	0,0046 AVG MIN	0,0046 AVG MIN	0,0046 AVG MIN	0,0046 AVG MIN	0,0023 AVG MIN	0,0023 AVG MIN
Durability	+	years	0,0309	0,0034 AVG MIN	0,0034 AVG MIN	0,0034 AVG MIN	0,0034 AVG MIN	0,0034 AVG MIN	0,0034 AVG MIN	0,0034 AVG MIN	0,0034 AVG MIN	0,0034 AVG MIN
Light transmission of double glazing unit	+	%	0,022	0,0025 AVG MIN	0,0023 AVG MIN	0,0023 AVG MIN	0,0025 AVG MIN	0,0026 AVG MIN	0,0026 AVG MIN	0,0024 AVG MIN	0,0025 AVG MIN	0,0025 AVG MIN
Pay-back period	-	years	0,0262	0,0029 AVG MIN	0,0029 AVG MIN	0,0029 AVG MIN	0,0029 AVG MIN	0,0029 AVG MIN	0,0029 AVG MIN	0,0029 AVG MIN	0,0029 AVG MIN	0,0029 AVG MIN
Duration of works	-	days	0,0225	0,003 AVG MIN	0,003 AVG MIN	0,003 AVG MIN	0,0021 AVG MIN	0,0021 AVG MIN	0,0021 AVG MIN	0,0021 AVG MIN	0,003 AVG MIN	0,0021 AVG MIN
Quantity of windows with two opening positions (horizontal and vertical) (in percent of the area of all windows)	+	%	0,0215	0,0031 AVG MIN	0,0031 AVG MIN	0,0031 AVG MIN	0,0015 AVG MIN	0,0015 AVG MIN	0,0015 AVG MIN	0,0015 AVG MIN	0,0031 AVG MIN	0,0031 AVG MIN
Quantity of windows with closing infiltration air vent or the third opening position (in percent of the area of all windows)	+	%	0,0258	0,0031 AVG MIN	0,0031 AVG MIN	0,0031 AVG MIN	0,0025 AVG MIN	0,0025 AVG MIN	0,0025 AVG MIN	0,0025 AVG MIN	0,0031 AVG MIN	0,0031 AVG MIN
The sums of weighted normalized maximizing (projects 'pluses') indices of the alternative				0,025	0,025	0,025	0,0229	0,0231	0,023	0,0226	0,023	0,0227
The sums of weighted normalized minimizing (projects 'minuses') indices of the alternative				0,0684	0,0698	0,0737	0,0728	0,0814	0,1368	0,1107	0,0696	0,0843
Significance of the alternative				0,1043	0,1035	0,101	0,1004	0,0944	0,0716	0,0854	0,1349	0,1019
Priority of the alternative				2	3	5	6	7	9	8	1	4
Utility degree of the alternative (%)				77,3%	76,7%	74,85%	74,4%	69,96%	53,06%	63,29%	99,97%	75,52%

- The sign "" indicates that a greater (less) criterion value corresponds to a greater significance for a user (stakeholders)

To ascertain what price will make the alternatives under assessment competitive on the market, the author develops a method for determining the utility degree and market value of alternatives, which is based on the complex analysis of all their benefits and drawbacks. According to this method, an alternative’s utility degree and its estimated market value are directly proportional to the system of criteria adequately describing them and the values and weights of these criteria. Table 3.7 presents a fragment of the market value analysis of the Fakro PPP-V U3 window.

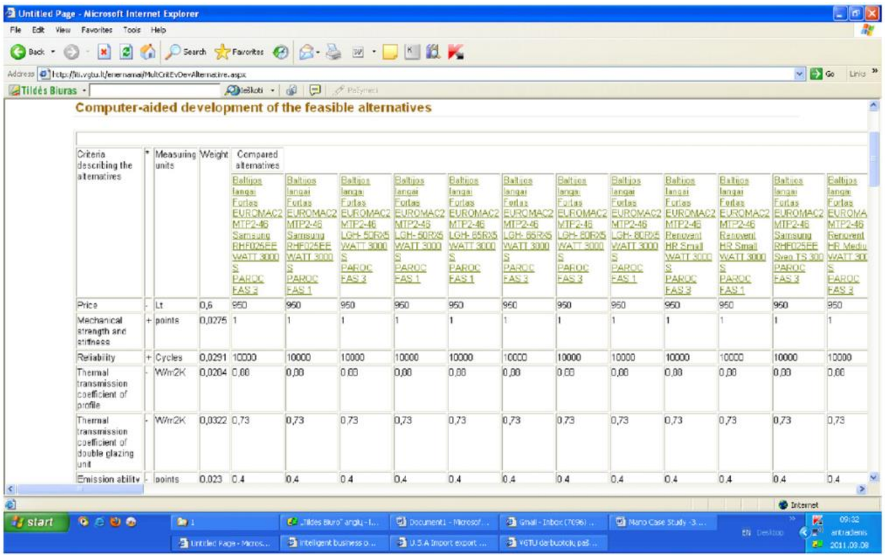
Once the multiple criteria analysis is completed on smart windows, roofs, walls, solar collector, wind generators, geothermic boilers, gas boilers and the like, alternative variants are developed automatically (see Table 3.8), and the best alternative combinations are provided. The alternative, multiple criteria variant design method was developed by the author for this purpose.

Table 3.7 Fragment of the Fakro PPP-V U3 window market value analysis



Approximation cycle	The corrected value	It is determined whether the corrected value being valuated had been calculated accurately enough
0	1127.83	43.85%
1	633.28	8.68%
2	578.33	1.06%
3	572.2244	0.12%

Table 3.8 Fragment of the computer-aided development of Passive House alternatives



Computer-aided development of the feasible alternatives

Criteria describing the alternatives	*	Measuring units	Weight	Compared alternatives: Baltijos langai Fortas EUROMAC2 MTP2-46 Samsung RHF025EE WATT 3000 S PAROC FAS 3	Baltijos langai Fortas EUROMAC2 MTP2-46 Samsung RHF025EE WATT 3000 S PAROC FAS 1	Baltijos langai Fortas EUROMAC2 MTP2-46 LGH-50RX5 WATT 3000 S PAROC FAS 3	Baltijos langai Fortas EUROMAC2 MTP2-46 LGH-50RX5 WATT 3000 S PAROC FAS 1	Baltijos langai Fortas EUROMAC2 MTP2-46 LGH-65RX5 WATT 3000 S PAROC FAS 1	Baltijos langai Fortas EUROMAC2 MTP2-46 LGH-65RX5 WATT 3000 S PAROC FAS 3	Baltijos langai Fortas EUROMAC2 MTP2-46 LGH-80RX5 WATT 3000 S PAROC FAS 3	Baltijos langai Fortas EUROMAC2 MTP2-46 LGH-80RX5 WATT 3000 S PAROC FAS 1	Baltijos langai Fortas EUROMAC2 MTP2-46 Renovent HR Small WATT 3000 S PAROC FAS 3	Baltijos langai Fortas EUROMAC2 MTP2-46 Renovent HR Small WATT 3000 S PAROC FAS 1	Baltijos langai Fortas EUROMAC2 MTP2-46 Samsung RHF025EE Sveo TS 300 PAROC FAS 3	Baltijos langai Fortas EUROMA MTP2-46 Renovent HR Medu WATT 30 S PAROC FAS 3
Price	-	Lt	0,6	950	950	950	950	950	950	950	950	950	950	950	950
Mechanical strength and stiffness	+	points	0,0275	1	1	1	1	1	1	1	1	1	1	1	1
Reliability	+	Cycles	0,0291	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000	10000
Thermal transmission coefficient of profile	-	W/m2K	0,0284	0,88	0,88	0,88	0,88	0,88	0,88	0,88	0,88	0,88	0,88	0,88	0,88
Thermal transmission coefficient of double glazing unit	-	W/m2K	0,0322	0,73	0,73	0,73	0,73	0,73	0,73	0,73	0,73	0,73	0,73	0,73	0,73
Emission ability	-	points	0,023	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4

After the activation of the item “Multiple criteria analysis of the developed alternatives”, the multiple criteria analysis of the feasible Passive House alternatives is performed.

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Chapter 4. Biometric and Intelligent Self-Assessment of Student Progress System

Abstract All distance learning participants (students, professors, instructors, mentors, tutors and the rest) would like to know how well the students have assimilated the study materials being taught. The analysis and assessment of the knowledge students have acquired over a semester are an integral part of the independent studies process at the most advanced universities worldwide. A formal test or exam during the semester would cause needless stress for students. To resolve this problem, the author in conjunction with colleagues have developed a Biometric and Intelligent Self-Assessment of Student Progress (BISASP) System. The obtained research results are comparable with the results from other similar studies. This chapter ends with two case studies to demonstrate practical operation of the BISASP System. The first case study analyses the interdependencies between microtremors, stress and student marks. The second case study compares the marks assigned to students during the e-self-assessment, prior to the e-test and during the e-test.

4.1 Introduction

Various methodologies (Big Five Factors and Five Factor Model, intelligence quotient tests, self-assessment) are employed to predict a student's academic motivation, achievement and academic attainments. However, in the opinions of academics and practitioners alike, more than merely a student's personal attributes affects that student's advancement. Rutter and Maughan (2002) hold the opinion that the quality of a school makes a significant difference on a student's progress. A concise analysis of each of these methodologies follows.

A number of academics in the world (Komarraju et al. 2009; Noftle and Robins 2007) analyzed the role of the Big Five Factors (Openness, Conscientiousness, Extraversion, Agreeableness and Neuroticism) for predicting the academic motivation, achievement and academic attainment of students.

Noftle and Robins (2007) examined the relationships between the Big Five personality traits and academic attainments, specifically SAT scores and grade-point averages (GPA). Openness was the strongest predictor of SAT verbal scores, and Conscientiousness was the strongest predictor of GPAs both at the high school and college levels. These relationships replicated across four independent samples and across four different personality inventories. Further analyses showed that Conscientiousness predicted college GPA, even after controlling for secondary school GPA and SAT scores and that increased academic effort and higher levels of perceived academic ability intervened both concurrently and longitudinally in the relationship between Conscientiousness and college GPA (Noftle and Robins 2007).

Komarraju et al. (2009) analyzed the role of the Big Five personality traits for predicting academic motivation and achievements among college students. College undergraduates (308 students) completed the Five Factor Inventory and the Academic Motivations Scale and reported their college grade point average (GPA). A correlation analysis reveals an interesting pattern of significant relationships. Further four personality traits (Conscientiousness, Openness, Neuroticism and Agreeableness) explain 14% of the variances in GPA, and an intrinsic motivation for accomplishment explained 5% of the variances in GPA. Finally Conscientiousness emerges as a partial mediator of the relationship between intrinsic motivation to accomplish and GPA. These results are interpreted in the context of what educators can do to encourage and nurture student motivation and achievement (Komarraju et al. 2009).

Although IQ scores are good predictors of academic achievement in elementary and secondary school, the correspondence between IQ and academic performance is less consistent at higher levels of education, and many have questioned the ability of IQ tests to predict success later in life. The tests don't measure many of the qualities necessary for achievement in the world of work, such as persistence, self-confidence, motivation, and interpersonal skills, or the ability to set priorities and to allocate one's time and effort efficiently. In addition, the creativity and intuition responsible for great achievements in both science and the arts are not reflected by IQ tests (Intelligence Quotient 2009). As education progresses, other factors (motivation, opportunity, organisation, background, intelligence, teaching) come into play, such that the limits are determined by the strength of the weakest link in the chain (Intelligence 2009).

Self-assessment in an educational setting involves students making judgments about their own work. Students can make assessment decisions regarding their own essays, reports, projects, presentations, performances, dissertations and even exams. Self-assessment can be extremely valuable in helping students critique their own work and form judgments about its strengths and weaknesses. For obvious reasons, self-assessment is usually employed as part of a formative assessment rather than a summative process which requires certification by others (Self-assessment 2009). Academics and practitioners (Austin et al. 2008; Ballantine et al. 2007; Sundström 2008; Sung et al. 2009; Zimmerman and Kitsantas 2007) performed tests on self-assessment in an educational setting with groups of various ages (teenagers, college students, adults and such) in various areas (schools, universities, workplaces).

Many academics are seeking to diversify assessment tasks, broaden the range of skills assessed and provide students with more timely and informative feedback on their progress. Others wish to meet student expectations for more flexible delivery and to generate efficiencies in assessment that can ease academic staff workloads. As more students seek flexibility in their courses, it seems inevitable that there will be growing expectations for flexible assessment as well (Formative Assessment 2009). The said reasons and the desire to protect students against psychological traumas during their progress assessment have encouraged us to develop the Biometric and Intelligent Self-Assessment of Student Progress (BISASP) System.

The Biometric and Intelligent Self-Assessment of Student Progress system is developed on the basis of the aforementioned methodologies (Big Five Factors and Five Factor Model, intelligence quotient tests, self-assessment), the sixteen years of experience with e-learning by the author of this book and the technology for biometric voice stress analysis. These methodologies are very helpful and significant, while the results of their practical application are often, though not always, reliable. Therefore, the analysis how the Big Five Factors, intelligence quotient tests and self-assessment helped to deal with the reliability issues of self-assessment in practical applications was particularly significant in development of the BISASP System. Also special attention was paid to self-, peer- and teacher-assessments (the criteria systems used, integration of such criteria into one general assessment, use of aggregation methods, the level of reliability of the results, tendencies in the results gained) and to a comparison of this assessment with actual learning results.

The structure of this chapter is as follows. Following this introduction, Section 4.2 describes self-assessment. Section 4.3 provides a description of the Biometric and Intelligent Self-Assessment of Student Progress System. Sections 4.4 and 4.5 provide a brief review of the Self-assessment Integrated Scoring Model and the Self-assessment Integrated Scoring Adjustment Model. Section 4.6 follows with case studies.

4.2 Reliability of Self-assessment

Numerous studies have been conducted worldwide which analyze the reliability of self-assessment. There are many controversial opinions on this issue. For example, in the opinion of Matsuno (2009), a number of researchers have reported high correlations between student- and teacher-assessments, while other studies have shown low correlations between them. Despite meta-analyses of self-assessment in higher education deeming that students will be able to self-assess accurately, the reported correlations between self and tutor evaluations within medical PBL programs are uniformly low (Papinczak et al. 2007). A great many researchers (AlFallay 2004; Braak 2004; Fitzgerald et al. 2003; Marsh et al. 1979; Mynttinen et al. 2009; Sung et al. 2005; Xiao and Lucking 2008 and others) reached reliable results proving that the reliability of self-assessment is sufficient. Several examples of such research are further presented.

Xiao and Lucking (2008) examined the validity and reliability of student generated assessment scores. Two hundred and thirty two, predominantly undergraduate students were selected by convenience sampling during the fall semester of 2007. The findings indicate that the validity and reliability of student generated rating scores were extremely high.

AlFallay (2004) investigates the role of some selected psychological and personality traits of learners of English as a foreign language for accuracy in their self- and peer-assessments. AlFallay (2004) obtained high reliability indices similar to those reported in the literature. The study also shows that long periods of practice and sufficient feedback have a positive effect on the accuracy of assessments. Finally the study demonstrates that students with low self-esteem are the most accurate in assessing their performance, whereas learners with instrumental motivation are the least accurate (AlFallay 2004).

Although studies have examined the abilities of medical students to self-assess their performance, there are few longitudinal studies that document the stability of self-assessment accuracy over time (Fitzgerald et al. 2003).

Ballantine et al. (2007) examined the reliability of self-assessment as an indicator of students' knowledge across a variety of disciplines. As per the opinions of Ballantine et al. (2007), an agreement between self-evaluation and alternative measures of assessment has been reported in a number of studies.

Sung et al. (2005) describe the web-based self- and peer-assessments system. Sung et al. (2005) show that significant consistency is found between the results of student self- and peer-assessments and the results of teacher assessments.

Marsh et al. (1979) analyzed a comparison of faculty self-evaluations and the evaluations by their students. Considerable student–faculty agreement was found when 83 college courses were evaluated. Separate factor analyses indicated similar dimensions in both student and faculty evaluations. Validity coefficients were significant for all evaluation factors. Mean differences between student and faculty ratings were low, and the two groups agreed on the behaviors most descriptive of the faculty (Marsh et al. 1979).

Mynttinen et al. (2009) examined overconfidence among novice drivers by comparing their self-assessed driver competence with the assessments made by driving examiners. A Finnish ($n = 2739$) and a Dutch sample ($n = 239$) of driver's license candidates assessed their driver competence in six areas and then took the driving test. In contrast to previous studies where drivers assessed their skills in comparison to an average driver, a smaller proportion overestimated and a larger proportion made realistic self-assessments of their driver competence in the present study, where self-assessments were compared with examiner assessments. Between 40% and 50% of the candidates in both samples made realistic assessments, and 30–40% overestimated their competence.

Ballantine et al. (2007) evaluate the reliability of self-assessment as a measure of computer competence. The scores achieved by students in self-assessed computer competence tests are compared with scores achieved in objective tests to evaluate the reliability of self-assessed computer competence. The results reveal a statistically significant over-estimation of computer competence among the surveyed students.

Braak (2004) analyzed the self-perceived computer competence of university students. Questionnaires were administered to two samples of first-year university students in psychology and education. The results indicated a high correlation between the two scales of computer competence (Braak 2004).

The System developed by Kaklauskas et al. (2010) is also based on the same presumption that, by assigning students questions in accordance with some certain methodology (entirely unrelated with the contents of the exam) and then processing them in accordance with a certain algorithm, it is possible to determine a student's level of knowledge rather accurately. In other words, internally a student senses the rating that his/her knowledge is worth. The existing experience, intuition and analysis of the learning process give students a rather accurate indication of what mark they can expect to earn on an exam.

What makes the System developed by Kaklauskas et al. (2010) superior to the traditional systems is the use of biometric voice stress analysis which permits a more detailed analysis of the knowledge a student has assimilated.

4.3 Biometric and Intelligent Self-assessment of Student Progress (BISASP) System

The human voice reflects that person's spiritual and emotional state of being, motivation and preparedness to complete an assignment. The internal resolve of an individual to complete an assignment (an assessment of the self and one's chances for doing so) and an external evaluation according to corresponding objective criteria always differ. This is why various tensions arise between an examiner and the person being examined during an exam. These tensions are caused by the different imaginings regarding the degree of preparedness for the exam; the self-assessment of an individual taking the exam influences such an imagining. In an effort to decrease such tension, restore an educational sphere and teach collegial team work, tolerance and the goal of a better and more objective appraisal of knowledge and abilities, the author along with their colleagues (E.K. Zavadskas, V. Pruskus, A. Vlasenko, M. Seniut, G. Kaklauskas, A. Matuliauskaite, V. Gribniak) developed the Biometric and Intelligent Self-Assessment of Student Progress (hereafter – BISASP) System.

The test questionnaire is composed to contain three dimensions of a student's preparedness to take an exam—the psychological assessment of one's own preparedness to take an exam, the objective assessment of preparedness and expectations.

Our research was based on two hypotheses: (1) a well-prepared self-assessment process may enable a rather reliable forecasting of student academic achievement; (2) microtremor frequencies depend on the student's stress and, therefore, of the level of his/her readiness for the exam. Questionnaires were used as the method of data collection. Each question in the questionnaires was formulated and their evaluation procedure was set enabling students to assess themselves on a 10-point scale during the self-assessment. It facilitated estimation of their self-rated forecasted exam marks. Application of a specific corresponding algorithm establishes how much a student's self-assessment and expectations conform to the realistic level of that student's preparedness.

Furthermore, our research revealed that such self-assessment done during the psychological test helps to adjust a module to student needs better.

Initially students answer thirteen questions both verbally and electronically; these questions are not directly related with the learning contents. Afterwards the students complete an electronic questionnaire which serves as the basis for establishing the level of a student's self-assessment (high, average, low). By employing a special algorithm, the system evaluates the microtremors and digital information submitted by a student and writes a subjective rating of a psychological assessment. After this the students are able to take a real exam electronically and compare the received subjective and objective rating marks amongst themselves. This model can be employed for evaluating student progress and, additionally, for resolving conflictual situations.

Kaklauskas et al. (2010) have developed a voice stress database which contains the answers given by students during an e-psychological test and a specific algorithm, the core of the BPASP System, which can evaluate a student's knowledge by assigning a subjective rating mark to the psychological test performed prior to the exam.

The Biometric and Intelligent Self-Assessment of Student Progress (BISASP) System consists of the following components (see Fig. 4.1): Database management system and Intelligent Database, Equipment Subsystem, Model-base Management Subsystem and the Model Bases with Context-aware Interface. The components of BISASP System are briefly analyzed below.

Sound recording and data input equipment: microphone, sound card and a PC for recording audio files. Sound recorder software: mostly software that converts sound recordings of different formats and media and saves such recordings as 16 bit 44.1 kHz WAV files on HDD. Sound processing equipment: either software or hardware for audio file/signal processing in order to single out the parameters that help to determine emotional state. Such processing may be done either by hardware with special controllers for Fourier transforms, wavelet transforms, determination of MFCC coefficients and other operations or by software using special applications for digital signal processing.

The *Intelligent Database* contains the developed Historical statistics database, Domain database, Question database, Self-assessment DB, Self-assessment Integrated Rating DB, Self-assessment Adjusted Integrated Rating DB, Examination results DB, Knowledge Representation of the Students Progress, Computer learning systems database, and Intelligent database engine (see Section 1.4).

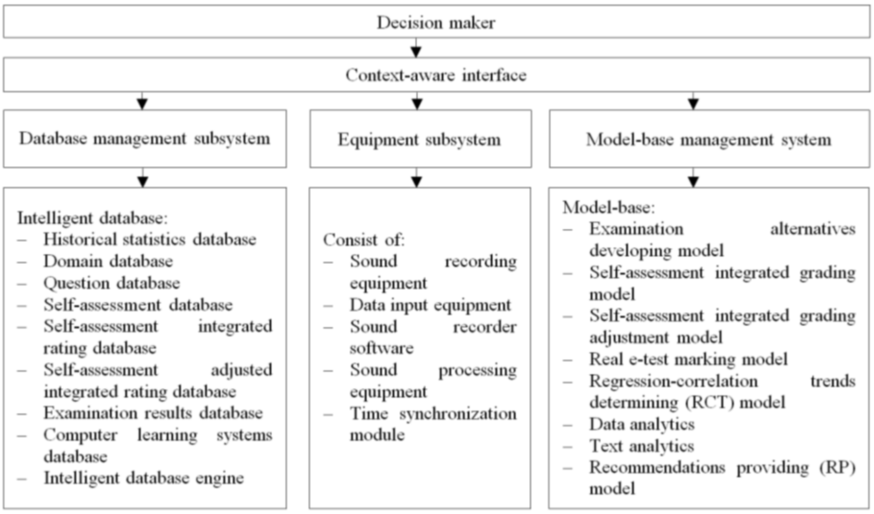

Fig. 4.1. Composite parts of the Biometric and Intelligent Self-Assessment of Student Progress (BISASP) system

The *Historical statistics database* accumulates historical statistical data gathered from the Self-assessment Integrated Grading Model, Self-assessment Integrated Grading Adjustment Model and real e-test (testing questions, testing results [information on correct and incorrect answer, time distribution to every question, number of times a student has changed an answer to each question of a test], voice stress data, correlation between emotional stress, correct answers data and such).

The *Domain database* contains information and knowledge that an instructor is teaching. Over three semesters in the master study courses, students complete seven core modules and five optional modules. Students choose an elective from 21 modules within “Real Estate Management” and 17 modules within “Construction Economics”, both Master’s degree study programs, and they should optionally pass five examinations. During the fourth semester, master students write a final thesis. After registration, students mark the sections of the elective modules they want to study onto electronic questionnaires. The *Domain* database also offers study materials to students according to the repetitive key words in the different optional modules. A mixed approach is also possible and available. The received information is used for action plans, i.e., “mini curricula” that are used to guide the learner/student.

The *Question database* accumulates the following information: questions according to modules, possible answers to a question and evaluation of the correctness of possible answer versions.

The *Computer learning systems database* enables use of different Web-based computer learning systems: construction, real estate, facilities management, international trade, ethics, innovation, sustainable development, building refurbishment and others (Kaklauskas et al. 2005, Kaklauskas et al. 2006a, 2006b; Kaklauskas et al. 2007; Zavadskas and Kaklauskas 2000; Zavadskas et al. 2000; Zavadskas et al. 2008; Vainiunas and Kaklauskas 2005).

The *Equipment Subsystem* consists of sound recording equipment, data input equipment, sound recorder software, sound processing equipment and a time synchronization module.

The *Model-base* consists of six models: the Examination alternatives developing model, Self-assessment Integrated Grading Model, Self-assessment Integrated Grading Adjustment Model, Real e-test marking model, Regression–correlation trends determining model, Recommendations providing model, Data analytics (Ordered Logit (regression model for ordinal dependent variables [see Figure 1.4]) and Anova (analysis of variance)) and Text analytics (see Section 1.4).

The *Real e-test marking model* provides several possible answers for students to select as the best for the multiple-choice questions during the time of the real testing. An incorrect answer is denoted as 0 and a correct answer, as 1; intermediate answers are scored from 0 to 1. The difficulty of a question is determined on the basis of the results from previous tests taken by other students.

The *Regression–correlation trends determining (RCT) model* was developed by Kaklauskas et al. (2010) as an aid to collect and organize numerical information into tables, graphs and charts, to analyze and interpret numerical data and to make informed decisions. By applying the RCT Model, it is possible to discover interesting patterns that identify a student's behavior on the system and to store student interactions and feedbacks in the BISASP System; thereby past memory experiences are maintained, and then new teaching paths are derived. The RCT Model provides information on a testing process in matrix and graphical form including information on correct and incorrect answers, time distribution for every question, number of times a student changes an answer to a test question and the like. Complex parameters are also presented whereby not only is the correctness of an answer evaluated but also the time required for a student to answer it along with hesitancies of selection. The knowledge assessment can possibly change once an answer is evaluated by a complex parameter. The RCT Model, which is based on statistical information accumulated from the Self-assessment Integrated Grading Model, Self-assessment Integrated Grading Adjustment Model and the real e-test, presents various regression–correlation dependencies between different parameters and data. Some such dependencies are presented and explained in the Case Study.

By having such integrated information on the testing process along with the Question database, it is possible to create tests in a nonrandom manner that individualizes tests for each student according to the number of questions, their difficulty and the proportion of questions from different subjects. This is performed by the *Examination alternatives developing model*. The gained test results are stored in the Examination results database. Students can use the statistics provided by the RCT Model to see the difficulty of a question and the average assessment for the entire group; thus students are able to learn about their position in the group before and after their studies. Once data is stored about the difficulty of questions, an opportunity opens to offer easier questions first and later to move onto more difficult ones.

The question subjects can also be selected similarly, by moving from a simpler subject to a more difficult one and then repeating the most difficult. Therefore, by forming a compiled base of questions, the questions for tests are not formulated randomly but individually adapted for each student according to the number of questions, their difficulty and the proportion of questions from different modules. Furthermore easier questions can be given at the beginning, and then the test can proceed to the more difficult questions. Similarly the subjects taught can be selected from the easier to the more complex, and subjects that are not yet mastered can be repeated.

The *Recommendations providing (RP) model* collects information on the history of a student's responses, provides feedback which helps to determine the strengths and weaknesses of that student's knowledge and then provides various recommendations for further education. The RP Model explains why one or another answer is incorrect and offers use of certain additional literature and multimedia to clarify the incorrectly answered questions. Analogically the RP Model, since its basis is integrated information on the testing process, can show areas of improvement to the instructor of a module. If, for example, more than 200 students spend, on average, more than 25% of their time answering the test questions in the "Real Estate Market Analysis" section (as compared to the rest of the modules), and the rating marks for this section of the exam are more than 2 points lower than the average number of points for the module, then the RP Model makes recommendations to the instructor to supplement and more thoroughly explain the more difficult areas and the like.

The system provides a Context-aware interface (see Section 1.3) to facilitate use of the teaching services easily.

Psychological examination consists of two modules:

- Self-assessment Integrated Grading Model.
- Self-assessment Integrated Grading Adjustment Model.

Next, a more detailed analysis of how the integrated self-assessment mark is estimated during a student's self-assessment is provided as an example.

4.4 Self-assessment Integrated Grading Model

Self-assessment Integrated Grading Model was being developed, similar studies that were conducted worldwide were analyzed (Big Five Factors and Five Factor Model, intelligence quotient tests, self-assessment and others). Special attention was paid to self-, peer- and teacher-assessments (the criteria systems used, integration of such criteria into one general assessment, use of aggregation methods, the level of reliability of the results, tendencies in the results gained) and to a comparison of this assessment with actual learning results.

