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New paradigms of cognitive management extending computational intelligence approaches

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Abstract This publication presents new paradigms of cognitive management in information systems. The cognitive management aspects dedicated to support management processes are based on interpretations of the meaning of the analyzed data/situation, etc. The management processes are shown as it is applied to different subjects because of the diverse possibilities of executing management processes. This publication shows the versatility of the presented approaches. Cognitive management processes were defined on the basis of methods for the cognitive interpretation of information applied to semantic information contained in data sets. Semantic data interpretation used to determine the meaning of the analyzed information, and semantic layers contained in data sets. Also is dedicated to significance for the whole-process of cognitive management. Cognitive management processes were discussed as they are applied to various subjects, i.e. data, information, structures, processes or situations. Cognitive management processes were defined for the purpose of supporting existing data management solutions.

Keywords Cognitive management · Information systems · Semantic interpretation · Cognitive data analysis

1 Introduction

Data management processes apply to various information sets, ranging from information of low importance to information that is strategic or secret. They are used for information contained in numerical sets, signals, sounds, images, biometrics etc. They concern both sets containing few pieces of information and also large, complex data sets or large databases.

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However, regardless of how different these sets are, the methods of managing this type of information must be determined. Processes described in publications (Anderson et al. 2016; Banares et al. 2016; Ogiela and Ogiela 2014; Winston and Albright 2016), which focus on the optimal execution of all possible information processes occurring in any structure (Hachaj and Ogiela 2011; Ogiela 2013c; Zhang et al. 2016), form the most widespread methods of managing information. This process consists in executing control tasks at the data acquisition stage, creating information sets, analysing data, storing it and providing (transmitting) information. At the acquisition stage, information undergoes data collection and recording processes. The essence of this stage is to acquire information from the broadest possible area concerning the data to be processed. Not all pieces of information have to be significant for the analysed data set, but their significance will be confirmed at the stage of selecting important data which is necessary for the information analysis process carried out. The process of separating significant data from all the information that is not significant at the selected information analysis stage is executed in the next phase of information management.

At the stage when data sets are created using information collected before, a process is carried out to extract data of significance for the analysed aspect, information set or process. Significant data that is semantically associated with the main element of data analysis should be extracted from the entire information set, while the remaining elements of this set are stored for the purpose of their possible future analysis. At this stage, the elements of the set to be analysed should be fully consistent with the following:

- the defined data analysis method,
- the subject of the analysis,
- expectations about the information assessment process to be carried out,
- the contents of the elements of the set which is being analysed.

The next stage in the information management process is the data analysis stage. During this stage, which consists of the broadest process in data management, the method of analysing sets is chosen and then the analysed sets are evaluated. The data analysis process itself can be varied. Data sets can be described and evaluating with regard to their type, nature, significance, impact on specific phenomena, whether they contribute to or impede the development of a specific situation etc. In this sense, the choice of the description, assessment and analysis method can vary and depends only on the defined research tasks. At the data analysis stage, an assessment and an analysis of information sets subjected to these processes should take place. However, the data description process itself is not sufficient to correctly evaluate the analysed situation or phenomenon. This is because the results obtained must be evaluated by verifying conclusions. This process marks the beginning of the stage of reasoning, which is important for the future evaluation of the phenomenon studied. At the reasoning process stage, a projection process is carried out to predict the future state, evaluate the possibility that the given situation will occur in the future and to assess the credibility of the projected future state.

The results obtained at each of the aforementioned data analysis stages form elements of the output set from the information analysis. Together with the data sets, they are subject to the information storage process. Its essence is to prevent the disclosure of the collected information and the results of analyses to unauthorised individuals. If the data is secret or strategic in nature, it can be protected from disclosure using the appropriate information security and concealment algorithms (Ogiela and Ogiela 2008, 2009a, b, 2015b). This process is about securely storing information and is associated with the next stage in data management, i.e. the stage of sending information and making it available.

