Cognitive Information Systems for Medical Pattern Analysis and Diagnosis Support Technologies

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Abstract. This publication presents a new concept of the intelligent analysis and interpretation of image-type data. The concept presented is based on a cognitive-semantic model of data learning and interpreting. The application of this model makes it possible to extract significant semantic information from the set of analysed data in order to understand it. It is also possible to execute the stage of reasoning based on the semantic contents of the analysed data. The proposed model for the cognitive analysis and interpretation of data is discussed using the example of a selected class of cognitive categorisation systems - UBIAS (Understanding Based Image Analysis Systems) analysing image-type data.

Keywords: cognitive informatics, cognitive image analysis, medical pattern interpretation, UBIAS systems.

1 Introduction

Information systems designed for the cognitive interpretation of data are based on psychological/cognitive subjects of which the cognitive process itself seems to the most important. This process is understood as a certain, rarely encountered ability of the IT system to acquire information from its surroundings and receive it from the outside. The ability itself to acquire and receive information is not enough to talk of intelligent cognitive information systems. This is because an important role

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is played here by information processing, which is a stage in the effective control of the entire cognitive system operation. This is why cognitive information systems are designed not just to acquire information for its subsequent analysis, but their main purpose is the in-depth processing and interpretation of information acquired from the outside. What is also of great significance is acquiring information from inside the system - information, which is stored in the system but is frequently not directly disclosed. A cognitive data analysis and interpretation system can acquire such information using the processes of learning based on data contained in it. This type of data acquisition is much more complicated and requires an additional element in the system - the system learning stage.

A new class of systems which conduct meaning-based data analysis has been distinguished within the entire set of systems that analyse and interpret data. This type of systems belongs to the class of cognitive data interpretation and analysis systems. What is novel in the presented approach is using the approach of the purely human data analysis to system operation. Such a presentation of the problem is possible if we claim that the human brain is a system for processing, analysing and interpreting any type of data, and is also an exceptional reasoning system. This claim makes it possible to build information processing systems based on the human cognitive system.

The key to the presented approach is to show the similarities between the human reasoning system and an information system designed for executing the analysis and reasoning process. Information processing taking place in the human brain is described by all operations due to which the stimuli received by the individual are transformed, converted, reduced, amplified, stored (e.g. in memory) and recalled. The same stages of information (data) processing can be attributed to information systems, as every one of them can execute the above activities. Information systems which can execute these types of jobs based on activities taking place in the human brain are referred to as cognitive data analysis systems. If they can additionally conduct reasoning based on the semantic contents of the analysed data, they belong to the cognitive categorisation system group. Descriptions of this system type are presented in publications [8-13].

2 The Essence of In-Depth Data Analysis

Information systems conducting data analysis are currently described in great detail in various scientific publications. However, the processes of data analysis itself are so widespread that it is impossible to point out a significant difference between systems of this type. Consequently, it makes sense to approach the data analysis problem from a completely different angle: intelligent information systems should be built based on the cognitive informatics trend which is currently being developed [15, 16].

The essence of the announced scientific approach is to implement processes taking place in the human brain for data analysis and interpretation, as a result of which it will be possible to extend the entire analysis process to include the semantic reasoning stage.

Semantic data analysis is an extremely important type of analysis, as it is based on extracting the meaning contained in the analysed data set. The notion of meaning itself is understood as some cognitive information or data representation which can define the characteristics, function or the classification of the analysed data. The classification is very frequently the classification to a category which defines either some fragment of knowledge applied in the system or a type of knowledge referred to with certain notions or definitions.

What is very important in the reasoning process based on the aspects of semantic data analysis is to indicate the meaning/denotation bases for data analysis. This type of reasoning makes use of the knowledge possessed by the information system, derived from recognised sources (usually experts) and referring to the characteristics possessed and functions fulfilled (by the analysed data). We should remember that it would be very difficult to build cognitive data analysis systems based on meaning/connotation aspects. This type of meaning interpretation and reasoning would have to be based on subjective characteristics of the analysed data, and this would be quite complicated for information systems.