By basing their work on the aforementioned and other studies, Kaklauskas et al. (2010) performed the following:

- Formulated a 16-questions/criteria system to use as the basis to conduct the psychological tests,
- Utilized the Voice Stress Analyzer,
- Developed multi-criteria analysis methods as the basis for integrating the criteria under discussion into the psychological test assessment,
- Developed the model for assigning a rating mark to the e-psychological test on the basis of the formulated criteria system, the developed methods and the Voice Stress analyzer.

The analysis of questions used in self-evaluation which were developed by researchers (Komarraju et al. 2009; Noftle and Robins 2007) from various countries helped Kaklauskas et al. (2010) to create 16-questions/criteria system of their own. For example, Noftle and Robins (2007) examined the relationships between the Big Five personality traits and academic attainments, specifically SAT scores and grade-point averages (GPA). Conscientiousness was the strongest predictor of GPAs (Noftle and Robins 2007). Komarraju et al. (2009) analyze the role of the Big Five personality traits for predicting academic motivation and achievements among college students. These results are interpreted in the context of what educators can do to encourage and nurture student motivation and achievement (Komarraju et al. 2009). As education progresses, other factors (motivation, opportunity, organisation, background, intelligence, teaching) come into play, such that the limits are determined by the strength of the weakest link in the chain (Intelligence 2009).

Next 16 criteria used as the basis for the e-self-assessment are named:

- What mark are you expecting for the exam?
- How many days have you spent studying?
- What was your average for the last semester?
- In your opinion, is the subject you've been studying essential and necessary for your future profession?
- Were the studies of this course interesting?
- Did the time you spent studying this discipline correspond with the benefit you received?
- What average do you expect for this semester?
- What was your average for your undergraduate studies?
- What percent of the exam material have you assimilated?
- Did you attend all lectures and practice sessions?
- How many days did you need to prepare for this exam to get the expected mark?
- How many days, in average, did you need to prepare for past exams to get the expected mark?
- What is you accuracy, as a percentage, at guessing your exam mark?
- If this subject was an elective, and you were able to choose, would you have chosen this or some other subject?
- Did the instructor present the material understandably and clearly?
- Was the subject you studied personally interesting and important to you?

It was noticed that, during the time of the self-assessment, students experimented with the BISASP System. They would submit answers that had nothing to do with reality, ones they'd dreamed up. Such falsified answers were eliminated using the Voice Stress Analyzer. Whenever microtremor frequencies that exceeded the limit of 11 Hz were discovered in a student's voice, no attention was paid to that answer.

The author here developed multi-criteria analysis methods as the basis for integrating the criteria under discussion into the sum of the psychological test assessment as follows:

1. A new method for the complex determination of the weight of the criteria was developed taking into account their quantitative and qualitative characteristics. This method allows calculating and coordinating the weights of the quantitative and qualitative criteria according to the aforementioned characteristics.
2. A new method of a multiple criteria complex, proportional evaluation of results from the psychological test was suggested that would enable an examiner to obtain a reduced criterion to determine the complex (overall) efficiency of the test. This generalized criterion is directly proportional to the relative effect of the values and weights of all the criteria considered.
3. The results from the psychological test were reviewed in consideration of the psychological test results of other students whose difference between the results from their psychological and their real test was not greater than 0.5 points. According to this method, the result from the psychological test being estimated is directly proportional to the system of adequately descriptive criteria and the values and weights of such criteria.

Self-assessment Integrated Grading Model was developed on the basis of the formulated criteria system, developed multiple criteria analysis methods and the Voice Stress Analyzer.

4.5 Self-assessment Integrated Grading Adjustment Model

Undoubtedly other individuals and socio-cultural factors influence self-assessment. These include the temperament of an individual, social conditions of life, features of interactions and communications in society, support for taking initiatives and others (Trandis 1989). Despite this, many researchers are inclined to distinguish the major levels of self-assessment which are applicable to members of all socio-cultural communities. These are the high, average and low levels of self-assessment. Actually certain Kaklauskas et al. (2010) indicate another two levels—too high and too low.

Each one of the aforementioned types of self-assessment has characteristics of its own.

4.5.1 Characteristics of High Self-assessment

- Overconfidence in one's own strengths
- Desire to change one's social status and situation
- Inclination to make risky decisions
- Exploitation of all opportunities in the pursuit of a defined goal
- Desire to explain and look for the "guilty" when facing a lack of success

4.5.2 Characteristics of Average Self-assessment

- Critical (self-critical) outlook on the self and surrounding others
- Raising realistic goals
- Ability to coordinate one's own possibilities with the demands raised by life
- Rejection of unmeasured risk
- Search for reasons in one's own actions when facing a lack of success

4.5.3 Characteristics of Low Self-assessment

- Lack of desire to make an essential change
- Learned powerlessness (let others seek a career; I'm happy with the way things are)
- Lack of confidence in one's own strengths
- Lack of desire to make independent decisions leaving that right to others

Research shows that a student's behavior and carriage during an exam, as well as expectations, depend on self-assessment. Therefore it is important to establish to what degree the student's attained knowledge and practical skills are suitable in regards to that student's real expectations.

First, the Self-assessment Integrated Scoring Adjustment Model gives 14 questions to a student and determines the student's level of self-assessment based on his/her answers. The level of self-assessment (high, average and low) is determined as a percent between 0% (the lowest self-assessment level) and 100% (the highest self-assessment level). The obtained results are used to adjust the calculations of the self-assessment integrated mark, and such mark is displayed to the student before the actual exam.

4.6 Case Studies

The e-learning, Master degree studies program, “Real Estate Management”, was introduced at Vilnius Gediminas Technical University by its Department of Construction Economics and Property Management in August of 1999. The Master degree studies program, “Construction Economics”, has been in effect since 2000, the Master degree studies program, “Internet Technologies and Real Estate Business”, since 2003 and the Master degree studies program, “Intelligent Built Environment”, since 2009 (see http://odl.vgtu.lt/).

Different multimedia and communication means are used during these studies, namely electronic format textbooks, video and audio equipment, computer software, computer learning systems, intelligent testing systems, intelligent tutoring system, computer conferencing, computer networks, a discussion forum and “face-to-face” contacts. To increase the efficiency and quality of e-learning studies, the Biometric and Intelligent Self-Assessment of Student Progress (BISASP) System was developed. The practical application (two case studies) for the previously mentioned e-learning studies is described in brief (see Kaklauskas et al. 2010).

4.6.1 Case Study 1: Analysis on the Interdependencies between Microtremors, Stress and Student Marks

According to Hans Selye’s Stress Model (Selye 1951), known as the General Adaptation Syndrome (GAS), stress develops in three stages (anxiety, resistance and exhaustion). Lippold et al. (1957) begin exploring the correlation between muscle activity and stress. Lippold (1970) first discovers the physiological tremor in the human voice in the 8–12 Hz range.

Many studies have been performed globally that analyze the interdependency of microtremors and stress. Different scientists and practitioners do not agree with one another about this issue. Such opposing opinions are further presented in brief. Below are studies validating the technical and operational efficacy of voice stress analysis (VSA).

Under conditions of normal speech, the vocal-wave signal is modulated by a speaker in values of approximately 8 and 14 Hz when speaking in the range of 8–10 Hz. These changes in the frequency spectrum are known as microtremors. However, when a speaker is under psychological or physical pressure, the frequency of the modulation increases typically peaking in a higher range, between 10 and 12 Hz (Clarke 2005). Ruiz et al. (1990) examine voice analysis to predict the psychological or physical state of a speaker.

Hopkins et al. (2005) have found that VSA technology can identify stress better than chance with a performance approaching that of current polygraph systems. Haddad et al. (2002) determined that voice stress analysis achieved an accuracy rate of 100% when used to detect stress in 45 known-conclusion responses. Cestaro (1995) reports that the lab simulations established that the CVSA performs electrically according to the manufacturer's theory of operation and, even in the absence of jeopardy, which is a basic requirement in detection of deception.

Tippett (1994) examined 54 individuals who were convicted sex offenders on probation and in treatment for their crimes. Tippett (1994) notified that with these 54 examinations, there was a 100% agreement between the CVSA and the polygraph. The number of examinees that were found to be deceptive (DI) were 35 and the number of examinees found to be not deceptive (NDI) were 19. As a result of this study, it appears that the CVSA is as effective as polygraph, which is the question this study set out to answer (Tippett 1994).

Ruiz et al. (1990) reports that their research suggests that psychological stress may be detected as acoustic modifications in the fundamental frequency of a speakers voice and that the fundamental frequency of the vocal signal is slowly modulated (8–14 Hz) during speech in an emotionally neutral situation. In situations demanding increased 'mental or psychomotor' activity, the 8–14 Hz modulation then decreases as the striated muscles surrounding the vocal cords contract in response to the arousal, thus limiting the natural trembling (Ruiz et al. 1990).

Chapman (1989) selected 211 criminal responses at random from 2109 known-conclusion responses where voice stress analysis was used to test suspects. Chapman's (1989) study confirmed that voice stress analysis was accurate when utilized as a truth verification device and produced a confirmed confession rate of 96.4% where deception was indicated by VSA (Chapman 1989).

Brockway's (1979) study reports that voice stress analysis does depict predictable and self-reported anxiety. Smith (1977) concludes that voice stress analysis is a valid measure of anxiety. Borgen and Goodman (1973) indicated that voice stress analysis of the verbal responses correlated well with the other physiological responses to acute stress.

Inbar and Eden (1976) were able to independently verify the existence of the 8–14 Hz 'microtremor' and to trace its origins to the central nervous system. Wiggins et al. (1975) concluded that audio stress can be detected with a voice stress analyzer in psychiatric patients during the course of therapy and that the VSA could serve as a useful tool for this purpose.

Heisse (1974) analyzed 91 known-conclusion criminal responses utilizing voice stress analysis and determined that audio stress analysis seems to be valid in detecting changes in various psycho physiological parameters so that a trained examiner utilizing standard techniques can evaluate these changes and thus utilize the instrument in truth and deception. Brenner (1974) utilizing a voice stress analyzer, established that vocal stress increased as a function of audience size.

It should be noted that not all researchers support this hypothesis. Bell et al. (1976) developed a device and described the method for microtremor registration. Moreover he claimed that the state of a microtremor at 8–12 Hz occurs in the human voice in a quiet, relaxed state and disappears in the case of stress.

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Cestaro (1995) used the CVSA system in his research and concluded that the CVSA instrument has been shown to detect discrete changes in the fundamental frequency of speech when laboratory instruments have been used to simulate a voice microtremor. Thus Cestaro (1995) confirms NITV’s underlying theory of operation. However, these results do not confirm: (1) the existence of a voice microtremor, (2) a relationship between the microtremor amplitude and psychological or physical levels of stress, (3) a reduction in microtremor amplitude during an act of deception and (4) that a voice microtremor—if it exists at all—has sufficient signal value to be detected by the CVSA (Cestaro 1995).

In our research, the X13-VSA software was used to collect data on microtremors in voices of tested students.

The research involved a group of some 200 volunteer students who took a real, computer-based examination and had to select (tick) the correct answer on a computer display; in addition they were asked to say the selected answer aloud. During the exam, students had to mark and say the correct answers aloud to 20 questions within 10 min. The oral answers were analyzed using the VSA application, which is part of the Equipment Subsystem. During the research, a total of 4000 voice recordings in four student groups were examined and analyzed.

Based on this analysis, the BISASP System created a database with the following fields: student ID, question ID, a student’s answer (correct/incorrect) and the microtremor frequency in the answer’s utterances with intonational significance. This information was used to calculate the correct answers by percent and by average microtremor frequency.

The percentage of correct answers to each question was calculated using the equation, $ca=(Nc/Ta)\times 100ca=(Nc/Ta)\times 100$. *Nc* is the number of correct answers to a specific question. *Ta* is the total amount of answers (correct and incorrect) to a specific question. For example, if a certain question was answered correctly 90 times and incorrectly 60 times, then *Nc* = 90, *Ta* = 90 + 60 = 150 and $ca=(90/150)\times 100\%=60\%ca=(90/150)\times 100\%=60\%$. Correct answers by percent constitute the linear trend of the Correct Answers Index for all questions asked at the experiment.

Average microtremor frequency (amtf) is the index calculated for each question using the following equation $amtf=(\sum mtf)/Taamtf=(\sum mtf)/Ta$ (here $\sum mtf \sum mtf$ is the sum total of average microtremor values for all answers to a particular question, Ta is the total number of answers). For example, if a certain question was asked 7 times during the testing and the average microtremor values of significant utterances for each answer were 10.5, 11.2, 11.5, 9.8, 10.7, 11.8 and 9.5, then $amtf = (10.5 + 11.2 + 11.5 + 9.8 + 10.7 + 11.8 + 9.5)/7 = 10.7$ Hz. This index was used to arrive at a conclusion on the intensity of stress among students who answered this question: if the majority of students are stressed when answering this question (voice microtremor frequency of 10–12 Hz), then the average microtremor frequency is also high (10–12 Hz). Linear (average microtremor frequency) is the linear trend of the average microtremor frequency index for all questions asked at the experiment.

The calculated parameters were charted as presented in Fig. 4.2.

Fig. 4.2 shows the relation between correct answers and the ID numbers of the questions (bright line of the trend) and the average microtremor frequency of the answers to test questions and ID numbers of the questions (dark line of the trend). The *x*-axis shows the numbers of the test questions for students who had passed the exam. The left side of the *y*-axis shows the correct answers by percent. The right side of the *y*-axis shows the average microtremor frequency to each question in the exam.

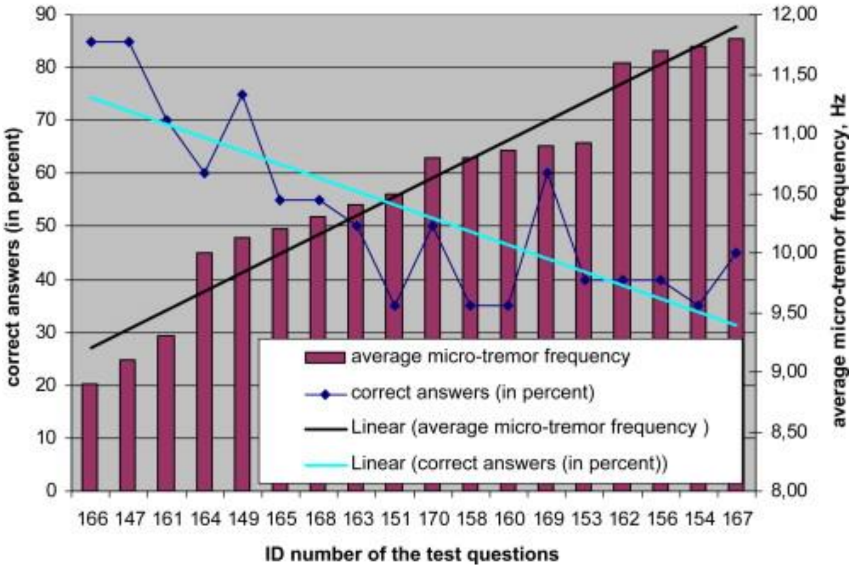

Fig. 4.2. Correlation between emotional stress and correct answers (by percent) in the e-test: the *x*-axis indicates ID numbers of the test questions and the *y*-axis indicates the average microtremor frequency (Hz) in a student's voice (on the right) and correct answers by percent (on the left) (Kaklauskas et al. 2010)

In addition Fig. 4.2 shows two correlating curves obtained during the research:

- The direct relationship between a correct answer and the ID number of the question (broken line);
- The direct relationship between the average microtremor frequency and the ID number of the question (dark columns).

The reliability of the results was assessed by performing a correlation analysis between emotional stress (microtremor frequency) and the evaluations of correct answers (by percent) to the test questions. The analysis showed that:

- A correlation exists between emotional stress and the correctness of an answer.

- High values of microtremor frequency (11–12 Hz) were established when analyzing the oral answers to questions with a low value of correct answers. Therefore higher than average emotional stress was experienced when answering the "unknown/difficult" questions, and zero or minor emotional stress was found in the case of the "known/simple" questions.

Fig. 4.3 shows the results of the dependence between the examination mark and the average microtremor frequency in answers of each student.

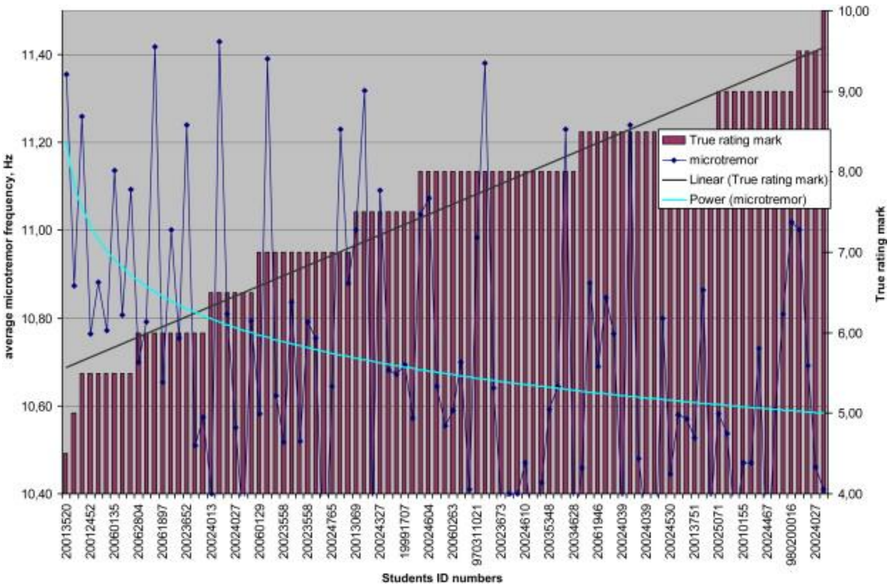

Fig. 4.3. Correlation between emotional stress and examination mark in the e-test: x-axis – student Ids; y-axis – examination marks of students on a 10-point scale (on the right) and the average microtremor frequency (Hz) in a student's voice (on the left)

Fig. 4.3 shows the relation between real mark given students during exam and students ID number (dark line of the trend) and the average microtremor frequency of the answers to test questions and students ID number (bright line of the trend). The x-axis shows the students ID number who had passed the exam. The right side of the y-axis shows the correct answers (by %). The left side of the y-axis shows the average microtremor frequency of each student.

In addition Fig. 4.3 shows two correlating curves obtained during the research:

- The direct relationship between exam marks and students ID numbers (dark columns);
- The direct relationship between average microtremor frequency and ID number questions (dark broken line).

The charts shown in Fig. 4.3 lead to the following conclusions:

- A correlation between the level of emotional stress during the examination and the marks scored in the actual examination was determined for students who took part in the experiment.
- Considerably higher stress levels (microtremor frequencies) were recorded for students who scored less than 6 points in the examination.

4.6.2 Case Study 2: Comparison of Marks Assigned to Students during the Psychological Examination, prior to the E-test and during the E-test

Psychological examination consists from two modules:

- Self-assessment Integrated Grading Model.
- Self-assessment Integrated Grading Adjustment Model.

Currently students' knowledge can be automatically assessed (instead of by an exam) by using the BPASP System on the basis of student psychological tests, accumulated historical voice stress data, determined regression equation and the specially-developed algorithm. The BPASP System automatically assesses a student's knowledge before an exam according to the student's verbal/oral answers and a filled-out questionnaire. The rating mark assigned during the psychological test is also verified on the basis of the answers a student provides in the electronic, self-assessment questionnaire. For example, when a teacher/lecturer gives a student questions such as "How many days did you study?" or "Was this course interesting to learn?" or "Was the material provided by the instructor understandable and clear?" and the like before an exam, the student can be assessed precisely by using the BPASP System to assign him/her a rating mark. Fig. 4.4 illustrates the comparison of marks assigned to students during the e-psychological test performed prior to the exam and of the marks assigned during the exam itself (using the BPASP System). The regression–correlation curves seen in Fig. 4.4 show the interrelation between the marks assigned during the e-psychological test and the marks assigned during the e-examination itself.

It was established during the testing that students who had received higher rating points on an exam had poorer psychological test results than did those students who had received the higher rating points. As such a conclusion can be drawn that the students who receive high rating grades evaluate themselves as average on the psychological test. Meanwhile the students who receive the lower rating grades often over-evaluate their abilities. This is quite clearly seen in Fig. 4.4. Such dependencies were also noticed by Sung et al., 2009, Papinczak et al., 2007 and Lejk and Wyvill, 2001 and other researchers. In the opinion of Sung et al. (2009), low- and high-achieving students tended respectively to over- and underestimate the quality of their own work in self-assessments. Lejk and Wyvill (2001) present the results of an experiment which compared secret and agreed peer- and self-assessment of contributions to a group project. There was a tendency for students towards the top end of the group to under-assess themselves in comparison with the assessment by their peers and for students towards the bottom end of the group to over-assess themselves. In the opinion of Papinczak et al. (2007) opinion, the tendency exists for students to overestimate their competence, especially lower-performing students and young or highly capable students are more likely to undermark their work.

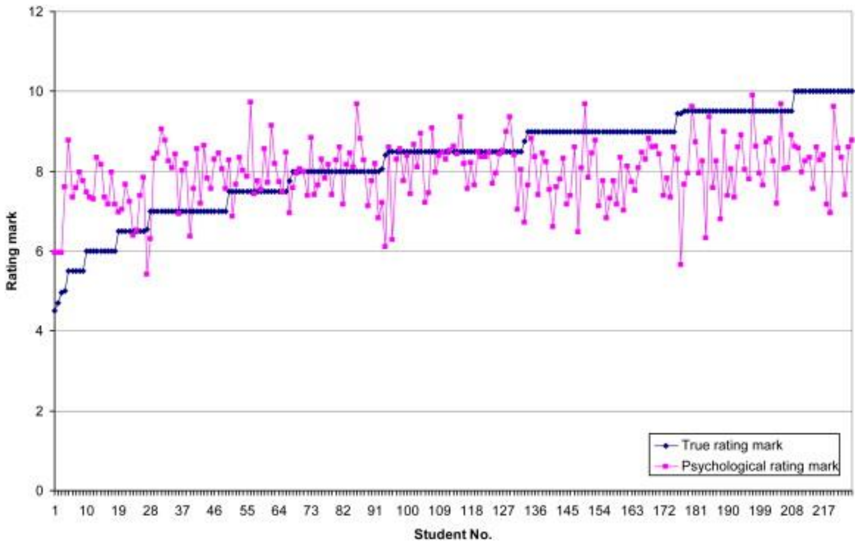

Fig. 4.4. Comparison of marks assigned to students during the e-psychological test, prior to the e-test and during the e-test; Legend: *y*-axis – rating marks of students on a ten-point scale; *x*-axis – student IDs; *"rating marks of the e-psychological test"* – marks assigned to students during the e-psychological test, prior to the e-test using the BPASP System; *"marks of the real test"* – actual marks assigned to students during the e-test using the Intelligent Testing System; *"linear (marks of the psychological test)"* – regression–correlation linear trend which describes the marks assigned to students during the e-psychological test, prior to the e-test using the BPASP System; *"linear (marks of the real test)"* – regression–correlation linear trend which describes the actual marks assigned to students during the real e-test.

Fig. 4.5 presents the curves relating to the conformity of the psychological test taken by both sexes to the real test. The *x*-axis shows how many of the psychological test results were in full conformance with the real test results taken by female students (a) and male students (b). The farther the psychological test results distance from the *x*-axis upwards or downward, the less the results of the real test are in conformance. Nonetheless, the accuracy is sufficiently great. For example, 55 (or 61%) of the 90 female students (see Fig. 4.5a) had a one-point difference between the psychological and real tests. Analogically 43 (or 69%) of the 62 male students (see Fig. 4.5b) had a one-point difference between the psychological and real tests. It can be noticed that, in this case, the psychological testing of the male students is more effective. The average rating grade of the psychological test for male students is 8.16 and of the real test – 8.24. The average rating grade of the psychological test for female students is 8.47 and of the real test – 8.5. It can also be noticed that the difference between the psychological and real tests does not exceed 2 points for male and female students alike.

The circles in Fig. 4.6 illustrate rating point differences between the results of psychological and real tests of up to 0.5, from 0.5 to 1.5 and over 1.5 for female students (a) and male students (b) (Fig. 4.6).

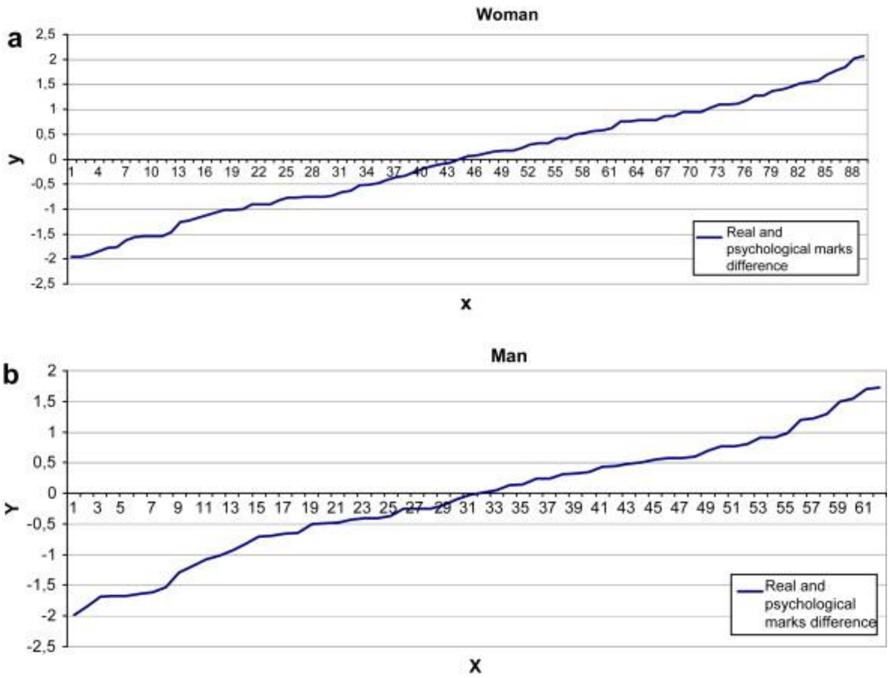

Fig. 4.5. Curve of the conformance of psychological test results with real test results by female students (a) and male students (b)

A scatter plot, shown in Fig. 4.7, was set up for visual analysis of the interrelation between student self-evaluation and their results after testing. The *x*-axis of the diagram shows student marks calculated on the basis of their self-evaluation, and the *y*-axis shows their marks scored for the test. The obvious scatter of the observations made the visual analysis of the data noticeably more complicated; therefore, the dependencies between marks were studied using the methods of regression analysis. The analysis consisted of three phases.

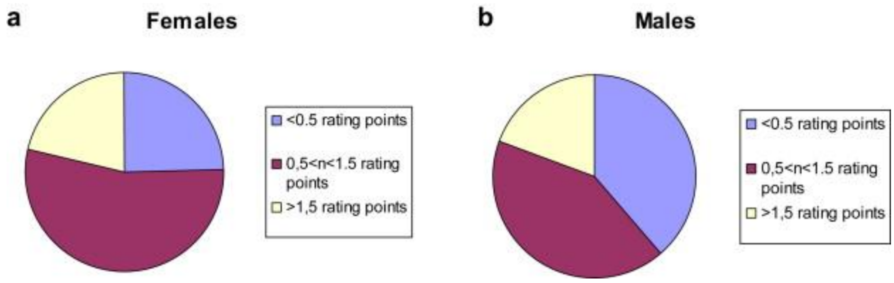

Fig. 4.6. Conformity of psychological test results to real test results for female students (a) and male students (b)

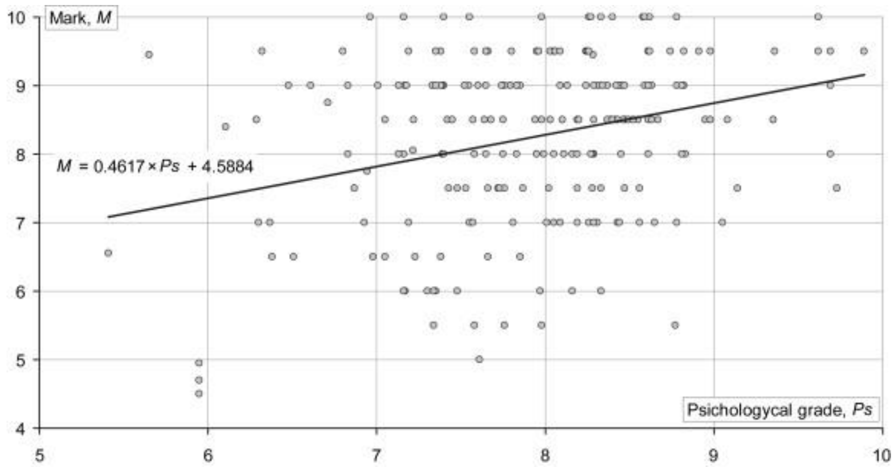

Fig. 4.7. The scatter plot of the student marks scored for the test and the marks based on their self-evaluation

The obtained data were used by V. Gribniak to set up a linear regression model. The regression equation was derived using the least squares method. The numerical expression of the regression dependence is shown in Fig. 4.7.

