COGNITIVE REASONING IN INTELLIGENT MEDICAL INFORMATION SYSTEMS

Visual Data Perception Algorithms in Medical Decision Support Systems

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Abstract: This paper presents new approach in application of picture languages for cognitive analysis and reasoning of selected medical visualization. It will be shown new opportunities for applying these methods to undertake tasks of the automatic understanding of image semantics in intelligent medical information or computer-aided diagnosis systems. These systems are applied in various tasks supporting decisions taken in the wide area of health care and medical imaging. The possibility of obtaining the information about semantic content of the medical images may contribute considerably to the creation of new intelligent cognitive medical systems. This article shows that structural techniques of artificial intelligence may be applied in the case of tasks related to automatic classification and machine perception of semantic pattern content in order to determine the medical meaning of the images. In the paper, we describe some examples presenting ways of applying such techniques in the creation of cognitive vision systems for selected classes of medical images.

1 INTRODUCTION

In the foundations of image understanding there are many algorithms and AI approaches to the task of intelligent visual data perception and analysis. Among them one is the most important enabling to make a deeper semantic and cognitive analysis. These are picture languages consisting formal grammars for pictorial pattern analysis as well as languages of shape features description allowing multidimensional pattern classification. In this paper will be presented the way of application of such formalisms to the task of understanding of medical visual data, especially in the intelligent medical information systems. We try to show how the tasks of automatic understanding of medical data may be done using cognitive analysis approach, which allow to make a semantic perception of analyzed visualization. Generally, the perception of an image requires a deeper analysis aimed at the determination of significant semantic features (Albus, 2001). Such features enable a further semantic image interpretation or a semantically oriented indexation in databases (especially when objects are retrieved from various diagnostic examinations or determine different disease entities). A proper semantic interpretation of the data being analyzed is very important because in the case of medical images often happens that the same illnesses are visualized in various forms of images that are registered and processed (Fig.1). This is the main reason why attempts have been made to create a system that would automatically find the message (i.e. the content) carried by analyzed medical images.

Due to the fact that the number of combinations of features that characterize images is not limited, it can be assumed that perception may refer the image to potentially unlimited number of classes. This may be achieved by cognitive analysis, in which specified languages of image description must be used.

The general approach in the cognitive analysis is the initial interpretation of images and specification of important features. The proper selection of such features is conducted by means of image pre-processing. Next features are subsequently described with the use of a picture language generated by an appropriately defined attributed grammar. Properties described in this way can be later reproduced in the

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course of structural reasoning conducted by the prepared information system.

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.

For such interpretation of the mentioned structures and for a verification of lesion advancement level, a graph grammar (Ogiela, 2003), and an attributed grammar have been proposed.

Before coming to the cognitive interpretation of the changes, it is necessary to preserve the sequence of preliminary operations, which are included in the image pre-processing. The goal of this analysis is to obtain new representation in the form of width graphs, which show the pathological changes occurring in these structures.

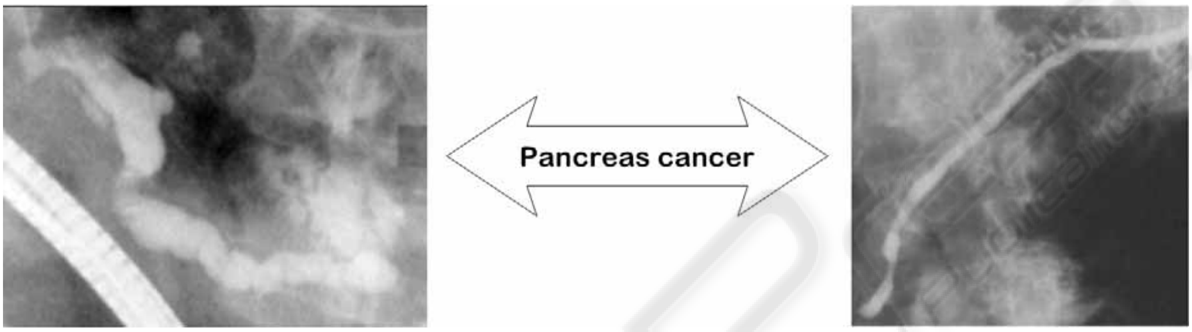

Figure 1: Two images carrying the same message. In both cases, the symptoms of pancreas cancer are visible

During the initial analysis of visualisations, the following operations are executed: segmentation, skeletonization, and the application of a straightening transformation to transform the contour of the analysed structure into two-dimensional graph, which shows a profile of a straightened organ. The graphs obtained in such way are the starting point in the classification of morphological features by using context-free grammars. In order to define primary components on the obtained width graphs as terminal symbols describing these components, an algorithm of linear approximation was used. As a result of approximation the sequences of terminal symbols for every graph was received, which constitute an input to syntax analysers and semantic classifiers.

