Analysis of the Age and Gender Detection Methods Using Forensic Anthropology on Hand Bones Datasets

[1]Shakiv Pandit, [2]Dr. Sumit Kaur

Department of CSE,
CEC, Chandigarh Group of Colleges, Landran (Punjab)

Abstract: Bone age assessment is the scientific approach that utilised in recognising of age assessment of children and youths. The growth of bone age is affected by the number of features like as nourishment level, hormone growth rate, genes and so forth. Bone age assessment is mainly depending on the maturity of the skeleton bone age. Presently, skeleton bone age reliant on two methods which are Greulich and Pyle method, other is Tanner and Whitehouse method. Greulich and Pyle's method is a simpler method and that is used by the radiologists. On the other hand, Tanner Whitehouse method is consistent as compared to GP technique. An automatic bone age assessment has been used by many medical experts through various methods such as x-ray, ultrasound, Magnetic Resonance Imaging. In this paper, Forensic Anthropology is utilised to examine the skeleton bone age assessment. Forensic Anthropology includes Radiograph and Ultrasonography Method. Hence, the radiograph method comprises of Greulich-Pyle Method and Tanner Whitehouse Method. Ultrasonography is of two types which are atlas and scoring method. However, the Forensic Anthropology technique is explained in detail. In addition, applications of bone age are also described in this research.

Keywords: Forensic Anthropology, Greulich- Pyle method, Ultrasonography, Tanner Whitehouse.

I. INTRODUCTION

BAA is the method which is performed in paediatric patients for the evaluation of the growth and diagnosis of the endocrine disorder and the paediatric syndromes. The skeleton growth of the hand and wrist the bone can be evaluated utilising the Greulich and Pyle atlas. With the advancement in the digital image, the morphological characteristics of ossification in hand bones extracted using pre-processing methods. The automatic evaluation of the bone age based on the shape, size recognised in the large number of the ossification based on hand and wrists. The skeleton bone maturity is measuring the development of the shape; size and the degree of the maturation of the bone. The multiple factors involved in the development of the bones in different processes. The long bones are extracted in the endochondral ossification process. The primary ossification centre of the bones is done in flat pelvic bones, scapulae.

The non-efficiency analyses at the maturity age in youngsters, hence the maturation of the skeletons are used as signage for growth problems. The X-ray picture of the left hand, hand wrist is used because it is a trustable index of bone skeletal maturation and nevertheless can be used to indicate the organic development of the bones based on ossification regions and calcium deposits in the ossification area. The endocrine disorders, chromosomal disorders and early sexual maturity can be identified using the differences among the calculated skeletal bone age and organic age in children [1].

1.1 Background of Bone Age

The skeleton bone age assessment with the clinical methods is Greulich & Pyle (GP) technique, Tanner & Whitehouse (TW) technique. The matching technique is the GP method and score assigning method is Tanner white house method. The comparison is done between the two methods and it was recognised that Tanner White house is the more accurate and the advanced method [2]. The left-hand wrist radiograph is linked with an arrangement of radiograph and then assembled in accordance with the bone age and gender in the atlas. The images are selected from the atlas pattern. In Tanner Whitehouse method, the individual age is analysed and then classified at the development stage [3]. The bone age defines in the score and the sum of the scores used to assess the bone age. Tanner Whitehouse provides high complexity with the more consistent and automotive results. Tanner Whitehouse 2 is the advanced version of the Tanner Whitehouse 1. The TW2 method combines the score of every stage to discriminate between the genders. The region of Interest located in the main bone in the TW2 method use to evaluate the bone age. The Region of Interest at each time described in three phases which are Epiphysis, Metaphysis and Diaphysis. The Region of Interest is used to identify the diverse ossification centres in the phalanx proximity. Each ROI are described in different stages in which every stage given by alphabetical letter (A, B, C, D..., I) that imitate the development stage. Fig 1 described that the different development stages and bone density are determined from stage A to stage I. In stage A it is absent, in stage B- deposit of the calcium, stage C-centre with the different form, stage D- the width is the half or height of the width of metaphysic, stage E- edge of the epiphysis is concave, stage F-– epiphysis and metaphysic is wider, stage G- epiphysis covers the metaphysic, stage H-combine process of the epiphysis and metaphysis features, stage I-completion of the epiphyseal fusion. Maturity scores are obtained using the mean of ROI. Scores are related to the age of bones of the males and the females [4].
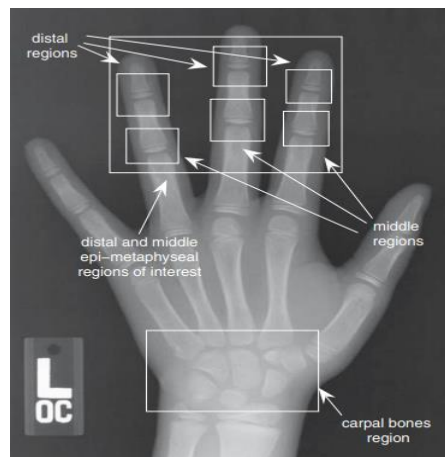
Figure 1. Left-hand bone wrist image with the region of interest [23]