The second phase focused on the analysis of the probability distribution of the regression model residuals. It is a known fact that most regression analysis methods demand normality in the probability distribution of residuals (the assumption is that the residuals are independent random observations from a normal distribution). The modified Durbin's method (Durbin 1961) was used to test the normality of the distribution of the residuals. The dissertation (Gribniak 2009) describes the use of this method in detail; thus we skip the description here. The analysis of the regression model residuals revealed that their probability distribution is *normal* (with 95% probability).

The third phase included statistical evaluation of the parameters of the regression equation to test its *adequacy*. Table 4.1 dveloped by V. Gribniak presents the main statistics of the regression model. Part one of the table shows the significance analysis of the equation's coefficients, while part two focuses on the results obtained after the adequacy analysis of the regression model. The student's *t*-test was used to test the significance of the coefficients (i.e. to test the hypothesis that they are all equal to zero). Columns three and four of Table 4.1 show the calculated values of *t*-statistics and the probability for each of the coefficients to take the value of zero (the probability of obtaining a value for the test statistic that is as extreme). It should be noted that the probability for coefficients to be insignificant is negligible. The table further presents 95% confidence intervals for each coefficient. The obvious difference between the lower and upper boundaries of the obtained intervals results from the scatter of observations shown in Fig. 4.7. The same scatter of observations also explains the considerably low values of the coefficient of regression r and the coefficient of determination r^2, which *undeservedly* are regarded as the accuracy indicators of the regression model (Brendt 1991). The model's adequacy, on the other hand, may only be evaluated using the statistical testing of the hypothesis (null hypothesis) H_0: $r^2 = 0$, which is performed using *F*-test (ANOVA). The last two columns of Table 4.1 show the calculated values of *F*-statistic and the probability for the determination coefficient to take the value of zero. The results lead to a conclusion that the significance of the regression coefficients and the adequacy of the equation are unquestionable.

Table 4.1 The main statistical indicators of the regression model

Coefficient	Value	t-test		95% Confidence		r	r^2	F-test	
		Value	p-value	Lower	Upper			Value	p-value
Slope	0.462	4.635	6.066×10^{-6}	0.265	0.658	0.296	0.088	21.49	6.066×10^{-6}
Intercept	4.588	5.768	2.661×10^{-8}	3.021	6.156				

The analysis, therefore, reveals that the dependence between the marks scored by students for the test and the marks based on their self-evaluation is substantially justified. However, an additional investigation on the possibilities to use the suggested methodology in practical evaluation of learners on the basis of their psychological test is required.

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Chapter 5. Web-based Biometric Computer Mouse Advisory System to Analyze a User's Emotions and Work Productivity

Abstract This chapter describes the analysis of emotional state and work productivity using a Web-based Biometric Computer Mouse Advisory System to Analyze a User's Emotions and Work Productivity (Advisory system hereafter) developed by author in conjunction with colleagues. The Advisory system determines the level of emotional state and work productivity integrally by employing three main biometric techniques (physiological, psychological and behavioral). By using these three biometric techniques, the Advisory system can analyze a person's eleven states of being (stress, work productivity, mood, interest in work) and seven emotions (self-control, happiness, anger, fear, sadness, surprise and anxiety) during a realistic timeframe. Furthermore, to raise the reliability of the Advisory system even more, it also integrated the data supplied by the Biometric Finger (blood pressure and pulse rates). Worldwide research includes various scientists who conducted in-depth studies on the different and very important areas of biometric mouse systems. However, biometric mouse systems cannot generate recommendations. The Advisory system determines a user's physiological, psychological and behavioral/movement parameters based on that user's real-time needs and existing situation. It then generates thousands of alternative stress management recommendations based on the compiled Maslow's Pyramid Tables and selects out the most rational of these for the user's specific situation. The information compiled for Maslow's Pyramid Tables consists of a collection of respondent surveys and analyses of the best global practices. Maslow's Pyramid Tables were developed for an employee working with a computer in a typical organization. The Advisory system provides a user with a real-time assessment of his/her own productivity and emotional state. This chapter presents the Advisory system, a case study and a scenario used to test and validate the developed Advisory system and its composite parts to demonstrate its validity, efficiency and usefulness.

5.1 Introduction

As the tempo of contemporary life quickens along with the increasing rates of competition on the job market, uncertainty about the future and continual demands for greater competency, the risk of experiencing stress unavoidably rises. Research studies have shown that, at work, if stressors are especially intense, the speed of processing information decreases by as much as 30–50 percent. Thus, on the job, a person is unable to focus attention, makes many mistakes, suffers memory lapses, frequently feels tired, speaks tersely at bubbling speed, loses satisfaction in activities and is either constantly hungry or lacks appetite. Typical illnesses caused by stress are hypertension, stomach and intestinal ulcers, migraine headaches, heart (myocardial) attack and certain immuno-allergic illnesses.

People are also most interested in resolving and managing various emotions (self-control, happiness, anger, fear, sadness, surprise and anxiety), mood and the level of interest in work during specific times, in addition to the aforementioned stress levels and work productivity. The latest worldwide studies show that these eleven states of a person's being, under study herein, can be determined by applying three main biometric techniques (physiological, psychological and behavioral).

Physiological signals can provide information regarding the intensity and quality of an individual's internal affect experience (Zimmermann et al. 2003). A physiological trait tends to be a more stable physical characteristic, such as a fingerprint, skin conductance, heart rate, blood vessel pattern in the hand, blood pressure, respiration, face or back of the eye, electroencephalography or muscle action.

Psychology analyzes an individual's mind and mental processes, especially in relation to behavior, emotion, cognition and personality. Emotion is a transient psychological, physiological and behavioral response to thoughts, events and social activities (Mustafa et al. 2008). Emotions can be defined as feelings, such as happiness, sadness, anger, elation, irritation and others (Real Voices 2009). Diverse writers have proposed that there are from two to twenty "basic emotions" (Plutchik 1980). As per the opinions of Zimmermann et al. (2003), self-reports are widely used and still serve as a primary method for ascertaining emotion and mood.

Behavior regards expectations of how a person or persons will behave in a given situation based on established protocols, rules of conduct or accepted social practices (ASQ Glossary). A broad field of behavioral methods can measure affect: facial expressions, voice modulation, gestures, posture, cognitive performance, cognitive strategy, motor behavior (e.g., hand muscles, head movement) and others (Zimmermann et al. 2003). A behavioral characteristic reflects an individual's psychology. Different methods (e.g., voice stress analysis, face recognition and others) are used in practice.

Worldwide a sufficient number of studies have been performed and quite many systems have been developed that apply biometric technologies to establish different human states of being. The global innovativeness of the Advisory system, developed by the Kaklauskas et al. (2011), is primarily that it automatically determines the level of stress (work productivity), compiles numerous alternative recommendations applicable to a specific user (how to reduce stress or/and increase productivity), performs a multiple criteria analysis of these recommendations and selects out the ten most rational ones for that user. No other system in the world performs these functions to date.

The developed Advisory system can assist in determining the level of negative stress and resolve the problem for lessening it. It can help in managing a currently stressful situation and minimizing future stress by making the level of future needs

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satisfaction more rational. First, the Advisory system facilitates individuals in making real-time assessments of their stress levels and receiving rational tips to reduce the level of current stress based on the best global practice accumulated therein. Multi-variant design and multiple criteria analysis methods are used for that purpose. The generation of recommendations and the selection of the most rational are based on criteria systems and on Maslow's Hierarchy of Needs (Maslow 1943; Maslow 1954). Since this is an interdisciplinary area of research, psychologists, philosophers and experts in information management, decision-making theories and intelligent and biometric technologies participated in the development of the Advisory system.

The results achieved by the Kaklauskas et al. (2011) are compared to those from analogical studies conducted worldwide in this chapter.

This chapter is structured as follows: Section 5.2, following this introduction, describes dependency of human blood pressures, heart rate, skin conductance and temperature on experienced stress and emotions. Section 5.3 describes the Web-based Biometric Computer Mouse Advisory System to Analyze a User's Emotions and Work Productivity. Section 5.4 provides a case study (determining stress level and providing recommendations). Section 5.5 presents a scenario that was used to test and validate the Advisory system and its composite parts. Section 5.6 presents the reliability calculations of stress dependencies on diastolic and systolic blood pressures and finger temperature by analyzing the entire user's biometric database.

5.2 Dependency of Human Blood Pressures, Heart Rate, Skin Conductance and Temperature on Experienced Stress and Emotions

A comprehensive analysis was performed by the Kaklauskas et al. (2011) on how blood pressures, heart rate, skin conductance and body temperature depend on the stress and emotions that a person experiences. Table 5.1 summarizes the results of this analysis. The detailed explanations of this table appear further in this section along with a discussion on the conformance of the studies performed by Kaklauskas et al. (2011) with results achieved worldwide.

Table 5.1 Dependency of blood pressures, heart rate, skin conductance and body temperature on experienced stress and emotions (Fragment of the Best Worldwide Practices Database)

Emotions	Systolic blood pressure	Diastolic blood pressure	Heart rate	Skin temperature	Skin conductance
Self-control	↓Averill (1969)		←Schwartz et al. (1981) ↓Averill (1969)		
Happiness, joy, cheerfulness, satisfaction	←Averill (1969)	←Schwartz et al. (1981) ←Averill (1969) ←Ekman et al. (1983) ←Albert (1953)	←Schwartz et al. (1981) ←Averill (1969) ←Ekman et al. (1983) ←Levenson et al. (1997)	↑Ekman et al. (1983) ↑Crosby et al. (2001) ↑Rimm-Kaufman and Kagan (1996) ↑Baumgartner et al. (2006)	←Cacioppo et al. (1997) ↑Levenson et al. (1997)
Anger	↑Albert (1953) ↑Schwartz et al. (1981) ↑Averill (1969) ↑Weerts and Roberts (1976) ↑Cohen and Cohen (1975) ↑Funkenstein et al. (1954) ↑Schachter (1957) ↑Cacioppo et al. (1997)	↑Albert (1953) ↑Schwartz et al. (1981) ↑Averill (1969) ↑Weerts and Roberts (1976) ↑Cohen and Cohen (1975) ↑Funkenstein et al. (1954) ↑Schachter (1957) ↑Cacioppo et al. (1997)	↓Albert (1953) ↑Schwartz et al. (1981) ↑Cohen and Cohen (1975) ↑Ekman et al. (1983) ↑Levenson et al. (1997) ↑Averill (1969)	↑Ekman et al. (1983) ↓Crosby et al. (2001)	↑Albert (1953) ↑Cacioppo et al. (1997)
Fear	↑Schwartz et al. (1981) ↑Levenson et al. (1997)	←Weerts and Roberts (1976) ←Schwartz et al. (1981) ←Averill (1969) ←Ekman et al. (1983) ←Albert (1953)	←Levenson et al. (1997) ←Averill (1969) ←Albert (1953) ↑Schwartz et al. (1981) ↑Ekman et al. (1983)	↓Ekman et al. (1983) ↑Crosby et al. (2001) ↓Baumgartner et al. (2006)	←Albert (1953) ↓Levenson et al. (1997)
Sadness	←Albert (1953)	←Weerts and Roberts (1976)	←Averill (1969)	↑Ekman et al. (1983)	↑Levenson et al. (1997)

	←Averill (1969)	←Schwartz et al. (1981) ←Averill (1969) ←Ekman et al. (1983) ←Albert (1953)	↑Levenson et al. (1997)	↑Crosby et al. (2001)	
Surprise			←Levenson et al. (1997)	↓Ekman et al. (1983) ↓Crosby et al. (2001)	↑Albert (1953) ↑Levenson et al. (1997)
Stress	↑Light et al. (1999) ↑Gray et al. (2007) ↑Adrogué and Madias (2007) ↑Gasperin et al. (2009)	↑Light et al. (1999) ↑Gray et al. (2007) ↑Adrogué and Madias (2007) ↑Gasperin et al. (2009)	↑Blair et al. (1959)	↑Oka et al. (2001) ↑Briese (1992) ↑Okada et al. (2007)	

5.2.1 Effect of Experienced Emotions on Blood Pressure, Heart Rate, Skin Conductance and Body Temperature

Since systolic and diastolic blood pressures, heart rate and skin conductance directly associate with a person's emotional state and experiences, the studies conducted worldwide on this topic and published in scientific literature were analyzed for this chapter.

Numerous scientists have examined the dependency of systolic and diastolic blood pressures on human emotions. Written sources generally refer to five types of emotions: self-control, happiness, anger, fear and sadness. Many scientists tested blood pressure dependency on a person's emotional state and found that both the diastolic and systolic blood pressures rise most, when a person experiences anger as compared to the other, aforementioned four types of emotions (Albert 1953; Schwartz et al. 1981; Averill 1969; Weerts and Roberts 1976; Cohen and Cohen 1975; Funkenstein et al. 1954; Schachter 1957; Cacioppo et al. 1997). The results obtained from the research described herein are compared with the research conducted worldwide.

For example, Schwartz et al. (1981) examined the dependency of systolic and diastolic blood pressures and heart rate on emotions (happiness, sadness, anger, fear, self-control and relaxation). This research employed dispersion analysis and the Newman (1939) and Keuls (1952) test of calculations to process the results. The research results indicate that diastolic blood pressure rises much more, when a person is angry than when a person experiences the other, aforementioned types of emotions. Anger causes diastolic blood pressure to rise by as much as happiness does, and sadness—by as much as self-control does. The only emotional state that causes diastolic blood pressure to drop is relaxation. Kaklauskas et al. (2011) obtained the same results while conducting the research presented herein and tracking the blood pressure readings and emotional changes of the experiment subjects. Both the systolic and diastolic blood pressures of the subjects rose (see Fig. 5.1a).

Weerts and Roberts (1976) employed imagery to induce anger and happiness artificially in the subjects of their experiment. Their research found that diastolic blood pressure increased significantly more in a state of anger than it did in a state of fear. Averill (1969) tested fluctuations in blood pressure by analyzing people's reactions while watching a film about J.F. Kennedy after his death. Averill claims, in the research conclusions, that diastolic blood pressure sharply increases when experiencing anger whereas it remains unchanged under states of happiness and self-control. Numerous authors substantiate the claim that diastolic blood pressure remains stable under states of happiness, fear or sadness or that it rises but not as significantly as it does under a state of anger (Schwartz et al. 1981; Averill 1969; Ekman et al. 1983; Weerts and Roberts 1976; Albert 1953).

Ekman et al. (1983) and Levenson et al. (1997) were the first to publish about the dependency of heart rate, finger temperature and skin conductance on the emotional state of a person in a *Science* article in 1983. These scholars analyzed six emotional states: anger, fear, sadness, happiness, surprise and disgust. Ekman et al. (1983) thoroughly researched heart rate and its sharp rise under states of anger, fear and sadness as compared to a state of disgust. They also established that happiness, as compared to disgust, associates with an increased heart rate. Under a state of disgust, the heart rate remains the same as it does under self-control. Their research showed that anger and fear cause greater skin conductance than happiness does. Later Levenson et al. (1997) performed a number of studies and experiments arguing that heart rate increases the most when feeling negative emotions, such as anger, fear and sadness.

According to Albert (1953), there are greater diastolic blood pressure rises, heart rate decreases and skin conductance increases, when anger is experienced rather than when fear and, particularly, surprise are. Cacioppo et al. (1997) assert that skin conductance increases less relative to the state of happiness than it does relative to disgust; however, in this case, the state of disgust is the same as self-control is. Under fear, skin conductance increases less than it does under sadness, whereas the level of skin conductance drops more under sadness than it does under anger or disgust. Levenson et al. (1997) concluded, upon performance of their research, that skin conductance decreases under states of fear and disgust whereas it increases the most under states of happiness and surprise.

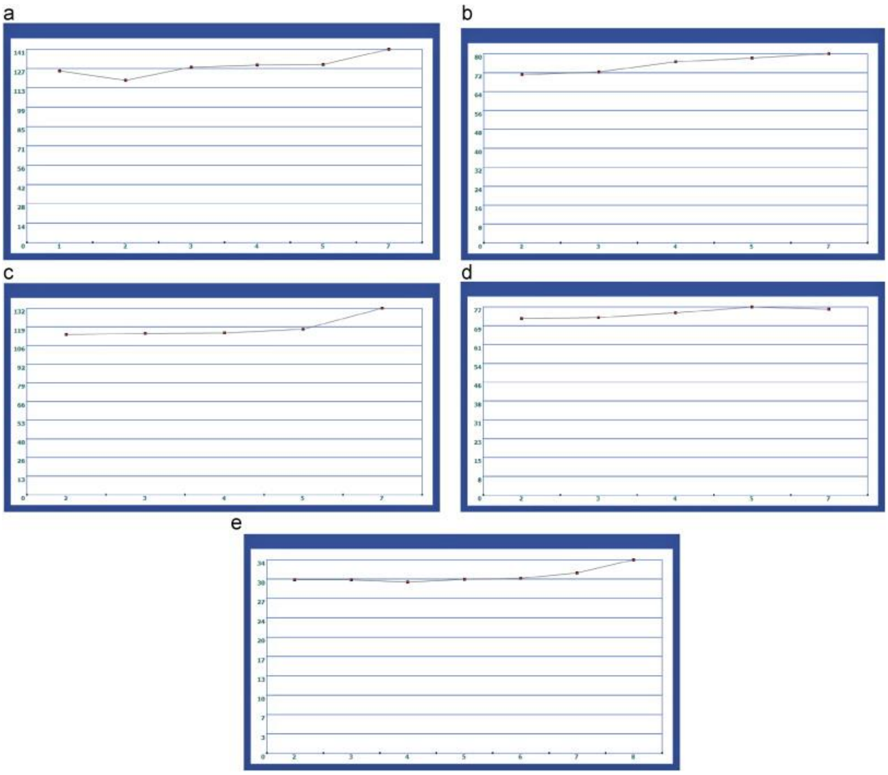

Fig. 5.1. Historical report on the correlations between stress (anger) level (abscissa/horizontal axis by points) and biometric parameters (ordinate/vertical axis). (a) Systolic blood pressure dependency on anger, (b) Heart rate dependency on stress, (c) Systolic blood pressure dependency on stress, (d) Diastolic blood pressure dependency on stress and (e) Results of palm temperature dependency on a person s experienced stress.

Crosby et al. (2001) and Ekman et al. (1983) discussed the dependence of a person's finger temperature on six main emotions (surprise, disgust, sadness, anger, fear and happiness). The research result attained by Crosby et al. (2001), who deliberated the emotions of happiness, sadness and surprise, substantiated the findings of Ekman et al. (1983) that, when a person feels happy or sad, body temperature rises and, when surprised, body temperature falls. However, when examining anger and fear, the results were conflicting. Ekman et al. (1983) claimed that, when a person feels angry, body temperature rises and, when afraid, body temperature drops; meanwhile, Crosby et al. (2001) claimed the opposite. Ekman et al. (1983) claimed that, with finger temperature, the change associated with anger was significantly different than it was with the other emotions.

Rimm-Kaufman and Kagan (1996) and Baumgartner et al. (2006) studied the dependency of body temperature on happiness and established that a person's body temperature rises when that person is happy. Ekman et al. (1983) and Crosby et al. (2001) found similar results.

When Baumgartner et al. (2006) researched the dependency of temperature on three emotions (fear, happiness and sadness), they determined that emotion had the main and significant effect on the temperature of the left little finger. Their study revealed that fear, as compared to happiness, affected a decreased temperature. No other significant temperature differences were observed with these three emotions. One finding of Krumhansl (1997) and Stemmler et al. (2001) was that the skin temperature of the left little finger dropped under the state of fear as compared to the happy state. Another finding was that respiration rates dropped in the sad state as compared to the happy and fear states.

McFarland (1985) and Rimm-Kaufman and Kagan (1996) studied the dependency of body temperature on positive and negative emotions (without more specific differentiation). They established that, when a musical selection played to arouse negative emotions, it stopped skin temperature increases and induced decreases whereas, when music played to evoke calm, positive emotions, it stopped skin temperature decreases and evoked increases. Rimm-Kaufman and Kagan (1996) played film clips intended to evoke a happy state, and these affected an increase in hand skin temperature. Hands generate greater temperature changes than those on face skin do. Further, this research found that most subjects were cooler on the left side of the face and on the left hand than they were on the right side of face and the right hand.

5.2.2 Dependence of Blood Pressures and Heart Rate on a Person's Experienced Stress

Statistics show that the cost of work-related stress in the EU countries is no less than 20 billion Euros annually. Stress on the job can cause depression, anxiety, increased chronic fatigue and heart disease. This has tremendous effects on work productivity, creativity and competitiveness.

Worldwide scientific research has shown that stress causes increased blood pressure and that heart rate increases during stressful times. Light et al. (1999) analyzed cases of daily and of heavy stress as well as their effects on systolic and diastolic blood pressure fluctuations. Gray et al. (2007) investigated the effect of psychological stress on systolic and diastolic blood pressures. Adrogué and Madias (2007) described the effects of psychological, emotional and chronic stress on blood pressure. All of these scholars unanimously concluded that diastolic as much as systolic blood pressure and heart rate are dependent on stress and increase depending on the level of stress.

The results from the research presented in this chapter show that increases in heart rate and systolic and diastolic blood pressures occur depending on the strength of the stress experienced (see Fig. 5.1b–d).

Blair et al. (1959) researched the effect of stress on heart rate and concluded that heart rate rises sharply in 3 min after stress strikes and only begins to fall after another 5–6 min pass. The article by Gasperin et al. (2009) concludes that chronic stress has an effect on high blood pressure. The results from a number of studies showed that patients with a pulse count higher than 70 beats/min are more likely to develop heart and blood vessel diseases or to die from them. Tests have proven that a rapid pulse rate increases the risk of death by 34 percent, of myocardial infarction (heart attack) by 46 percent and of heart insufficiency by 56 percent.

Briese (1992) and Okada et al. (2007) discussed stress and body temperature dependencies in animals. They assert that, under stress, animals experience a rise in temperature.

Briese (1992) claims that changes in ambient temperature should not affect changes in core temperature due to set-point shifts. Nevertheless, when the colonic temperature of rats was taken in a cold environment, the usual emotional rise was higher and, when the colonic temperature was taken in a warm environment, the emotional rise was lower. The results of Briese (1992) contradict the hypothesis that an emotionally induced rise in the temperature of rats is a fever. Okada et al. (2007) exposed rats to restrained stress for 60 min. Biting on a wooden stick while restrained significantly inhibited the rise in core temperature for 30, 60, 120 and 180 min, as compared to rats that were restrained but did not bite anything.

However, the results gained from all the studies were not the same. For example, Nakayama et al. (2005) monitored facial temperature changes of monkeys under stressful and threatening conditions. Their study revealed that a decrease in nasal skin temperature is relevant to a change from a neutral to a negative affective state. Vianna and Carrive (2005) monitored temperature changes in rats when they were experiencing fearful situations. They observed that temperature increased in certain body parts (i.e., eyes, head and back) while, in other body parts (i.e., tail and paws), temperature dropped simultaneously.

Most findings indicate that the psychological stress-induced rise in core temperature is a fever, a rise in the thermoregulatory set point. Thus these mechanisms might be involved in psychogenic fever in humans (Oka et al. 2001).

The research performed by Kaklauskas et al. (2011) analyzing the dependency between stress and palm temperature, substantiated the results gained by Briese (1992), Okada et al. (2007) and Oka et al. (2001) that temperature rises in a stressful situation. Fig. 5.1e displays the results of this research and shows that, as stress rises, the palm temperature of a person also rises.

5.3 Web-based Biometric Computer Mouse Advisory System to Analyze a User's Emotions and Work Productivity

The Web-based Biometric Computer Mouse Advisory System to Analyze a User's Emotions and Work Productivity (i.e., Advisory system) developed by the author

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of this book in conjunction with colleagues (E.K. Zavadskas, M. Seniut, G. Dzemyda, V. Stankevic, C. Simkevičius, T. Stankevic, R. Paliskiene, A. Matuliauskaite, S. Kildiene, L. Bartkiene, S. Ivanikovas, V. Gribniak) consists of ten subsystems:

1. e-Self-Assessment
2. Biometric computer mouse
3. Mouse Events Capture, Collection and Feature Extraction
4. Biometric Finger
5. User's biometric database
6. Maslow's pyramid tables
7. Model-base management and model base
8. User's interdependence between biometric and self-assessment parameters
9. Multimodal input interface (see Section 1.3)
10. Intelligent database engine (see Section 1.4)

The subsystems are briefly analyzed below.

5.3.1 E-self-assessment Subsystem

Numerous studies have been conducted worldwide that analyze the reliability of self-assessment. There are many controversial opinions on this issue. For example, in the opinion of Matsuno (2009), a number of researchers have reported high correlations between user- and teacher-assessments, while other studies have shown low correlations between them. Despite meta-analyses of self-assessment in higher education deeming that users will be able to self-assess accurately, the reported correlations between self and tutor evaluations within medical PBL programs are uniformly low (Papinczak et al. 2007). A great many researchers (AlFallay 2004; Braak 2004; Fitzgerald et al. 2003; Marsh et al. 1979; Mynttinen et al. 2009; Sung et al. 2009; Xiao and Lucking 2008 and others) reached reliable results proving that the reliability of self-assessment is sufficient. Due to the experiences of these authors, including Kaklauskas et al. (2011), a decision was made to gain information about a user's personal mood, productivity, stress and seven emotions (self-control, happiness, anger, fear, sadness, surprise and anxiety) among other matters by means of self-assessment.

Kaklauskas et al. (2011) based their developed Advisory system on the presumption that, by assigning a user self-assessment questions and then searching for the interdependency with that user's biometric parameters at that time, it is possible to determine this interlink rather accurately. In other words, a user internally senses the value of the rating regarding his/her own personal mood, productivity, stress, the above-named seven emotions and such. Existing experiences and intuition give users a rather accurate indication about their personal mood, productivity, stress and the seven emotions under analysis.

Before starting the work, a user must subjectively assess his/her own personal mood, productivity, stress and the already named seven emotions and must select an expected mark, when the test is for an examination, or to assess the interest in work, when it is for a job and suchlike, by using the e-Self-Assessment questionnaire. The user conducts the self-analysis by attributing values to each of these parameters (mood, work productivity, stress level, temperament, interest in work and such) on a ten-point scale. The self-analysis questionnaire is shown in Fig. 5.2. The self-analysis data remains confidential.

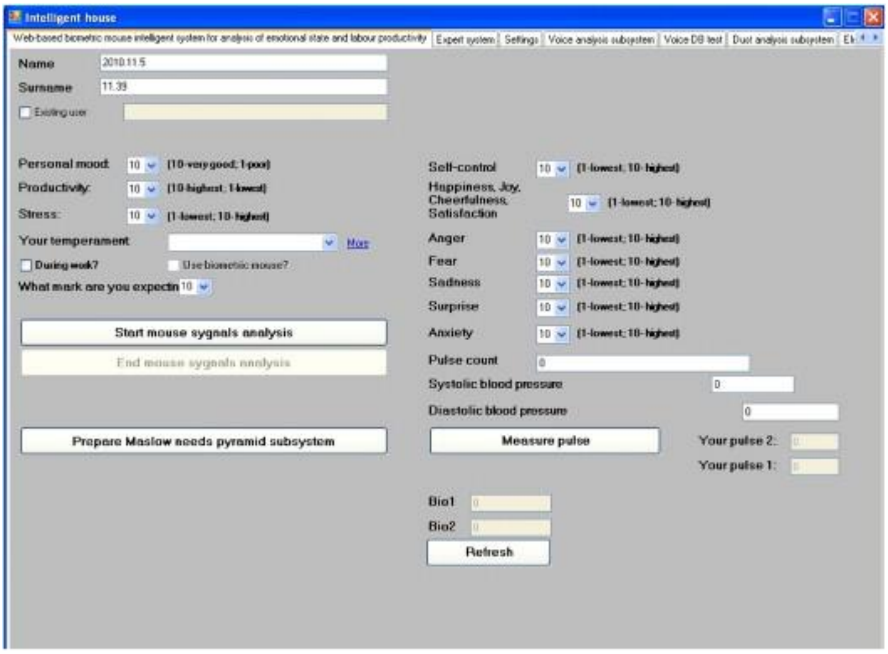


Fig. 5.2. User window of the launched system with the e-Self-Assessment

The user fills out the questionnaire and clicks on the button labeled “Start working”. The biometric computer mouse and the Biometric Finger begin selecting the biometric data on the user; these accumulate in the User's Biometric Database.

One of the main purposes of the Advisory system is to determine the interdependency, at the time of a user's self-assessment, between the eleven pieces of data submitted about that user's own state of being and eighteen of that user's biometric parameters (see Table 5.2). For example, an analysis of a user's stress level is an effort to determine and then outline the interdependency between that user's eighteen biometric parameters (see Table 5.2).

