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EDGE DETECTION OF MANDIBULAR BOUNDARY CONTOUR IN PANORAMIC X-RAY TO DETECT OSTEOPOROSIS

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Abstract. *The development of panoramic X-ray image processing has been carried out by several researchers recently to detect osteoporosis in the mandible by showing changes in trabecular structure and width of the mandibular cortex. This research proposed a method of images processing algorithm to produce the contour of the mandibular cortex to detect osteoporosis. The purpose of this study is to apply edge detection procedure to getting the upper border contour of the inferior mandibular cortex. The parameters used in this study are Canny, Polynomial Interpolation and Quantum Sobel. Our proposed method consists of several steps. The first step is the pre-processing stage, which is to crop a panoramic X-ray image of the mandible, to get rid of unnecessary parts of the image. The next step is the extraction of resorption features that indicate the occurrence of damage to the mandibular cortex. The results of this study can detect the contour of the inferior mandibular cortex to make it visible to the human eyes; hence it can be used to detect bone resorption as an indication of osteoporosis.*
Keywords: Mandibular cortex, Panoramic X-ray, Polynomial interpolation, Quantum Sobel, Osteoporosis

1. **Introduction.** Osteoporosis is a degenerative disease that is closely related to the aging process which can be shown by a rapid reduction of bone density and thinning of bone trabeculae resulting in decrease in bone strength [1]. The osteoporosis control program is one of the programs of the Ministry of Health of Indonesia with the aim of early detection of osteoporosis cases in the high-risk group community. It is expected to reduce morbidity and mortality due to osteoporosis [2].

The standard method that can be used to detect osteoporosis is DEXA [3]. However, in Indonesia the existence of DEXA devices is still limited in hospitals in large cities, so it is not easy to perform osteoporosis examination using DEXA device. In addition to the DEXA method, in several studies, panoramic X-ray imaging can be used to detect osteoporosis. Panoramic X-ray imaging is an extra oral type of imaging that dentists often use before taking action. Panoramic X-ray can display enough information to diagnose osteoporosis [4]. The osteoporosis diagnosing cost by using panoramic X-ray can be cheaper than by using DEXA device.

Detection of osteoporosis in panoramic X-ray image is performed by measuring the width of inferior mandibular cortex, the density of mandibular bone trabeculae, mandibular cortex and image improvement [3,5-9]. Detection of cortical erosion in the mandible in panoramic X-ray image is superior to identifying women with a high risk of fracture by using the osteoporosis self-assessment score [10].

Panoramic X-ray images have all parts of the nose and jaw from the left ear to the right ear and not only the tooth structure [11]. Thick changes in the inferior border

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of the mandible show signs of osteoporosis. Oral signs in the rest number of teeth, cortical thickness, bone resorption and thinning of inferior mandibular cortex in X-ray image denotes sufficient information for the diagnosis of osteoporosis [12]. Changes in the inferior border of the mandible can be observed by performing edge detection of the lower mandibular cortex through the High-pass Filter (Sharpening) method. Filtering is done to improve image quality while maintaining the important elements of the image [13].

Several studies related to panoramic X-ray have been carried out by Na'am et al., namely research on caries detection on panoramic X-ray with classic edge detection with bits where edges are stated only with a value of 0 or 1, namely edge detection using conventional computing [11]. Computational development has led to quantum computing which is expressed in the form of a qubit where the edge is expressed as a value of 0, 1, or 0 and 1. Edge detection research using quantum computing has been carried out in several studies, and one of them is conducted by Sundani [14].

This study proposes the development of edge detection algorithms by combining classical and quantum edge detection [14]. The operator to be used in the classical edge detection is Canny edge detection. Canny edge detection is an optimal edge detection method, which will obtain smooth edge results that are free of noise [15].

This study is expected to produce detection of the edge of the mandibular boundary which can be used as a starting point for finding the lower and upper boundaries of the inferior mandibular cortex. Then, the results of detection of the inferior edge of the mandibular cortex can be used for subsequent processes to show osteoporosis in the mandibular cortex on panoramic X-ray. The difference in the shape of the edges at the upper and lower boundaries that are not sharp is one indication of the resorption of the mandibular bone to detect osteoporosis.

