Feature Analysis with Bone Age Assessment based on Phalangeal and RUS Bones

Mohamed Uvaze Ahamed .A (*Author*)
Assistant Professor, Department of IT
Sri Ramakrishna Engineering College
Coimbatore, Tamilnadu, India.
Email: mohamed.ayoobkhan@srec.ac.in

S.S.Sugantha Mallika
Assistant Professor, Department of IT
Sri Ramakrishna Engineering College
Coimbatore, Tamilnadu, India.

S.Jansi Rani
Assistant Professor, Department of IT
Sri Ramakrishna Engineering College
Coimbatore, Tamilnadu, India.

B.Aravind
UG Scholar, Department of IT
Sri Ramakrishna Engineering College
Coimbatore, Tamilnadu, India.

Abstract— **Skeletal age assessment is a common and time-consuming task in pediatric radiology. There are different feature selections in a bone age assessment (BAA) system for various stages of skeletal development. For example, diameters of epiphysis and metaphysic are used as sensitive factors during the early stage. Once the epiphyseal fusion has started, an additional feature such as the degree of fusion is extracted at the later stage. Image analysis is a critical point for feature selections to get a fine BAA, which includes ROI processing and feature extraction. Radius (R) and Ulna (U) bones are also considered for bone age calculation or assessment using Neural Network (NN). This system includes two parts. The first part gathers the features from the middle fingers Epiphysis / Metaphysis of Phalangeal region, which satisfy feature development of epiphysis and metaphysis. The second part gathers information from the Radius / Ulna bones by splitting-up ROI into quadrants and calculating the length of the bone in each quadrant. Experimental results reveal that the presented NN system provides a very good ability to assign a hand radiograph to an appropriate bone age. Furthermore, the related feature analysis for various stages is discussed to provide an accurate quantitative evaluation of specific features for the final BAA.**

Keywords **- Phalangeal and radius/ulna bones, epiphysis and metaphysic, bone age, quadrants.**

I. INTRODUCTION

Bone age is a way of describing the degree of maturation of child's bones. As a person grows from fetal life through childhood, puberty, and finishes growth as a young adult, the bones of the skeleton change in size and shape. These changes can be seen by x-ray. The "bone age" of a child is the average age at which children reach this stage of bone maturation.

A child's current height and bone age can be used to predict adult height. At birth, only the metaphyses of the "long bones" are present. The long bones are those that grow primarily by elongation at an epiphysis at one end of the growing bone. The long bones include the femurs, tibias, and fibulas of the lower limb, the humeri, radius and ulnas of the upper limb (arm + forearm), the phalanges of the fingers and toes. The long bones of the leg comprise nearly half of adult height. The other primary skeletal component of height is the spine and skull.

As a child grows the epiphyses become calcified and appear on the x-rays, as do the carpal and tarsal bones of the hands and feet, separated on the x-rays by a layer of invisible cartilage where most of the growth is occurring. As sex steroid levels rise during puberty, bone maturation accelerates. As growth nears conclusion and attainment of adult height, bones begin to approach the size and shape of adult bones. The remaining cartilaginous portions of the epiphyses become thinner. As these cartilaginous zones become obliterated, the epiphyses are said to be "closed" and no further lengthening of the bones will occur. A small amount of spinal growth concludes an adolescent's growth.

Pediatric endocrinologists are the physicians who most commonly order and interpret bone age x-rays and evaluate children for advanced or delayed growth and physical development. Bone age assessment is a procedure frequently performed in pediatric radiology. Based on a radiological examination of skeletal development of the left-hand wrist, bone age is assessed and then compared with the chronological age.

A discrepancy between these two values indicates abnormalities in skeletal development. The procedure is often used in the management and diagnosis of endocrine disorders and it can also serve as an indication of the therapeutic effect of treatment. Generally, it can indicate whether the growth of a patient is accelerating or decreasing. In many cases the decision whether to treat a patient with growth hormones depends on the outcome of this test. Another relevant application is in the social field. In fact, a considerable percentage of asylum seekers that come to European countries claim to be a minor to increase their chance to obtain a residence permit. Since these people usually don't have identity papers, determination of the skeletal maturity can help in the determination of the true age of such a person.