Table 5.2 A main purpose of the recommender system is to determine interdependency between the eleven pieces of data submitted on a user's own state of being and eighteen of that user's biometric parameters at the time of self-assessment

Biometric parameters under measurement	Data on a user's state of being at the time of self-assessment										
	Personal	Productivity	Interest in work	Stress	Self-control	Happiness	Anger	Fear	Sadness	Surprise	Anxiety
Biometric computer mouse:	**Interdependency diagrams determined and outlined**										
– Temperature											
– Humidity											
– Skin conductance											
– Touch intensity											
– Heart rate											
Mouse events subsystem:											
– Speed of mouse pointer's movement											
– Acceleration of mouse pointer's movement											
– Amplitude of hand tremble											
– Scroll wheel use											
– Right- and left-click frequency											
– Idle time											
Biometric Finger:											
– Humidity											
– Electrogalvanic skin conductance											
– Skin temperature											
– Heart rate											
Blood pressure and heart rate data:											
– Heart rate											
– Systolic blood pressure											
– Diastolic blood pressure											

5.3.2 Biometric Computer Mouse

This biometric computer mouse developed by V. Stankevic, C. Simkevičius and T. Stankevic is able to measure the temperature and humidity of a user's hand, skin conductance, touch intensity and heart rate. These biometric parameters give more information about the user and help to evaluate that user's general emotional state and work productivity.

The biometric computer mouse, which Kaklauskas et al. (2011) have developed, is presented in Fig. 5.3. The schematic diagram of the sensors section of a biometric computer mouse is presented in Fig. 5.4. The USB microcontroller PIC18F2458 with an internal 12-bit ADC reads the signals from two pressure (force) points, skin temperature, skin conductance, humidity and heart rate sensor. After reading these signals, the microcontroller calculates the values of pressure (force), temperature and humidity and sends these data to the computer through its USB port. The microcontroller is connected to the computer through the AT43301 USB hub, which multiplexes data from the microcontroller and mouse IC to one channel; thus, only one USB cable for both sensors and the mouse is sufficient.

Fig. 5.3. The Biometric computer mouse developed by V. Stankevic, C. Simkevičius, T. Stankevic

The Type TC1047A temperature sensor (Microchip Technology Inc., USA) is used to measure skin temperature. The TC1047A is a linear output temperature sensor with an output voltage that is directly proportional to the measured temperature (TC1047A linear output… 2009). Fig. 5.5 shows the calibration curve (including tolerance limits) of the temperature sensor, as per the manufacturer's data. The maximal temperature measurement error calculates at ±2 °C. Each sensor was calibrated for the experiments herein. The maximal temperature measurement error, which depends on the calibration error, is about ±0.5 °C. It is evident that the temperature of skin is noticeably lower than body temperature is (at about 36.5 °C). Here only the change in skin temperature is a significant parameter.

The electrical resistance of skin was measured by obtaining the current flowing between two flat metallic contacts (each about 3 mm^2 in area). These contacts were mounted onto the casing of the mouse at a distance of 4 mm from each other, and a constant, 3 V voltage was charged between these contacts.

Pulse rate is measured by applying the oximetry principle, which is based on the measurement of oxygen concentration changes in the blood due to the blood pulsations in finger capillaries (Severingham and Kelleher 1992). Oxygen concentration in blood is measured by the degrees of light absorption. A light-emitting diode and photodiode were used for this purpose (see Fig. 5.6). The diodes were mounted on a special holder that was attached to the right side of the mouse case.

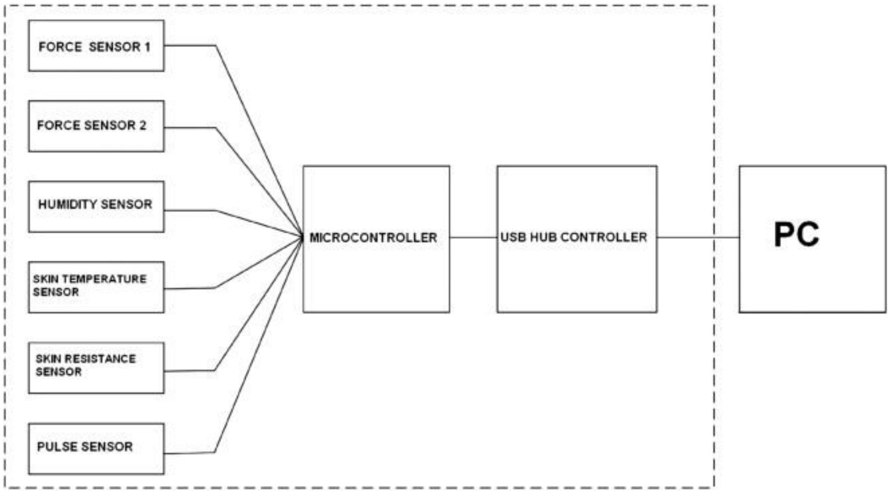


Fig. 5.4. Sensors section of the Biometric computer mouse

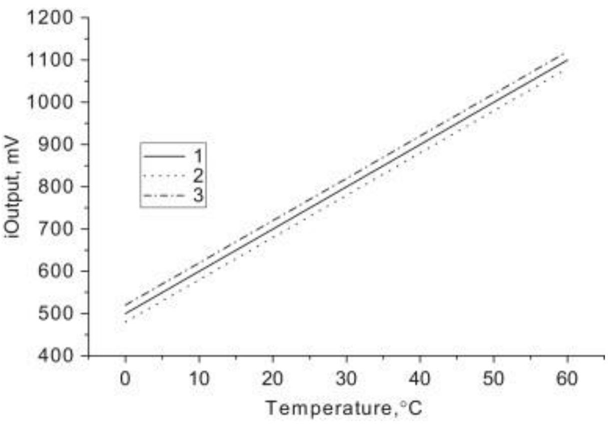


Fig. 5.5. Calibration curve of the temperature sensor: 1—typical curve, 2—minimal tolerance limit curve, 3—maximal tolerance limit curve.

The Type 808H5V5 capacitive humidity sensor (module) with a DC voltage output and 20–100 percent relative humidity measurement range (Sencera Co. Ltd., Taiwan) was used in the mouse (Humidity module 2010). The output of the sensor was 0.8–3.9 V in relative humidity ranges of 30–80 percent.

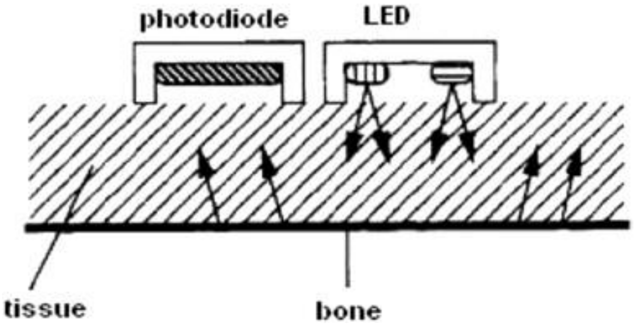


Fig. 5.6. Schematic of the oximetry heart rate sensor

Two types of pressure sensors were used in the biometric computer mouse. The first was the micro-machined pressure sensor designed by the Semiconductor Physics Institute (Vilnius, Lithuania) (Stankevič and Šimkevičius 2000) and the second—the Type HSSF015 pressure sensor (Hope Microelectronics Co. Ltd., China) (Relative pressure sensor 2010). The pressure sensors were modified to measure force. The design of the force sensor is shown in Fig. 5.7. The force sensor consists of: 1—a silicon chip, 2—an FR4 epoxy fiberglass carrier with 3—contact pads, 4—a metallic cap, 5—protective gel, 6—a plastic tube and 7—external plastic plate. This plate was fastened by means of 8—a silicon rubber to 6—the tube. When the finger acts on the external plate, it moves 9—the epoxy layer and activates the silicon chip through the gel. It was found that the force sensor of such a design has a linear output characteristic of up to 4 N.

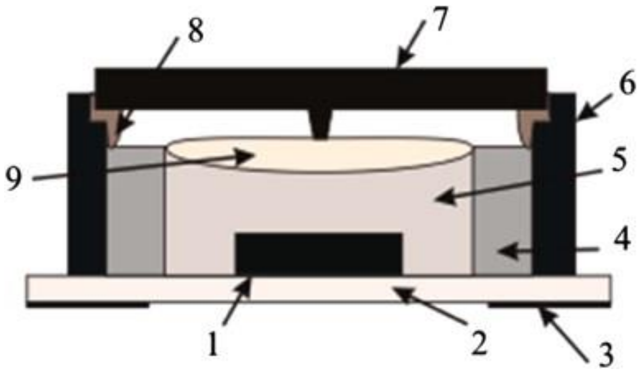


Fig. 5.7. Force sensor design

5.3.3 Mouse Events Capture, Collection and Feature Extraction Subsystem

Mouse Events Capture, Collection and Feature Extraction Subsystem was developed by S. Ivanikovas. The collection of data by the Mouse Events Capture is implemented in Collection and Feature Extraction Subsystem (hereafter referenced as the Mouse Events subsystem). Mouse Events Capture is handled by a background process; therefore, it is hidden from the user. The global system hook is used to track mouse events. The Mouse Events subsystem to enable the remote visualization of user activity in a page and record this information to determine user's real time behavioral information. All the measured parameters are captured when a user works with the computer and stored in a CSV format in an excel file as raw data. Raw data consists of mouse clicks and movements, as well as moments when a hand simply rests on the mouse. Each time the user clicks and moves the mouse or holds his/her hand on the mouse, the Mouse Events Subsystem collects and stores the raw data respectively in a csv file. Any event of mouse use is recorded, whether the mouse is moved, dragged and dropped, clicked (pressed or released) or simply hand-held. The time of the event is recorded in milliseconds. The X and Y coordinates of the mouse pointer on the screen are recorded. A text file is being generated continuously in a csv format.

Once captured the raw data is then processed and displayed in various graphs. Each curve is described by the following set of features: size, length, speed, acceleration, curvature and the like.

The tracking of mouse events makes it possible to determine the coordinates of the mouse pointer on the screen while the mouse is moving, the coordinates of mouse clicks and the parameters of scrolling. These are the basic mouse events, but these parameters are insufficiently informative to determine the peculiarities of mouse motions.

Several additional parameters are calculated using basic mouse events. Those parameters are the speed, acceleration and oscillation of the mouse pointer. These parameters provide more information about mouse motions than the basic ones do.

The speed of the mouse pointer is the distance covered by the pointer during a fixed time period. It is possible to use Euclidean or Minkowski distance to calculate the speed of the mouse pointer

$$D_E = \sqrt{(x_2 - x_1)^2 + (y_2 - y_1)^2} \tag{5.1}$$

D_E is the Euclidean distance, x_i and y_i are the coordinates of two analised points.

$$D_M = |x_2 - x_1| + |y_2 - y_1| \tag{5.2}$$

D_M is the minkowski (Manhattan) distance, x_i and y_i are the coordinates of two analised points.

The acceleration is calculated as the difference between the current speed and the speed measured during the previous time period.

$$a = s_t - s_{t-1} \tag{5.3}$$

The parameter of the hand tremble indicates the oscillation of the mouse pointer. This parameter is calculated as follows:

- Ten values of the mouse pointer's coordinates are stored ($C_i(x_i, y_i)$, i=1…10).
- The differences between neighboring coordinate values are calculated. $d_{xi}=x_i-x_{i-1}$, i=2…10; $d_{yi}=y_i-y_{i-1}$, i=2…10.
- The minimum and the maximum differences are estimated $(\min_{i=2}^{10}(d_{xi}), \max_{i=2}^{10}(d_{xi}), \min_{i=2}^{10}(d_{yi}), \max_{i=2}^{10}(d_{yi}))$.
- If the minimum and the maximum differences are of different signs, then the average value of stored coordinate values is calculated ($A_x = \frac{(\sum_{i=1}^{10} x_i)}{10}, A_y = \frac{(\sum_{i=1}^{10} y_i)}{10}$), and the maximum deviation from the average is estimated ($dev_x = \max_{i=1}^{10} = \left(|x_i - A_x|, dev_y = \max_{i=1}^{10}(\left|y_i - A_y\right|\right), dev = \max(dev_x, dev_y)$).
- If the deviation is small enough ($dev \leq k$), the movement of the pointer is treated as shaking.
- The value of the shaking parameter k can be changed according to the user and the mouse type.

Several features are stored for later comparison and analysis with the biometric computer mouse movement. These can be used to develop a model of a user's work productivity and emotional state. Currently the Mouse Events Subsystem collects data on the following parameters for correlations with a user's emotional state and work productivity:

- speed of mouse pointer's movement;
- acceleration of mouse pointer's movement;
- amplitude of hand tremble;
- scroll wheel use;
- right- and left-click frequency;
- idle time.

All these data are accumulated in the mouse tracking databases.

5.3.4 Biometric Finger

The Biometric Finger developed by V. Stankevic, C. Simkevičius and T. Stankevic collects data on the following parameters for correlations with a user's emotional state and work productivity:

- humidity (humidity sensor);
- electrogalvanic skin conductance (electrogalvanic skin response sensors);
- skin temperature (thermistor);
- heart rate (pulse sensor).

The schematic diagram of the sensors section of the Biometric Finger is presented in Fig. 5.8. The signals from the skin temperature, resistance, humidity and heart rate sensors were read by the microcontroller PIC18F2458 with an internal 12-bit ADC. After reading these signals, the microcontroller calculates the values of skin temperature, humidity, resistance and pulse count and then sends the data to the computer via USB.

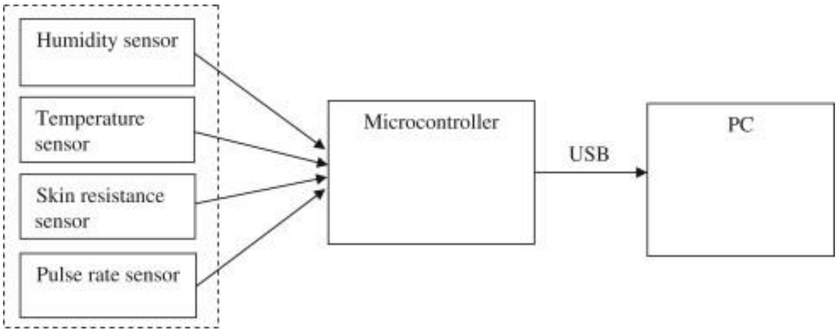


Fig. 5.8. Schematic diagram of the Biometric Finger

All sensors and the pulse signal amplification and filtering circuit were mounted on a 15×25 mm^2 printed circuit board (PCB) (see Fig. 5.9). The board is covered with resin and can be attached to any finger with a Velcro strip. The microcontroller and the supporting circuit are also mounted on a PCB, which can be attached to the wrist with a Velcro strip.

The Type TC1047A temperature sensor (Microchip Technology Inc., USA) was used to measure skin temperature. The Type 808H5V5 capacitive humidity sensor was used in the Biometric Finger (see Section 5.3.2). The electrical resistance of skin was measured in the same manner as in biometric mouse.

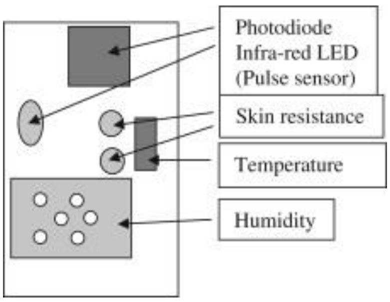


Fig. 5.9. Sensors placed on a PCB with a pulse signal amplification circuit on the bottom

Pulse rate was measured using the finger plethysmography (pulse oximetry) method. Absorption of infrared radiation is dependent on blood volume and oxygen saturation in arterial blood and tissue. An infrared (IR) light emitting diode (LED) was used as the radiation source, and a sensitive IR photo-detector TSL262R was used to detect reflected radiation. Output voltage of a photo-detector is proportional to the intensity of reflected IR radiation. The voltage was sampled and sent to a PC in real-time. Digital signal processing techniques were used to get the pulse rate data from the raw signal.

The Type 808H5V5 capacitive humidity sensor (module) with DC voltage output and 20–100 percent relative humidity measurement range (Sencera Co. Ltd., Taiwan) was used for the Biometric Finger. The output of the sensor was 0.8–3.9 V in 30–80 percent relative humidity ranges.

5.3.5 User's Biometric Database

Once a user fills out the e-Self-Assessment questionnaire and clicks on the button labeled "Start working", the biometric computer mouse and Biometric Finger begin to gather the biometric data of that user for storage in the User's Biometric Database. This way the biometric parameters of different users with different emotional states, temperaments and work productivity rates are collected in the database. Different biometric parameters have been tested for correlations between the user's emotions, work productivity and such and the e-Self-Assessment.

Each user can view his/her biometric parameters and their interrelationships with the e-Self-Assessment parameters. Fig. 5.10 shows a typical historical report on the correlation between historical work productivity (horizontal axis by points) and the touch intensity (pressure) on the mouse, when a user presses down on the mouse button (vertical axis).

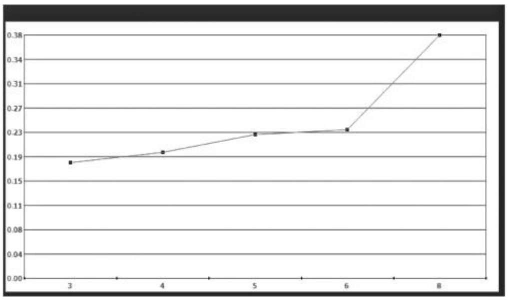


Fig. 5.10. A typical report on the correlation between historical work productivity (horizontal axis by points) and touch intensity on the mouse when a user clicks on the button (vertical axis)

5.3.6 Maslow's Pyramid Tables

Ensuring employee work efficiency includes maintaining good quality work environments and work conditions as well as sufficiently satisfying needs, such as physiological, safety, social and self-actualization (self-expression) needs along with esteem and recognition. In other words, the internal and external work environments of the employee must be motivating.

Employee motivation may be defined as a measure that provides energy as well as directs and maintains human behavior. Employee motivation is one of the three most difficult tasks encountered by the employer who wants to manage a business successfully. Dubin (1958) defines motivation as a certain something that pushes a person to act and continues pushing once the activity starts. One of the most popular theories of needs is Abraham Maslow's Hierarchy of Needs (Maslow 1943).

One of the ways to explain human behavior is related to understanding the needs that humans strive to satisfy. According to the theory proposed by Maslow, there are five levels of needs, which determine human behavior (Maslow 1954):

- physiological needs;
- safety needs: protection against dangers, threats and hardships;
- social needs: belonging to a group, friendship, support;
- the need for esteem and recognition: self-esteem, reputation, status, respect and recognition by others;
- self-actualization (self-expression) need: the need to express one's own potential by continuous improvements.

Needs arise step by step. Satisfaction of physiological needs leads to safety needs, the satisfaction of this leads to social needs and so forth up the pyramid.

One of the results of Maslow's theory is the fact that the higher level needs—esteem and self-actualization—substantially affect behavior, because satisfaction of the other needs intensifies these. The importance of lower level needs decreases in the process of their satisfaction. Thus, a salary plan for employees should be developed in a way that would help an individual go from one level of needs to another. In practice this means that the role of management is to help an employee find meaning in his/her work and improve his/her potential to the maximum. Maslow substantially contributed to a better understanding of the nature of human behavior at work.

The basis for the compilation of Maslow's Pyramid Tables involves ethical, psychological, economic, esthetic, technical, technological, legal and social needs as well as other aspects such as comfort (see Fig. 5.11).

Respondent surveys and analyses of the best global practices provide the information for Maslow's Pyramid Tables (see Fig. 5.12). Maslow's Pyramid Tables were developed for a regular employee working with a computer in a typical organization.

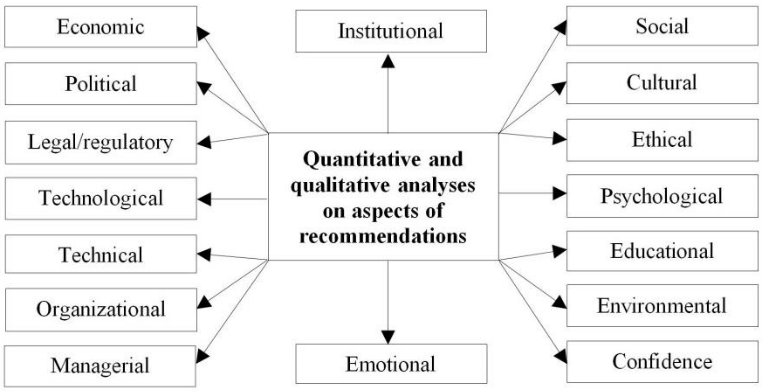
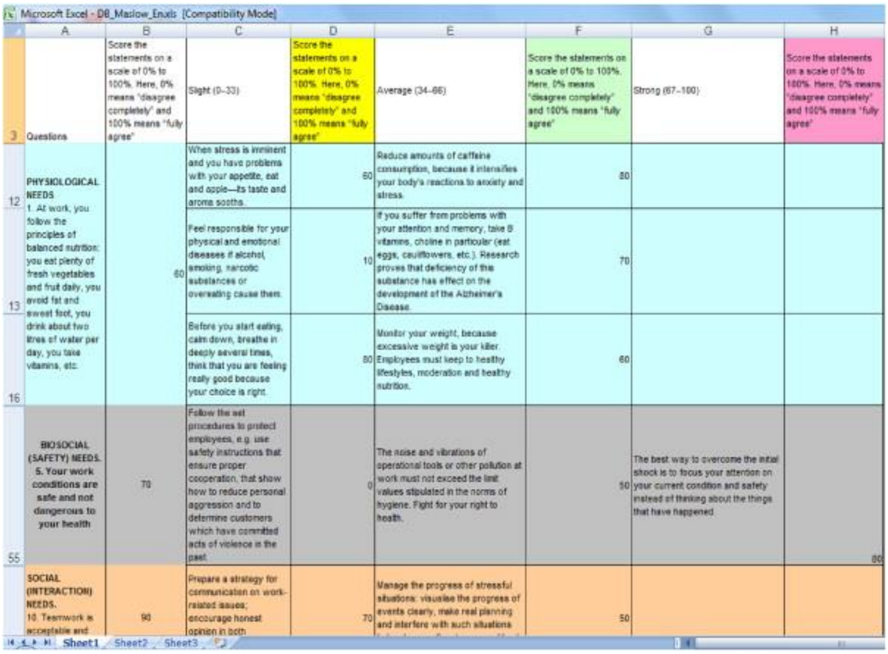


Fig. 5.11. A system of criteria to evaluate the efficiency of alternative recommendations

The literature based on the Maslow Theory was used to compile the tables relative to Maslow's Pyramid. These tables provide information and recommendations about physiological, safety, social/recognition, esteem and self-expression/self-actualization needs. They include the following segments: names and significances of needs and their components, questions given to users, subjective and objective assessments of such questions, recommendations and the source of those recommendations.

Maslow's Pyramid Tables, based both on the developed Maslow's Pyramid and on the models from the Model Base, provide recommendations on how to improve a user's work efficiency and how to reduce stress.



Microsoft Excel - DB_Maslow_En.xls [Compatibility Mode]

	A	B	C	D	E	F	G	H
3	Questions	Score the statements on a scale of 0% to 100%. Here, 0% means "disagree completely" and 100% means "fully agree"	Slight (0–33)	Score the statements on a scale of 0% to 100%. Here, 0% means "disagree completely" and 100% means "fully agree"	Average (34–66)	Score the statements on a scale of 0% to 100%. Here, 0% means "disagree completely" and 100% means "fully agree"	Strong (67–100)	Score the statements on a scale of 0% to 100%. Here, 0% means "disagree completely" and 100% means "fully agree"
12	PHYSIOLOGICAL NEEDS 1. At work, you follow the principles of balanced nutrition: you eat plenty of fresh vegetables and fruit daily, you avoid fat and sweet foot, you drink about two litres of water per day, you take vitamins, etc.	60	When stress is imminent and you have problems with your appetite, eat and apple—its taste and aroma sooths.	60	Reduce amounts of caffeine consumption, because it intensifies your body's reactions to anxiety and stress.	80		
13			Feel responsible for your physical and emotional diseases if alcohol, smoking, narcotic substances or overeating cause them.	10	If you suffer from problems with your attention and memory, take B vitamins, choline in particular (eat eggs, cauliflowers, etc.). Research proves that deficiency of this substance has effect on the development of the Alzheimer's Disease.	70		
16			Before you start eating, calm down, breathe in deeply several times, think that you are feeling really good because your choice is right.	80	Monitor your weight, because excessive weight is your killer. Employees must keep to healthy lifestyles, moderation and healthy nutrition.	60		
55	BIOSOCIAL (SAFETY) NEEDS. 5. Your work conditions are safe and not dangerous to your health	70	Follow the set procedures to protect employees, e.g. use safety instructions that ensure proper cooperation, that show how to reduce personal aggression and to determine customers which have committed acts of violence in the past.	0	The noise and vibrations of operational tools or other pollution at work must not exceed the limit values stipulated in the norms of hygiene. Fight for your right to health.	50	The best way to overcome the initial shock is to focus your attention on your current condition and safety instead of thinking about the things that have happened.	80
	SOCIAL (INTERACTION) NEEDS. 10. Teamwork is acceptable and	90	Prepare a strategy for communication on work-related issues; encourage honest opinion in both	70	Manage the progress of stressful situations: visualise the progress of events clearly, make real planning and interfere with such situations	50		

Sheet1 Sheet2 Sheet3

Fig. 5.12. Fragment of Maslow's Pyramid Tables

5.3.7 Model-base Management System and Model Base

The Model-base consists of the following models:

- model to determine the correlation between the user's seven emotions (self-control, happiness, anger, fear, sadness, surprise and anxiety), mood, stress, work productivity and interest in work and the parameters of the user's physiology, psychology and behavior/movement (Model for Dependence Analysis);
- model to automatically evaluate the user's seven emotions (self-control, happiness, anger, fear, sadness, surprise, anxiety), mood, work productivity, stress and interest in work;
- model to determine initial criteria weights (data and user characteristics and recommendations) using expert evaluation methods;
- model to determine criteria weights (data from Maslow's Pyramid Tables and a user's biometric characteristics);
- module to develop the model of a user's work productivity and emotional state;
- model to design multi-variant recommendations;
- model to analyze multiple criteria and to prioritize recommendations;
- model to determine the utility degree of recommendations;

- model to deliver the recommendations;
- data analytics (Ordered Logit (regression model for ordinal dependent variables [see Figure 1.4]) and Anova (analysis of variance));
- text analytics (see Section 1.4).

The models are briefly reviewed below.

First, the Advisory system collects information about a user's physiological, psychological and behavioral/movement parameters and accumulates them in the User's Biometric Database. Then the Interdependency Analysis Model starts analyzing these data and makes a real-time determination of their correlation with a user's mood, stress, work productivity, interest in work and the seven emotions. Based on the determined relationships, the Advisory system automatically establishes a user's mood, work productivity, stress, seven emotions and interest in work and then displays them in a digital form.

The main designation of the Module for Dependence Analysis is to search for interdependencies between the biometric and self-assessment parameters of various users and to accumulate these in the User's Interdependence between Biometric and Self-Assessment Parameters Subsystem. It must be verified how the different parameters correlate with a user's emotional state, work productivity, seven emotions and the e-Self-Assessment. The User's Interdependence between Biometric and Self-Assessment Parameters database accumulates a sufficient amount of historical biometric results, which can be analyzed by a user at any time.

The rest of the Model Base models are intended to formulate possible recommendation variants (how to improve a user's work productivity and how to reduce stress) and then to select the most rational variants for a specific user. One of the main innovative elements of the Advisory system on a global scale is specifically this.

The methods developed by the author herein provide the bases for the development of these models as follows:

- A method for the complex determination of criteria weights that takes into account their quantitative and qualitative characteristics (Kaklauskas 1999)—this method allows calculating and coordinating the weights of the quantitative and qualitative criteria according to the above characteristics.
- A multiple criteria method for a complex and proportional evaluation of alternatives was developed (Šliogerienė et al. 2009; Tupenaite et al. 2010) to enable a user to obtain a reduced criterion for determining the complex (overall) efficiency of an alternative.
- This generalized criterion is directly proportional to the relative effect of the values and weights of the criteria considered on the efficiency of alternatives.
- A method to define the utility degree of an alternative (Kaklauskas et al. 2006; Kaklauskas et al. 2007a) by which the utility degree and the market value of the alternatives being estimated are directly proportional to the system of criteria that adequately describes them and the values and weights of such criteria.

- A method for the multiple criteria, multi-variant design of the life cycle of an alternative was developed (Kaklauskas et al. 2005; Kaklauskas et al. 2007b) and later followed by a new, improved method for such. It enables a user to produce a computer-aided design of up to 100,000 alternative versions. Any alternative life cycle variant obtained in this way is based on quantitative and conceptual information.

