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# Automatic Segmentation of Lower Jaw and Mandibular Bone in Digital Dental Panoramic Radiographs

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## Abstract

**Objectives:** Panoramic x-ray is a medical imaging technique used in dentistry. This paper aims to present fully automatic segmentation algorithm to extract lower jaw and mandible from panoramic x-ray. **Methods/Analysis**: Panoramic x-rays provide features of various diseases like advanced periodontal diseases, cysts, tumors, impacted teeth, fractures in lower or upper jaw, etc. Image processing techniques are applied on these images to detect diseases automatically. Segmentation is an inevitable step in automation to extract disease features. Majority existing literature use semi-automatic method for segmentation of panoramic x-ray. The algorithm proposed in this paper is fully automatic method of segmentation. **Findings**: Panoramic x-rays give entire view of mouth and facilitate assessment of hard tissue structures of the facial area rather than assessment of dental carries. Segmentation of panoramic x-rays is an inevitable step in automating diagnosis of oral disorders like, tumor, cysts, fracture, etc. In this paper, an algorithm is developed for automatic segmentation of lower jaw and then mandibular bone in dental digital panoramic x-ray. Dental digital panoramic x-ray is a good quality image which does not require noise removal. The segmentation algorithm uses novel strips method where input image is subdivided in number of strips. These strips are further processed to separate lower jaw and mandible from input image. The algorithm is fully automatic and does not involve human intervention at any level. Paper presents analysis of number of strips as 3, 5, 7 and 9. The algorithm presented in this paper gives 93% success for segmentation of lower jaw and 90% success in segmentation of mandible structure when strip count is 5. **Applications/Improvement:** Strip method focuses ROI and ignores components like teeth, spinal cord shadow, etc. Central strip is useful to segment lower jaw whereas side strips are useful to detect mandible edge points.

**Keywords:** Automatic Segmentation, Mandible, Digital Dental Panoramic X-ray, Lower Jaw, Orthopantomograph (OPG)

## 1. Introduction

Provide Dental imaging modalities are divided into two categories namely intraoral and extraoral radiography. In intraoral radiography, the position of x-ray film is placed inside the mouth and it focuses on dental cavities. In extraoral radiography, film is placed outside the mouth and it focuses on jaw and skull. Bitewing x-rays, periapical x-rays and occlusal x-rays are some of the categories of intraoral radiographs. Panoramic x-rays, tomograms, cephalometric projections, computed tomography, etc. are some of the categories of extraoral radiographs. According to patients' clinical observations, these imaging modalities are suggested by dental practitioners to plan the treatment. Dentists locate the illness from these images and decide severity of the illness. The literature available shows necessity of automation of analyzing these images to extract abnormalities or features of illnesses[1–9]. The essential step to extract diseased features from these images is segmentation. Selection of segmentation method is based on the spatial features of an abnormality and a type of imaging modality. As some research papers, are focused on detection of abnormalities, segmentation of images is performed manually or in semiautomatic manner[4,5]. As outcome of manual intervention varies from person to person, algorithms developed by researchers[1–9] may not be able to

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claim good accuracy in finding illnesses. Therefore, fully automatic segmentation without any manual intervention is required and is the aim of this paper.

The proposed algorithm performs automatic segmentation on extraoral digital panoramic x-ray or Orthopantomograph (OPG). OPG gives view of entire mouth that is lower jaw together with upper jaw as shown in Figure 1. It doesn't contain details needed to show cavities. However, panoramic X-rays emphasize problems such as bone abnormalities, fractures, cysts, impacted teeth, infections, tumors, assessment of dental implant, orthodontic assessment, etc. According to National Institutes of Health (NIH), the relation between periodontal diseases and systemic conditions such as cardiovascular disease, type 2 diabetes mellitus and osteoporosis, can also be found from panoramic X-rays[1].

The present research deals with OPG. Input to the developed algorithm is panoramic x-ray as, variety of jaw abnormalities[2,3] and systemic disease features[5,7,10,11] may be found from extraoral images. Among different modalities of extraoral radiography, OPG is cost effective and is an effective tool to find out structural abnormalities.