The stage of information provision in the data management process includes the following steps: securing data during its transmission, possibly processing data to make the contents of the information available and decrypting encrypted information if the right to access it has been successfully verified. The process of making information available is about giving individuals, groups of individuals, institutions, computer systems etc. who are allowed to use data sets access to these sets. At this stage of the data management process, the person trying to obtain information sets, or if the data is secret, to obtain access to such sets is verified (their identity is confirmed. If the verification is successful, full access to the sets is allowed. On the other hand, if the verification fails, the specific entity may not be given access to the information sets possessed. Data sets form the most important element at all the information management stages presented. Their processing, evaluation, analysis, storage and future use means that processes of managing sets of information used for various purposes and in various ways are constantly carried out. Processes of managing data/information are aimed at processing it so that the information can be used in the best, the fastest and the most complete way, in other words: optimally.

In Sect. 2 will be presented the semantic analysis process in management aspects. In Sect. 3 will be described the cognitive management processes especially the process of cognitively managing process, the managing structures, and managing a state. In last section will be presented the conclusions and summary new proposition of cognitive management processes extending computational intelligence approaches.

The main result of our research is defining a new paradigm of cognitive management, including semantic analysis in management processes. Linguistic description of analysed processes and their semantic interpretation, can support all management processes.

2 Semantic analysis in management processes

Classical management processes are enhanced by adding a new perspective. With regard to management processes, we can distinguish various entities which are the basis of those processes. Such entities include institutions, enterprises and organisations, however, the entities of management processes can also be defined as the type of information or data sets which are managed. In this aspect, management processes apply not only to the selected structure, but may concern various structures which hold complementary information or data sets. In this case, every structure can try to obtain the missing information from other entities, but it can also cooperate by entering into an agreement to transfer its data to a common set possessed by all beneficiaries. As a result, al partners will manage common data and will be entitled to use this set. In this context, the sets of information undergoing management processes can be deposited within various configurations of structures, as shown in Fig. 1.

The management process can also concern various entities. This is because one can manage an enterprise, resources, finances, capital, but also a production process, time, quality, or even information, risk or a crisis. In this context it is important to specify what the management process applies to (Fig. 2).

In all types of management, the most important element is the subject of the process carried out and the method of reaching the intended goal based on defined means used in this process. The management process boils down to using specific, available means to achieve the intended goals in the optimum way.

Supporting management processes, in turn, is understood as taking possible actions to improve the entire management process. One possible action is to enhance management

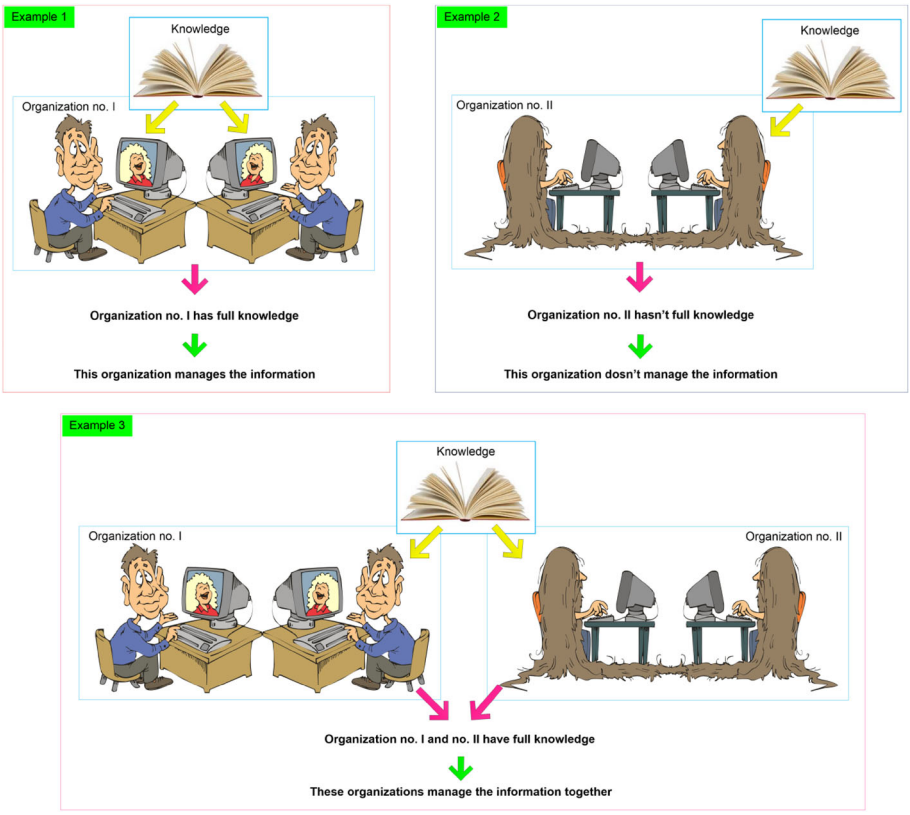

Fig. 1 Information sets subject to management processes, deposited in various configurations of structures

