Human centered computing for future generation computer systems

著者	Ogiela Lidia
その他のタイトル	次世代コンピュータシステムのための人間中心コンピューティング
page range	1-85
year	2018-03-24
学位授与番号	32675乙第231号
学位授与年月日	2018-03-24
学位名	博士(工学)
学位授与機関	法政大学 (Hosei University)
URL	http://hdl.handle.net/10114/14085

HOSEI UNIVERSITY
TOKYO, JAPAN

Human centered computing for future generation computer systems

Ph.D. DISSERTATION

for the degree of

DOCTOR OF ENGINEERING

in Systems Engineering and Science

by

Lidia Dominika Ogiela

Ph.D. Committee:

Professor Makoto Takizawa, Committee Chair
Professor Tetsuo Tamai
Professor Takao Miura
Professor Leonard Barolli

Tokyo, 2018

Human centered computing for future generation computer systems

This Ph.D. Dissertation by

Lidia Dominika Ogiela

is approved and is acceptable in quality and form for publication:

Professor Makoto Takizawa, Ph.D. Committee Chair

Professor Tetsuo Tamai

Professor Takao Miura

Professor Leonard Barolli

Hosei University
Tokyo, Japan

2018

Contents

List of Figures

Acknowledgments

The author of this Ph.D. dissertation would like to express her deep gratitude to the Professor Makoto Takizawa, for the opportunity to conduct scientific research under his scientific supervision, for extremely valuable recommendations and a number of comments that determined the course of the research and the shape of the dissertation. The Professor's Makoto Takizawa support and scientific help give me invaluable help in conducting research and contribute to my further development.

I am very grateful to the reviewers of this Ph.D. dissertation, whose valuable comments will contribute to further research work and improve the scientific projects that I am still pursuing.

I would also like to cordially thank the honorable Ph.D. Committee Professor Makoto Takizawa, Professor Tetsuo Tamai, Professor Takao Miura, and Professor Leonard Barolli, for the time they devoted and their constructive comments concerning the scientific work I carry out.

I would also like to express my heartfelt thanks to my entire family, whose support for me cannot be overestimated, as my continuous scientific development is guided by the constructive discussions with my relatives. I would like to give these thanks to my mother Izydora, my sister Urszula and my brothers Marek and Waldemar. I also keep my father Julian and my little brother Mariusz in special memory.

Curriculum Vitae

Lidia Dominika Ogiela, Ph.D.

2000	Master of Business Administration – AGH University of Science and Technology, Poland
2000	Master of Science in Mathematics – Pedagogical University of Cracow, Poland
2005	Ph.D. in Computer Science – Faculty of Electrical Engineering, Automatics, Computer Science and Electronics, AGH University of Science and Technology, Krakow, Poland
2016	Docent in Computer Science – Faculty of Electrical Engineering and Computer Science, VŠB Technical University of Ostrava, Czech Republic

Research areas

computer science, cognitive informatics, cognitive science, mathematics

Abstract

The computer science is now mainly achieved by scientific circles and constitutes a kind of indicator of the position of centers dealing with this area. This is because nowadays one cannot talk of highly developed scientific units or world-class achievements in various disciplines of knowledge if one does not conduct research in computer science (whether technical or mathematical). The development of computer science is now so rapid that new solutions are necessary to understand the new directions and new stages. The purpose of analytical approach is to show that for an in-depth analysis of data, the layers of semantics contained in these sets must be taken into account. This approach is possible by combine the subjects of information systems and many types of analysis as well as aspects of the human analysis processes.

Computer systems are oriented to many kinds of different processes for example collecting, analysis and transmitting data for many different transmitting points. Also computing processes are realize by those types of systems. The new paradigms of computing methods are oriented by use of human aspects for definition new types of computer systems. Human centered computing are proposed for definition future generation computer systems.

The basis of proposed human centered computing methods are the new paradigms of use of knowledge. One of them – the main paradigms – is grounding knowledge paradigms. This paradigm will be propose by Author of this dissertation and after evaluation of this parts of theory, will be describe step by step. Generally, the grounding knowledge paradigm will be define for construction new stage of knowledge. Basis of this theorem is the knowledge based on human centered processes of data analysis. Those types of analysis create new computing methods concentrated by human aspects of computing processes. The main solution of proposed methods is creation of future generation computer systems by used new computing methods.

The interdisciplinary nature of the solutions proposed means that the subject of computer systems forming part of informatics becomes a new challenge for the research and application work carried out.

Keywords: human computing, future generation computer systems, grounding knowledge, computational paradigms, distributed computing

Chapter 1

Introduction

Abstract. This chapter will present the main aspects of scientific and research goals. It will form an introduction to human centered computing for future generation computer systems topics. The development of cognitive science will be portrayed with particular emphasis on the growth of computer science, which is fundamental for the topics analysed and presented in this Ph.D. dissertation.

1.1. The main scientific and research goals

Executing computing processes focused on the similarity of operation to the human mind has become the leading subject of this dissertation. At the same time, it represents the direction of the current and future development of information technology in the field of computer system development [1], [27], [39], [45]. Adopting models of human cognitive processes [2], [4], [9] and data analysis algorithms [8], [15], [18], [19], [28] to build a new generation of computer systems is becoming a new direction in the development of previously known system solutions. At the same time, it determines the methods of data analysis and interpretation in various fields of science and practice [5], [6], [17], [21]-[24], [30]-[71], [74]-[78]. When developing new solutions based on the above methodology, it is worth explaining the reason for undertaking this direction of research work. The leading reason for undertaking this type of research is the development of cognitive science and its ability to spread into other fields of science. The impressive interdisciplinary nature of cognitive science has opened up new directions of its application.

The development of cognitive science is now becoming an important direction in the development of technology, information theory and mathematics. It is perceived as extremely important and of a priority significance for researchers from various disciplines of science and observers of everyday life. The influence of cognitive science is increasingly visible in the development of everyday life and the main factors determining this situation can be identified at the same time [7], [12]. The assessment of the degree of development of businesses, scientific units and state agencies is also increasingly frequently based on the cognitive aspects of interpreting and analysing the reasons for a given state, various phenomena developing the current state and those that can influence the future. The same applies to assessing the development of units and charting their future direction. In addition, it is oriented towards the semantic assessment of the consequences of taking specific decisions when interpreting, analysing and solving different problems.

A similar aspect currently applies to the development of information technology, which is the engine driving the rapid and strong development of information and cognitive science. The development of science at the interface of information theory and cognitive science determines the ability to assess the method of analysing and solving problems which forms the foundation of these scientific disciplines. One example of this type of interdisciplinary problems is describing and analysing datasets that differ in terms of both their form and their contents. The method of analysing and solving various problems can be assessed using semantic data interpretation techniques [42], [43], [52], [58], [73] which include the methods of perceiving, describing and characterising the analysed datasets. A question thus arises what is the main cause and the reason for this type of interpretation of the semantic data analysis.

To answer this question, it should be noted that we increasingly frequently receive (register) news which we often treat as a kind of novelty from the technology world. We receive such news increasing frequently because science is more and more open to practical areas and its possible applications. A special feature in the process of understanding all these novelties is the presence of new elements of semantic nature. Hence the ability to understand new situations, solutions, components of larger processes etc. Results from the ability to semantically interpret all features characteristic for the analysis processes executed by the human mind. These operate at the interface of the real and virtual worlds. These worlds, all of their components and characteristic features are very often intertwined in human observations, knowledge and everyday life. This is why it seems natural to try to understand what forms the basis of this type of activity and how far the virtual world can seep into and influence human actions and decisions. This is the scope within which the development of information and cognitive science is currently seen. Cognitive science is undergoing a kind of revival now. Its development is aimed at the cognitive aspects of the functioning and operation of perception, interpretation, understanding, analysis and reasoning processes, i.e. all the key processes characteristic for the proper execution of decision-making processes taking place in the human mind [4], [20], [25].

The cognitive processes referred to above, combined with algorithmic solutions developed based on applications from various fields of science, offer the opportunity to develop a new discipline of science called cognitive informatics [40], [45], [66].

Cognitive informatics charts new directions of the development of information theory, mathematics and technology, and creates new opportunities to apply the previously proposed theoretical solutions. Algorithmic solutions based on the similarity and a kind of identity with human intellectual processes form the leading subject of this dissertation. The main the role of this dissertation is to assess the capabilities of the algorithmic solutions presented for a new generation of computer systems.

One of the main goals of the author of this dissertation is the incessant development of cognitive and decision-making theory which she has also described in, among others, the following scientific publications [44], [46]-[50], [53], [54], [56]-[59], [61], [63]. In addition, it is extremely important to be able to define new generation systems based on human analysis processes. This means that the processes of automatic, semantic interpretation of data can be transferred to the discipline of information theory. The solutions presented are to enhance the currently known and widely used decision-making processes which carry the risk of taking the wrong decision as a result of analysing incorrect or incomplete datasets. The semantic interpretation and analysis of extensive data sets forms an indispensable stage of the correct data analysis process.

The aforementioned semantic data analysis processes will be described in subsequent chapters of this dissertation. In addition, aiming them at the correct interpretation of data and the ability to apply the discussed solutions in a new generation of computer systems will be discussed.

1.2. Overview of Ph.D. thesis

The rest of the dissertation is organized as follows.

Chapter 2 presents the fundamentals of computing approaches in computer science, especially basic formalisms of computing methods, known techniques of data analysis. Also, intelligent computer data analysis methods and computational intelligence aspects will be described.

Chapter 3 presents the human centered computing methods with selected aspects of human methods of data analysis and new definition of grounding knowledge. Also, grounding knowledge algorithm in computing theory and new computational paradigms for computational systems and distributed computing will be presented.

Chapter 4 discuss future generation computer systems, as well as human computing algorithms for new classes of computer systems and new generation computer systems.

Chapter 5 presents the conclusions, results and suggested future work.

Chapter 2

Fundamentals of Computing Approaches in Computer Science

Abstract. This chapter will discuss topics associated with the development of fundamentals of computing appraches in computer science. It will present processes that contributed to the creation of the new branch of computer science. Cognitive description and interpretation processes were created by combining knowledge fields in which an important role is played by processes by which the human brain operates and those taking place in it.

When analysing possible new solutions from the scope of semantic possibilities of interpreting and describing data, the genealogy of early cognitive science should be quoted.

This discipline of science was first developed in the times of Aristotle [3]. The works of Aristotle, who is now seen as the initiator and the creator of two primary classification methods, described cognitive science. The foundation of the considerations presented was the notion of a category which, as a result of those considerations, formed the basis for distinguishing various cognitive categories. Accidental and substance categories were proposed as the most important. They were distinguished based on significant differences between the subject of the sentence, that is the substance, and the predicate understood as the accidental category. The main rule for identifying the substance category was to include notions that describe "something concrete" in it, as a result of which these notions were understood as something tangible and concrete. In contrast to this type of notions, there are accidental categories among which nine primary concepts have been distinguished, namely: quantity, quality, relation, place, time, location, state, action and affection.

The considerations carried out led to creating the foundations of, and initiating the method which is now referred to as 'top-down'. It defined the type (*genus*) and the presence of one or several differences (*differentiae*), allowing new types of forms to be distinguished from other forms of the same genus. These logical theses were criticised because of the limitations of the proposed solutions, and this resulted in the introduction of a new approach today known as 'bottom-up'. Its main advantage was the introduction of descriptions and the definition and identification of the unit described, which classified groups of units as a species and type and grouped their individual types.

The top-down method was used to present and describe results of completed considerations, while the bottom up method was useful for the discovery of research processes related to a new object, notion, definition.

The introduction of an initial description and characteristics of various notions started the further development of cognitive science. However, it should be noted that it was not called cognitive science then. The ability to apply simple (uncomplicated) solutions became the foundation of the further, continued development of cognitive science.

One of the solutions which influenced the subsequent development of the cognitive school consisted in works by Gottfried Wilhelm Leibniz – *Characteristica Universalis* [26]. Looking back, the solution which made it possible to present simple sentences using numbers was used to define a universal dictionary. This dictionary was capable of replacing words, sentences or syllogisms with numbers. These numbers were analysed using a reasoning based on arithmetical rules. To simplify the calculations, the first computing machine able to execute multiplications and divisions was proposed. Thus this work marks the beginning of computational linguistics, whose origins lie in the definition and implementation of Leibniz's dictionary.

When describing computational linguistic methods, one should remember that the solutions used today, which include modern computer systems, transform high-level concepts (complex concepts) into lower-level concepts (concepts). Such systems may have a constructive form, which takes simple concepts and builds complex ones from them, but this is optional, not obligatory.

The available knowledge was constantly used to try to develop systems of a learning nature, to propose a cognitive system. Such a system would be used to describe the human process of gaining knowledge, and at the same time, based on the available knowledge, science would be able to describe similar processes taking place in a computer system. This was the reason for developing methods leading to formal notations, creating definitions, defining logical solutions, fuzzy algorithms and prototyping. These solutions were aimed at defining words, concepts, meanings etc. that were to be used for the semantic interpretation.

Thus the development of computer science aimed at enabling the identification of various attitudes and states that triggered and then executed cognitive processes, and also at analysing these states and situations. One of the scientific disciplines dealing with the cognitive processes taking place in the human mind is cognitive science, an experimental discipline of knowledge that studies various expressions of the cognitive activity of the mind. Human methods of analysing information and states of mind accompanying these learning and understanding processes have become a somewhat natural subject of research, albeit hard to conceptualise theoretically and test empirically.

In the research on the human learning process, work that requires the involvement of researchers from various scientific disciplines was undertaken. This significantly enhanced the approach to studying the human mind. The research of the above problems was carried out by scientists among whom the following deserve mention: researchers from computational disciplines, including cybernetics (Norbert Wiener), information theory (John von Neumann), artificial intelligence (John McCarthy, Marvin Minsky, Lotfi A. Zadeh), and also studies of the brain (Donald Olding Hebb, David Hubel, Torsten Nils Wiesel) as well as theories of generative grammar in linguistics or of formal grammars (Noam Chomsky) [11], [50], [51], [53].

Research work within the scope of cognitive science has been carried out at the interface of many diverse scientific disciplines (Fig. 2.1.).

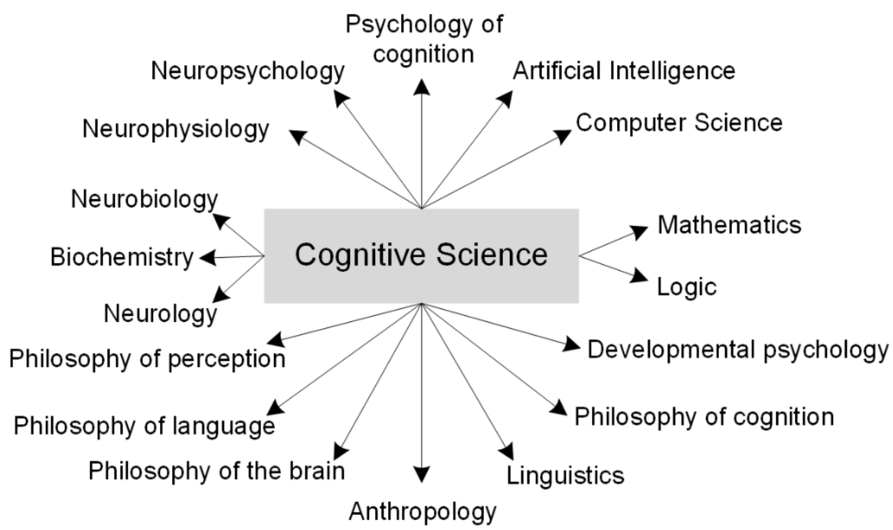

Figure 2.1. Disciplines making up cognitive science [50]

Cognitive science solutions were aimed at creating machine solutions in which the human mind was to some extent systemically represented. It was also important that the recognition and understanding processes could be identified (presented) as a multi-stage computational process. From this perspective, every mental process taking place in the human mind is treated as information interpretation and processing. The computational approach to cognitive processes focused on creating IT models of complex biological and psychological processes. The complexity of the studied object turned out to be an extremely important subject. In order to represent it properly, the model approach turned out to be useful. This was due to the fact that models can be not only created, but also studied experimentally using computer simulations. In addition, the adequacy of the models constructed (proposed) could be compared to the neuro-biological knowledge of the structures and functions of the systems and subsystems in the human nervous system. This knowledge was accumulated in a continuous manner, and constantly enriched by using and developing new research techniques in the field of brain biology.

The development of cognitive science was founded on understanding that learning processes and the ability to transfer them to system solutions were much more complex than generally thought. This field of science was multidisciplinary in nature. The approach to subjects describing the operation of the human mind and the ability of transferring the results of this work to system (computer) solutions started opening broad opportunities for theoretical scientific solutions and their practical applications. There were great hopes that if all the research work ended in success, this would make it possible to create a solution whose features would be identical to those of the human mind. Hence, a field popularly known as artificial intelligence was born.

The research work lead to finding that today's science can distinguish and research small fragments of the complex topic of learning and understanding processes. Research covered selected cognitive problems, such as perception, imagination, memory, learning, abstract thinking, understanding, remembering etc.

Cognitive science started being seen as a synthesis of the knowledge about the mind containing philosophical elements associated with identifying the nature of the mind, the knowledge of psychological phenomena and human behavior. In addition, it included research on natural language, the biological foundation of psychological phenomena that can occur and the topics of cybernetics. Due to the very broad definition of the new scientific discipline being developed, its primary fields of operation were identified [33], [34], [40], [41], [50]:

- the impact of mega- and micro-information on human behavior,
- the emotional modelling of human behavior,
- the cultural modelling of human behavior,
- the impact of the physical on the spiritual world,
- the description of human impressions and their quality,
- the interpretation of the consciousness functions,
- the description and analysis of brain functions,
- the formal system design and determining the meaning of symbols,
- the neural model design,
- the description and analysis of basic artificial intelligence functions,
- determining the mind-brain relationships.

The analyses of cognitive processes become a starting point for various processes of description and interpretation carried out by different scientific disciplines. An important element of the entire process of analysis carried out by the human mind and at the same time transferred to system solutions is the execution of basic perception phases, which include [40], [41], [50]:

- information recording – may refer to a single act of perception or to a complex process, when it takes the complex form,
- remembering information – may consist in the simple fixing, in memory, of detailed information, i.e. facts, patterns of objects and methods of action, but also in creating a universal memory trace (a gnostic unit) which is able to generate features that are needed to understand new situations previously not known,
- coding of the information obtained – based on executing the processes of hiding, encrypting, decrypting and splitting information,
- information storage – the latent stage of mental processes,
- information retrieval – the execution of the processes of recalling, recognising, understanding and relearning of new skills.

The most important role in the analysis process is played by the retrieval phase, which is a measure of the memory processes, memory capacity and the ability to execute information-processing. It is inseparably linked to executing the processes of remembering, recognising, understanding and learning. These processes describe the relationships which exist in the human brain between the nervous system and individual analysers. Memory is called a peripheral ability, in contrast to the general ability characteristic for the action of complex stimuli. The general ability is achieved as a result of the operation of many analysers. The most important features of memory used to assess the mental process are [50]:

- permanence – a criterion related to the storage stage,
- speed – the ease of recording new facts and links between them,
- accuracy – defines the relationships between the retrieved information and the contents of the information acquired during the remembering phase,
- readiness – determines whether the recall process can be executed immediately and whether it is necessary for additional activating stimuli to occur,
- capacity – indicates how large the capabilities of memory processes are.

The execution, by IT systems, of analysis processes similar to those taking place in the human mind is aimed at semantic data analysis. In these processes, recognising and understanding the data analysed becomes the most important. The recognition process is strictly linked to the processes of perception and decision-taking, as a result of which it becomes a complex process which is the effect of executing many stages of data interpretation and analysis.

Processes of the machine interpretation and understanding of data were developed in the field of information theory, mathematics and technology. An important role in cognitive analysis is played by artificial intelligence which makes it possible to create computer systems executing certain cognitive activities. In this perspective, it allows cognitive tasks to be performed by artificial solutions designed to imitate the human mind. The most important jobs of artificial intelligence include the ability to create applied solutions that imitate the operation of the human mind as accurately as possible.

Whether the proposed solutions are right is assessed from the point of view of their utility and the ability to use them to execute fundamental research of the learning process. An example solution of this type is the computer modelling aimed at implementing artificial solutions similar to human cognitive processes. The development of the topics of semantic data analysis in the field of information technology caused work to start on topics of computer interpretation, analysis and understanding of data. This work has led to the development of computer cognitive science, a discipline which also uses the foundations of analytical and semantic mathematics [78]-[80]. A new area of science at the interface of such disciplines as cognitive informatics, computational intelligence, software engineering, knowledge engineering and mathematics was defined and called *denotational mathematics* by Wang [78]-[80].

An innovative solution is the ability to use cognitive solutions for computer data analysis. The proposed type of description and design of cognitive structures leads to the structural and semantic analysis of various datasets. Structural analysis is based on applying cognitive methods to the information about the structure, the form and the shape of the analysed object. On the other hand, semantic analysis uses the information contained within the data sets, i.e. the semantic information.

2.1. Basic formalisms of computing methods

Computational methods modelled on human computational processes form the basis of cognitive solutions, particularly in the area of cognitive informatics [40], [45], [50], [53], [66], [78]. Cognitive informatics lies at the interface of cognitive science, information theory and mathematics and allows information mechanisms used to describe and interpret processes taking place in the human mind to be defined.

The foundation for the operation of cognitive informatics is the ability to use mechanisms characteristic for human intelligence to combine its characteristic features with engineering applications. Cognitive informatics makes use of mathematical theories as well as data interpretation and analysis algorithms. It also makes use of information contained in broad knowledge bases. It includes engineering, mathematics, computer science, cognitive science, neuro-psychology, systems theory, cybernetics, computer engineering, knowledge engineering and computational engineering [50].

Formal models describing cognitive informatics theories are created using computational intelligence algorithms, and cognitive informatics itself uses defined mathematical concepts. Computational intelligence algorithms used to describe cognitive theories are based on human methods of information analysis for which analogous or similar machine solutions can be designed. Key applications of cognitive informatics include [50]:

- cognitive computers,

- cognitive knowledge bases,
- cognitive simulations of the human mind operation,
- autonomous agent systems,
- cognitive robots,
- avatars and computational intelligence.

Human centered computing is seen as the ability to execute various calculations modelled on human computational processes. Hence it relates to the ability to use solutions from the scope of interdisciplinary studies of the human mind, i.e. information theory, mathematics, cybernetics, cognitive science, neuro-psychology, knowledge engineering, computational intelligence, life science and neuro-science.

The ability to combine the results of research from various knowledge disciplines and extract problems associated with the processes of interpreting, analysing, understanding, reasoning about and processing information constitute the starting point for the innovative solutions being developed [33]-[69].