The results of this study could help dentists diagnose patients for further treatment, and indicate resorption in the inferior mandibular cortex. The detection of edges produced as resorption in the inferior mandibular cortex in each patient will be a different diagnosis and type of treatment.

2. **Materials.**

2.1. **Edge detection.**

This study is a preliminary one of image preprocessing that will be applied in subsequent ones to identifying osteoporosis. The image to be processed is a digital panoramic X-ray. In this study the panoramic X-ray image of the mandible will be processed to detect any change in the thickness of inferior mandibular cortex which shows the sign of osteoporosis. In the panoramic X-ray image, there are also a lot of noises.

The edge in an image is defined as the difference in intensity or color between one pixel and the neighboring pixel. The higher the difference is, the more clear the edge is. This shows that the edge is a point, and the contour is the edges that connect the points so that it forms a boundary between two different areas [17].

Image sharpening process is carried out to clarify the edges of lower mandibular cortex with a high-pass filter. The high-pass filter will strengthen high-frequency components and reduce the low-frequency component of the object. Therefore, the edges of the object will appear sharper than the surrounding [18]. Because image sharpening is more influential on the edges of objects, image sharpening is called edge sharpening.

The first gradient based edge detection is Canny edge detection. The classic edge detection methods consist of Robert, Prewitt and Sobel operators. The Canny method is the optimal edge detection. This method uses the Gaussian Derivative Kernel to filter out noise from the original image to get smooth edge detection results. The edge can be defined as the change in pixel values that reaches its maximum when the first derivative value reaches its maximum value or the second derivative value is 0.

2.2. **Interpolation.** Interpolation is a method for determining the points of n points by using a particular approach function. There are several interpolation methods, namely Linear Interpolation, Quadratic Interpolation, and Lagrange Interpolation. In this study the interpolation method to be used is Polynomial Interpolation.

Polynomial Interpolation is used to find the points between n points $P_1(x_1, y_1), P_2(x_2, y_2), P_3(x_3, y_3), \ldots, P_n(x_n, y_n)$ using the polynomial function approach of rank $n-1$. Polynomial Interpolation is defined in Equation (1):

$$y = a_0 + a_1 x + a_2 x^2 + \cdots + a_{n-1} x^{n-1} \tag{1}$$

where x is the value on the x axis which is known; y is the value on the y axis that will be calculated; n is the number of points known; $a_0, a_1, a_2, \ldots, a_n$ are coefficient values.

2.3. **Quantum computing.** Quantum bits (qubits) are bit statements in quantum bit processes that can be in more than two states other than 0 or 1 and superposition states which are simultaneously 0 or 1 states. Qubits can be in the state of 0 and 1, unlike ordinary digital computers, bits are only 0 or 1. Quantum computers do not use bits but quantum bits (qubits), which means there are many possible calculation results. The right measurement results can be done by measuring qubit. Measuring qubits will stop the calculation process and force the system to choose one of all possible answers [19].

Edge detection by the Quantum Sobel method was developed and introduced by Dini Sundani in 2015, and the algorithm steps performed are as follows.

1) Read the input image.
2) Read the pixels above the contour.
3) Calculation of edge strength values is called Gradient Magnitude.

The Gradient Magnitude value is calculated by Equation (2):

$$G_m(i,j) = \sqrt{G_x(i,j)^2 + G_y(i,j)^2} \tag{2}$$

where G_x is vertical edge gradient; G_y is horizontal edge gradient; G_m is gradient magnitude.

4) Calculation of the probability of edge strength can be calculated by Equation (3) [19]:

$$F\left(G_m\right) = \frac{1}{1 + e^{-(G_m - a)/b}} \tag{3}$$

where $F\left(G_m\right)$ is probability function of quantum computing.

5) Qubit measurement to determine edges or not edge, where each result of a random number probability is between $\left[0 - |F_1|^2\right]$ and then the results of the possible qubit measurements are pixels in state 1 (edge) and continued with the edge localization process.

6) Localize the edges, that is by detecting the diagonal edge where the detected edge must be as close as possible to the actual edge.

7) Edge normalization.

8) Finish.