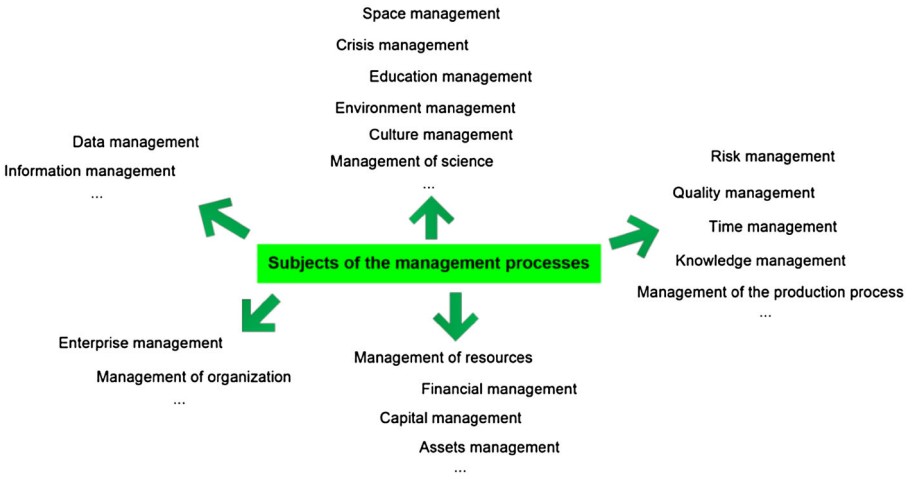

Fig. 2 Examples of subjects of the management processes

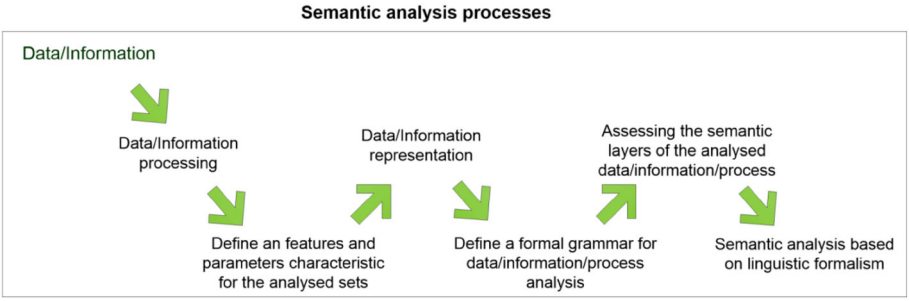

Fig. 3 The semantic analysis processes

processes by adding the semantic analysis of the subject managed. Semantic analysis can improve the management process by indicating the correct direction of work to achieve the intended goal. Semantic analysis is a process consisting in assessing the semantic layers of the analysed data sets (Fang et al. 2016; Grossberg 2012; Ogiela 2014; Ogiela and Ogiela 2015a), which include the features and parameters characteristic for the analysed sets (Fig. 3).

If the set which is the object managed is a set of information, the semantic features of the information set are determined. They include:

- the frequency of information occurrence,
- the number of recurrences of this information in the set,
- quantitative and qualitative parameters of information sets,
- the significance of the information for the analysed process.

However, if the object managed is a certain state, e.g. a crisis, risk, quality etc., then the semantic features are determined for the entire analysed process/state. The set of semantic features then includes the following:

- the frequency of occurrence of this state,
- the number of recurrences of the features studied,
- qualitative and quantitative parameters of feature sets defining the state,
- parameters causing the given state, defined independently for each,
- the influence of the meaning of the analysed feature set on the state caused.

The semantic analysis process thus forms the stage at which the meaning of the analysed situation, data set, structure etc. is assessed. Regardless of the set analysed, its characteristic features and their meaning for the entire set are determined in every case. This meaning defines both the influence of reasons which may cause the state, and also of future situations. The assessment of characteristic features of a given set forms the main element of the entire semantic analysis process.

