RECOGNITION OF CRANIOFACIAL LANDMARKS APPLYING FUZZY LOGIC

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ABSTRACT

Application of advance image processing techniques in recognition and detection of craniofacial landmarks [1] has been investigated here by implementation of new a method in pattern analysis. Accurate estimation of the landmarks highly increases efficiency and speed of diagnosis and treatment monitoring in orthodontics. The major objective of the paper is to develop a suitable system including application of ISODATA pattern recognition technique together with a fuzzy logic decision making algorithm [2] in order to increase accuracy of the results.

1 INTRODUCTION

X-ray cephalographs are lateral skull (craniofacial) radiographs. These images are highly used in orthodontic and anatomical surgery. Geometrical description of A set of points in hard and soft tissues provide necessary clinical information. Since X-ray images are usually very blurred, even recent orthodontic pathology is often based on detection of craniofacial landmarks using Human Visual System (HVS) and manual geometrical measurement and analysis of the profile. Since popular manual methods are very time consuming process, automatic cephalometry becomes of great importance. Manual technique can be replaced by Computerized methods only if a high degree of accuracy is achievable. Recently developed techniques in this area either are based on simple and inaccurate estimation of desired features or only special good quality images are selected for processing [3].

The proposed method in cephalogram analysis includes effective pattern recognition procedures followed by implementation of fuzzy logic systems for detection of the most important landmarks among about 30 landmarks depicted in the lateral skull profile of Figure 1 [1]. These features are Nasion, Sella Turcica, Tip of nose, Sub-nasal, Point A, Point B, Menton, Incisor Superiors, Gnathion, Maxillary plane, Mandibular plane, Occlusal plane, Porion and Orbitale. All above landmarks are successfully detected with very high accuracy.

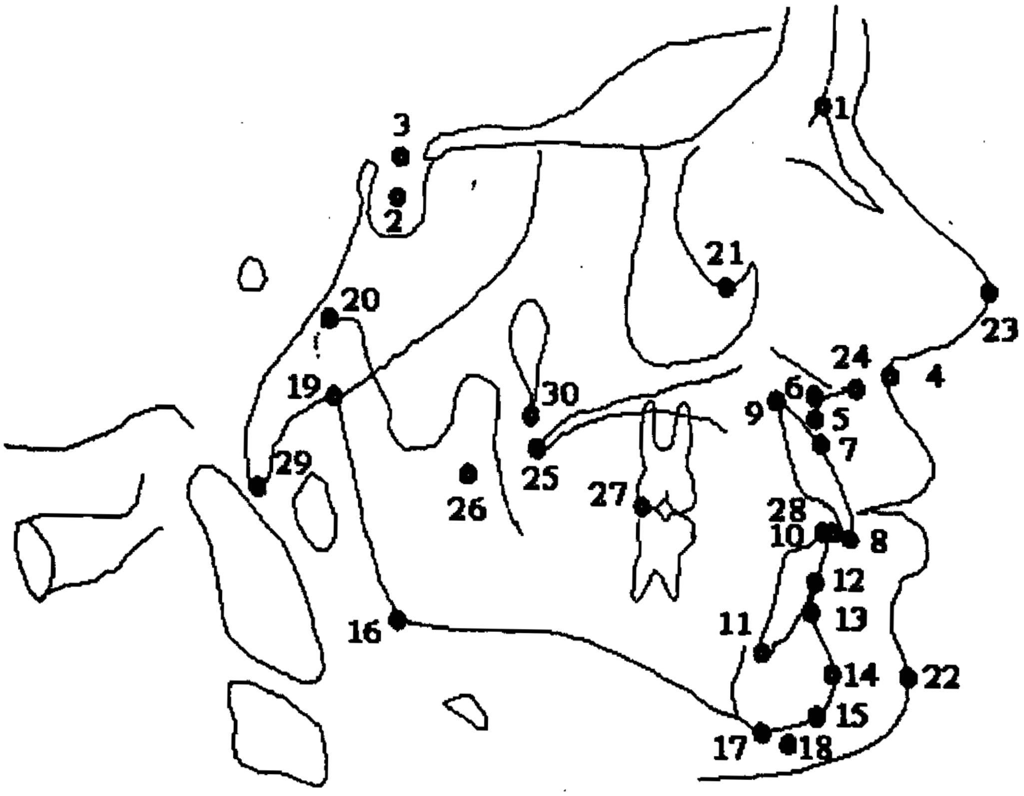

Figure 1; Location of landmarks

Suitable pre-processing algorithms have been applied for restoration and enhancement of the noisy data. In the following sections different steps in the proposed method are explained