Possible alternative suggestions require analysis to provide a user with rational recommendations. It is also necessary to compile tables of interrelations, compatibilities and combinations and to produce a multi-variant design of the recommendation components to enable an automated multi-variant design of the recommendations. The Model-base Management System, which is based on Maslow's Pyramid Tables, may produce numerous alternative variants according to the suggested multi-variant design method. A determination is made on whether or not the generated suggestion variants meet applicable requirements. The variant that fails to comply with requirements is discarded. Problems of compatibility between criteria weights occur during the multi-variant design of recommendations. In such cases, the weight of a specific criterion during the integrated assessment of an alternative depends on the entire set of assessed criteria along with their values and initial weights.

Although the efficiency of alternative recommendations is often evaluated by considering ethical, psychological, economic, esthetic, technical, technological, comfort, legal, social and other aspects, the Advisory system model facilitates an integrated analysis of the alternative recommendations and the selection of the most rational of them. With the above models serving as the basis, the Advisory system automatically creates alternative variants of recommendations, generates their multiple criteria analysis, determines their utility degree and selects the most efficient variants.

The user of the Model-base Management System may select various models on demand. When the Model-base Management System is used, the results that some of the models calculate (initial criteria weight determination) become the initial data for other models (multi-variant design of recommendations and multiple criteria analysis of recommendations). These, in turn, produce results that are used as the starting point in still other models (determination of the utility degree of recommendations and submission of recommendations).

5.4 Case Study: Determining Stress Level and Providing Recommendations

This case study discusses the situation of a hotel manager who must constantly interact with clients, suppliers and the service staff on her job to demonstrate how the developed Advisory system operates.

The number of people staying at hotels and the flow of tourists decreased in Lithuania when the global financial crisis hit. Under such unfavorable conditions, survival and ultimate success depend on the provision of high quality services to clients at affordable prices, especially since hotels are highly competitive. Furthermore assurance of high-quality client services is the most important task of each hotel. The accomplishing this under existing conditions is not easy, because many hotels had to terminate some of their personnel due to the decrease in overnight guests and to cut the salaries of the rest. All these circumstances have caused a great deal of tension among hotel employees.

Hotel employees generally lack opportunities for job advancement. These jobs often involve huge workloads at inhumane hours with limited time off on weekends (Karatepe and Uludag 2008). Additionally hotel employees are assigned to the emotional labor category, which demands a display of certain emotions while promoting organizational goals. This phenomenon exists in the sphere of most services and it is an essential and marketable component of an organization's offerings (Van Dijk et al. 2011). In this type of work, stressful situations and nervous exhaustion are unavoidable, and these cause a negative influence on the quality of the work performed.

Work-related factors, i.e., employment conditions, need for concentration at work and dissatisfaction with the work content and work environment, are not the only factors to impact the aforementioned hotel manager. Family-related factors, such as marital status, satisfactory family life, the economic situation, daily life, disagreements with the husband/or cohabitant and the like, affect her as well (Jönsson et al. 2003).

No sooner does the hotel manager walk into her office at the beginning of a new workday, when a colleague walks in with a new employee ready to discuss issues of importance for the job. The manager glances at her desk and sees a new pile of papers stacked on it. Just then the telephone rings. It is the hotel administrator announcing the arrival of an important guest from abroad who had stayed in the hotel's apartments a couple months ago but, for some inexplicable reason, these apartments are currently occupied. No sooner does she hang up, when the phone rings again. This time she hears the strict and displeased voice of her superior telling her to come to his office immediately.

The manager is now nervous and somewhat confused. She asks her colleagues to wait and rushes out to see the boss. The talk with her superior is most unpleasant, pressured and accusatory. The manager, now worried about the unpleasant situation that has unfolded as well as the disrespectful behavior of her boss during their talk, has no idea how to handle all the piled up work. She suddenly feels tension, anger and helplessness wash over her. She returns to her office. Without even looking at her colleagues, she asks them to return later. Her anxiety and anger do not lessen, and she realizes that she is unable to control herself, calm down and concentrate on her work and that she needs help in this situation.

Many a person has landed in a situation when work-related stress causes strong, negative experiences, which have a harmful influence on the employee's physical and mental health. Then professional help becomes necessary. The Advisory system can provide appropriate service in such instances. The manager can use this system in the following stages:

Stage 1. Determine the level of needs satisfaction and the significance of recommendations in Maslow's pyramid of needs.

Stage 2. Get ready to work with the Advisory system by launching it.

Stage 3. Establish stress dependencies on biometric data and submit the stress level:

Step 1. Using the Biometric Finger.

Step 2. Using the blood pressure gauge.

Step 3. Filling out the e-Self-Assessment questionnaire.

Step 4. Starting the measurements.

Step 5. Using the biometric computer mouse.

Step 6. Interlinking to the User's Interdependence between Biometric and Self-Assessment Parameters Subsystem.

Stage 4. Receive the best recommendations to manage the stressful situation.

Stage 1. The universal Maslow's Pyramid Tables, which are compiled during this stage, are adapted to a specific individual (see Section 5.3.6, Maslow's Pyramid Tables). If the system user's outlook on the factors that cause and lessen his/her stress level does not change, then there is no need to repeat this stage in the future. If it does change, then the changes must be quantitatively named in Maslow's Pyramid Tables. First, the manager must evaluate 20 statements based on Maslow's Hierarchy of Needs, which are grouped according to Maslow's five basic needs, i.e., physiological, safety, social, esteem and self-actualization needs, starting from the lowest and going to the highest level needs. The submitted statement descriptions are evaluated by the percentage of needs satisfaction for each one. The evaluation scale ranges from 0–100 percent, where 0 percent indicates that a need is entirely satisfied and 100 percent—entirely unsatisfied.

Once these are evaluated, each submitted recommendation must be evaluated separately by importance on a scale ranging from 0–100 percent, where 0 percent means it is not important at all and 100 percent—very important. The system user also pays heed to the environment when evaluating the received recommendations by some certain percentage—is the system to be used at work or home, at the gym, shopping center or some other environment, because opportunities for implementing certain recommendations are limited in different areas. The recommendations are grouped by the level of stress being experienced, i.e., the level of slight stress ranges from 0–33 percent, average – from 34–66 percent and strong – from 64–100 percent. The user of the system evaluates the statements depending on the complexity of the personal situation, the location, and the consequent recommendations only once.

Thus, the aforementioned manager first evaluates the 20 submitted statements relevant to the level of needs satisfaction and then the importance of the recommendations (see Fig. 5.12).

Stage 2. Now the manager readies the system for work. She connects the Biometric Finger and biometric computer mouse into the USB port. If the system had been used previously, she merely checks that the connection is intact. Then she runs the Advisory system (see Fig. 5.2). Once the system is launched, the manager goes to Step 1 of Stage 3.

Stage 3. Establishing stress dependencies of the biometric data and changing the stress level:

Step 1. The manager puts on the Biometric Finger (see Section 5.3.4, for a detailed description). Pulse readings are submitted immediately upon clicking the button labeled "Measure pulse" (see Fig. 5.2 for an example of the manager's measured pulse count by the window labeled "Your pulse", where the upper window shows the pulse count from the biometric computer mouse and the lower window—from the Biometric Finger). The Biometric Finger also aids the measurements of humidity, electrogalvanic skin conductance and skin temperature along with heart rate. These data are stored in the User's Biometric Database. Once the pulse count is read, Step 2 follows.

Step 2. Now the manager takes her systolic and diastolic blood pressures using the blood pressure gauge. She enters the blood pressure gauge readings into the appropriate multimodal input interface fields (see Fig. 5.2).

Step 3. Once she has completed the previous steps, the manager goes to the Self-assessment questionnaire (see Section 5.3.1). This can be filled out now or even at Step 1, prior to using the Biometric Finger. She subjectively evaluates her emotional state, i.e., her personal mood, levels of the seven emotions (self-control, happiness, anger, fear, sadness, surprise and anxiety), productivity and stress in light of her current situation. Finally, she indicates her own temperament type. The statements are rated on a 10-point system (see Fig. 5.2 for examples).

Step 4. After the self-assessment questionnaire is filled out, the button labeled "Start mouse tracking" is clicked. This begins the biometric computer mouse measurements: the user's hand humidity, skin conductance, intensity of touch and heart rate. This device also assists in accumulating data such as the speed and acceleration of mouse pointer's movement, amplitude of hand tremble, scroll wheel use, right- and left-click frequency and idle time. All such biometric data are stored in the User's Biometric Database analogically to those taken from the Biometric Finger to use in determining the dependencies between self-assessment and the biometric parameters (see Fig. 5.1 for several examples of dependencies) (Fig. 5.13).

Step 5. Now that the appropriate data has been selected, the manager clicks on the indicator field found below the button labeled "End mouse tracking" (see Fig. 5.2). This prompts the appearance of data diagrams on that day's observations and the dependencies of the self-assessment on biometric parameters. If the Advisory system was used previously, it is possible to view the historical report on the correlation between the historical, biometric and self-assessment parameters by selecting the month and day for the desired comparison. Fig. 5.14 shows this manager's historical report on the correlation between stress and biometric parameters, where this

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manager's stress level, determined during the self-assessment, appears on the abscissa axis and the biometric parameters—on the ordinate axis.

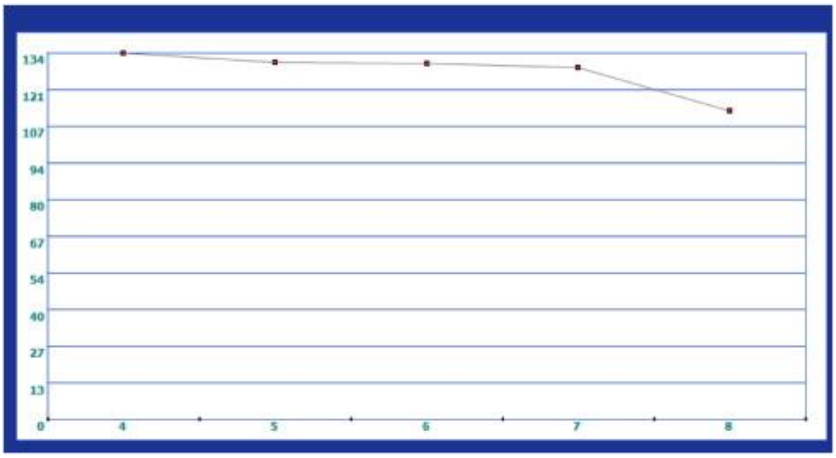

Fig. 5.13. Fragment of the User's Interdependence between Biometric and Self-Assessment Parameters database

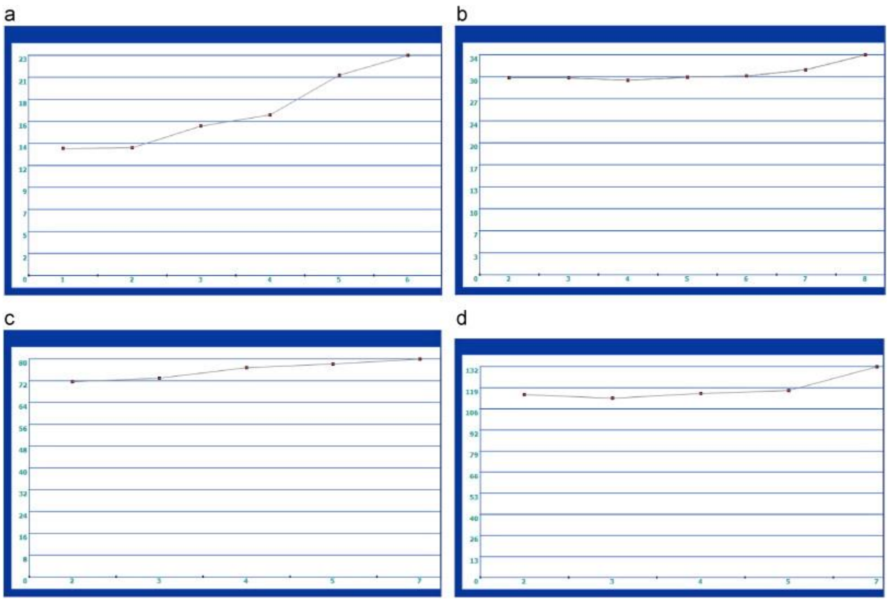

Fig. 5.14. Historical report on the correlations between stress level (abscissa/horizontal axis) and biometric parameters (ordinate/vertical axis). (a) Stress level and skin resistance correlation, (b) Stress level and hand temperature correlation, (c) Stress level and pulse correlation and (d) Stress level and systolic blood pressure correlation

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Fig. 5.14 shows that, as the level of stress rises, there are also respective rises in the manager's temperature and pulse count from the biometric computer mouse along with skin resistance as well as the systolic blood pressure. These dependencies correspond with data from analogical tests worldwide (see Section 5.2). The existing stress level is determined for each of the dependencies according to the biometric parameters taken at some certain moment, and their average significance is calculated. In the case of our manager, when her temperature—30 °C, her pulse—78 times/min, her systolic blood pressure—125 mmHg and her diastolic blood pressure—77 mmHg, her average stress level was 52 percent.

Stage 4. Once the average stress level is determined by the dependency diagrams, here at 52 percent, the Model-base Management System and Model Base (see Section 5.3.7) selects fifteen of the most important stress reduction recommendations (see Fig. 5.15).

The manager should repeat the steps of the first stage of the Advisory system during the daytime each 45 min, i.e., refresh her self-assessment and biometric parameters. However, whenever productivity, stress and/or emotions change, the work with the system can be terminated by clicking the button labeled “End mouse tracking”. The process can then be started anew.

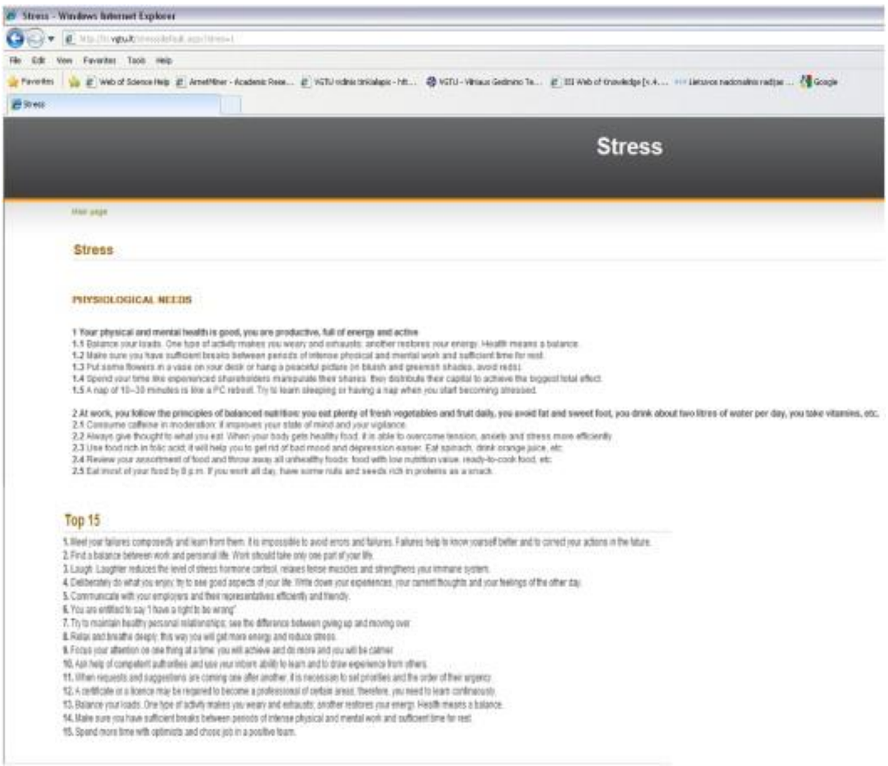

Fig. 5.15. Best stress reduction recommendations compiled per Maslow’s Hierarchy of Needs

Use of this developed system to establish the level of stress being experienced by an individual involves answering several questions during an actual timeframe. Then the system selects recommendations compiled according to Maslow's Needs Pyramid, which can assist in lessening stress level and increasing work productivity.

5.5 Scenario Used to Test and Validate the Advisory System and Its Composite Parts

The initial version of the Web-based Biometric Computer Mouse Advisory System to Analyze a User's Emotions and Work Productivity was invented in 2006. The testing of the Advisory system has been ongoing since that time. There were 33 employees involved in testing the system and 206 distance-learning students and employees of Vilnius Gediminas Technical University testing its composite parts. The preliminary results of the tests on the Advisory system were announced at the 25th International Symposium on Automation and Robotics in Construction in 2008 (Kaklauskas et al. 2008; Zavadskas et al. 2008). The Advisory system was improved in light of the continuous testing results. Some 20 final master theses were completed on the testing of the Advisory system. All of the 239 test subjects used computers on their jobs constantly. Women who wanted to apply such acquired experiences in their actual lives expressed a greater desire to take part in the experiment. They were interested, for example, in learning how to manage stress better. Men were less interested in such a social issue.

Similar studies conducted in other countries had fewer subjects in their experiments. For example, 40 students participated in the Krumhansl study (1997), 100 psychology students in the McFarland study (1985), 24 healthy, right-handed women in the Baumgartner et al. study (2006) and 32 women in the Rimm-Kaufman and Kagan study (1996).

Other researchers also partially applied a scenario analogical to this one. Their studies are briefly described heretofore.

McFarland (1985) described how 100 introductory psychology students listened to music that caused changes in these students' skin temperatures. The students listened to two selected pieces of music that they appraised themselves: one as arousing negative emotions and the other, as arousing calm, positive emotions. During that time, their body temperatures were being measured. (In the scenario herein, the respondents also appraised their own emotions.)

In the dynamic emotion rating experiment, subjects were randomly assigned to one of four emotional states. The ten subjects in the first state were instructed to adjust the position of the slider on the display continuously to indicate the degree of sadness they felt while listening to the music. The instructions to the ten subjects in each of the other three states were identical except that they involved fear, happiness and tension, respectively. All subjects had a short practice experiment to become familiar with the display and ask any questions they might have about their assigned task (Krumhansl 1997).

Subjects also filled out a short questionnaire about the emotional effects of the music after each piece. They were asked to rate how they felt while listening to the music using a rating scale from 0 to 8. These feelings were afraid, amused, angry, anxious, contemptuous, contented, disgusted, embarrassed, happy, interested, relieved, sad and surprised. Additionally they were asked to rate, on the same scale, the pleasantness and intensity of the music and their familiarity with the music before the experiment. At the end of the experiment, they filled out a short questionnaire that included questions about their musical training (Krumhansl 1997).

In the physiological experiment, physiological sensors were attached to subjects seated in a comfortable chair. They were told they would hear several short musical excerpts while their physiological responses were being monitored. They filled out the same questionnaire after each piece about emotional effects and the same questionnaire at the end of the experiment about their musical training (Krumhansl 1997).

The duration of the Advisory system testing scenario by Kaklauskas et al. (2011) lasted one month. It was conducted in three stages that included eleven steps as follows:

Stage 1. A diagram of interdependency between a user's biometric parameters and the data submitted during the self-assessment is determined (see Table 5.2).

Step 1. Experiment subjects subjectively record the level of their productivity and emotional state every 45 min using the e-Self-Assessment questionnaire.

Step 2. The physiological and behavioral/movement parameters of the experiment subjects are measured as they perform specific work on the computer. This process repeats on the job for one month.

Step 3. Next the Advisory system determines and outlines a diagram of interdependency between the biometric parameters of an experiment subject and the self-assessment data. Dependencies that do not conform to the trends of Best Worldwide Practices (see Table 5.1, fragment of the best worldwide practices database) are not deliberated any further. Actually 74 percent of the trends appearing in the experiment subjects' diagrams (on blood pressures, heart rate, skin conductance and temperature dependencies on experienced stress and emotions) were in conformance with the trends of the Best Worldwide Practices (see Section 5.2).

Step 4. The reliability of the interdependencies between a user's biometric parameters and the submitted self-assessment data is determined. The reliability calculations are submitted at the end of this section by an example on the dependency of average temperature on anxiety level.

Stage 2. Reliability of the experiment subjects' productivity and emotional states is determined.

Step 5. Experiment subjects assess their productivity and emotional states using the e-Self-assessment questionnaire.

Step 6. They perform their usual work on the computer for 45 minutes, while their physiological and behavioral/movement parameters are measured.

Step 7. The system provides each experiment subject with an assessment of his/her own productivity and emotional state, in real-time. The bases of these assessments are the dependencies determined at Step 3 and the physiological and behavioral/movement parameters obtained at Step 6 by using the method of the multiple criteria, complex and proportional evaluation of alternatives (Kaklauskas et al. 2006).

Step 8. The self-assessments of the experiment subjects taken during Step 5 are compared with the system's assessments produced during Step 7. The results determined that 76 percent of these results were in conformance at 15 percent reliability.

Stage 3. Submitted recommendations are validated.

Step 9. The compiled, universal Maslow's Pyramid Tables are applied to a specific person (see Section 5.3.6, Maslow's Pyramid Tables).

Step 10. The system submits the best recommendations to manage a stressful situation to an experiment subject.

Step 11. The experiment subject judges whether or not those are indeed the best recommendations for managing the stressful situation.

The results obtained in Stage 3 are reliable, taken from the perspective of a specific user. Each experiment subject applied Maslow's Pyramid Tables to his/her specific needs. Since these Tables were compiled in reflection of Best Worldwide Practices, such a selection by an experiment subject is sufficiently objective. Rather subjective suggestions can be approached by discussing merely a few alternative recommendations. However, when tens of thousands alternative recommendations are analyzed by mathematical methods, the objectivity level of the analysis is substantially raised, since solely multiple criteria analysis methods are employed, and they are objective.

5.5.1 Statistical Analysis of Average Temperature Dependency on Anxiety

These experiments were conducted by G. Dzemyda on subjects using the Biometric mouse by solely considering the dependency of average temperature on anxiety. Temperature t was recorded m=393,732 times. In all these instances, the level of anxiety i respective to temperature was also recorded. A subject assessed the level of anxiety for his/herself by subjectively assigning a meaning on a scale of 1–10.

Denotations:

- t_i^j is the temperature when the test subject indicates anxiety level i: $i \in \{1, \ldots, 10\}$, $j = \overline{1, m_i}$;
- m_i is the number of times anxiety level i is noted: $\sum_i m_i = m$;

- $\bar{t}_i$ is the average value of the anxiety level i respective to temperature: $\bar{t}_i = \frac{1}{m_i}\sum_{j=1}^{m_i} t_i^j$;
- p_i is the probability of the test subject indicating anxiety level i: $p_i=(m_i/m)$;
- S_i^2 is the dispersion of anxiety level i respective to temperature: $S_i^2 = (1/(m_i-1))\sum_{i=1}^{m_i}(t_i^j - \bar{t}_i)^2$;
- Q is the confidence probability, usually Q=0.95.
- $t_q(l)$ is the Student's t-distribution quantum q under number of degrees of freedom l.

In general a confidence interval is an interval within which, it is probable, there is a measurable parameter of some size (e.g., an average). This is named the confidence interval or the confidence equation (usually 0.95 is sufficient). The confidence interval of average temperature $\bar{t}_i$ under the confidence probability Q is

$$A_i = [\bar{t}_i - \Delta_i, \bar{t}_i + \Delta_i] = \left[\bar{t}_i - \frac{S}{\sqrt{m_i}} t_{\frac{i-Q}{2}}(m_i - 1), \bar{t}_i + \frac{S}{\sqrt{m_i}} t_{\frac{i-Q}{2}}(m_i - 1)\right] \quad (5.4)$$

Table 5.3 shows the summary of the calculation results. It is obvious that the confidence intervals of average temperature are very narrow, and they do not intersect under differing significances of anxiety level i. This shows that the obtained average temperatures respective to different levels of anxiety may be used when summarizing conclusions and making decisions.

Table 5.3 Significances of average temperature confidence intervals under differing anxiety levels i

i	$\bar{t}_i$	S_i^2	m_i	P_i	Δ_i	A_i	
						$\bar{t}_i - \Delta_i$	$\bar{t}_i + \Delta_i$
1	28.929	1.633	50.841	0.13	0.014	28.914	28.943
2	28.618	2.073	88.277	0.22	0.014	28.605	28.632
3	28.129	2.145	98.435	0.25	0.013	28.116	28.142
4	27.296	2.302	59.565	0.15	0.018	27.278	27.315
5	27.229	2.078	57.996	0.15	0.017	27.212	27.246
6	27.002	1.154	20.162	0.05	0.016	26.986	27.018
7	25.546	1.049	13.653	0.03	0.018	25.528	25.564
8	26.170	0.632	4803	0.01	0.018	26.152	26.188

The significances of the dependency of average temperature on anxiety level i are presented in Fig. 5.16. It can be seen that, as the anxiety level increases from 1 to 7, temperature decreases monotonically. However, following that, temperature begins rising —great anxiety stipulates a rise in temperature. Additional research is needed to explain and justify this phenomenon. One more thing that requires attention is that the values of great anxiety are less probable—then the probability is over 12 times less than average.

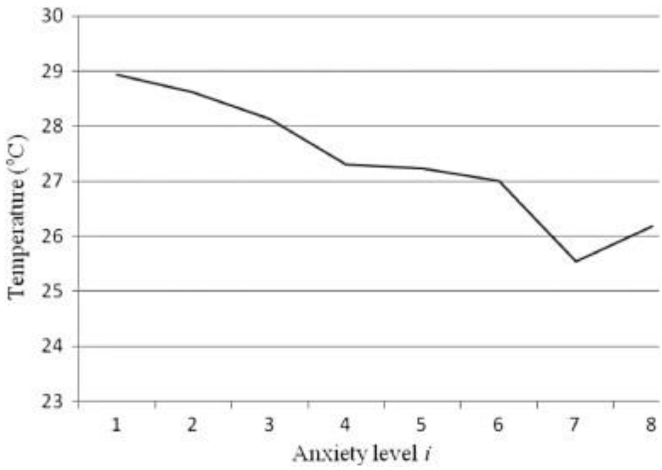

Fig. 5.16. Significance of average temperature dependency on anxiety level *i*

5.6 Calculating Reliability of Stress Dependencies on Diastolic and Systolic Blood Pressures and Finger Temperature by Analyzing the Entire User's Biometric Database

Variations in stress level (Y) relative to the analyzed variables (diastolic blood pressure, systolic blood pressure, finger temperature), listed in Table 5.4, were investigated by V. Gribniak using the regression method. These variables are obtained from the entire User's Biometric Database. The linear regression models Y=a·X+bY=a·X+b were constructed for each variable using over one million observations. In this model, Y represents the stress level, whereas other notations are established in Table 5.4 which presents the raw regression coefficients with their significance parameters (z-value and p-level) and the standardized regression coefficients (*Beta*). The magnitude of these last coefficients allows comparing the relative contribution of each independent variable in the prediction of the dependent variable (stress level Y). Since a huge amount of data provide the base for the analysis, all the variables become statistically significant (as p-level approaches zero). Table 5.4 provides clear evidence that all the variables under analysis are important predictors of stress.

Table 5.4 Regression analysis summary

Variable (X)	Regression coefficients			z	p-level	Beta	
	Name (notation)	Value	Std. error			Value	Std. error
1. Diastolic blood pressure	Slope (a)	0.040	0.0002	213.7	0.000	0.198	0.0009
	Intercept (b)	−0.121	0.0135	−9.0	0.000	-	-
2. Systolic blood pressure	Slope (a)	0.022	0.0001	242.3	0.000	0.222	0.0009
	Intercept (b)	0.205	0.0106	19.3	0.000	-	-
3. Temperature (finger)	Slope (a)	0.057	0.0007	78.1	0.000	0.157	0.0020
	Intercept (b)	0.712	0.0255	28.0	0.000	-	-

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Chapter 6. Student Progress Assessment with the Help of an Intelligent Pupil Analysis System

Abstract Students and lecturers would like to know how well students have learned the study materials being taught. A formal test or exam would cause needless stress for students. To resolve this problem, the author along with their colleagues have developed an Intelligent Pupil Analysis (IPA) System. A sufficient amount of studies worldwide prove an interrelation between pupil size and a person's cognitive load. The obtained research results are comparable with the results from other similar studies. The original contribution of this chapter, compared to the research results published earlier, is as follows: the IPA System developed by the authors in conjunction with colleagues is superior to the traditional pupil analysis research due to the integration of pupil analysis with subsystems of decision support, recommender and intelligent tutoring systems and innovative Models of the Model-base, which permit a more detailed analysis of the knowledge attained by a student. This chapter ends with a case study to demonstrate the practical operation of the IPA System.

