Robust Cephalometric Landmark Identification on Cephalometric Downs Analysis

Ika Purwanti Ningrum, Agus Harjoko, and Munakhir Mudjosemedi, *Member, IACSIT*

***Abstract*—Cephalometric landmark identification on cephalometric analysis Downs has been developed. Here we identify a 10 point landmarks used in cephalometric Downs analysis: Gnation, Gonion, Menton, Nation, Orbital, Porion, Point A, Point B, Pogonion, and Sella. The research was conducted in three phases: preprocessing, feature extraction and identification. In the preprocessing phase, the things we do are: image size normalization, Enhance contrast, and took the ROI for each landmark. We use of PPED algorithms for image feature extraction and to measure the similarity between the template vector and vector test, euclidean distance gives good results, despite the large number of image samples do not always give the results was always good. To improve systems performance, we use a multithreading technique. The experimental results showed that the methods used can work well although still found deficiencies and inaccuracies. Accuracy of projections mainly on bilateral landmarks greatly affect the outcome of the identification.**

***Index Terms*—Cephalometrics landmark, cephalometric downs analysis, PPED algorithm.**

I. Introduction

Medical imaging is today becoming one of the most important visualization and interpretation methods in biology and medicine. Pattern recognition techniques play a critical role when applied to medical imaging by fully automating the process of abnormality detection and thus supporting the development of computer-aided diagnosis (CAD) systems. In most cases, CAD systems are designed to be used for screening purposes, in which large numbers of images need to be examined. They are adopted as an alternative "second opinion" that can assist a radiologist in making diagnostic decisions [1].

In cephalometric radiographs, CAD systems are used to identify landmarks which are one of the most important procedures for the diagnosis requirement. This system will identify a number of landmarks to analyze the relationship between form and elements of cranio-facial bones [1]. Research on cephalometric landmark identification has been done, but the focus on one particular method of cephalometric analysis is rarely found. In this paper, identifying landmarks is used in cephalometric Downs analysis. There are 10 points to be identified as Gnation, Gonion, Menton, Nation, Orbital, Porion, Point A, Point B, Pogonion, and Sella. Explanations include pattern recognition techniques to support and improve the accuracy and efficiency of cephalometric landmark identification system so that the diagnosis can be done quickly and precisely.

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II. Problem Description

A. Cephalometric Downs Analysis

Cephalometric analysis is a measurement system that was created to determine the relationship between the various elements of skeletal, dental and soft tissue in the cranio-facial complex [2]. Cephalometric analysis is used to determine the treatment plan and evaluation of treatment success orthodonti [3]. Downs analysis methods is to analyze the relationship maxilla and mandibular, used to evaluate the relationship of the teeth to the facial skeletal [4]. Downs analysis is using the Frankfort Horizontal Plane (FHP) that connects Porion (Po) and Orbital (Or) as the reference plane [4], [5]. Standard anatomical points used in the cephalometric Downs analysis is Gnation, Gonion, Menton, Nation, Orbital, Porion, Point A, Point B, Pogonion, and Sella, see Fig. 1.

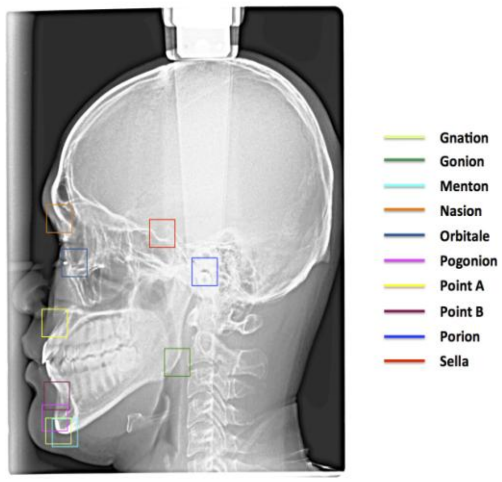

Fig. 1. Landmark of cephalometric Downs analysis.

