Panoramic X-Ray Analysis Using Edge Detection Method on Mandibular Cortex

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***Abstract*— Panoramic X-Ray is one type of image that can be used in the health world to identify various diseases and damage that occur in the jaw and teeth. This study aims to identify the inferior mandibular cortex and detecting mandibular resorption as an indication of osteoporosis. Several stages are conducted in the proposed method. The first step in the pre-processing stage to be done is cropping, to obtain the Region of Interest (ROI). The next step in the pre-processing stage is image improvement to get image with favorable quality. The extraction stage is conducted in two steps. In the first step the image is processed using the edge detection method. In the second step of the extraction stage we use quantum edge detection to produce the upper edge of inferior mandibular cortex. Then, the lower border of inferior mandibular cortex is projected to obtain a difference between the upper and the lower border of the inferior mandibular cortex. As the result of study, we can identify bone resorption in the inferior mandibular cortex. Resorption of the mandibular cortex is an indication of osteoporosis. It is concluded that damage to the jaw bone can be seen from the result of panoramic X-Ray images after performing image processing.**

Keywords*— *edge detection, mandible cortex, panoramic x-ray, translation, resorption

I. INTRODUCTION

Several studies related to panoramic X-Ray have been carried out namely research on osteoporosis detection on panoramic X-Ray with high pass filter images [1], osteoporosis detection with morphology [2], detection of jaw and tooth cancer [3] and caries detection teeth with morphology [4]. Panoramic X-Ray is one type of image that is important in the world of health. Panoramic X-Ray examination is needed in most analyzes performed by the dentistry department. The results of the panoramic analysis of X-Ray are referred to as the primary diagnosis aid doctors [5]. Panoramic X-Ray images can provide poor bone-related signs, namely the occurrence of fractures or resorption and osteoporosis [6]. But not all of these images are of good quality. So that we need to improve image quality to get a better image.

The image is an information conveyed in the form of two-dimensional images. Image processing is the process of processing image or image information that produces images or images as well. Image information processing is related to changes in image size, position changes, contrast changes, noise reduction, segmentation, extraction, image recognition and others [7].

Edge detection is an important step taken in processing digital image processing [8]. The Canny edge detection method is a method for detecting edges that are commonly used to detect edge images [9] and is the best edge detection method when used in an image state that has a lot of noise [10]. Edge detection is the process of finding and identifying edges of images that are very sharp. In images that have a lot of noise, the edge detection process is difficult, because edges and noise both have high-frequency values. Edge is the limit of an object in an image. Edge detection is done to reduce noise and find the edge of the image without losing the information needed [11].

In some studies related to the mandible, studies were conducted for indications of osteoporosis [1-3] and cancer [6]. This study uses edge detection to determine the edge of the mandibular cortex in panoramic X-Ray images. Changes in the shape of the mandibular cortex can be used to determine bone quality as identification of abnormalities in the patient's jaw. Signs of the mouth and jaw are the number of teeth present, cortex thickness, bone resorption, decreased mandibular inferior cortex is important information for diagnosing osteoporosis [6].

This research proposes the development of edge detection algorithms by combining classical edge detection and quantum edge detection [12]. The operator of the classic edge detection used is the Canny edge detection. Canny Edge Detection is an optimal edge detection method, compared to Roberts and Prewitt methods. The Canny method will produce images with smooth edges and free of noise [13].

This study is expected to produce edge detection in the form of a mandibular boundary edge that can be used as the initial point to look for the inferior border of the lower and upper mandibular cortex. This study also resulted in the translation of the inferior lower edge of the mandibular cortex to obtain differences in distance and shape with the upper inferior border of the cortical mandible and can be used for subsequent processes to indicate the presence of disease and damage to the mandible on panoramic X-Ray.

II. METHODOLOGY

The edge detection method is categorized into two edge detection groups, namely edge detection based on the first derivative operator or based on gradient and edge detection based on the second derivative. Edge detection based on the first gradient is Canny edge detection and classical edge detection consisting of operators Robert, Prewitt, and Sobel, and the second derivative detection consists of detecting the edge of Marr Hildritch [14].

