Finding Stomach in X-ray Film Using Computational Geometry

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ABSTRACT

The human stomach is difficult to recognize in an X-ray because of its elasticity. Global information of the stomach or areas of similar density is required for easy recognition. The authors have developed a method for finding the border line of a stomach by using computational geometry. The method is composed of three steps. In the first step, the edge is enhanced, and then edge pieces are selected as candidates for the border. Because the resulting border is almost always incomplete, a method for connecting the pieces is required. In the second step, we use computational geometry to create the global structure from the selected edge pieces. A Delaunay graph is drawn from the end points of the pieces. This enables us to decide which pieces are most likely to connect. In the third step, we use the shape of a stomach to find the most appropriate sequence of the pieces. The knowledge is described as simple LISP functions.

Because a Deraunay graph is planer, we can suppress the number of candidate pieces while searching the most likely sequence. We applied this method to seven stomach pictures of double contrast method and found the greater curvature in six cases. Enhancement of the shape knowledge will improve the the recognition accuracy.

1. DESCRIPTION OF GLOBAL STRUCTURE

1.1 Characteristics of The Stomach:

Though the study of automatic recognition of the human stomach started in early 1970's [1], there is still no algorithm with sufficient accuracy. There are two major reasons for this. One is that since the stomach is an elastic object, the template matching is inadequate. The other is that the X-ray picture contains many obstacles such as the spine or ribs. These obstacles have edges with properties almost the same as that of the stomach. Thus, stomach edges are difficult to distinguish from spine edges when matched filtering is used.

Because of these matched filtering limitations, the knowledge of global structure must be used under specified control [2] to select appropriate edges from among those in the picture. Nakamura et al. [3] proposed an algorithm that considers the global shape of a stomach border line. In their algorithm, edge detection by filtering is applied first. The resultant picture is composed of many edges of both the stomach border line and the obstacles (spine). As usual with edge detection, the stomach border line is not continuous due to the noise. To find the true border line (i.e., edge pieces) of the stomach, they search the most likely sequence of edge pieces. Then, they used regional search to find the neighboring pieces, and connected these pieces to form curve candidates for the border line. The shape of the curve was evaluated using the knowledge of the stomach shape. After several iterations of connection and evaluation, the most likely sequence was found.

The algorithm proposed by Nakamura et al. is important because it shows the effectiveness of the knowledge of global shape. However, this algorithm has two areas that require improvement. The first is the enormous amount of computation required by the regional search. The second is the inflexibility of the knowledge, because it is implanted within a procedural computer language. In other words, the global structure expressions are implicit.

1.2 Using Computational Geometry:

The authors propose the use of computational geometry to overcome the problems mentioned in the last section. We used a Delaunay graph to express the global structure of the picture. This method has many excellent features. First, it gives an explicit expression of the structure of an object. This enables us to use the knowledge of the stomach shape to write a program having an explicit expression, and thus, making the knowledge flexible. Second, many fast, effective algorithms have been developed by specialists in this field. Ohya's algorithm [4] for making a Voronoi diagram is especially advantageous. Because this algorithm runs with a linear order relative to the number of points, we can create a fast program for determining the structure of the picture. Third, the Delaunay graph reduces the amount of computation when searching the neighboring edge pieces. Because the Delaunay graph is a planer graph, we can limit the number of candidate edge pieces to 6, which is a constant independent of the input size. Use of the Computational Geometry is described in the next section.

2. PROPOSED ALGORITHM

The proposed algorithm has three steps, which are described in the following sections.

