Cephalometric analysis for finding facial growth abnormalities

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Abstract— Cephalometric analysis of lateral radiographs of the head is an important diagnosis tool in orthodontics. Based on physically locating specific landmarks, it is a boring, lengthy and error prone task. The objective of this work is to calculate the SNA angle, SNB angle and ANB angle between the landmarks to identify the input and output parameters pertaining to skeletal abnormalities. By doing so the patients data for training and testing the backpropagation neural network (BPNN), generalized regression neural network (GRNN), support vector machine (SVM) and extreme learning machine (ELM) classifiers by nine fold cross validation. The performance of skeletal is found out using the BPNN, GRNN, SVM and ELM models. This will be useful to identify whether the patient is normal or abnormal (need for treatment). This will classify condition of the different patients with severity of abnormalities in skeletal.

Keywords- backpropogation neural network (BPNN), generalized regression neural network (GRNN), support vector machine (SVM), extreme learning machine (ELM)

I. Introduction

All Cephalometric analysis is the study of the dental and skeletal connections in the head. It is regularly used by dentists, repeatedly orthodontists in exacting, as a treatment-planning tool. Cephalometrics has established itself as one of the pillars of comprehensive Orthodontic diagnosis. It is also a variable tool in treatment planning and follows up of patients undergoing orthodontic treatment. Certain irregularities of the position of the jaw can also show up in the analysis. One can provide a computerized analysis that will measure and compare the anatomy to assist in the treatment plan.

Cephalometric analysis requires an expert system to be developed for computer applications in this field. So a preliminary research is necessary using cephalometric for making the computers to detection of abnormalities in skeletal. The dental and skeletal relationships in the head are studied in cephalometric analysis. Cephalometric analysis depends on cephalometric radiography to study relationships between bony and soft tissue landmarks and can be used to diagnose facial growth abnormalities prior to treatment, in the middle of treatment to assess growth or at the finish of treatment to ascertain that the goals of treatment have been met.

There is lack of skilled personnel proficient enough in cephalometric analysis and also to assist the doctor. There is a growing need for the computer as an aid for cephalometric analysis. Calibrating cephalogram is a necessary step in making the computers to detection of abnormalities in skeletal. Artificial neural networks (ANNs) are the result of academic investigations that use mathematical formulations to model nervous classification operations. The resultant technique are being successfully applied in a variety of everyday applications.

Classification is an essential decision making tool, especially to the diagnosis of diseases. Unfortunately, while many classification procedures exist, many of the methods suffer in the presence of statistical outliers or overlapping groups. Recently, artificial neural networks have been suggested as tools for classification.

Neural networks represent a meaningfully different approach to using computers in the place of work. A neural network is used to study pattern and associations in data. The data may be the results of market investigate endeavor, a manufacture process given varying operational conditions, or to diagnose the diseases in medicine as well as dental. Regardless of the specifics involved, applying a neural network is substantially different from traditional approaches.

II. Summary

The major task of medical science is to prevent and diagnose the diseases. A computer system never gets weary or uninterested, can be efficient easily in a substance of seconds, and is quite cheap and can be easily spread. Broadbent and subsequently revolution the analysis of malocclusion and the underlying skeletal structures first introduced cephalometry. Studies related to cephalometrics, it is an important tool in orthodontics. Based on physically locating specific landmarks, it is a dull, lengthy and error prone task. Two approaches may be used to perform a cephalometric analysis: a manual approach, and a computer-aided approach. To describe the techniques used for automatic landmarking of cephalograms, importance the strength and weakness of each one and reviewing the percentage of success in locating each cephalometric point.

III. CEPHALOMETRICS

The assessment of cranio-facial structures forms a part of orthodontic diagnosis. The earliest method used to assess facial proportions was by artistic standards with harmony, symmetry and beauty as key points. Craniometry can be said to be the forerunner of cephalometry. Craniometry involved capacity of cranio-facial size of skulls of lifeless persons. This method was not realistic in living individuals due to the soft tissue envelope, which made direct measurements difficult and far less reliable. This static study of the starting point for the dynamic cephalometrics that will allow predicting:

IV. CEPHALOMETRIC LANDMARKS

Cephalometric makes use of certain landmarks or points on the skull, which are used for quantitative analysis and measurements. The cephalometric landmarks (Fig. 3. 1) can be of two types. First one is anatomic and the second one is a derived landmark.