6.1 Introduction

A sufficient amount of studies worldwide prove an interrelation between a person's cognitive load and pupil size. This sensitivity of the pupil can provide exhaustive data about the cognitive loads (Andreassi 2006; Beatty 1982; Beatty and Lucero-Wagoner 2000; Goldwater 1972; Hyona et al. 1995; Kahneman and Beatty 1966; Klingner et al. 2008; Partala and Surakka 2003; Valverde et al. 2010; Klingner 2010). Different research (Klingner et al. 2008; Partala and Surakka 2003; Valverde et al. 2010; Klingner 2010; Just and Carpenter 1993; Backs and Walrath 1992; Porter et al. 2007) demonstrate that task-induced dilations can serve as reliable proxies for cognitive load, and the sizes of blink pupil dilations reliably reflect a diverse scale of the difficulty of different activities thus validating pupillary dilations.

For example, whenever somebody recalls something from memory, pays close attention, parses a complicated sentence or otherwise thinks hard, his/her pupils dilate slightly and then return to their previous size within a few seconds of completing the mental work (Beatty 1982; Beatty and Lucero-Wagoner 2000; Klingner et al. 2008). This reaction, called the task-evoked pupillary response, is slight (usually less than 0.5 mm dilation), involuntary and reliably associates with a broad set of cognitive processes characterized as cognitive load. These include short and long-term memory access, mental arithmetic, sentence comprehension, vigilance and visual and auditory perception tasks (Beatty and Lucero-Wagoner 2000; Klingner et al. 2008).

The IPA System was developed in consideration of worldwide research results involving the interrelation between a person's cognitive load and pupil size along with instances of available subsystems of a decision support system (Uraikul and Chan 2007; Lou and Huang 2003), recommender systems (Blanco-Fernández et al. 2011; Papagelis and Plexousakis 2005) and intelligent tutoring systems (Barros et al. 2011; Whiting 1988). The results obtained from testing the IPA system were in concord with the results obtained worldwide from the research mentioned herein.

Fundamental components of decision support system (DSS) architecture are the databases and database management system, the models and models management system and the user interface. Decision makers are also a substantial part of the architecture. This chapter describes all these fundamental components, which are a composite part of the IPA System.

Recommender systems are software tools and techniques that recommend items of information likely to be of interest to the user or that provide suggestions for items useful to a user. The suggestions can relate to various decision-making processes, such as what items to buy, what music to listen to or what online news to read (Mahmood and Ricci 2009; Resnick and Varian 1997; Burke 2007; Ricci et al. 2011). The Recommendations Providing Model of the IPA System is similar to traditional recommender system components.

Traditionally Intelligent Tutoring Systems (ITS) consist of four different subsystem modules: the expert (domain) module, student module, tutor module and interface module. All these modules are components of the IPA System's ITS. This chapter introduces them in brief.

The innovations involved in the IPA System are several. One is that the pupil size analysis technologies available across the world are integrated with the known subsystems of decision support, recommender and intelligent tutoring systems. Another aspect is that the research on the IPA System is superior to other research due to innovative Models of the Model-base which permit testing and a more detailed analysis of the knowledge attained by a student.

The IPA System includes:

- Intelligent Database: Historical statistics DB, Domain DB, Question DB, Examination results DB, Computer learning systems DB and Intelligent database engine (see Section 1.4)
- Models of the Model-base: Student Model, Tutor and Testing Model, Sliding Window Filter Model, Student's Answer Correctness Estimate per Pupillary Response Model, Regression–Correlation Trends determining Model and Recommendations Providing Model

Kaklauskas et al. (2013) found no mention of the described integration and automated assessment of a student's level of knowledge by means of analyzing a student's changes in pupil size after analyzing the most recent research from across the world. Furthermore the IPA System can determine the level of difficulty of the questions by observing changes in pupil size during an examination and, as a result, offer certain suggestions to tutors such as which lecture segments need additional clarification to help students understand them better and which examination questions need clearer wording.

The IPA System also incorporates other innovative albeit less scientifically significant achievements such as the Regression–Correlation Trends determining Model and the Recommendation providing Model.

Despite these innovations, Kaklauskas et al. (2013) did not discover anything new regarding the correlation between a person's cognitive load and pupil size. Facts, e.g., that task-induced dilations can serve as reliable proxies for cognitive load, that the sizes of pupil blink dilations reliably reflect a diverse scale of the difficulty of different activities thus validating pupillary dilations and others have been known for a long time. The scientists who conducted the research relevant to such facts are cited in this chapter.

The structure of this chapter is as follows: after this introduction, Section 6.2 describes the Intelligent Pupil Analysis System. Section 6.3 follows with Case Studies.

6.2 Intelligent Pupil Analysis System

The Intelligent Pupil Analysis System (IPA) System developed by the author of this book in joint with colleagues (A. Vlasenko, V. Raudonis, E. K. Zavadskas, M. Seniut, A. Juozapaitis, I. Jackute, G. Kaklauskas) consists of the following components (see Fig. 6.1): Database Management System and Intelligent Database, Remote Eye Tracking Device, Model-base Management Subsystem and Model Bases and Context-aware Interface. The components of IPA System are briefly analyzed below.

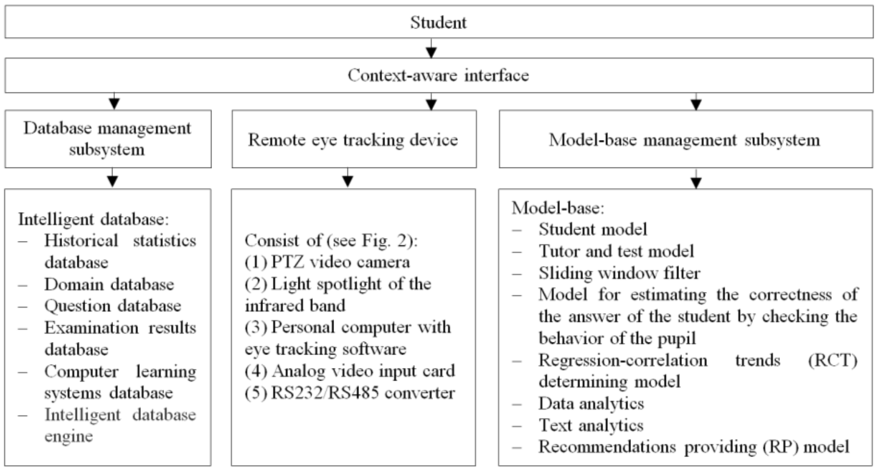

Fig. 6.1. Composite parts of the student progress assessment with the help of an intelligent pupil analysis system

6.2.1 Database Management System and Intelligent Database

The *Intelligent Database* contain the developed Historical statistics database, Domain database, Question database, Examination results database, Computer learning systems database and Intelligent database engine (see Section 1.4).

The *Historical statistics database* accumulates historical statistical data gathered from the real e-test (testing questions, testing results [information on correct and incorrect answers, time distribution for every question and number of times a student changed an answer to each test question] pupil dilations data, correlation between pupil dilations, correct answers data and such).

The *Domain database* contains information and material that an instructor is teaching. Students complete seven core modules and five optional modules for the aforementioned master study programmes over three semesters. Students choose an elective from 21 modules within "Real Estate Management" and 17 modules within "Construction Economics", both Master degree study programs, and they should optionally pass five examinations. Master students write a final thesis during their fourth semester. Students mark the sections of the elective modules they want to study onto electronic questionnaires after their registrations. The Domain database also offers study materials to students according to the repetitive key words in the different optional modules. A mixed approach is also possible and available. The received information is used for action plans, i.e., "mini curricula" that are used to guide the learner/student.

The *Question database* accumulates the following information: questions according to modules, possible answers to a question and evaluation of the correctness of possible answer versions.

Examination results database collects the real and integrated examination results (the time distribution to every question, number of times a student changed an answer to each test question, the difficulty of a question from least confusing to most confusing) are also evaluated. Meanwhile pupil dilation and constriction are evaluated as each question is being answered (see Fig. 6.2), as well as over the entire time of the exam.

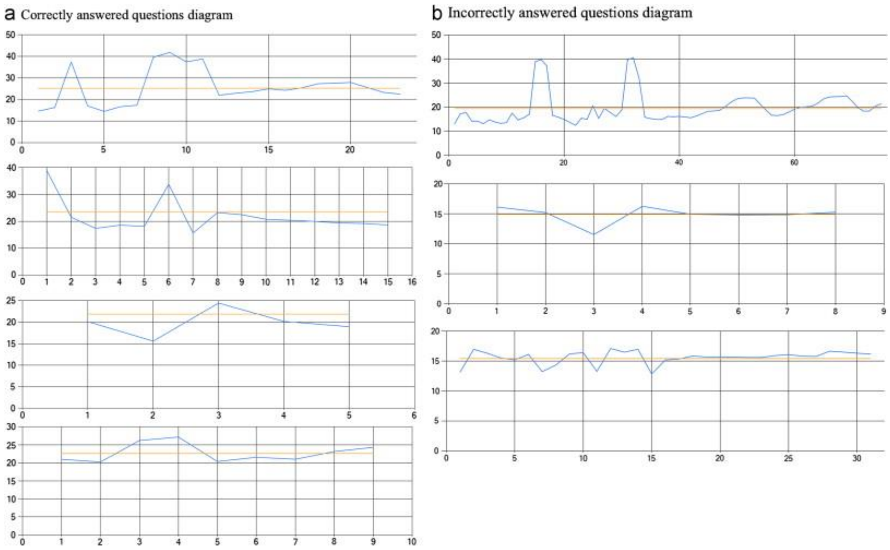

Fig. 6.2. Student pupil size diagram at the time of correctly (a) and incorrectly (b) answering a specific question during an exam: *x* axis—answering time in s. *y* axis—relative change in pupil size

The Computer learning systems database enables use of different Web-based computer learning systems: construction, real estate, facilities management, international trade, ethics, innovation, sustainable development, building refurbishment and others.

A Database Management System was used to design the structure of a database and perform its completion, storage, editing, navigation, searching, browsing and other functions.

6.2.2 Model-base Management Subsystem and Model-bases

The Model-base consists of eight models (subsystems): Student Model, Tutor and Testing Model, Sliding Window Filter Model, Student's Answer Correctness Estimate per Pupillary Response Model, Regression–Correlation Trends determining Model, Recommendations Providing Model, Data Analytics (Ordered Logit (regression model for ordinal dependent variables [see Figure 1.4]) and Anova (analysis of variance)), text analytics (see Section 1.4). The analyses of these models (subsystems) in brief follow.

The Student Model stores data that is specific to each individual student. The use of the Student Model is to accumulate information about the education of a student, his/her study needs, training schedule, results of previous tests (if he/she has studied earlier in the above-listed e-learning MSc programmes or qualification improvement courses) and study results. Therefore, the Student Model accumulates information about the entire learning history of a student. It first assesses a student's knowledge of a subject, i.e., what the student already knows. Then the Student Model uses that data to create a representation of the student's knowledge and his/her learning process. It represents the level of a student's knowledge as deviations from expert knowledge. These deviations base the system's decision on what curriculum module or module section (subsection) should be incorporated next and how it should be presented (text, multimedia, computer learning system and others). The purpose of the Student Model is to provide data for the Tutor and Testing Module. Therefore, the Tutor module must be capable of using all the gathered data.

The Tutor and Testing Model provides a model of the teaching process and supports the transition to a new state of knowledge. For example, this model controls the information about when to test, when to present a new topic and which topic to present. The Tutor and Testing Model reflects the teaching experiences of associate professors or professors. Its input comes from the Student Model, so the Tutor and Testing Model's decisions reflect the differing needs of each student in their optional modules.

The Tutor and Testing Model specifies sources for additional studies and helps select literature and multimedia for further studies. It also specifies a computer learning system to be used during studies. Traditional testing systems evaluate a student's learning with a grading mark. However, they do not provide a student a chance to learn about his/her gaps in knowledge or about how to improve that knowledge in some other way. The Tutor and Testing Model compares a student's knowledge tested prior to studies with his/her knowledge tested after completion of the studies and diagnoses the difference. The Tutor and Testing Model provides feedback based on the historical information it has collected on a student's responses, thus helping to determine the strengths and weaknesses of that student's knowledge. It summarizes the student's new level knowledge after completing studies and then provides various recommendations and suggestions. Once the feedback has been provided, the system reassesses and updates the student's model of skills, and the entire cycle is repeated. As the system is assessing what a student knows, it is also considering what the student needs to know and which part of the curriculum is to be taught next.

There are also options for selecting the next question in a test depending on the correctness of the answers to the previous questions. Correct answers lead to more difficult tasks, whereas incorrect—to easier ones. The obtained knowledge is the difference between the possessed knowledge (test before studies) and the final knowledge (test after studies). The Tutor and Testing Model also explains why one or another answer is correct/incorrect and offers certain additional literature and multimedia relevant to the incorrectly answered questions.

This system offers two options to determine the difficulty of questions. In one case, the teacher is the one who determines the difficulty of questions by choosing one of three degrees: difficult, medium or easy. In the other case, the Tutor and Testing Model provides its stored statistics, so a student can see a question's difficulty and the average evaluation of the entire student group. Thus the student realizes his/her position in the group before and after the studies. Here a question is considered easy when the rate of success is 80% or more and difficult when the rate of success is 20% or less. All the others are considered as questions of medium difficulty.

Usually the examinations present about 50% of questions in random order and deliberately choose about 50% of the questions per their different degree of difficulty. The technique for choosing questions of various difficulties is the following. The system takes the information about a student's achievements from the Student Model and starts with questions of corresponding difficulty. For instance, a student, who had been assigned grades of 9 s and 10 s for courses taken in the hard sciences, such as mathematics, physics and such in secondary school and strength of materials, reinforced concrete and steel structures and such at the university level, would start the exam from the difficult questions. Conversely, a student struggling with the hard sciences would start the examination from the least difficult questions. Once the student has answered three easy questions in a row, he/she then moves on to questions of average difficulty. Again, once the student answers three questions of average difficulty, he/she goes on to the more difficult questions and so on, until the examination has been passed successfully.

Similarly a subject's topics can be selected from the simpler to the more difficult, and the most complicated topics can be repeated. Therefore such questions from a base of compiled questions are not formulated randomly for tests. The examination is adjusted for each student individually by the number of questions, their complexity and the proportion of questions from different modules. It is also possible to give easier questions at the beginning and then proceed to more complex questions. Additionally it is similarly possible to select the taught subjects from the easier to the more complex, and to subjects not yet mastered can be repeated.

The Sliding Window Filter Model is based on the technology for signal filtering from randomly appearing noises, which is widely used in many applications. This method is inexpensive in respect to computational resources and relatively simple to implement. Its iterative processing manner allows filtering out unwanted peaks from the signal without losing important and informative data. The filtering algorithm proposed here performs offline filtering using three sliding windows of different sizes, which reflect the different characteristics of the entire signal. The wider sliding window characterizes the trend of the source signal *y(t)* but adds the certain delay τ. Meanwhile, the shorter sliding window reflects the dynamics of the signal with a smaller delay but with greater sensitivity to noise. The three types (*K*=3) of sliding windows are used to work together, where *Θ*=[5, 10, 20] describes the number of samples used for a sliding window. The combination of different filters provides better filtering results, and the resulting filtered signal retains most of the dynamics and the more useful information. The signal x_k' that is filtered using the *k*-th filter is expressed as:

$$X_k'(t) = \frac{\sum_{r=0}^{\Theta(k)} X(t+r)}{\Theta(k)} \tag{6.1}$$

The resulting filtered signal *y* is computed by calculating the mean value of the three filter outputs. The filtered signal is expressed below as:

where *K* is the number of filters (sliding windows). An example of a filtered signal is displayed in the Fig. 6.3.

The *Regression–Correlation Trends (RCT) determining Model* was developed by V. Raudonis as an aid to collect and organize numerical information into tables, graphs and charts, to analyze and interpret numerical data and to make informed decisions. Application of the RCT Model makes it possible to discover interesting patterns that identify a student's behavior on the system and to store student interactions and feedbacks in the IPA System; thereby past memory experiences are maintained, and then new teaching paths are derived. The RCT Model provides information on a testing process in matrix and graphical forms including information on correct and incorrect answers, time distribution for every question, number of times a student changes an answer to a test question, pupillary changes by dilation and constriction at the time of answering a specific question (see Fig. 6.2) as well as over the entire time of the examination and the like. Complex parameters are also presented whereby not only is the correctness of an answer evaluated but also the time required for a student to answer it along with hesitancies involved in the selection. The knowledge assessment can possibly change once an answer is evaluated by a complex parameter. The RCT Model, which is based on statistical information accumulated from the real e-test, presents various regression–correlation dependencies between different parameters and data. Some such dependencies are presented and explained in the Case Study.

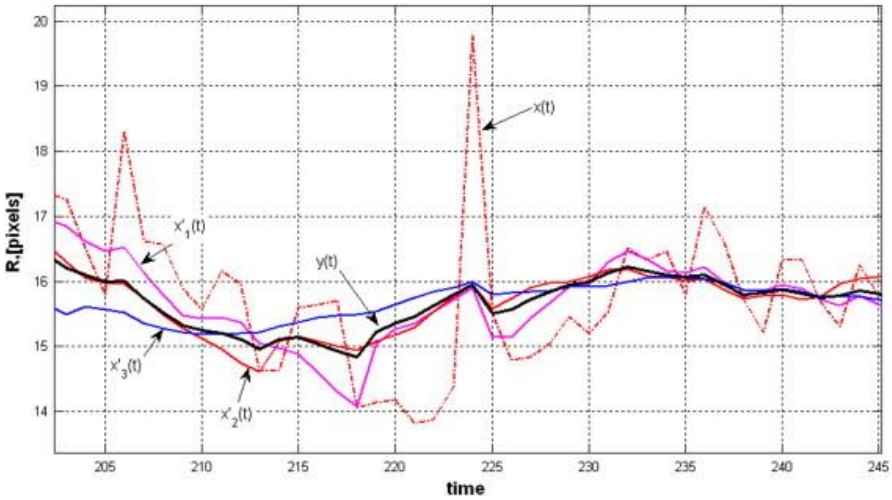

Fig. 6.3. Example of a noisy signal $x(t)$ and its resulting signal $y(t)$

The *Recommendations Providing* (RP) Model collects information on the history of a student's responses, provides feedback which helps to determine the strengths and weaknesses of that student's knowledge and then provides various recommendations for further education. The RP Model explains why one or another answer is incorrect and offers use of certain additional literature and multimedia to clarify the incorrectly answered questions. Analogically the RP Model can show areas of improvement to the instructor of a module, because its basis is integrated information on the testing process. If, for example, more than 200 students spend, on average, more than 25% of their time answering the test questions in the "Real Estate Market Analysis" section (as compared to the rest of the modules), and the rating marks for this section of the exam are more than 2 points lower than the average number of points for the module, then the RP Model makes recommendations to the instructor to supplement and more thoroughly explain the more difficult areas of the subject.

The IPA System can also determine the level of difficulty of questions by observing changes in pupil size during an examination. Thus it is able to offer some suggestions to tutors regarding:

- which lecture note segments require supplementation for better student understanding and
- which examination questions need clearer wording.

The *Model-base Management Subsystem* keeps track of all the possible models that might be run during the analysis, as well as controls for running the models. The Model-base Management Subsystem also links between models so that the output of one model can be input into another model.

The system provides a context-aware interface to facilitate use of the teaching services easily. It provides an introduction to the system, a comprehensive window-based menu of services and other relevant information.

6.2.3 Student's Answer Correctness Estimate per Pupillary Response Model

6.2.3.1 Analysis of the General Trends in the Research Performed

While analyzing the interdependence between student grading marks (correct and incorrect answers) and pupillary reflexes (dilation and constriction), these Kaklauskas et al. (2013) noticed that:

- correct answers to multiple choice questions correlate with dilated pupils
- happy excitement, such as when a student sees a known questions on the screen (indicating a high probability of a correct answer), causes the pupils to dilate.

These interdependencies commonly correspond to the results of research conducted worldwide. A review of such similar studies is presented below in brief.

6.2.3.1.1 Correct Answers to Multiple Choice Questions Correlate with Dilated Pupils

Papesh et al. (2012) demonstrate results that the strength and specificity of memory are observable in a physiological index of cognitive effort, the pupillary reflex. These scientists used the subsequent memory paradigm and found that, when participants devoted greater cognitive effort to encoding (reflected by larger pupils), they were more accurate in a test (the same as found by Võ et al. 2008). Meanwhile the authors herein further demonstrated that the encoding effort is directly related to subsequent memory strength, as overt confidence ratings and recognition accuracy reflect. This effect was not limited to encoding. When participants accurately recognized old items during a test, their pupils dilated again even more, relative to when they missed a question or experienced a false alarm. High confidence decisions reliably associated with larger peak diameters. Results revealed that study trials leading to high confidence hits yielded the largest peak diameters, relative to all other confidence estimates. However, there was a trend for the peak diameter to decrease with decreases in subsequent confidence (Papesh et al. 2012). According to Papesh et al. (2012), high-confidence decisions yielded the largest peak diameters. Nevertheless, there appeared to be a gradual decrease in peak diameter with decreasing confidence estimates.

6.2.3.1.2 Large Pupils on Happy Faces and Small Pupils on Sad Faces

Numerous studies analyzing the reliability of self-assessment have been conducted worldwide. For example, as per Matsuno (2009), a number of researchers reported high correlations between student- and teacher-assessments. A great many researchers (AlFallay 2004; Braak 2004; Fitzgerald et al. 2003; Mynttinen et al. 2009 and others) reached reliable results proving that self-assessment is sufficiently reliable. Hess (1975) also came to an opinion that can be considered safely reliable after noting that people, when allowed to draw-in the pupils of subjects in different pictures, consistently drew large pupils on happy faces and small pupils on sad faces.

Barlow (1969) came to a similar conclusion upon analyzing the pupillary responses to political leaders. It was noted that, upon displaying pictures of Lyndon Johnson, George Wallace and Martin Luther King:

- Liberals displayed pupillary responses of dilation to Johnson and King but of constriction to Wallace
- Conservatives, however, displayed dilation to Wallace and constriction to Johnson and King.

Peavler (1974) arrived at similar results upon analyzing digit string recall: pupil size increased with each successive digit (no increase after the 10th digit).

The results of the research described here are also similar. When students would see a known question on the screen, their spirits would rise and, as a result, the diameter of their pupils would increase. Conversely, when confronted with a difficult question, their mood would drop, and their pupils would constrict.

The two general trends mentioned above (correct answers to multiple choice questions correlate with dilated pupils and happy excitement upon seeing a known questions on the screen causes the pupils to dilate) reflect the results obtained from the research by Kaklauskas et al. (2013) (see Fig. 6.2). The range of the fluctuations of pupil dilation/constriction is also comparable to the aforementioned studies.

Fig. 6.2 provides a diagram of the pupil sizes of student at the time of correctly (a) and incorrectly (b) answering a specific question during an exam. As seen the average increase in pupil size upon correctly answering (22 to 23 comparable questions) at the time of answering is greater than it is upon incorrectly answering (15 to 19 comparable questions) at the time of answering.

An exam on “Electronic business” was taken by 13 students who had to answer twenty questions. At the time of answering correctly, the pupils of the students dilated a total of 14,767 times (up to 18.88% on average). Meanwhile, during the time of answering incorrectly, their pupils dilated a total of –4,446 times (up to 11.9% on average). Thereby the average increase in pupil size at the time of correctly answering is greater than at the time of incorrectly answering (up to 18.88% compared to 11.9% on average). The grading marks on the students' examinations fluctuated from 4 to 10 points. Therefore their pupils increased in size more often, because correct answers were submitted several times more often than incorrect answers were at the time of answering.

The average increase in pupil size also showed the same trend. During the time of correctly answering, pupils increased by 1.71 as compared to 1.39 when answering incorrectly.

6.2.3.2 Analysis of Specific Dependencies in the Research Performed

A number of scientists (Andreassi 2007; Porter et al. 2007; Papesh et al. 2012; Beatty and Lucero-Wagoner 2000; Granholm and Steinhauer 2004; Hess and Polt 1964; Kahneman and Beatty 1966; Wang 2010; Ahlstrom and Friedman-Berg 2006) observed that pupil size increased as the difficulty of a task increased. Brief descriptions of these studies follow.

It becomes clear as one considers research in pupillometry and pupillary behavior that variables such as information-processing load and task difficulty (whether the task is mental multiplication or developing images to abstract terms) will cause pupillary diameter to increase. This is true for a variety of different cognitive tasks, including short-term memory, language processing, reasoning, perceptual discrimination and detection. However, once active processing declines, pupillary diameters decrease. Pupillary reflexes have proven to be very sensitive indicators of variations in the intellectual effort involved in completing a task (Andreassi 2007).

Porter et al. (2007) investigated the processing effort during visual search and counting tasks using a measure of pupil dilation. A more difficult visual search resulted in greater pupil dilation than did a less difficult search. These results confirm a link between effort and increased pupil dilation. The moment-to-moment dilation pattern during a search suggests little effort in the early stages, but increasingly more effort towards gaining an adequate response. Meanwhile the counting task involved an increased effort initially, though it was sustained throughout the trial. These patterns can be interpreted in terms of the differential memory load for item locations in each task. In an additional experiment, increasing the spatial memory requirements of a search evoked a corresponding increase in pupil dilation. The mean pupillary response of an easy search was 0.00 mm (small set size) and 0.06 mm (large set size), of a hard search −0.04 mm (small set size) and 0.15 mm (large set size) and of counting −0.10 mm (small set size) and 0.39 mm (large set size). The mean pupillary response of an easy search was 0.21 mm (small set size) and 0.29 mm (large set size), of a hard search −0.24 mm (small set size) and 0.38 mm (large set size) and of counting −0.33 mm (small set size) and 0.63 mm (large set size). These results support the view that search tasks involve some albeit limited memory for item locations, and the effort associated with this memory load increases during the trials. In contrast, counting involves a heavy locational memory component from the start (Porter et al. 2007).

The more "strongly encoded" items result in larger pupils during a test (Papesh et al. 2012). According to Beatty and Lucero-Wagoner (2000), the pupillary response provides a quantitative index of how much cognitive load is being placed on the nervous system. Granholm and Steinhauer (2004) believe that changes in pupil diameter provide a unique view of brain activity.

Hess and Polt (1964) showed differential pupillary dilation responses while mentally calculating the product of two numbers. Pupil dilation in particular increased about twice as much (22% vs. 11%) when a subject calculated 16 times 23, compared to 7 times 8. Kahneman and Beatty (1966) reported how the more difficult memory tasks (memorizing numbers with more digits vs. less digits) induced a greater pupillary response (0.1 mm vs. 0.55 mm for 3 vs. 7 digits), which established the link between pupil dilation and memory load (Wang 2010).

According to Ahlstrom and Friedman-Berg (2006), the accumulated load of pupil dilation was 2.8 times higher for the most complex puzzle scenario. The peak load was higher for the complex puzzle than it was for the easy one (4.25 vs. 4.16 mm). A smaller difference was also found for the average load (3.54 vs. 3.4 mm), and such a difference was considered to be significant according to Ahlstrom and Friedman-Berg (2006).

The results of the investigations confirm the ideas of the other, aforementioned authors. For one, a more difficult question resulted in greater pupil dilation than did a less difficult question. At first glance, this thought seems to contradict the idea presented earlier: “When students would see a known question on the screen, their spirits would rise and, as a result, the diameter of their pupils would increase.”

Students who participated in an experimental exam were interviewed to explain such a discrepancy. Most declared that first they read a question when taking an exam. The initial emotion upon reading the question is either positive (if the question is from a section they had learned) or negative (if the question is not especially familiar). Then they go over to the multiple-choice answers. Mental activity becomes active while analyzing potential answers.

6.3 Case Studies

6.3.1 Case Study 1: A Sample of IPA System's Recommendations to a Tutor

The experiment reviewed in the chapter mostly involves distance-learning masters students who seek to improve their knowledge related to their current jobs. Students who are not indifferent to the quality and efficiency of studies may (in order to improve the system):

- suggest for the Domain Database any additional links to online written sources with more extensive explanations concerning individual chapters or subchapters of modules;

- rate the *interestingness* and *difficulty* of module's chapters and subchapters on a 10-point scale;
- suggest some new chapters and subchapters;
- during an examination, reword any *examination question* to make it clearer (the time spent on rewording will not be added to the test time);
- rate a question's difficulty.

The aforementioned information is presented for lecturer together with the information on correct and incorrect answers, time distribution for every question, number of times a student changes an answer to a test question, pupil size variations (dilation and constriction) for an individual question and a recommendation based on that. Now it is up to the tutor to make use of these student suggestions. These socially active students believe their suggestions might help their peers to absorb the learning materials better. Research shows that students often share attitudes and the phenomenon is known as “student-to-student correlation”. Names and groups of contributors will be specified next to student suggestions approved by the tutor.

