MEDICAL VISUALISATION INTELLIGENT CONTENT ANALYSIS AND UNDERSTANDING

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ABSTRACT

The paper presents new ideas and possibilities of automatic understanding of the image semantic content. It will explain, how procedures of cognitive analysis can give us the full information about semantics meaning of the merit content in the image. The general idea of automatic images understanding will be than presented, as well as some remarks about the successful applications of such ides both for increasing possibilities of computer vision, and intelligent information systems, dedicated to advanced medical images analysis. Such systems can be directed at tasks supporting medical diagnosis, or the task of multimedia data indexation based on semantic information.

1. INTRODUCTION

This paper presents new way of application of structural pattern recognition techniques in the field of artificial intelligence, and cognitive analysis of selected medical visualizations. In the tasks of advanced pattern analysis very often we need an intelligent method of extraction of semantic content information, which is present in the image, but is not simply visible on it [1]. This stage is difficult, because the matter of things is often hidden and needs precisely understanding of the image instead of its simple analysis, and recognition. On the base of analysis of selected medical examples, we try formulate such three assumptions:

- Semantic interpretation of images cannot be solved by traditional image processing, and pattern recognition methods [2,4,5].
- A promising way leading to extract the semantic meaning is formulating of new paradigm of images interpretation, and development of new method of its full automatisation based on application of advanced tools of artificial intelligence [7].
- Automatic reasoning about images semantic content, performed on the base of picture analysis is called by us automatic understanding of the image.

Such approach for cognitive analysis of semantic content has a few following features:

- It try to simulate natural method of thinking of the human being, who needs to understand the visual content presented on the image [1].
- It is based on linguistic description of the of the image merit content, making using special kind of image description language [6,7], which allow to describe any image without pointing to any limited number of a priori selected classes.
- During automatic understanding process must be used knowledge base, in which most important expected features of the images are listed according to many kinds of semantic interpretations of images under consideration.

Very important difference between all traditional ways of automatic image processing (or recognition) and the new paradigm of images understanding includes one directional scheme of the data flow in traditional methods and definitely two-directional interaction between signals (features) extracted from the image analysis and demands taken from the merit knowledge about the images, given by experts.

In typical expert system the knowledge is treated only as a static formation of data, serving as a material for processing and discovering of answer and explanation. In described image understanding systems we try to apply knowledge in its dynamical form. Knowledge works as a source of some hypothesis about merit sense of the images. From each hypothesis can be further taken many suppositions, expectations, and demands about image under consideration. It is obvious that not every supposition must be proven and not every expectation can be satisfied also if our image includes interesting merit content. This enable to realize the process named cognitive resonance.

2. COGNITIVE RESONANCE IN SEMANTIC ANALYSIS

In automatic image understanding methodology important role plays linguistic description of the image. After description of the image in the form of elements selected from image description language, it must be realised cognitive resonance concept. During cognitive resonance process the generated hypothesis about semantic meaning of the image must be verified with real image features. Mentioned activities are performed by the parser of the introduced picture grammar. Hypothesis generation stage is connected with the use of selected production from formal description of the grammar. Verification of the hypothesis is performed by permanent comparing of the selected image features with the expectations taken from the source of knowledge.

The validation process is similar to physical processes named interference phenomena. Validation is also based on the specific interference between two streams of data. First stream is coming from digital image and all its algorithmically extracted properties. Second is stream of expectations coming form knowledge base and controlled by the linguistic rules represented by graph-grammar parser.

By means of generation of several hypothesis and consecutive increasing or decreasing of its plausibility during special kind of cognitive interference with streams of real and mined data, we can eventually obtain "understanding" of the image content in form of one hypothesis with evident highest (peak) plausibility.

The main advantage of this approach is its possibility to interpret the meaning of a much bigger class of images than the ones, which were used for the writing of the formal language. This results from the fact that the used grammar rules generalise the descriptions introduced and allow one to interpret new cases, previously not defined.

3. INITIAL IMAGE ANALYSIS

For a semantic interpretation of the selected structures from medical examinations and for a verification of lesion advancement level, a graph grammar, and attributed picture grammars may be used. These methods have been applied to describe changes in the width of different structures, visible in special graphs, which are obtained at the image pre-processing stage, using a straightening transformation. This transformation enables the production graphs of straightened structures, which show the morphological changes occurring in them. Besides the straightening transformation during the initial analysis of the images the segmentation and thinning operations are also executed. Details of this operation and the advantages resulting from the application of this transformation are presented in [7,8]. Having such graphs for defining the primary components with linguistic symbols describing these components, an algorithm of linear approximation was used [7,9]. As a result of this operation the sequences of terminal symbols are received, which are next become the input strings to syntax analysers.

4. INTELLIGENT INTERPRETATION OF MRI VISUALIZATIONS

While presenting methods of image understanding we shall relate to examples of medical images. Application of structural pattern analysis methods to extract important semantic information from images will be shown on the example of analysis of spinal cord images.

In the case of analysis of backbone and spinal cord MRI images, the recognition objective is to detect and diagnose lesions, which could evidence a whole range of various disease units: beginning with myelomeningocele, numerous forms of inflammatory conditions or cerebral or spinal cord ischaemia, ending with most serious cases of intra- and extradullary tumours. Un unambiguous identification of all units with the use of recognising software is extremely difficult due to rather subtle differences, decisive for the correct classification of every one of them. As it turns out, however, structural analysis can turn out to be extremely useful in the specification of the degree of the disease unit development by means of specifying the size of lesions in the morphology of the cord and by defining the compression of the spinal cord and meninges [3].