A. Anatomic Landmarks: These landmarks represent actual anatomic structures of the skull.

B.Derived Landmarks: These are landmarks that have been obtained secondarily from anatomic structures in a cephalogram.

The landmarks that are used in cephalometrics should fulfill certain requirements, which are given below:

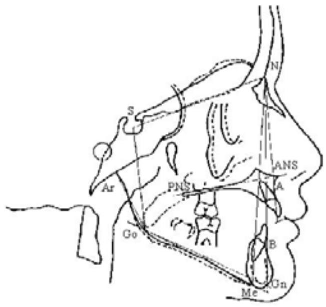

Fig. 1. Cephalometric Landmarks

V. LANDMARKS

Nosion (N): The most anterior point midway between the frontal and nasal bones on the fronto-nasal suture.

Sella (S): The point representing the midpoint of the pituitary fossa or sella turcica. It is a construct point in the mid-sagittal plane.

Articulare (Ar): This point was introduced by Bjork (1947). It provides radiological direction being the point of connection of the posterior margin of the ascending ramus and the outer margin of the cranial base.

Gonion (Go): A construct tip, the junction of the lines tangent to the posterior margin of the ascending ramus and the mandibular base.

Menton (Me): According to krogman and sassouni, Menton is the most caudal point in the outline of the symphysis; it is regarded as the lowest point of the mandible and corresponds to the anthropological gnathion.

Point A, subspinale (A): The deepest midline point in the curved bony outline from the base to the alveolar process of the maxilla, i.e. at the deepest point between the anterior nasal spine and prosthion. In anthropology, it is known as subspinale.

Point B, supramentale (B): Most anterior part of the mandibular base. It is the nearly all posterior point in the outer contour of the mandibular alveolar progression, in the median plane. In anthropology, it is identified as supramentale, between infradentale and pogonion.

Gnathion (Gn): This point is defined in a number of ways. It is located in the median plane of the mandible, where the anterior curve in the draw round of the chin merges into the body pf the mandible.

Anterior Nasal Spine (ANS): Point ANS is the tip of the bony anterior nasal spine in the median plane. It corresponds to the anthropological anthion.

Posterior Nasal Spine (PNS): This is a construct radiological point, the junction of a persistence of the anterior wall of the pterygo palatine fossa and the ground of the nose. It marks the dorsal limit of the maxilla Ease of Use.

VI. MAXILLARY AND MANDIBULAR BASES ANALYSIS

This maxillary and mandibular bases analysis consists of determining the SNA (angle formed by those points Sella, Nosion, point A), SNB (angle formed by those points Sella, Nosion, point B) and ANB (angle formed by those points point A, Nosion, point B) angles. Various analyses like dental and soft tissue analysis are also available to determine the growth pattern of face whether it is retrognathic and prognathic.

A. SNA Angle: The SNA angle defines the anteroposterior position of point **A** relative to the anterior cranial base. Its mean value is 81°, indicates a normal relationship between maxilla and anterior cranial bottom. If the angle is a smaller amount than ordinary, the maxilla lies more posterior in relative to the cranial base, if the angle is too huge, the maxilla lies more anterior. The angle therefore define the degree of prognathism for the maxilla. A large SNA angle (greater than 84°) makes the anteroposterior position of the maxilla prognathic; a small angle (less than 78°) makes it retrognathic. Variations due to age and sex are minimal with this angle (80.5 - 82°).

B. SNB Angle: The SNB angle defines the anteroposterior position of the mandible in relation to the anterior cranial base, equivalent to the SNA angle for the maxilla. This angle define prognathism for the mandible, the mean value being 79°. If it is greater than 82°, the mandible is prognathic relative to the anterior cranial base, if it is less than 77°, the mandible is retrognathic. The mandible is describe as orthognathic if the angle is between 77° and 82°. The size of this angle increases with age (from 76° at 6 years to 79° at 16 years of age).