1.2 Applications of Bone Age

The most popular and popular applications in real-world applications are concerned to identify the age of an individual [5].

*i) Age-specific Computer Interaction for security Control:-*The age is a key approach for human-computer communication. Internet access is necessary for the prediction of age through computer vision. For instance, denying the underage individuals to access the adult age social websites that cover the inappropriate material or the restricted movies, avoidance of the minors from purchasing the tobacco yields from the retailing machines.

ii) Monitoring of Surveillance: - Monitoring cameras for the approximation of the below age drinkers warn s or stop from entering the bars. For instance, in Japan, maximum money transfer frauds in automated transaction machine are convoluted in the specific age determined by the police department.

iii) Electronic Customer Relationship Management: - It is the method for the management of the relation between the customers and communication between persons. The main issue is to recognise the personal information of all the clients so computer-based automatic machine for the age estimation is used to estimate the age of persons.

iv) Biometrics: - The identity and assessed age of an individual can be identified using the biometric method. The multimodal biometrics like as face, fingerprint, eyes, hand bone geometrical features is used for enhancing the presentation of the biometric scheme. The face can be recognised after a gap of the several years using biometric technology. For instance, border security and passport renewal demonstrate the significance of the age synthesis.

v) Monitoring treatment of the growth hormones: - The issue in growth disorder is due to growth hormones is treated using synthetic growth hormones. The treatment of the growth hormone is of very high cost and some companies have different facts for monitoring and controlling of growth hormones. The expensive cost is the main approach to finding a new treatment for this method. The different nations have different criteria for that are relevant to bone age assessment and in treatment optimization of the growth hormones. The different physicians use the bone age for deciding the time limit of the treatment. The bone maturity depends on the bone growth hormones. For instance, the department of the health and the ageing used to control the growth hormones for bone age assessment annually. To continue the diagnosis of a person must have 50% growth rapidity in hand bone age or the synthetics hormone rate increase after 6 months [6].

*vi) Treatment of growth illness: -*The development disorder in the children may be due to hormone or non-hormone issues. The non-hormone is because of the sickness of the genes, kidney disease, and undernourishment. On the other hand, hormone change is gender disorder or the change in the thyroid hormones and issue related to diabetes disease. The different tests can be done but the growth hormones are difficult to detect.The deficiency of the growth hormones has the main effect on the hand bone and skeleton development. Mainly, growth disorder in the children may be examined through the height, weight and scientific assessment of bone age. BAA can be a pointer of the disagreement among bone development and maturation of skeletal bone. The research institute of the growth hormones examined the bone age of the children by a professional but the mean error in the bone age is acceptable [7].

II. RELATED WORKS

(Bian, Z. and Zhang, R.., 2018) [8] Proposed research on the convolutional neural network which is based on the deep learning method. The x-ray film of the hand is extracted to identify the bone age. The 301 cases of X-ray films of hand were applied to improve the Google net convolutional neural network. In this research, the data set is expanded by 30 times using the augmentation method [8]. The accurateness of the investigation can be identified using in bone age assessment. The automated age assessment is done using the two-stage neural network. (**Chu, M and Liu, B et al., 2018) [9]** Studied on the clinical practice of the diagnosis of the maturity of children in skeleton bone age assessment. They proposed an automatic bone age assessment method using deep convolution network. The technique based on the two phases which are the mask generation and the age assessment network. The mask of the bones is extracted using U-net convolutional neural network. The images are fused using differentiated hand bone image [9]. Accurate BAA can be built using multiple convolutional neural networks. The paediatric bone age data set can be tested using the classified method of the bone age assessment. In this research, mean absolute error outperforms in bone age assessment.

