International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2024.0084
e ISSN: 2584-2854
Volume: 02
Issue: 04 April 2024
Page No: 609-618

Machine Learning Techniques for Gender Recognition and Age Prediction Using Digital Images of Human Dentition

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Abstract
In today's digital age, the utilization of digital medical imagery is on the rise, since the increased computational power that enables the development of more advanced machine learning techniques. We have implemented a system capable of determining the gender and estimating the age of individuals based on digital images of their teeth. Teeth, being a robust and relatively unchanging part of the human body, serve as an ideal source for such analysis. By examining Orthopantomogram images, our system systematically extracts gender and age-related information. Developed using the Python programming language, our application is particularly valuable in forensic contexts, where traditional prediction methods can be time-consuming, often taking days. In contrast, our model delivers results in under a minute. We employed the Random Forest (RF) Classifier algorithm to deploy the prediction model, as it effectively addresses the overfitting issue associated with growing input sample sizes. With this approach, we have achieved an impressive accuracy rate of 94% in gender and age prediction.

Keywords: *Teeth Images, Orthopantomogram, Medical Images, Forensic Field, Age Estimation, Gender Determination.*

1. Introduction
In the era of Information Technology field what we call it as computer age or digital age, new revolution and advanced computational power has already occupied the traditional manual method in almost every field. Medical field is not an exception case. Due to technical advancement in modern medicine helps researchers to understand medical terminology more effectively and to achieve goals in better way [1]. Thus we can see every day that medical sector rising up with refined development. In our present study we use digital radiography of teeth also called as orthopantomogram as input in sex determination and age of human. Traditional method for this is time consuming and it requires professionalism to analyze the features exhibited from teeth. The human body is prone to changes throughout life due to various external factors and internal metabolic shifts. However, unlike other bodily structures, teeth remain unaffected by these changes due to their inherent hardness and low metabolism. Dental x-ray images are valuable tools for identification purposes. Even in lifeless bodies, teeth can remain intact for extended periods. Therefore, identifying individuals based on dental images yields more accurate results than relying on other body parts. Several atlases depict the stages of teeth development and factors related to dental eruption, aiding forensic investigations. In forensic medicine, gender identification and age determination are highly sensitive issues within civil law and criminal investigations. Therefore, predicting age and gender based on anatomical features of teeth must be done with minimal errors. Our proposed system for age and gender identification utilizes a dataset of dental images. Pre-processing methods are applied to these

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images, followed by subsequent stages of image processing outlined in the following subsections. Forensic odontology, a branch of dentistry, focuses on the scientific examination of tooth anatomy to determine gender and age. It involves careful analysis of tooth eruption patterns as evidence. Age estimation methods encompass various techniques including anthropological, psychological, radiological, odontological, and skeletal analyses. While skeletal analysis can be influenced by environmental factors, dental features, being less susceptible to such influences, remain relatively stable over time. Consequently, teeth are invaluable for gender and age assessment in both living and deceased populations, serving as excellent material for genetic, odontological, anthropological, and forensic investigations [2]. Sexual dimorphism in dental morphology, particularly in canines, is well-documented and aids in gender determination. The robust nature and disease resistance of canines further enhance their significance. This study aims to contribute cutting-edge evidence and insights, addressing gaps in age and gender determination experiments through Machine Learning techniques, particularly in medical image analysis—a rapidly evolving and challenging domain within the machine learning community. Although dental structures are largely similar between genders, subtle differences exist. Discrepancies in tooth size can offer clues to gender distinctions. Forensic experts utilize tooth dimensions and craniofacial morphologies to discern gender and age variations. Tooth dimensions, especially those of the permanent mandible and maxillary canines, are crucial indicators due to their resistance to decay. Canine teeth, in particular, are widely utilized for gender identification purposes. One of the very first radiographic techniques for gender and age assessment was done by Goldstener, Demirjian and Tanner. They developed a scoring technique for age assessment by considering tooth calcification. Calcification process occurs on teeth as a natural aging process. Adult human body consists of 32 teeth that are organized in semi-circle shape (arch) inside mouth on top and bottom jaws. On upper jaw it consist of 16 teeth known as maxillary teeth, on the other side lower jaw has 16 set of tooth referred as mandible teeth. Mandibular bone is considered as strongest in human body. Compared to other bone, the mandibular bone can be well-stored for longer time [3]. On this account, mandible morphological features are commonly used by forensic dentists and anthropologists for gender determination and age estimation. A complete 32 set of adult humans is depicted in Figure 1. Figure 2 illustrates three different types of dental image scanning. 2(a) is a type of bitewing dental scanning, 2(b) is Periapical digital scanning and lastly 2(c) is OPG imaging which is widely used as advanced dental scanning.