C. ANB Angle: The ANB angle represents the difference between the SNA and SNB angles and defines the mutual association, in the sagittal plane, of the maxillary and mandibular bases. The ANB angle is positive if point **A** lies anterior to NB. If NA and NB match, the angle will be zero. If, though, point **A** lies posterior to NB, ANB will be negative. separately from establish the relationship between the maxillary and mandibular bases, the angle also mainly determines the position of the incisors. On normal, the angle is 2°.

VII. Analysis of the Facial Skeleton

This analysis consists of determining the saddle angle, articular angle and gonial angle.

A. Saddle Angle: The NS-ar angle is the angle between the anterior and posterior cranial base. Within the region of the posterior cranial base lies a sagittal growth centre, the sphenooccipital symchondrosis. The position of the fossa is determined by growth changes in this area. A large saddle angle indicates a posterior position, a small saddle angle an anterior position of the fossa. The mean value is 123° ± 5°.

B. Articular Angle: The S-ar-Go angle is one of those rare angles that may be altered by orthodontics. If the gnaw is open by extrusion of the posterior teeth or by distalisation, the angle increases, whilst mesial movement of the teeth will create it lesser. A large articular angle imposes retrognathic changes on the profile, a small angle on the other hand prognathic change. The mean value is 143° ± 6°.

C. Gonial Angle: The ar-Go-Me is an expression for the form of the mandible, with position to the relation flanked by body and ramus. The gonial angle also plays a role in growth prognosis. The mean value is 128° ± 7°.

VIII.Modules Necessary for Cephalometric Analysis

The following modules are very much needed for finding landmarks and SNA angle, SNB angle, ANB angle for maxillary and mandibular bases analysis.

A. Blocking Method: The blocking method, which takes care of the imaging geometry as well as constructing the whole model in a same coordinate system without any additional coordinate transformations, is called the Image Block method. This guarantees that the 3-D model determined by intersecting image rays from multiple cameras will have correct shape and size (Fig. 3.2). In case of stereo imaging the cameras are installed to look in parallel and the distance of projection centers along their common x-axis is determined through calibration. But there are cases like aerial photography where you only know the approximate pose and orientation of images.

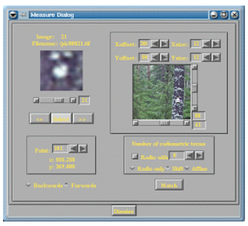

Fig. 2. Before applying

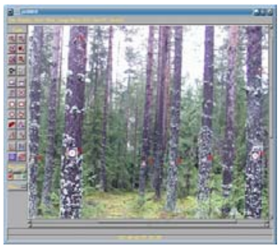

Fig. 3. Image after applying

B. Line Drawing : The points S (Sella), N (Nosion), A (point A, subspinale) are connected and thus formed an angle SNA, S (Sella), N (Nosion), B (point B, supramentale) are connected and thus formed an angle SNB, A (point A,subspinale), N (Nosion), B (point B, supramentale) are connected and thus formed an angle ANB.

C. Angle Finding: The angle is to be calculated by the following formula. The distance between the two points is calculated as in equation $\sqrt{(x2-x1)^2 + (y2-y1)^2}$.

For any triangle with plane lengths a, b, c.

Law of Cosines is $C^2=a^2+b^2- 2ab \cos C$ (1)

$\cos C = (a2 + b2 - c2) / 2ab$ (2)

$C = \cos^{-1} [(a2 + b2 - c2) / 2ab]$ (3)

IX. Extraction of Parameters

Following parameters are extracted from the above module such as saddle angle, articular angle, gonial angle, sum of posterior angles, SNA angle, SNB angle and ANB angle.