2.1 Step 1 - Edge Detection:

The first step is to find the edge pieces, which are candidates for the stomach border line. This first step has three sub-steps: edge enhancement, thresholding, and line tracking. Edge enhancement is accomplished by enhancing the high-frequency component of the picture by using spatial filtering. Any high-pass filter can be used. We chose the most simple filter, a 3x3 Lapracian, since the aim of this study is not to find an effective filter, but to show the usefulness of computational geometry. Next, we converted the filtered picture into a binary picture by using a threshold of theta. Theta is selected so that 1% of the pixels remain '1' (black). Since our picture size is 1024x1024, this is about 10,000 black pixels. On the other hand, since the length of the border line is approximately 1,000-2,000 pixels, this 1% threshold is appropriate since there is always some noise. Figure 2 shows the result of edge enhancement and thresholding of the original picture in figure 1. After thresholding, line tracking is performed to find edge pieces. Local direction of the '1' pixels is decided for all 8x8 pixel subareas. Next, the connectivity of local directions are checked. If there is a sequence of subareas whose shape is consistent to form a longer curve, the subareas are marked with the same label, and the sequence is labeled an edge piece. Figure 3 shows an example of edge detection results. After finding all edge pieces in the picture, their end point locations, which will be used in the next step, are listed.

2.2 Step 2 - Global structuring:

In this step we create the global description of the picture, i.e., express the relations of the end points. This expression is required so that the global knowledge of the stomach shape can be applied to the picture. We adopt the technique of computational geometry, a Delaunay graph, for this purpose. A Delaunay graph is defined as a planer graph whose edges connect all the pairs of neighboring points. Here the notion of "neighboring" is defined clearly in computational geometry. Thus Delaunay graph is effective in searching for edge pieces that are likely to succeed to the previous one.

To draw a Delaunay graph, it is necessary to make a Voronoi diagram from the points, by using the algorithm by Ohya [4]. It is easy to draw the Delaunay graph from the Voronoi diagram. Figure 4 shows the Delaunay graph drawn from the end points of the edge pieces in figure 3.

2.3 Step 3 - Border line selection:

In this step we search for the most appropriate border line, i.e. sequence of edge pieces. We use the Delaunay graph drawn in the last step. Selecting an appropriate path in the Delaunay graph is defined as the problem. This can be solved using a tree-search. The knowledges of the stomach shape is represented as selection rules of continuing edges.

In this study, the following three features of the stomach shape are used to find the border line: (1) the border line is smooth, (2) the stomach is placed almost at the center of the picture, and (3) the border line is convex. The selection rules are programmed as (1) the relative direction of the continuing edge must be in the range from +80 degree (clockwise) to -10 degree (Fig.5(a)), (2) the gravitational center decided by the nodes must be in the central area (a circle with a 400-pixel radius at the center of the picture), and (3) the direction in a sequence must start at about 60 degree (downward) and must stop before 270 degree (upward) (Fig.5(b)).

Under these rules, tree search is applied and some edge sequence candidates are found for the border line. An additional rule is used to select the most appropriate of these candidates. That is, (4) the border line is the longest curve in the picture.

In this study the candidate selected by rule (4) is the final recognition result. The way to improve the recognition accuracy is discussed in section 4.

3. EXPERIMENT

To confirm the effect the authors applied the proposed method to real pictures. Seven stomach pictures taken by the double contrast method are used in the experiment. These pictures are input using a digitizer of 2048x2048x10 bit resolution, and a 5x5 median filter is applied for noise reduction. Then, the pictures are reduced to 1024x1024. None of the pictures showed any diseases.

The algorithm is implemented on an engineering work station, Apollo DN570T (4 MIPS). To implement the software, Pascal is used in step 1, C in step 2 and LISP in step 3.

To simplify the experiment, we restricted the target of recognition to the greater curvature (the major curve forming the lower border line of a stomach). Thus other parts of the stomach is not recognized in this experiment. However, finding the greater curvature is enough to determine the position of the stomach in the picture.

It takes about 2.5 minutes to process one picture; 1.5 for step 1 and 0.5 each for steps 2 and 3.

Among the seven pictures we found the greater curvature in six cases. The remaining picture requires the improvement of the edge detection. Figures 1 through 4 shows the typical result of the proposed algorithm.

4.CONCLUDING REMARKS

There are 2 remarks to improve the result in last section.