Use[2] semi-automatic method to calculate bone growth around implant using digitized intraoral radiographic film images. Starting point on the implant screw is manually marked to locate its position. Because of digitization process, additional noise is added. Thus, in the proposed algorithm, input is digital dental panoramic x-ray giving very good picture quality and preprocessing of these images for noise removal is not required.

Use[3] extraoral imaging method namely Cone Beam Computerized Tomography (CBCT). Authors synthesize orthopantomographic views of mandibular bone to extract needed information from CBCT. CBCT is a medical imaging technique consisting of X-ray computed tomography producing three dimensional (3-D) images of teeth, soft tissues, nerve pathways and bones in a single scan. Here, authors extract OPG views from CBCT to understand bone geometry. In practice, CBCT is costlier than OPG. Algorithm developed in the present research work automatically extracts mandible from OPG which is cost effective as compared to CBCT.

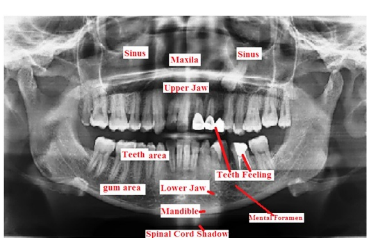


**Figure 1.** Digital dental panoramic x-ray or OPG.

Analyzes[4] panoramic x-rays or OPGs using image processing techniques. Here segmentation of lower jaw from OPG is performed to detect fracture, using texture analysis. Segmentation of lower jaw is influenced by a fixed position (500th row). Selection of this fixed position is automatic and has been decided after resizing OPG images. Resizing results in loss of data. Therefore, in the proposed algorithm, input image is not resized and lower jaw segmentation position is not fixed.

Research is carried out to classify cysts from OPG images using live wire segmentation method[5]. Cyst is segmented using its shape and statistical properties. Live-wire segmentation method is semi-automatic in nature where few edge points of Region of Interest (RoI) are marked manually. In the present research work, lower jaw and mandible are the RoIs and the proposed algorithm completely extracts RoI automatically.

Osteoporosis (thinning of bones) is a condition in which the bones become fragile due to hormonal changes or deficiency of calcium or vitamin D. It may result in a fracture even from a minor fall. Osteoporosis can be detected using a test called Dual-energy X-ray Absorptiometry (DXA). This DXA test measures total body bone density. Recent research articles[6, 7] present evidences that osteoporosis can be predicted from OPG images by analyzing mandible for its width and texture. Dentists often recommend OPGs in diagnosis of dental diseases. However, while planning dental treatment, awareness of osteoporosis will be a great help.

Establish[6,7] a method for detection of osteoporosis from Dental Panoramic Tomograms (DPT). They use Active Shape Model (ASM) to analyze width of mandible from lower jaw, automatically. [7] uses additional texture feature and ensures further accuracy in results. The method in[7] is called as Active Appearance Model (AAM). In (6) and (7), the process of segmentation of mandible is semi-automatic and its accuracy depends on manual selection of initial points. This limitation is overcome in the proposed algorithm by locating mandible edge using morphological operations.

Extract[8] trabecular structures of mandible from OPG film images using mathematical morphological operations. They digitize OPG image manually and use it as input data[9] establish association between osteoporosis and mandible using co-occurrence matrix and semiautomatic AAM to measure width and texture[10] use sequence of operations like contrast stretching, histogram equalization, thresholding, high-pass filtering, etc. to detect osteoporosis where lower border of the mandible is cropped manually.

Compare[11] various segmentation techniques like region growing, watershed, thresholding, etc. These segmentation methods are applied on x-rays having only two types of components like bony and non-bony area. OPG images contain various components like teeth, gum, vacuum, etc. and their intensities also overlap. Thus, it is not adequate to use single segmentation technique.

Literature discussed above extracts diseased features from intraoral and extraoral imaging modalities. Segmentation processes carried out are more or less manual and complete automation of this process is required. In this paper an algorithm has been developed for fully automatic segmentation of lower jaw and mandible. Segmented lower jaw and mandible can then be used for further processing like estimation of osteoporosis and detection of fracture. Following sections of this paper present, the proposed algorithm module wise, results and conclusions.