Skeletal maturation estimation or bone age assessment (BAA) of children is a common procedure performed in pediatrics. Its object is to determine the skeletal maturation through a detailed examination of left-hand-wrist radiograph, which includes all relevant regions of interest (ROI).

An incongruity between the bone age (developmental age of bones) and the chronological age (actual age at inspection time) indicates abnormalities in the skeletal development. This procedure is used in evaluating the growth disorder [1,2], monitoring the hormone therapy, and predicting adult height [3,4].

Generally, the system involves an image analysis the radius, ulna bones and epiphysis of tubular bones including distal, middle, and proximal phalanges based on Greulich and Pyle [5,6] and Tanner and Whitehouse (TW2, TW3) [3,4] methods. Following a classical learning scheme, these methods utilize automatic analysis of epiphyseal/metaphyseal regions of interest (EMROI) in a hand radiograph by first extracting a set of quantitative features sensitive to skeletal development and then creating a classifier according to these features. Once the mature size is reached, both epiphysis and metaphysis start to fuse from the middle and expand toward the edges.

D.B. Darling, 1979, [1] Analysis skeletal development of the left-hand wrist, bone age is assessed and then compared with the chronological age.

Pietka E et al., 1991, [18] proposed a computer assisted Bone Age assessment method using phalanx lengths, atlas lengths, and atlas matching under some restrictions of the quality of hand radiographs.

D.G. King, 1994, [5] involves an image analysis of the ossification degree for carpal bones and epiphysis of tubular bones including distal, middle, and proximal phalanges.

Mahmoodi S et al., 1997, [19] constructed the automatic region of interest locating algorithm by computer vision technique. The survey is based on multi-scale method, roughly finding the contour of hand then identifying the contour of the fingers by analyzing the geometry of finger.K.S. Pospiech, 2000, [10] for the early stage of development, regions of interest are subjected to an image segmentation procedure, which separates the epiphysis from the metaphysic and so wavelet analysis is used when the epiphyseal fusion starts.

J.M. Tanner, 2001, [3] skeletal maturity is monitored on the basis of the hormone therapy, and predicting adult height, which in turn predict the bone age.

Eklof.O and Ringertz.H, 2001, [25] proposed a method which included for the evaluation of the age, the processing of the EMROIs, of the Ulna and of some carpal bones. D. Giordano, 2007, [11] proposed a method used three shape factors to compute the development stage of each bone for child between 1 and 12 years old.

II. PROPOSED SYSTEM OVERVIEW

The assessment of skeletal age maturity is a commonly used procedure in pediatric radiology. A discrepancy between bone maturity and biological age indicates the presence of some abnormality in skeletal growth. The assessment is commonly performed using a radiogram of the left hand, due to the relatively small patient exposure and the high degree of simplicity of the test. Moreover, the hand presents a large number of ossification centers which can he used to obtain an accurate estimation of the degree of maturity.