Edge detection is a change in the intensity value of a large gray degree of a pixel with its neighbor. The edges are usually located on the boundary between two different regions and different directions, depending on the direction of change in intensity. There are three types of edges in ideal digital, namely steep edges, sloping edges, and noise-containing edges. Steep edges are edges with large intensity changes. The purpose of edge detection is to increase the appearance of boundaries in an area with other regions in an image [7]. In this study, there are four methods used to test panoramic X-Ray images, namely Canny Edge Detection, Roberts Edge Detection, Prewitt Edge Detection, and Quantum-Sobel Edge Detection. The first three edge detection methods to detect the mandibular boundary and the fourth method are used to detect the edge of the upper border of the mandible.

A. Canny Edge Detection

Edge detection with the Canny method was developed and introduced by John F. Canny in 1986. The steps of the algorithm performed on Canny Edge Detection are:

1. Read the input image
2. The convolution process is the implementation of a Gaussian derivation calculated with the following kernel functions:

$$H_{i,j}\frac{1}{2\pi\sigma^2}exp\left(-\frac{\left(i-(k+1)\right)^2+\left(j-(k+1)\right)^2}{2\sigma^2}\right); 1 \le i,j \le (2k+1) \quad (1)$$

The Gradient Magnitude value is calculated by the equation:

$$M[i,j] = \sqrt{P[i,j]^2 + Q[i,j]^2} \quad (2)$$

3. Pressing the value that is not maximum to brush the edge that is not needed, resulting in a slimmer line using the orientation value to determine the direction of the pixel [14]

$$[i,j] = arctan(Q[i,j], P[i,j]) \quad (3)$$

4. Thresholding: removes the edges that appear due to noise by filtering the lower gradient values or not considered as edges of the image and maintaining a higher gradient value as the edge of the image
5. Finish

B. Prewitt Edge Detection

The Prewitt method is the development of the method using a high pass filter (HPF). This method has the ability to reduce noise before calculating edge detection. In the Prewitt operator to calculate the Gradient Magnitude is done with the following equation:

$$M = \sqrt{P_x^2 + P_y^2} \quad (4)$$

Then the Px and Py forms can be expressed by:

$$P_x = \begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix} and\ P_y = \begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$$

The direction of the edge is calculated by the equation:

$$a(x) = tan^{-1}\left(\frac{P_x}{P_y}\right) \quad (5)$$

C. Roberts Edge Detection

Robert's method is an edge detection technique in the horizontal and differential directions in a vertical direction. Robert operator is a 2x2 kernel [7].

$$R_+ = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix} and\ R_- = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}$$

Small filter sizes make computing very fast. But this creates weaknesses which are very affected by noise. Robert's operator responds weakly to the edges, unless the edges are very sharp. This operator calculates by taking a diagonal direction to calculate the gradient which is also called a cross operator. Robert's gradient in the direction of x and y is calculated by the following formula:

$$R_+ (x,y) = f(x+1, y+1) - f(x, y) \quad (6)$$

$$R_- (x,y) = f(x, y+1) - f(x+1, y) \quad (7)$$

The R + operator is a derivative with a direction in 45° direction, and Ry is a derivative with a direction of 135° [7]. In the Roberts Method to calculate the Gradient Magnitude, the equation is used:

$$a(x) = tan^{-1}\left(\frac{P_x}{P_y}\right) \quad (8)$$

The direction of the edge is calculated by the equation:

$$\alpha(x,y) = \frac{\pi}{4} + tan^{-1}\left(\frac{R_+}{R_-}\right) \quad (9)$$

D. Quantum_Sobel Edge Detection

By using the quantum principle, each pixel will be mapped into a qubit that has a variety of possible pixel value states that can be in the state of 0 (black), 1 (white) or in the state of both (0 and 1) where the state represents the edge state(1) or not edge(0). Gradient Magnitude on Quantum_Sobel Edge Detection is calculated by the equation [15]:

$$f(g) = \frac{1}{1+e^{-(g-a)/t}} \quad (10)$$

E. Projection of dots (lines)

Line projection is the process of transformation or the transfer of points in a two-dimensional plane. Some point transformation processes are translation (reflection shift), rotation (rotation) and dilation (multiplication). In this study the transformation process used is translation. Translation (Shift) is a transformation that moves points with a certain distance and direction. If $x' - x = m$ and $y' - y = n$ then $x' = x + m$ and $y' = y + n$ translation is

$$x'=x+m \text{ and } y'=y+n \quad (11)$$

F. Proposed method

The proposed research phase was to detect the inferior edge of the mandible on panoramic X-Ray for disease detection and damage to the cortical mandible shown in Figure 1. The development of the proposed research was the development of edge detection algorithms by combining classical and quantum edge detection consisting of several steps are: panoramic X-Ray image acquisition, pre-processing (Cropping and image sharpening), extraction (Canny Edge Detection, Edge Detection Roberts or Prewitt