## 2. Methods

As panoramic x-ray images contain various objects like teeth, vacuum, sinus, spinal cord shadow, etc. (Figure 1), segmentation of panoramic x-ray images is a challenge as compared to other x-ray images taken to find illness from various body parts. Intensities of these objects are close to each other, as such, segmentation based on intensity slicing is difficult.

Proposed algorithm uses digital dental panoramic x-ray as an input image. It is a good quality colored .jpg file with no noise and no human error. The algorithm includes various phases like vertical partitioning of input image in number of strips, finding cut position to segment lower jaw, finding position of mandible edge and segmentation of mandible structure. Block diagram of the proposed algorithm is shown in Figure 2. Coding is carried in MatLab R2013a.

### 2.1 Block Diagram

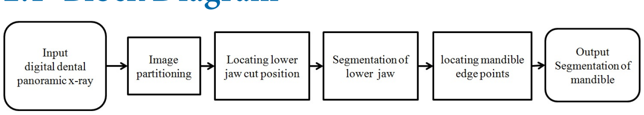


**Figure 2.** Block diagram of proposed system.

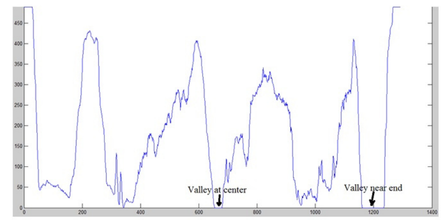


**Figure 3.** Valley positions in horizontal projection of OPG.

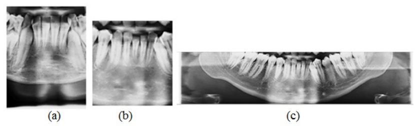


**Figure 4.** Segmented lower jaw (**a**) Center strip segmented at center valley (cut-1) (**b**) Center strip segmented near end near mandible (cut-2) (**c**) Segmented lower jaw.

### 2.2 Proposed Algorithm

#### *2.2.1 Input Digital Dental Panoramic X-ray*

Input image is converted to gray scale image. In colored images, each pixel is represented by three channels e.g. Red, Green and Blue (RGB). Gray scale image is a single channel image where each pixel is represented by a single number indicating intensity value, ranging from 0 to 255. Thus, processing time for gray scale image is around 1/3rd as compared to colored image. Digital OPG images are colored images containing only gray shades and their conversion to gray scale reduces execution time without any considerable loss of data.

#### *2.2.2 Image Partitioning*

In OPG image, lower and upper jaws appear in arc like structure. Vacuum between teeth of the two jaws may contain unwanted shadows. Thus, for correct segmentation of lower jaw, algorithm divides the OPG image in five vertical equidistance strips. The strips are numbered as st1, st2…st5 from left where st3 is the middle strip. Middle strip is considered for segmentation of lower jaw from upper jaw as central part of an arc structure is obviously horizontal. Strip st2 is considered to locate points on the mandible edge as shadows of spinal cord do not appear in this strip.

#### *2.2.3 Locating Cut Position of Lower Jaw*

To find the cut, st3 is binarized using global thresholding by applying Otsu method. Then, horizontal projection of this binary image is a row wise summation of all intensities in horizontal direction of image matrix. A typical horizontal projection of an OPG image is plotted and shown in Figure 3. This plot shows valleys and peaks. After studying horizontal projection of 100 OPG images, it has been concluded that valley can be found around centre of the image which is a vacuum between lower jaw and upper jaw. A cut position (cut-1) is a valley position above center of the image and is the point of consideration for separation of lower jaw as shown in Figure 4(a). For the images, where valley is not located above center, center position is a cut position.

### 2.2.4 Segmentation of Lower Jaw

A center strip is segmented from the cut position found in previous module such that it is split in two halves. Lower half portion is shown in Figure 4(a). A vacuum below mandible from this lower half can be detached by finding cut position (cut-2). The cut-2 position is obtained by performing operations like binarization, taking horizontal projection and selecting valley position near bottom end. It is observed that, only 35% images get exact cut close to mandible. This is because; OPG image contains shadow of spinal cord at the center. Figure 4(b) shows exact cut below mandible. The cut positions cut-1 and cut-2 found on center strip are reflected on actual OPG image and lower jaw is segmented from OPG image as shown in Figure 4 (c).