(**Chen, C. Y., and Hwang et al., 2014**) **[1**0] Proposed research on BAA by utilising hand knuckle radiogram. The main goal of the research is to determine the bone age of children on the basis of radiogram of epiphyseal/metaphyseal ROI(ROIs). Firstly, 9 EMROI from the index finger, ring finger, middle finger are analysed for the extraction of the geometrical features. In addition, knowledge nearest neighbour classification in the binary decision tree was used to determine the bone age. In the classification method, the method was measured to identify the bone age [10]. Firstly, the features from the 9 knuckles were combined and then the classification process was done. The other method was to analyse the 9 knuckles of a person for producing the 9 bone age output. The results evaluated the 60% accuracy in one year error and 80% in two-year error rate for the algorithm and then about 65% in 1-year error rate and 80% in 2-year error rate using a proposed algorithm, individually. (**Souza, D. and Oliveira, M. M et al., 2018**) **[11]** Presented an algorithm for the approximation of hand bone age from medical radiographs. An efficient result for 200 medicinal radiographs was prepared by Radiological Culture of North America (NA). They represented an automotive approach on the bone age assessment using a convolutional neural network. In this research, a data set contains 12500 radiographs using paediatric method for bone age assessment by the Radiological Society of North America [11]. The greatest resolution is predictable by the qualified medicinal radiologist and relates information group that need minimum time. The main approach provides the free international service that is related to the medicinal doctors in sensed areas without bone age assessment professionals. **Agrawal, A. and Patil, U et al., 2011**) **[12]** explained an automatic technique for the removal of the epiphysis in the bone. Division of the epiphysis and metaphysis is completed in the accompanying advances: pre-handling for force alterations, hand introduction redress, finger arrangement, and extraction of fingers, extraction of phalanges, and extraction of the epiphysis from the phalanges. The calculation has been approved on a computerized digital; atlas information with close 95% precision and the disappointment methods are the identification of non-appearance of the epiphysis. Catchphrases: division, skeletal development, hand bone-age [12].

III. TECHNIQUES IN FORENSIC ANTHROPOLOGY

Forensic Anthropology is the method that is used to solve the issue of medicinal permissible significance and have applications in physical anthropology. The main goal of this method is to investigate the human skeletal remains for the law enforcement departments to recover human remains and also to recognise the unidentified human remains and valuation of the death since the death rate happens. Another goal of the forensic anthropology is done through anthropologist related to principles, linguistic approach, and bodily remains of the social individuals. Forensic anthropology is the bone microarchitecture for solving medical forensic problems.

A.   DETERMINE BONE AGE USING FORENSIC ANTHROPOLOGY

The different bone age of the child is skeleton age and the chronological bone age. The growth rate of a person varies and there is a difference in the development of the skeleton of the teenagers when reached a particular stage.Hence, the change in the skeleton growth is the same as the development of each bone when passes throughout the same stage. The chronological age and the skeleton age are compared to get the accurate degree of the maturation stage. The potential growth and the development of the children can be recognised through the skeleton age.

1. Radiograph Method:-In this method, non-uniform material can be viewed using the X-rays like a social body. The patient is located among an X-ray foundation and a thin film sensitive to X-ray power for the generation of the radiograph.The maturity of the bone skeleton to use the radiographs of the hands is the other application in medical radiology. The bone hand wrist with a high amount of ossification centre and can be medically radiographed with less exposure to the radiation. In this procedure, the lower degree of the radiation is neglected [13]. The three radiographs techniques are:-

*i) Tanner Whitehouse Method:-*The accessing of the skeleton maturity in radiology is used in the TW method. TW1 method was settled in 1962 and alsoTW2 is presented in 1975. The score of the TW1and TW2 is combined at the different standards of the male and the females. TW3 was established in 2002. The score is projected from age 10-11 years of age. The TW3 method is used to examine the 20 bones of the hand and wrist hand bone for each bone. Each bone is determined through the numerical score in Tanner Whitehouse tables. The maturity score of scale ranges from 0 to 1000. In this technique, x-rays of the hand bone and the wrist hand bones are associated population of the British children lived in the UK in 1950. The different stages are analysed using the contour of radius which is segmented automatically. Secondly, shape, texture and the size of the bones are extracted. In the final approach, lines are deducted by the selection of predictable characteristics. Therefore, the approximate score of the hand bone age can be detected. Tanner white-house utilises three differences that contain ulna, radius and short length bone. The figure describes the maturity of the bones based on the TW method that includes ulna, radius, carpal bone, metacarpal bone [14].