Research conducted by Fu et al. stated that with edge detection carried out by the quantum method it will have better edge detection capability for medical images, which can extract not only strong edges but also weak ones [20].

3. Proposed Method.

3.1. **Proposed scheme.** The proposed research is to detect the inferior edge of the mandible on panoramic X-ray for detection of osteoporosis. The research is to develop edge detection algorithms by combining classical and quantum edge detection. There are several steps of the proposed method: panoramic X-ray images acquisition, pre-processing

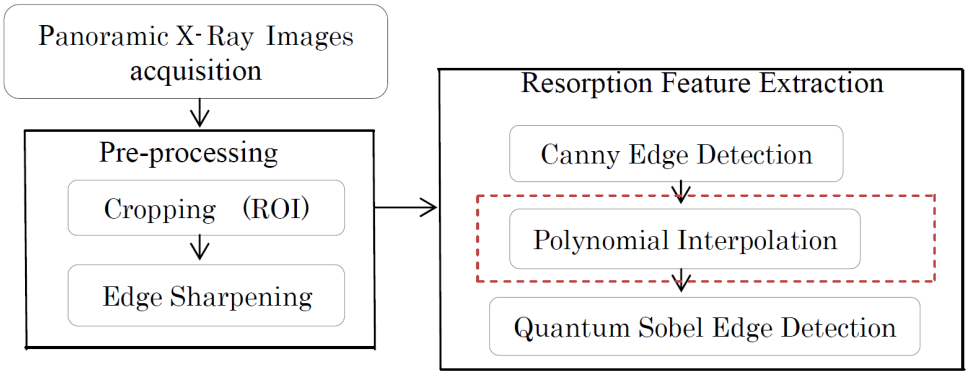


FIGURE 1. Proposed method scheme

(cropping and image sharpening) and resorption feature extraction (Canny Edge Detection, Polynomial Interpolation and Quantum Sobel Edge Detection). The proposed method scheme is shown in Figure 1.

3.2. **Panoramic X-ray acquisition.** The initial step to be taken is the acquisition, namely the process of taking X-ray panoramic image data. The results of image acquisition have a file format * .png for data obtained from the hospital.

3.3. **Pre-processing.** The pre-processing stage consists of two parts, namely cropping and image quality improvement using edge sharpening.

3.3.1. *Cropping.* The panoramic X-ray that becomes the ROI (Region of Interest) is the part of the mandible which contains teeth.

3.3.2. *Edge sharpening.* The next pre-processing stage is image sharpening. Sharpening contrast of image is a way to improve the appearance by maximizing the contrast between lighting and darkening or increasing and lowering the pixel values of an image. In this study one function is available in Matlab, namely "imsharpen". The complete functions used are as follows.

Sharp_image = imsharpen (Original_image, 'Radius', 50, 'Amount', 1.2).

3.4. **Resoption feature extraction.** The next stage after the image has been successfully improved of its quality is resorption feature extraction. Resorption describes the occurrence of damage to the bone cortex, in this case the mandible. This damage is one sign that can indicate the occurrence of osteoporosis. The process used to extract resorption features is the examination of the inferior border of the mandibular cortex. The feature extraction stage consists of Detect Mandibular Boundary using Canny Method and Contour Repair using Polynomial Interpolation.

3.4.1. *Canny edge detection.* Detection of the mandibular cortex boundary is performed using edge detection methods. Image boundary lines describe the edges of objects in the image. The edge is defined as the change in pixel value that reaches its maximum when the first derivative value reaches the maximum value or the value of the second derivative (2nd derivative) is 0. The Canny method is executing to process the image to obtain sharpening of the mandibular cortex boundary area.

3.4.2. *Polynomial interpolation.* The results of edge detection at the mandibular cortex boundary are not perfect with any type of operators. To improve the contour, the 3rd order polynomial interpolation method is used.

3.4.3. *Quantum Sobel detection.* The process carried out to detect the upper border of the inferior mandibular cortex is used by edge detection method using the Quantum Sobel Edge Detection method. The upper mandibular detection process begins with reading the interpolated image in the form of a binary value that represents the mandibular cortex boundary contour. This edge is then mapped into the original image. Then on the Y-axis towards the point on vertical 0, the pixel reading process starts from the point of each contour along the X-axis. This process is carried out until the last stage which localizes the edges.