The next stage is to acquire knowledge about the analysed phenomenon, structure, state or data set. The purpose of the knowledge acquisition process is to collect the largest possible knowledge bases in the systems which will execute the semantic analysis. Knowledge bases are built based on expert knowledge, so they are sets of the knowledge available about the analysed situation.

The most important stage in the semantic analysis process is to define a suitable formalism which will make it possible to correctly evaluate the information analysed. The formalisms used for this type of tasks are linguistic formalisms (Ogiela and Ogiela 2015b; Ogiela 2013a). The aim of building formalisms of this type is to propose a formal grammar appropriate for the

analysis conducted. The structure of a properly selected formal grammar depends on the type of analysed data, in particular on the form of the analysed sets. Grammatical formalisms are built in the form of sequential, tree or graph grammars. Each of the above formalisms applies to a different form of sets to be analysed (Hachaj and Ogiela 2011; Ogiela and Ogiela 2015a; Ogiela 2008). If the right linguistic formalism is proposed for the semantic analysis, it allows significant semantic information to be extracted from data sets. This semantic information leads to the appropriate interpretation and evaluation during the process of describing the data or the reasons causing a given state etc.

Semantic analysis is used to evaluate and describe various data sets. It has been presented, among others, in the publications (Ogiela 2008, 2010), where image data (Hachaj and Ogiela 2011; Ogiela 2013a), ratio data (Ogiela and Ogiela 2014; Ogiela 2013b) signals or biometrics (Ogiela 2013c; Ogiela and Ogiela 2015b) constituted the main elements analysed. What is innovative in the presented approach is the use of cognitive analysis processes for management tasks.

3 Cognitive management processes

The purpose of cognitive management processes is to manage based on the meaning (semantics). So what is cognitive management? The Authors present the cognitive management paradigm in this publication.

Cognitive management is the process of semantically (cognitively) executing tasks aimed at achieving a defined goal by using the appropriate means and the assessment of the significance of the analysed data for basic management processes, i.e. acquiring, creating, analysing, storing and providing data.

Cognitive management will thus be defined both for information sets and for situations or states being described. The following will be distinguished in cognitive management tasks:

- cognitive data management,
- cognitive management processes,
- cognitive structure management,
- cognitive state (situation) management.

Cognitive data management refers to processes of managing information and data sets. In this area, it is important to determine the meaning of the sets managed, which stems from the data (is contained in the managed information sets). This process is based on a cognitive analysis of data executed using the linguistic description and assessment of information sets. The linguistic formalisms used to describe data in cognitive data management processes are as follows:

- sequential formalisms for information/data in the numerical form,
- graph formalisms for information/data in the form of images.

The process of cognitive data management is presented in Fig. 4.

The cognitive management of processes refers to managing whole processes and the sets of data which occurs in these processes or describes them. In this area it is important to determine the meaning of the processes managed, which stems from these processes (is contained in them). This process is based on the cognitive analysis of whole processes, the factors which influence the course of these processes, the factors causing the current state as well as projections (forecasts) for the future. It is executed using a linguistic description and