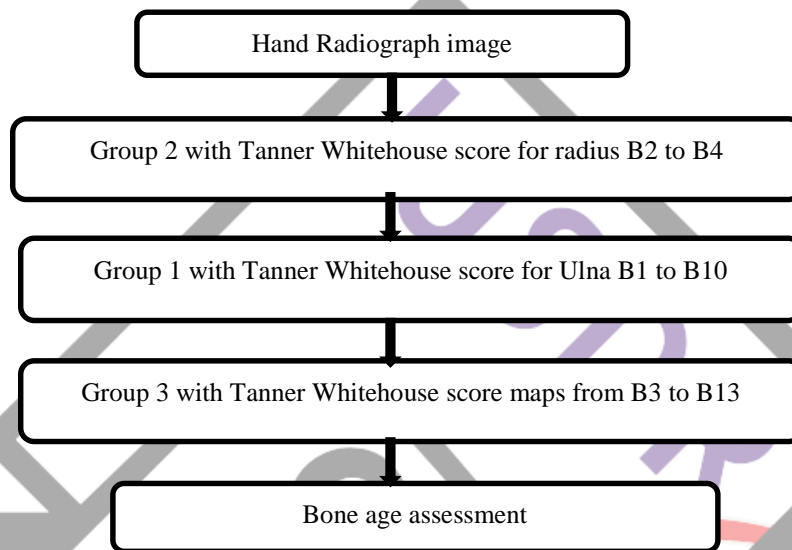Figure 2. Skeletal maturity growth points based on TW method

Figure 3. Bone Age Verification based on Tanner white house method Flow Chart

*ii) Greulich-Pyle Method:-*This method was established in 1959.The reference images of the female and male samples of the hand bone and wrist hand bones having age 18 years for female and 19 years for a male. The bone age is computed using left-hand wrist radiographs and that is matched with the reference radiographs in atlas having standard values for various ages. This method is used for the estimation of the skeleton age where Greulich and Pyle is an atlas for comparison of the left Hand-Wrist radiograph with the standard orientation. This was established in the 20th century through data of the North American children. This method is the most reliable method with the ethnic difference between the original sample (1000 topics in Ohio among the years of 1931 and 1942) and the analysed sample (535 Italian topics produced up during the period of 2000–2010) [15]. In this method, the 20 bones of the hand are compared and selected with the closest atlas radiograph. The growth method is perceived in the figure which is feature bones when carpal bones are illustrated.

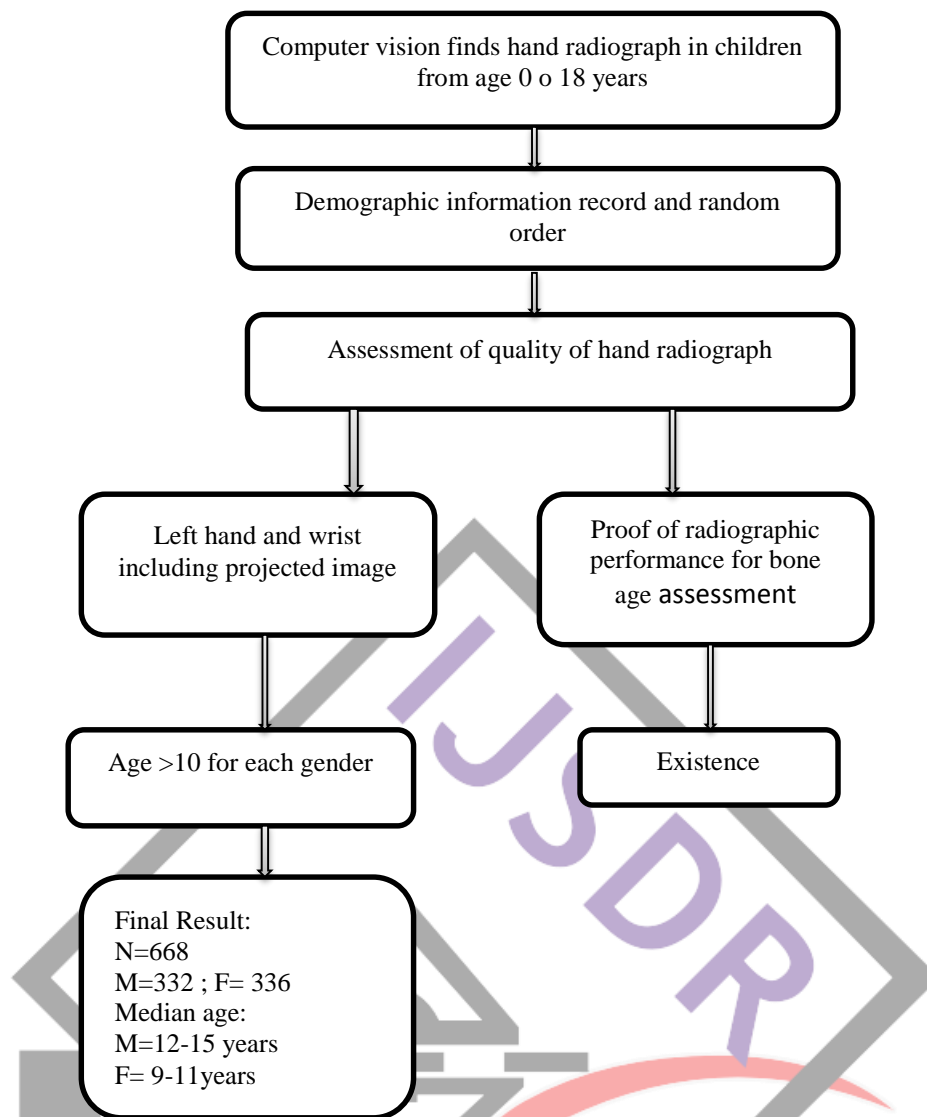Figure 4. Skeleton maturity based on GP method

