

A Method for Tumor Shape Extraction from X-ray Mammography

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ABSTRACT

In this paper, we propose a method to extract an exact shape of breast cancer tumor from X-ray mammography. The tumors usually have a lot of variety of their shape and size. Therefore, it is difficult to utilize exact object models which are often used in industrial applications. However, as tumors in the grown stage have comparably a large structure, it is considered to be possible to recognize it even in a blurred image. Then we adopt the scale-space filtering, in which we can trace edge elements from the lowest resolution to the highest one. Furthermore, we utilize Delaunay net in order to get a connected contour of the tumor. Finally, some experimental results are shown.

1. INTRODUCTION

The breast cancer has been examined by the physical examination now in Japan. This means the present examination of the breast cancer depends on human resources, i.e. experienced medical doctors, because it is difficult to detect the breast cancer if the surgeons are not skillful. In the present group examination, as the number of candidates who are detected to have tumor in the examination is very small, the surgeons usually waste a lot of time. Furthermore, the earlier breast cancer cannot be detected by the physical examination, because the tumor is too small to be picked up. From these reasons, the study of the automatic image processing of X-ray mammography is strongly desired. The mammography is the X-ray slide of vertically or horizontally pressed human breast.

In this research area, the study of the improvement of the quality of X-ray mammography has been widely made, because of low quality of the X-ray image due to low S/N (signal-noise ratio). For example, blurring noise processing in the real X-ray image and enhancement of the tumor shape in X-ray mammography were studied[1]. For example, Jin et al. studied the decision rule if the tumor given as the model pattern is

benign or malignant from the shape of the contour[2]. But there is few study on automatic recognition of tumors from the real mammography. Using the technique in computational geometry, Aisaka et al. proposed the method[3]. This study finds the border line of the stomach by using the Delaunay net, a method in computational geometry. In this paper, we extract a contour of the tumor that is considered as candidates of breast cancer from a digitized image of film-mammography by using the features of breast cancer.

Generally, as X-ray images contain many kinds of tissues (dense breast, ducts, blood vessels etc.), other than objective tumors, and noise, it is impossible to extract a tumor contour just using simple edge extraction technique. So we adopt the technique of scale-space filtering, in which we can trace edges continuously from lower resolution images to higher ones. Furthermore we utilize the Delaunay net, a planer graph representing "neighboring" in order to connect edge segments on the higher resolution images.

2. FEATURES OF BREAST CANCER IN THE IMAGE

The surgeons have used the features of the breast cancer when they detect the breast cancer from X-ray mammography. The information, which could be available for pattern recognition, is divided into two groups according to the type of lesions. One of the feature is the characteristics of tumors, where tumor shadow can be detected as high density region. If the shape of the tumor shadow is not regular, the tumor is considered malignant. In this case tumor has spicules. The other feature is the existence of calcification, where the calcium particles with high contrast can be seen. If there is a cluster of calcification in the tumor, it could form a malignant tumor. Therefore, the existence of calcification can be utilized for the detection of breast cancer in early stage, which can not be inspected in a physical examination.

However as the tumor does not have a particular shape

and size, it is difficult to detect tumors by using the specified characteristics of their shapes. Therefore we should adopt simple and general features of tumors as followings: 1) the contrast of the tumor shadow is comparatively high, 2) the size of one is usually larger than other tissues. In general smaller patterns can be eliminated by applying low-pass filter in terms of spatial frequency, but the contour of the tumor would be also made smooth. Therefore, in order to extract exact contours of tumors, we introduce the technique of scale-space filtering. It isn't, however, guaranteed that the extracted contour would become closed. For the purpose we use Delaunay net a planar graph studied in computational geometry. The details of these two techniques are discussed in the following section.

3. EXTRACTION OF TUMOR CONTOUR

3.1 Scale-space filtering

When we see a noisy image, we first tend to pay attention to global structure of the image, and gradually try to find the details. To realize such hierarchical viewpoint, the scale-space filtering has been studied[4]. It can grasp the image in the different resolution such as Fig.1 by degradating the image by convoluting with two-dimensional Gaussian as follows.

$$F(x, \sigma) = f(x) * g(x, \sigma) \quad \dots (1)$$

The Fig.1 shows traced zero-crossings in the scale-space. In this method, it is considered that we can extract a fine contour of a tumor suppressing the influence of noise by tracing the zero-crossings starting from ones in lower resolution image as shown as dashed lines in Fig.1.

