



Survey on Different Bone Age Estimation Methods

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Abstract— *The Bone age estimation methods can be useful for evaluating the growth rate, whether it is accelerating or decelerating. The common methods for assessing bone maturity are: 1)Greulich and Pyle ,2)Tanner and Whitehouse and 3)Eklof and Ringertz .The aim of this paper is to evaluate or compare the results obtained from each bone age estimation methods and suggests the best method based on the accuracy and efficiency. The result shows that the ER method is estimating the bone age with high accuracy, when comparing with GP and TW methods.*

Keywords— *Medical Imaging, Segmentation, Bone age, Eklof and Ringertz, Greulich & Pyle, Tanner & Whitehouse.*

I. INTRODUCTION

A bone age study helps doctors estimate the growth rate of children is normal or not. Single x-ray of left hand is usually used for estimating the bone maturity, and the bone age is measured in years. It is a safe and painless procedure that uses a small amount of radiation. A difference between a child's bone age and chronological age might point to a growing problem [7]. Bone age can be used to predict: how much time a child will be growing, when a child will enter puberty and what will be the child's height associated with the bone age

Study of bone age has started so many years ago. Estimation of bone maturity had some restriction in the past, but nowadays the technology and the medical science researches are improved and advanced a lot. So the area of bone age estimation is an interesting and most useful research in the field of medical image processing. Study of bones tells about the diseases, height prediction and bone maturity of the person efficiently. But the study is always depends on some factors like region where the people living, their eating habits and some physical properties [7].

The Greulich and Pyle (GP), Tanner and Whitehouse (TW) and Eklof and Ringertz(ER) are the clinical methods used for finding the skeletal age. GP method estimate the hand bones by observing left hand radiographic images with an Atlas; 2) TW method analyses a set of twenty hand and wrist bones which are given specific scores according to sex. Then by adding such scores of all regions of interests, an overall maturity score is obtained; and 3) ER method is based on measurements of ten ossification centres. There is a table for finding the age which corresponds to the length of each ossification centre and separate table is there for men and women.

II. SKELETAL BONE AGE ASSESSMENT

Concetto Spampinato et.al [1] describes about 2 bone age estimating methods- GP and TW. These methods are entirely different from each other and also produce different values for bone age. Todd was published an “Atlas of Skeletal Maturation of the Hand” in 1937. General practitioner methodology is primarily based on the atlas by Todd. The atlas contains two components, one for the male patients and other one for female patients. Each component contains left hand radiographic image of youngsters ordered by age. The initial step in bone age analysis is to check the given exposure with the image within the atlas that corresponds nearest with the age of the patient. In next step the image should be compared with the nearest pictures representing each younger and older kid. After comparing the exposure image against a picture within the atlas, there is some measure which a medical doctor ought to use as maturity indicator.

In TW methodology twenty regions of interest (ROI) set within the main bones are used for the bone age analysis. Every ROI is separated in 3 parts, the expansion of every ROI is split into distinct stages and a letter is given to every stage (A, B, C, D. . . I). A numerical score is associated with every stage of every bone. By adding such scores of all ROI, an overall maturity score is obtained. The age related to the overall score is completely different for males and females.

III. THE RELIABILITY OF USING GREULICH-PYLE METHOD TO DETERMINE CHILDREN'S BONE AGE IN TAIWAN

Kuo-Hsien Chiang et al. [2] used GP method for determining the skeletal maturity of children in Taiwan. The following criteria should be fulfilled in this investigation: 1) Left hand x-ray image without any bone fracture; 2) No medical record of inherited disorder or developmental disorder. Bone ages were calculated using the GP Atlas by two radiologists separately, with no information of the children's chronological ages. The study result shows that, there is no statistically significant variation in the interpretation of bone age between the two radiologists. The final result shows a retardation of bone age before puberty followed by an increase at puberty, resulting advancement by the end of puberty. In some cases there is a difference of more than one year between the chronological age and the measured bone age [2].

The result shows that some alteration of the GP Atlas is essential to success the capability to determine skeletal maturation with effectiveness and consistency.

IV. THE RELIABILITY OF THE GREULICH-PYLE METHOD IN BONE AGE DETERMINATION AMONG AUSTRALIAN CHILDREN

Mark L Paxton et al. [3] examines the accuracy of GP method in Bone age determination among Australian children. Bone age (BA) determination in skeletally immature children has been used as a measurement of growth for many years. The GP method of estimating BA is most commonly used. The standards used within this atlas were compiled from research conducted on normal Children. It aids in the identification of children with growth abnormalities, assesses their response to treatment and helps to calculate approximate adult height. The overall agreement between BA and Chronological age (CA) in all fairness high once victimization the G&P methodology. The standards of G&P stay a helpful means that of BA determination in Australian youngsters. Our results have shown that once victimization this methodology the BA of Australian youngsters is slightly delayed in comparison with CA. This distinction became additional apparent with increasing age. Single readers will estimate serial BA examinations systematically; however there is also variation between completely different readers. Clarification of the precise distinction between BA and CA for each sex at numerous ages in addition as inter-observer variations desires additional investigation.