The analysed research problems focus on understanding the operating mechanisms of human intelligence, as well as the cognitive processes taking place in the human mind. The process by which cognitive mechanisms operate is transferred to (adopted in) engineering solutions. This creates the opportunity to build computer systems which, to a smaller and greater extent, imitate the operation of the human mind. This solution is chosen to describe the information aspects of the analysis, the methods of acquiring information, building perception models, analysing and interpreting data and the ability to acquire knowledge used in data analysis processes.

The data description and interpretation processes that are executed are aimed at the cognitive and semantic analysis of the data. Information is understood as one of the elements of reality, treated as the most characteristic representative of a group of similar and semantically convergent pieces of information. Information may be treated as an unknown element, a kind of exception that had not been the basis of analyses before. The characteristic feature of this situation is that there is no knowledge about the element – information – being described. The ability to present information in two different perspectives – as a representative of a group of semantically similar pieces of information or as a completely new element – makes completely independent (dissimilar, outside of schemes) methods of information analysis and interpretation possible. Hence this is a process of a complex and ambiguous character resulting from its similarities to the process by which the human brain operates.

The correct assessment of the analysed situations, datasets and information leads to their correct analysis. The processes of this analysis aim at understanding the analysed situation, information and data. Their consequence is the design of computer systems that execute similar tasks, i.e. data understanding. Based on the description and the characteristics of natural intelligence, it can be used for information, engineering and technical tasks in a broad interdisciplinary perspective. Information, system or engineering solutions are used to support previous solutions, while at the same time indicating the directions of further development. The most important of them include:

- the development of computer systems for the semantic description and interpretation of data,
- the development of cognitive machines, computers, robots and avatars,
- analysing human behavior processes and the ability to build their automatic imitators (counterparts).

The development of human centered computing is seen in different directions:

- application solutions for computer science, particularly computer techniques and cognitive analyses, system and application solutions based on the convergence of human perception processes – i.e. memory, learning, reasoning, drawing conclusions, analysis – and their machine counterparts,
- using cognitive theories to assess and solve problems in computer science, knowledge engineering, software engineering and computational intelligence.

The ability to progress in the above research directions is determined by the processes taking place in the human brain, of which the most important are:

- obtaining and acquiring information,
- identifying the information representation,
- describing the memory process,
- the ability to recover lost information,
- knowledge generation processes,
- the communication process operation.

2.2. Techniques of data analysis

Data analysis techniques depend on the datasets being analysed, the interpretation possibilities and the research problem postulated. Semantic data analysis is an equally important component of analysis processes aimed at the complete interpretation of information. This consists in extracting semantic information contained in the analysed datasets. The performance of the semantic data analysis is modelled on the execution of processes taking place in the human mind as a model of data analysis processes.

The processes of describing, analysing, and interpreting the meaning of information play a special role in solutions used to determine the meaning of information. This meaning constitutes the semantic layers contained in the analysed datasets. This is why all description processes are combined with semantic analysis processes.

Semantic analysis constitutes the foundation of human centered computing. The main stages in the execution of the process of semantic data analysis are the interpretation, description, analysis, reasoning about and the understanding of data aimed at the following tasks [51], [53]:

- data preprocessing: the stages of filtration, segmentation, approximation and coding,
- data representation description: the stage of defining primitives, of determining relations between these primitives and also identifying the relations between objects,
- linguistic perception,
- syntactic analysis,
- pattern and data classification,
- feedback,
- cognitive resonance,
- data understanding.

Semantic analysis includes the processes of data interpretation and understanding. Syntactic analysis, in turn, is used to describe and recognise data with the use of a defined formal grammar. The execution of this stage is aimed at determining the semantics of the data being interpreted, i.e. its meaning.

The analysed data can be interpreted based on the identification and description of the characteristic features of the sets undergoing this interpretation. The achievable outcome is taking a decision which, at the same time, represents the effect of the data interpretation process completed. The traditional data interpretation process is understood as the description of the data being interpreted, which is aimed only at its simple analysis. However, this method of describing and interpreting data is often insufficient when the analysis process should end in taking a decision which will enable the full use of the analysed data. In such situations, the data interpretation process must be enhanced with elements of semantic data analysis.

This process consists in extracting the characteristic features of the interpreted datasets in the form of pairs of consistent and inconsistent characteristic features. These features are produced as a result of generating sets of features of the interpreted data, similarly to the expectations concerning the interpreted datasets, which are obtained from on the expert knowledge base collected in the system.

The next step in executing semantic data interpretation is to compare the feature/expectation pairs, which results in indicating consistent and inconsistent pairs which are significant for the semantic data interpretation process carried out. The pairs identified as consistent become the basis for the further semantic description aimed at understanding the meaning of the analysed datasets. Semantic data interpretation is possible as a result of using linguistic data description methods and the definition of grammatical formalisms. The semantics is identified using a formal grammar defined in the system and the right set of productions. The set of productions is used for executing the linguistic reasoning algorithm. The data interpretation and analysis process is based on a grammar analysis aimed at examining the semantic consistency and identifying whether the dataset is semantically correct in relation to the appropriate grammar.

If the consistency is found, the system conducts further data interpretation and analysis aimed at identifying the consistencies and determining the names. Otherwise, the system does not conduct the further analysis. The lack of semantic consistency can result from [50], [53]:

- the incorrect definition of the formal grammar,

- no definition of the appropriate semantic reference,
- an incorrectly defined pattern,
- taking the representative of the wrong data class for analysis.

No semantic consistency between the analysed individual and the formal language defined during the analysis process. In this case, it is necessary to verify the definition process because an error may have occurred already at this stage.

Human centered computing is used for a three stage analysis. The first stage is the traditional data analysis, during which qualitative and quantitative analysis processes are executed. Enhanced with the linguistic description of the data being interpreted, it is used to determine the semantic features of this data. Determining the semantics forms the basis of the next interpretation stage: the semantic analysis. With the correct definition of useful grammatical formalisms, this analysis is used to determine the linguistic perception and to analyse the data. The next stage is the cognitive data analysis, which leads to interpreting the results obtained earlier.

2.3. Intelligent computer data analysis

Human centered computing is aimed at defining systems that execute processes of interpreting data based on its characteristic features. This system uses the knowledge base to generate expectations of the analysed data. Expectations are generated automatically as an element of the operation of the whole system. The system defines characteristic features and assigns them to the analysed datasets. The characteristic features of the analysed datasets are combined with the expectations which the system generates by determining the consistency between the above elements of the analysis process.

In human centered computing, expectation generation relates to the process of the semantic interpretation of the analysed data sets. The set of expectations formulated from the knowledge collected in the system, which expectations can be obtained from the semantic information contained in those sets, is used to identify similarities between the expectations and the elements of the knowledge bases. This comparison leads to identifying pairs of consistent expectations and characteristic features. Consistent pairs gain importance and become significant. Inconsistent pairs lose importance and become insignificant. This process is the confirmation of the hypothesis about the analysed data whose contents can be understood. If the contents of data cannot be understood, then this process shows the lack of consistency between expectations and characteristic features. The first case represents the success of human centered computing, and the second indicates the failure of this method of data analysis [35], [40].

Human centered computing for future generation computer systems users structural reasoning techniques to correctly match patterns to the datasets analysed [40], [41], [52], [53]. The definition of the pattern depends on the type of datasets being analysed. Multi-object data, e.g. images, has the most complex structure and represents an example of complex, multi-object forms. In the case of multi-object structures, the data analysed is compared to the structure which constitutes the pattern of complex data. This comparison is made possible by introducing strings of derivative rules to generate a representative pattern. Derivative rules are identified as productions and defined in the grammar which establishes the formal language. The recognised data is assigned to the class to which the pattern representing it belongs.

Human centered computing also refers to syntactically describing the data analysed. During the interpretation of data, its input representations are subjected to the preprocessing stage, which includes the following phases [10], [13], [14], [29], [41], [53], [72]:

- filtering and pre-processing of the input data,
- approximating the shapes or locations of the analysed objects,
- coding the data with terminal elements of the introduced description language.

The preprocessing produces a new data representation. It takes the form of hierarchical semantic tree structure and the subsequent steps of deriving this representation from the initial symbol of the grammar [14], [15], [53].

During data preprocessing, human centered computing systems segment and identify primitives and describe the relations between them. The correct classification consists in determining whether the given representation of input data belongs to the class of data generated by the formal language defined by the introduced grammar. Defined formal grammars may take the form of sequential, tree and graph grammars [50], [51], [53].

2.4. Computational intelligence description approaches

Artificial intelligence algorithms used to analyse complex data rich in semantics are dedicated to various areas of application [8], [14], [72], [76], [77], [81].

Both artificial intelligence and computational intelligence dedicated to the processes of computer interpretation and analysis of data represent the diversity of applications of the methods discussed. This diversity is due to the ability to use the techniques discussed for the description, interpretation and analysis.

Neural networks, widely described in literature [72], [81], are a very popular method of data analysis. However, semantic data interpretation using human centered computing and linguistic data description methods is more useful [45], [51], [53].

Data contained in information systems is subject to its appropriate description, interpretation, analysis and processing. The processing includes improving data quality, its semantic analysis, recognition and understanding.

In systems for the semantic analysis of data, it is frequently not enough to execute the preprocessing, description and classification of the analysed data. The simple description of data is characteristic for traditional data analysis systems.

The new generations solutions characteristic for human centered computing for future generation computer systems use the semantic description and analysis in data analysis processes. The development of the new generation of systems is aimed at the automatic understanding of the data being processed.

The universality of the described linguistic methods of data analysis makes them suitable for use in various fields and for various purposes [33]-[71]. What is innovative in the approach presented is the ability to adopt what happens in the human brain in the computer description and interpretation of various datasets. In other words, this process is an attempt to use, in computer data analysis processes, solutions designed by imitating analysis processes executed by the human mind.

Human centered computing systems have been defined to execute semantic reasoning processes with the possibility of using advanced artificial intelligence techniques. The purpose of these techniques is to extract important semantic information which enables the semantic analysis of data in a certain context. This is because it is impossible to simultaneously define the goal of the analysis and its result.

The two-source and two-directional flow of information in the process of understanding is similar to the human process of interpreting and understanding information, and this is why it forms the basis for designing the new generation of systems based on the human centered computing.

Chapter 3

Human Centered Computing Methods

Abstract. This chapter will present the main aspects of human centered computing methods. It will form a discussion of selected aspects of human methods of data description, interpretation and analysis. Also will be presented a new definition of so called „grounding knowledge" paradigm dedicated to development of future computing technologies. The development of human centered computing methods is fundamental of new computational paradigms for computational systems and distributed computing.

Human centered computing methods are aimed at executing intelligent data analysis. The form a sub-class of intelligent information systems which run data processing and interpretation processes and an analysis aimed at understanding and reasoning. Data understanding processes represent the essence of practicable data interpretation methods and are based on the convergence between human perception processes and systems imitating them. This type of analysis is carried out using the semantic contents of the data sets being processed. These sets include layers of collected knowledge contained in the data being interpreted.

Human centered computing methods are defined to analyse diverse data sets. This analysis is carried out based on identifiable characteristic features of the analysed data sets. Human centered computing methods allow these features to be compared, in a way, with the knowledge available within the scope of the analysis conducted. This knowledge is indispensable in the process of the complete interpretation and analysis of data, while it is simultaneously possible to generate expectations about the interpretation carried out. Methods using the similarity of the human and system methods of data analysis are focused on the most complete possible ability to use human analysis methods in machine data description and interpretation. The ability to use semantic description in data interpretation processes points to new directions of development of computer data analysis methods. A comparative analysis of the similarity between the human and computer methods of data analysis allows the opportunities for developing human centered computing methods to be identified.

In computer data analysis processes, the above characteristic features of the analysed data sets are combined with certain expectations about the interpretation reasoning conducted. When the analysis process is carried out in every independent case, certain expectations of the interpretation process carried out appear. These expectations concern the semantic content of the sets being described. The ability to indicate this type of expectations also enables a comparison identifying similarities that may occur between the expectations and characteristic features of information sets. This type of process allows the degree of consistency or inconsistency between the characteristic features and expectations to be identified.

Human centered computing methods include methods of data analysis and interpretation using grounding knowledge techniques. The author has proposed these techniques as an innovative approach to currently developed structural reasoning techniques, in order to match the most representative, definable patterns. Systems designed to use human centered computing methods can analyse various datasets recorded in numerical, image and similar forms. In order to define the most representative pattern and then match data to the patterns defined in the system, the analysed datasets are compared with the pattern defined in the system. This process is to determine the degree of similarity and convergence between the (analysed) element and the most characteristic representative of a given class (the pattern). The comparison process is based on defining sequences of derivative rules necessary to generate the element characteristic for each group of data. This element represents the most complete reflection of the data being interpreted and at the same time has all the characteristic features describing the selected set. It makes it possible to determine the degree of similarity between itself and the remaining elements of the set that are described and characterised. Determining the level of similarity makes it possible to recognise the analysed element if there is a determinable similarity between the element being analysed and the pattern (Fig. 3.1.).

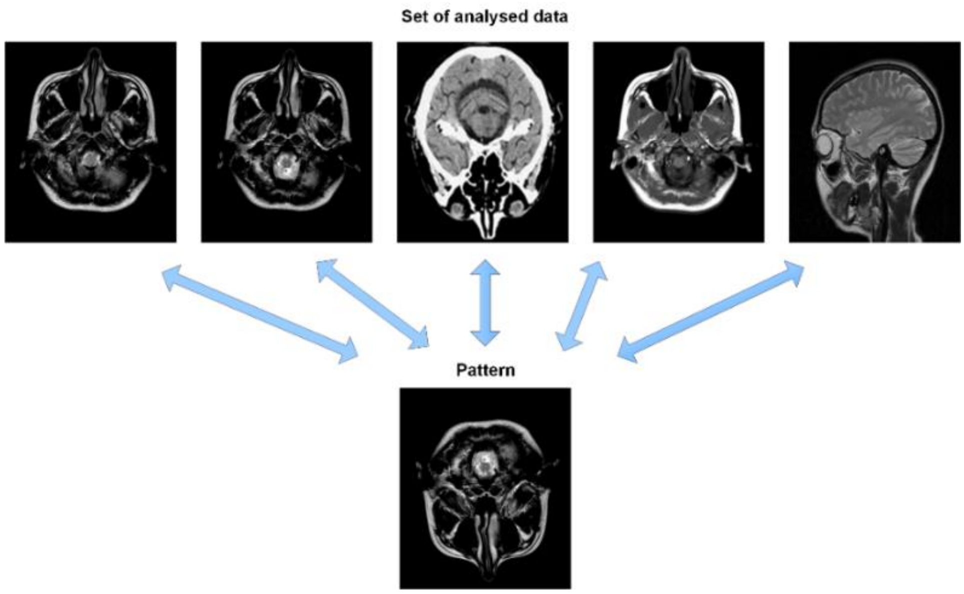

Figure. 3.1. The process of comparison the selected elements of the analysed set by comparing data to the pattern element

Human centered computing methods are also aimed at running processes of comparing all elements of the analysed set with the pattern. If consistent features of the pattern and the data being analysed are identified, recognition takes place. If no similarities can be identified between the selected element of the analysed set and the pattern, the element cannot be recognised (Fig. 3.2.).

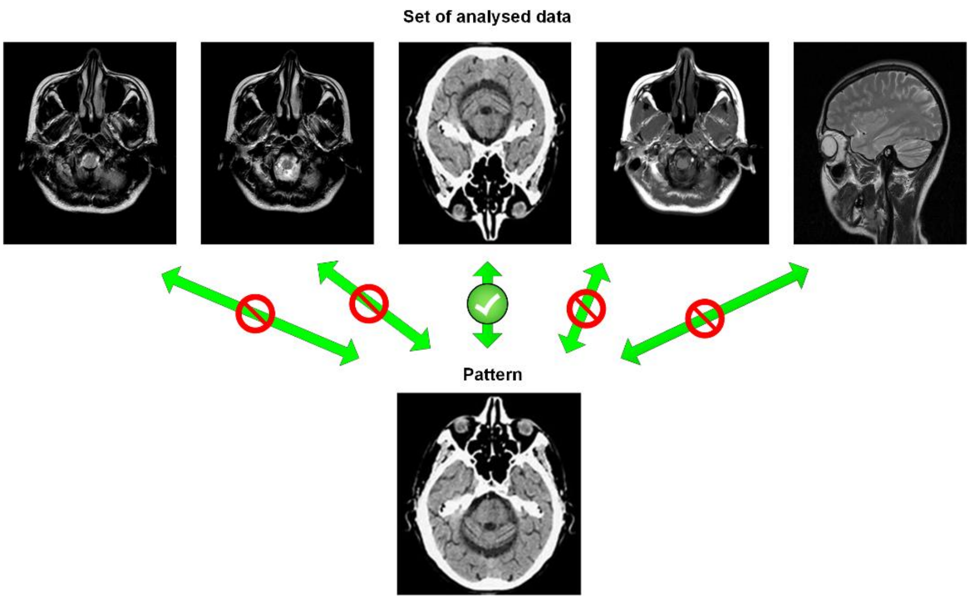

Figure. 3.2. The process of recognising the analysed elements of the set by comparing data to the pattern element

Human centered computing methods dedicated to data interpretation processes make comparisons using the definition of a formal grammar containing specified sequences of derivative rules in the form of a defined set of productions. The formal grammar defines the formal language which supports the process of semantic data analysis. The set recognised during the semantic analysis is assigned to the class to which the pattern that represents it belongs.

Processes of interpreting the analysed data sets are carried out using the syntactic approach on the basis of the semantic description of these sets. The so-called functional blocks are used for this purpose. Human centered computer analysis starts with data processing stages. Depending on the type of data being analysed, the stages of coding, shape approximation, filtering and processing are executed. The data being analysed is input into the system and after its preprocessing, a new representation of the dataset being described can be produced. This set takes the form of hierarchical structures of a semantic tree. Then, the subsequent steps of deriving the representation from the initial symbol of the grammar defined in the system are executed. The preprocessing of data may also include the processes of segmentation, identifying primitives and determining the relations between these primitives.

The correct classification of data leads to the stage at which the sets being described and interpreted are recognised. The completion of this process is to answer the question whether the input representation of the sets belongs to the indicated data class generated by the formal language of the grammar introduced. The formal language is defined by the specific formal grammar at the linguistic description stage.

Human centered computing methods are aimed at the cognitive interpretation of the data being analysed. Semantic data analysis processes focus on identifying elements together with all definable factors which condition their form. Hence this process is to define the determinants of the given past, present and future states. Human centered computing methods are used for complex, two-way processes of semantically interpreting data. Their two-way nature means that it is possible to execute processes of data description and interpretation during which the system independently collects knowledge and describes the sets being interpreted.

3.1. Selected aspects of human methods of data analysis

Human centered computing methods dedicated to processes of data interpretation and analysis are based on perception models characteristic for the human mind. The use of perception models to describe and interpret data is based on employing algorithms for the automatic semantic description and analysis of this data. The degree of similarity between the algorithms used and the perception solutions determines the degree of convergence of the solutions introduced for data interpretation tasks. This means that the computing models used to analyse data imitate the operation of the human mind to various degrees.

Perception models and their system counterparts use the operating rules of human perception and thus become the foundation for developing human centered computing methods.

Primary models of human perception adopted for supporting decision-making processes include [16], [50]:

1. The model of information representation in the human brain.

   This model is used to demonstrate that every piece of information reaching the analysis centre is stored in the form of an unambiguous representation. This representation of information is individual and unique. This means that this representation is different for every recipient and the computer systems they design. At the same time, every recipient assigns various representations to the information they receive.

2. Neural informatics model.

   This model is used to demonstrate the characteristic neural structures which illustrate the similarities between the human and the computer process of interpreting information. This interpretation of the knowledge and information representations portrays, at the neural level, representations of data that can be described by mathematical models. This class of models makes it possible to describe memory processes understood as the components of natural and artificial intelligence.

3. Cognitive informatics model.

This model is designed for defining and describing the similarities between the structure of the human mind and its artificial equivalent. The mind, responsible for executing cognitive tasks, creates its artificial equivalent by defining features of the convergence of these two solutions. The ways in which intellectual processes – i.e. perception, memory, thinking, analysis, interpretation or reasoning – work are transferred to the domain of algorithmic solutions. Building models of this class makes it possible to use cognitive informatics for the semantic analysis of data.

4. Cognitive machine and computer models.

   The purpose of these models is to define the dependencies and relationships between the three main areas, namely artificial intelligence, cognitive science, as well as system applications and solutions. These models have been built by combining semantic analyses carried out in the fields of artificial intelligence with natural intelligence processes. They are used to perform computer (machine) data analysis and execute cognitive processes which form the basis of the semantic data description. In the artificial intelligence area, cognitive solutions are used to define system applications and the software for the applications developed.

Human centered computing methods are aimed at executing semantic data analysis processes. These processes can be performed to the extent to which the degree of similarity between perception models and their algorithmic (system) presentation has been determined. The way perception processes have been described and the precision of the interpretation of their individual stages make it possible to create algorithmic solutions that imitate perception models. This type of solutions is used for data analysis processes. Broadly understood data analysis determines the way that data is described, interpreted, semantically reasoned about, and supports decision-making processes at various levels. These processes are understood as helping to take optimal decisions based on the semantic interpretation of data, i.e. data understanding. Data understanding is founded on executing semantic data interpretation. This type of process produces complete information about the meaning of the analysed datasets. Hence this information enables the complete, semantic description of data. However, executing this type of process may result in the lack of complete control over the future fate of the interpreted data. In order to ensure this type of control, the notion of grounding knowledge has been introduced.

3.2. New definition of grounding knowledge

Human centered computing methods are aimed at executing computational tasks to fully interpret the analysed datasets. Such tasks can be executed based on the knowledge, contained in systems, about the sets being interpreted. Knowledge contained in system knowledge bases makes it possible to compare the elements contained in the knowledge bases with the analysed datasets. The more precise the description of the analysed sets, the more complete and correct the analysis carried out. Knowledge elements contained in system knowledge bases allow the correct assignment of a pattern to every analysed element, but when there is no knowledge about the analysed data, the attempts to describe and interpret it fails because the system knowledge bases are closed.

Such situations can be eliminated if the system can learn new, unknown solutions. The processes of learning can be performed if new situations occur, new features of the analysed elements are extracted, and the new elements and patterns are added to the knowledge bases.

The processes whereby the system learns new solutions can take place when the system encounters something it does not understand. In this situation, it cannot fully (correctly) classify this element. In order to avoid such situations, it is expected to make another attempt to interpret the data. This process is made possible by adding new elements to the knowledge base.