2 Pre-processing of the cephalograph

The histogram of the image is divided into two parts, belonging to soft and hard tissues. Different aspects of enhancement including adaptive median filtering [4] and andpass Gaussian spatial-frequency filtering are used for the two above segments separately. Most of the processes are based on local data statistics. Two-dimensional Gaussian filter effectively highlights the edges while reduces the high spatial frequency noise. In Figure 2 original image, The image when soft tissue is enhanced and the image when hard tissue is enhanced are illustrated. The edges have to be detected in order to enable accurate template matching in the vicinity of the features. Since

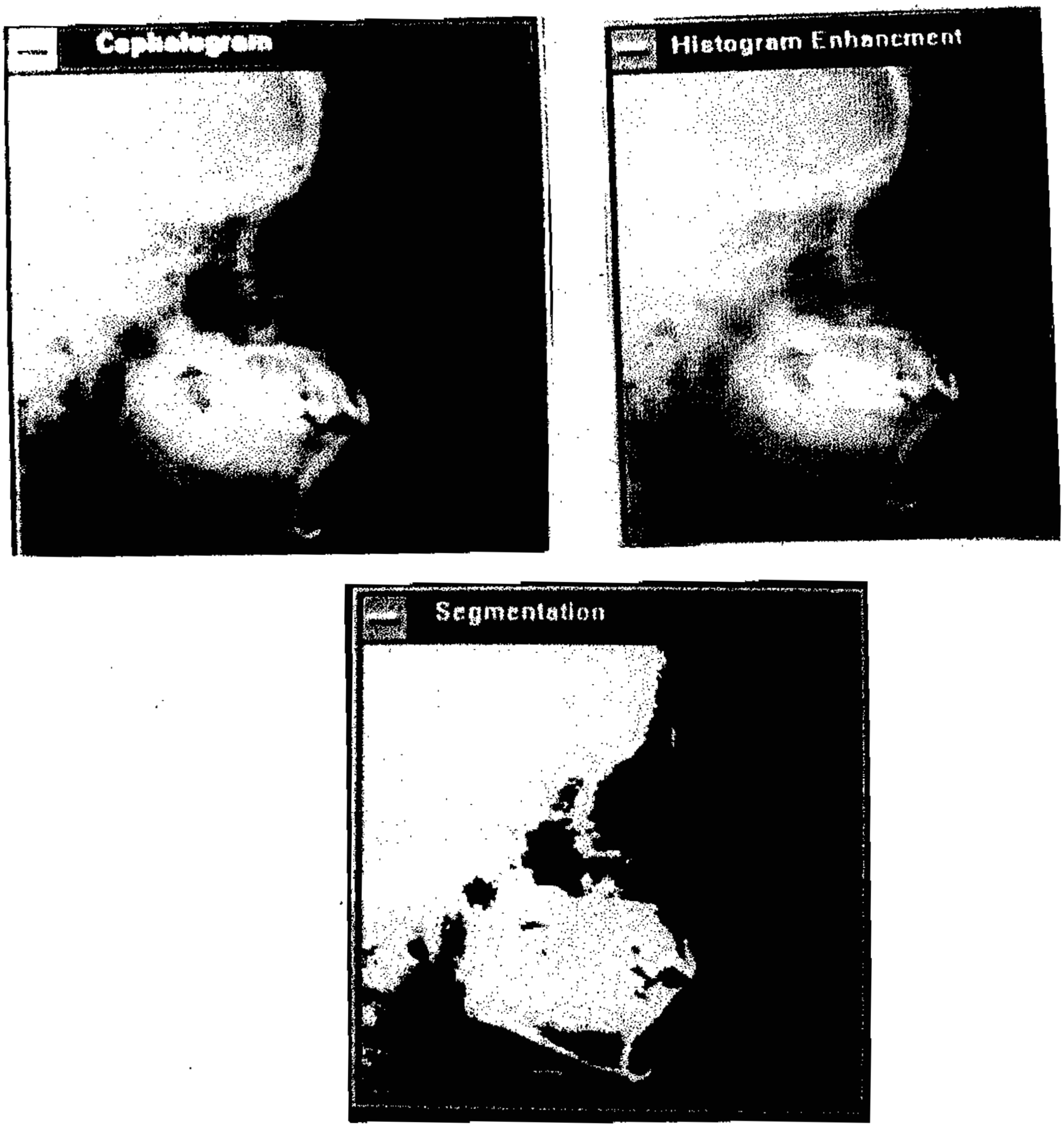

Figure 2 a) Original image, b) Soft tissue enhanced, c) Hard tissue enhanced

the image is very noisy edge detection based on gradient measurement such as sobol etc. does not work efficiently. The method applied here, fits two lines to the adjacent segments of each row or columns of the image. Assuming the lines to be y_1 and y_2 as:

$$y_1=a_1x+b_1$$
$$y_2=a_2x+b_2$$

Then a simple fuzzy decision making leads to detection of an edge if a_1 and a_2 are different by a threshold or b_1 and b_2 are different when a_1 and a_2 are almost equal.

3 Recognition of Landmarks

Before all, a search area is estimated for each feature. These regions are determined based on primary knowledge about the organ, type of tissue (soft or hard) and image statistics. The criterion decreases computation cost, simplifies the processor and increases the speed of computation. Proper matrices of suitable size are used as templates to match the selected candidates of the features. Definition of similarity functions using suitable window size for each feature (except Sella, Maxillary and Mandible planes) is considered to find maximum similarity between the landmarks and the selected templates. One dimensional cross correlation is effectively used for this purpose. As an example, the function Z defined as

