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Efficient Bone Age Assessment Methods

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Abstract

The Bone age assessment (BAA) is used to estimate the skeletal maturity of children. Performing bone age assessment is an important path of the diagnostic and management pathway in children with a variety of growth and endocrine disorder. Bone age assessment methods are popular to estimate the growth rate of children. BAA is used to find hormone problems such as thyroid, diabetes, obesity and also finds genetic disorders such as deletion of genes, chromosome abnormalities. The growth problem is determined by the difference between a skeletal bone age and chronological age (The age from the birth). But such differences are not to always mean there is a skeletal maturity problem, because sometimes healthy kids can have the differences between bone ages and the birth age. The Appearances of the carpal bones, metacarpal bones, phalanges, radius and ulna of left hand wrist is used to calculate the bone age efficiently. This paper presents an efficient survey on Bone Age Assessment methods. The various methods are used to estimate bone age such as Epiphysis/Metaphysis Region of Interest (EMROI), Greulich and Pyle (GP), Tanner and Whitehouse (TW2, TW3), Eklof and Ringertz (ER3, ER5), Hausdroff distance and Histogram based BAA. This paper aims that to define the best method for estimating bone age based on comparisons of these four methods with their accuracy and efficiency.

Keywords: Bone Age Assessment (BAA), Greulich and Pyle (GP), Tanner and Whitehouse (TW2, TW3), and Eklof and Ringertz (ER3, ER5), Region of Interest (ROI).
Reviewed by* **ICETSET'16 *organizing committee*

1. Introduction

Bone age assessment is to estimate the degree of maturity of a child's bone. A human growth as childhood, puberty, young adult, middle adult, and senior citizen. These changes can be seen by x-ray. There are 206 different bones in human body. In paediatric radiology Bone Age Assessment is clinical procedure to estimate the growth rate

of the children.BAA uses Left hand wrist radiograph (x-ray) image is taken as input and the bone age of a children will be estimated. There are several methods are available to estimate the skeletal maturity of a children. Pediatric radiology mainly uses Greulich and Pyle which involves visual inspections and comparison of bone of hand based on the digital atlas. Tanner Whitehouse (TW2, TW3), Eklof and Ringertz methods. A bone age assessment study helps doctors to calculate the maturity of a child's skeletal system. The BAA estimation is usually done through a single X-ray of the left hand, wrist, and fingers. It is very simple, safe and painless that uses a small amount of radiation. The bone age is measured in years. The fingers and wrist of the child's radiographic images contain growth plates in growth zoning at both ends. The special cells in growth plates will determine the growth of the finger. Because of fewer minerals in radiograph images the growth plates can be finding easily in x-rays. As a person grows the growth plate of the radiograph will change in appearance on the X-ray images and become thinner, eventually the growth plates are closed. A doctor can assign a bone age based on the appearance of the bones and growth plates. A child's skeletal maturity is assigned by using digital atlas which determining standard X-ray images with the atlas which is most closely related to the appearance of the child's bones on the X-ray.

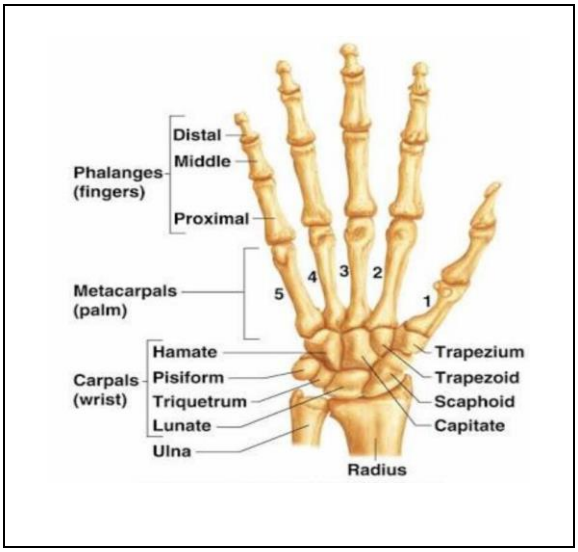

Figure 1: Bones of left hand wrist

1.1 Bone Age Assessment Dataset

The left hand wrist radiograph images of children for the age group (1 to 10) years for both boys and girls are used as input for bone age assessment (BAA). The following figures show that the sample datasets.BAA methods uses carpal region of interest, phalangeal region of interest, Radius and ulna to estimate the bone age efficiently. The following Figure 2 shows that the sample dataset for bone age assessment.