Figure 5. The flow chart is creating the process of GP method.

The information established on the left-hand wrist bone of 355 boys and 322 girls who take birth between 1928 and 1974, registered in the FELS Longitudinal Learning. The radius, carpals, metacarpals and phalanges are age standard based on the radiographs.

2. Ultrasonography: - In this method, the structure of the bones are measured with two parameters such as the velocity of the sound and broadband digital ultrasound attenuation. The sound digital wave is communicated from end to end of wrist bone and then that is rejected back. The images are reconstructed using the level of the attenuation with suitable algorithms. The function of the frequency of the transmissions penetrated through ultrasound. Mentzel et al [16] compared the accuracy with the standard radiographic method. The result is dependent on the evaluation of the Greulich-Pyle Method. The ionisation radiation rated the accurate range and evaluating the radiographic image.

Table 1: Merits and Limitations of techniques for bone determination

Technique	Merits	Limitations
Tanner–White house	The accurate result showed due to the complex nature. Lower subjectivity based on personal opinion.	The method is very complex so the scale of the maturity score is maximum ranges from 0 to 1000 which can give the inappropriate result.
Greulich-Pyle	Simpler and can be normal users and usually used in medical radiology.	Leads to miss-classification due to subjectivity.
Ultrasonography	Slightest effect on the ionised radiation	Limited age and may not be perfectly accurate.
Score Based Method	Normal error bone assessment use in forensic locations	Doesn't completely eliminate the radio logistic [22].
Computer Assisted Method	Accurate and Precision [20]	Limited Experience

. The hand bones mainly based on two approaches:-

i) Atlas Method: - dental maturity can be assessed by using the forensic and ultrasonic method. The diseases can be analysed through the diverse procedure. The Atlas method is the method in which phases along with different teeth that are gathered using orthopantomography and matching is done with the standard images in the atlas. In addition, various recognition methods of the different teeth bones are specifically recognised.

ii) Scoring based Method: - The numerical based mainly based on the mathematical approaches in 1973 where the level of the recognition is assigned bone maturity score to the tooth. In this method, the computation of the maturity score can be done using a unique maturity score and calculation of the bone age of the dental. The bone age assessment was related to the chronological age. The bone age is estimated using the GP method and recognising wrist radiographs. Along with that, bones are replaced from orthopantomographs with Demirijian method

B. DETERMINE GENDER USING FORENSIC ANTHROPOLOGY

The gender identification of the adult's skeleton traits is done through human and non-human primates. The grades and designs of the difference of these bone skeletal traits among males and females are relatable to the bio-diversity in physical anthropology in forensic tools [17]. The shape and the size of the gender prediction is the contribution factor.The bone mass that susceptible to osteoporosis identify the regulate bones. The increase in the osteoporosis is done by a medicated process. Inform example, the different pelvic bones of the men and the female identify the gender of the individual. The sexuality of an individual can be recognised using forensic anthropology which is:-

