A RULE-BASED EXPERT SYSTEM FOR LOW LEVEL IMAGE PROCESSING

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ABSTRACT

Image understanding and object recognition require description of those segments of the image that correspond to objects or parts of objects present in the scene. This suggests partitioning of the input image into reliable and meaningful segments. An attempt has been made to design a rule-based expert system that can partition a digitised image into meaningful segments. Both region growing and line detection techniques are employed separately for segmentation. Segments that are found consistent in both region and line analyses may be considered as more reliable segments that correspond to objects in the scene. Features of consistent regions are computed and stored which may be used for object recognition.

INTRODUCTION

In contemporary researches in computer vision attempts have been made to analyse images originating from three dimensional scenes in order to understand their contents. This may be accomplished by assigning appropriate interpretations to objects within the scene. Thus the input image has to be first segmented into regions that should, at least, roughly correspond to objects, surfaces, or parts of objects in the scene represented by that image. From the descriptions of the segments generated recognition of objects within the image can be made. Thus, the whole process has been divided into two phases: low level processing and high level processing. Processing starts with low level. This includes some pre-processing like filtering, thresholding, etc and segmentation. Segmentation is then followed by generating descriptions which are measurements of the properties of a single or relationship between regions. The high level processing includes scene matching and recognition of objects. Appropriate interpretations are then assigned to the segmented results so that objects can be recognised.

Two well-known techniques of image segmentation are region growing and line detection. The first one is based on uniformity of image features of connected pixels while the second is on the basis of their non-uniformity features. As the two techniques are, in principle, mutually exclusive, attempts have been made to employ knowledge of both the techniques, either in disjoint or in connected fashion, to obtain reliable segment. Hanson and Riseman (1978) employed region and line analyses separately for their low level image processing system. The resulting regions and lines were then combined if they had reasonable parity. Nazif (1983) designed a rule-based system for image segmentation that employed both the techniques. Both region and line analyses are combined at the earlier stage of processing. In region analysis, line information was used and vice versa. In the work presented in this report an attempt has been made to design a simple rule-based expert system for low level image processing employing both region and line analyses separately. Sobel operator(Duda and Hart 1973) is used to compute gradient image for edge detection and local features of pixels are considered for region growing. Knowledge for refinement of regions and lines are incorporated in the two analyses separately. Parity checking between their outputs is effected at the later stage. Regions that are found consistent in both the analyses are considered as the most reliable regions present in the input image. The system generates descriptions of the consistent regions.

SYSTEM OVERVIEW

The expert system, IMAGEX, is designed around an expert system shell, DEXT, developed in the Department of Computer Science and Engineering, Indian Institute of Technology, Kharagpur. The system has been structured in the form of a modular set of processes with two associative databases. Data that will not be changed frequently are stored in long-term database (LTDB). Algorithms for low level processing coded into executable programs are stored in this database. The short-term database (STDB) holds data that will be changed frequently. The input image, segmentation data during processing, and final results are stored in this database. Each of the system processes has access to both LTDB and STDB.

Rules governing the whole process are stored in the rule base. A system process tests the conditions of firing of rules in the rule base against the data stored in the STDB. When a condition matches, the rule fires and the appropriate action is performed. It may be a change or update of data in STDB or executing a program in LTDB. To reduce the requirement of main memory at a time as well as to reduce the searching time, the rule base is divided into four rule blocks : INITIALISER, REGION ANALYSER, LINE ANALYSER and CONSISTENCY TESTER, as shown in Fig.1. Each block consists of rules that perform specific task as implied by the names of rule blocks.

All the rule blocks have access to both STDB and LTDB.

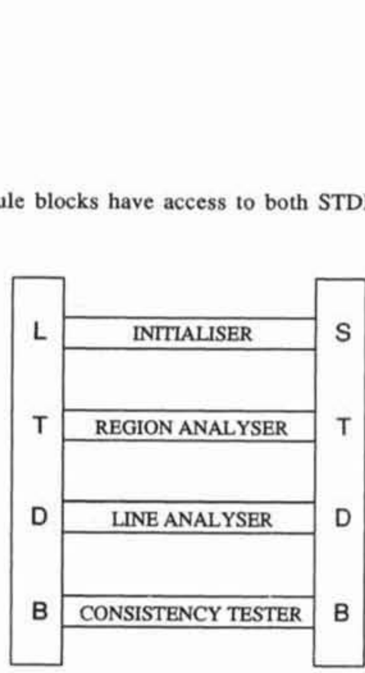

Fig.1 : Rule blocks with two associated databases

SEGMENTATION TECHNIQUES

Segmentation is partition of the input image in components or regions that are homogeneous with respect to one or more image features. Two sorts of segments are natural: regions and boundaries or lines. Though one seems to be redundant in presence of the other, they can co-operate to produce more reliable segments.