The process of inputting new solutions into the system, i.e. system learning, consists of completing the following stages [50], [53]:

- extracting additional semantic information whose meaning for the data analysis processes carried out can be determined,
- identifying additional characteristic features of the interpreted datasets – extracting undefined features may lead to a change of the previous solution,
- identifying changes in sets of characteristic features of the analysed sets,
- redefining the set of features describing the analysed data,
- the repeated interpretation of data based on the extended set of characteristic features and the supplemented knowledge base.

During the process in which the system learns new solutions, it is necessary to repeat the data interpretation stage. The execution of analysis processes using the new, extended knowledge base leads to a fuller interpretation of the analysed datasets. Processes taking place during the extension of the knowledge bases are characteristic for the newly defined (proprietary) grounding knowledge processes.

Definition 1.

Grounding knowledge is a process aimed at acquiring the complete knowledge about the analysed datasets, consisting of updating and deepening the knowledge as well as consolidating and growing the layers of knowledge contained in system bases used for data analysis processes, by using human centered computing methods.

Hence grounding knowledge supports consolidating knowledge for the purpose of its better use in the semantic interpretation and description of data based on the application of human centered computing methods.

3.3. Grounding knowledge algorithm in computing theory

Grounding knowledge algorithms are used when executing computational tasks in the processes of the semantic interpretation of various types of data. The use of computational methods for data processing demonstrates the need to constantly update their knowledge held. Knowledge updating is understood as deepening the resources of knowledge which is used for the semantic interpretation of data.

The algorithms described are universal in application because they can be used in various areas of analysis. This is because grounding knowledge processes concern the method of enriching knowledge bases which are used for data analysis and not the type of data that is being analysed. They represent a universal method of enhancing previously known data analysis methods.

Supplementing knowledge bases with new elements obtained as a result of the system learning unknown solutions is aimed at:

- building broad knowledge bases enriched with new solutions that can appear during data analysis processes,
- the system learning new solutions based on a semantic analysis for which the system originally did not collect resources of knowledge,
- extracting characteristic features about the analysed datasets,
- identifying elements characteristic for the analysed datasets in the form of patterns,
- modifying pattern elements as a result of the change (enlargement) of the analysed sets,
- comparing the resources of knowledge held with the resources that can be acquired as a result of executing the learning process.

3.4. New computational paradigms for computational systems and distributed computing

Human centered computing methods describe the possibilities of semantic data interpretation. Semantic interpretation can be carried out by using computational methods convergent with human cognitive processes and makes it possible to interpret data based on its meaning. This meaning is understood as coming from an analysis the determines the semantic content layers of the interpreted sets.

Human centered computing methods make it possible to carry this analysis out based on human perception processes. Reflecting the perception processes in system solutions makes it possible to perform a computer data analysis offering the opportunity to understand this data.

Determining the reasons for the features of the analysed data, extracting characteristic features, foreseeing changes and assessing the future state can be described based on the semantic characterisation of data. The execution of such processes, which are aimed at assessing the semantic information, makes it also possible to understand the analysed data. This leads to determining the reasons for the occurrence of a certain state, situations, the value of sets, the course of processes etc.

The characteristic features of the solutions described here are as follows [50], [51], [53]:

- it is possible to identify a broad range of data analysed – human centered computing methods are used to analyse various types of data,
- the universality of the implemented data interpretation and analysis methods,
- wide opportunities of using human centered computing methods in various fields of science and practical applications,
- using linguistic formalisms envisaged for the semantic description and interpretation of data,
- the ability of using structural techniques of artificial intelligence,
- broad opportunities to implement cognitive processes characteristic for human thought processes in semantic data interpretation,
- the ability to combine the results obtained through implementing cognitive processes with reasoning processes, e.g. at the stage of defining the directions of further action,
- the ability to make unlimited use of expert knowledge bases,
- the possibility of applying theoretical solutions in practice.

Human centered computing methods make it possible to describe the semantic information contained in the analysed datasets. They are also used to determine the meaning of the analysed sets in relation to the remaining data. They identify the influence of the layers of semantics contained in the analysed sets on their present and future state. The possibilities of assessing this influence are varied and result from the degree of knowledge of the analysed data. This degree identifies the amount of knowledge held about the analysed sets. The possibilities of a assessing the influence of the semantic content depend on the solutions adopted for the analysis, the time available, the expert knowledge held, the hardware capacity and the access to it. The collected knowledge resources indisputably constitute the most important element of the processes described.

Chapter 4

Future Generation Computer Systems

Abstract. This chapter describes future generation computer systems for the semantic description and interpretation of data sets. These systems will be aimed at supporting and improving data management processes, which can be executed by using linguistic techniques and the semantic interpretation of the analysed data. Semantic interpretation allow describes the role and the meaning of the analysed data for the entire analysis process to be extracted from the sets of analysed data.

New generation computer systems use human centered computing methods for the semantic description and interpretation of data as part of processes of its semantic analysis.

The innovative solution is to introduce a class of systems dedicated to supporting decision-making problems in the interpretation data in the form of ratios. Such solutions are very desirable, and the ability to apply them would contribute to supporting decision-making in areas in which financial data is used. In addition, they improve the management of economic and financial information (for ratios), limit the costs of taking decisions and minimise the risk of taking the wrong decision.

A new example where data management processes are executed is the semantic interpretation of data, including the stages of its analysis and understanding. Systems which include the stages of the semantic interpretation and understanding of data are used for the correct assessment of the analysed information. Understanding the essence of the object being managed allows the decision to be taken correctly. In addition, it eliminates superfluous information, thus making the decision-making processes more efficient.

A new class of systems has been proposed to support and improve the semantic interpretation of data presented in the form of ratios. This type of data may refer to economic and financial ratios, and their analysis is to support the processes of the complete interpretation and understanding of the situation of the characterised entity and its future standing.

The proposed new generation of systems executing the semantic interpretation of data has been subdivided into various classes according to the type of data analysed. They are used to execute decision-making processes and help manage strategic information. This subdivision is made for the purpose of the complete interpretation of specific groups of financial ratios which determine the situation of the analysed entity. In addition, the reasons causing the current situation of the entity can be assessed and its significance described.

Four main system classes have been distinguished in the group of the proposed systems [50]:

- UBMLRSS systems – Understanding Based Management Liquidity Ratios Support Systems – systems for analysing enterprise liquidity ratios,
- UBMARSS systems – Understanding Based Management Activity Ratios Support Systems – systems for analysing turnover ratios,
- UBMPRSS systems – Understanding Based Management Profitability Ratios Support Systems – systems for analysing profitability ratios,
- UBMFLRSS systems – Understanding Based Management Financial Leverage Ratios Support Systems – systems for analysing financial leverage ratios (financial debt ratios).

The most important task of the new generation of systems for the semantic interpretation of data is the complete, correct assessment (interpretation) of the current state. This assessment also includes the past state and an assessment of the future state. It is carried out by identifying and understanding the determinants of the state being assessed. This process is executed using algorithms for semantic interpretation and analysis of data in the description and reasoning processes, and algorithms for supporting strategic decision-making in data management processes.

The data description and interpretation completed are used to identify the current state of the analysed entity (e.g. a business). They also identify the type and nature of the decisions that have to be taken in order to improve the current state, or if the entity is in a satisfactory standing, they are used to take a decision that will maintain this current standing. The analysis does not only concern the selected entity. It also includes the influence and the development of the external environment. The new generation of systems using human centered computing methods focus on [50]:

- analysis of the internal and external situation, and predicting the future situation,
- improving decision-making processes,
- support strategic decision-making,
- support management processes in the local and global aspects.

This situation is presented in Figure 4.1.

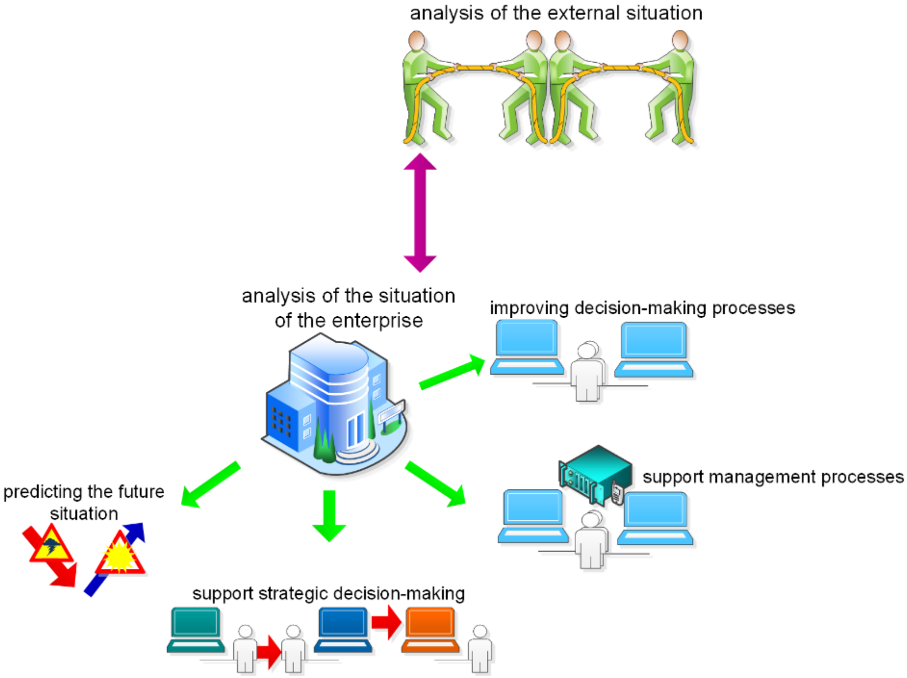

Figure. 4.1. The enterprise management processes

Processes of the semantic description of the data being interpreted have been proposed for diverse sets of ratios characterising the given entity.

Data analysis processes are used to determine the meaning of this data. Linguistic formalisms in the form of sequential grammars have been proposed for its description.

Because the proposed new generation of systems interpret data semantically, they play the role of systems supporting the financial and strategic analysis of the specific entity.

Systems for the semantic description and analysis of economic and financial data have been divided into the following four classes [50], [57]:

- UBMLRSS – Understanding Based Management Liquidity Ratios Support Systems – systems for analysing enterprise liquidity ratios, which reason about the amount and the adequacy of the working capital of the company as well as about the company's current operations,
- UBMARSS – Understanding Based Management Activity Ratios Support Systems – systems for analysing turnover ratios, which reason about how fast assets rotate and how productive they are,
- UBMPRSS – Understanding Based Management Profitability Ratios Support Systems – systems for analysing profitability ratios which reason about the financial

efficiency of the business operations of a given unit based on the relationship between financial results, the sales of goods and services, and the cost of sales,

- UBMFLRSS – Understanding Based Management Financial Leverage Ratios Support Systems – systems for analysing financial leverage ratios (financial debt ratios), which reason about the sources financing the company's assets and the proportion of external capital by analysing short-term and long-term liabilities, they also reason about the effectiveness of expenditure and the interest paid.

The classification of new classes of computer systems is shown in Fig. 4.2.

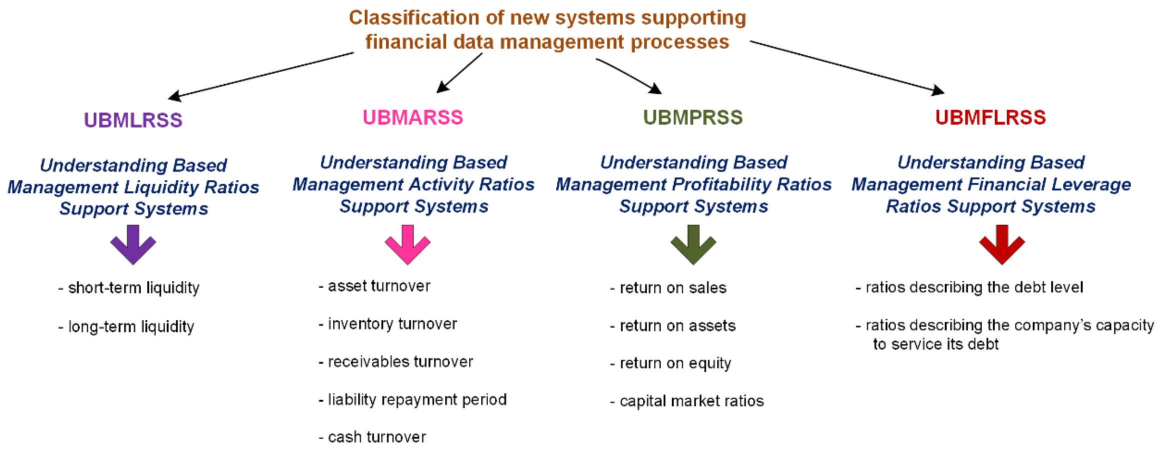

Figure. 4.2. Classification of new classes of computer systems supporting management processes [50], [56]

Figure 4.2. presents the main groups of new classes of information systems with selected types of ratios in each sub-class of proposed systems.

Groups of ratios adopted for further analysis have been selected from individual groups of financial ratios.

The first group of ratios are those describing the financial liquidity. The liquidity of an enterprise is understood as its ability to pay its current liabilities to, for example, employees, suppliers or banks, at maturity. This ability is determined by both the standing of the enterprise and the external situation independent outside its control [50].

The following ratios are distinguished in the group of ratios measuring liquidity [50]:

- current ratio,
- quick ratio,

- cash ratio,
- mature payables ratio,
- cash flow indicator,
- cash flow coverage.

Within the group of ratios describing the cash flow of the enterprise, ratios of the cash flow to the following values are distinguished sales, operating profit, assets, fixed assets, working capital [50].

Within the group of ratios defining cash flow coverage, the following indicators of cash flow coverage are distinguished [50]:

- operating cash for paying total liabilities,
- operating cash for paying current liabilities,
- operating cash for paying long-term liabilities,
- general operating cash flow coverage,
- operating cash flow for fixed asset purchases.

Within the group of ratios describing the liquidity of an enterprise, the following indicators were adopted for the semantic analysis of ratios [50]:

- the value of the current ratio,
- the value of the quick ratio,
- the value of the cash ratio,
- the value of the treasury ratio,
- the value of the mature payables ratio.

The next group of ratios are those describing the turnover cycles within the enterprise. The turnover is understood as the efficiency of the enterprise, i.e. the ability to make optimal use of the resources held by the enterprise in specific external conditions. Consequently, the turnover denotes the ability of the assets to generate revenues [50].

The following ratios are distinguished in the group of turnover indicators [50]:

- asset turnover,
- fixed asset turnover,
- working asset turnover,
- liquid asset turnover.

Within the group of indicators describing the turnover cycles of an enterprise, the following were adopted for the semantic analysis of indicator data [50]:

- the total asset turnover,
- the working asset turnover,
- the liquid asset turnover.

The next group of ratios are those describing the profitability (rate of return) of the enterprise. The profitability of the enterprise is understood as its ability to generate revenue from its operations, which revenue exceeds the operating cost of the enterprise. Profitability indicators measure the effectiveness of the entity's activities in the given (analysed) period of time. Profitability ratios are very frequently used to assess the business of the company from the perspective of its ability to generate profit from the means that it uses. These ratios are employed to measure the degree to which the company has achieved its strategic goal of raising its value by boosting profitability [50].

The following ratios are distinguished in the group of profitability/rate of return indicators [50]:

- return on sales,
- operating profitability of sales,
- profitability of business operations,
- return on gross sales,
- return on net sales,
- net profitability,
- cost level,
- return on assets,
- return on gross assets,
- return on net assets,
- return on gross assets including interest,
- return on fixed assets,
- return on working assets,
- return on clear assets,
- return on equity,
- equity market indicators.

Within the group of indicators measuring the profitability of an enterprise, the following were adopted for the semantic analysis of indicator data [50]:

- the return on net assets,

- the return on gross assets,
- the return on gross assets including interest,
- the return on fixed assets,
- the return on working assets,
- the return on clear assets.

The last group of ratios are those describing the debt of the enterprise. Enterprise debt applies to a situation in which the enterprise uses any form of financial support and not exclusively its own capital. Hence it describes every situation in which the enterprise uses outside capital, which leads to the enterprise being in debt [50].

The assessment of the enterprise debt situation is aimed at determining the extent to which the enterprise finances itself with its own funds and to which it is financed with external funds. If the operations of the entity are financed with external funds, it is possible to assess the proportion of own equity to external capital in the entire financing of the enterprise. The most important element in assessing the debt situation is to determine the impact of external capital on enterprise operations and the degree to which the financial independence of the enterprise is at risk. This type of assessment leads to calculating the costs of using external capital and the cost-effectiveness of this solution [50].

The analysis of the value of debt ratios can concern debt level indicators and the ability of the enterprise to service this debt. The following ratios are distinguished in the group of ratios identifying the debt level [50]:

- total debt ratio,
- long-term debt,
- debt to equity,
- long-term debt to equity,
- liability structure,
- long-term liability coverage with net fixed assets,
- interest coverage.

The following ratios are distinguished in the group of ratios measuring the ability of the enterprise to service its debt [50]:

- debt service coverage,
- interest coverage,
- debt service coverage with the cash surplus.

Semantic data analysis systems are used to assess the current situation of the enterprise based on the semantic description and interpretation of a selected group of ratios [50].

These classes of new information systems may analyse [50]:

- the economic situation of enterprise,
- the surroundings of enterprise,
- the situation and condition of:
  - customers,
  - providers,
  - others companies,
- and the influence of the environment of the company.

In information systems for the semantic description and analysis of data dedicated to understanding debt ratios, it is possible to determine [50]:

- the degree to which enterprise operations are financed with its own funds,
- the degree to which enterprise operations are financed with external funds – the enterprise's debt,
- the proportion of own capital to external capital in corporate finance,
- the debt situation – by determining the impact of external capital on enterprise operations and the degree to which the financial independence of the enterprise is at risk,
- the costs and profitability of using external capital for enterprise operations.

Within the group of indicators measuring the financial leverage of an enterprise, the following were adopted for the semantic analysis of indicator data [50]:

- the total debt ratio,
- the long-term debt ratio,
- the debt service coverage ratio,
- the value of the interest coverage ratio.

Based on the groups of indicators selected and adopted for the analysis, semantic analysis systems were proposed that are based on analysing the value of selected groups of ratios characteristic for the operations of enterprises. Those analysis is especially important for [50]:

- description of the present situation of enterprise,
- supporting the enterprise management processes,
- understanding of the current state of company,
- understanding of the reasons of the current state of the company,
- description of the future situation of enterprise.

The process of data mining in computer-aided semantic systems is shown in Fig. 4.3.

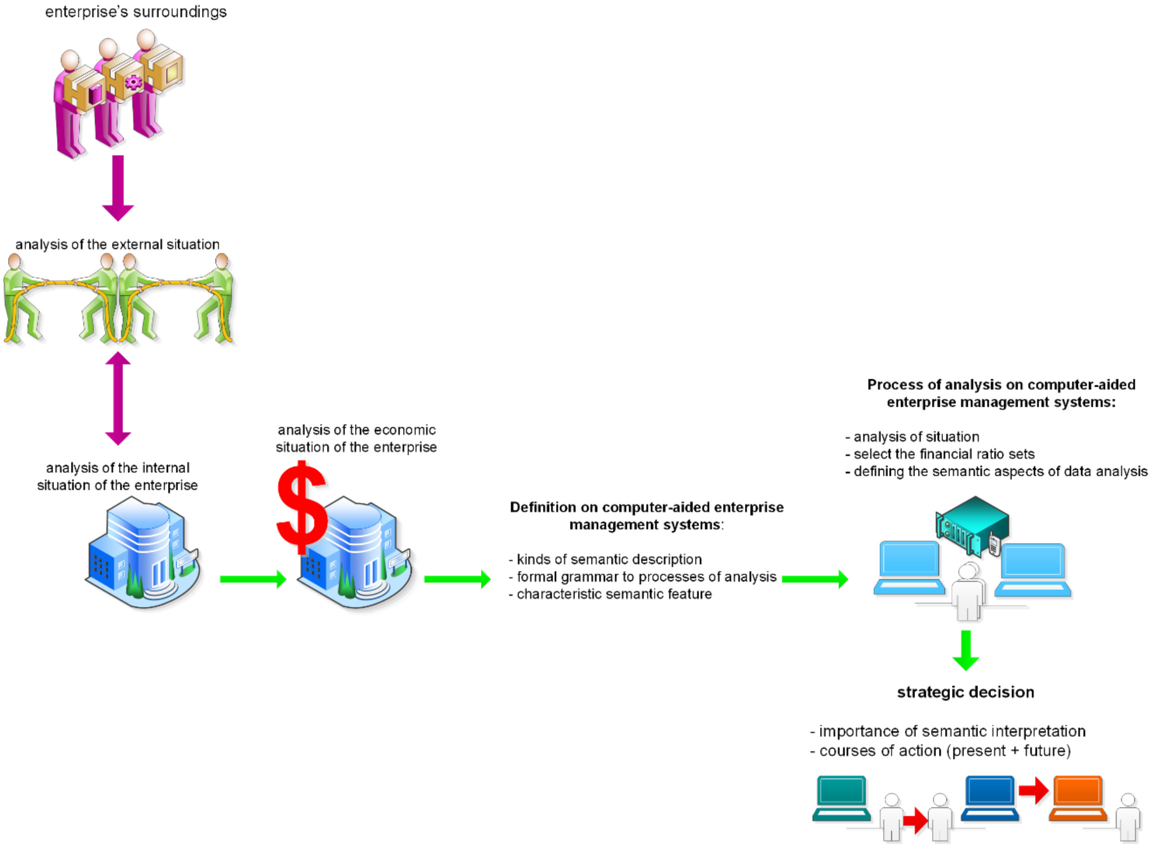

Figure. 4.3. Data mining process in computer-aided semantic systems

Processes of the semantic interpretation of economic and financial data are about assessing of the standing of the entity being analysed. The information forming the basis of the analysis processes carried out makes it possible to understand the analysed situation more fully. In addition, it is used to improve decision-making processes in terms of the ability to take optimal decisions about the future state. At the same time, adding the semantic reasoning stage to the decision-making processes makes it possible to indicate groups of data of material importance for the development of the entity. It also allows the influence of factors that are not material in this process on the development of this entity to be limited.

4.1. Human computing algorithms for new classes of computer systems

This chapter has been developed based on [50].

The new classes of computer systems have been proposed to perform semantic description of financial data. The semantic description of financial data allow to understand the global situation. These systems were divided to the different subsystems [50].