(1) We restricted the recognition target to the greater curvature only, as mentioned in sec. 3. Though this is not enough to extract the whole stomach, the greater curvature represents the position of the stomach and gives informations of other parts of the stomach. For example, the position of the lessor curvature can be found by using the relative position from the greater curvature. The authors think that it is best to present any part of the stomach with the relative position from the greater curvature.

(2) In step 2 in sec.2, we draw the Delaunay graph from the end points of the line pieces only. This is insufficient when the edge piece is a long curve and the Delaunay edge is far away from that piece. (In this study the picture is noisy enough to avoid such cases.) To correct this insufficiency we had better use the intermediate points of a edge piece to draw the Delaunay graph.

However, our result shows that global structure expressed with computational geometry is useful to find the border line. This technique also considered useful for other objects that change its shape, such as human faces. To widen the application of this algorithm, father more study on the description of the global structure is recommended. Changing the future extraction step (step 1) will also widen the application of this algorithm, for example, application to the stomach pictures taken by full-stomach method. Another improvement method is to feed back the results of step 3 to step 1 [2]. Researches on this improvements is the next target of the authors.

ACKNOWLEDGEMENT

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Fig.1 Original picture
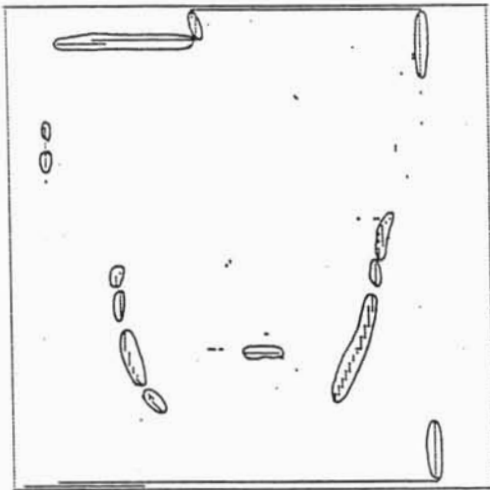

Fig.2 Edge enhancement
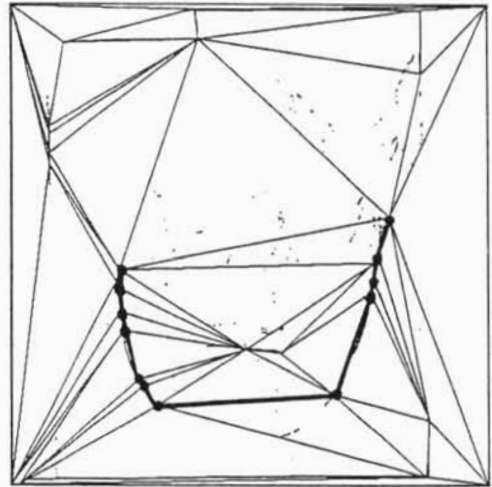

Fig.3 Edge detection
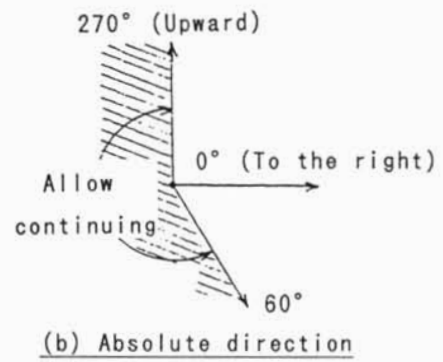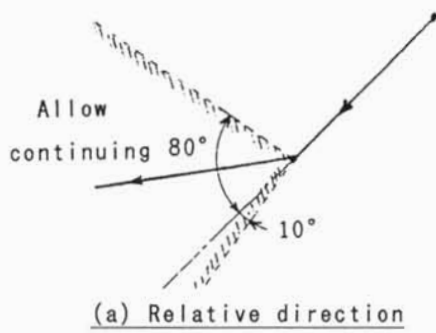

Fig.4 Delaunay graph and the result

Allow
continuing 80°

10°

(a) Relative direction

270° (Upward)

0° (To the right)

Allow
continuing

60°

(b) Absolute direction

Fig.5 Selection rules