A. Region Growing : Region growing is mapping of individual pixels of the input image to sets of pixels called regions. This is done on the basis of the uniformity of image features. Region growing generates a region map of the input image in which every pixel is attached a label that indicates the region number it belongs to. Some of the techniques of region growing are :

Local : Pixels are placed in a region on the basis of their properties or the properties of their close neighbourhood.

Global : Pixels are grouped into regions on the basis of the properties of large number of pixels distributed throughout the image.

These two techniques are related to individual pixel or sets of pixels.

Splitting and Marging : Region growing initiates with arbitrary division of the input image into regions. The initial number of regions may be one or equal to the total number of pixels of the input image depending on whether the whole image or each pixel of the image is considered as a region. The image may also be divided into 2x2 or 3x3 pixel arrays to obtain initial regions. Then a region is either splitted or two regions are merged depending on their characteristics. The process of splitting and merging are continued till the conditions for doing so are satisfied.

In our design, the initial region map has been developed by following the local and global techniques. Statistical features like average and variance of intensity and gradient over each region are computed. Co-ordinates of the minimum bounding rectangle and the centroid are evaluated as position features. Shape features like area, perimeter, circularity, aspect ratio are computed. Also, the spatial features of each region, i.e., knowledge of each adjacent region as well as the amount of adjacency are computed. The rule-based merging of regions is implemented. Instead of arbitrary selection of initial regions, this technique of region growing reduces the processing time.

B. Line Detection : This is the complementary approach for segmentation. Line analysis deals with local features that involve abrupt changes in gray levels.

Gradient operators are the tools for edge detection, which give high values to points where the gray level is changing rapidly. For digital images, instead of derivatives, spatial difference operators are used. In the present study, spatial differentiation operation is carried out by using the image by 3x3 Sobel operators in the X and Y directions :

$$\begin{matrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{matrix} \qquad \begin{matrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{matrix}$$

The magnitude and direction of the gradient were obtained by

$$G = |S_x| + |S_y|$$

and

$$\varnothing = \operatorname{atan}[S_x / S_y]$$

The direction has been digitised similar to the directions of the eight-connected pixels starting from 0 to 7 in the anticlockwise direction with 0 as the positive X-direction.

Thus, we get a gradient image. Pixels having low gradient values indicate regions of uniform intensity in the image, whereas high values correspond to smart changes in intensity levels and represent the boundaries between regions. An edge image is then computed by applying a suitable threshold to the gradient image. Initial lines are formed by grouping eight-connected edge-points. Each line is marked by a specific label and pixels belonging to that line are attached that label. A pixel can belong to utmost one line. Overlapping of lines is not allowed. Pixels that do not belong to any line, bears a null label. Thus, a line map is generated that describes the lines within the image. Like regions, statistical and position features for each line are computed. Rule-based deletion of lines is incorporated in line analysis.

Table-I represents data structures for regions and lines. Thus, segmentation replaces the pixel level information of the input image by more structured higher level information, regions and lines.