### 2.2.5 Locating Edge Points of Mandible

Segmented lower jaw, shown in Figure 4(c) is again subdivided in 5 equal numbers of vertical strips. These strips are considered for further processing. Edge points of mandible are located from st2 or st4. For the following discussion st2 strip is considered. St2 strip is binarized. Edge detection is now performed on binarized st2 using Canny operator in horizontal direction. This is followed by application of morphological dilation operation to eliminate discontinuities found on edges. Figures5(a), (b), (c) and (d) show st2 for segmented image, binarized st2, Canny edges with discontinuities and continuous edges after dilation, respectively.


**Figure 5.** Edge detection and dilation for st2. (**a**) st2 (**b**) Binarization (**c**) Edge detection (**d**) Dilation.

### 2.2.6 Segmentation of Mandible

Figure 5(d) shows various edge components. Here, an edge component is a line object with no discontinuity. Unwanted edge components other than mandible edge needs to be removed. These edge components are separated and pixel count for each is calculated. An edge component present at lower half of the image with highest pixel count represents the edge of mandible. All other edge components are removed. Result after removal of unwanted edge components from $st_2$ is shown in Figure 6(a). The edge extracted in above module is a reference point to segment mandible. Considering these reference points, mandible intensities from segmented lower jaw are extracted and are seen in Figure 6(b).

## 3. Results

Algorithmuses digital dental panoramic x-ray as an input image which contains objects with overlapping intensities. Partitioning the image vertically, in number of strips for separation of lower jaw and upper jaw helps to decide the cut position as structural distribution of the objects in each vertical strip is different. An odd number of strips are considered so that middle strip contains central part of the image. Therefore, middle strip is considered for separation of lower jaw from upper jaw.

Experiments are performed with various strip counts as 3, 5, 7 and 9. In many images shadow is observed at the center vacuum position and getting zero count in horizontal projection is difficult. Strip count 3 results

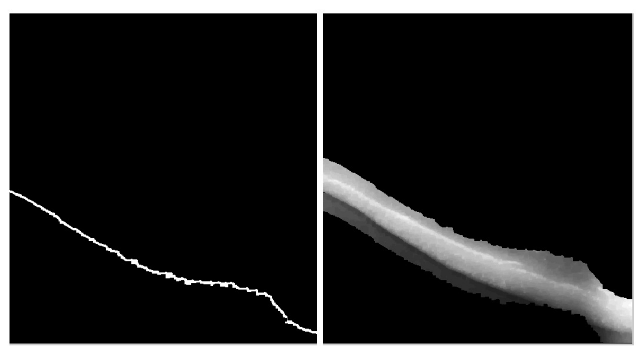

**Figure 6.** Segmented mandible (**a**) Lower edge of mandible (**b**) Segmented mandible.

**Table 1.** Results

| Title | Success Count | |
|---|---|---|
| No of Strips used | Lower jaw cut | Mandible edge detection |
| 3 | 88% | Not possible |
| 5 | 93% | 90% |
| 7, 9 | 89% | High complex algorithm |

in a wider strip and it is observed that arc structure of mandible poses difficulty in obtaining clear cut position of the lower jaw. Strip counts 5, 7 and 9 result in to obtaining clear cut positions for lower jaw separations.

Same experimentation is performed for segmentation of mandible from subimage of lower jaw using 3, 5, 7 and 9 number of strips. As central strip contains shadow of spinal chord below mandible, only side strips are considered for segmentation of mandible. For strip count 3, enough portion of mandible is not available on side strips and thus, strip count 3 is rejected. For strip count 7 and 9, to extract sufficient length of mandible, at least 2-3 consecutive strips need to be considered. This increases time complexity. In strip count 5 maximum mandible area is included in side strips st2 and st4. Therefore, strip count is finalized as 5.

While edge detection of mandible, both Canny and Sobel operators are tried. It is observed that Sobel operator is useful for segmentation of lower jaw whereas, Canny operator gives clear detection of lower edge of mandible with less discontinuities.

Algorithm is tested on 100 OPG images obtained from practicing dental professionals. For majority of the images, image sizes in pixel are 2440 x 1292 or more. Pixel resolution is 235 dpi with 24 bit depth.

The algorithm is tested for segmentation of lower jaw and mandible. Results of strip counts, 3, 5, 7 and 9 are shown in Table 1.