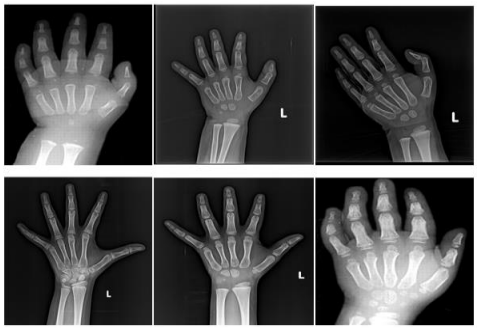

Figure 2: Sample Datasets

1.2 Overall Structure

The raw hand radiographic images are fed into image pre-processing in which the input image is enhanced using filters and segmented using PSO segmentation technique. From the segmentation the features are extracted and then it selects relevant features to estimate the bone age. Finally the features are fed into classifier to categories the bone age. Different classification algorithms used to calculate the bone age. The Figure 3 explains the overall architecture of BAA methods.

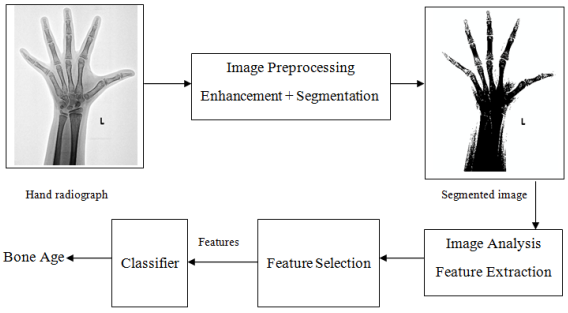

Figure 3: Overall Structure

2. Literature Review

2.1 Skeletal maturity of a child's Bone Age Using EMROI Technique

The bone age of children was calculated using epiphysis and metaphysic of a radiograph of a child's bone **[3].** The region of interest (ROI) of an epiphysis and metaphysic was used to estimate the bone age efficiently. The radiographic images were divided into 4 different image set. First set consists of 50 radiographic images, second set consists of 100 radiographic images, third set consists of 250 radiographic images, and fourth set consists of 500 radiographic images. The left hand wrist x-ray image was taken as input and image pre-processing was done using discrete wavelength transformation, the edge was detected using ISEF edge detector, and the segmentation was done

by energy based segmentation. The pattern based features of pre-processed image was extracted by the carpal ROI and Ephiphysial/Metaphysical region of interest (EMROI).The cell full, vertex full and Jacobi methods were used for feature analysis and extraction. K-means classifier was used to classify the extracted features of carpal region and epiphysis and metaphysic region.

Figure 4: Carpal feature and Phalangeal Feature

2.2 Skeletal maturity of a child's bone from epiphysis/metaphysic of phalanges using Hausdorff Distance

This paper explains the skeletal maturity of a bone of children from the phalange's epiphysis/metaphysis using Hausdorff distance [6] which used as the measure for classification. Hausdroff distance technique was worked based on the method of Tanner and Whitehouse (TW2) to calculate bone age. This system will guarantee the accurate Bone age of children for the age range day 1-10 years for both boys and girls. The database consists of 110 male x-ray images and 110 female x-ray images. The radiograph image of a left hand wrist was taken as input image which was preprocessed and eight joins of Epiphysis and metaphysic of region of interest (EMROI) were identified. Difference of the Gaussian (DoG) method was used to segment the cropped EMROI and 14 features were extracted from each EMROI which was stored as feature vector. Feature extracted images were classified using Hausdorff distance into one of the ten bone age classes. The Hausdorff distance is defined as the distance between the trained feature vector and the tested feature vector. The final bone age was mapped into age class (Class A – J).The performance of bone age assessment measured in terms of precision, recall, specificity, and accuracy. The following formulae are used to calculate the performance metrics.

$$\text{Precision} = \frac{TP}{TP+FP} \quad (1)$$

$$\text{Recall} = \frac{TP}{TP+FN} \quad (2)$$

$$\text{Specificity} = \frac{TP}{TP+FP} \quad (3)$$

$$\text{Accuracy} = \frac{TP}{TP+FP} \quad (4)$$

Where,

TP = True Positive

TN = True Negative

FP = False Positive

FN = False Negative

2.3 Histogram technique for estimating automated bone age assessment

This paper explains a new novel approach for estimating bone age of a children using histogram based technique. This approach uses web based system for BAA which was based upon content-based image retrieval. Histogram technique **[2]** aims to overcome the limitations of traditional methods used for bone age assessment. This system used to calculate the age prediction of a human using left hand wrist x-ray images up to 18 years. The input for the BAA using Histogram technique uses 1100 left hand and wrist radiograph images which consisting of 551 male and 549 female left hand and wrist radiographic images.