In UBMLRSS systems were developed the following subclasses [50]:

- UBMLRSS-$G_{(cu\text{-}q)}$ – for analysing ratio values:
  - v_{cu} – denotes the value of the current ratio,
  - v_q – denotes the value of the quick ratio,
- UBMLRSS-$G_{(cu\text{-}q\text{-}ca)}$ – for analysing ratio values:
  - v_{cu} – denotes the value of the current ratio,
  - v_q – denotes the value of the quick ratio,
  - v_{ca} – denotes the value of the cash ratio,
- UBMLRSS-$G_{(cu\text{-}q\text{-}mp)}$ – for analysing ratio values:
  - v_{cu} – denotes the value of the current ratio,
  - v_q – denotes the value of the quick ratio,
  - v_{mp} – denotes the value of the mature payables ratio,
- UBMLRSS-$G_{(cu\text{-}ca\text{-}mp)}$ – for analysing ratio values:
  - v_{cu} – denotes the value of the current ratio,
  - v_{ca} – denotes the value of the cash ratio,
  - v_{mp} – denotes the value of the mature payables ratio,
- UBMLRSS-$G_{(q\text{-}ca\text{-}mp)}$ – for analysing ratio values:
  - v_q – denotes the value of the quick ratio,
  - v_{ca} – denotes the value of the cash ratio,
  - v_{mp} – denotes the value of the mature payables ratio,
- UBMLRSS-$G_{(cu\text{-}q\text{-}ca\text{-}tr)}$ – for analysing ratio values:
  - v_{cu} – denotes the value of the current ratio,
  - v_q – denotes the value of the quick ratio,

- v_{ca} – denotes the value of the cash ratio,
- v_{tr} – denotes the value of the treasury ratio.

In UBMARSS systems were developed the following subclasses [50]:

- UBMARSS-$G_{(ta\text{-}la)}$ – for analysing turnover indicators:
  - v_{ta} – denotes the total asset turnover,
  - v_{la} – denotes the liquid asset turnover,
- UBMARSS-$G_{(ta\text{-}wa)}$ – for analysing turnover indicators:
  - v_{ta} – denotes the total asset turnover,
  - v_{wa} – denotes the working asset turnover,
- UBMARSS-$G_{(ta\text{-}wa\text{-}la)}$ – for analysing turnover indicators:
  - v_{ta} – denotes the total asset turnover,
  - v_{wa} – denotes the working asset turnover,
  - v_{la} – denotes the liquid asset turnover.

In UBMPRSS systems were developed the following subclasses [50]:

- UBMPRSS-$G_{(rna\text{-}rga\text{-}rgi)}$ – for analysing values:
  - v_{rna} – denotes the return on net assets,
  - v_{rga} – denotes the return on gross assets,
  - v_{rgi} – denotes the return on gross assets including interest,
- UBMPRSS-$G_{(rfa\text{-}rwa\text{-}rca)}$ – for analysing values:
  - v_{rfa} – denotes the return on fixed assets,
  - v_{rwa} – denotes the return on working assets,
  - v_{rca} – denotes the return on clear assets.

In UBMFLRSS systems were developed the following subclasses [50]:

- UBMFLRSS-$G_{(td\text{-}ld)}$ – for analysing the debt value:
  - v_{td} – denotes the total debt ratio,
  - v_{ld} – denotes the long-term debt ratio,
- UBMFLRSS-$G_{(td\text{-}ls)}$ – for analysing the debt value:
  - v_{td} – denotes the total debt ratio,
  - v_{ls} – denotes the value of the liability structure ratio,
- UBMFLRSS-$G_{(dsc\text{-}ic)}$ – for analysing the debt value:
  - v_{dsc} – denotes the debt service coverage ratio,

- v_{ic} – denotes the value of the interest coverage ratio.

The semantic description was conducted to merge the above selected subsystems of proposed solution. A semantic description was proposed for particular classes [50]:

- UBMLRSS-UBMPRSS-$G_{(mp\text{-}irr)}$ – for analysing values:
  - v_{mp} – denotes the value of the mature payables ratio,
  - v_{irr} – denotes the value of the internal rate of return,
- UBMLRSS-UBMPRSS-$G_{(q\text{-}irr)}$ – for analysing values:
  - v_{q} – denotes the value of the quick ratio,
  - v_{irr} – denotes the value of the internal rate of return,
- UBMLRSS-UBMPRSS-$G_{(mp\text{-}q\text{-}irr)}$ – for analysing values:
  - v_{mp} – denotes the value of the mature payables ratio,
  - v_{q} – denotes the value of the quick ratio,
  - v_{irr} – denotes the value of the internal rate of return,
- UBMLRSS-UBMPRSS-$G_{(cu\text{-}irr)}$ – for analysing values:
  - v_{cu} – denotes the value of the current ratio,
  - v_{irr} – denotes the value of the internal rate of return,
- UBMLRSS-UBMPRSS-$G_{(cu\text{-}q\text{-}irr)}$ – for analysing values:
  - v_{cu} – denotes the value of the current ratio,
  - v_{q} – denotes the value of the quick ratio,
  - v_{irr} – denotes the value of the internal rate of return,
- UBMLRSS-UBMPRSS-$G_{(ca\text{-}irr)}$ – for analysing values:
  - v_{ca} – denotes the value of the cash ratio,
  - v_{irr} – denotes the value of the internal rate of return,
- UBMLRSS-UBMPRSS-$G_{(ca\text{-}q\text{-}irr)}$ – for analysing values:
  - v_{ca} – denotes the value of the cash ratio,
  - v_{q} – denotes the value of the quick ratio,
  - v_{irr} – denotes the value of the internal rate of return,
- UBMARSS-UBMPRSS-$G_{(ta\text{-}irr)}$ – for analysing values:
  - v_{ta} – denotes the value of the total asset turnover indicator,
  - v_{irr} – denotes the value of the internal rate of return,
- UBMARSS-UBMPRSS-$G_{(wa\text{-}irr)}$ – for analysing values:
  - v_{wa} – denotes the value of the working asset turnover indicator,

   - v_{irr} – denotes the value of the internal rate of return,
- UBMARSS-UBMPRSS-$G_{(ta\text{-}wa\text{-}irr)}$ – for analysing values:
   - v_{ta} – denotes the value of the total asset turnover indicator,
   - v_{wa} – denotes the value of the working asset turnover indicator,
   - v_{irr} – denotes the value of the internal rate of return.

Semantic description in new classes of computer systems, may analysed combinations of different kinds of turnover ratios, financial leverage ratios, profitability ratios and liquidity ratios. All proposed new classes of computer systems shows Fig. 4.4.

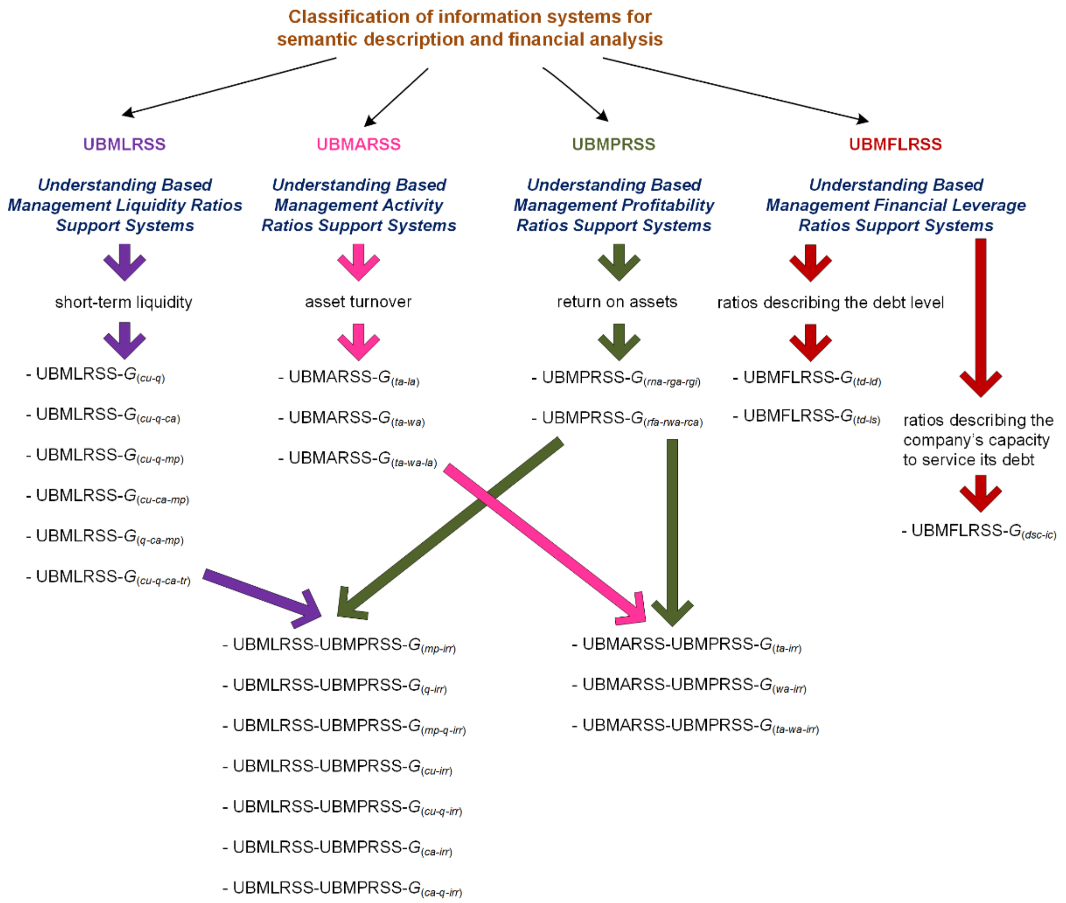

Figure. 4.4. Classification of new classes of computer systems dedicated to semantic description and financial analysis [50]

The processes of interpreting and analysing various types of financial ratios are executed in new classes of information systems by assessing indicator parameters characteristic for the given group of ratios. To analyse and interpret the ratios, certain numerical intervals are adopted, which are characteristic of the specific standing of the entity and the behaviours resulting from it – steps that need to be taken. The proper definition of the presentation of ratios in the numerical, interval form, is necessary to understand the situation of the analysed entity (e.g. an enterprise). These definitions are made at the stage of building the semantic description in the form of formal grammars. A sequential grammar makes it possible to account for all classes characteristic for the assessed situations [50].

The description process is executed by using linguistic formalisms to define the indicator parameters adopted for a given entity. The number of parameters analysed depends on the quantity of data acquired. The interpretation process consists in assessing the similarity of the analysed data to models adopted when defining the new information system as the best reflection of the optimal standing of an entity. Determining the level of similarity may impact the analysis of a given situation, but one should remember that the system can be taught new solutions that are more adequate for the analysed ratios and which describe the condition of the analysed entities [50].

4.2. New generation computer systems

This chapter has been developed based on [50].

Examples of new generation computer systems supporting management processes have been developed by analysing the different groups of ratios. There are many examples of the use of semantic description and interpretation for the purpose of understanding a given situation. They will be presented below as examples of using the semantic description and analysis of financial data in the process of is understanding [50].

In UBMLRSS systems the following subclasses were proposed [50]:

- UBMLRSS-$G_{(cu\text{-}q)}$ – for analysing ratio values:
  - v_{cu} – denotes the value of the current ratio,
  - v_q – denotes the value of the quick ratio,

$$G_{(cu\text{-}q)} = (V_{N(cu\text{-}q)}, V_{T(cu\text{-}q)}, P_{(cu\text{-}q)}, S_{(cu\text{-}q)}) \qquad (1)$$

where:

$V_{N(cu\text{-}q)}$ = {LIQUIDITY1, EXCESS_LIQUIDITY1, OPTIMAL_LIQUIDITY1, SOLVENCY_PROBLEMS1} – the set of non-terminal symbols,

$V_{T(cu\text{-}q)}$ = {a, b, c, d, e} – the set of terminal symbols,

where: a ∈ [0; 1), b ∈ [1; 1,2], c ∈ (1,2; 1,5), d ∈ [1,5; 2], e ∈ (2; +∞)

$S_{(cu\text{-}q)} \in V_{N(cu\text{-}q)}$, $S_{(cu\text{-}q)}$ = LIQUIDITY1,

$P_{(cu\text{-}q)}$ – set of productions:

1. LIQUIDITY1 → EXCESS_LIQUIDITY1 | OPTIMAL_LIQUIDITY1 | SOLVENCY_PROBLEMS1
2. **EXCESS_LIQUIDITY1** → DB | DC | DD
3. **OPTIMAL_LIQUIDITY1** → CB | CC | CD | DA | DE | EB | EC | ED
4. **SOLVENCY_PROBLEMS1** → AA | AB | AC | AD | AE | BA | BB | BC | BD | BE | CA | CE | EA | EE
5. A → a
6. B → b
7. C → c
8. D → d
9. E → e

- UBMLRSS-G$_{(cu\text{-}q\text{-}ca)}$ – for analysing ratio values:
  - v_{cu} – denotes the value of the current ratio,
  - v_q – denotes the value of the quick ratio,
  - v_{ca} – denotes the value of the cash ratio,

$$G_{(cu\text{-}q\text{-}ca)} = (V_{N(cu\text{-}q\text{-}ca)}, V_{T(cu\text{-}q\text{-}ca)}, P_{(cu\text{-}q\text{-}ca)}, S_{(cu\text{-}q\text{-}ca)}) \qquad (2)$$

where:

$V_{N(cu\text{-}q\text{-}ca)}$ = {LIQUIDITY2, EXCESS_LIQUIDITY2, OPTIMAL_LIQUIDITY2, SOLVENCY_PROBLEMS2} – the set of non-terminal symbols,

$V_{T(cu\text{-}q\text{-}ca)}$ = {a, b, c, d, e} – the set of terminal symbols,

where: a ∈ [0; 1), b ∈ [1; 1,2], c ∈ (1,2; 1,5), d ∈ [1,5; 2], e ∈ (2; +∞)

$S_{(cu\text{-}q\text{-}ca)} \in V_{N(cu\text{-}q\text{-}ca)}$, $S_{(cu\text{-}q\text{-}ca)}$ = LIQUIDITY2,

$P_{(cu\text{-}q\text{-}ca)}$ – set of productions:

1. LIQUIDITY2 → EXCESS_LIQUIDITY2 | OPTIMAL_LIQUIDITY2 | SOLVENCY_PROBLEMS2
2. **EXCESS_LIQUIDITY2** → EEE | EDE | EED
3. **OPTIMAL_LIQUIDITY2** → DCA | DCB | DBB | DBC | DBA | CBA | CCA | CBD
4. **SOLVENCY_PROBLEMS2** → DEE | AAA | ABA | AAB | ABB | BAB | BBA | ABC | BAC | ACB | BCA | AAC | ACA | CAA | AAD | ADA | DAA | AAE | AEA | EAA | ACD | ADC | ABD | ADB | DAB | ABE | AEB | BAA | BAD | BAE | BEA | EAB | EBA | CAB | ACC | CAC | BCC | CAD | CDA | CAE | CEA | ACE | ADE | AED | DAE | DEA | EAD | EDA | BBB | CCC | DDD | BBC | CBB | BDA | BCB | BBD | BDB | BBE | BEB | EBB | CCD | CDC | DCC | CCE | CEC | ECC | DDE | DED | EDD | BCD | BDC | CDB | BCE | BEC | ECB | EBC | CBE | CEB | CDE | CED | EDC | ECD | DEC

| DCE | EEA | EAE | AEE | EEB | EBE | BEE | CEE | ECE | EEC | DDA | DAD | ADD | BDD | DBD | DDB | DDC | CDD | DCD | BDE | BED | CBC | CCB | DAC | DBE | EAC | EBD | ECA | EDB | AEC | DEB

5. A → a
6. B → b
7. C → c
8. D → d
9. E → e

- UBMLRSS $G_{(cu\text{-}q\text{-}mp)}$ – for analysing ratio values:
  - v_{cu} – denotes the value of the current ratio,
  - v_q – denotes the value of the quick ratio,
  - v_{mp} – denotes the value of the mature payables ratio,

$$G_{(cu\text{-}q\text{-}mp)} = (V_{N(cu\text{-}q\text{-}mp)}, V_{T(cu\text{-}q\text{-}mp)}, P_{(cu\text{-}q\text{-}mp)}, S_{(cu\text{-}q\text{-}mp)}) \qquad (3)$$

where:

$V_{N(cu\text{-}q\text{-}mp)}$ = {LIQUIDITY3, EXCESS_LIQUIDITY3, OPTIMAL_LIQUIDITY3, SOLVENCY_PROBLEMS3} – the set of non-terminal symbols,

$V_{T(cu\text{-}q\text{-}mp)}$ = {a, b, c, d, e} – the set of terminal symbols,

where: a ∈ [0; 1), b ∈ [1; 1,2], c ∈ (1,2; 1,5), d ∈ [1,5; 2], e ∈ (2; +∞),

$S_{(cu\text{-}q\text{-}mp)} \in V_{N(cu\text{-}q\text{-}mp)}$, $S_{(cu\text{-}q\text{-}mp)}$ = LIQUIDITY3,

$P_{(cu\text{-}q\text{-}mp)}$ – set of productions:

1. LIQUIDITY3 → EXCESS_LIQUIDITY3 | OPTIMAL_LIQUIDITY3 | SOLVENCY_PROBLEMS3
2. **EXCESS_LIQUIDITY3** → EEE | EDE | EED
3. **OPTIMAL_LIQUIDITY3**→ DCA | DCB | DCC | DCD | DCE | DBB | DBC | DBA | DBD | DBE | CBA | CBB | CBC | CBD | CBE | CCA | CCB | CCC | CCD | CCE
4. **SOLVENCY_PROBLEMS3** → DEE | AAA | ABA | AAB | ABB | BAB | BBA | ABC | BAC | ACB | BCA | AAC | ACA | CAA | AAD | ADA | DAA | AAE | AEA | EAA | ACD | ADC | ABD | ADB | DAB | ABE | AEB | BAA | BAD | BAE | BEA | EAB | EBA | CAB | ACC | CAC | BCC | CAD | CDA | CAE | CEA | ACE | ADE | AED | DAE | DEA | EAD | EDA | BBB | DDD | BBC | BDA | BCB | BBD | BDB | BBE | BEB | EBB | CDC | CEC | ECC | DDE | DED | EDD | BCD | BDC | CDB | BCE | BEC | ECB | EBC | CEB | CDE | CED | EDC | ECD | DEC | EEA | EAE | AEE | EEB | EBE | BEE | CEE | ECE | EEC | DDA | DAD | ADD | BDD | DDB | DDC | CDD | BDE | BED | DAC | EAC | EBD | ECA | EDB | AEC | DEB
5. A → a
6. B → b
7. C → c
8. D → d
9. E → e

- UBMLRSS $G_{(cu\text{-}ca\text{-}mp)}$ – for analysing ratio values:

- v_{cu} – denotes the value of the current ratio,
- v_{ca} – denotes the value of the cash ratio,
- v_{mp} – denotes the value of the mature payables ratio,

$$G_{(cu\text{-}ca\text{-}mp)} = (V_{N(cu\text{-}ca\text{-}mp)}, V_{T(cu\text{-}ca\text{-}mp)}, P_{(cu\text{-}ca\text{-}mp)}, S_{(cu\text{-}ca\text{-}mp)}) \quad (4)$$

where:

$V_{N(cu\text{-}ca\text{-}mp)}$ = {LIQUIDITY4, EXCESS_LIQUIDITY4, OPTIMAL_LIQUIDITY4, SOLVENCY_PROBLEMS4} – the set of non-terminal symbols,

$V_{T(cu\text{-}ca\text{-}mp)}$ = {a, b, c, d, e} – the set of terminal symbols,

where: a $\in$ [0; 1), b $\in$ [1; 1,2], c $\in$ (1,2; 1,5), d $\in$ [1,5; 2], e $\in$ (2; +∞),

$S_{(cu\text{-}ca\text{-}mp)} \in V_{N(cu\text{-}ca\text{-}mp)}$, $S_{(cu\text{-}ca\text{-}mp)}$ = LIQUIDITY4,

$P_{(cu\text{-}ca\text{-}mp)}$ – set of productions:

1. LIQUIDITY4 → EXCESS_LIQUIDITY4 | OPTIMAL_LIQUIDITY4 | SOLVENCY_PROBLEMS4
2. **EXCESS_LIQUIDITY4** → EEE | EDE | EED | EEC
3. **OPTIMAL_LIQUIDITY4**→ DCA | DCB | DCC | DCD | DCE | DBA | DBB | DBC | DBD | DBE | CBA | CBB | CBC | CBD | CBE | CCA | CCB | CCC | CCD | CCE
4. **SOLVENCY_PROBLEMS4** → DEE | AAA | ABA | AAB | ABB | BAB | BBA | ABC | BAC | ACB | BCA | AAC | ACA | CAA | AAD | ADA | DAA | AAE | AEA | EAA | ACD | ADC | ABD | ADB | DAB | ABE | AEB | BAA | BAD | BAE | BEA | EAB | EBA | CAB | ACC | CAC | BCC | CAD | CDA | CAE | CEA | ACE | ADE | AED | DAE | DEA | EAD | EDA | BBB | DDD | BBC | BDA | BCB | BBD | BDB | BBE | BEB | EBB | CDC | CEC | ECC | DDE | DED | EDD | BCD | BDC | CDB | BCE | BEC | ECB | EBC | CEB | CDE | CED | EDC | ECD | DEC | EEA | EAE | AEE | EEB | EBE | BEE | CEE | ECE | DDA | DAD | ADD | BDD | DDB | DDC | CDD | BDE | BED | DAC | EAC | EBD | ECA | EDB | AEC | DEB
5. A → a
6. B → b
7. C → c
8. D → d
9. E → e

- UBMLRSS $G_{(q\text{-}ca\text{-}mp)}$ – for analysing ratio values:
  - v_q – denotes the value of the quick ratio,
  - v_{ca} – denotes the value of the cash ratio,
  - v_{mp} – denotes the value of the mature payables ratio,

$$G_{(q\text{-}ca\text{-}mp)} = (V_{N(q\text{-}ca\text{-}mp)}, V_{T(q\text{-}ca\text{-}mp)}, P_{(q\text{-}ca\text{-}mp)}, S_{(q\text{-}ca\text{-}mp)}) \quad (5)$$

where:

$V_{N(q\text{-}ca\text{-}mp)}$ = {LIQUIDITY5, EXCESS_LIQUIDITY5, OPTIMAL_LIQUIDITY5, SOLVENCY_PROBLEMS5} – the set of non-terminal symbols,

$V_{T(q\text{-}ca\text{-}mp)}$ = {a, b, c, d, e} – the set of terminal symbols,

where: $a \in [0; 1)$, $b \in [1; 1{,}2]$, $c \in (1{,}2; 1{,}5)$, $d \in [1{,}5; 2]$, $e \in (2; +\infty)$,