Evidence suggests that people tend to rely more on recommendations from their friends (Sinha and Swearingen 2001). This observation, combined with the growing popularity of open social networks, is generating a rising interest in community-based systems or, as or as they usually referred to, social recommender systems (Golbeck 2006). This type of RSs models and acquires information about the social relations of the users and the preferences of the user's friends. The recommendation is based on ratings that were provided by the user's friends. In fact these RSs are following the rise of social-networks and enable a simple and comprehensive acquisition of data related to the social relations of the users (Ricci et al. 2011).

The IPA system is giving the list of recommendations for:

- Students (possibilities of improving knowledge).
- Teachers (opportunities of improving quality of conspectus and books).

We proceed with a brief review of the Case Study concerning IPA system's operation to provide recommendations to a tutor.

Petras Petrauskas, a student, had been studying for four days and then took the examination “Online decision support”. While getting ready for the examination, the student answered online questions about ways to improve the module's efficiency. Petras Petrauskas's suggestions submitted to Artūras Kaklauskas, a tutor, are shown in Table 6.1a. During the examination (comprising of 20 test questions) the IPA was collecting statistical information about Petras Petrauskas and comparing it to equivalent statistical information about other students who had taken this examination.

Table 6.1 Statistical information in the IPA system (a), as well as suggestions to the tutor Artūras Kaklauskas by the student Petras Petrauskas (b) and the IPA system (c)

(a) Suggestions to the tutor Artūras Kaklauskas by the student Petras Petrauskas

IPA system's question to the student	Student's (Petras Petrauskas's) answers
Links to additional online written sources with more extensive explanations of the subchapter in question that may be added to the Domain Database	http://www.metla.fi/silvafennica/full/sf36/sf362585.pdf http://www.hcibook.com/e3-docs/slides/notes-pdf/e3-chap-19-6up.pdf http://en.wikipedia.org/wiki/Group_decision_support_systems http://dssresources.com/faq/index.php?action=artikel&id=37 http://www.slideshare.net/poerslide/lecture4-group-decision-support-and-groupware-technologies
Please rate the subchapter related to this question.	
– Its interestingness:	7 points
– Its difficulty:	9 points
Suggested new subchapter	Application of group decision support systems in construction and real estate sector (because the module is part of the Property Management programme)
Suggested new wording of the question to make it clearer.	Advantages of group decision support systems (compared to personal)
Question's difficulty:	7 points

(b) Statistical information for the tutor

Question: What are the advantages of group decision support systems?

Answer statistics of one particular student (for this question)

Correct or incorrect answer	Incorrect
Answered in	48 s
Number of times the student changed the answer to this test question	0
Pupil size variations (dilation and constriction) compared to the previous question	+8.19%

Average answer statistics of different students (for this question)

Correct answers to this question in average (%)	44%
Average time of answering	55.08 s
Number of times students changed their answers to this test question	0.46 times

(c) The IPA system's suggestions to the tutor Artūras Kaklauskas

The statistical information (a) shows that this particular question and subchapter are rather complex and thus demand for additions/corrections. Historical trends show that incorporation of student's suggestions in such cases adds to the quality and clearness of the module.

The statistical information about one question ("What are the advantages of group decision support systems?") is shown in Table 6.1b. In view of the student's learning history, his suggestions (see Table 6.1a) and the statistical information about this examination (see Table 6.1b), the IPA system offered some recommendations to the tutor (see Table 6.1c).

In view of the statistical information (see Table 6.1b) and the recommendations suggested by the student Petras Petrauskas (Table 6.1a) and the IPA system (Table 6.1c), the tutor Arturas Kaklauskas approved the student's suggestions:

- added to the Domain Database the additional links suggested by the student;
- the scores of interestingness and difficulty of the subchapter (for this question) are used in the Database Management and Model-base Management Subsystems;
- a new subchapter “Application of group decision support systems in construction and real estate sector” was prepared;
- the question was reworded as follows: “Advantages of group decision support systems (compared to personal)”.

6.3.2 Case Study 2. Study of the Dependence linking a Student's Pupil Size to the Student's Psychological and Emotional State during an Examination

The research involved a group of 120 volunteer students who took a real, computer-based examination and had to select (tick) the correct answer on a computer display. Students had to mark the correct answers to 20 questions within 15 min to complete this exam.

The student–subjects participated in the study voluntarily, with their full consent and cooperation. Female students were more willing to take part in this experiment. The examination grade for participants in the experiment was raised by one point. This incentive helped to attract more students to the experiment.

There were no special requirements placed on the participants in this experimental study. They were ordinary students with normal motivation to take their exam and participate in our experiments. Students wearing glasses or contact lenses were eliminated because of issues regarding pupil detection.

The pupil tracking system used in this experiment is based on a motorized image capturing device (PTZ camera) and external IR light source. The tracking system captures an image of an eye with a dark pupil. The parameters of the pupil are estimated from this image. Glasses or contact lenses create additional unwanted reflections of the IR light source. These reflections partly or, in some cases, totally obstruct the region of the eye where the pupil is. Therefore future estimations of pupil parameters became a very frustrating task. The students with glasses and contact lenses were eliminated based on this tracking system limitation.

All the experiments were performed indoors with artificial, standard room lighting. There were no special requirements for illumination intensity, but the lighting was reasonably constant during the experiments. The tracking system analyses only near infrared images; therefore there are no strict limitations for lighting and no need to eliminate the influence of lighting on the human eye.

A "normalized" subject or, as named here, a "base pupil" was used to measure variations in pupil size. The base pupil diameter was taken in the first stage of these experiments as the student participant answered simple questions, such as "what is your name", "how old are you" and the like. This was required to prepare the student for the exam and eliminate the influence of any initial stress.

Students were seated at a computer to take an exam consisting of 20 multiple-choice questions. The questions were classified according to their complexity, from the easiest to the most difficult. The complexity of a question was determined according to the percentage of the students who answered it. Most of the students gave correct answers to the easier questions. Certainly what constitutes a difficult question differs for each person. However, previously data has been collected and statistically processed by levels of complexity taking into consideration the exam results of the majority of students.

Answers to the exam questions had to be given within 15 min. A video camera recorded changes in the pupil of the eye during the exam. Photos of a pupil were taken every three seconds to determine the instant of change in the diameter as precisely as possible. The next step was to measure the diameters of all the pupils. An eye pupil is then digitized and stored in a PC database of enrolled students. In addition the statistical information is saved in the database about examination questions that the student answered (see Table 6.2 and Table 6.3). The entire procedure takes less than a few seconds. Moreover, as a student answered, the time spent to progress to another question and the times spent to push the button to choose an answer were recorded automatically. The photos taken were matched to the provided questions with reference to time, and the average pupil diameter of that student was calculated. Thus, a pupil diameter is determined, which corresponds to a particular question. Accordingly it was possible to determine a student's reaction to each provided question. The changes in the eye pupil of some students were very clear and obvious. It can be concluded that the students who exhibited minor changes in their pupil diameters were better prepared for the exam, and the questions did not seem so complicated to them; therefore they underwent a lesser cognitive load. The exam results also reflected that the complexity of the other questions had a greater influence on the answers. The research results are presented by diagrams.

Table 6.2 Answer statistics about this examination question

Question: Components of the expert system	
Answer statistics of one particular student (for this question)	
Correct or incorrect answer:	Correct
Answered in	53 s
Number of times a student changes an answer to a test question	0
Pupil size variations (dilation and constriction)	±6.4%

Table 6.3 Answer statistics about this examination question

Question: What is integrated projects analysis?	
Answer statistics of one particular student (for this question)	
Correct or incorrect answer:	Incorrect
Answered in	45 s
Number of times a student changes an answer to a test question	0
Pupil size variations (dilation and constriction)	±5.7%

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Chapter 7. Recommender System to Analyze Student's Academic Performance

Abstract A sufficient amount of studies worldwide prove an interrelation linking student learning productivity and interest in learning to physiological parameters. An interest in learning affects learning productivity, while physiological parameters demonstrate such changes. Since the research by the author along with colleagues confirmed these interdependencies, a Recommender System to Analyze Student's Academic Performance (Recommender System hereafter) has been developed. The Recommender System determines the level of learning productivity integrally by employing three main techniques (physiological, psychological and behavioral). This Recommender System uses motivational, educational persistence and social learning theories and the database of best global practices based on above theories to come up with recommendations for students on how to improve their learning efficiency. The Recommender System can pick learning materials taking into account a student's learning productivity and the degree to which learning is interesting.

7.1 Introduction

The Recommender System is intended for bachelor's, master's and Ph.D. students in various years of their degree. Their educational achievements are different, as are their needs, notions of life, practical experience, etc. They therefore need different support.

The Recommender System developed by author in joint with colleagues (E. K. Zavadskas, M. Seniut, V. Stankevic, C. Simkevičius, T. Stankevic, A. Matuliauskaite, L. Bartkiene, L. Zemeckyte, R. Paliskiene, and V. Gribniak) uses motivational, educational persistence and social learning theories and the database of best global practices based on above theories to come up with recommendations for students on how to improve their learning efficiency. Research showed that the e-learning students studying at the Department of Construction Economics and Property Management of Vilnius Gediminas Technical University want to be active participants in shaping strategic alternatives for their learning productivity and interest in learning.

Further we analyze a *social learning theory* as an example.

Bandura's social learning theory sets three dimensions of the structure of personality, all closely interrelated: personal qualities (feelings, emotions, motivation, expectations); behavior (goals, working style, strategies, planning); environment (the influence of family, society, culture). According to Bandura (1986), self-efficacy is our belief in our ability to succeed in certain situations. Self-efficacy is the measure of one's own ability to complete tasks and reach goals (Ormrod 2006). Self-efficacy affects every area of human endeavor. By determining the beliefs a person holds regarding his or her power to affect situations, it strongly influences both the power a person actually has to face challenges competently and the choices a person is most likely to make (Luszczynska and Schwarzer 2005). Bandura 1986 and Bandura 1997 proposed triadic model of reciprocality (personal (i.e., feelings and cognition), behavioral (i.e., learning strategies or test performance), and environmental dimensions (i.e., classrooms or family units)), which focuses on how personality is shaped by social experience and observational learning:

- The *personal dimension* includes motivation such as self-efficacy and outcome expectancies. Self-efficacy refers to individuals' beliefs in their capability to accomplish a specific task.
- The *behavioral dimension* involves self-regulated learning.
- The *environmental dimension* includes socialization experiences, ethnic influences, and sex-roles.

Many research show that self-efficacy influences academic achievement motivation, learning and academic achievement (Meral et al. 2012). Schunk and Pajares (2002) reported that there was a positive relationship between self-efficacy and academic achievement and that if students are trained to have higher self-efficacy beliefs their academic performance also improves. Students with strong senses of self-efficacy tendency involve in challenging tasks, invest more effort and persistence, and show excellent academic performance in comparison with students who lack such confidence (Bong 2001).

According to Yazici et al. (2011), there are meaningful relationships between the students' academic achievement and self-efficacy beliefs in positive direction. Self-efficacy beliefs are positively related with the academic achievement (Schunk and Swartz 1993) and are qualified in prediction of academic success (Pajares and Voliante 2002). Lane et al. (2005) reported significant positive intercorrelations between vigor, self-efficacy, self-set goals and examination performance among a sample of 50 undergraduate students for a practical examination. Prior to each of the examinations, participants were asked to indicate the grade that they set as a goal for the examination. They were also asked to rate the confidence that they have for achievement of the goal. With this in mind, it is likely that negative or unpleasant moods will associate with a difficult or problematic situation, where information regarding the self, task and coping strategies are negatively phrased. Should this occur, it is also likely that the negative moods will relate to low self-efficacy (Bandura 1990). Pre-examination mood states are not only predictive of performance, but are also related to the difficulty of self-set goals, and self-efficacy estimates to achieve these goals (Lane et al. 2005).

Research on Australian science students showed that those with high self-efficacy showed better academic performance than those with low self-efficacy. Confident individuals typically took control over their own learning experiences, were more likely to participate in class, and preferred hands-on learning experiences.

Those with low self-efficacy typically shied away from academic interactions (Andrew 1998). In certain circumstances, lower self-efficacy can be helpful. One study examined foreign language students' beliefs about learning, goal attainment, and motivation to continue with language study. It was concluded that over-efficaciousness negatively affected student motivation, so that students who believed they were "bad at languages" had greater motivation to study (Jernigan 2004).

Childhood science socialization experiences include exposure to social modeling, parental expectations and stereotypes, fieldtrips to science museums, science books, chemistry sets, computer games, science clubs, and working or volunteering in science related locations such as museums and laboratories. Socialization experiences affect students' self-efficacy, outcome expectancies, and self-regulatory behavior; and findings show that differences among cultures may result in biases between boys and girls (Eccles and Wang 2012; Meece and Courtney 1992).

Schunk and Meece (2006) found that when effective interactions with the environment are fostered by families, students have enhanced self-efficacy and competency beliefs, which can ultimately affect their choice of courses to enroll in Eccles (1987).

Senler and Sungur (2009) found that parents' educational level affected elementary and middle school students' science achievement.

When students enroll in a science undergraduate course, they are equipped with a certain degree of knowledge about the subject, have some expectations, academic goals, and skills, but they are also influenced by their childhood and adolescent socialization experiences with their parents, teachers, and peers and are metacognitively aware of their gender, ethnicity, culture, confidence levels, and career goals. For example, the interaction between gender and mothers' educational level approached a significant level but only for female students with regard to academic performance. Also students learn to be selective about the strategies they will use, and they often will keep using those that have helped them in the past. Self-efficacy changes were also positively related to outcome expectancies, homework self-regulation, and final course grades (DiBenedetto and Bembenutty 2012).

According to Bandura, boys are often socialized to be independent, and directive whereby girls are socialized to be dependent and emotional. These environmental socialization experiences could explain why males were more likely to engage in autonomous actions, such as using the library, which could be perceived as an independent task, while females preferred to send e-mails to their professors, which can be perceived as a more dependent task. Interviewing the students could shed some light about how specific parental socialization practices and social modeling influence their science trajectories (DiBenedetto and Bembenutty 2012).

7.2 Analysis of the Interdependence linking Physiological Parameters of Students to their Learning Productivity and Interest in Learning

A sufficient amount of studies worldwide prove an interrelation between a student's productivity and physiological parameters.

Mental stress is a general term encompassing mental arousal and/or emotional stress. Mental stress can be evoked by a number of mental tasks – e.g., mental arithmetic, public speaking, mirror trace, type A structured interviews (McGraw-Hill Concise Dictionary of Modern Medicine 2002). A wide range of stimuli are regarded as mental stressors, including mental arithmetic, simulated public speaking tasks, problem solving tasks, cognitive tasks like the Stroop color/word interference task, psychomotor challenges such as mirror tracing, and tasks involving the recall of negative emotion (Strike and Strptoe 2003). As we have seen, there are different types of mental stress: "arithmetic stress" is just one of the components of "mental stress". We consider "arithmetic stress" and "mental arithmetic stress" to be among the most appropriate operational definitions in our research context and they are used in the chapter.

Scientists from all over the world study the interdependence between students' physiological parameters and their mental stress (arithmetic stress). Kobayashi et al. (2003); Kamei et al. (1998); Fechir et al. (2009) analyzed changing skin humidity parameters caused by changes in the intensity of mental activity. Fechir et al. (2009); Harris et al. (2000); Vuksanović and Gal (2007); Murata et al. (1999); Sloan et al. (1991); Turner et al. (1987); Szabo et al. (1994); Tanida et al. (2004); Furedy et al. (1996) examined the interdependence between heart rate and mental stress (arithmetic stress). Fechir et al. (2009); Harris et al. (2000); Sloan et al. (1991) investigated changes in blood pressure caused by changing the intensity of mental activity (see Fig. 7.1).

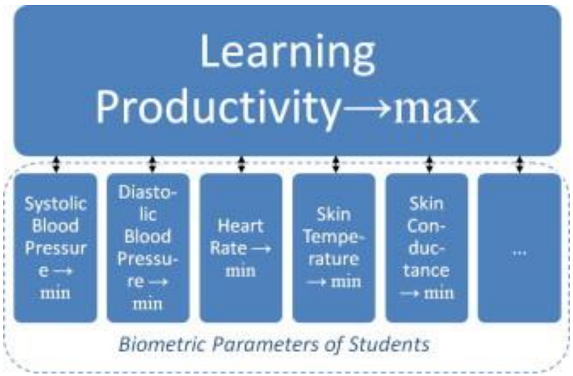

Fig. 7.1. Interrelations between physiological parameters and learning productivity among students

The results of these studies reveal that changing physiological parameters over time can help to determine the level of a student's learning efficiency. Increasing skin conductance and rising systolic and diastolic blood pressures, for instance, lead to decreasing learning efficiency in students (see Table 7.1). The studies of the aforementioned scientists are briefly reviewed below.

In their research, Kamei et al. (1998) and Kobayashi et al. (2003) analyzed the interdependences linking arithmetic calculations with human palm humidity and sweating, while Fechir et al. (2009) analyzed the interdependencies linking mental stress to sweat rate. The said authors point out that arithmetic calculations and the intensity of mental stress cause an increase of human palm humidity and sweating. For example, Kobayashi et al. (2003) examined the effects of repetitive mental stimulation, such as arithmetic calculations, with sequential subtraction on active palmar sweating responses in humans. Mental stimulation caused a rapid and oscillatory response of active palmar sweating during the operation of stimulation or tasks. The research of Kamei et al. (1998) also indicates that sweat rate significantly increased during mental arithmetic. Fechir et al. (2009) argue that the effect of "stress" on emotional sweating revealed that difficult mental arithmetic induced stronger emotional sweating than the easy task. Emotional sweating increased during mental arithmetic tasks.

Table 7.1 Interdependence linking physiological parameters of students to their learning productivity

	Skin humidity	Heart rate	Blood pressure
Arithmetic calculations	↑ Kobayashi et al. (2003)		
	↑ Kamei et al. (1998)		
Mental stress (Stroop task, mental arithmetic task)	↑ Fechir et al. (2009)	↑ Fechir et al. (2009)	↑ Fechir et al. (2009)
Mental stress (provoked by a standard arithmetic challenge)		↑ Harris et al. (2000)	↑ Harris et al. (2000)
Arithmetic stress		↑ Vuksanovic and Gal (2007)	↑ Vuksanovic and Gal (2007)
Mental stress		↑ Murata et al. (1999)	
Mental arithmetic		↑ Sloan et al. (1991)	↑ Sloan et al. (1991)
		↑ Turner et al. (1987)	
		↑ Szabo et al. (1994)	
		↑ Tanida et al. (2004)	
Arithmetic and combined arithmetic-with-cycling tasks		↑ Furedy et al. (1996)	

A number of scientists examined the interrelations linking mental, arithmetic stress and arithmetic tasks to the human heart rate. All authors confirm that the said factors make the heart rate increase.

Heart rate was monitored while 20 young males completed MATH, a computer-operated mental arithmetic task specifically designed for use in experiments involving subjects of heterogeneous numerical ability and a standard mental arithmetic task used in this laboratory on several occasions. Both tasks elicited sizeable increases in heart rate (Turner et al. 1987). Sloan et al. (1991) studied heart rate responses of ten subjects to two different versions of mental arithmetic and a control condition in which vocalization of answers was manipulated. Heart rate was measured. Results indicate that the two task conditions produced similar heart rate increases. Mental arithmetic has been shown to produce significant increases in heart rate. Szabo et al. (1994) studied combined effects of exercise and mental challenge on heart rate. Subjects performed a series of mental arithmetic problems for one minute each time: two min before cycling, 10 min into low intensity cycling, 10 min into medium intensity cycling and two min and 20 min, respectively, after cycling. During both exercise workloads, the mental arithmetic elicited significant additional increases in heart rate. In one Furedy et al. (1996) experiment, twenty subjects performed 1-min arithmetic and combined arithmetic-with-cycling tasks while their heart rate is being measured. In another experiment, eighteen males performed 1-min arithmetic tasks, before, during and following sustained low and moderate intensity cycling. The results showed that heart rate increased reliably to all challenges. Murata et al. (1999) recorded simultaneously the two rhythms during finger tapping as a simple model of rhythmical motion for identifying whether spontaneous cardiac rhythm and voluntary motor rhythm are modified in parallel or influenced separately when imposing mental stress. Mental stress was given intermittently three times for 10–15 s. at intervals of 40 s. during tapping for 150 s. Heart rate and tapping rate and their variations (standard deviation) during finger tapping with and without mental stress were compared. Heart rate and tapping rate increased significantly in response to mental stress during tapping. After mental stress ended, heart rate returned rapidly to the initial level, but tapping rate remained at a higher level. The present results indicate that the cardiac and motor rhythms are influenced simultaneously by mental stress. Harris et al. (2000) used two-dimensional ultrasound to measure brachial artery, flow-mediated vasodilation before and after mental stress (provoked by a standard arithmetical challenge). During mental stress, heart rate increased on average by 29.6%. The Tanida et al. (2004) study evaluated the relationship between the asymmetrical prefrontal cortex activity and the automatic nervous system response during a mental arithmetic task. Employing near infrared spectroscopy, Tanida et al. (2004) compared cerebral blood oxygenation changes in the right and left prefrontal cortices during a mental arithmetic task with heart rate changes. During the mental arithmetic task, eight subjects (high-heart rate group) showed large heart rate increases (14.2 ± 3.0), while eight subjects (low-heart rate group) showed small heart rate increases. Vuksanović and Gal (2007) stated that investigations on arithmetic stress with verbalization showed that spectral measures of heart rate variability did not assess changes in autonomic modulation, although the heart rate increased. Fechir et al. (2009) determined that stress co-activated heart rate.

Sloan et al. (1991); Harris et al. (2000); Fechir et al. (2009) examined the interdependencies linking mental stress and mental arithmetic with blood pressure. In their research, Sloan et al. (1991) determine that the mental arithmetic stress has been shown to produce significant increases not just in the heart rate but in the blood pressure too. Harris et al. (2000) determined that, during mental stress, blood pressure increased by 17.9% on average. Fechir et al. (2009) confirm the results achieved by Sloan et al. (1991) and Harris et al. (2000) arguing that the stress also co-activated blood pressure.

The results achieved show that the same mathematical operation performed within the same period but at a different level of productivity demands a different level of mental stress. Fig. 7.2(1a) and (1b) show how students' mental stress levels and physiological parameters change during the day. Higher mental stress (meaning less productivity (see Fig. 7.2(1a) and (1b)) is needed, for instance, at 6 p.m., when a person is emotionally and mentally tired after a workday, in contrast to 9 a.m., when a person, after a night's sleep, is mentally and emotionally rested (meaning high productivity (see Fig. 7.2(1a) and (1b)). Fig. 7.2 shows that higher mental stress was needed to perform the same mathematical operation within the same period at 6 p.m. and, therefore, diastolic blood pressure increased. The results of this research are fully in line with the research results by the aforementioned researchers (see Fig. 7.3).

	Systolic blood pressure	Diastolic blood pressure
Learning productivity	2.1a 	2.1b 
Interest in learning	2.2a 	2.2b 

Fig. 7.2. Interdependences linking physiological parameters to student learning productivity and interest in learning

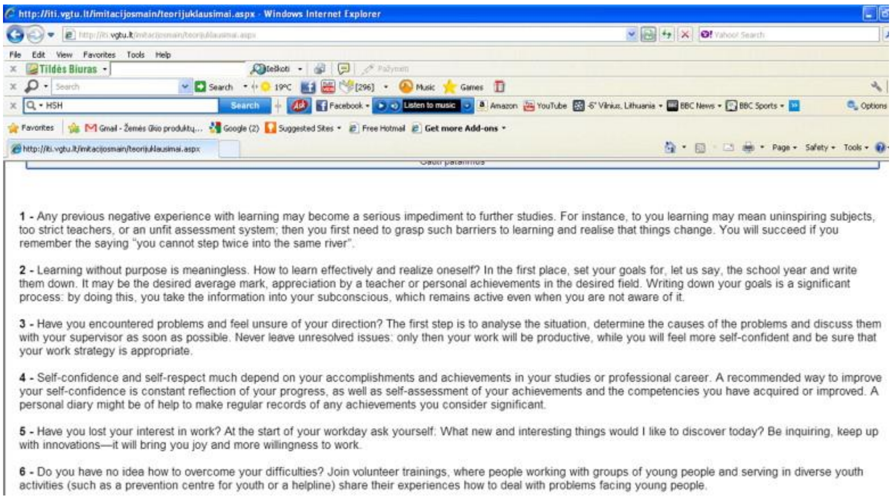

Fig. 7.3. Recommendations for best learning productivity as per motivational, educational persistence and social learning theories

There is also an indirect connection between the interest in studies and the experienced stress (Fig. 7.2(2a) and (2b)). The less a person is interested in studies, the more he/she needs to put more effort to concentrate, this increases the blood pressure (systolic and diastolic) goes higher. These facts confirm the studies by other scientists (Carnegie 2004; Brill 1946), who determined that emotional factors reduce human productivity.

Comparisons of the available diagrams and global practices (see Table 7.1) suggest that systolic and diastolic blood pressures are directly related to current interest in learning and to learning productivity. As argued by Harris et al. (2000); Sloan et al. (1991); Fechir et al. (2009) and backed up by tests carried out by these authors, the higher the mental stress (unappealing and boring work), the greater are the fatigue and the reduction in human productivity and the higher are the systolic and diastolic blood pressures.

The said above studies show a common interdependence suggesting that declines in motivation to learn and in the appeal of studies (the number of mental activities, however, must be the same within an equivalent period) contribute to increasing systolic and diastolic blood pressures, heart rate and skin humidity which, in turn, causes a decline in learning efficiency. Increasing students' motivation to learn and their interest in learning, on the contrary, contribute to better academic progress among students.

The results achieved herein are compared in this chapter to those from analogical studies conducted worldwide. This chapter is structured as follows: Section 7.3 describes the Recommender System to Analyze Student's Academic Performance. Section 7.4 analyzes development of learning materials by the Recommender System based on a students' learning productivity and the level of interestingness. Section 7.5 provides a Case Study (the Recommender System as a means to increase student productivity in learning and to improve their achievements). Section 7.6 presents the reliability analysis of the physiological parameters influence on interest in learning using the entire Student's Physiological Database.

7.3 Recommender System to Analyze Student's Academic Performance

7.3.1 Introduction

Recommender System is innovative to the traditional physiological parameters analysis systems due to the integration of physiological parameters analysis with subsystems of decision support, recommender and intelligent tutoring systems and Models of the Model-base, which permit a more detailed analysis of the learning productivity.

In this chapter, references to research developed by other authors concern the research which analyses the interrelation process between person's mental stress (arithmetic stress) and physiological parameters, rather than intelligent, smart and other systems. We may state that the Recommender System has been developed:

- considering the research results from across the world (interrelation between a person's mental stress (arithmetic stress) and physiological parameters) and instances of available subsystems of decision support (Lou and Huang 2003; Uraikul and Chan 2007), recommender (Blanco-Fernández et al. 2011; Papagelis and Plexousakis 2005) and intelligent tutoring (Arendasy and Sommer 2007; Barros et al. 2011; Whiting 1988) systems. To make things more clear, the chapter also briefly reviewed similar recommender and intelligent tutoring systems;
- by an innovative integration of the Physiological computer mouse, Physiological Finger, Models of Model-base and Models of Data-base, thus leading to a new synergy.

The Recommender System to Analyze Student's Academic Performance (i.e., Recommender System) comprises of the following components (see Fig. 7.4): the Database Management System and Intelligent Database, the Equipment Subsystem, the Model-base Management Subsystem and the Model Bases with Multimodal Input Interface (see Section 1.3). The architecture (see Fig. 7.4) and components of BISPA system are briefly analyzed below.

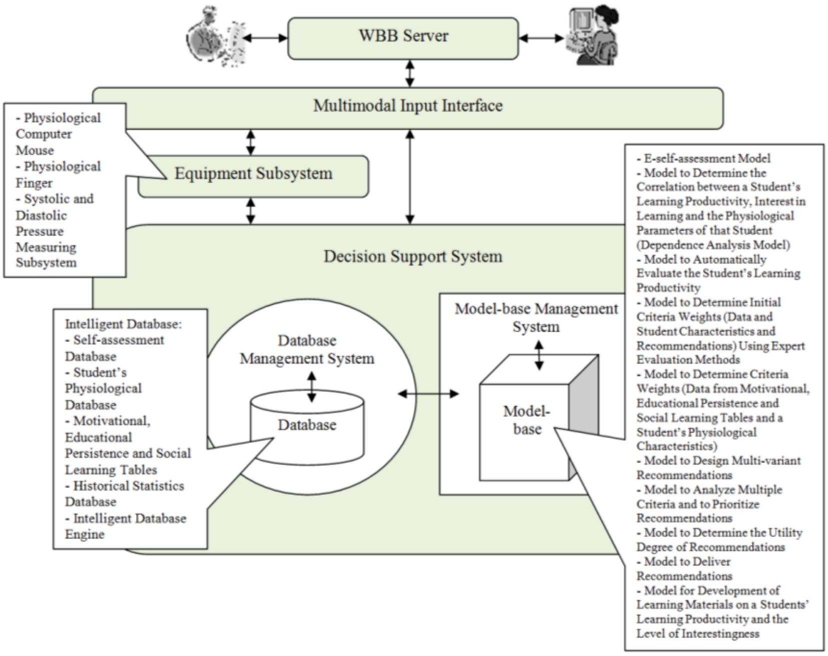

Fig. 7.4. The architecture of the Recommender System.