B. Cephalometric Landmark Identification System

Research on cephalometric landmark identification has been done, some of which are carried out by [6]-[10]. Reference [6] developed CNNs (Cellular Neural Networks) to achieve an accuracy in automated landmarks detection suitable for clinical practice, and have applied the method for 8 landmarks located on the bone profile. Reference [7] developed an automated method for the localization of cephalometric landmarks in craniofacial cone-beam computed tomography images. This method makes use of a statistical sparse appearance and shape model obtained from training data. Representation algorithm compatible with VLSI-matching-engine-based image recognition system has been developed by [8]. The spatial distributions of four-principal-direction-edges in a 64x64 pels gray scale image are coded to form a 64-dimension feature vector. Since two-dimensional edge information is reduced to a feature vector by projecting edge flags to the principal directions, it is named Projected Principal-Edge Distribution (PPED) representation. Reference [9] developed cephalometric landmark identification system used PPED algorithm and Manhattan distance. Automated system based on the use of Active Appearance Models (AAMs) has been developed by [10]. In this research, a top-hat transformation was used to correct the intensity inhomogeneity of the radiographs generating a consistent training set. As generally pattern recognition system, cephalometric landmark identification system has a knowledge base that stores the results of the image feature extraction for each landmark. These data that will be used as a reference for identifying cephalometric landmarks on the images tested. Mostly, landmark identification system entailing excessive cost.

III. Proposed Methode

Block diagram of the system designed to identify cephalometric landmarks is presented in Fig. 2.

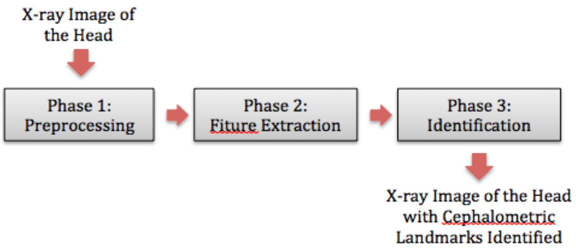

Fig. 2. Processing phases.

In the preprocessing stage, the image quality was improved. First, the dimension of the image was reduced by a third (766×983 pels) using interpolation of a single pixel selection method. Rescale done so that the pattern around the landmarks that will be used as characteristic of the the landmarks can be represented by 64×64 pels, it is to the needs of feature extraction. Then increased the image contrast using histogram equalization method by using the histogram value of the square root, it made the effects of less extreme equalization and noise reduction. For template image, each landmark was taken Region of Interest of 64×64 pels (see Fig. 3).

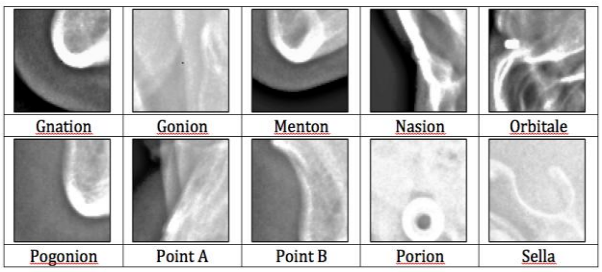

Fig. 3. ROI of each landmarks.

In the feature extraction stage, we used Projected Principal-Edge Distribution (PPED) algorithm which has been developed by [11]. In this step, pattern feature from each landmark was extracted. For template image, the vector feature PPED then saved in system database as a knowledge base, for the next to use in identification process. PPED algorithm is illustrated in Fig. 4.

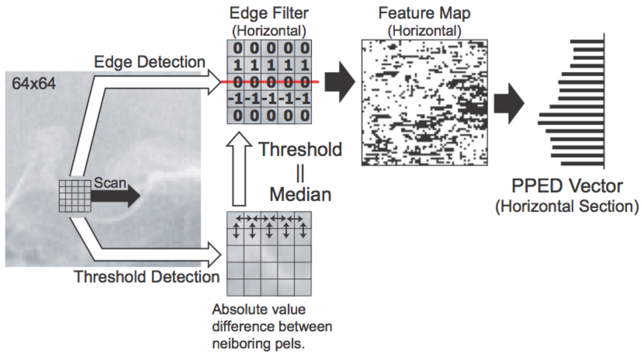

Fig. 4. PPED vector generation algorithm [8].

