Cognitive Systems for Medical Pattern Understanding and Diagnosis

Lidia Ogiela

AGH University of Science and Technology
Al. Mickiewicza 30, PL-30-059 Krakow, Poland
logiela@agh.edu.pl

Abstract. In the paper will be presented a new way of intelligent cognitive systems and pattern analysis using cognitive categorization. Such an understanding will be based on the linguistic and cognitive mechanisms of pattern recognition and classification. The goal is making computer analysis of the meaning for some selected classes of medical patterns. The approach presented will show the possibilities of automatic and intelligent disease detection and its classification based on cognitive resonance processes. Cognitive categorisation systems operate by executing a particular type of thought, cognitive and reasoning processes which take place in the human mind and which ultimately lead to making an in-depth description of the analysis and reasoning process.

1 Introduction

The process of computer data analysis that has been developing incessantly for a number of years is now moving to jobs of not just simply interpreting analysed data, but it concentrates mainly on deeper reasoning and an attempt at the computer understanding of that data. It is precisely for activities aimed at understanding the analysed data that a special class of intelligent information and decision-support systems called cognitive categorisation systems has been developed. Such systems do not just conduct simple analyses, but mainly strive to reveal the semantic information contained in image data, and then run procedures leading to its machine understanding based on previously defined semantic information. Such a process was possible due to applying formalisms of linguistic perception and understanding of data to automatic reasoning processes combined with the purely human process of interpreting, analysing, understanding and reasoning which occurs in the human mind.

The most important element in this analysis and reasoning process is that it occurs both in the human cognitive/thinking process and in the system's information/reasoning process that conducts the in-depth interpretation and analysis of data. It should be added that this process is based on cognitive resonance (Fig. 1) which occurs during the examination process, and which forms the starting point for the process of data understanding consisting in extracting the semantic information and the meaning contained in the analysed type of data that makes reasoning possible.

The applications of Computational Intelligence (CI) methods in the area of biomedical engineering problems, and creation of intelligent information systems, include some

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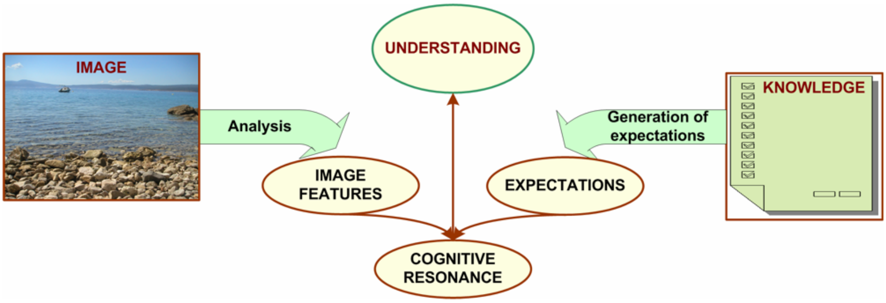

Fig. 1. Cognitive resonance in automatic understanding process

classical algorithms like data processing and analysis procedures, pattern classification, neural modeling, and genetic computation [1, 4]. Such algorithms allow to make description of the analyzed objects, its classification, creation of behavioral models, or solve optimization problems connected with particular task. However in many biomedical, economical, or engineering problems such traditional techniques of analysis may occur completely insufficient. This is especially visible when solving problems leads to the necessity of merit content understanding. Automatic understanding is something more than signal processing – it needs also some knowledge and it demands special type of data processing. Details of natural understanding are very complicated therefore, we can talk about understanding in terms of cognitive science.

Nevertheless in this paper I propose methods of artificial imitation of understanding processes. I describe the general methodology of the machine understanding procedures and show how to use this methodology for solving selected biomedical, economical and also engineering problems [2, 7].

2 Automatic and Machine Analysis and Understanding

Trying to explain what automatic understanding is, and how we can force the computer to understand the image content we must demonstrate the fundamental difference between a formal description of an image and the content meaning of the image, which can be discovered by an intelligent entity, capable of understanding the profound sense of the image in question.

The most important difference between traditional methods of image processing and the new concept of image understanding is that there are two-directional interactions between features extracted from the image and expectations resulting from the knowledge of image content. Applying automatic understanding the input data stream must be compared with the stream of demands generated by a dedicated source of knowledge. Such demands are always connected with a specific hypothesis of the image content semantic interpretation. As a result, we can emphasise that the proposed ‘demands’ are a kind of postulates, describing (basing on the knowledge about the image contents) the desired values of some (selected) features of the image. The selected parameters of the image must have desired values when some assumption about semantic interpretation of the image content is to be validated as true. The fact that the parameters of the input image are different can be interpreted as a partial falsification of one of possible hypotheses about the meaning of the image content, however, it still cannot be considered the final solution. Such a specific model of inference we can name the ‘cognitive resonance’ (fig. 1).