$$Z[i] = \frac{\sum_{l=-7}^{8} \sum_{m=-7}^{8} N1[l+7,m+7]*X[l+7,m+7]}{\sum_{l=0}^{15} \sum_{m=0}^{15} N1[l,m]^{2} * \sum_{l=-7}^{8} \sum_{m=-7}^{8} X[i+l,j+m]^{2}}$$

determines cross correlation of a 16 by 16 square region centred at a point on the *jth* column of the image for detection of tip of nose. Letter *i* denotes *ith* pixel value of the *jth* column. The same Z is evaluated for values of *j* up to the point where the most matched points are detected.
Maximum and mean values are calculated in order to define a suitable threshold such as

for determination of local maxima. A set of classes may be detected for above landmark. The method is based on Iterative Self Organizing Data Analysis (ISODATA). A number of distinct groups of candidates is firstly recognized for each point. Winner group will then be one which has more candidates and also satisfies the anatomical conditions. A fuzzy table is then established based on a) the number of members for each class, location of the class and position of the next two classes belonged to tip of lips. When the right class is determined an smaller size template is used for further convergence to the point and finally detection of the landmark.

Maxillary and Mandible planes are nicely detected by application of a search algorithm started from Incisor Superiors followed by a clever detection of direction by LSF-based minimisation of Euclidean distances. In paediatric skull cephalograms, however, auxiliary planes are firstly defined in order to locate Maxillary and Mandible planes in the right positions.

In detection of sella turcica a number of familiar patterns are utilised as templates, to detect points, curves and corners in the vicinity of the landmark. Relative distances of the matched patterns are used as inputs to an already defined fuzzy system. the membership functions are practically extracted in order to cover all possibilities in shape of sella. The programme significantly converges to highlight accurate position of sella.

Figure 3 shows suitable templates for detection of Sella turcica.