$S_{(q\text{-}ca\text{-}mp)} \in V_{N(q\text{-}ca\text{-}mp)}$, $S_{(q\text{-}ca\text{-}mp)}$ = LIQUIDITY5,

$P_{(q\text{-}ca\text{-}mp)}$ – set of productions:

1. LIQUIDITY5 → EXCESS_LIQUIDITY5 | OPTIMAL_LIQUIDITY5 | SOLVENCY_PROBLEMS5
2. **EXCESS_LIQUIDITY5** → EEE | EDE | EED | EEC | DDC | DDD | DDE | DED | DEE | EDD
3. **OPTIMAL_LIQUIDITY5** → DCA | DCB | DCC | DCD | DCE | DBA | DBB | DBC | DBD | DBE | CBA | CBB | CBC | CBD | CBE | CCA | CCB | CCC | CCD | CCE | BBA | BBB | BBC | BBD | BBE | BCA | BCB | BCC | BCD | BCE | BDA | BDB | BDC | BDD | BDE | BEA | BEB | BEC | BED | BEE
4. **SOLVENCY_PROBLEMS5** → AAA | ABA | AAB | ABB | BAB | ABC | BAC | ACB | AAC | ACA | CAA | AAD | ADA | DAA | AAE | AEA | EAA | ACD | ADC | ABD | ADB | DAB | ABE | AEB | BAA | BAD | BAE | EAB | EBA | CAB | ACC | CAC | CAD | CDA | CAE | CEA | ACE | ADE | AED | DAE | DEA | EAD | EDA | EBB | CDC | CEC | ECC | CDB | ECB | EBC | CEB | CDE | CED | EDC | ECD | DEC | EEA | EAE | AEE | EEB | EBE | CEE | ECE | DDA | DAD | ADD | DDB | CDD | DAC | EAC | EBD | ECA | EDB | AEC | DEB
5. A → a
6. B → b
7. C → c
8. D → d
9. E → e

- UBMLRSS-$G_{(cu\text{-}q\text{-}ca\text{-}tr)}$ – for analysing ratio values:
  - v_{cu} – denotes the value of the current ratio,
  - v_q – denotes the value of the quick ratio,
  - v_{ca} – denotes the value of the cash ratio,
  - v_{tr} – denotes the value of the treasury ratio,

$$G_{(cu\text{-}q\text{-}ca\text{-}tr)} = (V_{N(cu\text{-}q\text{-}ca\text{-}tr)}, V_{T(cu\text{-}q\text{-}ca\text{-}tr)}, P_{(cu\text{-}q\text{-}ca\text{-}tr)}, S_{(cu\text{-}q\text{-}ca\text{-}tr)}) \quad (6)$$

where:

$V_{N(cu\text{-}q\text{-}ca\text{-}tr)}$ = {LIQUIDITY6, EXCESS_LIQUIDITY6, OPTIMAL_LIQUIDITY6, SOLVENCY_PROBLEMS6} – the set of non-terminal symbols,

$V_{T(cu\text{-}q\text{-}ca\text{-}tr)}$ = {a, b, c, d, e} – the set of terminal symbols,

where: $a \in [0; 1)$, $b \in [1; 1{,}2]$, $c \in (1{,}2; 1{,}5)$, $d \in [1{,}5; 2]$, $e \in (2; +\infty)$,

$S_{(cu\text{-}q\text{-}ca\text{-}tr)} \in V_{N(cu\text{-}q\text{-}ca\text{-}tr)}$, $S_{(cu\text{-}q\text{-}ca\text{-}tr)}$ = LIQUIDITY6,

$P_{(cu\text{-}q\text{-}ca\text{-}tr)}$ – set of productions:

1. LIQUIDITY6 → EXCESS_LIQUIDITY6 | OPTIMAL_LIQUIDITY6 | SOLVENCY_PROBLEMS6
2. **EXCESS_LIQUIDITY6 →** EEEE | EDEE | EDED | EEDE | EEDD | EEED
3. **OPTIMAL_LIQUIDITY6 →** DCAA | DCAB | DCAC | DCAD | DCAE | DCBA | DCBB | DCBC | DCBD | DCBE | DBBA | DBBB | DBBC | DBBD | DBBE | DBCA | DBCB | DBCC | DBCD | DBCE | DBAA | DBAB | DBAC | DBAD | DBAE | CBAA | CBAB | CBAC | CBAD | CBAE | CCAA | CCAB | CCAC | CCAD | CCAE | CBDA | CBDB | CBDC | CBDD | CBDE
4. **SOLVENCY_PROBLEMS6 →** DEEA | DEEB | DEEC | DEED | DEEE | AAAA | AAAB | AAAC | AAAD | AAAE | ABAA | ABAB | ABAC | ABAD | ABAE | AABA | AABB | AABC | AABD | AABE | ABBA | ABBB | ABBC | ABBD | ABBE | BABA | BABB | BABC | BABD | BABE | BBAA | BBAB | BBAC | BBAD | BBAE | ABCA | ABCB | ABCC | ABCD | ABCE | BACA | BACB | BACC | BACD | BACE | ACBA | ACBB | ACBC | ACBD | ACBE | BCAA | BCAB | BCAC | BCAD | BCAE | AACA | AACB | AACC | AACD | AACE | ACAA | ACAB | ACAC | ACAD | ACAE | CAAA | CAAB | CAAC | CAAD | CAAE | AADA | AADB | AADC | AADD | AADE | ADAA | ADAB | ADAC | ADAD | ADAE | DAAA | DAAB | DAAC | DAAD | DAAE | AAEA | AAEB | AAEC | AAED | AAEE | AEAA | AEAB | AEAC | AEAD | AEAE | EAAA | EAAB | EAAC | EAAD | EAAE | ACDA | ACDB | ACDC | ACDD | ACDE | ADCA | ADCB | ADCC | ADCD | ADCE | ABDA | ABDB | ABDC | ABDD | ABDE | ADBA | ADBB | ADBC | ADBD | ADBE | DABA | DABB | DABC | DABD | DABE | ABEA | ABEB | ABEC | ABED | ABEE | AEBA | AEBB | AEBC | AEBD | AEBE | BAAA | BAAB | BAAC | BAAD | BAAE | BADA | BADB | BADC | BADD | BADE | BAEA | BEAB | BAEC | BAED | BAEE | BEAA | BAEB | BEAC | BEAD | BEAE | EABA| EABB | EABC | EABD | EABE | EBAA | EBAB | EBAC | EBAD | EBAE | CABA | CABB | CABC | CABD | CABE | ACCA | ACCB | ACCC | ACCD | ACCE | CACA | CACB | CACC | CACD | CACE | BCCA | BCCB | BCCC | BCCD | BCCE | CADA | CADB | CADC | CADD | CADE | CDAA | CDAB | CDAC | CDAD | CDAE | CAEA | CAEB | CAEC | CAED | CAEE | CEAA| CEAB | CEAC | CEAD | CEAE | ACEA | ACEB | ACEC | ACED | ACEE | ADEA | ADEB | ADEC | ADED | ADEE | AEDA | AEDB | AEDC | AEDD | AEDE | DAEA | DAEB | DAEC | DAED | DAEE | DEAA | DEAB | DEAC | DEAD | DEAE | EADA | EADB | EADC | EADD | EADE | EDAA | EDAB | EDAC | EDAD | EDAE | BBBA | BBBB | BBBC | BBBD | BBBE | CCCA | CCCB | CCCC | CCCD | CCCE | CDCD | DCDC | DCEB | DDDA | DDDB | DDDC | DDDD | DDDE | BBCA | BBCB | BBCC | BBCD | BBCE | CBBA | CBBB | CBBC | CBBD | CBBE | BDAA | BDAB | BDAC | BDAD | BDAE | BCBA | BCBB | BCBC | BCBD | BCBE | BBDA | BBDB | BBDC | BBDD | BBDE | BDBA | BDBB | BDBC | BDBD | BDBE | BBEA | BBEB | BBEC | BBED | BBEE | BEBA | BEBB | BEBC | BEBD | BEBE | EBBA | EBBB | EBBC | EBBD | EBBE | CCDA | CCDB | CCDC | CCDD | CCDE | CDCA | CDCB | CDCC | CDCE | DCCA | DCCB | DCCC | DCCD | DCCE | CCEA | CCEB | CCEC | CCED | CCEE | CECA | CECB | CECC | CECD | CECE | ECCA | ECCB | ECCC | ECCD | ECCE | DDEA | DDEB | DDEC | DDED | DDEE | DEDA | DEDB | DEDC | DEDD | DEDE | EDDA | EDDB | EDDC | EDDD | EDDE | BCDA | BCDB | BCDC | BCDD | BCDE | BDCA | BDCB | BDCC | BDCD | BDCE | CDBA | CDBB | CDBC | CDBD | CDBE | BCEA | BCEB | BCEC | BCED | BCEE | BECA | BECB | BECC | BECD | BECE | ECBA | ECBB | ECBC | ECBD | ECBE | EBCA | EBCB | EBCC | EBCD | EBCE | CBEA | CBEB | CBEC | CBED | CBEE | CEBA | CEBB | CEBC | CEBD | CEBE | CDEA | CDEB | CDEC | CDED | CDEE | CEDA | CEDB | CEDC | CEDD | CEDE | EDCA | EDCB | EDCC | EDCD | EDCE | ECDA | ECDB | ECDC | ECDD | ECDE | DECA | DECB | DECC | DECD | DECE | DCEA | DCEC | DCED | DCEE | EEAA | EEAB | EEAC | EEAD | EEAE | EAEA | EAEB | EAEC | EAED | EAEE | AEEA | AEEB | AEEC | AEED | AEEE | EEBA | EEBB | EEBC | EEBD | EEBE | EBEA | EBEB | EBEC | EBED | EBEE | BEEA | BEEB | BEEC | BEED | BEEE | CEEA | CEEB | CEEC | CEED | CEEE | ECEA | ECEB | ECEC | ECED | ECEE | EECA | EECB | EECC | EECD | EECE | DDAA |

DDAB | DDAC | DDAD | DDAE | DADA | DADB | DADC | DADD | DADE | ADDA | ADDB | ADDC | ADDD | ADDE | BDDA | BDDB | BDDC | BDDD | BDDE | DBDA | DBDB | DBDC | DBDD | DBDE | DDBA | DDBB | DDBC | DDBD | DDBE | DDCA | DDCB | DDCC | DDCD | DDCE | CDDA | CDDB | CDDC | CDDD | CDDE | DCDA | DCDB | DCDD | DCDE | BDEA | BDEB | BDEC | BDED | BDEE | BEDA | BEDB | BEDC | BEDD | BEDE | CBCA | CBCB | CBCC | CBCD | CBCE | CCBA | CCBB | CCBC | CCBD | CCBE | DACA | DACB | DACC | DACD | DACE | DBEA | DBEB | DBEC | DBED | DBEE | EACA | EACB | EACC | EACD | EACE | EBDA | EBDB | EBDC | EBDD | EBDE | ECAA | ECAB | ECAC | ECAD | ECAE | EDBA | EDBB | EDBC | EDBD | EDBE | EDEA | EDEB | EDEC | EEDA | EEDB | EEDC | EEEA | EEEB | EEEC | AECA | AECB | AECC | AECD | AECE | DEBA | DEBB | DEBC | DEBD | DEBE

5. A → a
6. B → b
7. C → c
8. D → d
9. E → e

Presented examples of new information systems, supported management processes, are combinations of two, three or four different types of financial ratios. The proposed information systems allow to analyse the following cases [50]:

- excess liquidity,
- optimal liquidity,
- solvency problems.

In UBMARSS systems were proposed the following subclasses [50]:

- UBMARSS-$G_{(ta\text{-}la)}$ – for analysing turnover indicators:
  - v_{ta} – denotes the total asset turnover,
  - v_{la} – denotes the liquid asset turnover,

$$G_{(ta\text{-}la)} = (V_{N(ta\text{-}la)}, V_{T(ta\text{-}la)}, P_{(ta\text{-}la)}, S_{(ta\text{-}la)}) \qquad (7)$$

where:

$V_{N(ta\text{-}la)}$ = {ASSET_TURNOVER1, LOW_TURNOVER1, MEDIUM_TURNOVER1, HIGH_TURNOVER1} – the set of non-terminal symbols,

$V_{T(ta\text{-}la)}$ – denotes the set of terminal symbols:

$V_{T(ta\text{-}la)} = \{a, b, c\}$, where: $a \in [0; 1]$, $b \in (1; 3]$, $c \in (3; +\infty)$

$S_{(ta\text{-}la)} \in V_{N(ta\text{-}la)}$, $S_{(ta\text{-}la)}$ = ASSET_TURNOVER1

$P_{(ta\text{-}la)}$ – denotes the set of productions:

1. ASSET_TURNOVER1 → LOW_TURNOVER1 | MEDIUM_TURNOVER1 | HIGH_TURNOVER1
2. **LOW_TURNOVER1** → AA | AB | AC
3. **MEDIUM_TURNOVER1** → BA | BB | CA
4. **HIGH_TURNOVER1** → BC | CB | CC
5. A → a
6. B → b
7. C → c

- UBMARSS-$G_{(ta\text{-}wa)}$ – for analysing turnover indicators:
  - v_{ta} – denotes the total asset turnover,
  - v_{wa} – denotes the working asset turnover,

$$G_{(ta\text{-}wa)} = (V_{N(ta\text{-}wa)}, V_{T(ta\text{-}wa)}, P_{(ta\text{-}wa)}, S_{(ta\text{-}wa)}) \quad (8)$$

where:

$V_{N(ta\text{-}wa)}$ = {ASSET_TURNOVER2, LOW_TURNOVER2, MEDIUM_TURNOVER2, HIGH_TURNOVER2} – the set of non-terminal symbols,

$V_{T(ta\text{-}wa)}$ – denotes the set of terminal symbols:

$V_{T(ta\text{-}wa)} = \{a, b, c\}$ where: $a \in [0; 1]$, $b \in (1; 3]$, $c \in (3; +\infty)$

$S_{(ta\text{-}wa)} \in V_{N(ta\text{-}wa)}$, $S_{(ta\text{-}wa)}$ = ASSET_TURNOVER2

$P_{(ta\text{-}wa)}$ – denotes the set of productions:

1. ASSET_TURNOVER2 → LOW_TURNOVER2 | MEDIUM_TURNOVER2 | HIGH_TURNOVER2
2. **LOW_TURNOVER2** → AA | AB | AC
3. **MEDIUM_TURNOVER2** → BA | BB | CA
4. **HIGH_TURNOVER2** → BC | CB | CC
5. A → a
6. B → b
7. C → c

- UBMARSS-$G_{(ta\text{-}wa\text{-}la)}$ – for analysing turnover indicators:
  - v_{ta} – denotes the total asset turnover,
  - v_{wa} – denotes the working asset turnover,
  - v_{la} – denotes the liquid asset turnover,

$$G_{(ta\text{-}wa\text{-}la)} = (V_{N(ta\text{-}wa\text{-}la)}, V_{T(ta\text{-}wa\text{-}la)}, P_{(ta\text{-}wa\text{-}la)}, S_{(ta\text{-}wa\text{-}la)}) \quad (9)$$

where:

$V_{N(ta\text{-}wa\text{-}la)}$ = {ASSET_TURNOVER3, LOW_TURNOVER3, MEDIUM_TURNOVER3, HIGH_TURNOVER3} – the set of non-terminal symbols,

$V_{T(ta\text{-}wa\text{-}la)}$ – denotes the set of terminal symbols:

$V_{T(ta\text{-}wa\text{-}la)} = \{a, b, c\}$ where: $a \in [0; 1]$, $b \in (1; 3]$, $c \in (3; +\infty)$

$S_{(ta\text{-}wa\text{-}la)} \in V_{N(ta\text{-}wa\text{-}la)}$, $S_{(ta\text{-}wa\text{-}la)}$ = ASSET_TURNOVER3

$P_{(ta\text{-}wa\text{-}la)}$ – denotes the set of productions:

1. ASSET_TURNOVER3 → LOW_TURNOVER3 | MEDIUM_TURNOVER3 | HIGH_TURNOVER3
2. **LOW_TURNOVER3** → AAA | ABA | ACA | AAB | AAC | BAA | CAA | ABB
3. **MEDIUM_TURNOVER3** → BAB | BBB | BAC | CAB | CAC | ABC | ACB | ACC | BBA | BCA | CBA | CCA
4. **HIGH_TURNOVER3** → BCB | CBB | BBC | CCC | CCB | BCC | CBC
5. A → a
6. B → b
7. C → c

Presented examples of new generation information systems, supported management processes, are combinations of two or three different types of financial ratios. The information systems allow to analyse the following cases [50]:

- low turnover,
- medium turnover,
- high turnover.

In UBMPRSS systems were proposed the following subclasses [50]:

- UBMPRSS-$G_{(rna\text{-}rga\text{-}rgi)}$ – for analysing values:
  - v_{rna} – denotes the return on net assets,
  - v_{rga} – denotes the return on gross assets,
  - v_{rgi} – denotes the return on gross assets including interest,

$$G_{(rna\text{-}rga\text{-}rgi)} = (V_{N(rna\text{-}rga\text{-}rgi)}, V_{T(rna\text{-}rga\text{-}rgi)}, P_{(rna\text{-}rga\text{-}rgi)}, S_{(rna\text{-}rga\text{-}rgi)}) \quad (10)$$

where:

$V_{N(rna\text{-}rga\text{-}rgi)}$ = {PROFITABILITY_1, HIGH_PROFITABILITY1, PROFITABILITY1, UNPROFITABILITY1} – the set of non-terminal symbols,

$V_{T(rna\text{-}rga\text{-}rgi)}$ – denotes the set of terminal symbols:

$V_{T(rna\text{-}rga\text{-}rgi)}$ = {a, b, c} where: a ∈ [-1; 0), b ∈ [0; 0,65), c ∈ [0,65; 1]

$S_{(rna\text{-}rga\text{-}rgi)} \in V_{N(rna\text{-}rga\text{-}rgi)}$, $S_{(rna\text{-}rga\text{-}rgi)}$ = PROFITABILITY_1

$P_{(rna\text{-}rga\text{-}rgi)}$ – denotes the set of productions:

1. PROFITABILITY_1 → HIGH_PROFITABILITY1 | PROFITABILITY1 | UNPROFITABILITY1
2. **HIGH_PROFITABILITY1** → CCC
3. **PROFITABILITY1** → BBB | BBC | BCB | CBB | CBC | BCC | CCB
4. **UNPROFITABILITY1** → AAA | ABA | AAB | ABC | ACB | BAA | BAC | BCA | BAB | ABB | BBA | AAC | ACA | CAA | CAB | CBA | ACC | CAC | CCA
5. A → a
6. B → b
7. C → c

- UBMPRSS-$G_{(rfa\text{-}rwa\text{-}rca)}$ – for analysing values:
  - v_{rfa} – denotes the return on fixed assets,
  - v_{rwa} – denotes the return on working assets,
  - v_{rca} – denotes the return on clear assets,

$$G_{(rfa\text{-}rwa\text{-}rca)} = (V_{N(rfa\text{-}rwa\text{-}rca)}, V_{T(rfa\text{-}rwa\text{-}rca)}, P_{(rfa\text{-}rwa\text{-}rca)}, S_{(rfa\text{-}rwa\text{-}rca)}) \quad (11)$$

where:

$V_{N(rfa\text{-}rwa\text{-}rca)}$ = {PROFITABILITY_2, HIGH_PROFITABILITY2, PROFITABILITY2, UNPROFITABILITY2} – the set of non-terminal symbols,

$V_{T(rfa\text{-}rwa\text{-}rca)}$ – denotes the set of terminal symbols:

$V_{T(rfa\text{-}rwa\text{-}rca)}$ = {a, b, c} where: a ∈ [-1; 0), b ∈ [0; 0,60), c ∈ [0,60; 1]

$S_{(rfa\text{-}rwa\text{-}rca)} \in V_{N(rfa\text{-}rwa\text{-}rca)}$, $S_{(rfa\text{-}rwa\text{-}rca)}$ = PROFITABILITY_2

$P_{(rfa\text{-}rwa\text{-}rca)}$ – denotes the set of productions:

1. PROFITABILITY_2 → HIGH_PROFITABILITY2 | PROFITABILITY2 | UNPROFITABILITY2
2. **HIGH_PROFITABILITY2** → CCC
3. **PROFITABILITY2** → BBB | BBC | BCB | CBB | CBC | BCC | CCB
4. **UNPROFITABILITY2** → AAA | ABA | AAB | ABC | ACB | BAA | BAC | BCA | BAB | ABB | BBA | AAC | ACA | CAA | CAB | CBA | ACC | CAC | CCA
5. A → a
6. B → b
7. C → c

Presented examples of information systems, supported management processes, are combinations of three different types of financial ratios. The proposed system allows to analyse the following cases [50]:

- high profitability,
- profitability (good),
- unprofitability.