The subsystems are briefly analyzed below.

7.3.2 Equipment Subsystem

The Equipment Subsystem consists of Physiological computer mouse, Physiological Finger and Systolic and diastolic pressure measuring subsystem.

Different researchers, including Shin et al. (2009); Kong et al. (2006); Pan et al. (2003), are working in the same field as that of the Physiological computer mouse.

This Physiological computer mouse is able to measure the temperature and humidity of a student's hand, skin conductance, touch intensity and heart rate. These physiological parameters provide more information about the student and help to evaluate that student's learning productivity and interest in learning. More detailed description of the Physiological computer mouse is presented in Section 5.3.2.

Systolic and diastolic pressure measuring subsystem collects systolic and diastolic pressure data.

The Physiological Finger collects humidity (humidity sensor), electrogalvanic skin conductance (electrogalvanic skin response sensors), skin temperature (thermistor), heart rate (pulse sensor) data for correlations with a student's work productivity and interest in learning and interest in learning. More detailed description of the Physiological Finger is presented in Section 5.3.4.

7.3.3 Intelligent Database and Database Management System

The *Intelligent database* contains the developed Self-assessment Database, Student's Physiological Database, Motivational, Educational Persistence and Social Learning Tables, Historical Statistics Database, and Intelligent database engine (see Section 1.4).

Studies by many scientists prove sufficient reliability of self-assessment (see Section 4.2). Due to the experiences of AlFallay (2004); Braak (2004); Fitzgerald et al. (2003); Marsh et al. (1979); Mynttinen et al. (2009); Sung et al. (2009); Xiao and Lucking (2008), including the author of this book, a decision was made to gain information about student learning productivity and interest in learning among other matters by means of self-assessment.

The Recommender System developed is based on the presumption that, by assigning a student self-assessment questions and then searching for the interdependency with that student's physiological parameters at that time, it is possible to determine this interlink rather accurately. One of the main purposes of the Recommender System is to determine interdependencies between eleven pieces of data submitted on a student's own state of being and twelve of that student's physiological parameters at the time of self-assessment (see Table 7.2).

Table 7.2 A main purpose of the Recommender System is to determine interdependencies between eleven pieces of data submitted on a student's own state of being and twelve of that student's physiological parameters at the time of self-assessment

Psychological	Data on students' state of being at the time of self-assesment										
parameters under measurement	Personal mood	Productivity	Interest in learning	Stress	Self-control	Happiness	Anger	Fear	Sadness	Surprise	Anxiety
Physiological computer mouse:		Interdependency diagrams determined and outlined									
– temperature											
– humidity											
– skin conductance											
– touch intensity											
– heart rate											
Physiological Finger:											

– humidity
– electrogalvanic skin conductance
– skin temperature
– heart rate
Blood pressure and heart rate data:
– heart rate
– systolic blood pressure
– diastolic blood pressure

Once a student fills out the e-Self-Assessment questionnaire (Fig. 5.2) and clicks on the button labeled "Start working", the Physiological computer mouse and Physiological Finger begin to gather the physiological data of that student for storage in the Student's Physiological Database. This way the physiological parameters of different students with different emotional states, temperaments and learning productivity rates are collected in the database. Different physiological parameters have been tested for correlations with student's learning productivity and interest in learning.

Development of best global practice database (Motivational, Educational Persistence and Social Learning Tables) based on motivational, educational persistence and social learning theories was focusing on eliminating barriers that directly affect students' low academic performance:

- social conditions (i.e. class attendance, completion of assignment, family status, socio-economic status, allowance);
- physical factors (diet, exercise, health, age, sex, heredity);
- psychological, emotional and environmental factors: self-efficiency, motivation and attitude towards the subjects, academic related skills, academic objectives, perceived social support, social involvement, personal (laziness, addicted to computer games), institutional commitment, university climate, learning environment, the teaching method being employed by the lecturer's, instructional materials).

Description of above factors is follows.

There are significant differences between students' socio-economic status and their academic achievements (Yazici et al. 2011). Academic Self-Concept (ASC) refers to the personal beliefs someone develops about their academic abilities or skills (Trautwein et al. 2009). Due to the variety of social factors that influence one's ASC, developing a positive ASC has been related to people's behaviors and emotions in other domains of their life, influencing one's happiness, self-esteem, and anxiety levels to name a few (Marsh and Martin 2011). Social factors such as romantic relationships, organizations and clubs, and sports activities have been found to have effects on students' academic performance. These social factors affect academic performance in terms of time demanded and the psychological state they may cause. A student may be influenced to be involved in any of the stated variables. The question is how one strikes a balance between the stressful academic attainment and social activities (Umar et al. 2010).

Social class impacts on the future achievement and academic performance of the upper/middle class children within our society. In that the lack of money by the working-class (or lower class) inhibits their ability to provide the instructional resources, the diet, the psychological advantage and the access of human resources to enhance productivity of their children on examinations. Meaning, if the children is/are not provided with the appropriate and adequate instructional resources that effectively and comprehensively covers a syllabus, the child is automatically placed at a disadvantage of high academic attainment. In addition, with the proper diet, many of the working class children's brain is properly nourished to enable them to enter the class home as high recipient of information to write the various examination at some future date. No money spells low performance that indicates the disparity in achievement in educational achievement of the various classes in our society (Haralambos and Holborn 1996).

Material factors, such as family income, play a part in determining levels of attainment. Lower social classes may lack the money to provide their children with the same educational opportunities as middle and upper class parents. Greater resources may allow parents to provide children with toys that are more educational, a greater range of books, the psychological advantage, a superior diet, and more space in the home to do homework, greater opportunities for travel, private tuition and access to private fee-paying schools. In all these ways more affluent parents can provide their children with advantages before they attend school and during their school career (Haralambos and Holborn 1996).

The families' socio-economical level (incomes, educational level and parents' occupational status) is strongly related to students' academic performance (Sirin 2005). Schlee et al. (2009) supporting the idea that the resource capital of the parents is a better predictor of the child's academic performance than social capital.

In fact, many of today's problems with students are actually health-related. Kids cannot learn if they are hungry, tired, hung over from alcohol, or worried about violence. We need to eliminate barriers that affect students' readiness to learn. A variety of physical and mental conditions impact students' school attendance and their ability to pay attention in class anger, and restrain from self-destructive impulses (Rudiger 2005).

Chinaveh et al. (2010) examined the effectiveness of Multiple Stress Management Intervention (MSMI) on academic performance and mental health among undergraduate students. Sixty students were randomly assigned to either a stress-management training group, or a non-training control group. Results indicated that there

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is an increase in the academic performance and mental health measures in the experimental group. This study implies that stress management could be learned and coping skills could be acquired (Chinaveh et al. 2010).

Rudiger (2005) posited that asthma, multiple sclerosis, arthritis, heart disease have had temporary to chronic impact on students' academic performances. The secondary effects of illness and the side effects of medications can have a significant impact on memory, attention, strength, endurance, and energy levels (Rudiger 2005).

Schools offering intensive physical fitness programs found positive effects on academic achievement even when time for physical activity is taken from the academics including increased concentration; improved mathematics, reading, and writing test scores; and reduced disruptive behavior. Study found physically fit children perform better academically showing a distinct relationship between academic achievement and the physical fitness of California's public school students (Rudiger 2005).

Age is a negative predictor of the academic success. Accordingly, it can be said that a decline will occur in academic success with increasing the age (Pajares and Voliante 2002).

In analysis for determine of differences between the genders, has been seen that the academic success of female students were significantly higher than male students. This result is similar to other research results that show the females' academic motivation was higher than the males' (Pajares and Voliante 2002).

Student–teacher interactions are crucial for the promotion of academic success (Moreira et al. 2012).

The students' motivational factors are one of the greatest predictors of academic performance (Covington 2000). Pekrun et al. (2011) reports on the construction, reliability, internal validity, and external validity of the Achievement Emotions Questionnaire (AEQ) which is designed to assess various achievement emotions experienced by students in academic settings. The instrument contains 24 scales measuring enjoyment, hope, pride, relief, anger, anxiety, shame, hopelessness, and boredom during class, while studying, and when taking tests and exams. The instrument was tested in a study using a sample of university students ($N = 389$). Findings indicate that the scales are reliable, internally valid as demonstrated by confirmatory factor analysis, and externally valid in terms of relationships with students' control-value appraisals, learning, and academic performance (Pekrun et al. 2011).

The present study investigated relationships between mood, performance goals, and both written and oral examination performance. Fifty-seven undergraduate students completed a mood measure that assessed the subscales of anger, calmness, confusion, depression, fatigue, happiness, tension and vigor, indicated the grade set as a goal for the examinations, and rated their confidence to achieve this goal. Findings indicate that positive mood states are associated with self-efficacy to achieve self-set goals (Thelwell et al. 2007).

Turner et al. (1987) found that 91% of a sample of 99 individuals with social phobia reported interference with their academic adjustment. For example, these individuals reported receiving poor grades due to lack of class participation, avoiding classes requiring public speaking, making decisions not to attend graduate school, and deciding to transfer to another college in order to avoid giving oral presentations. There is also some evidence that, for male students at least, high degrees of social anxiety correlate with lower self-image and lower grade point average (DiMaria and DiNuovo 1990).

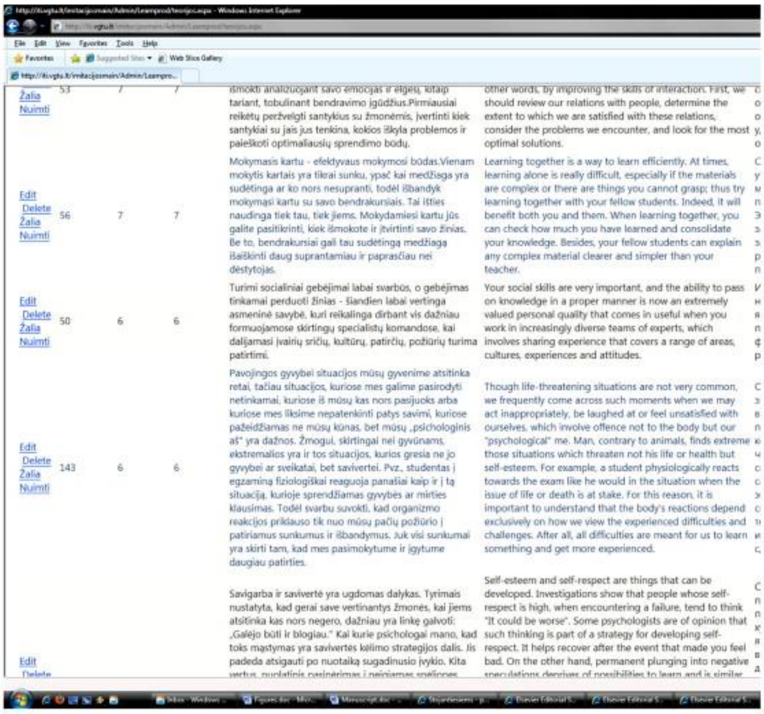
The author of this book in conjunction with R. Paliskiene surveyed and analyzed the information on the best global practices regarding Motivational, Educational Persistence and Social Learning. Tables (see Fig. 7.5) were developed for a regular student learning in a typical Lithuanian university.

The literature based on the Motivational, Educational Persistence and Social Learning theories was used to compile the relational tables.

Around 5000 recommendations on ways to improve learning productivity are available worldwide. Some of them were included in Motivational, Educational Persistence and Social Learning Tables, the structure of which is relational and corresponds to that of the Recommender System. Since the Recommender System's users are very different and come from various occupational backgrounds, the recommendations on ways to improve productivity must be highly customized, adapted to a specific situation of a particular person. A student who gets up in the morning in bad mood, for instance, will get recommendations on ways to improve learning efficiency different than those given when he/she is studying in the evening and in good mood.

The *Historical Statistics Database* accumulates historical statistical data collected from the Self-assessment Database, Student's Physiological Database, Motivational, Educational Persistence and Social Learning Tables.

(a)



(b)

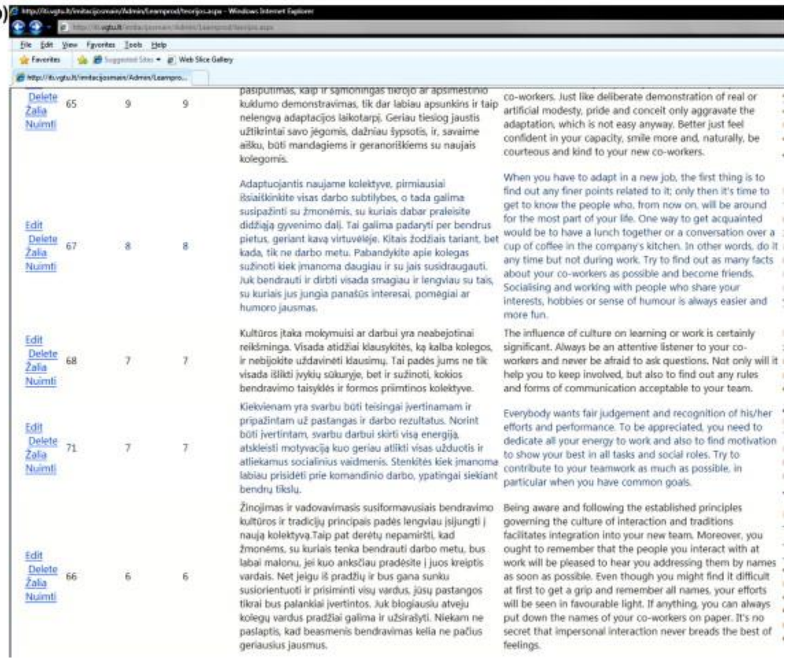


Fig. 7.5. Fragment of Motivational (a) and social learning (b) tables

The database management system was used to design the structure of a database and perform its completion, storage, editing, navigation, searching, browsing and other functions.

7.3.4 Model-base Management System and Model Base

The model-base consists of the following:

- model to determine the correlation between a student's learning productivity, interest in learning and the physiological parameters of that student (Dependence Analysis Model)
- model to automatically evaluate the student's learning productivity
- model to determine initial criteria weights (data and student characteristics and recommendations) using expert evaluation methods
- model to determine criteria weights (data from Motivational, Educational Persistence and Social Learning Tables and a student's physiological characteristics)
- model to design multi-variant recommendations
- model to analyze multiple criteria and to prioritize recommendations
- model to determine the utility degree of recommendations
- model to deliver the recommendations

The models are briefly reviewed in Section 5.3.7.

7.4 Development of Learning Materials on a Students' Learning Productivity and the Level of Interestingness

One of the main goals in our research was to demonstrate that the interest in learning affects learning productivity, while physiological parameters demonstrate such changes and this provide another source of data for substantiating the impact of emotional states on learning. The former statement is a central consideration for the Recommender System. Globally, Sony Corporation is involved in similar research. Sony will be able to offer "almost dangerous kinds of interactivity" with the player within the next ten years. Games will know more about the player on a whole, know how they could be feeling by reading more than just player movements. Talking about sensors, the game will eventually know more about the player. Not just movement, but where you are looking and how you could be feeling. In ten years game developers will have access to player information in real-time and be able to form a map of the player, combining other sorts of sensory data together, from facial expressions to heart rate, over a period of time, you can form a map of the player and their emotional state, whether they're sad or happy (Sony 2011). Kaklauskas et al. (2013) are currently involved in a comparable research, aiming to base the choice of learning materials on a students' learning productivity and the level of interestingness. These functions are briefly reviewed below.

The Recommender System uses a two-step procedure to estimate the learning productivity. The first step is e-self-assessment, when users assess their own learning productivity. Then, having completed the learning phase, the Recommender System later determines the correlation between a student's learning productivity, interest in learning and the physiological parameters of that student (Dependence Analysis Model).

During self-assessments students assess their own learning productivity. Simultaneously, the Recommender System is measuring a student's physiological parameters (Physiological computer mouse (temperature, humidity, skin conductance, touch intensity, heart rate), Physiological Finger (humidity, electrogalvanic skin conductance, skin temperature, heart rate), Blood pressure and heart rate data (heart rate, systolic blood pressure, diastolic blood pressure) and then displays the dependencies that link the student's learning productivity and physiological parameters (see Table 7.2). Eventually sufficient amounts of such statistically reliable dependencies pile up. It means the Recommender System has completed its training and can now determine a user's learning productivity unassisted. And that is what it does, should a user request it. Once the Recommender System has learned to find out a particular user's learning productivity from the variation of his/her physiological parameters, self-assessments that helped to determine learning productivity before can be discontinued.

The Recommender System can pick learning materials taking into account a student's learning productivity and the degree to which learning is interesting. The process is briefly described below.

The system is able to base its choice of learning materials on the level of student's learning productivity and interest in learning. There are four levels that match the student's learning productivity and interest in learning: 0–25% (the lowest learning productivity and the easiest learning materials), 26–50%, 51–75%, 76–100% (the highest learning productivity and the most difficult learning materials). In the morning, when a student is the most productive (76–100%), for instance, the system (at the student's request) may pick the most difficult learning materials (the level of difficulty at 76–100%). Conversely, when the student is the least productive (0–25%), the system (at the student's request) may pick the easiest learning materials (the level of difficulty at 0–25%). The difficulty of learning materials may be set either by the tutor or statistically, taking into account e-test results. Say, only 57% of the answers to the examination questions for a certain chapter or subchapter were correct; the paragraph will then be attributed the difficulty level of 51–75%.

The system can pick learning materials taking into account student's interest in them. In view of the student's information about the subjects taken before (the exam marks, the difficulty, the level of interest, and the stress caused), the system can pick out from the notes those sections that are more interesting. If the student, for instance, enjoyed economics and management and did well in them, the system can take, say, the subject "Construction Technology and Management" and pick out the sections dealing with business management. When a student feels bad, then, and wants to study something interesting, he/she can make use of this function of the system.

7.5 Case Study: the Recommender System as a Means to Increase Student Productivity in Learning and to Improve their Achievements

A case involving an e-learning student from the Department of Construction Economics and Property Management of Vilnius Gediminas Technical University is analyzed to illustrate how the developed Recommender System operates. This student is a sales manager, whose primary job is to retain long-term customers and to attract as many new customers as possible. The top managers of his company strive to increase sales to recover from the financial crisis faster; thus employees often are given ever-bigger sales plans. Fulfillment of such plans determines their wages and bonuses. The rather strong competition in the market for this company's services often makes the plans seem unattainable. It causes much tension and competition among the company's employees. Although the student likes his job, the tension and stress at work drain him and, by the end of the workday, he has hardly any strength left to learn anything.

The student enjoys the lectures of his study program and finds the lecture notes provided by his teachers very interesting but he lacks time to do all assignments. Furthermore his learning productivity after work is often considerably lower than it is after a good rest. Usually he studies at home over weekends. He must use the time remaining for lectures in the most efficient manner.

The student must work with his computer, because the e-learning materials are delivered by internet. Therefore he accesses the developed Recommender System to see if he can improve his learning productivity and efficiency and, in turn, his achievements, i.e., to learn as much as possible from the materials he receives.

The student uses the Recommender System in the following stages:

Stage 1. Determines the significance of recommendations

Stage 2. Gets ready to work with the Recommender System by launching it

Stage 3. Establishes learning productivity and interest in learning dependencies on physiological data by:

Step 1. using the Physiological Finger

Step 2. using the blood pressure gauge

Step 3. filling out the e-Self-Assessment questionnaire

Step 4. starting the measurements

Step 5. using the Physiological computer mouse

Step 6. interlinking to the Student's Interdependence between Physiological and Self-Assessment Parameters Subsystem

Stage 4. Receives the best recommendations that will help to boost learning productivity and, in turn, learning achievements.

Stage 1. The Motivational, Educational Persistence and Social Learning Tables, which are compiled during this stage, are adapted to a specific individual. If the student's outlook on the factors that influence learning productivity does not change, then there is no need to repeat this stage in the future. If it does change, then the changes must be quantitatively named in Motivational, Educational Persistence and Social Learning Tables.

First, the student evaluates the influence of the recommendations provided on learning productivity. These are grouped by the level of learning productivity being experienced. The evaluation scale ranges from 1 to 3, where 1 indicates that the productivity level is very low (0–33%), 2 – average productivity (34–66%) and 3 – very high productivity (67–100%). The score/weight of a statement/recommendation shows the relevancy of the recommendation to a specific activity of the user (work, studies, leisure, etc.). For instance, by giving 9.2 points to the recommendation for studies “Learning the most difficult subjects is recommended in the morning, leaving the easier ones for the evening” and 4.6 points to the recommendation “Limit contacts with people who cause negative stress”, the student states that the first recommendation is twice as important to him/her as the second one.

Once influence is evaluated, each submitted recommendation must be evaluated separately by its importance on a scale ranging from 1 to 3 points, where 1 means it is not important at all and 3 – very important. The student evaluates the statements depending on the complexity of the personal learning productivity, the location.

Thus the aforementioned student first evaluates the influence of the recommendations on learning productivity and then the importance of each recommendation (see Fig. 7.5, Fragment of Motivational, Educational Persistence and Social Learning Tables).

Stage 2. Now the student readies the System for work. He connects the Physiological Finger and Physiological computer mouse into the USB port. If the System had been used previously, he merely checks that the connection is intact. Then he runs the Recommender System (see Fig. 5.2, e-Self-Assessment window of the launched system for students). Once the system is launched, the student goes to Step 1 of Stage 3.

Stage 3. Establishing learning productivity and interest in learning dependencies on the physiological data (see Section 5.4, Steps of the Stage 3).

Fig. 7.2(1a) and (1b) illustrate that, as the level of learning productivity rises, the systolic and diastolic blood pressures respectively decrease. The existing learning productivity level is determined for each of the dependencies according to the physiological parameters taken at some certain moment, and their average significance is calculated. In the case of our student, when his systolic blood pressure was at 130 mmHg and his diastolic blood pressure – 78 mmHg, his average learning productivity was 47 percent. Stage 4. Once the average learning productivity level is determined by the dependency as per Fig. 7.2(1a) and (1b), which here, as an example, is at 47 percent, the Model-base Management System and Model Base

(Section 7.3.4) selects fifteen of the most important learning productivity reduction recommendations (see Fig. 7.5).

The student should repeat the steps of the first stage of the Recommender System during the daytime each 45 min, i.e., refresh his self-assessment and physiological parameters. The work with the system can be terminated by clicking the button labeled “End mouse signals analysis”. The process can then be started anew.

The use of this developed system entails an individual answering several questions to assist in establishing the level of learning productivity he/she is experiencing during an actual timeframe. Then the system selects some recommendations, which are composed using the motivational, educational persistence and social learning theories and which can help boost learning productivity and improve learning achievements.

In order to assess the *Recommender System’s impact on* learning productivity, a student questionnaire was compiled (see Fig. 7.6). The results of the questionnaire how the Recommender System’s tips improved student learning productivity are presented in Fig. 7.7.

1. As I was getting ready for my exam, I used the system’s recommendations: once a week; 2–3 times a week; daily
2. The system’s recommendations made studying for my exam more efficient by: give a score between 0 and 100%
3. The time I needed to get ready for my exam became shorter by: give a score between 0 and 100%
4. The system helped me get better exam scores than I expected: completely agree; agree rather than disagree; I don’t know
5. The Recommender System’s tips improved my productivity by: give a score between 0 and 100%
6. The Recommender System’s tips improved my motivation to learn by: give a score between 0 and 100%
7. The Recommender System’s tips made studying easier by: give a score between 0 and 100%
8. I’d recommend the Recommender System: to my friends; to academic staff; to office staff; other (please add your suggestions)

Fig. 7.6. The student questionnaire to assess the Recommender System’s impact on learning productivity

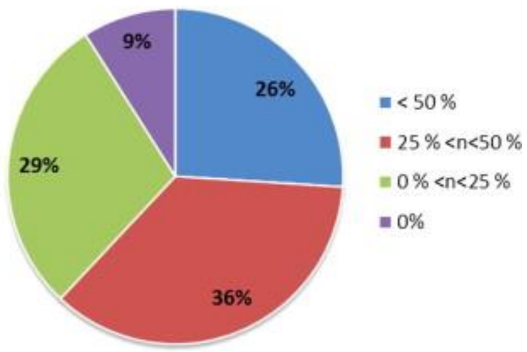


Fig. 7.7. How Recommender System’s tips improved student learning productivity

7.6 Reliability Analysis of the Influence of Physiological Parameters on Interest in Learning Using the Entire Student's Physiological Database

The influence of physiological parameters (systolic blood pressure, physiological finger's and physiological mouse's skin conductance and physiological mouse's temperature) on interest in learning was treated by V. Gribniak using the linear regression method. The regression model $Y = a \cdot X + b$ was constructed for each independent variable using over one million observations from the entire Student's Physiological Database. In this model, Y represents the predicted parameter (i.e., interest in learning). Meanwhile the other notations established in Table 7.3 present the raw regression coefficients with their significance parameters (z-value and p-level) and the standardized regression coefficients (Beta). The magnitude of the last coefficients allows comparing the relative contribution of each independent variable in the prediction of the dependent variable (Y). Since a huge amount of data provide the base for the analysis, all the variables become statistically significant (as p-level approaches zero). Table 7.3 provides the independent variables (physiological parameters) that have a major effect on the variance of the dependent variable, ranged by their significance. The Beta coefficient is used to assess the significances of the variables. The influence of a parameter is recognized as significant, when the appropriate Beta is greater than 10%.

The performed analysis by V. Gribniak reflects that the physiological parameters, provided in Table 7.3, serves as a homogeneous indicator of a variation in the interest in learning, which continuously decreases with an increase in interest. Taking into consideration that it was not obvious which was the dependent variable in the analyzed data, a regression model is employed to allow a prediction of systolic blood pressure relevant to the interest in learning. Fig. 7.8 presents the developed linear regression model. The gray-filled area between the regression lines represents the uncertainty within the developed regression model: in an ideal case, these two lines should coincide, indicating no dependence results in the right angle between the lines. The simplicity of the model permits the uncertainty shown in Fig. 3.20 to emerge. Meanwhile systolic blood pressure shows a 30% effect on interest in learning (see Table 7.3). Thus this factor can be assumed to be a base input parameter of an advanced model. However, effect of the physiological parameters on interest in learning becomes complex and it should be studied additionally due to a trick correlation between the variables listed in Table 7.3.

Table 7.3 Regression analysis summary (physiological parameters vs. interest in learning)

Variable (X)	Regression coefficients			z	p-level	Beta	
	Name (notation)	Value	Std. error			Value	Std. error

1. Systolic blood pressure	Slope (a)	−0.031	0.0001	−350.3	0.000	−0.298	0.0009
	Intercept (b)	10.696	0.0105	1022.5	0.000	–	–
2. Skin conductance (physiological finger)	Slope (a)	−0.017	0.0002	−77.3	0.000	−0.171	0.0022
	Intercept (b)	6.711	0.0041	1642.6	0.000	–	–
3. Skin conductance (physiological mouse)	Slope (a)	−0.012	0.0001	−100.3	0.000	−0.168	0.0017
	Intercept (b)	6.958	0.0036	1946.1	0.000	–	–
4. Temperature (physiological mouse)	Slope (a)	−0.048	0.0004	−113.0	0.000	−0.101	0.0009
	Intercept (b)	8.068	0.0129	623.8	0.000	–	–

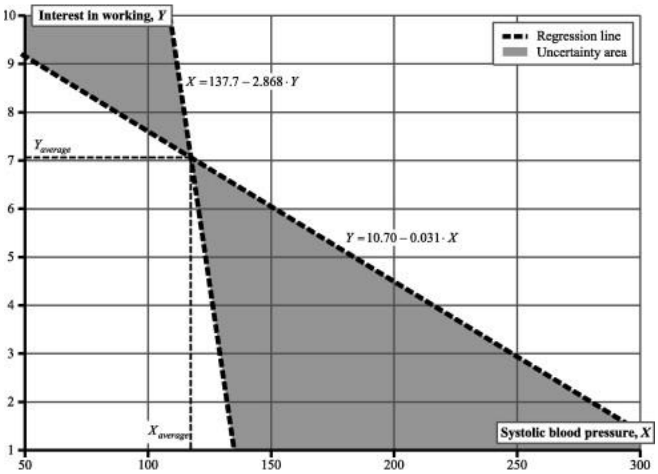


Fig. 7.8. Regression analysis summary (systolic blood pressure vs. interest in learning)

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