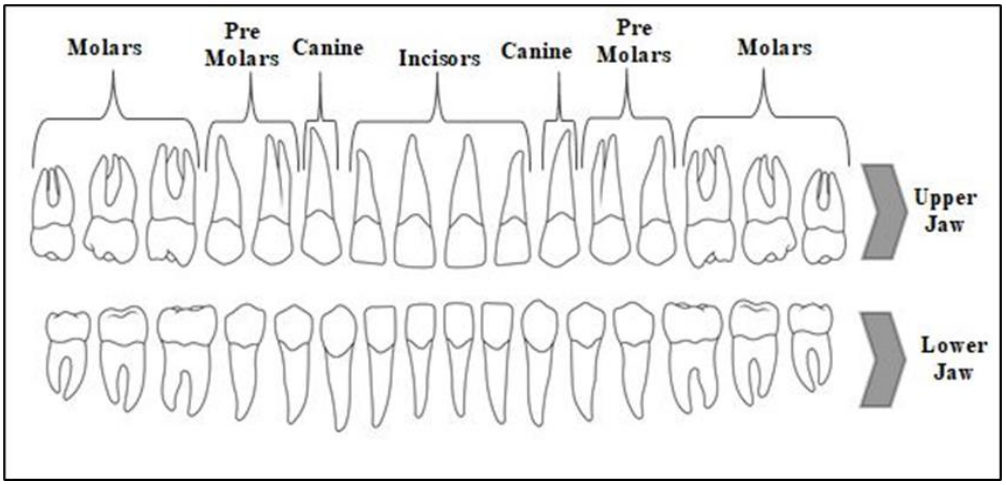

Figure 1 Anatomy of Human Teeth

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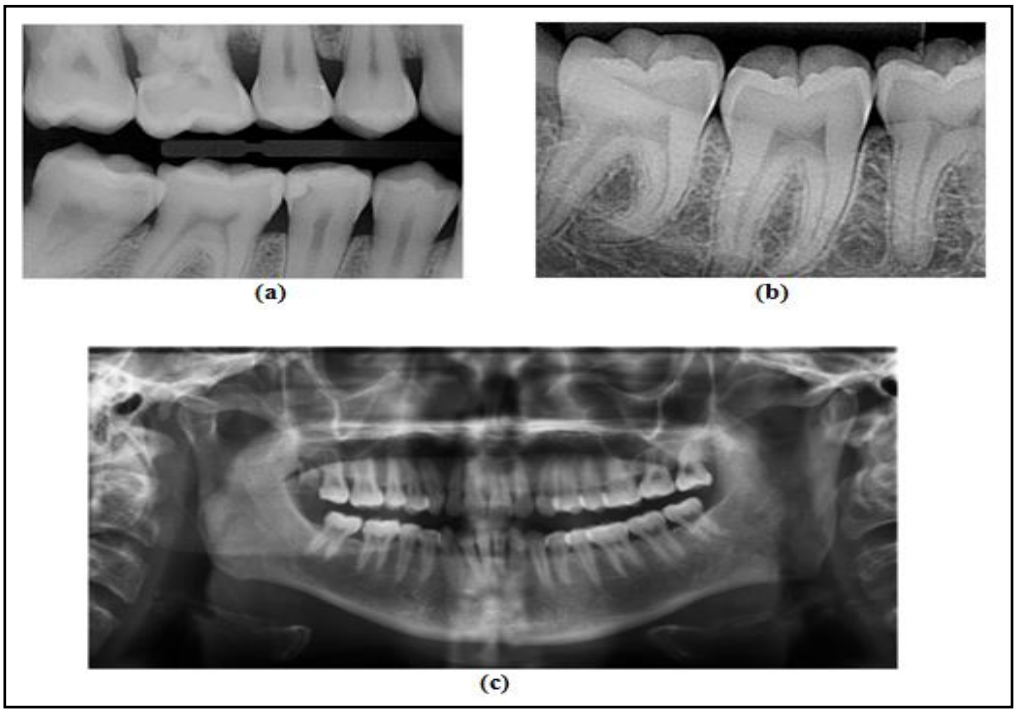

Figure 2 Types of Dental Imaging
2(a) Bitewing X-Ray - 2(b) Periapical X-Ray - 2(c) Orthopantomogram X-Ray