In UBMFLRSS systems were proposed the following subclasses [50]:

- UBMFLRSS-$G_{(td\text{-}ld)}$ – for analysing the debt value:
  - v_{td} – denotes the total debt ratio,
  - v_{ld} – denotes he long-term debt ratio,

$$G_{(td\text{-}ld)} = (V_{N(td\text{-}ld)}, V_{T(td\text{-}ld)}, P_{(td\text{-}ld)}, S_{(td\text{-}ld)}) \quad (12)$$

where:

$V_{N(td\text{-}ld)}$ = {DEBT1, HIGH_DEBT1, OPTIMAL_DEBT1, LOW_DEBT1} – the set of non-terminal symbols,

$V_{T(td\text{-}ld)}$ = {a, b, c}– the set of terminal symbols,

where: a $\in$ [0; 0,57), b $\in$ [0,57; 0,67], c $\in$ (0,67; 1]

$S_{(td\text{-}ld)} \in V_{N(td\text{-}ld)}$, $S_{(td\text{-}ld)}$ = DEBT1,

$P_{(td\text{-}ld)}$ – denotes the set of productions:

1. DEBT1 →HIGH_DEBT1 | OPTIMAL_DEBT1 | LOW_DEBT1
2. **HIGH_DEBT1** → BC | CB | CC
3. **OPTIMAL_DEBT1** → BB
4. **LOW_DEBT1** → AA | AB | AC | CA | CB
5. A → a
6. B → b
7. C → c

- UBMFLRSS-$G_{(td\text{-}ls)}$ – for analysing the debt value:
  - v_{td} – denotes the total debt ratio,
  - v_{ls} – denotes the value of the liability structure ratio,

$$G_{(td\text{-}ls)} = (V_{N(td\text{-}ls)}, V_{T(td\text{-}ls)}, P_{(td\text{-}ls)}, S_{(td\text{-}ls)}) \quad (13)$$

where:

$V_{N(td\text{-}ls)}$ = {DEBT2, HIGH_DEBT2, OPTIMAL_DEBT2, LOW_DEBT2} – the set of non-terminal symbols,

$V_{T(td\text{-}ls)}$ = {a, b, c}– the set of terminal symbols,

where: a ∈ [0; 0,57), b ∈ [0,57; 0,67], c ∈ (0,67; 1]

$S_{(td\text{-}ls)} \in V_{N(td\text{-}ls)}$, $S_{(td\text{-}ls)}$ = DEBT2,

$P_{(td\text{-}ls)}$ – set of productions:

1. DEBT2 →HIGH_DEBT2 | OPTIMAL_DEBT2 | LOW_DEBT2
2. **HIGH_DEBT2** → CC
3. **OPTIMAL_DEBT2**→ BB | BC | CB
4. **LOW_DEBT2** → AA | AB | AC | BA | CA
5. A → a
6. B → b
7. C → c

- UBMFLRSS-$G_{(dsc\text{-}ic)}$ – for analysing the debt value:
  - v_{dsc} – denotes the debt service coverage ratio,
  - v_{ic} – denotes the value of the interest coverage ratio,

$$G_{(dsc\text{-}ic)} = (V_{N(dsc\text{-}ic)}, V_{T(dsc\text{-}ic)}, P_{(dsc\text{-}ic)}, S_{(dsc\text{-}ic)}) \qquad (14)$$

where:

$V_{N(dsc\text{-}ic)}$ = {DEBT_SERVICE1, HIGH_DEBTSERVICE1, MEDIUM_DEBTSERVICE1, LOW_DEBTSERVICE1} – the set of non-terminal symbols,

$V_{T(dsc\text{-}ic)}$ = {a, b, c} – the set of terminal symbols,

where: a ∈ [0; 1), b ∈ [1; 1,5], c ∈ (1,5; 2,5]

$S_{(dsc\text{-}ic)} \in V_{N(dsc\text{-}ic)}$, $S_{(dsc\text{-}ic)}$ = DEBT_SERVICE1,

$P_{(dsc\text{-}ic)}$ – set of productions:

1. DEBT_SERVICE1 →HIGH_DEBTSERVICE1 | MEDIUM_DEBTSERVICE1 | LOW_DEBTSERVICE1
2. **HIGH_DEBTSERVICE1** → CC
3. **MEDIUM_DEBTSERVICE1** → BB | BC | CB
4. **LOW_ DEBTSERVICE1** → AA | AB | BA | AC | CA
5. A → a
6. B → b
7. C → c

Presented examples of information systems, supported management processes, are combinations of two different types of financial ratios. The proposed systems allow to analyse the following cases [50]:

- high debt service,
- medium debt service,
- low debt service.

In addition, the semantic description and interpretation was conducted to merge the above selected subclasses of proposed systems. A semantic analysis dedicated to new information systems was proposed for particular classes:

In UBMLRSS-UBMPRSS systems were proposed the following subclasses [50]:

- UBMLRSS-UBMPRSS-$G_{(mp\text{-}irr)}$ for analysing the following ratios:
  - v_{mp} – denotes the value of the mature payables ratio,
  - v_{irr} – denotes the value of the internal rate of return.

A sequential grammar being a grammatical formalism was defined for the above ratio describing the short-term liquidity and profitability of an enterprise [50].

The linguistic formalism has the following form:

$$G_{(mp\text{-}irr)} = (V_{N(mp\text{-}irr)}, V_{T(mp\text{-}irr)}, P_{(mp\text{-}irr)}, S_{(mp\text{-}irr)}) \quad (15)$$

where:

$V_{N(mp\text{-}irr)}$ = {LIQUIDITY_PROFITABILITY_MPIRR,
EXCESS LIQUIDITY_STRONG PROFITABILITY_MPIRR,
EXCESS LIQUIDITY_GOOD PROFITABILITY_MPIRR,
OPTIMAL LIQUIDITY_STRONG PROFITABILITY_MPIRR,
OPTIMAL LIQUIDITY_GOOD PROFITABILITY_MPIRR,
OPTIMAL LIQUIDITY_POOR PROFITABILITY_MPIRR,
SOLVENCY PROBLEMS_POOR PROFITABILITY_MPIRR,
SOLVENCY PROBLEMS_UNPROFITABILITY_MPIRR} – the set of non-terminal symbols,

$V_{T(mp\text{-}irr)}$ = {a, b, c, d, e}, where:

a ∈ [0; 1), b ∈ [1; 1,2], c ∈ (1,2; 2], d ∈ (2; +∞), e ∈ [-1; 0) – the set of terminal symbols,

$S_{(mp\text{-}irr)} \in V_{N(mp\text{-}irr)}$, $S_{(mp\text{-}irr)}$ = LIQUIDITY_PROFITABILITY_MPIRR,

$P_{(mp\text{-}irr)}$ – set of productions:

1. LIQUIDITY_PROFITABILITY_MPIRR →
   EXCESS LIQUIDITY_STRONG PROFITABILITY_MPIRR |
   EXCESS LIQUIDITY_GOOD PROFITABILITY_MPIRR |
   OPTIMAL LIQUIDITY_STRONG PROFITABILITY_MPIRR |
   OPTIMAL LIQUIDITY_GOOD PROFITABILITY_MPIRR |
   OPTIMAL LIQUIDITY_POOR PROFITABILITY_MPIRR |
   SOLVENCY PROBLEMS_POOR PROFITABILITY_MPIRR |
   SOLVENCY PROBLEMS_UNPROFITABILITY_MPIRR
2. **EXCESS LIQUIDITY_STRONG PROFITABILITY_MPIRR** → DC | DD
3. **EXCESS LIQUIDITY_GOOD PROFITABILITY_MPIRR** → DB
4. **OPTIMAL LIQUIDITY_STRONG PROFITABILITY_MPIRR** → BD | CD | BC | CC
5. **OPTIMAL LIQUIDITY_GOOD PROFITABILITY_MPIRR** → BB | CB
6. **OPTIMAL LIQUIDITY_POOR PROFITABILITY_MPIRR** → BA | CA | DA
7. **SOLVENCY PROBLEMS_POOR PROFITABILITY_MPIRR** → AA | AB| AC | AD
8. **SOLVENCY PROBLEMS_UNPROFITABILITY_MPIRR** → EA | EB | EC | ED | EE | AE | BE | CE | DE
9. A → a
10. B → b
11. C → c
12. D → d
13. E → e

- UBMLRSS-UBMPRSS-$G_{(q\text{-}irr)}$ for analysing the following ratios:
  - v_q – denotes the value of the quick ratio,
  - v_{irr} – denotes the value of the internal rate of return,

$$G_{(q\text{-}irr)} = (V_{N(q\text{-}irr)}, V_{T(q\text{-}irr)}, P_{(q\text{-}irr)}, S_{(q\text{-}irr)}) \qquad (16)$$

where:

$V_{N(q\text{-}irr)}$ = {LIQUIDITY_PROFITABILITY_QIRR,
EXCESS LIQUIDITY_STRONG PROFITABILITY_QIRR,
EXCESS LIQUIDITY_GOOD PROFITABILITY_QIRR,
OPTIMAL LIQUIDITY_STRONG PROFITABILITY_QIRR,
OPTIMAL LIQUIDITY_GOOD PROFITABILITY_QIRR,
OPTIMAL LIQUIDITY_POOR PROFITABILITY_QIRR,
SOLVENCY PROBLEMS_GOOD PROFITABILITY_QIRR,
SOLVENCY PROBLEMS_POOR PROFITABILITY_QIRR,
SOLVENCY PROBLEMS_UNPROFITABILITY_QIRR} – the set of non-terminal symbols,

$V_{T(q\text{-}irr)}$ = {a, b, c, d, e}, where:

a ∈ [0; 1), b ∈ [1; 1,2], c ∈ (1,2; 2], d ∈ (2; +∞), e ∈ [-1; 0) – the set of terminal symbols,

$S_{(q\text{-}irr)} \in V_{N(q\text{-}irr)}$, $S_{(q\text{-}irr)}$ = LIQUIDITY_PROFITABILITY_QIRR,

$P_{(q\text{-}irr)}$ – set of productions:

1. LIQUIDITY_PROFITABILITY_QIRR →
   EXCESS LIQUIDITY_STRONG PROFITABILITY_QIRR |
   EXCESS LIQUIDITY_GOOD PROFITABILITY_QIRR |
   OPTIMAL LIQUIDITY_STRONG PROFITABILITY_QIRR |
   OPTIMAL LIQUIDITY_GOOD PROFITABILITY_QIRR |
   OPTIMAL LIQUIDITY_POOR PROFITABILITY_QIRR |
   SOLVENCY PROBLEMS_GOOD PROFITABILITY_QIRR |
   SOLVENCY PROBLEMS_POOR PROFITABILITY_QIRR |
   SOLVENCY PROBLEMS_UNPROFITABILITY_QIRR
2. **EXCESS LIQUIDITY_STRONG PROFITABILITY_QIRR** → DC | DD
3. **EXCESS LIQUIDITY_GOOD PROFITABILITY_QIRR** → DB
4. **OPTIMAL LIQUIDITY_STRONG PROFITABILITY_QIRR** → BD | CD | BC | CC
5. **OPTIMAL LIQUIDITY_GOOD PROFITABILITY_QIRR** → BB | CB
6. **OPTIMAL LIQUIDITY_POOR PROFITABILITY_QIRR** → BA | CA | DA
7. **SOLVENCY PROBLEMS_GOOD PROFITABILITY_QIRR** → AB | AC | AD
8. **SOLVENCY PROBLEMS_POOR PROFITABILITY_QIRR** → AA
9. **SOLVENCY PROBLEMS_UNPROFITABILITY_QIRR** → EA | EB | EC | ED | EE | AE | BE | CE | DE
10. A → a
11. B → b
12. C → c
13. D → d
14. E → e

- UBMLRSS-UBMPRSS-$G_{(mp\text{-}q\text{-}irr)}$ for analysing the following ratios:
  - v_{mp} – denotes the value of the mature payables ratio,
  - v_q – denotes the value of the quick ratio,
  - v_{irr} – denotes the value of the internal rate of return,

$$G_{(mp\text{-}q\text{-}irr)} = (V_{N(mp\text{-}q\text{-}irr)}, V_{T(mp\text{-}q\text{-}irr)}, P_{(mp\text{-}q\text{-}irr)}, S_{(mp\text{-}q\text{-}irr)}) \quad (17)$$

where:

$V_{N(mp\text{-}q\text{-}irr)}$ = {LIQUIDITY_PROFITABILITY_MPQIRR,
EXCESS LIQUIDITY_STRONG PROFITABILITY_MPQIRR,
EXCESS LIQUIDITY_GOOD PROFITABILITY_MPQIRR,
OPTIMAL LIQUIDITY_STRONG PROFITABILITY_MPQIRR,
OPTIMAL LIQUIDITY_GOOD PROFITABILITY_MPQIRR,
OPTIMAL LIQUIDITY_POOR PROFITABILITY_MPQIRR,
SOLVENCY PROBLEMS_POOR PROFITABILITY_MPQIRR,
SOLVENCY PROBLEMS_UNPROFITABILITY_MPQIRR} – the set of non-terminal symbols,

$V_{T(mp\text{-}q\text{-}irr)}$ = {a, b, c, d}, where:

a ∈ [0; 1), b ∈ [1; 2], c ∈ (2; +∞), d ∈ [-1; 0) – the set of terminal symbols,

$S_{(mp\text{-}q\text{-}irr)} \in V_{N(mp\text{-}q\text{-}irr)}$, $S_{(mp\text{-}q\text{-}irr)}$ = LIQUIDITY_PROFITABILITY_MPQIRR,

$P_{(mp\text{-}q\text{-}irr)}$ – set of productions:

1. LIQUIDITY_PROFITABILITY_MPQIRR →
   EXCESS LIQUIDITY_STRONG PROFITABILITY_MPQIRR |
   EXCESS LIQUIDITY_GOOD PROFITABILITY_MPQIRR |
   OPTIMAL LIQUIDITY_STRONG PROFITABILITY_MPQIRR |
   OPTIMAL LIQUIDITY_GOOD PROFITABILITY_MPQIRR |
   OPTIMAL LIQUIDITY_POOR PROFITABILITY_MPQIRR |
   SOLVENCY PROBLEMS_POOR PROFITABILITY_MPQIRR |
   SOLVENCY PROBLEMS_UNPROFITABILITY_MPQIRR
2. **EXCESS LIQUIDITY_STRONG PROFITABILITY_MPQIRR** → CCC
3. **EXCESS LIQUIDITY_GOOD PROFITABILITY_MPQIRR** → CCB | CBC | BCC
4. **OPTIMAL LIQUIDITY_STRONG PROFITABILITY_MPQIRR** → BBC | BCB | CBB
5. **OPTIMAL LIQUIDITY_GOOD PROFITABILITY_MPQIRR** → BBB | BAB | BAC | ABC | CAB | BCA | ACB | CBA | ABB
6. **OPTIMAL LIQUIDITY_POOR PROFITABILITY_MPQIRR** → BBA | ACC | CAC | CCA
7. **SOLVENCY PROBLEMS_POOR PROFITABILITY_MPQIRR** → AAA | ABA | ACA | BAA | CAA | AAB | AAC
8. **SOLVENCY PROBLEMS_UNPROFITABILITY_MPQIRR** → AAD | ABD | ACD | ADD | ADA | BAD | BBD | BCD | BDD | CAD | CBD | CCD | CDD | DAD | DBD | DCD | DDD | ADB | ADC | BDA | BDB | BDC | CDA | CDB | CDC | DAA | DAB | DAC | DBA | DBB | DBC | DCA | DCB | DCC | DDA | DDB | DDC
9. A → a
10. B → b
11. C → c
12. D → d

- UBMLRSS-UBMPRSS-$G_{(cu\text{-}irr)}$ for analysing the following ratios:
  - v_{cu} – denotes the value of the current ratio,
  - v_{irr} – denotes the value of the internal rate of return,

$$G_{(cu\text{-}irr)} = (V_{N(cu\text{-}irr)}, V_{T(cu\text{-}irr)}, P_{(cu\text{-}irr)}, S_{(cu\text{-}irr)}) \qquad (18)$$

where:

$V_{N(cu\text{-}irr)}$ = {LIQUIDITY_PROFITABILITY_CUIRR,
EXCESS LIQUIDITY_STRONG PROFITABILITY_CUIRR,
EXCESS LIQUIDITY_GOOD PROFITABILITY_CUIRR,
EXCESS LIQUIDITY_POOR PROFITABILITY_CUIRR,
OPTIMAL LIQUIDITY_STRONG PROFITABILITY_CUIRR,
OPTIMAL LIQUIDITY_GOOD PROFITABILITY_CUIRR,
SOLVENCY PROBLEMS_GOOD PROFITABILITY_CUIRR,
SOLVENCY PROBLEMS_POOR PROFITABILITY_CUIRR,
SOLVENCY PROBLEMS_UNPROFITABILITY_CUIRR} – the set of non-terminal symbols,

$V_{T(cu\text{-}irr)}$ = {a, b, c, d, e}, where:

a ∈ [0; 1), b ∈ [1; 1,2], c ∈ (1,2; 2], d ∈ (2; +∞), e ∈ [-1; 0) – the set of terminal symbols,

$S_{(cu\text{-}irr)} \in V_{N(cu\text{-}irr)}$, $S_{(cu\text{-}irr)}$ = LIQUIDITY_PROFITABILITY_CUIRR,

$P_{(cu\text{-}irr)}$ – set of productions:

1. LIQUIDITY_PROFITABILITY_CUIRR →
   EXCESS LIQUIDITY_STRONG PROFITABILITY_CUIRR |
   EXCESS LIQUIDITY_GOOD PROFITABILITY_CUIRR |
   EXCESS LIQUIDITY_POOR PROFITABILITY_CUIRR |
   OPTIMAL LIQUIDITY_STRONG PROFITABILITY_CUIRR |
   OPTIMAL LIQUIDITY_GOOD PROFITABILITY_CUIRR |
   SOLVENCY PROBLEMS_GOOD PROFITABILITY_CUIRR |
   SOLVENCY PROBLEMS_POOR PROFITABILITY_CUIRR |
   SOLVENCY PROBLEMS_UNPROFITABILITY_CUIRR
2. **EXCESS LIQUIDITY_STRONG PROFITABILITY_CUIRR** → DC | DD
3. **EXCESS LIQUIDITY_GOOD PROFITABILITY_CUIRR** → DB
4. **EXCESS LIQUIDITY_POOR PROFITABILITY_CUIRR** → CA
5. **OPTIMAL LIQUIDITY_STRONG PROFITABILITY_CUIRR** → BD | CD | BC | CC
6. **OPTIMAL LIQUIDITY_GOOD PROFITABILITY_CUIRR** → BB | CB | BA | CA
7. **SOLVENCY PROBLEMS_GOOD PROFITABILITY_CUIRR** → AB | AC | AD
8. **SOLVENCY PROBLEMS_POOR PROFITABILITY_CUIRR** → AA
9. **SOLVENCY PROBLEMS_UNPROFITABILITY_CUIRR** → EA | EB | EC | ED | EE | AE | BE | CE | DE
10. A → a
11. B → b
12. C → c
13. D → d
14. E → e

- UBMLRSS-UBMPRSS-$G_{(cu\text{-}q\text{-}irr)}$ for analysing the following ratios:
  - v_{cu} – denotes the value of the current ratio,
  - v_q – denotes the value of the quick ratio,
  - v_{irr} – denotes the value of the internal rate of return,

$$G_{(cu\text{-}q\text{-}irr)} = (V_{N(cu\text{-}q\text{-}irr)}, V_{T(cu\text{-}q\text{-}irr)}, P_{(cu\text{-}q\text{-}irr)}, S_{(cu\text{-}q\text{-}irr)}) \qquad (19)$$

where:

$V_{N(cu\text{-}q\text{-}irr)}$ = {LIQUIDITY_PROFITABILITY_CUQIRR,
EXCESS LIQUIDITY_STRONG PROFITABILITY_CUQIRR,
EXCESS LIQUIDITY_GOOD PROFITABILITY_CUQIRR,
EXCESS LIQUIDITY_POOR PROFITABILITY_CUQIRR,
OPTIMAL LIQUIDITY_STRONG PROFITABILITY_CUQIRR,
OPTIMAL LIQUIDITY_GOOD PROFITABILITY_CUQIRR,
OPTIMAL LIQUIDITY_POOR PROFITABILITY_CUQIRR,
SOLVENCY PROBLEMS_POOR PROFITABILITY_CUQIRR,

SOLVENCY PROBLEMS_UNPROFITABILITY_CUQIRR} – the set of non-terminal symbols,

$V_{T(cu\text{-}q\text{-}irr)}$ = {a, b, c, d}, where:

a ∈ [0; 1), b ∈ [1; 2], c ∈ (2; +∞), d ∈ [-1; 0) – the set of terminal symbols,

$S_{(cu\text{-}q\text{-}irr)} \in V_{N(cu\text{-}q\text{-}irr)}$, $S_{(cu\text{-}q\text{-}irr)}$ = LIQUIDITY_PROFITABILITY_CUQIRR,

$P_{(cu\text{-}q\text{-}irr)}$ – set of productions:

1. LIQUIDITY_PROFITABILITY_CUQIRR →
   EXCESS LIQUIDITY_STRONG PROFITABILITY_CUQIRR |
   EXCESS LIQUIDITY_GOOD PROFITABILITY_CUQIRR |
   EXCESS LIQUIDITY_POOR PROFITABILITY_CUQIRR |
   OPTIMAL LIQUIDITY_STRONG PROFITABILITY_CUQIRR |
   OPTIMAL LIQUIDITY_GOOD PROFITABILITY_CUQIRR |
   OPTIMAL LIQUIDITY_POOR PROFITABILITY_CUQIRR |
   SOLVENCY PROBLEMS_POOR PROFITABILITY_CUQIRR |
   SOLVENCY PROBLEMS_UNPROFITABILITY_CUQIRR
2. **EXCESS LIQUIDITY_STRONG PROFITABILITY_CUQIRR** → CCC
3. **EXCESS LIQUIDITY_GOOD PROFITABILITY_CUQIRR** → CCB | CBC | BCC
4. **EXCESS LIQUIDITY_POOR PROFITABILITY_CUQIRR** → CCA
5. **OPTIMAL LIQUIDITY_STRONG PROFITABILITY_CUQIRR** → BBC | BCB | CBB
6. **OPTIMAL LIQUIDITY_GOOD PROFITABILITY_CUQIRR** → BBB | BAB | BAC | ABC | CAB | BCA | ACB | CBA | ABB
7. **OPTIMAL LIQUIDITY_POOR PROFITABILITY_CUQIRR** → BBA | ACC | CAC
8. **SOLVENCY PROBLEMS_POOR PROFITABILITY_CUQIRR** → AAA | ABA | ACA | BAA | CAA | AAB | AAC
9. **SOLVENCY PROBLEMS_UNPROFITABILITY_CUQIRR** → AAD | ABD | ACD | ADD | ADA | BAD | BBD | BCD | BDD | CAD | CBD | CCD | CDD | DAD | DBD | DCD | DDD | ADB | ADC | BDA | BDB | BDC | CDA | CDB | CDC | DAA | DAB | DAC | DBA | DBB | DBC | DCA | DCB | DCC | DDA | DDB | DDC
10. A → a
11. B → b
12. C → c
13. D → d

- UBMLRSS-UBMPRSS-$G_{(ca\text{-}irr)}$ for analysing the following ratios:
  - v_{ca} – denotes the value of the cash ratio,
  - v_{irr} – denotes the value of the internal rate of return,

$$G_{(ca\text{-}irr)} = (V_{N(ca\text{-}irr)}, V_{T(ca\text{-}irr)}, P_{(ca\text{-}irr)}, S_{(ca\text{-}irr)}) \quad (20)$$

where:

$V_{N(ca\text{-}irr)}$ = {LIQUIDITY_PROFITABILITY_CAIRR,
EXCESS LIQUIDITY_STRONG PROFITABILITY_CAIRR,

EXCESS LIQUIDITY_GOOD PROFITABILITY_CAIRR,
EXCESS LIQUIDITY_POOR PROFITABILITY_CAIRR,
OPTIMAL LIQUIDITY_STRONG PROFITABILITY_CAIRR,
OPTIMAL LIQUIDITY_GOOD PROFITABILITY_CAIRR,
OPTIMAL LIQUIDITY_POOR PROFITABILITY_CAIRR,
SOLVENCY PROBLEMS_GOOD PROFITABILITY_CAIRR,
SOLVENCY PROBLEMS_POOR PROFITABILITY_CAIRR,
SOLVENCY PROBLEMS_UNPROFITABILITY_CAIRR} – the set of non-terminal symbols,