Edge Detection, Quantum-Sobel Edge Detection and Projection) are shown in the following diagram:

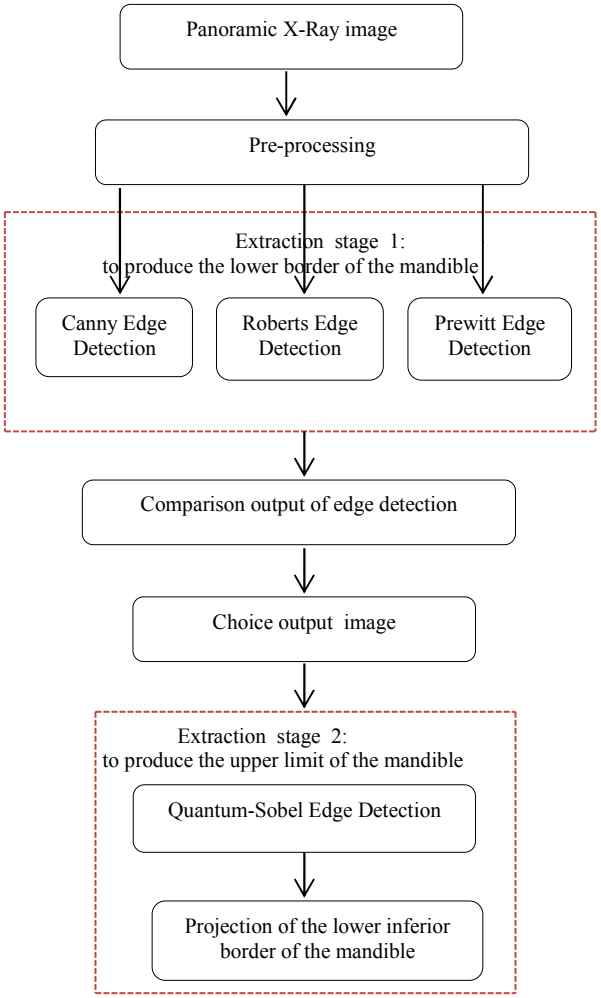

Fig.1. Proposed Method

The method developed in this study is a combination of Canny Edge Detection, Quantum-Sobel Edge Detection and Projection of the lower inferior mandibular line which is indicated by a red line that does not connect can be seen in Fig.1.

The steps taken in this study are

1) *Panoramic Imagery X-Ray:* Panoramic images of human dental panoramic X-Ray obtained from panoramic machines cannot be directly used as desired because the quality has not met the standards for processing needs. The image has a less uniform intensity variation due to uneven lighting, or weak in contrast so that objects are difficult to separate from the background. Images of this quality require corrective steps.

Panoramic image data retrieval is carried out through the acquisition process of dental image data carried out using X-Ray. From this process obtained dental radiograph data (dental panoramic image) with a Computed Radiography Equipment System. The results of image acquisition have a file format * .png for data from a hospital.

2) Pre-Processing: At the pre-processing stage consists of two processes, namely cropping and image quality improvement by doing edge sharpening. At the cropping stage, the technique used is manual cropping using dots obtained from marking in the selected image area. The Panoramic X-ray that becomes the ROI (Region of Interest) is the part of the mandible.

The next pre-processing stage is edge sharpening. Edge sharpening or commonly called edge transformation. Image sharpening aims to increase the contrast of color and light in an image. Sharpening contrast in images is a way to improve the appearance of an image by maximizing the contrast between lighting and darkening or raising and lowering the pixel value of an image.

3) Extraction: Extraction is the next step after pre-processing, which is the stage to extract the edge of the image to obtain resorption at the lower border and upper border of the inferior mandibular cortex. The resorption describes the occurrence of damage to the bone surface, in this study the mandibular bone. This damage is one parameter that can be a bone disorder, fracture or osteoporosis.