1. Analysis of Metrics: - The gender of a person can be recognised using metric analysis that is based on the theories, estimation and the number of the assumptions. The results can be analysed through the significant factors. The metrics approach is useful in the retrieval of the fragments during the skeleton remains. Gender is estimated by using various metric methods and measuring diverse pelvic bones [18]. The main benefit of this approach is that it is highly replicable and less dependent on preceding observers. The female is categorised with the different function mainly 60% of the samples are determined accurately.

2. Magnetic Resonance Method: - The whole body imaging system can be equipped using the magnetic resonance method. MRI imaging is the method is the radiation-free imaging that can be used to image the epiphyses of the ulna and the radius. The ossification centres can be recognised using the MRI imaging method.
 The age can be observed by recognising the difference of the ossification centres [19].

Table 2: Merits and Limitations of methods for sexual category determination

Method	Merits	Limitations
Analysis metrics	Independent and reliant on the previous users. Recognise through intra and inter observed faults.	Inaccurate result. The discriminant function for the sacrum may be 60% accurate. Male sacrum may vary more and large sized sample is used in this method
Magnetic Resonance Analysis	Evaluate the tabular standard for evaluating bone architecture.	Clarification of the performance metrics is most difficult. Cost is high and time-consuming.
FELS	Present a selective approach for skeleton bone age assessment linked through normal faults.[21]	Complex nature and utilised in medicinal radiology process. For instance, every bone has the grade level from 0 to 140 that may be assigned for every indication and then stored.

IV CONCUSSION AND FUTURE SCOPE

In conclusion, various methods are described in detail to determine the Skelton bone age. Tanner Whitehouse technique has the limitation from age 5-17 years of the age for boys and 5-15 years of the bone age for girls in measuring the maturity of the persons. Different techniques have their own benefits. In Tanner White house Method, the complexity of the hand bone can give accurate and desirable age through the automatic procedure. The different stages are analysed using the contour of radius which is segmented automatically. Secondly, shape, texture and the size of the bones are extracted. In the final approach, magnitude is decreased through the selection of conservative characteristics. In this way, an approximate scoring score of the skeleton bone age of an individual is detected. The Greulich-Pyle method is used in medical radiology due to its simple nature. The Greulich-Pyle method is the utilised through medicinal experts for the recognition of the basic height of the children and youth. This is done using ultrasonography technique that determines the accuracy of the skeleton bone age. In the metric analysis, the gender of the persons is recognised based on the estimation and assumptions

The future scope is based on the combination of the experimental results using various techniques such as Deep Learning and Machine Learning Methods. The parameters based on the shape, size and sex can be enhanced by novel technique to determine the bone and gender in an associated way.

REFERENCES

[1] Ontell, F. K., Ivanovic, M., Ablin, D. S., & Barlow, T. W. (1996). Bone age in children of diverse ethnicity. *AJR. American journal of roentgenology*, *167*(6), 1395-1398.

[2] Spampinato, C. (1995). Skeletal bone age assessment. *University of Catania, Viale Andrea Doria*, *6*, 95125.

[3] Bull, R. K., Edwards, P. D., Kemp, P. M., Fry, S., & Hughes, I. A. (1999). Bone age assessment: a large scale comparison of the Greulich and Pyle, and Tanner and Whitehouse (TW2) methods. *Archives of disease in childhood*, *81*(2), 172-173.

[4] Tanner, J. M., Whitehouse, R. H., Cameron, N., Marshall, W. A., Healy, M. J. R., & Goldstein, H. (1975). *Assessment of skeletal maturity and prediction of adult height (TW2 method)* (Vol. 16). London: Academic Press.

[5] Shejul, A. A., Kinage, K. S., & Reddy, B. E. (2017, August). Comprehensive review on facial based human age estimation. In *2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS)* (pp. 3211-3216). IEEE.

[6] Mansourvar, M., Kareem, S. A., Ismail, M. A., & Nasaruddin, F. H. (2014, June). Automatic method for bone age assessment based on combined method. In *2014 International Conference on Computer and Information Sciences (ICCOINS)* (pp. 1-5). IEEE.