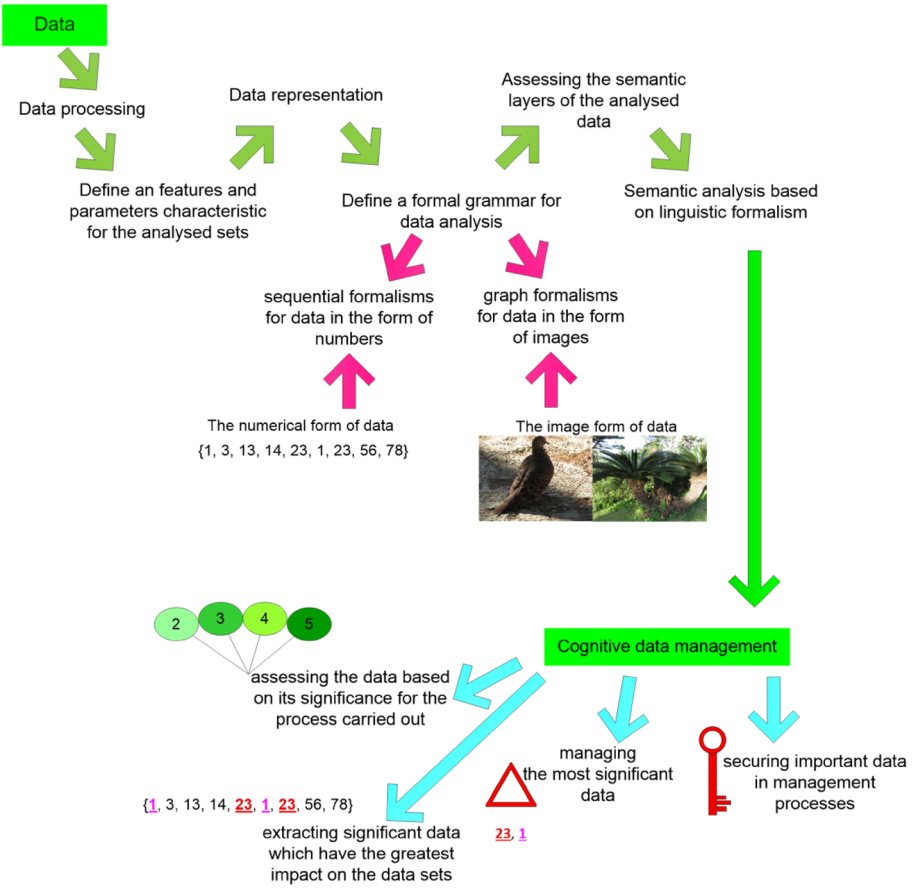

Fig. 4 The process of cognitive data management

assessment of processes and their components. The linguistic formalisms used in cognitive process management are as follows:

- sequential formalisms for processes described in the numerical form,
- tree formalisms for processes described in the form of trees,
- graph formalisms for processes described in the form of graphs.

The process of cognitively managing processes is presented in Fig. 5.

Cognitive structure management refers to managing a structure and the data sets which are found in this structure, which characterise it and allow the analysis to be performed. In this area, it is important to determine the meaning of the structures managed, which comes from the data sets describing these structures (is contained in them). This process is based on the cognitive analysis of whole structures, the factors which influence the structure shape, the factors causing the current state as well as projections (forecasts) for the future. It is executed using a linguistic description and assessment of the structure and its components. The linguistic formalisms used in cognitive structure management are as follows:

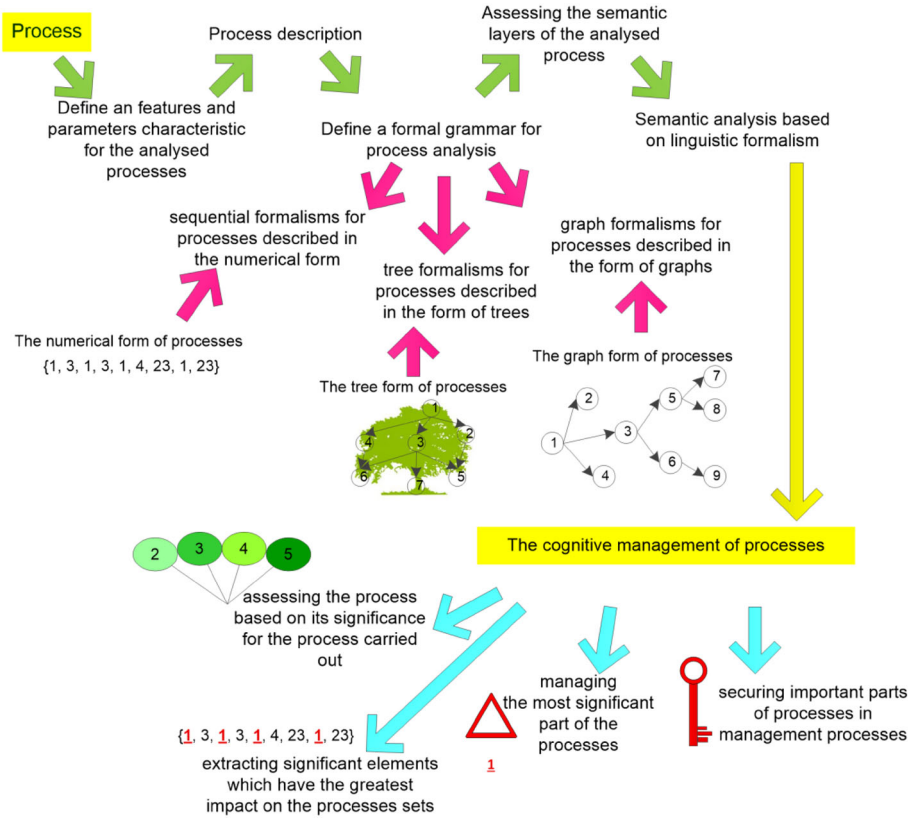

Fig. 5 The process of cognitively managing processes

- sequential formalisms for structures described in the numerical form,
- tree formalisms for structures described in the form of trees,
- graph formalisms for structures described in the form of graphs.