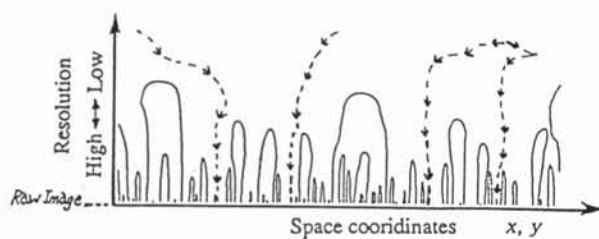


Fig.1 Traced edge in scale-space.

3.2 Delaunay net

The edge segments, which are considered as candidates for elements of the tumor contour, are generally

disconnected due to noise etc.. However, closed contours of tumors are desired as a result for further medical analysis. Therefore it is necessary to connect these edge segments. So we introduce a planar graph called the Delaunay net. The graph represents "neighboring" between points in terms of distance and their placement. It was once introduced by Aisaka et al. for contour detection of stomach in X-ray image[3].

Let $P = \{ p_1, p_2, \dots, p_n \}$: denote a set of points in the plane,

$$V(p_i) = \{ \mathbf{R}^2 \mid d(p, p_i) < d(p, p_j) \text{ for } j=1, 2, \dots, n; j \neq i \}$$

where $d(p, p_i)$ denoting Euclidean distance between the points p and p_i , and $V(p_i)$ Voronoi region. The Voronoi regions $V(p_1), V(p_2), \dots, V(p_n)$ is called Voronoi diagram. The points in set P is called the sites of Voronoi diagram. The Voronoi diagram is the regions which points closer to the site p_i than any other sites. Two sites of the Voronoi regions, which have a boundary edge in common, are regarded as "neighboring" ones. The graph drawn by connecting the sites corresponding to the neighboring Voronoi regions is called the Delaunay net.

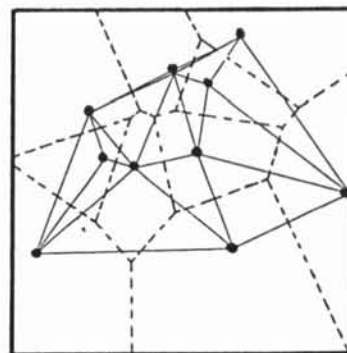


Fig.2 Voronoi diagram (---) and Delaunay net (—).

3.3 Method for contour extraction

Our purpose is to extract the exact contours of the tumors from an image of film-mammography. The procedures for it are described as follows. First, the edge points are extracted from each resolution image obtained by scale-space filtering. Then the edge points are traced between different resolution images. Furthermore the divided contours are connected by using arcs of a Delaunay net in each stage of resolution. The details of each procedure are explained in the following sections.

3.3.1 Extracting edge points

As the first, the original image is filtered by Humming window function for anti-aliasing. Next, to get the image in the different resolution, we use the low-pass filters with the different cut-off frequency. Then the zero-crossings are extracted as edge points from each filtered image.

3.3.2 Tracing edge points

In order to relate the edge points on neighboring resolution images, we introduce two constraints: 1) the distance between two points is sufficiently short, 2) the directions of the gradient vectors at edge points are similar. In other words, edges are traced in scale space by using their similarity. The constraints are shown as follows.

(a) Distance between edge points

Let $(x_i, y_i), (x_j, y_j)$ denote the coordinates of edge points in neighboring resolution images.

$$(x_j - x_i)^2 + (y_j - y_i)^2 \leq d \quad \dots (2)$$

(b) Difference between directions of gradient vectors

For each edge, the direction of the gradient vector is computed. Let θ_1 and θ_2 denote the directions in neighboring resolution images.

$$|\theta_1 - \theta_2| \leq \phi \quad \dots (3)$$

The edge points that hold the constraints (2) and (3) are regarded as candidates of corresponding.

3.3.3 Connecting edge segments

As explained before, the Delaunay net is used to connect the divided contours. We first make a Voronoi diagram from a set of end points of the edge segments, then draw a Delaunay net, a dual graph, from it. We select the paths, which connect the end points each other, from a set of arcs in this net. The process is as follows. First, the end points of edge segments, which should be connected, are extracted by eliminating connecting edge points between them based on eight neighborhood connectivity of pixels. We select pairs of end points whose directions face each other within a certain angle. If the candidates of opponents are two or more, we choose the shortest arc between two points(Fig.3). Thus we select the Delaunay arc between the end points. Above operation is performed in each resolution image. In general, we should consider all the combination of points, i.e. arcs of a complete graph, as a connecting arc, however the operation enables us to reduce the number of arcs to be involved using the concept of neighborhood.