The process of in-depth data analysis itself is aimed at extracting information from the data set, which information describes that data in a significant way, has a major importance in the process of data characterisation, interpreting and analysis, and can also unambiguously indicate changes in the process of reasoning and projecting into the future.

3 Cognitive Reasoning for Medical Patterns

Computer understanding and cognitive analysis used in cognitive systems and intelligent information systems is very often based on the syntactic approach [0. In cognitive systems:

- it first uses a pre-processing operation usually composed of image coding using terminal symbols, shape approximation, as well as some kind of filtration or segmentation
- as a result of executing these stages it is possible to obtain a new image representation in the form of hierarchic semantic tree structures and subsequent production steps of this representation from the initial grammar symbol.

An intelligent cognitive system distinguishing image data at the stage of preprocessing must, in the majority of cases, perform image segmentation, identify primitive components and determine spatial as well as semantic relations between them. An appropriate classification is based on the recognition of whether a given representation of the actual image belongs to a class of images generated by languages defined by one of the possible number of grammars. Such grammars can be considered to belong to sequential, tree and graph grammars while recognition with their application is made in the course of a syntactic analysis performed by the system.

In cognitive systems intelligence understood is built on many levels (intelligence levels) determined by three parameters: the computational power and the memory capacity of the system, the automatic searching for data and the automatic selection of their processing routines when the system is used to find solutions to problems which are not completely known at the time the system is built, and the quality and quantity of information collected in the system.

A cognitive method of interpreting disease units and pathological lesions forms the main element of a correctly functioning IT system supporting medical image diagnostics. Further down, such an interpretation of changes occurring in foot bone pathologies will be presented.

4 Cognitive Interpretation Systems for Image Analysis

Cognitive data analysis systems are very often used for the meaning-based interpretation and analysis of image-type data. Medical images, due to their great variety, provide a very practical approach to the subject of cognitive system operation. However, as it is difficult to unambiguously indicate patterns which define selected lesions observed in various types of medical images, this type of data gives us very interesting experience with cognitive processes conducted by information systems.

Such difficulties and at the same time challenges mean that the constantly developed subject of cognitive data analysis yields new results and solutions. A class of cognitive categorisation systems, called UBIAS (*Understanding Based Image Analysis Systems*), has been developed for the cognitive analysis and interpretation of data which uses semantic data interpretation.

Cognitive data analysis systems have been used for analysing and interpreting medical data showing various types of pathologies and lesions of various organs. The most important of those were lesions in the central nervous system, wrist bone deformations, fractures of long bones as well as foot bone deformations.

The essence of this type of analysis is to extract medical content concerning the lesions present from the analysed image, which content is then subjected to analysis, interpreting, diagnostics, understanding and reasoning. Medical images very often contain various types of information noise, i.e. diverse interference that can impact the correct understanding and interpretation of the image. In addition, they contain a whole range of various medical information, which may not be significant in the process of the semantic analysis conducted. And so a medical image - an X-ray - may show not just the organ examined for the presence of a given lesion, but also a wider picture containing organs which are not subjected to semantic analysis. Obviously, from the point of view of the cognitive process itself, such an image is much more interesting than the classical presentation of the organ examined.

Semantic analysis conducted by cognitive systems is based on a linguistic apparatus very rich in meaning reasoning and meaning interpretation rules. This

linguistic apparatus is usually contained in the appropriate grammar proposed for the analysis jobs (tree, sequential or graph) [14].

Cognitive categorisation systems for analysing images of the central nervous system and long bone fractures use a sequential grammar, while the grammar appropriate for analysing images showing wrist and foot bone deformations is a graph grammar. The right selection of grammatical methods depends on the type of organ analysed, its properties and characteristic features.

The main element of a correctly working information system to support medical image diagnostics is the development of a method for the cognitive analysis of disease entities and types of lesions which may appear in the case of a specific disease entity.