PPED algorithm is as follows [11]:

1) The input image (64×64 pels) is first subjected to pixel-by-pixel spatial filtering operations to detect edges in four directions: horizontal (H); +45°; vertical (V); and -45°. The spatial filtering is carried out by taking the convolution of 5×5 pixel data $I(x,y)$ and 5×5 kernel $Kd(p,q)$ as

$$I_d^*(x,y)=\left|\sum_{p=-2}^{2}\sum_{q=-2}^{2}K_d(p,q)\times I(x+p,y+q)\right| \quad (1)$$

where d represents the edge direction (H, +45°, V, or -45°). In this paper, we used 2 kernels, see Fig. 5.

K_H				
1	1	1	1	1
1	1	1	1	1
0	0	0	0	0
-1	-1	-1	-1	-1
-1	-1	-1	-1	-1

K_{+45}				
1	1	1	1	0
1	1	1	0	-1
1	1	0	-1	-1
1	0	-1	-1	-1
0	-1	-1	-1	-1

S_H				
0	0	0	0	0
1	1	1	1	1
0	0	0	0	0
-1	-1	-1	-1	-1
0	0	0	0	0

S_{+45}				
0	0	0	1	0
0	1	1	0	-1
0	1	0	-1	0
0	0	-1	-1	0
0	-1	0	0	0

K_V				
-1	-1	0	1	1
-1	-1	0	1	1
-1	-1	0	1	1
-1	-1	0	1	1
-1	-1	0	1	1

K_{-45}				
0	1	1	1	1
-1	0	1	1	1
-1	-1	0	1	1
-1	-1	-1	0	1
-1	-1	-1	-1	0

S_V				
0	1	0	-1	0
0	1	0	-1	0
0	1	0	-1	0
0	1	0	-1	0
0	1	0	-1	0

S_{-45}				
0	1	0	0	0
-1	0	1	1	0
0	-1	0	1	0
0	-1	-1	0	1
0	0	0	-1	0

Fig. 5. Filtering kernels for detecting four principal edges.

2) $TH(x,y)$ is a threshold value to detect an edge. Threshold value is determined based on the median value of the difference between the two pixels in the vertical and horizontal directions on each 5×5 block of pixels in the spatial filtering operation. The edge flag $Fd(x,y)$ is then determined according to the following algorithm:

$$F_d(x,y)=\begin{cases}0: if \max_d\{I_d^*(x,y)\}<TH(x,y)\\ 1: if \max_d\{I_d^*(x,y)\}TH(x,y)\end{cases} \quad (2)$$

3) The bit map of each edge flag Fd is called the feature map. The 64×64 bit array in a feature map is then reduced to a one- dimensional array of numeric values by projection. Namely, the horizontal edge flags are accumulated in the horizontal direction and projected onto the vertical axis, and the vertical edge flags are

projected onto the horizontal axis. Namely, projection sums *PH*(*j*) (0 - 63) and *PV*(*i*) (0 - 63) are obtained as

$$P_H(j) = \sum_{i=0}^{63} F_H(i,j)$$
$$P_V(i) = \sum_{j=0}^{63} F_V(i,j). \quad (3)$$

4) The +45° edge flags are accumulated in the +45° direction and projected onto the -45 axis. As a result, 127 = (63×2 - 1) diagonal projection sums are obtained as:

$$P_{+45^\circ}(m) = \sum_{i+j=m} F_{+45^\circ}(i,j) \quad (4)$$

where *m* is an integer from 0 to 126. The diagonal projection sums for the -45° edge flags $P_{-45}(m)$ (m = 0 - 126) are obtained in a similar way. The number of projection sums for each direction (64 P_d's for H and V and 127 P_d's for +45° and -45°) is finally reduced to 16 in order to form a 64-element PPED vector.

5) The four sets of projection sums, P_H, $P_{+45°}$, P_V, $P_{-45°}$, are then series connected in this order and a 64-dimension PPED vector is finally obtained.

In the identification stage, a 64×64 pels area was taken from test image, and was transformed to a PPED vector. The test image was then matched with the template vectors in database. The template having the minimum dissimilarity (the Euclidean distance was utilized as the measure [12]) was selected as a winner pattern. By pixel-by-pixel scanning the test image, cephalometric landmarks were identified as the minima of dissimilarity.