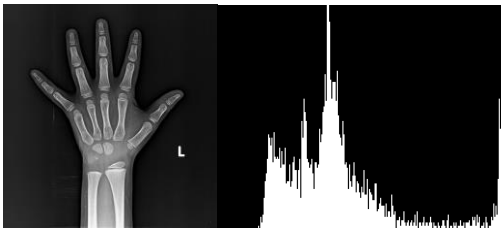

Figure 5: Left hand wrist x-ray image and Histogram of an x-ray image

The left hand wrist image is converted into histogram which is extracted from the pre-processed x-ray image. The three steps to calculate the skeletal age of a children bone.

- The histogram was extracted from the preprocessed input image and those images were was stored in feature database.
- The query was posted on a search engine which was applied by histogram.
- The exact matching of a bone age class was retrieved from the feature database.

2.4 Eklof and Ringertz method (ER5 and ER3) for Bone age assessment

This paper explains an efficient evaluation of bone age assessment using Eklof and Ringertz (ER3 and ER5) method simplification **[4].** The input was taken as Left hand wrist radiographic images of 685 children both male and female for the age group 6-16 years old. The bone age was estimated using simplifications of the ER5 and ER3 which uses five and three hand bone ossification centers. In ER5 simplification, the combinations of three metacarpals bones and two proximal phalangeals used for the skeletal maturity estimation. Minimum number of ossification centers was discovered by ER3 simplification to provide statistically significant results of a bone age. Different combinations of five ossification centers were tried such as two to two, three to three, and average of five bones to calculate the bone age. For image pre-processing the Heel effect method was used, and the noise was eliminated using low pass filter. The segmentation was done through Otsu, pun, nil black and Rosen field methods. Finally the bone maturity was estimated using Euclidian distance using ossification centers. The database for ER5 &ER3 consists of different age groups x-ray images. Database 1 consists of 350 male x-ray images and 387 female x-ray images. Database 2 consists of 150 male x-ray images and 110 female x-ray images. The Bone age assessment was estimated in terms of Mean age, Standard deviation, Pearson correlation and Student T-test.

2.5 Tanner and Whitehouse (TW3) method to estimate bone age assessment

The TW3 system aims to reduce the limitations of bone age estimation approaches and to estimating efficient bone age of a child. Tanner and Whitehouse (TW3) and fuzzy ID3 classification method [9] is used for efficient bone age assessment. This system uses the input as 142 radiographic images of both boys and girls for the age group from day 1 to 10 years. The TW3 method performing image pre-processing method to remove noise using Gaussian filter, the feature of radiographic image will extracted using principal component analysis (ICA), Features are analyzed and selected for classification. Fuzzy ID3 (Iterative Dichotomiser-3) algorithm is used to classify the bone age for the x-ray images.

3. Methodology for BAA

The bona age assessment methods involves image pre-processing which removes unwanted noise and then the features are extracted from the pre-processed radiographic images. The features required for BAA will be selected from the extraction and then bone age of a radiograph is estimated using classification algorithms.

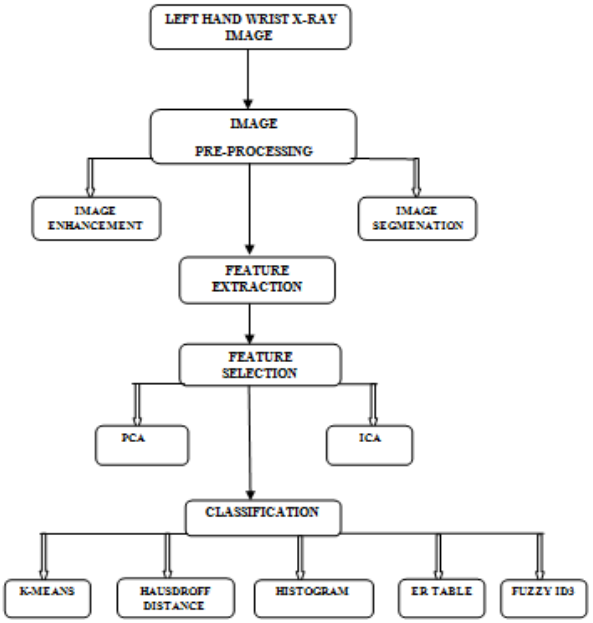

Figure 6: Various techniques for classification and feature selection

3.1 Image Pre-processing

Pre-processing is the initial step in any work. Image pre-processing is used to remove hand borders, eliminate unwanted noise using filters, and also removes non uniformity variations in background images. It can be performed in two steps

- Image Enhancement
- Segmentation

3.2 Feature Extraction

Once the radiographic image is pre-processed, features are extracted from the pre-processed image, which extracts 42 features from carpal features and phalangeal features. This process performed in the way to reduce the dimensionality of data.