Searching edges on Quantum Sobel edge detection edges not only in the horizontal direction 0° and vertical direction 90°, but also in diagonal directions 45° and 135°. Determination of edge search is expressed as an edge and the value is 1, if it satisfies the edge search in the direction. If edge tracking or localization of the edges does not meet one of the four directions, then the pixels at the traced point are stated not to be in the location of all of these directions so that it is not edge and the value is 0.

4. **Result.**

4.1. **Pre-processing result.** The pre-processing stage consists of two processes, namely cropping to determine the ROI (Region of Interest), i.e., the mandibular portion and the improvement of image quality by contrast sharpening. The results of image acquisition have a file format * .png for data obtained from the hospital.

The cropping stage is carried out on panoramic X-ray, at this stage the mandibular cortex region is determined as the ROI as a reference in detecting osteoporosis. Figure 2 is a panoramic X-ray image consisting of the maxilla and mandibular. The cropping result presented in Figure 3(a) appear to be only the mandibular part as the area to be studied.

Image sharpening is executed to obtain contrast images. In this study one function is available in Matlab, namely "imsharpen". The results of the sharpening process can be seen in Figure 3(b).

In Figure 3(b) it can be noted that the inferior part of the mandible is shown more contrast compared to the surrounding area. The inferior part of the mandible is the area that will be further processed to show resorption that occurs in the inferior mandibular cortex.

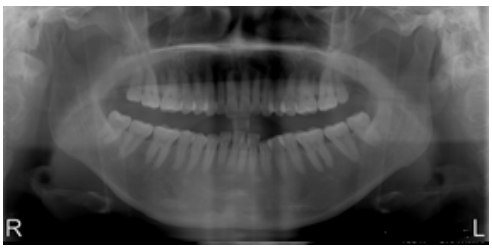
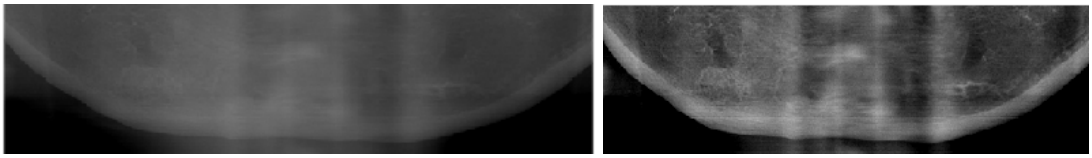


FIGURE 2. Image of panoramic X-ray image [11] (Source: Na'am et al., 2017)



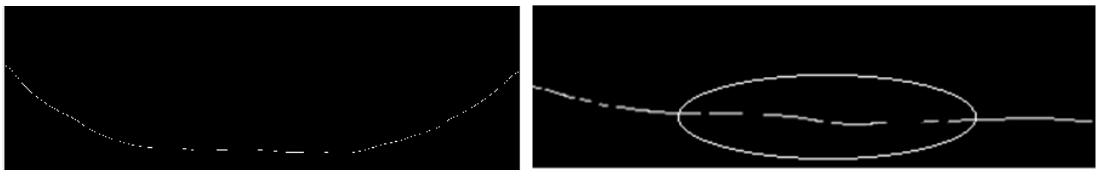
(a) (b)

FIGURE 3. (a) Cropping result from the original image; (b) The image produced from the sharpening process

4.2. **Extraction of resorption features result.** The results obtained from the resorption extraction feature consist of several images which can be seen in the following series. The edge detection results obtained by the Canny Edge Detection method are the mandibular inferior cortex boundaries.

In Figure 4(a) it can be seen that the results of edge detection on the mandibular cortex border are not perfect. There are parts that are disjointed. However, the noise in the area other than the edge is already wiped out.

It can be seen that there are contour parts that do not joint and are marked with white oval lines. To improve the contour, the 3rd order polynomial interpolation method is used.



(a) (b)

FIGURE 4. (a) Results with the Canny Edge Detection method; (b) the edge that is not jointed

To get a better edge of the inferior border of the mandibular cortex, 3rd order polynomial interpolation process is performed. Figure 5 presents the result of interpolation which shows the margins of the upper border of the inferior mandibular cortex have been fully jointed. In Kavitha et al.'s research, the second order polynomial function was used to determine the direction of measurement. At each point it is measured along the tangential line towards the polynomial curve, which is estimated to be near to the upper limit [9].