The process of cognitively managing structures is presented in Fig. 6.

The cognitive management of a state/situation refers to managing a state and the sets of data which cause this state, which characterise it and which allow the reasons for its occurrence to be identified. In this area, it is important to determine the meaning of the states managed, which stems from data sets describing the states (is contained in them). This process is based on the cognitive analysis of whole states, the factors which influence the current state, the factors causing the future state and projections (forecasts). It is executed using a linguistic description and assessment of the state and its components. The linguistic formalisms used in cognitive state management are as follows:

- sequential formalisms for states described in the numerical form.

The process of cognitively managing a state is presented in Fig. 7.

The cognitive (semantic) interpretation constitutes the most important element of every one of the cognitive management types listed above. Its foundation is the cognitive analysis of layers of the semantics contained in the sets analysed and managed. In management

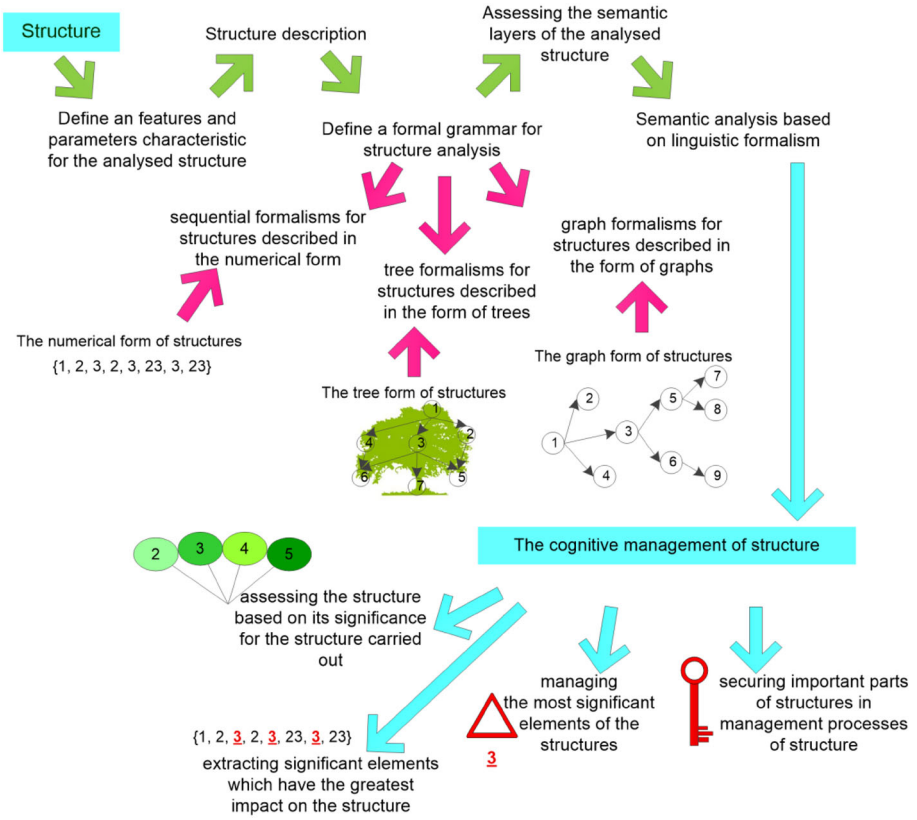

Fig. 6 The process of cognitively managing structures

processes, the semantic analysis stage improves the whole process. This is because it is used for:

- assessing the data/situation/process/structure based on its significance for the process carried out, but also for a broader context, such as e.g. an assessment of the global situation, the role of competitive markets, the significance for superior processes etc.,
- extracting significant elements which have the greatest impact on the course of processes from those complete processes,
- managing the most significant components,
- securing important information in management processes.