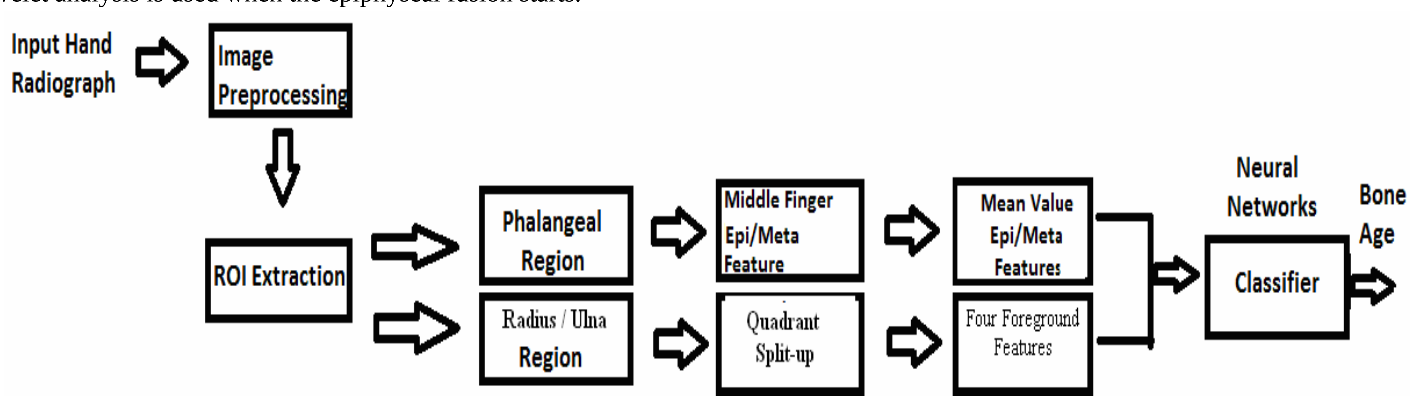

Figure 1. Block diagram of the system

The block diagram describes that the system composed of a user interface for input hand radiograph image acquisition, followed by a image preprocessing strategies and a localization method, which correctly positions the ROI for further processing, which extracts a set of suitable features from each ROI, and a neural classifiers which observed the bone complex and assign suitable bone-age as it was trained during its training phase.

A. User Interface

The user interface includes an acquisition module and a hand identification module. The acquisition module is used to control an optical scanner and to acquire the image with the selected resolution and pixel depth, allowing the user to check the image quality. When the image has been acquired, the user is requested to indicate the center of the bone complexes which the TW2 method uses to perform the classification.

B. Preprocessing

A preprocessing step has been introduced to remove background noise and to enhance structural features. Due to the large differences in size and shape of the bone complexes, different filtering strategy for each type of the bones are applied. Phalangeal epiphysal bones having a small dimension and a very elongated structure have been analyzed using a directional filtering.

On the other side, Radius / Ulna bones, having a larger size and similar axes, have been processed using a set of isotropic filters based on a Difference of Gaussian (DOG) operator. In order to avoid border effects, preprocessing filter is applied to the image after extraction of the ROI.

C. Segmentation

Segmentation is done with the reference to the axis representation of the resized radiograph of the given image. Phalangeal region are segmented from the image by the axis representation and the texture features are analyzed. Similarly the Radius / Ulna regions are segmented with the axis representation of 1000:1300.

D. Stage and Feature Analysis

Based on the Tanner and Whitehouse (TW2, TW3) [3, 4] methods, the feature development of epiphysis and metaphysis could be applied to feature analysis for BAA. According to most previously proposed schemes [7–14], the related EMROI processing techniques are various depending on the characteristics of different stages of bone maturity, which usually are taken as a priori knowledge. These ROI processing methods such as segmentation and wavelet decomposition are applied to early and later stages, respectively.

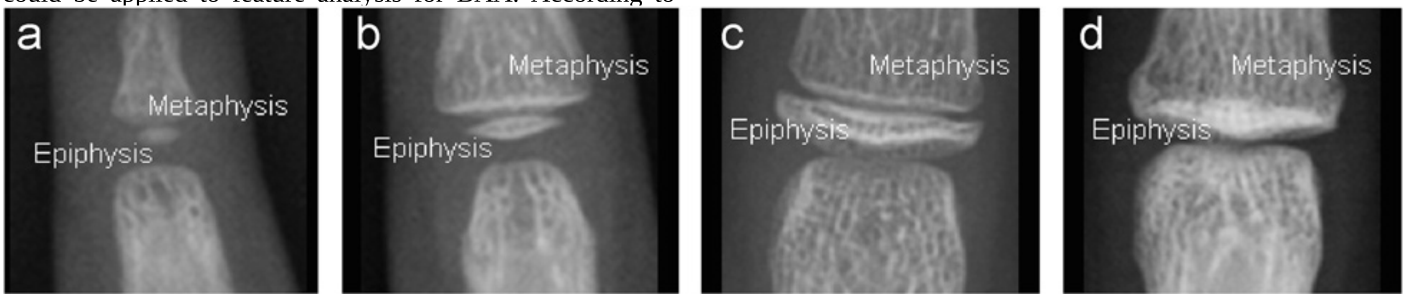

Figure 2. (a–d) Epiphyseal/metaphyseal ROI at various stages of skeletal development

III. METHODS

Neural Network classifiers has been used to classify each bone complex into one of the maturation categories. Therefore, the Neural Networks output falls in one for each complex considered in the TW2 method. In all cases feed-forward architecture is adopted and trained with the error back-propagation rule. The input of the classifier is composed of features extracted from the preprocessed ROIs of both Phalengeal and Radius / Ulna bones.