For analysis of this structure a special picture grammar was prepared. It allows to identify the symptoms, and to draw diagnostic conclusions concerning the essence of the visible pathology. The general form of the context-free grammar is the following: G = (VN, VT, SP, STS), where VN - set of non-terminal symbols, VT - set of terminal symbols, SP - set of production, STS - starting symbol of grammar.

In the case of analysis of spinal cord image, the grammar was defined in the following way:

VN = {LESION, NARROWING, ENLARGEMENT, H, E, N}

VT = {h, e, n} for $h \in [-10°, 10°]$, $e \in (10°, 180°)$,

$n \in (-10°, -180°)$

STS = LESION

SP:
LESION → ENLARGEMENT | NARROWING

NARROWING → N H E | N E | N H

$ENLARGEMENT \rightarrow E\,H\,N \mid E\,N \mid E\,H$

$H \rightarrow h \mid h\,H,\; E \rightarrow e \mid e\,E,\; N \rightarrow n \mid n\,N$

This grammar permits to detect different forms of narrowing and enlargements in spinal corsd, which may characterize the different disease units (for example neoplasm or inflammation processes).

Additionally using special defined attributes or semantic procedures allow to calculate the morphologic parameters of detected changes, which may describe the degree of lesion development.

The simplicity of such grammar results mainly from the big generation capacity of context-free type grammars, understood mainly as possibilities to describe complex shapes by means of a small number of introductory rules, that is grammar productions. A slightly different situation occurs in the analysis of pathological lesions in the more complex structures such main pancreatic ducts, where a bigger number of symptoms and the variety of their shapes result in a necessity to introduce a more complex grammar [7].

5. RESULTS

For the defined picture languages the parser were constructed to serve the syntactical analysis. Because of analysis of such images, in each case we have obtained the information regarding kind of recognized lesion and sequences of production numbers, which lead to grammar derivation of shape description of such lesions. Such sequences create a some kind of description of analysed shapes, which can be stored and used as indexing record for multimedia searches.

The results obtained thanks to the application of the presented approach, confirm the wide opportunities offered by structural methods, in the intelligent semantics analysis and interpretation of medical visualizations with pathological lesions. The efficiency of recognition and mining of information important for the analysed images, with semantic character exceeded the threshold of 93%. In Fig. 1 presented examples which show description of the lesions in question for spine and spinal cord images. Recognized symptoms are marked by a bold line.

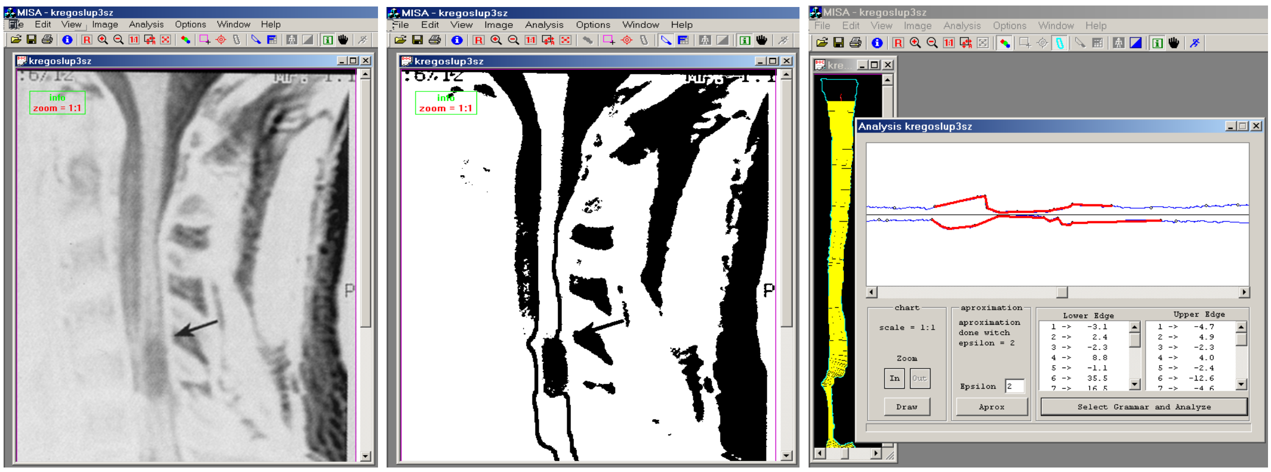

Figure 1.A-C Results of disease symptom interpretation by cognitive resonance procedure. Original and binarised images of spine and spinal cord are presented as well as the result of the lesion detection.

6. CONCLUSION

Because of research conducted on possibilities of application of linguistic approach for the intelligent content analysis of visual data, it was shown how to construct intelligent information systems allowing recognizing, and understanding important lesions visible on analysed patterns. These methods have turned out to be not only very efficient in direct morphological deformation recognition on various medical images, but also allow to introduce very effective methods of creation meaning description of the examined images. Research conducted proves that linguistic approach discussed in this paper enables such an intelligent cognitive analysis and pattern understanding. Owing to this, they allow to recognise efficiently pathological lesions of dangerous diseases. The fact of automatic understanding of the image content can have numerous further applications: for example such information can be used to monitor the therapeutic processes or to forecast the disease development as well as the patient's future state. Having efficient method guaranteeing automatic understanding of the medical image, it is possible to use the results obtained with this method as special descriptions for indexing images in a multimedia database. Preparing of this form of indexation, first for images stored in a data base and later also for images in the form of queries addressed to that data base will allow one to enhance the process of context search for image information.

7. ACKNOWLEDGEMENT

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