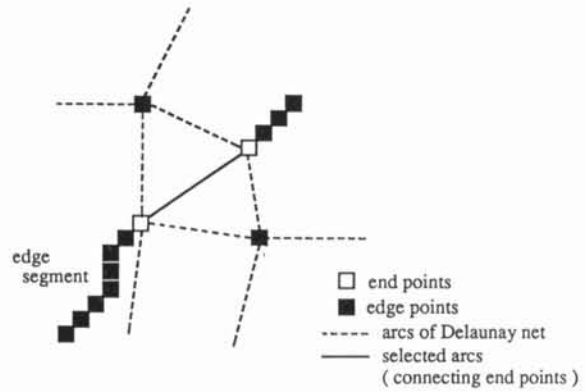


Fig.3 Connecting edges using arcs of Delaunay net.

4. EXPERIMENTAL RESULT

The real film-mammography(Fig.4) are used in the experiment. The input image is scanned from a copy of a simple film-mammography, and consists of 256×256 pixels with 256 levels of intensity.

The filtered images by using Gaussian convolution with different variance are shown in Fig.5. The extracted contour in each resolution is shown in Fig.6. In this results each extracted contour is connected, however it does not have a closed form. This is considered why the rules for tracing and connecting edges work so locally that the edge segments involve noise, or miss edges which should be involved. In order to get a complete contour, further investigation on diagnostic heuristics by surgeons is required.



Fig.4 Input image.

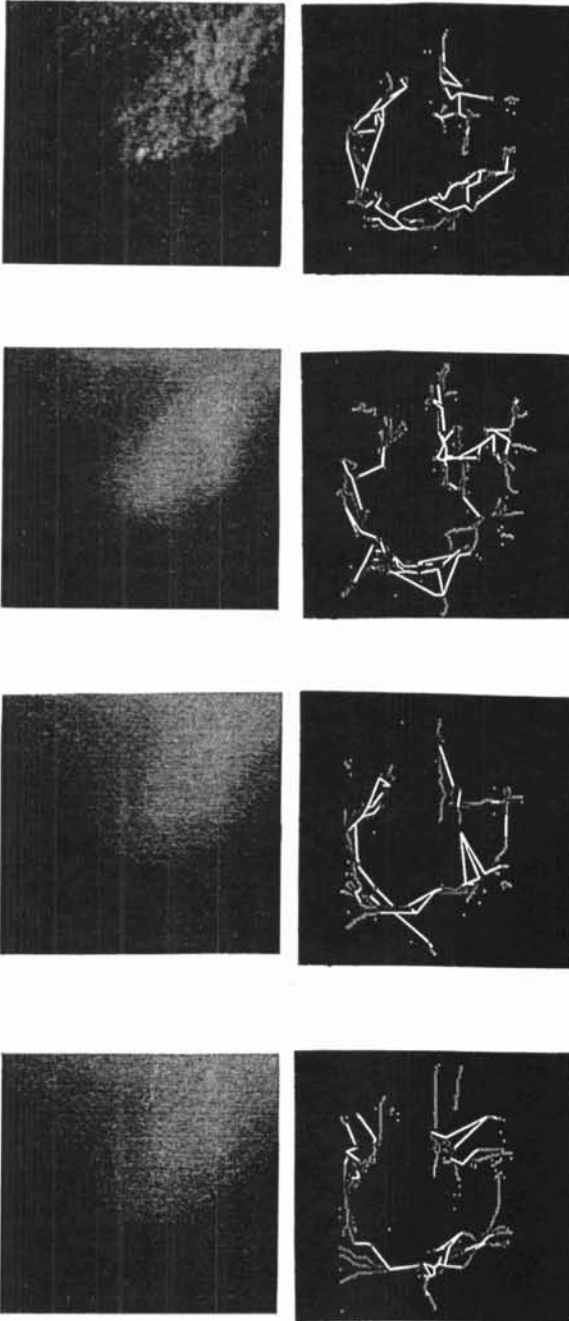


Fig.5
The filtered image by using
Gaussian convolution
with different variance.

Fig.6
The extracted contour
in each resolution.

5.CONCLUSION

In this paper, we proposed a method to extract contours of the tumors from X-ray mammography by using scale-space filtering, and Delaunay net. The edge points are traced from the lowest resolution image to highest, where edge segments are connected by adding arcs out of Delaunay net. However as these processes are performed locally, more global constraints should be introduced in order to obtain closed contours. Moreover, in earlier stage of cancer, there often exists microcalcification only. For further study it is necessary to consider the utilization of analysis of (micro)calcification.

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