A. Phalangeal Image Segmentation

The bone tissue regions of Epiphyseal / metaphyseal in an EMROI could be obtained using the modified adaptive 2-means clustering method proposed in [15–17] for separating epiphysis and metaphysic from the soft tissue.

The segmented results show that diameters of epiphysis and metaphysis change with different developmental bone age. In a BAA system, diameters of epiphyseal / metaphyseal area sensitive characteristic at different stage of skeletal development. Thus the diameters extracted from phalangeal image segmentation issued as an important feature for presented bone age assessment system.

The image is loaded from the database and the region of interest is obtained from the entire hand image. The three phalangeal EMROI of the image is shown in Figure 3.

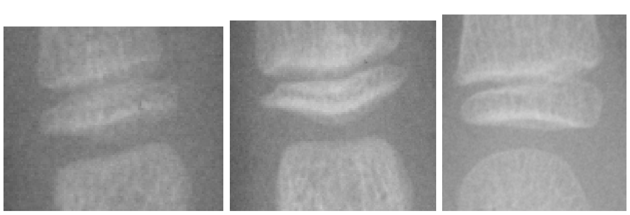

Figure 3 : Three region of Epiphysis and Metaphysis in Phalangeal region

Centroid technique (i.e figure 5) is used to obtain the mid point of the image and with that mid point, features are analyzed as follows with region of interest as specified in Figure 3.

B. Feature Analysis

The diameter is an important feature for bone age assignment. From the observation of the segmented results, the ratio (RD) between diameters of metaphysic and epiphysis can be defined as a feature, which is sufficient for the bone age and given as follows:

$$RD = Dia(epiphysis) / Dia(metaphysis)$$

Where Dia() denotes the length of the diameter of a specific bone. There are three EMROIs extracted from the middle finger of the hand radiograph by using the centroid formula, that is, three RD values are employed as the features. The RD values are overlapped over bone ages.

The reason for it is that a bone age is assigned to a hand radiograph, not a single EMROI. Thus different bone ages may be mapped into the same RD value for specific EMROIs.

The (spatial) spectral properties of the preprocessed images allow us to decimate the ROI samples, reducing the dimension of the input patterns and improving the generalization capability of the classifier. The output of each classifier is composed of eight to nine output units, each of them corresponding to one of the maturation classes. As the classification performed by the radiologist is the result of a discretization of a continuous growth process.

A degree of fuzziness is introduced in the teaching input of the network, letting the desired output of the correct class equal to 0.95, and the desired output for the two neighboring units equal to 0.25. Other units have a desired output equal to 0.05. In output, each bone is assigned to the class corresponding to the most active output unit.

C. Radius and Ulna Bones

The first step in Radius / Ulna analysis is the extraction of the Radius / Ulna bones from the entire hand, performed by a suitable application. First the image is preprocessed. For background separation, the image works only over the background pixels, i.e., those pixels satisfying some conditions is obtained.

The bone borders that covers Radius / Ulna bone is analyze, then Radius / Ulna ROI is identified and it is cropped automatically. The cropped image is resized into a standard size as shown in Figure 4.

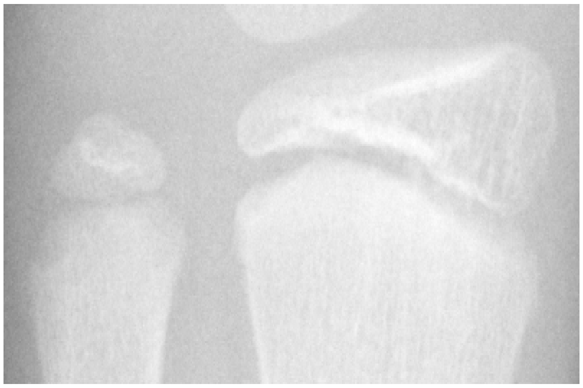

Figure 4. Extracted Radius / Ulna ROI

Radius and Ulna bones have been preprocessed using a DOG filter. The preprocessed image is separated in a quadrant manner with the specification of foreground values of the Ulna and its Epiphysis similarly Radius and its Epiphysis. The ROI region is divided into quadrant with specification towards the centroid of the rectangle.