X. NORMALIZATION OF PARAMETER VALUES

The development of the training network starts with the selection of a number of different combinations of input variables to evaluate the most reliable neural network model. For the pre-processing phase, all input and output data are normalized to values between 0 and 1. It is assumed that 'x' has only fixed real ideals, and that the elements of each row are not all equal. The method is described by the following equations for converting any 'x_i' value with normalized 'y_i' value.

$$y_i = (y_{max}-y_{min}) * (x_i-x_{min}) / (x_{max}-x_{min}) + y_{min} \quad (1)$$

This equation converts any 'x_i' value into corresponding 'y_i' value in the range of y_{min} to y_{max}. In this work normalized value between 0 and 1 is used for BPNN, GRNN and ELM. Therefore y_{min}=0 and y_{max}=1. Then y_{min} (0) and y_{max} (1) are substituted in equation which yields,

$$y_i = (x_i-x_{min})/(x_{max}-x_{min}) \quad (2)$$

The value -1 and +1 is used for SVM model. If y_{min}= -1 and y_{max}=1. Then y_{min} (-1) and y_{max} (1) are substituted in equation which yields,

$$Y_i = \left(\left(\frac{x - x_{\min}}{x_{\max} - x_{\min}} \right) \times \left(y_{\max} - y_{\min} \right) \right) - 1 \quad (3)$$

XI. NINE FOLD CROSS VALIDATION OF DATA

In this study the nine-fold cross-validation is applied for training and testing the BPNN, GRNN, SVM and ELM. In nine fold cross corroboration, the training set is arbitrarily divided into 9 disjoint sets namely fold 1 (say p1), fold 2 (say p2) to fold 9 (say p9), where each fold contains 20 patients case records. Further these folds are formed with the following groups for training and test data preparation for facial skeleton analysis and maxillary and mandibular bases analysis.

XII. MODELLING TECHNIQUES FOR TRAINING AND TESTING

In this phase backpropagation neural network (BPNN), generalized regression neural network (GRNN), support vector machine (SVM) and extreme learning machine (ELM) are considered.

XIII.PERFORMANCE INDEX

To measure the performance of backpropagation neural system, generalized regression neural system and extreme learning machine a confidence score (CS) is computed by the equation

$$CS = \exp(-mse(e)) * 100 \quad (1)$$

where e represents error. It can be written as

e = actual_target – simulated_target given by BPNN/GRNN/ELM.

XIV.CONCLUSION

In this work image processing methods are implemented to detect the landmarks manually and SNA angle, SNB angle and ANB angle are calculated. Reduction in time is achieved through this method. Depends upon the angle values of the skeleton image the classification are done. The identified input parameters are saddle angle (N-S-Ar), articular angle (S-Ar-Go), gonial angle (Ar-Go-Me), SNA angle, SNB angle and ANB angle for training and testing. These parameters are used as input and output to the BPNN, GRNN, SVM and ELM models.

In this work classification of patients abnormalities in skeletal by BPNN, GRNN, SVM and ELM model is presented. For this classification input parameters of cephalometric landmarks (input) and types of abnormalities (output) are identified, 181 data collected, normalized, trained, tested and classified using BPNN, GRNN, SVM and ELM models.

According to the simulation results, the BPNN (96.7%) and SVM (99.8%) approach are feasible and was found to give average performance for detecting and classifying the patients abnormalities in skeletal over the other models (GRNN and ELM) for taking into account of all the cephalometric analyses. From this one can conclude that the BPNN and SVM model are capable of reproducing the target output values with minimal error. This means that the BPNN and SVM model is able to learn from the input and output parameters and maps input data with output. So BPNN and SVM is good classification model in classifying patient’s abnormalities in skeletal analysis. So the BPNN and SVM model outputs supplements the dentist knowledge and decision in treatment plan.

XV. SUGGESTION FOR FUTURE WORK

In this study automatic cephalometric landmark detection is used to detect the landmarks easily and also BPNN, GRNN, SVM and ELM models are used to detect the abnormalities in skeletal. Further this study can be modeled by the other hybrid techniques like Two-Hybrid technique, Neuro-Fuzzy to see the further improvement in the performance.

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