In detection of nasion, primary knowledge about position of sella is very advantageous. The search zone is within -20 to +20 degree relative to horizontal line started from sella.

$$Y2_{10*10} = \begin{bmatrix} 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 255 & 255 & 255 & 255 & 255 & 255 & 255 & 255 & 255 & 255 \\ 255 & 255 & 255 & 255 & 255 & 255 & 255 & 255 & 255 & 255 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$Y2_{10*10} = \begin{bmatrix} 0 & 0 & 0 & 0 & 255 & 255 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 255 & 255 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 255 & 255 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 255 & 255 & 0 & 0 & 0 & 0 \\ 255 & 255 & 255 & 255 & 255 & 0 & 0 & 0 & 0 & 0 \\ 255 & 255 & 255 & 255 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

$$Y3_{10*10} = \begin{bmatrix} 0 & 0 & 0 & 0 & 000 & 000 & 000 & 000 & 000 & 000 \\ 0 & 0 & 0 & 0 & 000 & 000 & 000 & 000 & 000 & 000 \\ 0 & 0 & 0 & 0 & 000 & 000 & 000 & 000 & 000 & 000 \\ 0 & 0 & 0 & 0 & 000 & 000 & 000 & 000 & 000 & 000 \\ 0 & 0 & 0 & 0 & 0 & 255 & 255 & 255 & 255 & 255 \\ 0 & 0 & 0 & 0 & 255 & 255 & 255 & 255 & 255 & 255 \\ 0 & 0 & 0 & 0 & 255 & 255 & 000 & 000 & 000 & 000 \\ 0 & 0 & 0 & 0 & 255 & 255 & 000 & 000 & 000 & 000 \\ 0 & 0 & 0 & 0 & 255 & 255 & 000 & 000 & 000 & 000 \\ 0 & 0 & 0 & 0 & 255 & 255 & 000 & 000 & 000 & 000 \end{bmatrix}$$

Figure 3; The templates for recognition of sella turcica

Due to the nature of varying data for various skulls, a fuzzy decision making is required in order to verify relative possible positions of the landmarks.

Similar fuzzy criterion exploits relative geometrical positions and distances in accurate definition of the feature positions for different patients. All membership functions proportional to the similarity parameters are estimated using a large number of cephalograms derived from Iranian (white race) people. Figure 4 illustrates the steps in detection of sella and Figure 5 demonstrates detected landmarks for an arbitrary cephalogram.

Conclusion

More than 96% accuracy in average, with sufficient computation speed are considerable advantages of the proposed system over traditional automatic methods. Since the program has possibility of manual operation, it may also used for educational purposes.