Cognitive resonance and cognitive categorisation have been developed by combining intelligent information systems with cognitive systems in which cognitive resonance and cognitive analysis occur.

Our method of image understanding is based on the same processes connected with cognitive resonance.

3 Example of Understanding Medical Image

The connection between proposed methodology and mathematical linguistics, especially a linguistic description of images, is a very important aspect of the automatic image understanding method. There are two reasons for the selection of linguistic methods as a fundamental tool for understanding patterns.

The first one results from the fact, that during the understanding process no classes or templates are known a priori. In fact, the possible number of potential classes goes to infinity. So it must be a tool that offers us the possibilities to describe a potentially infinite number of categories.

The second reason owns to the fact that in the linguistic approach, after processing, we obtain a description of the image content without the use of any classification known *a priori.* This is possible because of a very strong generalisation mechanism within the grammar parsing process.

The only problem consists in a correct adjustment of the terms and methods of formal grammars and artificial languages when applying them in the field of images.

Cognitive categorization approach may be applied to medical visualization. Author has a great experience in application of such a way of semantic analysis for interpretation of various medical images [5, 6, 8]. Below, an example of interpretation of food bones will be presented.

The cognitive analysis of images showing foot bones has been conducted using formalisms for the linguistic description, analysis and interpretation of data, which include such formalisms as graph grammars and to identify and intelligently understand the analysed X-ray images of bones of the foot.

In order to perform a cognitive analysis aimed at understanding the analysed data showing foot bone lesions, a linguistic formalism was proposed in the form of an image grammar whose purpose is to define a language describing the possible layouts of foot bones which are within physiological norms and the possible lesions of foot bones.

The analysis of foot bones in the for example dorsoplanar projection formed the basis for defining a graph used to make a model description of the foot bone skeleton (Fig. 3) which employs the known anatomical rules of this part of the lower extremity (Fig. 2).

Topographic relationships were introduced for the thus defined, spanned graph describing the foot bone skeleton in the dorsoplanar projection. These relationships describe the location of particular structures in relation to one another, as well as the possible pathological changes within the foot (Fig. 4).

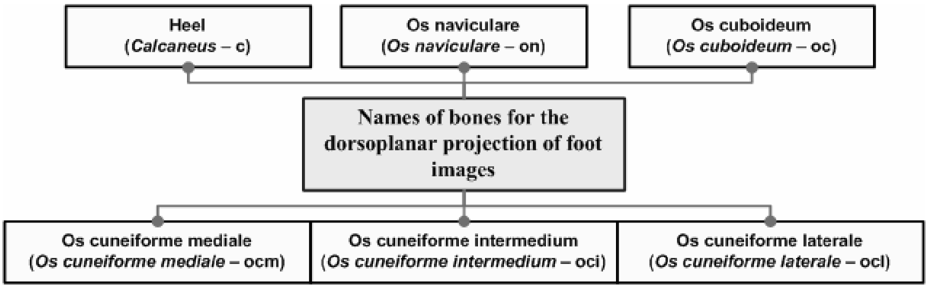

Fig. 2. Names of bones for the dorsoplanar projection of foot images

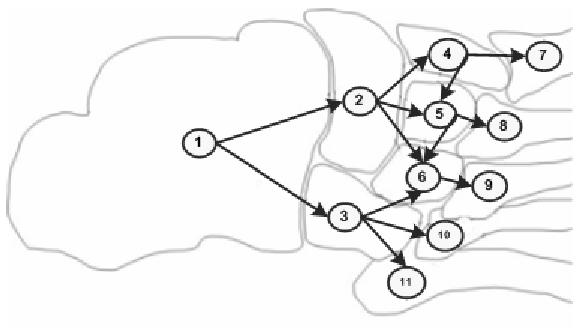

Fig. 3. A graph describing the foot bone skeleton in the dorsoplanar projection

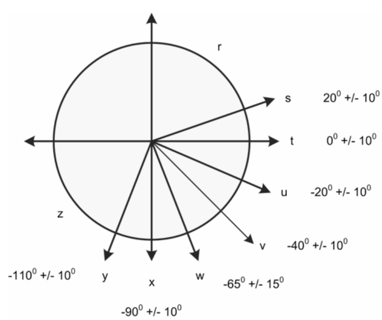

Fig. 4. A relation graph for the dorsoplanar projection of the foot

The introduction of such spatial relationships (Fig. 4) and the representation in the form of a graph spanned on the skeleton of foot bones were used to define the graph proper, in which all the adjacent foot bones were labelled as appropriate for the analysed dorsoplanar projection (Fig. 5). This graph shows bones that are already numbered and which have been assigned labels in line with searching the graph across. (bfs/wfs-wide first serach). Such a representation creates a description of foot bones using the so-called IE graph. This is an ordered and oriented graph for which the syntactic analysis will start from the distinguished apex number 1 (Fig. 5).