The initial step to extract is edge detection using the Canny method, Roberts method and Prewitt method. At this initial stage, the edge of the image obtained varies according to the method used. The Canny method is carried out to process the image to obtain sharpening of the mandibular cortex boundary area. At this stage, the results obtained are the lower border of the inferior mandibular cortex.

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

The steps taken to determine the upper border of the inferior mandibular cortex are the Quantum edge detection stage developed based on the classical method of Sobel edge detection. the process starts from reading the improved image, then calculating the vertical edge gradient (Gx), horizontal edge (Gy), and the total gradient (Gm) using convolution which multiplies the results with vertical and horizontal kernels defined respectively as Kx and Ky.

The final step in the extraction stage is the projection of the lower border of the inferior edge of the mandibular cortex using translation so that the upper edge projection is obtained. So that obtained two edges at the top of the inferior mandibular cortex, namely the edge localization results in the edge detection process with the Quantum-Sobel Edge Detection method and the results of projection of the lower border of the inferior edge of the mandibular cortex using translation.

III. Result and Discussion

The method developed in this study uses two main stages, namely pre-processing and extraction. Pre-processing stages are stages to prepare data to have better quality so that it can facilitate and/or produce more optimal data. The pre-processing stage consists of two processes, namely cropping and image sharpening.

Images that have better quality are reprocessed during the extraction stage. Bone resorption is a complex morphological process associated with erosion on the bone surface. To detect the presence of resorption in the mandibular bone, edge detection image processing is carried out for the outside of the mandible which is easier to detect than the (inferior) interior. Edge detection results in the form of contours that can be used as initial points to search for the inner contour. To detect the inner edge which is more difficult because the gray color that is in the bone is also owned by other parts.

A. Panoramic Image Data of X-Ray

The data used is X-Ray results in the form of dental panoramic images. The original X-ray panoramic image is shown in Fig. 2. A panoramic X-ray image can show a wider area, namely the jaw, teeth, sinuses, nose area. In this study, the mandible is an area that will be used as a research area. Fig. 2 below shows the cropping process with marking.

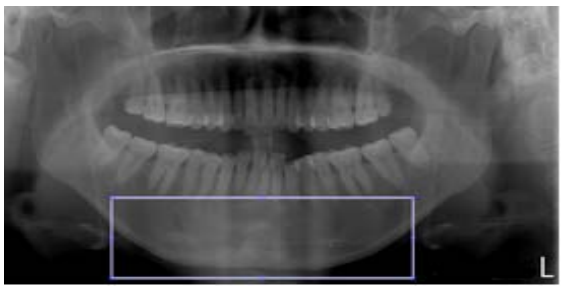

Fig. 2. Image of jaw image acquisition [4]
(Source: Na'am, J et.al, 2017)

B. Pre-processing

At the processing stage consists of two processes, namely cropping and image quality improvement:

1) Cropping: At the cropping stage, the image is changed to a size according to the desired area. The process is done manually by using the points obtained from marking in the selected image area. In this study, the mandible is an area that will be used as a research area. Fig. 3 below shows the cropping results from the original image.

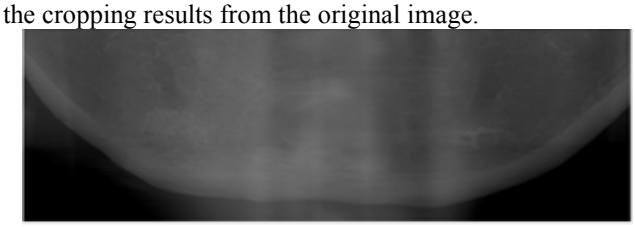

Fig. 3. cropping results

2) *Image sharpening:* Image sharpening or commonly referred to as image transformation. This process is carried out to facilitate the process of interpretation and image analysis. The image sharpening process is done to make it easier to interpret important objects in the image display. The sharpened image shown in Fig. 4 shows the boundary between the mandible and other objects.

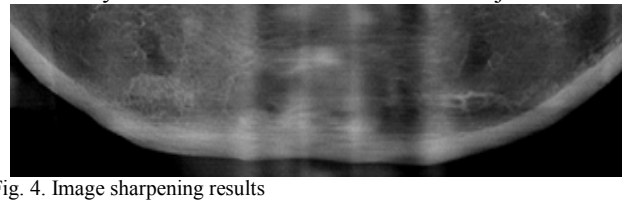

Fig. 4. Image sharpening results

C. Extraction

In the extraction stage, there are three stages, namely edge detection, Quantum-Sobel Edge Detection, and translation.