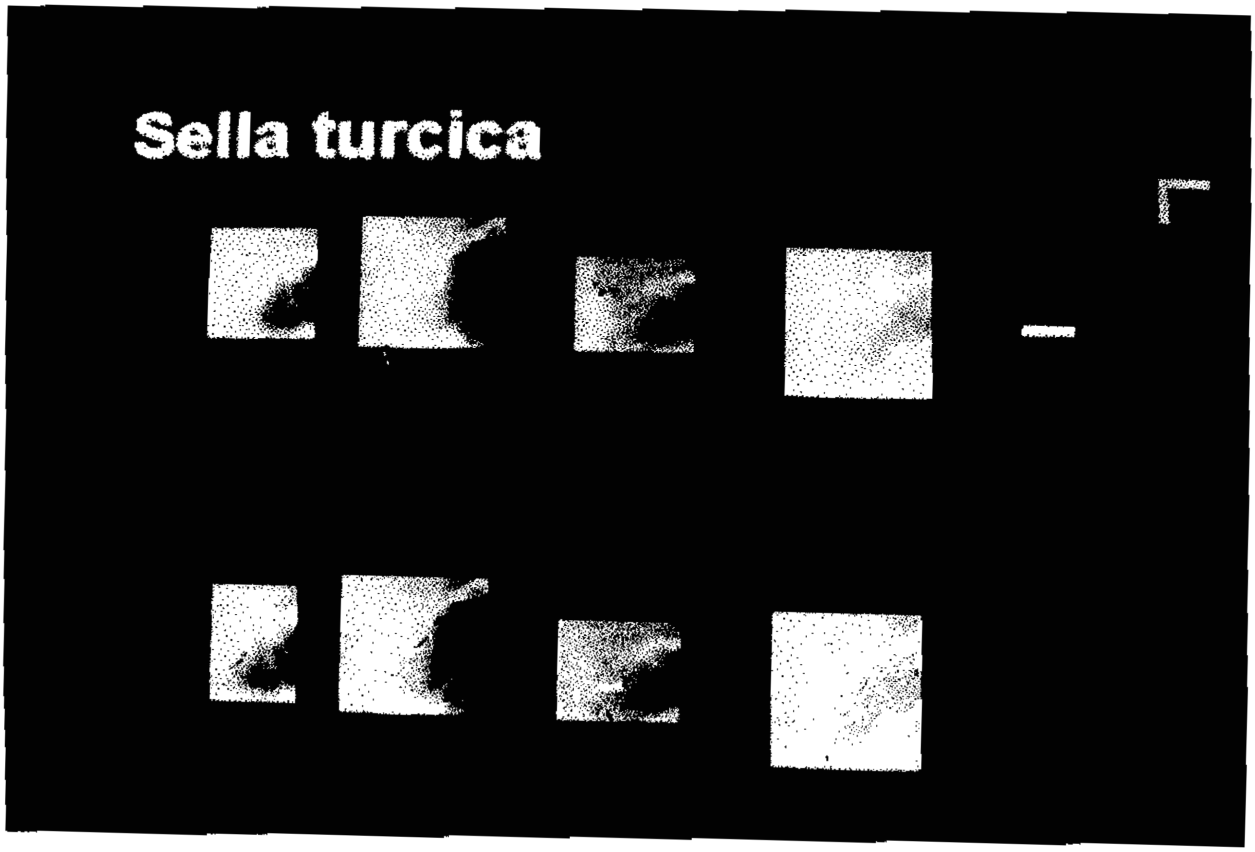

Figure 4; The steps for detection of sella Turcica

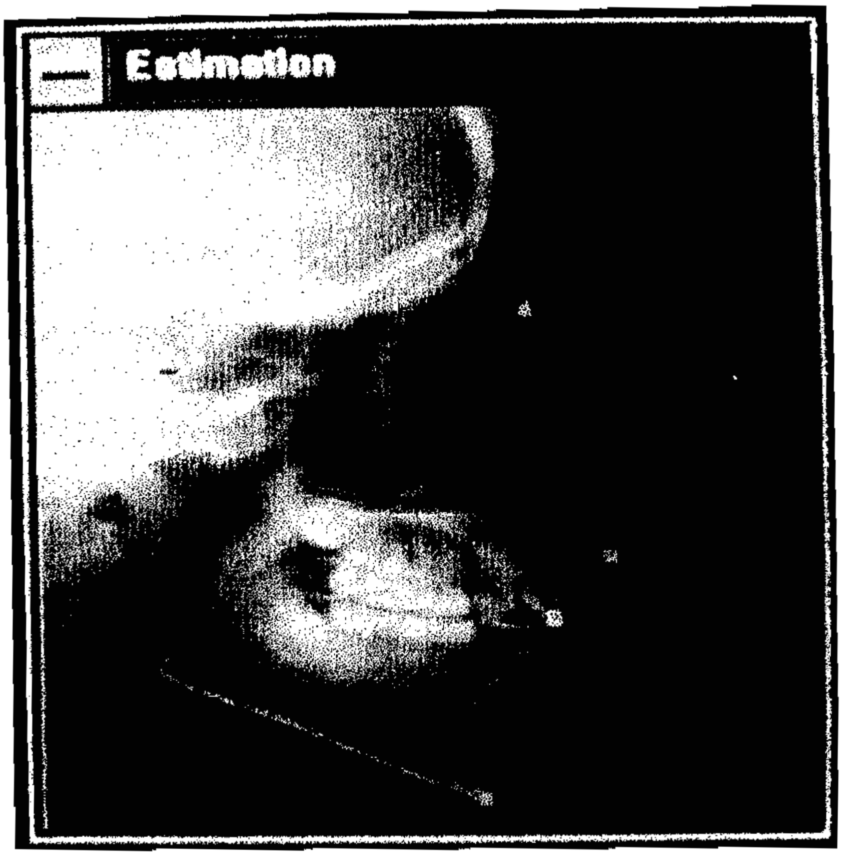

Figure 5; Detected Landmarks

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