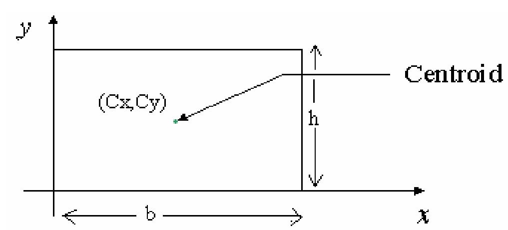

Figure 5: Centroid Calculation

$$Cx = h/2, \quad Cy = b/2$$

Centroid of the given rectangle = (Cx,Cy)

Where,

b is the breath of the rectangle,
h is the height of the rectangle and
Cx & Cy forms centroid of the rectangle.

As a combination in the Radius / Ulna region, about four features are extracted and in addition to that mean diameter of Epiphysis and Metaphysis feature from the Phalangeal region, as a total of five geometric features are feed as the input to the classfier.

D. *Age Assessment*

Neural Networks is used as a classifier in this project and so two separate networks are created, one for analyzing male radiograph and another for analyzing female radiograph. The features obtained in the previous module is given as the input to the Neural Network in the training phase along with the hidden neurons and then the trained network is tested with the testing radiograph and the calculated bone age is displayed.

IV. RESULTS

The table below shows the values measured from the selected features of both the phalangeal and the Radius and Ulna bone regions. This value gives the ratio between diameter of epiphysis and metaphysis between 1-16 age group.

Table 1(a,b,c): The ratio between diameter of epiphysis and metaphysis

AGE / SEX	1	2	3	4	5	6
MALE	0.4890	0.5109	0.5485	0.5739	0.5936	0.6216
FEMALE	0.4618	0.5015	0.5309	0.5615	0.5889	0.6133

(a)

AGE / SEX	7	8	9	10	11
MALE	0.6482	0.6867	0.7123	0.7799	0.8256
FEMALE	0.6310	0.6631	0.7351	0.7625	0.8006

(b)

AGE / SEX	12	13	14	15	16
MALE	0.8778	0.9506	0.9825	1.0143	1.2105
FEMALE	0.8632	0.9263	0.9590	0.9702	0.9868

(c)

The ratio value in the above table was entirely measured by our system with more accuracy rate and zero rejection rate. From the table it is understand that if the persons age is considered to be 11, then for male, his ratio between diameter of epiphysis and metaphysis should lie in the region related to 0.8256 and similarly for female of same age group should have 0.8006. This data is regard with the phalangeal region alone. The values of the RUS region are as follows.

Table 2(a,b): Feature set of Radius / Ulna Bones

Features / Age Group	F1	F2
1	42198	47230
2	47026	47665
3	31030	26174
4	27031	20494
5	25189	20764
6	39143	37147
7	34194	33172
8	52175	48167
9	43957	38954
10	39584	34352
11	32252	27466
12	28573	27116
13	41192	33881
14	45105	44417
15	38507	30629
16	33369	26390

(a)

Features / Age Group	F3	F4
1	11183	969
2	29377	8002
3	33763	15979
4	39336	17327
5	37210	20173
6	27567	21205
7	31032	22684
8	35114	23614
9	41717	23982
10	37026	24675
11	34382	24976
12	40715	25467
13	39245	25728
14	39304	26562
15	45134	27905
16	47625	29959

(b)

The above table gives feature set of radius and Ulna bones. Where,

F1 denotes length value of Radius bone
F2 denotes length value of Ulna bone
F3 denotes length value of Radius Epiphysis
F4 denotes length value of Ulna Epiphysis

Here from the table it is understand that if the persons age is considered to be 11, then the persons F1, F2, F3 and F4 features of RUS bones should resemble the nearby value to the given value, if the persons bone growth is normal else otherwise proper nutrition should be supplied with pediatricians advice. Finally both the values from the phalangeal and RUS region are sum up to get the overall senario.