## 4. Conclusions

Researches use various intraoral and extraoral dental radiographs to locate the abnormalities. Many of them are film radiographs and are digitized when taken as input images. Amongst these, OPG is comparatively cost effective and is found to be much more useful to detect abnormalities of jaws. Digitization of film radiographs may include human error and input may be of low quality. Thus, for the proposed algorithm, input is digital dental panoramic x-ray giving good picture quality and preprocessing of the image for noise removal is not required.

It is found that many of the researchers adopt the segmentation procedure of the OPG image to detect abnormalities related to jaw and segmentation of images is performed manually or in a semiautomatic manner. The presented algorithm segments lower jaw and mandible edge points automatically and manual intervention is eliminated completely.

Strip method used in the algorithm focuses ROI for segmentation. This helps to ignore components like teeth, implants, spinal cord shadow, etc. Central strip is useful to segment lower jaw whereas side strips are useful to detect mandible edge points. Experimentation has been carried out on 100 digital OPG images. Segmentation of lower jaw provides 93% results and the accuracy of extracting mandible edge and removal of unwanted objects from the image is 90 % with strip count as 5. The algorithm can further be modified to locate fracture, cyst and other abnormalities and separated mandible can be processed to predict osteoporosis.

## 5. References


1. Kim J, Amar S. Periodontal disease and systemic conditions: A bidirectional relationship, NIH Public Access. Odontology. 2006; 94(1):10–21.
2. Veronese E, Veronese M, Sivolella S, Grisan E. A radiographic-based method for marginal bone loss measurement in dental implants. 2013 IEEE 10th International Symposium on Biomedical Imaging; San Francisco, CA. 2013. p. 129–32.
3. Antila K, Lilja M, Kake M, Lotjonen J. Automatic extraction of mandibular bone geometry for anatomy based synthetization of radiographs. 30th Annual International Conference on IEEE Engineering in Medicine and Biology Society Vancouver; British Columbia. 2008. p. 490–93.
4. Naik A, Tikhe S, Bhide S, Kaliyamurthie KP, Saravanan T. Algorithm to detect fracture from opg images using texture analysis. 6th IEEE International Advance Computing Conference (IACC-2016); 2016.
5. Mikulka J, Kabrda M, Gescheidtova E, Peina V. Classification of Jawbone Cysts via Orthopantomogram. 2012 35th International Conference on Telecommunications and Signal Processing (TSP); Prague. 2012. p. 449–502.
6. Allen PD, Graham J, Farnell DJJ, Harrison EJ, Jacobs R, Nicopolou-Karayianni K, Lindh C, van der Stelt PF, Horner K, Devlin H. Detecting reduced bone mineral density from dental radiographs using statistical shape models. IEEE

Transactions on Information Technology in Biomedicine. 2007; 11(6):601–10.

7. Roberts MG, GrahamJ, Devlin H. Improving the detection of osteoporosis from dental radiographs using active appearance models. 2010 IEEE International Symposium on Biomedical Imaging: From Nano to Macro; Rotterdam. 2010. p. 440–3.
8. Asano A, Tambe T, Taguchi A, Asano CM, Nakamoto T, Tanimoto K, Hinamoto T, Muneyasu M. Extraction of trabecular structures of mandible excluding tooth roots on dental panoramic radiographs using mathematical morphology.18th International Conference on Pattern Recognition (ICPR'2006); 2006. p. 988–91.
9. Roberts MG, Graham J, Devlin H. Image texture in dental panoramic radiographs as a potential biomarker of osteoporosis. IEEE Transactions on Biomedical Engineering. 2013; 60(9):2384–92.
10. Kavitha MS, Samopa F, Asano A, Taguchi A, Sanada M. Computer-aided measurement of mandibular cortical width on dental panoramic radiographs for identifying osteoporosis. Journal of Investigative and Clinical Dentistry. 2012; 3(1):36–44.
11. Karthikeyan B, Vaithiyanathan V, Venkatraman B, Menaka M. Analysis of image segmentation for radiographic images. Indian Journal of Science and Technology. 2012 Nov; 5(11):3660–64. DOI: 10.17485/ijst/2012/v5i11/30657.