$V_{T(ca\text{-}irr)}$ = {a, b, c, d, e}, where:

a ∈ [0; 1), b ∈ [1; 1,2], c ∈ (1,2; 2], d ∈ (2; +∞), e ∈ [-1; 0) – the set of terminal symbols,

$S_{(ca\text{-}irr)} \in V_{N(ca\text{-}irr)}$, $S_{(ca\text{-}irr)}$ = LIQUIDITY_PROFITABILITY_CAIRR,

$P_{(ca\text{-}irr)}$ – set of productions:

1. LIQUIDITY_PROFITABILITY_CAIRR →
   EXCESS LIQUIDITY_STRONG PROFITABILITY_CAIRR |
   EXCESS LIQUIDITY_GOOD PROFITABILITY_CAIRR |
   EXCESS LIQUIDITY_POOR PROFITABILITY_CAIRR |
   OPTIMAL LIQUIDITY_STRONG PROFITABILITY_CAIRR |
   OPTIMAL LIQUIDITY_GOOD PROFITABILITY_CAIRR |
   OPTIMAL LIQUIDITY_POOR PROFITABILITY_CAIRR |
   SOLVENCY PROBLEMS_GOOD PROFITABILITY_CAIRR |
   SOLVENCY PROBLEMS_POOR PROFITABILITY_CAIRR |
   SOLVENCY PROBLEMS_UNPROFITABILITY_CAIRR
2. **EXCESS LIQUIDITY_STRONG PROFITABILITY_CAIRR** → DC | DD
3. **EXCESS LIQUIDITY_GOOD PROFITABILITY_CAIRR** → DB
4. **EXCESS LIQUIDITY_POOR PROFITABILITY_CAIRR** → DA
5. **OPTIMAL LIQUIDITY_STRONG PROFITABILITY_CAIRR** → BD | CD | BC | CC
6. **OPTIMAL LIQUIDITY_GOOD PROFITABILITY_CAIRR** → BB | CB
7. **OPTIMAL LIQUIDITY_POOR PROFITABILITY_CAIRR** → BA | CA
8. **SOLVENCY PROBLEMS_GOOD PROFITABILITY_CAIRR** → AB | AC | AD
9. **SOLVENCY PROBLEMS_POOR PROFITABILITY_CAIRR** → AA
10. **SOLVENCY PROBLEMS_UNPROFITABILITY_CAIRR** → EA | EB | EC | ED | EE | AE | BE | CE | DE
11. A → a
12. B → b
13. C → c
14. D → d
15. E → e

- UBMLRSS-UBMPRSS-$G_{(ca\text{-}q\text{-}irr)}$ for analysing the following ratios:
  - v_{ca} – denotes the value of the cash ratio,
  - v_q – denotes the value of the quick ratio,
  - v_{irr} – denotes the value of the internal rate of return,

$$G_{(ca\text{-}q\text{-}irr)} = (V_{N(ca\text{-}q\text{-}irr)}, V_{T(ca\text{-}q\text{-}irr)}, P_{(ca\text{-}q\text{-}irr)}, S_{(ca\text{-}q\text{-}irr)}) \quad (21)$$

where:

$V_{N(ca\text{-}q\text{-}irr)}$ = {LIQUIDITY_PROFITABILITY_CAQIRR,
EXCESS LIQUIDITY_STRONG PROFITABILITY_CAQIRR,
EXCESS LIQUIDITY_GOOD PROFITABILITY_CAQIRR,
EXCESS LIQUIDITY_POOR PROFITABILITY_CAQIRR,
OPTIMAL LIQUIDITY_STRONG PROFITABILITY_CAQIRR,
OPTIMAL LIQUIDITY_GOOD PROFITABILITY_CAQIRR,
OPTIMAL LIQUIDITY_POOR PROFITABILITY_CAQIRR,
SOLVENCY PROBLEMS_GOOD PROFITABILITY_CAQIRR,
SOLVENCY PROBLEMS_POOR PROFITABILITY_CAQIRR,
SOLVENCY PROBLEMS_UNPROFITABILITY_CAQIRR} – the set of non-terminal symbols,

$V_{T(ca\text{-}q\text{-}irr)}$ = {a, b, c, d}, where:

a $\in$ [0; 1), b $\in$ [1; 2], c $\in$ (2; +∞), d $\in$ [-1; 0) – the set of terminal symbols,

$S_{(ca\text{-}q\text{-}irr)} \in V_{N(ca\text{-}q\text{-}irr)}$, $S_{(ca\text{-}q\text{-}irr)}$ = LIQUIDITY_PROFITABILITY_CAQIRR,

$P_{(ca\text{-}q\text{-}irr)}$ – set of productions:

1. LIQUIDITY_PROFITABILITY_CAQIRR →
   EXCESS LIQUIDITY_STRONG PROFITABILITY_CAQIRR |
   EXCESS LIQUIDITY_GOOD PROFITABILITY_CAQIRR |
   EXCESS LIQUIDITY_POOR PROFITABILITY_CAQIRR |
   OPTIMAL LIQUIDITY_STRONG PROFITABILITY_CAQIRR |
   OPTIMAL LIQUIDITY_GOOD PROFITABILITY_CAQIRR |
   OPTIMAL LIQUIDITY_POOR PROFITABILITY_CAQIRR |
   SOLVENCY PROBLEMS_GOOD PROFITABILITY_CAQIRR |
   SOLVENCY PROBLEMS_POOR PROFITABILITY_CAQIRR |
   SOLVENCY PROBLEMS_UNPROFITABILITY_CAQIRR
2. **EXCESS LIQUIDITY_STRONG PROFITABILITY_CAQIRR** → CCC
3. **EXCESS LIQUIDITY_GOOD PROFITABILITY_CAQIRR** → CCB | CBC | BCC
4. **EXCESS LIQUIDITY_POOR PROFITABILITY_CAQIRR** → CCA
5. **OPTIMAL LIQUIDITY_STRONG PROFITABILITY_CAQIRR** → BBC | BCB | CBB
6. **OPTIMAL LIQUIDITY_GOOD PROFITABILITY_CAQIRR** → BBB | BAB | BAC | ABC | CAB | BCA | ACB | CBA | ABB
7. **OPTIMAL LIQUIDITY_POOR PROFITABILITY_CAQIRR** → BBA | ACC | CAC
8. **SOLVENCY PROBLEMS_GOOD PROFITABILITY_CAQIRR** → AAB | AAC
9. **SOLVENCY PROBLEMS_POOR PROFITABILITY_CAQIRR** → AAA | ABA | ACA | BAA | CAA
10. **SOLVENCY PROBLEMS_UNPROFITABILITY_CAQIRR** → AAD | ABD | ACD | ADD | ADA | BAD | BBD | BCD | BDD | CAD | CBD | CCD | CDD | DAD | DBD | DCD | DDD | ADB | ADC | BDA | BDB | BDC | CDA | CDB | CDC | DAA | DAB | DAC | DBA | DBB | DBC | DCA | DCB | DCC | DDA | DDB | DDC
11. A → a
12. B → b
13. C → c
14. D → d

Presented examples of new information systems, supported management processes, are combinations of two or three different types of financial liquidity ratios, profitability ratios and asset turnover indicators. The proposed systems allow to analyse the following cases [50]:

- excess liquidity and strong/good/poor profitability,
- optimal liquidity and strong/good/poor profitability,
- solvency problems and good/poor profitability,
- solvency problems and unprofitability.

In UBMARSS-UBMPRSS systems were proposed the following subclasses [50]:

- UBMARSS-UBMPRSS-$G_{(ta\text{-}irr)}$ for analysing the following ratios:
  - v_{ta} – denotes the value of the total asset turnover indicator,
  - v_{irr} – denotes the value of the internal rate of return.

A sequential grammar formalism for this example has the following form:

$$G_{(ta\text{-}irr)} = (V_{N(ta\text{-}irr)}, V_{T(ta\text{-}irr)}, P_{(ta\text{-}irr)}, S_{(ta\text{-}irr)}) \qquad (22)$$

where:

$V_{N(ta\text{-}irr)}$ = {ASSET TURNOVER_PROFITABILITY_TAIRR,
HIGH TURNOVER_STRONG PROFITABILITY_TAIRR,
HIGH TURNOVER_GOOD PROFITABILITY_TAIRR,
MEDIUM TURNOVER_STRONG PROFITABILITY_TAIRR,
MEDIUM TURNOVER_GOOD PROFITABILITY_TAIRR,
MEDIUM TURNOVER_POOR PROFITABILITY_TAIRR,
LOW TURNOVER_POOR PROFITABILITY_TAIRR,
LOW TURNOVER_UNPROFITABILITY_TAIRR} – the set of non-terminal symbols,

$V_{T(ta\text{-}irr)}$ = {a, b, c, d, e}, where:

$a \in [0; 1)$, $b \in [1; 2]$, $c \in (2; 3]$, $d \in (3; +\infty)$, $e \in [-1; 0)$ – the set of terminal symbols,

$S_{(ta\text{-}irr)} \in V_{N(ta\text{-}irr)}$, $S_{(ta\text{-}irr)}$ = ASSET TURNOVER_PROFITABILITY_TAIRR,

$P_{(ta\text{-}irr)}$ – set of productions:

1. ASSET TURNOVER_PROFITABILITY_TAIRR →
HIGH TURNOVER_STRONG PROFITABILITY_TAIRR |
HIGH TURNOVER_GOOD PROFITABILITY_TAIRR |
MEDIUM TURNOVER_STRONG PROFITABILITY_TAIRR |
MEDIUM TURNOVER_GOOD PROFITABILITY_TAIRR |

MEDIUM TURNOVER_POOR PROFITABILITY_TAIRR |
LOW TURNOVER_POOR PROFITABILITY_TAIRR |
LOW TURNOVER_UNPROFITABILITY_TAIRR

2. **HIGH TURNOVER_STRONG PROFITABILITY_TAIRR** → DC | DD
3. **HIGH TURNOVER_GOOD PROFITABILITY_TAIRR** → DA | DB
4. **MEDIUM TURNOVER_STRONG PROFITABILITY_TAIRR** → BC | BD | CC | CD
5. **MEDIUM TURNOVER_GOOD PROFITABILITY_TAIRR** → BB | CB | AC | AD
6. **MEDIUM TURNOVER_POOR PROFITABILITY_TAIRR** → BA | CA
7. **LOW TURNOVER_POOR PROFITABILITY_TAIRR** → AA | AB
8. **LOW TURNOVER_UNPROFITABILITY_TAIRR** → EA | EB | EC | ED | EE | AE | BE | CE | DE
9. A → a
10. B → b
11. C → c
12. D → d
13. E → e

- UBMARSS-UBMPRSS-$G_{(wa\text{-}irr)}$ for analysing the following ratios:
  - v_{wa} – denotes the value of the working asset turnover indicator,
  - v_{irr} – denotes the value of the internal rate of return.

A sequential grammar being a grammatical formalism was defined for the above ratio describing the activity and profitability of an enterprise [50].

The linguistic formalism has the following form:

$$G_{(wa\text{-}irr)} = (V_{N(wa\text{-}irr)}, V_{T(wa\text{-}irr)}, P_{(wa\text{-}irr)}, S_{(wa\text{-}irr)}) \qquad (23)$$

where:

$V_{N(wa\text{-}irr)}$ = {ASSET TURNOVER_PROFITABILITY_WAIRR,
HIGH TURNOVER_STRONG PROFITABILITY_WAIRR,
HIGH TURNOVER_GOOD PROFITABILITY_WAIRR,
MEDIUM TURNOVER_STRONG PROFITABILITY_WAIRR,
MEDIUM TURNOVER_GOOD PROFITABILITY_WAIRR,
MEDIUM TURNOVER_POOR PROFITABILITY_WAIRR,
LOW TURNOVER_GOOD PROFITABILITY_WAIRR,
LOW TURNOVER_POOR PROFITABILITY_WAIRR,
LOW TURNOVER_UNPROFITABILITY_WAIRR} – the set of non-terminal symbols,

$V_{T(wa\text{-}irr)}$ = {a, b, c, d, e}, where:

a ∈ [0; 1), b ∈ [1; 2], c ∈ (2; 3], d ∈ (3; +∞), e ∈ [-1; 0) – the set of terminal symbols,

$S_{(wa\text{-}irr)} \in V_{N(wa\text{-}irr)}$, $S_{(wa\text{-}irr)}$ = ASSET TURNOVER_PROFITABILITY_WAIRR,

$P_{(wa\text{-}irr)}$ – set of productions:

1. ASSET TURNOVER_PROFITABILITY_WAIRR →
HIGH TURNOVER_STRONG PROFITABILITY_WAIRR |
HIGH TURNOVER_GOOD PROFITABILITY_WAIRR |
MEDIUM TURNOVER_STRONG PROFITABILITY_WAIRR |
MEDIUM TURNOVER_GOOD PROFITABILITY_WAIRR |
MEDIUM TURNOVER_POOR PROFITABILITY_WAIRR |
LOW TURNOVER_GOOD PROFITABILITY_WAIRR |
LOW TURNOVER_POOR PROFITABILITY_WAIRR |
LOW TURNOVER_UNPROFITABILITY_WAIRR
2. **HIGH TURNOVER_STRONG PROFITABILITY_WAIRR** → DC | DD
3. **HIGH TURNOVER_GOOD PROFITABILITY_WAIRR** → DA | DB
4. **MEDIUM TURNOVER_STRONG PROFITABILITY_WAIRR** → BC | BD | CC | CD
5. **MEDIUM TURNOVER_GOOD PROFITABILITY_WAIRR** → BB | CB
6. **MEDIUM TURNOVER_POOR PROFITABILITY_WAIRR** → BA | CA
7. **LOW TURNOVER_GOOD PROFITABILITY_WAIRR** → AB | AC | AD
8. **LOW TURNOVER_POOR PROFITABILITY_WAIRR** → AA
9. **LOW TURNOVER_UNPROFITABILITY_WAIRR** → EA | EB | EC | ED | EE | AE | BE | CE | DE
10. A → a
11. B → b
12. C → c
13. D → d
14. E → e

- UBMARSS-UBMPRSS-$G_{(ta\text{-}wa\text{-}irr)}$ for analysing the following ratios:
  - v_{ta} – denotes the value of the total asset turnover indicator,
  - v_{wa} – denotes the value of the working asset turnover indicator,
  - v_{irr} – denotes the value of the internal rate of return.

A sequential grammar formalism for this example has the following form:

$$G_{(ta\text{-}wa\text{-}irr)} = (V_{N(ta\text{-}wa\text{-}irr)}, V_{T(ta\text{-}wa\text{-}irr)}, P_{(ta\text{-}wa\text{-}irr)}, S_{(ta\text{-}wa\text{-}irr)}) \qquad (24)$$

where:

$V_{N(ta\text{-}wa\text{-}irr)}$ = {ASSET TURNOVER_PROFITABILITY_TAWAIRR,
HIGH TURNOVER_STRONG PROFITABILITY_TAWAIRR,
HIGH TURNOVER_GOOD PROFITABILITY_TAWAIRR,
MEDIUM TURNOVER_STRONG PROFITABILITY_TAWAIRR,
MEDIUM TURNOVER_GOOD PROFITABILITY_TAWAIRR,
MEDIUM TURNOVER_POOR PROFITABILITY_TAWAIRR,
LOW TURNOVER_GOOD PROFITABILITY_TAWAIRR,
LOW TURNOVER_POOR PROFITABILITY_TAWAIRR,
LOW TURNOVER_UNPROFITABILITY_TAWAIRR} – the set of non-terminal symbols,

$V_{T(ta\text{-}wa\text{-}irr)}$ = {a, b, c, d}, where:

a ∈ [0; 1), b ∈ [1; 3], c ∈ (3; +∞), d ∈ [-1; 0) – the set of terminal symbols,

$S_{(ta\text{-}wa\text{-}irr)} \in V_{N(ta\text{-}wa\text{-}irr)}$, $S_{(ta\text{-}wa\text{-}irr)}$ = ASSET TURNOVER_PROFITABILITY_TAWAIRR,

$P_{(ta\text{-}wa\text{-}irr)}$ – set of productions:

1. ASSET TURNOVER_PROFITABILITY_TAWAIRR →
   HIGH TURNOVER_STRONG PROFITABILITY_TAWAIRR |
   HIGH TURNOVER_GOOD PROFITABILITY_TAWAIRR |
   MEDIUM TURNOVER_STRONG PROFITABILITY_TAWAIRR |
   MEDIUM TURNOVER_GOOD PROFITABILITY_TAWAIRR |
   MEDIUM TURNOVER_POOR PROFITABILITY_TAWAIRR |
   LOW TURNOVER_GOOD PROFITABILITY_TAWAIRR |
   LOW TURNOVER_POOR PROFITABILITY_TAWAIRR |
   LOW TURNOVER_UNPROFITABILITY_TAWAIRR
2. **HIGH TURNOVER_STRONG PROFITABILITY_TAWAIRR** → CCC | BCC | CBC
3. **HIGH TURNOVER_GOOD PROFITABILITY_TAWAIRR** → CCA | CCB | CBB
4. **MEDIUM TURNOVER_STRONG PROFITABILITY_TAWAIRR** → BBC | ACC | BAC | BCB | CAC
5. **MEDIUM TURNOVER_GOOD PROFITABILITY_TAWAIRR** → BBB | ABB | ABC | ACB | BAB | CAB
6. **MEDIUM TURNOVER_POOR PROFITABILITY_TAWAIRR** → BBA | ACA | BAA | BCA | CAA | CBA
7. **LOW TURNOVER_GOOD PROFITABILITY_TAWAIRR** → AAB | AAC
8. **LOW TURNOVER_POOR PROFITABILITY_TAWAIRR** → AAA | ABA
9. **LOW TURNOVER_UNPROFITABILITY_TAWAIRR** → AAD | ABD | ACD | ADD | BAD | BBD | BCD | BDD | CAD | CBD | CCD | CDD | DAD | DBD | DCD | DDD | ADA | ADB | ADC | BDA | BDB | BDC | CDA | CDB | CDC | DAA | DAB | DAC | DBA | DBB | DBC | DCA | DCB | DCC | DDA | DDB | DDC
10. A → a
11. B → b
12. C → c
13. D → d

Presented examples of new information systems, supported management processes, are combinations of two or three different types of financial ratios. The proposed systems allow to analyse the following cases [50]:

- high turnover and strong/good profitability,
- medium turnover and strong/good/poor profitability,
- low turnover and good/poor profitability,
- low turnover and unprofitability.

Examples of systems for the semantic description and analysis of data dedicated to supporting processes of managing information show how these processes can be improved and in what area they can be applied. The presented examples of information systems related to analyses of selected types of data whose analysis is based on interpreting the current standing and projecting the future one. The determinants of the described standing are recognised by the system as one of a whole group of factors which influence the future condition of the analysed entity [50].

The main idea of presented information systems was the improve the management processes of data sets. The new classes of information systems supporting the management processes by [50]:

- analysis of the internal/external situation of the company, and also predicting the future situation,
- improving decision-making processes and supporting strategic decisions,
- supporting enterprise management processes in the local and global aspects.

The main measure for assessing new types of information systems supporting management processes and dedicated to analysing information contained in sets of financial ratios is the effectiveness of the proposed solutions [50].

The comparison of presented information systems supporting management processes by semantic description and analysis of financial ratios presents Fig. 4.5.

Class of systems	Sub-class of systems	Simple class of systems	Combined class of systems	Kind of analysed financial ratios				Number of analysed ratios	Name of analysed ratio
				Turnover ratio	*Financial leverage ratio*	*Profitability ratio*	*Liquidity ratio*		
UBMLRSS	UBMLRSS-$G_{(cu\text{-}q)}$	**x**	-	-	-	-	**x**	2	the current ratio the quick ratio
	UBMLRSS-$G_{(cu\text{-}q\text{-}ca)}$	**x**	-	-	-	-	**x**	3	the current ratio the quick ratio the cash ratio
	UBMLRSS-$G_{(cu\text{-}q\text{-}mp)}$	**x**	-	-	-	-	**x**	3	the current ratio the quick ratio the mature payables ratio
	UBMLRSS-$G_{(cu\text{-}ca\text{-}mp)}$	**x**	-	-	-	-	**x**	3	the current ratio the cash ratio the mature payables ratio
	UBMLRSS-$G_{(q\text{-}ca\text{-}mp)}$	**x**	-	-	-	-	**x**	3	the quick ratio the cash ratio the mature payables ratio
	UBMLRSS-$G_{(cu\text{-}q\text{-}ca\text{-}tr)}$	**x**	-	-	-	-	**x**	4	the current ratio the quick ratio the cash ratio the treasury ratio
UBMARSS	UBMARSS-$G_{(ta\text{-}la)}$	**x**	-	**x**	-	-	-	2	the total asset turnover the liquid asset turnover
	UBMARSS-$G_{(ta\text{-}wa)}$	**x**	-	**x**	-	-	-	2	the total asset turnover the working asset turnover
	UBMARSS-$G_{(ta\text{-}wa\text{-}la)}$	**x**	-	**x**	-	-	-	3	the total asset turnover the working asset turnover the liquid asset turnover
UBMPRSS	UBMPRSS-$G_{(rna\text{-}rga\text{-}rgi)}$	**x**	-	-	-	**x**	-	3	the return on net assets the return on gross assets the return on gross assets including interest
	UBMPRSS-$G_{(rfa\text{-}rwa\text{-}rca)}$	**x**	-	-	-	**x**	-	3	the return on fixed assets the return on working assets

									the return on clear assets
UBMFLRSS	UBMFLRSS-$G_{(td\text{-}ld)}$	**x**	-	-	**x**	-	-	2	the total debt ratio the long-term debt ratio
	UBMFLRSS-$G_{(td\text{-}li)}$	**x**	-	-	**x**	-	-	2	the total debt ratio the liability structure ratio
	UBMFLRSS-$G_{(dsc\text{-}ic)}$	**x**	-	-	**x**	-	-	2	the debt service coverage ratio the interest coverage ratio
UBMLRSS-UBMPRSS	UBMLRSS-UBMPRSS-$G_{(mp\text{-}irr)}$	-	**x**	-	-	**x**	**x**	2	the mature payables ratio the internal rate of return
	UBMLRSS-UBMPRSS-$G_{(q\text{-}irr)}$	-	**x**	-	-	**x**	**x**	2	the quick ratio the internal rate of return
	UBMLRSS-UBMPRSS-$G_{(mp\text{-}q\text{-}irr)}$	-	**x**	-	-	**x**	**x**	3	the mature payables ratio the quick ratio the internal rate of return
	UBMLRSS-UBMPRSS-$G_{(cu\text{-}irr)}$	-	**x**	-	-	**x**	**x**	2	the current ratio the internal rate of return
	UBMLRSS-UBMPRSS-$G_{(cu\text{-}q\text{-}irr)}$	-	**x**	-	-	**x**	**x**	3	the current ratio the quick ratio the internal rate of return
	UBMLRSS-UBMPRSS-$G_{(ca\text{-}irr)}$	-	**x**	-	-	**x**	**x**	2	the cash ratio the internal rate of return
	UBMLRSS-UBMPRSS-$G_{(ca\text{-}q\text{-}irr)}$	-	**x**	-	-	**x**	**x**	3	the cash ratio the quick ratio the internal rate of return
UBMARSS-UBMPRSS	UBMARSS-UBMPRSS-$G_{(ta\text{-}irr)}$	-	**x**	**x**	-	**x**	-	2	the total asset turnover the internal rate of return
	UBMARSS-UBMPRSS-$G_{(wa\text{-}irr)}$	-	**x**	**x**	-	**x**	-	2	the working asset turnover the internal rate of return
	UBMARSS-UBMPRSS-$G_{(ta\text{-}wa\text{-}irr)}$	-	**x**	**x**	-	**x**	-	3	the total asset turnover the working asset turnover the internal rate of return

Figure. 4.5. The comparison of information systems supporting management processes by semantic description and analysis of selected financial ratios [50]

Chapter 5
Conclusion and Future Works

Abstract. This chapter summarized the main topics discussed in all chapters of this Ph.D. dissertation. The main topic, namely the human centered computing for future generation computer systems, makes it possible to assess the impact of semantic description and interpretation methods on the development of the subject of data analysis. Aiming this type of interpretation at the semantic, cognitive analysis of the analysed data points to new directions in the development of future generation computer systems.