[7] Hsieh, C. W., Jong, T. L., Chou, Y. H., & Tiu, C. M. (2007). Computerized geometric features of carpal bone for bone age estimation. *Chinese Medical Journal*, *120*(9), 767-770.

[8] Bian, Z., & Zhang, R. (2018, June). Bone Age Assessment Method Based on Deep Convolutional Neural Network. In *2018 8th International Conference on Electronics Information and Emergency Communication (ICEIEC)* (pp. 194-197). IEEE.

[9] Chu, M., Liu, B., Zhou, F., Bai, X., & Guo, B. (2018, December). Bone Age Assessment Based on Two-Stage Deep Neural Networks. In *2018 Digital Image Computing: Techniques and Applications (DICTA)* (pp. 1-6). IEEE.

[10] Chen, C. Y., Hwang, C. H., Hsieh, C. W., Jong, T. L., Liu, H. C., Tiu, C. M., & Chou, Y. H. (2014, May). A study of bone age evaluation based on hand knuckles radiogram. In *2014 IEEE International Instrumentation and Measurement Technology Conference (I2MTC) Proceedings* (pp. 68-71). IEEE.

[11] Souza, D., & Oliveira, M. M. (2018, October). End-to-End Bone Age Assessment with Residual Learning. In *2018 31st SIBGRAPI Conference on Graphics, Patterns and Images (SIBGRAPI)* (pp. 197-203). IEEE.

[12] Agrawal, A., Patil, U., & Ranjan, S. (2011, October). Automated segmentation of epiphysis and metaphysis for computerized bone age analysis. In *2011 IEEE Applied Imagery Pattern Recognition Workshop (AIPR)* (pp. 1-4). IEEE.

[13] Darmawan, M. F., Yusuf, S. M., Haron, H., & Kadir, M. R. (2012, September). Review on Techniques in Determination of Age and Gender of Bone Using Forensic Anthropology. In *2012 Fourth International Conference on Computational Intelligence, Modelling and Simulation* (pp. 105-110). IEEE.

[14] Tristan-Vega, A., & Arribas, J. I. (2008). A radius and ulna TW3 bone age assessment system. *IEEE Transactions on Biomedical Engineering*, *55*(5), 1463-1476.

[15] Santoro, V., Roca, R., De Donno, A., Fiandaca, C., Pinto, G., Tafuri, S., & Introna, F. (2012). Applicability of Greulich and Pyle and Demirijan aging methods to a sample of Italian population. *Forensic science international*, *221*(1-3), 153-e1.

[16] Khan, K. M., Miller, B. S., Hoggard, E., Somani, A., & Sarafoglou, K. (2009). Application of ultrasound for bone age estimation in clinical practice. *The Journal of pediatrics*, *154*(2), 243-247.

[17] Arun, M., Nagesh, K. R., & Kumar, G. P. (2012). Estimation of sex from fragments of os coxa by metric analysis. *Australian Journal of Forensic Sciences*, *44*(2), 145-153.

[18] Steyn, M., & İşcan, M. Y. (2008). Metric sex determination from the pelvis in modern Greeks. *Forensic science international*, *179*(1), 86-e1.

[19] Boutry, N., Cortet, B., Dubois, P., Marchandise, X., & Cotten, A. (2003). Trabecular bone structure of the calcaneus: preliminary in vivo MR imaging assessment in men with osteoporosis. *Radiology*, *227*(3), 708-717.

[20] S. Sven, K. Beate, S. Ronald, R. Walter, S. Andreas, Studies in use of the Greulich–Pyle skeletal age method to assess criminal liability, Legal Medicine, July 2008, 10(4):190–195.

[21] S. Valeria, R. Roberta, D.D. Antonio, F. Chiara, P. Giorgia, T. Silvio, I. Francesco, Applicability of Greulich and Pyle and Demirijan aging methods to a sample of Italian population, Forensic Science International, May 2012, 221:153.e1–15 3.e5.

[22] N. Lynnerup, E. Belard, K. Buch-Olsen, B. Sejrsen, K. DamgaardPedersen, Intra and inter observer error of the Greulich–Pyle method as used on a Danish forensic sample, Forensic Science International, August 2008, 179(2-3):242.e1-242.e6

[23] Gertych, A., Piętka, E., & Liu, B. J. (2007). Segmentation of regions of interest and post-segmentation edge location improvement in computer-aided bone age assessment. *Pattern analysis and applications*, *10*(2), 115-123.