V. CONCLUSION AND FUTURE WORK

The system extracted the geometric information from the input hand radiograph, especially the Phalangeal and Radius / Ulna region of interest. The method has been developed and tested using a dataset composed of 180 radiograph, in which the training set consist of 16 male radiograph and 16 female radiograph images of [0-15] age group children and if the training dataset has been extends with its capacity, then the accuracy of the system is also high with very minimum in the error rate in the age assessment. Images of the training set have been used to train the neural classifiers. Afterwards, the system has been tested on the remaining images. At first, the performance of each bone classifier is tested. The average difference between the two values is equal to 0.05 years, with a maximum error equal to l.4 years, and a standard deviation of 0.7 years. Some future works will be carried out and illustrated as follows. First, although medical studies [15] point out that, the analysis in carpal bones does not provide accurate and significant information after 9–12years of age, it still can be considered for bone age assessment. Then, a friendly graphic user interface system should be further developed to integrate the proposed BAA system for clinical use. Finally, the fundamental medical supports of further research could exactly provide children with early diagnosis and effective monitoring of therapies in clinical practice.

VI. REFERENCES

[1] D.B. Darling, (1979) "Radiography of Infants and Children," 1st ed., Charles C Thomas, Springfield, IL, pp. 079-088.

2] D.R. Kirks, (1984) "Practical Pediatric Imaging. Diagnostic Radiology of Infants and Children," 1st ed., Little, Brown & Co, Boston, MA, pp. 154-166.

[3] J.M. Tanner, M.J.R. Healy, H. Goldstein, N. Cameron, (2001) "Assessment of Skeletal Maturity and Prediction of Adult Height (TW3 method)," WB Saunders, London, pp. 426-433.

[4] J.M. Tanner, R.H. Whitehouse, (1975) "Assessment of Skeletal Maturity and Prediction of Adult Height (TW2 Method)," Academic Press, London,pp. 221-240.

[5] D.G. King, D.M. Steventon, M.P. O'Sullivan, A.M. Cook, V.P. Hornsby, I.G. Jefferson, (1994) "Reproducibility of bone ages when performed by radiology registrars: an audit of Tanner and Whitehouse II versus Greulich and Pyle methods," Br. J. Radiol. 67 pp. 848–851.

[6] W.W. Greulich, S.I. Pyl, (1971) "Radiographic Atlas of Skeletal Development of Hand Wrist," 2 nd ed., Standford University Press, Stanford, CA, pp. 023-029.

[7] C.W. Hsieh, T.L. Jong, C.M. Tiu, (2003), "The phalangeal morphological characteristics for bone age recognition," Proceedings of the 13th IEEE-NPSS Real Time Conference, Montreal, Canada, pp. 452-456.

[8] C.H. Chang, C.W. Hsieh, T.L. Jong, C.M. Tiu, (2003) "A fully automatic computerized bone age assessment procedure based on phalange

ossification analysis," Proceedings of the 16th IPPR Conference on CVGIP, Kinmen, pp. 463–468.

[9] S. Aja-Fernandez, R.D. Luis-Garcia, M.A. Martin-Fernandez, C. Alberola-Lopez, (2004) "A computational TW3 classifier for skeletal maturity assessment: a computing with words approach," J. Biomed. Inform. 37 (2) pp. 99–107.

[10] K.S. Pospiech, A. Gertych, E. Pietka, F. Cao, H.K. Huang, (2000) "Wavelet decomposi- tion based features in description of epiphyseal fusion, analysis of biomedical signals and images," Proceedings of the 15th Euroconference Biosignal, Brno, pp. 246–248.

[11] D. Giordano, R. Leonardi, F. Maiorana, G. Scarciofalo, C. Spampinato, (2007) "Epiphysis and metaphysis extraction and classification by adaptive thresholding and DoG filtering for automated skeletal bone age analysis," Conference Proceedings of the IEEE Engineering in Medicine and Biology Society (United States), pp. 6552–6557.

[12] A. Gertych, E. Pietka, K.S. Pospiech, F. Cao, H.K. Huang, V. Gilzanz, (2004) "Computer- assisted bone age assessment: graphical user interface for image processing and comparison," J. Digit. Imaging 17 (3) pp. 175–188.

[13] B.J. Liu, E. Pietka, A. Gertych, (2007) "Segmentation of regions of interest and post- segmentation edge location improvement in computer-aided bone age assessment," Pattern Anal. Appl. 10 (2) 115–123.

[14] Sempe M, Pavia C.(1979), "Atlas de la maturation squelettique: ossification sequentielle du poignet et de la main,". Paris: SIMEP pp 354-365.

[15] Arkadiusz Gertych, Aifeng Zhang, James Sayre, Sylwia Pospiech-Kurkowska and Huang,H.K. (2001) "Bone age assessment of children using a digital hand atlas," Computerized Medical Imaging and Graphics vol.31, pp.322–331.