2 PICTURE GRAMMAR FOR COGNITIVE ANALYSIS

A possibility to conduct cognitive analysis will be presented on the examples of patterns received during the diagnostic examinations of renal pelvis, and coronary arteries.

2.1 Coronary Image Interpretation

Analysis of coronary arteries is extremely important from the point of view of correct diagnosis of myocardial ischaemia states caused by coronary atheromatosis sclerosis lesions resulting in stenoses of artery lumen, which in consequence lead to myocardial ischaemia disease. This disease can take the form of either stable or unstable angina pectoris or myocardial infraction (Khan, 1996).

The following attributed grammar has been proposed to diagnose various types of stenosis shapes:

V_N = {SYMPTOM, U, H, D}

V_T = {h, u, d} for $h \in [-10°, 10°]$, $u \in (10°, 90°)$, $d \in (-10°, -90°)$

STS = STENOSIS

SP:

STENOSIS $\rightarrow$ D H U STENOSIS $\rightarrow$ D U | D H	Lesion = Stenosis
H $\rightarrow$ H h | h D $\rightarrow$ D d | d U $\rightarrow$ U u | u	$w_{sym} = w_{sym} + w_h$ $h_{sym} = h_{sym} + h_h$ ...

This grammar allows to detect different forms of coronary artery stenosis, which may characterize the different disease units (angina pectoris or infarct). Using attributes permits to calculate the numerical parameters and semantic information of detected lesions, which allows to characterize the degree of lesion development.

The simplicity of this grammar results mainly from the big generation capacity of context-free grammars, understood mainly as possibilities to describe complex shapes by means of a small number of introductory rules, that is grammar productions.

2.2 Renal Pelvis Cognitive Analysis

In the case of analysis of renal radiograms, the main task is to recognise local stenoses or dilations of upper segments of urinary tracts and attempt to define the correct morphology of renal pelvis and renal calyxes. Lesions in those structures can suggest the occurrence of renal calculi or deposits, which causing ureter artresia can lead to diseases such as acute extrarenal uraemia or hydronephrosis. An analysis of the correct morphology of ureter lumen will be conducted with the use of context-free attributed grammar.

Diagnosing morphological lesions in the form of ureter stenosis or dilations has been conducted with the use of the following attributed grammar:

V_N = {LESION, STENOSIS, DILATATION, HOR, SLOPE_UP, SLOPE_DOWN}

V_T = {h, v, nv} for $h \in [-8°, 8°]$, $su \in (8°, 180°)$, $sd \in (-8°, -180°)$

STS = LESION

SP:

LESION → STENOSIS STENOSIS → SLOPE_DOWN HOR SLOPE_UP STENOSIS → SLOPE_DOWN SLOPE_UP STENOSIS → SLOPE_DOWN HOR	Lesion = Stenosis
LESION → DILATATION DILATATION → SLOPE_UP HOR SLOPE_DOWN DILATATION → SLOPE_UP SLOPE_DOWN DILATATION → SLOPE_UP HOR	Lesion = Dilatation
HOR → HOR h | h SLOPE_DOWN → SLOPE_DOWN sd | sd SLOPE_UP → SLOPE_UP su | su	$w_{sym} = w_{sym} + w_h$; $h_{sym} = h_{sym} + h_h$ ...

3 SELECTED RESULTS

As a result of cognitive analysis using linguistic approach it is possible to understand pathogenesis of the deformations viewed on x-ray images of the organs under consideration, what means the possibility of recognize some kind of diseases even on images absolutely not similar one to other.

Presented approach is applicable even if no templates of healthy and pathological organs at all or if number of recognized classes goes to infinity. In particularly applications of the presented grammars deliver almost complete information concerning the visual morphological irregularities of investigated organs. An analysis of the morphological changes was carried out based on a set containing few dozens of images. The efficiency of gaining recognition of information with semantic character, in all cases exceeded the threshold of 93%. In Fig. 2 are presented examples, which show the description of the changes in ureter ducts, and coronary arteries.

The results obtained owing to the application of the characterized methods, confirm the immense opportunities offered by syntactic methods in the cognitive analysis of medical visualizations showing dangerous pathological lesions.