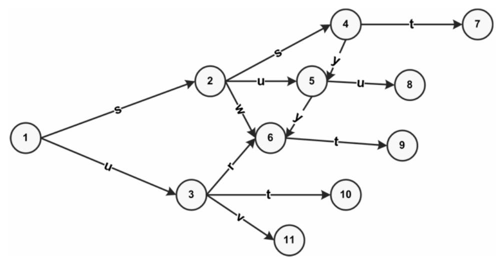

Fig. 5. A graph with numbers of adjacent bones marked based on the relation graph for the dorsoplanar foot projection

For the purposes of the analysis conducted, a formal definition of the graph grammar was introduced, which takes into account the developed linguistic description of correct connections between foot bones:

$$G = (N, \Sigma, \Gamma, ST, P)$$

where:

The set of non-terminal labels of apexes:

N={ST, CALCANEUS, OS NAVICULARE, OS CUBOIDEUM, OS CUNEIFORME MEDIALE, OS CUNEIFORME INTERMEDIUM, OS CUNEIFORME LATERALE, M1, M2, M3, M4, M5}

The set of terminal labels of apexes:

Σ ={s, t, u, v, w, x, y, c, on, oc, ocm, oci, ocl, m1, m2, m3, m4, m5},

Γ – the graph shown in Fig. 5, The start symbol S = ST,

P – a finite set of productions shown in Fig. 6.

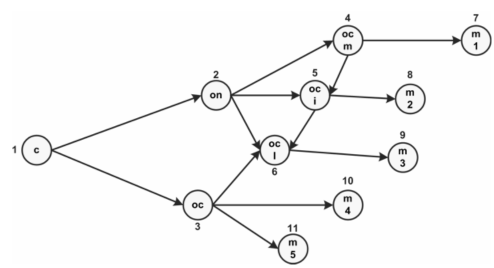

Fig. 6. A set of productions defining the interrelations between particular elements of the structure of foot bones for the dorsoplanar projection

Our analysis of image-type data understanding was aimed at an in-depth understanding of the images analysed, in this case also of specific lesions. Figure 7 shows the possibilities for describing various disease cases by expanding the set of linguistic rules to include additional grammatical rules.

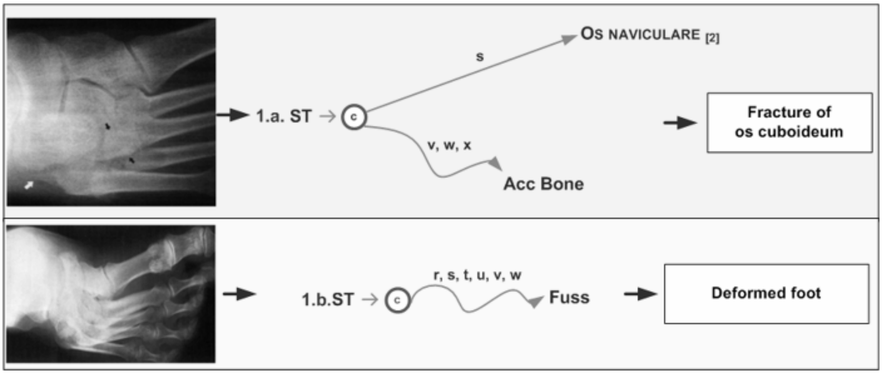

Fig. 7. Examples of using the automatic understanding of foot bone lesions detected by the UBIAS system in the dorsoplanar projection

The presented examples of the cognitive analysis and interpretation of data, describing the lesions appearing in foot bones, show possible cases, namely: fractures and deformations foot.

The types of foot bone lesions shown above and detected by an intelligent and cognitive system have been presented using a selected type of projection for foot bone imaging. Obviously, similar solutions can be proposed for the remaining projection types, that is the lateral projection (external and internal).

4 Conclusion

In the paper we present a new approach based on cognitive categorization to data analysis and pattern understanding. We have described the general concept of machine cognitive inference which allows extracting the semantic information from the analyzed patterns. Applying such a methodology we successfully attempted to develop an experimental implementation of the IT systems relevant to many decision support problems including the intelligent and cognitive systems.

Acknowledgement

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