[16] Tanner J.M, Whitehouse R.H, Marshall W.A, (1983) "Assessment of skeletal maturity and prediction of adult height (TW2 Method),"2nd ed., Academic Press pp. 127- 132.

[17] Ewa Pietka, Michael,F. McNitt-Gray, M. Kuo,L. and Huang, H. K. (1991) "Computer- Assisted Phalangeal Analysis in Skeletal Age Assessment," IEEE Trans on Med Img, vol.10,pp.4-9.

[18] Mahmoodi.S, Sharif.B.S, Chester.E.G, Owen.J.P, Lee.R.E.J (1997), "Automated vision system for skeletal age assessment using knowledge techniques," Proc. of the IEEE Sixth International Conference on Image Processing and Its Applications, vol 2, pp. 809–813.

[19] Ewa Pietka, Gertych.A, Pospiech.S, Cao.F, Huang H.K, Gilsanz (2001).V, "Computer-assisted bone age assessment: Image preprocessing and epiphyseal/metaphyseal ROI extraction," IEEE Trans. on Medical Imaging, vol. 20(8), pp. 715–729.

[20]Giordano.D, Leonardi.R, Scarciofalo.G, Spampinato.C (2007), "Epiphysis and Metaphysis Extraction and Classification by Adaptive Thresholding and DoG Filtering for Automated Skeletal Bone Age Analysis," Proc of the 29th Annual International on Engineering in Medicine and Biology Society, pp. 22-26, Lyon – France.

[21]Giordano,D. Spampinato,C. Scarciofalo,G. Leonardi,R. (2009) "Automatic Skeletal Bone Age Assessment by Integrating EMROI and CROI Processing," IEEE trans, vol 9, pp.809-813.

[22] Giordano,D. Spampinato,C. Scarciofalo,G. Leonardi,R. (2010), "An Automatic System for Skeletal Bone Age Assessment by Robust Processing of Carpal and Epiphysial/ metaphysial Bone," IEEE transactions on Instrumentation and Measurement, vol 59, pp.2539-2553.

[23] O. Eklof, H. Ringertz (2001), "A method for assessment of skeletal maturity," Ann Radiology, vol. 10, pp.330.

[24] E. Pietka, A. Gertych, S. Pospiech, F. Cao, H. K. Huang, V. Gilsanz(2001),"Computer-assisted bone age assessment: Image preprocessing and epiphyseal/metaphyseal ROI extraction," IEEE Trans. on Medical Imaging, vol. 20(8), pp. 715–729.

[25] Hsiu-Hsia Lin, San-Ging Shu, Yueh-Huang Lin, Shyr-Shen Yu (2012), "Bone age cluster assessment and feature clustering analysis based on phalangeal image rough segmentation," Elsevier journal on Pattern Recognition 45 (2012), pp. 322–332.

AUTHORS PROFILE

Mohamed Uvaze Ahamed. A received B.E. Degree in Computer Science and Engineering from Francis Xavier Engineering College, Tirunelveli and received my M.E. Degree in Computer Science and Engineering from Sri ramakrishna Engineering College, Coimbatore. Presently working as Assistant Professor in the Department of Information Technology at Sri Ramakrishna Engineering College, Coimbatore. Area of interest is Image Processing and Cloud Computing.

S.S.Sugantha Mallika received her B.E. Degree in Information Technology from Raja College of Engineering and Technology, Madurai. She has received her M.E. Degree in Computer Science and Engineering from Anna University of Technology, Coimbatore. She is presently working as Assistant Professor in the Department of Information Technology at Sri Ramakrishna Engineering College, Coimbatore. Her area of interest is Image Processing.

S.Jansi Rani received her B.E. Degree in Information Technology from Avinashilingam University for Women, Coimbatore. She has received her M.E. Degree in Computer Science and Engineering from Kumaraguru College of Technology, Coimbatore. She is presently working as Assistant Professor in the Department of Information Technology at Sri Ramakrishna Engineering College, Coimbatore. Her area of interest is Data Mining.

B. Aravind currently studing his B.Tech Information Technology in Sri Ramakrishna Engineering College, Coimbatore. His area of interest is image processing.