1) *Edge detection:* There are three methods tested on the image, namely the Canny method, the Roberts method, and the Prewitt method and produce different results.

- Canny Edge Detection
  The edge detection process with the Canny method is to calculate the Gradient Magnitude value, then press the value that is not the maximum to brush the edge, then thresholding is by removing the edges that appear due to noise. Fig. 5 shows the results of edge detection by the Canny method. The result of the Canny method is the edge without noise and produces one edge of the image that represents the lower border of the mandible.

Fig. 5. Canny Edge Detection results

- Roberts Edge Detection
  The edge detection process with Roberts method is faster but is affected by noise and gives a weak response to the edge unless the edge difference is very sharp. The results of the process with the Roberts method can be seen in Fig. 6, producing a lot of noise and a weak edge and not many edges can be detected.

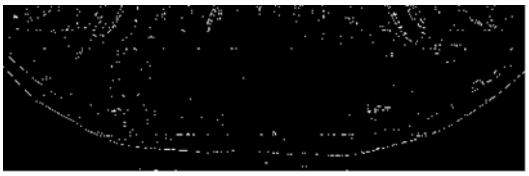

Fig. 6. Roberts Edge Detection results

- Prewitt Edge Detection
  In the edge detection process with the Prewitt method, the eight neighboring pixels have the same effect on the gradient calculation at the center point. The results of edge detection at the mandibular boundary can be seen in Fig. 7, resulting in more noise but more edges can be detected.

Fig. 7. Prewitt Edge Detection results image

2) *Quantum-Sobel Edge detection:* From the three results of edge detection with the above method it can be seen that the results of edge detection with Canny Edge Detection produce a better edge, and can be selected for the next process. The results of edge detection in the inferior mandible using the Quantum-Sobel-based edge detection method can be seen in Fig. 8. The upper edge of

the edge in the inferior mandible is the result of edge localization in the edge detection process with the Quantum-Sobel Method.

Fig. 8. Quantum-Sobel Edge Detection result images

3) *Projection of the inferior lower border of the mandibular cortex:* The process carried out is by translating the lower border of the mandibular cortex. To perform a mandibular boundary contour projection, it is translated at all mandibular boundary contour points with a determined *h* displacement value. The *h* value is gained by finding the nearest point within the contour of lower and upper border of the mandibular cortex. Fig. 9 shows the translational step of the mandibular boundary contour, thus touching the upper mandibular contour.

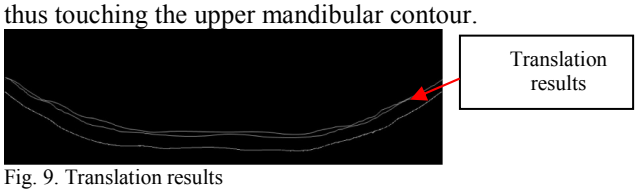

Fig. 9. Translation results

The final step in the extraction stage is the projection of the lower border of the inferior edge of the mandibular cortex using translation so that the upper edge projection is obtained. So that obtained two edges at the top of the inferior mandibular cortex, namely the edge localization results in the edge detection process with the Quantum-Sobel Edge Detection method and the results of projection of the lower border of the inferior edge of the mandibular cortex using translation. Mandibular upper line inequality and translation results indicate resorption as one indication of damage or fracture or resorption in the mandible.

IV. Conclusions

The proposed methods has been successfully conducted to detect the upper and lower bounds of inferior mandibular cortex through several process stages, i.e. pre-processing with cropping and image sharpening, and image extraction processes. Using Canny edge detection method, the preprocessing stage produces clear and free of noise edges result.

The quantum Sobel edge detection method is used to detect the upper edge of inferior mandibular cortex. The result of this method clearly shows the contour of the upper edge of inferior mandibular cortex.

The translation process produces two lines of edges. One is the upper border of inferior mandibular cortex and the other is the projection of lower border of inferior mandibular cortex to its upper one. The non-overlapping areas between these two lines show resorption in mandible, which indicate osteoporosis.

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