Cognitive management tasks are executed in information systems in which the proposed solutions make it possible to run not only processes of semantic data analysis, but primarily ones that support and improve management processes. Cognitive management systems are classified as follows:

- CDMSS—Cognitive Data Management Support Systems,
- CMPSS—Cognitive Management Processes Support Systems,
- CSMSS—Cognitive Structure Management Support Systems,
- CStMSS—Cognitive State Management Support Systems.

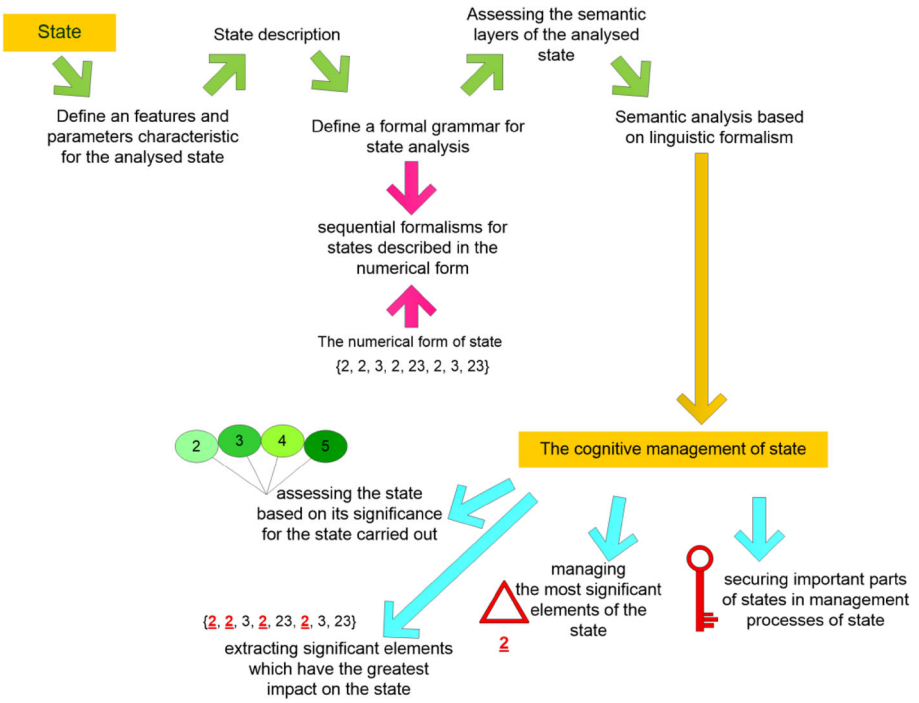

Fig. 7 The process of cognitively managing a state

The Authors propose classifying systems supporting cognitive management according to the subject of the management process. The proposed methods of cognitive management are very useful from a practical point of view. Used linguistic methods are universal for description, analysis, interpretation and decision processes. The case-sensitive of these solutions are different, depending on the:

- analysed problem, aspect, situation,
- analysed data, information,
- used formal definition, linguistics formalisms,
- data security techniques.

All proposed algorithms of cognitive management are dedicated to management processes of different data sets. Development new aspects of cognitive management, based on the linguistics formalisms are dedicated to data/processes/state descriptions and analyses processes. These processes support all management processes.

4 Conclusions

What is important in cognitive management processes is the assessment of the subject managed, which determines the selection of the appropriate management method. The situation assessment directly influences management methods. An improvement of a management process is always aimed at optimising the whole process. One of the possible ways of improving such a process is to apply semantic analysis and interpretation tasks when describing and

assessing the subject managed. If semantic information can be extracted from the set of managed elements, it is also possible to assess their significance for the entire process. This is because we manage both important information and also information of lesser significance. In this situation, we can use linguistic description formalisms to distinguish the information which has priority significance in the management process and assign the status 'less important' to the remaining information because of its lower or negligible significance. Linguistic formalisms used for cognitive management tasks enable the semantic interpretation of the data/information sets managed. Extracting semantic layers from those sets allows the unambiguous assessment of their impact on the entire object managed and the management process.

Future directions of cognitive management extending computational intelligence and semantic analysis, will be focus on the interpretation and analysis of the following areas:

- cognitive economy,
- extended cognitive management,
- cognitive strategic data interpretation,
- extended personal analysis and identification,
- biometric marking and personal cryptography,
- extended cognitive decision systems.

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