2. Literature Review

Determining gender and estimating age using digital images of teeth presents a significant and evolving challenge [4]. This section provides an overview of recent articles that discuss methodologies, technical aspects, and notable contributions by researchers aiming to improve identification accuracy. Saloni et al. (2020) introduced a technic using dental scans to analyze the morphometric characteristics of the mandible ramus in OPG samples. By employing discriminant function analysis, they found three parameters from the mandible ramus variables exhibited statistically significant gender differences, indicating that the mandible ramus displays considerable sexual dimorphism. In another study, Poornima Vadla et al. (2020) proposed a method based on the permanent mandible teeth of the left jaw side. Their experimental work used samples of dental radiographs varies from 5 years of age to 15 years, and they adopted Camerier method inculcating Indian-specific formulas, achieving high accuracy in human age estimation. Okkesim A and Erhamza S (2020) conducted research on determining human gender based on mandibular ramus, emphasizing the significant role of mandibular teeth due to the bone's size, dimorphism, and strength. Recent studies have highlighted the superiority of CBCT (cone beam computed tomography) over traditional techniques, with parameters such as gonial angle and ramus measurements being particularly informative. Dalessandri D et al. (2020) reviewed the effectiveness of 2D radiological methods versus 3D radiological methods for age determination based on teeth in 18-year-olds, concluding that CBCT offers superior accuracy compared to OPG in evaluating dental anatomy. Stella A and Thirumalai S (2020) developed an automation tool for age estimation based on dental OPG images, employing the Demirjian and Nolla methods. This tool, created using MS Excel Visual Basic Application (VBA), streamlines the age assessment process, considering different tooth stages and gender-specific score variations [5]. Ahima Bali B et al. (2020) proposed a panoramic evaluation method for mandible morphometric changes in Turkish populations, analyzing various parameters such as Bicondylar breadth and gonial angle measurements in post-

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pubertal and pre-pubertal individuals. Vanessa M A et al. (2019) developed a system for gender determination and age estimation using pulp cavity volumes based on CBCT scans. By analyzing 120 samples from the Brazilian population, they established equations predicting age and gender using pulp volumes from specific teeth, achieving high accuracy, especially in individuals over 35 years old.

3. Feature Identification

Teeth have vital roles to play in our daily lives . Healthy teeth help us in chewing food and digest. They also help to speak fluently also keep our face in proper shape. Teeth not only help us in all these activities, but they also play an important part in personal identification of human in forensic science. When a sample of teeth or digital images of teeth available, then first and foremost thing is to observe the features of teeth which helps to determine gender and age. Some of the salient and dominant features in teeth for identification process are illustrated in this section [6]. Appearance of teeth and eruption of tooth is important in tooth development process which plays an important feature in identification. Determination of gender based on skeletal part available is most challenging task for forensic experts when only fragmented parts of body are recovered. In this situation forensic dentistry will help in gender identification and age estimation based on the dental remaining and skull part. Several features of teeth like size of crown, number of teeth, root length etc., are few important characteristics in determination of female and male gender.

Figure 3 Appearance of Teeth Considered as A Feature for Prediction

The econometric features identified and analyzed for gender and age assessment are as follows:

- Number of teeth appeared on the OPG
- Mesiodistal width of first molar
- Incisor width
- Canine width
- Distance measured between canine

4. Materials and Methods

An experimental study was prepared to predict age and sex of human being based on digital x-ray images of teeth. Since dental x-ray images were not publicly accessible, samples were collected from two dental colleges, in Davangere, Karnataka, India. In total we have obtained a dataset of 1142 samples for the experiment [7].