4 CONCLUSION

Development of the intelligent information systems and techniques of visual data semantics analysis made possible to understand the medical meaning of any images coming from diagnostic research. However, the full automatic analysis and interpretation of such data is still a real problem, advanced techniques of artificial intelligence must be applied to enable the creation of systems that can both recognize and understand visual data (Ogiela 2003).

Thus the aim of the presented techniques was to show an innovative concept of the application of structural pattern analysis in the creation of cognitive information systems.

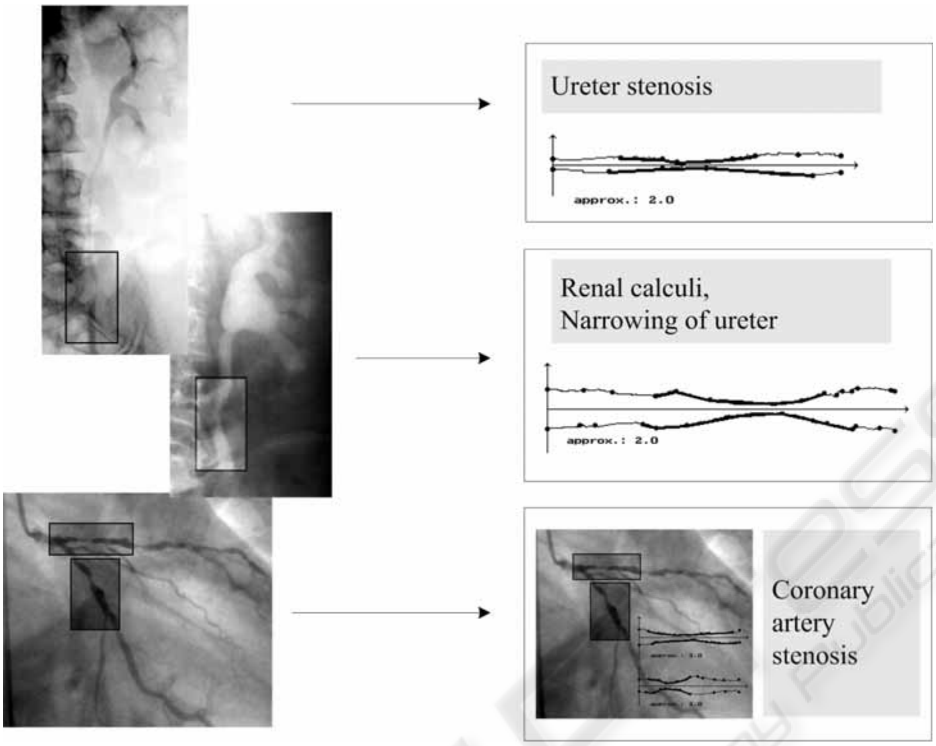

Figure 2: Results of disease symptom interpretation in intelligent diagnosis support system

Such systems are able to understanding and determining the semantic meaning of medical images of certain classes. It is worth mentioning that machine perception using such methods may lead to an automatic interpretation of medical images in the way it is done by a specialist. It may enable the determination of not only crucial changes but also the consequences of existing irregularities and finally the optimal directions and methods of conducting a suitable therapy. Automatic understanding of the image content can have numerous further applications for example such information can be used to monitor therapeutic processes or to forecast disease development as well as the patient's future state of health.

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REFERENCES

Albus, J.S., Meystel, A.M., 2001. *Engineering of Mind: An Introduction to the Science of Intelligent Systems.* John Wiley & Sons.

Khan, M.G., 1996. *Heart Disease Diagnosis and Therapy.* Williams & Wilkins, Baltimore.

Ogiela, M.R., Tadeusiewicz, R., New approach for cognitive analysis and understanding of medical patterns and visualizations. Proceedings of SPIE, vol. 5203 Andrew G. Tescher (eds.), SPIE, Bellingham WA, 2003, pp.615-622.

Ogiela, M.R., Tadeusiewicz, R., Cognitive Vision Systems in Medical Applications. Lecture Notes in Artificial Intelligence, 2871 (2003) 116-123.

Ogiela, M.R., Tadeusiewicz, R., Artificial Intelligence structural imaging techniques in visual pattern analysis and medical data understanding. Pattern Recognition, 36 (2003) 2441-2452.

Sonka, M., Fitzpatrick, J.M. (eds.), 2000. *Handbook of Medical Imaging: Vol. 2- Medical image processing and analysis.* SPIE PRESS, Bellingham WA.