3.3 Feature Analysis and Selection

Features are analyzed from the feature extraction process and 7 efficient features are selected for the bone age assessment methods. Principal component analysis (PCA) algorithm and independent component analysis (ICA) algorithm are used to select the features efficiently.

3.4 Classification

Classification algorithm used to classify the bone age according to the age group. Various techniques are used for classification such as K-means classifier, Hausdroff Distance classifier, histogram based classifier, ER table classifier, and Fuzzy Iterative Dichotomizer3 (ID3) decision tree classifier to identify the bone age from the selected features.

4. Result

The bone age of a person was identified by various BAA methods in which several feature selection methods and classification techniques were used. The performance accuracy may be varied from one exact technique to another technique. Different feature selection techniques that combine with the classification method provide better results. The Table 1 shows that the various accuracy levels of bone age assessment classification methods.

Table 1: Accuracy of various methods for BAA

S.No	BAA TYPES	PROCESSING AND CLASSIFICATION	SKILL
1	EMROI	Discrete wavelength transformation, ISEF edge detection and k-means classification	95%
2	Hausdroff distance	Difference of Gaussian(DOG) and Feature Vector Hausdroff distance Classification	91%
3	Histogram	Histogram conversion and extraction CBIR using Histogram matching	95%
4	Eklof & Ringertz (ER3 and ER5)	Ossification centre making ER table Classification	92.5% & 94.3%

5	Tanner & White house (TW3)	Feature Extraction using ICA Fuzzy ID3 Classification	97%

5. Discussion

5.1 Issues on manual approaches for bone age assessment

- The bone age measurement is may vary from doctors to doctors and from observations to observations.
- Manual approaches are not time efficient.
- The chance of occurring errors in manual approaches such as laboratory tools and observations.
- Manual approaches will give an accurate bone age for dead human bones only.

5.2 Issues on hand wrist x-rays for bone age assessment

- The radiographic images are used to calculate the bone age for limited age group from day 1 to 18 years.
- The development and collection of atlas may differ from country to country.
- The accurate bone age doesn't obtain from the cracked bones, joint fingers, and hand with less number of fingers.
- The bone age is varying for male and female.
- Left hand x-ray only used to find bone age of a child.

The bone age was estimated using various approaches such as EMROI, which produce 95% accuracy **[3],** Hausdorff distance approach gives 91% accuracy **[6],** Histogram matching technique give the accuracy as 95% **[2],** Eklof and Ringerz methods such as ER3 and ER5 produces 92.5% and 94.3% **[4]** and Tanner and Whitehouse (TW3) method gives 97% as the bone age assessment accuracy **[9].** The Chart 1 shows that the performance accuracy based on the BAA techniques.

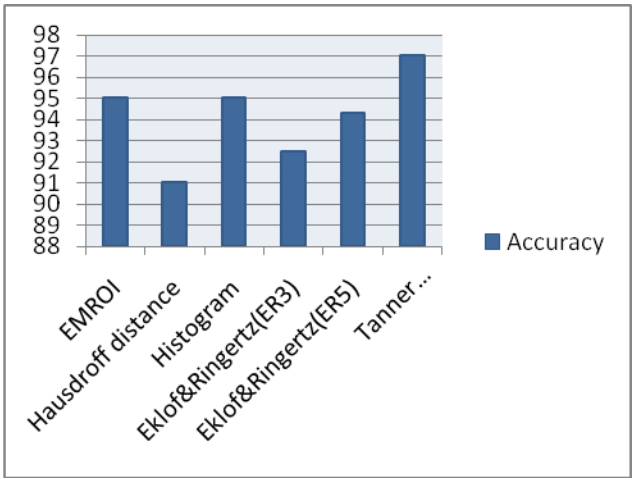

Chart 1: Performance analysis

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6. Conclusion

This paper discussed about various methods for estimating skeletal maturity of a human bones. The BAA systems are widely used in medical field to estimating the growth rate of a children and finding the growth disorders, endocrine disorders and hormone problems. This study will helps to find the efficient bone age assessment methods. Different implementation methods were discussed to evaluate the bone age such as image pre-processing, image enhancement, segmentation, ossification center making, feature extraction, feature selection and classification.

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