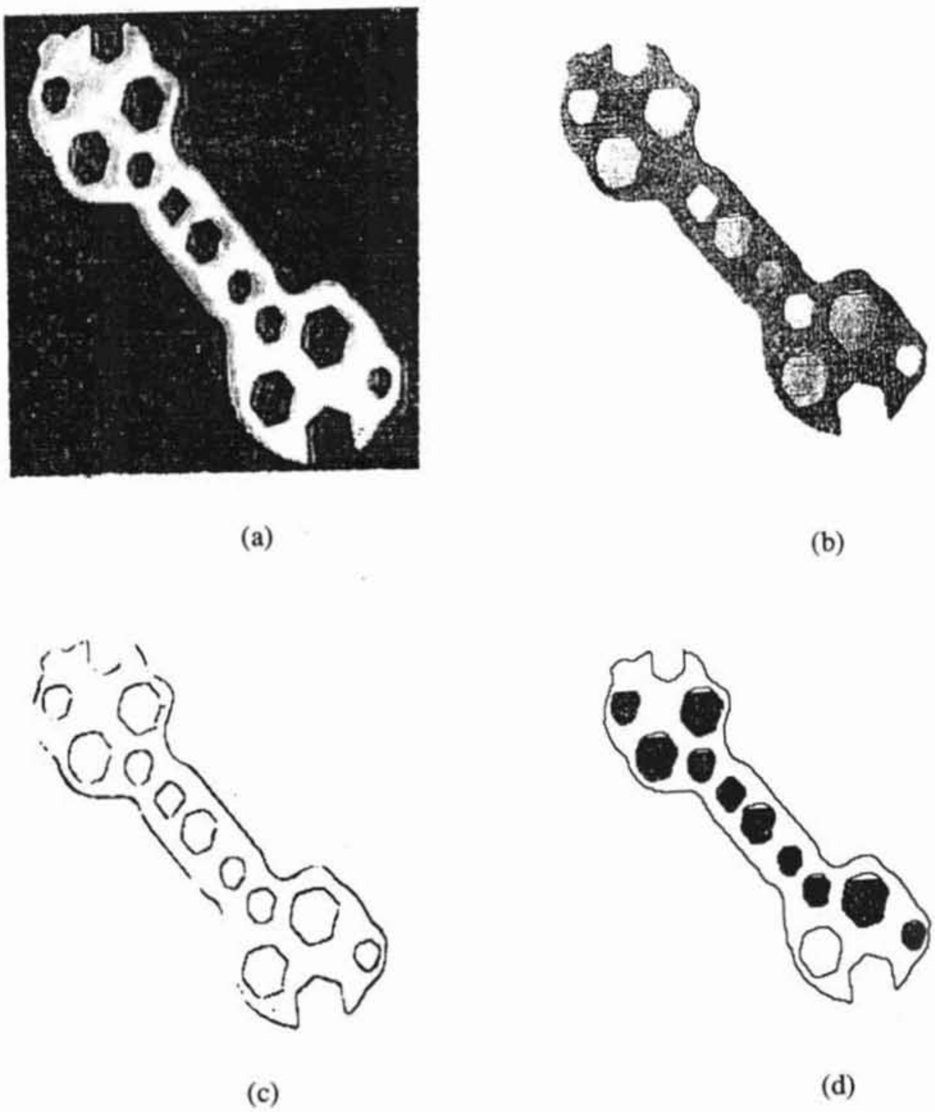

Fig.2 : (a) original image (b) region segmentation
(c) line segmentation (d) consistent regions

Table-I

Region		*Line*	
region number	n	line number	n
		line type	T
average intensity	I	average intensity	I
intensity variance	σ_I	intensity variance	σ_I
average gradient	G	average gradient	G
gradient variance	σ_G	gradient variance	σ_G
bounding rectangle	X_{min}, Y_{min} X_{max}, Y_{max}	bounding rectangle	X_{min}, Y_{min} X_{max}, Y_{max}
centroid	X_c, Y_c	centroid	X_c, Y_c
area	A	area	A
perimeter	P	starting co-ord.	X_s, Y_s
circularity	Θ	ending co-ord.	X_s', Y_s'
aspect ratio	δ	length	l
number of adjacent regions	m		
adjacent region number	adjacency		
...	...		
...	...		

IMPLEMENTATION

The system has been designed around the expert system shell, DEXT, on the basis of general-purpose program modules and knowledge that can process an image in low level. Rules for controlling the whole process are contained in the rule base of DEXT. There are four rule blocks in the rule base. The system initiates processing in the first rule block, INITIALISER. On receiving the image array, this block computes thresholded image and magnitude and direction of gradient at each pixel of the image. It also generates the edge image. On completion of all the tasks, it passes control to the next block, REGION ANALYSER.

The REGION ANALYSER starts processing with generating the initial region map on the basis of local and global features of the pixels of the input image. Region analysis is then started. In the module for the region analysis, the statistical, position and spatial features of regions generated are computed. Two regions are merged if the conditions for region merging are satisfied. The region map is updated accordingly. The process continues until there is no rule to fire. It stores the descriptions of all the final regions and transfers the control to the subsequent block.

The next rule block, LINE ANALYSER, performs all tasks related to lines. First, it generates the initial line map from the edge image data computed by the INITIALISER. Second, by invoking the line analysis module, it obtains different features of the newly generated lines. Rules related to the lines are tested. The line map is accordingly updated and features of lines are computed. While all the tasks are duly completed, appropriate rule for switching the control fires and the final rule block is initiated.

Both region growing and line detection techniques segment the input image on their own way. Thus, the outputs of both the methods for an image can be consulted in order to get the more reliable segments. The rule block, CONSISTENCY TESTER, does essentially this task. First, it checks whether all the tasks of REGION ANALYSER and LINE ANALYSER are duly completed. Second, if yes, it starts searching for the segments that are consistent in both the outputs of region and line analyses. Third, it stores the region number along with its descriptions for each region that is found consistent in both the analyses. It displays the consistent regions of the image graphically and finally, stops the system.

RESULTS AND DISCUSSION

Segmentation of an input image done by the system is shown in Fig.2. The image(256x256) is represented by Fig. 2(a). Region and line segmentation performed by the system are shown respectively in Figs. 2(b) and 2(c). Fig. 2(d) presents the segments that were found consistent in both region and line analyses.

The results reveal that, in spite of the simpler design, the performance of the system is hopeful and it yields good results for segmenting an image in which objects are fairly distinct. However, these are scopes for improving the system. In a second phase of processing, region analysis can use the results of line analysis and vice-versa. This might improve the performance of the system.

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