IV. Experimental Result

Fivety-five digital x-ray head image (2300×2950 pel, image format is .bmp) were taken from patient files at the Prof. Soedomo Dental and Oral Hospital, Gadjah Mada University, Indonesia, and utilized for experiments. 20 images were used for template generation and other 35 images were used for recognition tests. For template image, preprocessing and feature extraction were employed. The identification steps, test images are also subject to preprocessing. Furthermore identification was performed as described in the section above Proposed Method identification phase.

A. Cephalometric Landmark Identification

The performances of all cephalometric identifications are demonstrated in Table I.

The first test using 10 image templates. The results obtained, PPED algorithm successfully identifies the position of each landmark identification although the percentage of truth different. Identification is highest in Menton landmark that is equal to 86% and the lowest was on landmark identification Porion at 14%.

In the second test with 20 images in the template, the highest identification found on the landmark Point B is equal to 80% and the lowest was on landmark identification Porion that is equal to 17%.

The second test of the above, the lowest percentage of identification is equally porion landmark. This is because of the medicine was, Porion is a landmark of the most difficult to identify because the location of the ear-rod is sometimes inappropriate and porous edges acusticus externus unclear, causing it to be very individual landmark [3]. It also affects the vector template is formed to be very individual. As a result to match the pattern that one would be higher. Plus because of the formation process of feature vectors PPED experienced reduced dimensional vector space [11].

Successful identification of landmarks with 20 images in the template are not always better than 10 image templates. Evidenced by the results of landmark identification Gnation, Gonion and Menton, presentations on testing the truth of identification with the image of the template 10 is higher than the test results with 20 images in the template. Referring to research conducted by [11], states that the increase in the number of vector template does not always improve recognition performance. This is due to the addition of increasing variations of vector template template vector vector template is added so that was matched with the wrong pattern.

TABLE I: Recognition Performances

Landmarks	Correct Identification (%)	
	10 Sample Image	20 Sample Image
Porion	14	17
Gnation	77	74
Gonion	37	34
Menton	86	62
Nasion	49	60
Orbitale	63	65
Pogonion	57	74
Point A	49	71
Point B	74	80
Sella	60	60

For Gonion landmark, precision projection when image acquisition greatly affect the shape of the pattern of this landmark. This was due Gonion a bilateral point because it is located in the mandibular plane [2], [13]. Based on our observations, there are some images that are not symmetrical cephalometric causing Gonion patterns become increasingly varied. Fig. 6 shows an example of the location of landmarks Gonion and Porion the mandibular plane.

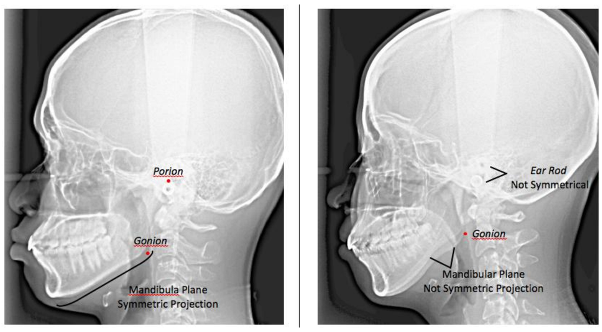

Fig. 6. Porion and Gonion landmark position: projections symmetrical (left) and projection not symmetrical (right).

B. System Performance

To speed system performance, we use multithreading in the identification process. The image in the horizontal direction is made with blocks of 68 pixels width according to the width of the ROI landmark. Each pixel block is considered as a thread so that when the scanning process is running, the system will process each thread in parallel in the vertical downward direction. The timing of the execution of each thread is done by the system. The average processing time is 13 seconds, with computer specs: processor Intel (R) Core-i5-2400s 2.50 GHz; RAM 2.00 GB; system 32 Bit (x86); VGA ATI Radeon HD 4300/4500 series.

V. Conclution and Future Works

1) In this paper we present the identification of 10 cephalometric landmarks used in cephalometric analysis Downs.
2) The experimental results showed that the methods used can work well although still found deficiencies and inaccuracies.
3) The use of multi-aspect method for the selection of the sample data should be developed to improve the accuracy of identification.
4) Forecast accuracy at the time of image acquisition greatly influence the shape of the pattern, especially in the landmark bilateral landmarks.
5) In the future this system will be developed to the stage of cephalometric analysis.

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