Human centered computing methods for future generation computer systems are dedicated to the semantic processes of data description and interpretation. The factor that distinguishes this type of solutions is their ability to use the perception elements of analysis systems in data analysis algorithms. Systems built by extracting similarities between the processes of perceptual data analysis and their artificial imitations make it possible to add new analysis stages to the processes executed. Now it is not only the description and interpretation of data that allows its suitability to be evaluated, but the correct analysis of the meaning of data makes it possible to assess how the phenomenon will develop in the future. Constantly adding new elements to sets of knowledge makes it possible to interpret and understand situations which were originally impossible to understand.

5.1. Summary

Human centered computing methods help develop new generation systems by adding aspects of semantic interpretation to them. Extracting semantic layers contained in data sets makes it possible to describe them more fully. The stages of analysis, reasoning and projecting can be executed using linguistic algorithms in the definition processes. In addition, introducing elements taken from perception models to the processes of the defined algorithms of semantic data analysis allows the processes carried out to be similar to the natural (human) analysis processes.

This dissertation presents the foundations for the development of the described analysis methods aimed at building a new generation of systems. Human cognitive processes taking place in the human mind have been adopted as the basis for the operation of the solutions chosen. They make it possible to define the relationship between the perception processes characteristic for humans and their computer imitations. Adapting the techniques of the semantic description and interpretation of data to analysing complex datasets makes it possible to execute semantic interpretation and reasoning processes while using linguistic methods in the process of the semantic description interpretation.

In addition, a new generation of systems performing the semantic analysis of data has been discussed. The characteristic feature of the proposed new generation of systems is their ability to assess the influence of the analysed datasets on the discussed phenomena, situations, states etc. The systems discussed have been characterised using perception models associated with the analysis processes carried out. A classification of the systems introduced was proposed. This special role of the decision-making process enhanced with the semantic interpretation of the analysed data has been recognised.

5.2. Future works

There are diverse opportunities for and areas of the possible application of human centered computing methods. They range from image analysis, personal identification, biometric verification and marking to systems that support decision-making processes in various areas of life, such as systems for the semantic interpretation of economic and financial data. Due to the diverse opportunities to use universal linguistic techniques to describe data, it is planned to continue exploring the subjects presented in this Ph.D. dissertation.

The directions in which human centered computing methods dedicated to the new generation of systems should be developed are suggested by the current directions in which individual scientific disciplines are developing. With regard to interpreting economic and financial data, there are reasons to develop the solutions discussed for the purpose of analysing the strategic situation of organisations, managing confidential/secret data, supporting the operations of organisation, analysing individual sectors of the public life.

In addition, systems built using linguistic techniques of data description and interpretation can be developed in such areas as medicine, defense, transport, logistics, etc. Their development is only conditional on access to data that constitutes the starting point for building new solutions in the above fields.

Bibliography

[1] Albus J.S., Meystel A.M.: *Engineering of Mind – An Introduction to the Science of Intelligent Systems*, A Wiley-Interscience Publication John Wiley & Sons Inc 2001

[2] Anderson J.R.: *The Architecture of Cognition*, Harvard Univ. Press, Cambridge, MA, 1983

[3] Aristotle: *The Basic Works of Aristotle*, by Richard McKeon. Random House Inc. 1941

[4] Atkinson R.C., Shiffrin R.M.: *Human memory, A proposed system and its control processes*, w: Spence K. W., Spence J.T. (Eds.), The psychology of learning and motivation: Advances in research and theory, New York, Academic Press, 1968, pp. 89-195

[5] Barolli L., Spaho E., Xhafa F., et al.: *Performance evaluation of an integrated fuzzy-based trustworthiness system for P2P communications in JXTA-overlay*, Neurocomputing vol. 122, 2013, pp. 43-49

[6] Barolli L., Chen X., Xhafa F.: *Advances on cloud services and cloud computing*, Concurrency and Computation – Practice & Experience, vol. 27 (8), 2015, pp. 1985-1987

[7] Bechtel W., Abrahamsen A., Graham G.: *The live of cognitive science*, in: Bechtel W., Graham G. (Eds.), A companion of cognitive science, Blackwell Publishers, UK Oxford, 1998, pp. 1-104

[8] Bender E.A.: *Mathematical Methods in Artificial Intelligence*, IEEE CS Press, Los Alamitos, CA, 1996

[9] Branquinho J. (Eds.): *The Foundations of Cognitive Science*, Clarendon Press, Oxford 2001

[10] Brejl M., Sonka M.: *Medical image segmentation: Automated design of border detection criteria from examples*, Journal of Electronic Imaging, vol. 8, no 1, 1999, pp. 54-64

[11] Chomsky N.: *Language and Problems of Knowledge: The Managua Lectures*, MIT Press, Cambridge, MA, 1988

[12] Cohen H., Lefebvre C. (Eds.): *Handbook of Categorization in Cognitive Science*, Elsevier, The Netherlands, 2005

[13] Davis L.S. (Eds.): *Foundations of Image Understanding*, Kluwer Academic Publishers 2001

[14] Duda R.O., Hart P.E., Stork D.G.: *Pattern Classification*, Second Edition, A Wiley-Interscience Publication John Wiley & Sons, Inc. 2001

[15] Edelman S.: *Representation and Recognition in Vision*, MIT Press, Cambridge, MA, 1999

[16] Edwards W.: *The theory of decision making*, Psychological Bulletin, 51, 1953, pp. 380-417

[17] Enokido T., Takizawa M.: *Differentiating the Starting Time of Computation Process Replicas in the Improved Redundant Delay Time-Based (IRDTB) Algorithm*, 31st IEEE International Conference on Advanced Information Networking and Applications (IEEE AINA), Tamkang University, Taipei, Taiwan, MAR 27-29, 2017, pp. 99-106

[18] Gabrieli J.D.E.: Cognitive Neuroscience of Human Memory, *Annual Review of Psychology*, vol. 49, 1998, pp. 87-115

[19] Huang H. K.: *Picture Archiving and Communication Systems in Biomedical Imaging*, VCH Publishers, Inc., 1996

[20] Hubel D.: *Eye, Brain and Vision*, W. H. Freeman, New York 1988

[21] Kickhard M., Terveen L.: *Foundational Issues in Artificial Intelligence and Cognitive Science*, Elsevier, Amsterdam, 1996

[22] Kihlstrom J.F.: The Cognitive Unconscious, *Science*, 237, 1987, pp. 1445 – 1452

[23] Kitao T., Miura T.: *Accelerating Reinforcement Learning by Mirror Images*, 26th International Conference on Information Modelling and Knowledge Bases (EJC), Tampere, Finland, June, 2016, Frontiers in Artificial Intelligence and Applications, vol. 292, 2017, pp. 145-160

[24] Kitao T., Miura T.: *Fast Reinforcement Learning By Mirror Images*, IEEE/WIC/ACM International Conference on Web Intelligence (WI), Omaha, NE, October 13-16, 2016, pp. 660-663

[25] Lazarus R.S.: *Emotion and Adaptation*, New York, Oxford University Press, 1991

[26] Leibniz G.W.: *Dissertatio de arte combinatoria*, Leibnizens Mathematische Schriften 5, Georg Olms, Hildesheim, 1666

[27] Meystel A.M., Albus J.S.: *Intelligent Systems – Architecture, Design, and Control*, A Wiley-Interscience Publication John Wiley & Sons, Inc., Canada 2002

[28] Minsky M.: *Semantic Information Processing*, MIT Press, Cambridge, MA, 1968

[29] Minsky M.: *A Framework for Representing Knowledge*, in: Winston P. (Ed.), The Psychology of Computer Vision, McGraw-Hill, New York 1975

[30] Nakamura S., Ogiela L., Enokido T., Takizawa M.: *Evaluation of Protocols to Prevent Illegal Information Flow in Peer-to-Peer Publish/Subscribe Systems*, IEEE AINA 2017 – The 31st IEEE International Conference on Advanced Information Networking and Applications (AINA 2017), Tamkang University, Taipei, Taiwan, March 27-29, 2017, pp. 631-638

[31] Nakamura S., Ogiela L., Enokido T., Takizawa M.: *Flexible Synchronization Protocol to Prevent Illegal Information Flow in Peer-to-Peer Publish/Subscribe Systems*, in: L. Barolli, O. Terzo (Eds.), Complex, Intelligent, and Software Intensive Systems, Advances in Intelligent Systems and Computing, vol. 611, 2018, pp. 82-93

[32] Nakamura S., Ogiela L., Enokido T., Takizawa M.: *Evaluation of Flexible Synchronization Protocol to Prevent Illegal Information Flow in P2PPS System*s, in L. Barolli et al. (eds.), Advances in Network-Based Information Systems, Lecture Notes on Data Engineering and Communications Technologies, vol. 7, 2018, pp. 66-77 – *Best Paper Award of the 20th International Conference on Network-Based Information Systems (NBIS-2017), Ryerson University, Canada, August 24th-26th, 2017*

[33] Ogiela L.: *Cognitive Systems for Medical Pattern Understanding and Diagnosis*, in: I. Lovrek, R.J. Howlett, L.C. Jain (Eds.), Knowledge-Based Intelligent Information and Engineering Systems, KES 2008, Part I, LNAI 5177, Springer-Verlag Berlin Heidelberg 2008, pp. 394-400

[34] Ogiela L.: *Modelling of Cognitive Processes for Computer Image Interpretation*, in: Al-Dabass D., Nagar A. Tawfik H., Abraham A., Zobel R. (Eds.), EMS 2008 European Modelling Symposium, Second UKSIM European Symposium on Computer Modeling and Simulation, Liverpool, United Kingdom, 8-10 September 2008, pp. 209-213

[35] Ogiela L.: *Cognitive Computational Intelligence in Medical Pattern Semantic Understanding*, 4^{th} International Conference on Natural Computation ICNC'08, 18-20 October 2008, Jinan, China, vol. 6, pp. 245-247

[36] Ogiela L.: *Innovation Approach to Cognitive Medical Image Interpretation*, Innovation'08, 5^{th} International Conference on Innovations in Information Technology, Al Ain, United Arab Emirates, December 16-18, 2008, pp. 722-726

[37] Ogiela L.: *Syntactic Approach to Cognitive Interpretation of Medical Patterns*, in: Caihua Xiong, Honghai Liu, Yongan Huang, Youlun Xionh (Eds.), Intelligent Robotics and Applications, First International Conference, ICIRA 2008, Wuhan, China, 15-17 October 2008, LNAI 5314, Springer-Verlag, Berlin Heidelberg, 2008, pp. 456-462

[38] Ogiela L.: *UBIAS Systems for the Cognitive Interpretation and Analysis of Medical Images*, Opto-Electronics Review 17(2), Springer, 2009, pp.166-179

[39] Ogiela L.: *Computational Intelligence in Cognitive Healthcare Information Systems*, in: Bichindaritz I., Vaidya S., Jain A., Jain L. (Eds.), Computational Intelligence in Healthcare 4, Advanced Methodologies, Studies in Computational Intelligence, vol. 309, Springer-Verlag Berlin Heidelberg, 2010, pp. 347-369

[40] Ogiela L.: *Cognitive Informatics in Automatic Pattern Understanding and Cognitive Information Systems*, in: Yingxu Wang, Du Zhang, Witold Kinsner (Eds.), Advances in Cognitive Informatics and Cognitive Computing, Studies in Computational Intelligence (SCI), vol. 323, Springer-Verlag Berlin Heidelberg, 2010, pp. 209–226

[41] Ogiela L.: *Pattern Classifications in Cognitive Informatics*, in: Ogiela M., Jain L. (Eds.), Computational Intelligence paradigms in advanced pattern classification, Studies in Computational Intelligence, vol. 386, Springer-Verlag Berlin Heidelberg, 2012, pp. 39–57

[42] Ogiela L.: *Semantic Analysis in cognitive UBIAS & E-UBIAS systems*, Computer & Mathematics with Applications, vol.63, issue: 2, 2012, pp. 378-390
[43] Ogiela L.: *Semantic analysis and biological modelling in selected classes of cognitive information systems*, Mathematical and Computer Modelling, vol. 58, issue: 5-6, 2013, pp. 1405-1414
[44] Ogiela L.: *Data management in cognitive financial systems*, International Journal of Information Management, vol. 33, 2013, pp. 263-270
[45] Ogiela L.: *Cognitive informatics in image semantics description, identification and automatic pattern understanding*, Neurocomputing, vol. 122, 2013, pp. 58-69
[46] Ogiela L.: *Towards cognitive economy*, Soft Computing, vol. 18, issue: 9, 2014, pp. 1675-1683
[47] Ogiela L.: *Advanced techniques for knowledge management and access to strategic information*, International Journal of Information Management, vol. 35 (2), 2015, pp. 154–159
[48] Ogiela L.: *Intelligent techniques for secure financial management in the cloud computing*, Electronic Commerce Research and Applications, vol. 14 (6), 2015, pp. 456-464
[49] Ogiela L.: *Cryptographic techniques of strategic data splitting and secure information management*, Pervasive and Mobile Computing 29, 2016, pp. 130-141
[50] Ogiela L.: *Cognitive Information Systems in Management Sciences*, Elsevier, Academic Press, 2017
[51] Ogiela L., Ogiela M.R.: *Cognitive Techniques in Visual Data Interpretation*, Studies in Computational Intelligence 228, Springer-Verlag Berlin Heidelberg, 2009
[52] Ogiela L., Ogiela M.R.: *Semantic Analysis Processes in Advanced Pattern Understanding Systems*, in: Kim T.H., Adeli H., Robles R.J. et al. (Eds.), Advanced Computer Science and Information Technology, Communications in Computer and Information Science, vol. 195, Conference: 3rd International Conference on Advanced Science and Technology (AST 2011), Jeju Island, South Korea, Jun 15-17, 2011, pp. 26-30
[53] Ogiela L., Ogiela M.R.: *Advances in Cognitive Information Systems*, Cognitive Systems Monographs COSMOS 17, Springer-Verlag Berlin Heidelberg, 2012
[54] Ogiela L., Ogiela M.R.: *Cognitive systems for intelligent business information management in cognitive economy*, International Journal of Information Management, vol. 34, issue: 6, 2014, pp. 751-760
[55] Ogiela L., Ogiela M.R.: *Data Mining and Semantic Inference in Cognitive Systems*, 6-th International Conference on Intelligent Networking and Collaborative Systems (INCoS 2014), Salerno, Italy, September 10-12, 2014, pp. 257-261
[56] Ogiela L., Ogiela M.R.: *Efficiency of Cognitive Information Systems Supporting Enterprise Management Tasks*, 9th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS-2015), Blumenau, Santa Catarina, Brazil 08-10 July 2015, pp. 166-170
[57] Ogiela L., Ogiela M.R.: *Comparison of Cognitive Information Systems Supporting Management Tasks*, The 7th International Conference on Intelligent Networking and Collaborative Systems (INCoS-2015), September 2-4 2015, Taipei, Taiwan, pp. 49–56
[58] Ogiela L., Ogiela M.R.: *Semantic Data Analysis Algorithms Supporting Decision-making Processes*, BWCCA 2015 Tenth International Conference on Broadband and Wireless Computing, Communication and Applications, IEEE Computer Society Order Number E5746, 4-6 November 2015, Krakow, Poland, pp. 494-496
[59] Ogiela L., Ogiela M.R.: *Knowledge management approaches for data understanding*, 8-th International Conference on Intelligent Networking and Collaborative Systems (INCoS-2016) Ostrava, Czech Republic, September 7-9, 2016, pp. 270-273
[60] Ogiela L., Ogiela M.R.: *Insider Threats and Cryptographic Techniques in Secure Information Management*, IEEE Systems Journals, vol. 11, no. 2, 2017, pp. 405-414
[61] Ogiela L., Ogiela M.R., Ogiela U.: *Efficiency of strategic data sharing and management protocols*, IMIS 2016 – The 10th International Conference on Innovative Mobile and Internet Services in Ubiquitous Computing (IMIS-2016), July 6-8, 2016, Fukuoka, Japan, pp. 198-201
[62] Ogiela L., Ogiela M.R., Takizawa M.: *Safety and Standardization of Data Sharing Techniques and Protocols for Management of Strategic Data*, IEEE AINA 2017 – The 31st IEEE International

Conference on Advanced Information Networking and Applications (AINA 2017), Tamkang University, Taipei, Taiwan, March 27-29, 2017, pp. 1076-1081
[63] Ogiela L., Ogiela U.: *Information Security in Intelligent Data Management Processes*, BWCCA 2015 Tenth International Conference on Broadband and Wireless Computing, Communication and Applications, IEEE Computer Society Order Number E5746, 4-6 November 2015, Krakow, Poland, pp. 169-172
[64] Ogiela L., Takizawa M.: *Medical Image Analysis by Cognitive Information Systems – a Review*, Journal of Medical Systems, vol. 40 (10):212, DOI 10.1007/s10916-016-0566-6
[65] Ogiela L., Takizawa M.: *Personalized cryptography in cognitive management*, Soft Computing 21, Springer, 2017, pp. 2451-2464
[66] Ogiela M.R., Ogiela L.: *Cognitive Informatics in Medical Image Semantic Content Understanding*, in: Kim T.H., Stoica A., Chang R.S., Security-Enriched Urban Computing and Smart Grid, Communication in Computer and Information Science, vol. 78, 1st International Conference on Security-Enriched Urban Computing and Smart Grid, Daejeon, South Korea, September 15-17, 2010, pp. 131-138
[67] Ogiela M.R., Ogiela L.: *Towards New Classes of Intelligent Cognitive Information Systems for Semantic Pattern Classification*, Computing and Informatics, vol. 30, issue: 6, 2011, pp. 1099-1114
[68] Ogiela M.R., Ogiela L.: *Medical Visualizations in Secure Bio Computing*, WAINA 2012 – 26th IEEE International Conference on Advanced Information Networking and Applications Workshops & BICom-2012 – The 5th International Workshop on Bio and Intelligent Computing, Fukuoka Institute of Technology, Fukuoka, Japan, March 26-29, 2012, pp. 997-980 – *Best Paper Award at the AINA 2012 conference*
[69] Ogiela M.R., Ogiela L.: *Security of Cognitive Information Systems*, in: J. J. Park et all (eds.), Information Technology Convergence, Lecture Notes in Electrical Engineering, vol. 253, pp. 427-433, (STA 2013 – The 10th FTRA International Conference on Secure and Trust Computing, Data Management, and Applications, July 8-10, 2013, FIT, Fukuoka, Japan) – *Best Paper Award by STA 2013* Organizing Committee, Fukuoka, Japan 8-10 July 2013
[70] Ogiela U., Takizawa M., Ogiela L.: *Security of selected secret sharing schemes*, in: L. Barolli, T. Enokido (Eds.), Innovative Mobile and Internet Services in Ubiquitous Computing, Advances in Intelligent Systems and Computing, vol. 612, 2018, pp. 395-400
[71] Ogiela U., Takizawa M., Ogiela L.: *Security of Visual Captcha for Authentication Procedures*, in L. Barolli et al. (eds.), Advances in Network-Based Information Systems, Lecture Notes on Data Engineering and Communications Technologies, vol. 7, 2018, pp. 148-152
[72] Pratt W. K.: *Digital Image Processing*, New York, Wiley & Sons 1991
[73] Schachter S., Singer J.: *Cognitive, Social and Physiological Determinants of Emotional State*, Psychological Review 63, 1962, pp. 379-399
[74] Shioya I., Oh'Uchi H., Miura T.: *Document retrieval by projection based frequency distribution*, 17th International Conference on Tools with Artificial Intelligence, Hong Kong, China, November 14-16, 2005, International Journal on Artificial Intelligence Tools, vol. 16 (4), 2007, pp. 647-659
[75] Shioya I.: *A traffic flow analysis from psychological aspects*, Fifth International Conference on Digital Information Processing and Communications (ICDIPC), Sierre, Sierra Leone, October 07-09, 2015, pp. 7-12
[76] Tamai T.: *Social Impact of Information System Failures*, Computer, vol. 42 (6), 2009, pp. 58-65
[77] Tamai T.: *Software Engineering View of a Large-Scale System Failure and the Following Lawsuit*, 2nd International Workshop on Software Engineering Research and Industrial Practice (SER&IP), Florence, Italy, May 17, 2015, pp. 18-24
[78] Wang Y.: *On Cognitive Informatics*, *Brain and Mind:* A Transdisciplinary Journal of Neuroscience and Neurophilosophy, 4(2), 2003, pp.151-167
[79] Wang Y.: *The Theoretical Framework of Cognitive Informatics*, International Journal of Cognitive Informatics and Natural Intelligence, IGI Publishing, USA, 1(1), Jan, 2007, pp.1-27

[80] Wang Y.: *The Cognitive Processes of Formal Inferences*, International Journal of Cognitive Informatics and Natural Intelligence, IGI Publishing, USA, 1(4), Dec., 2007, pp. 75-86

[81] Zadeh L. A.: *Fuzzy logic, neural networks, and soft computing*, Communications of the ACM, 37(3), 1994, pp. 77-84