New Aspects of Using the Structural Graph-Grammar Based Techniques for Recognition of Selected Medical Images

Marek R. Ogiela and Ryszard Tadeusiewicz

This report will describe the application of syntactic pattern recognition methods for analysis of morphology and recognition of pathologic symptoms of chronic diseases such as upper urinary tract disorders. Detection of these lesions will be assisted by the special graph-grammar developed in our institute for efficient analysis and recognition of such lesions. We present key points of methodology and practical results of its application.

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IN OUR WORK we propose a new approach for recognition of morphologic changes in medical images showing ureters, renal pelvis, and renal calyx morphology. Lesions in the upper segments of the urinary tract may indicate the presence of renal calculi or deposits causing artresia of urinary tracts, leading to diseases such as extrarenal uremia or hydronephrosis. Our methodology is based on syntactic methods of shape feature description.¹ Starting from recognition of simple shape elements, we try to build a general description of the actual form of object under consideration. The base for this description is a special kind of graph-grammar developed in our institute over the past 10 years, which is especially efficient for analysis and early detection of cancerous and inflammatory lesions in the pancreas.² Using the actual shape of an interesting organ image and our special graph-grammar, we can obtain a description of the organ as a sentence in our graph-grammar. For every image, of both healthy and diseased organs, we obtain a different sentence, because every organ is unique. However, using our grammar base, we can parse this sentence and reduce it to one of the known categories—separately for normal shapes of interesting organs, and separately for many disorders. For each case of disease, we obtain a unique result from the parsing, belonging to one of several classes. In case of equivalence of some classes, from the medical point of view, we can establish a recognizable result using simple post-processing methods.

Recognition of the lesions is possible due to an earlier application of a special sequence of operations included in the early processing of the examined images.²

GRAPH-GRAMMAR IN THE DESCRIPTION AND ANALYSIS OF RENAL PELVIS AND RENAL CALYX SHAPES

Analysis of renal pelvis and renal calyces has been conducted with the application of an expansive graph-grammar G_{edt} .¹ In particular, this analysis of features has been conducted with the application of a graph grammar defined to describe the correct morphology of skeletons of the examined renal pelvises and renal calyces. To diagnose morphologic changes in renal pelvises the following graph-grammar was used:

$$G_{\text{edt}} = (\Sigma, \Gamma, r, P, Z), \text{ where}$$

$$\Sigma = \Sigma_N \cup \Sigma_T,$$

$$\Sigma_T = \{\text{pelvis, calyx_b, calyx_s, 1}\},$$

$$\Sigma_N = \{\text{RENAL_PELVIS, B, C}\}$$

$$\Gamma = \{x \in (30^\circ, 180^\circ),$$

$$y \in (30^\circ, -30^\circ),$$

$$z \in (-30^\circ, -180^\circ)\},$$

$$Z = \{\text{RENAL_PELVIS}\}$$

P:

1. RENAL_PELVIS $\rightarrow$ pelvis (xB yB zB)|pelvis (xB yB)|pelvis (xB zB)|pelvis (yB zB)
2. B $\rightarrow$ calyx_b (xC yC zC)|calyx_b (xC yC)|calyx_b (xC zC)|calyx_b (yC zC)
3. C $\rightarrow$ calyx_s (x1)|calyx_s (y1)|calyx_s (z1)|calyx_s (x1 y1)|calyx_s (x1 z1)|calyx_s (y1 z1)

STRUCTURAL DESCRIPTION AND RECOGNITION OF URINARY TRACT LUMEN STRICTURES

Detecting morphologic lesions in the form of stenosis and dilation of the ureter duct has been

From the University of Mining and Metallurgy, Institute of Automatics, Krakow, Poland.

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Address reprint requests to Marek R. Ogiela, University of Mining and Metallurgy, Institute of Automatics, PL-30-059 Krakow, 30 Mickiewicza Ave, Poland. E-mail: mogiela@agh.edu.pl.

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conducted with the use of the following attributed grammar: $G_U = (V_N, V_T, SP, START)$,

where $V_N = \{LESION, STENOSIS, DILATATION, H, V, NV\}$ – non-terminal symbol set

$V_T = \{h, v, nv\}$ for $h \in (-8^\circ, 8^\circ)$, $v \in (9^\circ, 180^\circ)$, $nv \in (-9^\circ, -180^\circ)$ – terminal symbol set

SP – production set, START – starting symbol

START = LESION

The set of grammar production is defined in Table 1.

The presented grammar allows various types of stenosis and dilation, characteristic for different diseases, to be discovered.

RESULTS

Thanks to the application of the presented context-free grammars it is possible to detect quite precisely different kinds of irregularities in the form of stenoses, or a dilatation of investigated structures. The detection of irregularities appearing in the set of test data is carried out by syntax analyzers, generated on the basis of the formal description of grammars. Analysis of the morphologic changes in upper urinary tracts was performed on the basis of a set of dozens of kidney roentgenograms containing images that showed both congenital changes in renal pelvises and ureter morphology, and the acquired changes showing the existence of a disease process. Efficacy of these

Table 1. Grammar Recognizing Lesions in Morphology of Ureters

start LESION			
LESION :	DILATATION	STENOSIS	
DILATATION :	V H NV	V NV	V H
STENOSIS :	NV H V	NV V	NV H
H :	H h	h	
NV :	NV nv	nv	
V :	V v	v

Fig 1. Roentgenogram with visible ureter stenosis. Width diagram with marked results of stenosis recognition.

methods can be estimated at 90%; however, the methods are constantly being improved on larger data sets. Figure 1 presents an example of recognition of the looked-for lesions on an image of the urinary tract.

SUMMARY

We have presented syntactic methods of pattern recognition and examples of their use in tasks of specialist analysis of morphologic shapes of the upper segments of ureters and the renal pelvis. Analysis of the correct morphology of these structures has been conducted with the use of sequential and graph methods. These methods allow extremely efficient description and recognition of lesions on width diagrams of the obtained structures. We use our methodology to detect pathologic signs in many types of medical images.² We find syntactic methodology to be very useful and fruitful in almost every considered application in the analysis of medical images. It may also constitute an additional tool to support early diagnosis of disease states in picture archiving and communication systems (PACS).⁴

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