The cognitive analysis contained in a UBIAS system is aimed at proposing an automatic method for the correct interpretation of extremely complex medical images which are generated by imaging e.g. fragments of long bone fractures, wrist bone deformations, foot bone deformations or other lesions in other organs.

To illustrate the whole versatility of the method presented in this publication, below we show selected examples of UBIAS systems performing the automatic interpretation of image-type data and its meaning analysis. We have selected two medical images for this comparison.

The first represents UBIAS systems conducting cognitive analysis using sequential formalisms for images showing long bone fractures.

The second represents UBIAS systems conducting cognitive data interpretation using graph formalisms to analyse images showing foot bone deformations. Both results of the automatic analysis of data and reasoning based on it in UBIAS systems are shown in Fig. 1.

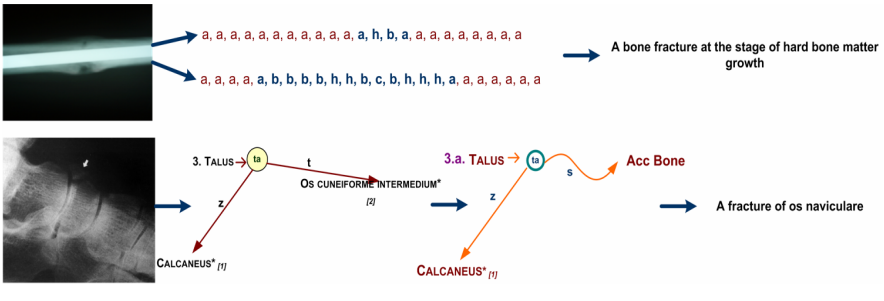

Fig. 1 Image-type data analysis using UBIAS cognitive systems for the semantic interpretation of data showing the bone fracture at the stage of hard bone matter formation in the case of a long bone fracture, and a fracture of *os naviculare* in the case of a foot bone deformation

The above figure shows the essence of the data analysis conducted by a UBIAS system. As mentioned above, a characteristic feature of the cognitive systems discussed is the correctly selected linguistic apparatus used to describe the data correctly. In our case, we have analysed two types from very different groups of medical images.

The first comprises long bone fractures. In this case, the appropriate sequential grammar was entered in the UBIAS system and this grammar supported the correct image analysis using defined terminal symbols and specific angle values expressed in degrees assigned to them. Figure 1 shows a sequence of individual terminals characteristic for the lower and upper edges of a long bone. These sequences, expressed in visible forms using a set of productions, are converted into semantic information, which for both of them is a statement that the analysed fracture type is a fracture at the stage of hard bone matter generation. Reasoning is conducted in a similar way for other types of fractures (transverse, longitudinal, spiral, bone during remodelling etc.).

The stage of image data analysis based on a linguistic description of data presented using a graph has a different form. This analysis type has been proposed for interpreting data in the case of foot bone deformation [8, 9]. The results of the analysis conducted for a selected foot bone image are also shown in Fig. 1, where a graph characterising the lesion being described is presented for a selected image.

It is worthwhile to emphasise the versatility of the presented method. Regardless of what formalism of the linguistic data description is selected, UBIAS systems perform the data identification, analysis and reasoning taking into account the semantic characteristics of this data. This is because all linguistic description formalisms can be used correctly and unambiguously to define and correctly identify the semantic contents of data.

5 Conclusion

The approach to the subject of cognitive data analysis systems presented here is illustrated with the semantic analysis of image-type data. The essence of the presented approach is to apply human data analysis processes and cognitive/ interpretation/ reasoning processes to the operation of systems.

Systems can be built based on human cognitive and decision-making processes only if the system will analyse and interpret data as well as conduct the reasoning and projecting stages using the semantic characteristics of data. The semantics of data supports their in-depth analysis and becomes the starting point for projecting changes that may take place in the future. Consequently, this type of system analysis makes it possible to at least partly eliminate errors that may occur in the future, which could not be identified in traditional data analysis systems.

So the characteristic feature which also distinguishes cognitive systems is the process of reasoning on the basis of analysed data and the process of projecting based on the data analysis conducted.

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