V. SKELETAL AGE ASSESSMENT: A COMPARISON OF 3 METHODS

Francisco Haiter-Neto et al., [4] proposes three strategies for calculating the age from skeleton .The objective of this paper is to search out the pertinence of those 3 strategies. The 3 strategies developed to estimate skeletal age are: Greulich and Pyle (GP), Eklof and Ringertz (ER), and Tanner et al (TW3). For a sample study they took a sample of 360 healthy patients in Brazil. Based on sex and chronologic age the patients (aged seven to fifteen years) were divided into eighteen groups. The result of these strategies shows that the GP and TW3 strategies were near chronologic age for both sexes. The ER technique cared-for overestimate skeletal age for the lower age groups, to correspond for the intermediate age groups, and to underestimate for the upper age groups in each sex. The boldness interval confirmed that this knowledge failed to represent a statistically vital distinction between chronologic and assessed skeletal ages. This implies there's a high relationship between the studied sample knowledge and therefore the three customary strategies. Determinate correction factors build every technique additional helpful for the studied population. For each sex, a high relationship between chronologic and skeletal ages was found.

VI. PSO FOR GRAPH-BASED SEGMENTATION OF WRIST BONES IN BONE AGE ASSESSMENT

Thangam et.al [5] proposes an efficient graph based segmentation method for bone age assessment. The methods used for bone age assessment are GP and TW, the segmentation needed for TW only. Here author introduces PSO for graph based segmentation the entire region of interest or the specific region of interest can be segmented. The time needed for segment each ROI is calculated, results shows that the PSO-Graph needs less time compare to other methods. In PSO the main process are swarm formation and objective function evaluation.

In TW methods the results are highly depends on the segmentation process. The 2D Gaussian low pass filter is used in the preprocessing stage for noise removal. Then the x-ray image is converted into gray scale image. Then the Sobel edge detection process is performed. A pair of 3×3 convolution masks is used by Sobel edge detector, one estimates the gradient in the x-direction (columns) and the other estimates the gradient in the y-direction (rows).Then the PSO for graph based segmentation is performed.

VII. BONE MATURITY: ESTIMATION BY MEANS OF EKLOF AND RINGERTZ SIMPLIFICATIONS

According to Celso et.al [6] for overcoming the carpal and wrist bones overlap troubles, the ER methodology excludes those bones for bone age analysis (Figure: 1). ER methodology includes 2 tables, one for men and other for women. The bone age is calculated by calculating mean age of every ossification center. The ER5 and ER3 are the simplified Eklof & Ringertz methodology.



Fig: 1. Ossification Centers in the ER5 Method

In this paper the result of ER method is compared with the clinical reports that done by GP, TW and ER method. In past years almost every clinical study of age are based on GP and TW methods. But the result obtained by GP and TW method has no correlation or similarity. The ER method, which is recently used in Odontology and other major areas. Author tries to prove that ER method produce the result which is comparatively more accurate than the GP and TW methods.

In ER5 simplified method, the bone age assessment is based on the analysis of only five ossification centers, which including two proximal phalanges and three metacarpal bones, excluding the carpal and wrist bones. In figure: 1 the bones marked as 8, 7 and 6 are the end points of the 4th, 3rd and 2nd metacarpal bones respectively. The bones marked as 9 and 10 are the end points of the 2nd and 3rd proximal phalanges respectively [6]. In the process of bone age estimation by using ER method includes 5 stages. The different stages of the ER bone evaluation methods are showed in figure 2. A low-pass filter is used in the preprocessing stage for minimize the noises and eliminating the variations of the image background. The most common low pass filter is 2D Gaussian filter. For segmenting the region of interest, an efficient thresholding algorithm is used.

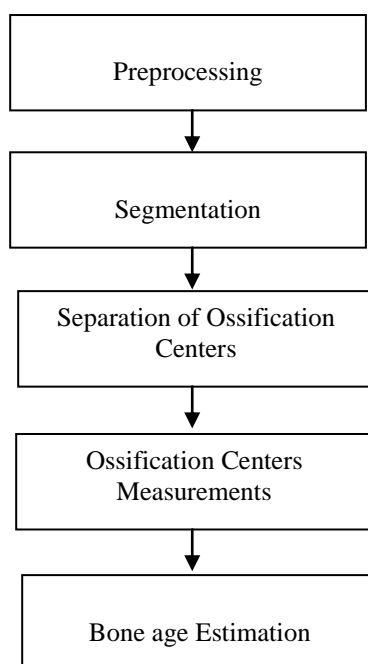


Fig. 2. Processing Sequence Utilized in the ER5 Method

The markers are inserted for separating each ossification centers. After markers insertion, the length of every bone in pixels (the geometer distance) is calculated. Then the pixel distance is converted into millimetre. For every ossification activity, the table was probe for finding corresponding age.

VIII. CONCLUSION

This paper discusses about different methods for bone age estimation. Three main methods for bone age estimation were analysed and the advantages and disadvantages of each method were found. Bone age estimation methods are widely used for evaluating growth rate of for the children. The commonly used methods GP and TW results have no correlation or similarity. The ER method result is very close to the clinical reports and hence the accuracy is high. So the survey, we recommend ER method for assessing the bone maturity by analysing left hand radiographic images for the children. The survey suggests that the ER method with automated bone age assessment improves the accuracy, time consumption and reduces error rates.

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