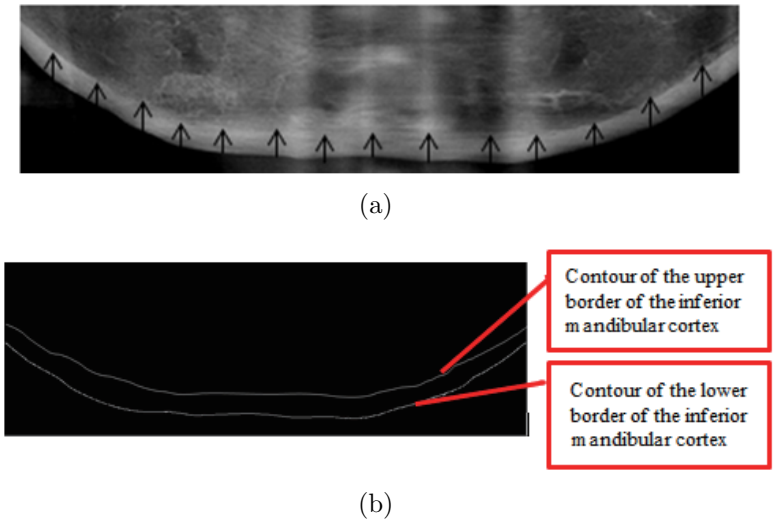
FIGURE 5. Interpolation results to improve the contour

4.3. **Mandibular edge detection result.** In the edge localization result, the edge of the image in the last result is multiplied with vertical and horizontal gradient calculation to get the closest edge from the edge of the previous result image. The illustration of the process can be seen in Figure 6(a).

In Figure 6(a) the white line is the lower edge of inferior mandibular cortex and the upward black arrows are illustrations to show the closest distance between the lower and upper boundaries of inferior mandibular cortex. The nearest edge obtained will then be processed to obtain the upper border of the inferior mandibular cortex.

The result of edge detection in the inferior mandibular cortex using Quantum Sobel based edge detection method can be seen in Figure 6(b).

In Figure 6(b) the lines designated with the white line are the upper and lower borders of inferior mandibular cortex. There are 2 lines presented in Figure 6(b), namely the contour of the lower border of the inferior mandibular cortex and the results of edge detection by the Quantum Sobel method which is the edge contour of the upper border of the inferior mandibular cortex.



(a)

(b)

FIGURE 6. (a) The result of the pixel reading process is above the inferior edge of the mandibular cortex to find the contour above it; (b) results of mandibular edge detection.

The results of the proposed edge detection are shown in Figure 6(b). Figure 6(b) shows the results of the edge detection in the mandibular cortex with the Quantum Sobel based edge detection method. Edge detection with Quantum Sobel based edge detection methods can produce clearer images and can identify mandibular cortex more clearly in the panoramic X-ray image [21].

The edge detection process with the Canny and Quantum Sobel method produces the inferior edge of the mandibular cortex which is free of noise and the upper and lower border edges of the inferior mandibular cortex. These results are used in subsequent processes to detect the sign of osteoporosis in panoramic X-ray.

5. **Conclusions.** In this study, the proposed method can identify the upper and lower bounds of the inferior mandibular cortex through several processing stages. The pre-process steps consist of cropping and image sharpening, and then the image extraction process steps consist of Canny edge detection, interpolation polynomials and Quantum Sobel edge detection. The process result of Canny edge detection is a clear but fragmented line of edge. To make a perfectly continous line edge, polynomial interpolation was later performed.

The Quantum Sobel edge detection method is used to detect the upper border of the inferior mandibular cortex. Our overall proposed method successfully detects the contour of the inferior mandibular cortex. Edge detection with Quantum Sobel method produces clearly visible contour of the inferior mandibular cortex for the human eyes. The result can then be used further to detect osteoporosis in panoramic X-ray image.

In further research, a right Quantum Sobel edge detection measurement method is needed to measure edge detection Quantum Sobel performance.

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