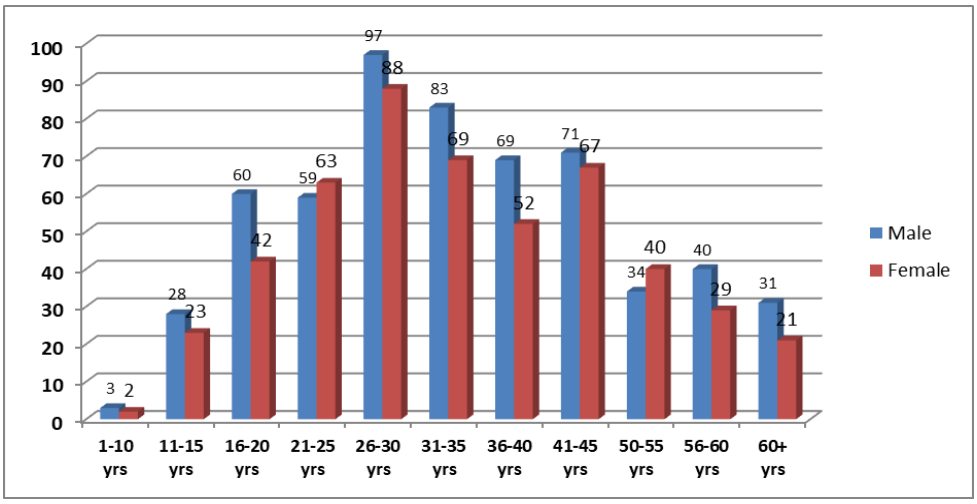

Figure 4 Dataset Distribution Based on Gender and Age Group

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The age distribution of these samples was categorized into 11 groups, each spanning a range of 5 years, except for the first and last groups, which encompassed ages 1-10 years and 60 years and above, respectively. Figure 3 illustrates the distribution of these datasets based on 5-year age intervals, distinguishing between male and female counts per group and Figure 4 depicts statistics for different age groups [8].

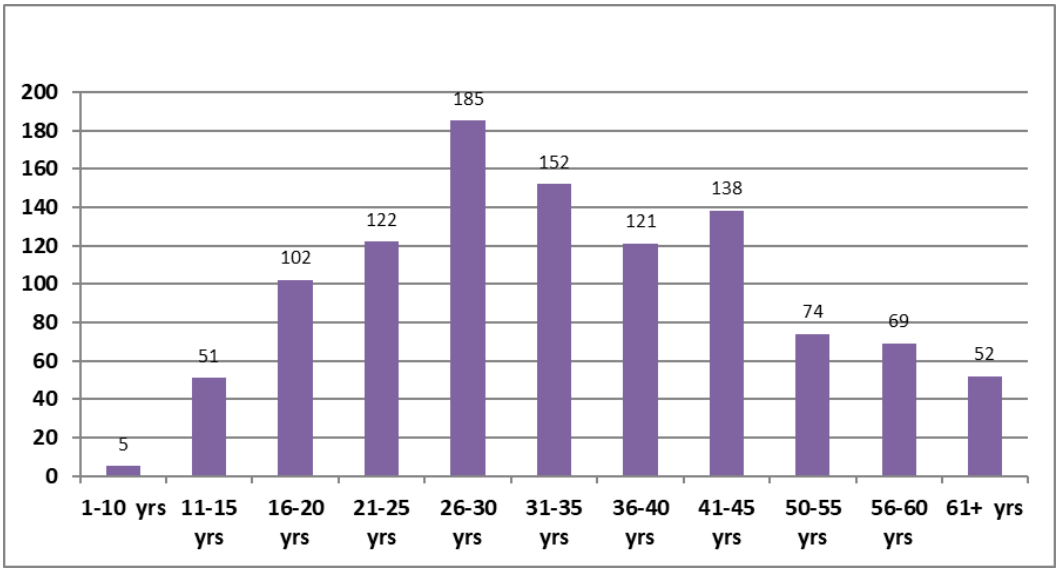

Figure 5 Dataset Statistics Based on Age Group

Details of total number of male samples and female samples per age groups are displayed in Figure 6. In total there are 632 male and 510 female radiographs, which were collected for experimental analysis and it is depicted in Figure 5. In our research work radiographs from patients with age of 01–77 years were included in the dataset [9].

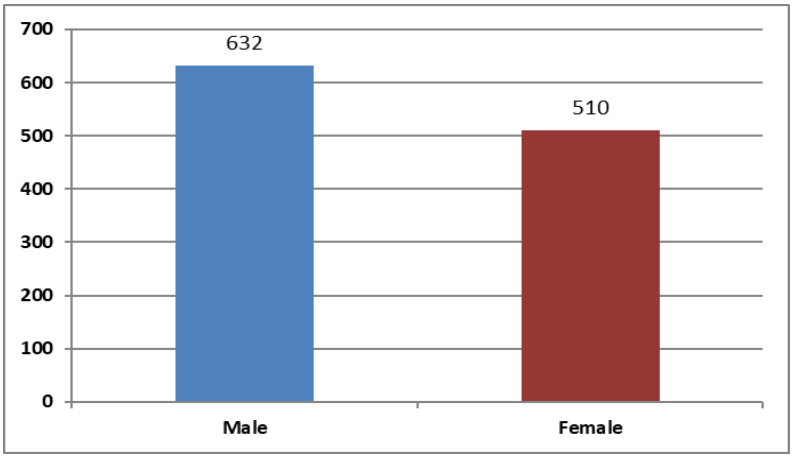

Figure 6 Total Number of Males and Females

Methodology for age estimation and determination of sex is illustrated in Figure 7. Basic blocks in prediction are: Data collection, Pre-processing of input image, features extraction and Random forest classifier for classification of age and gender. We have collected 1142 dental samples and from these total samples were distinguished as training data samples and test data samples [10].

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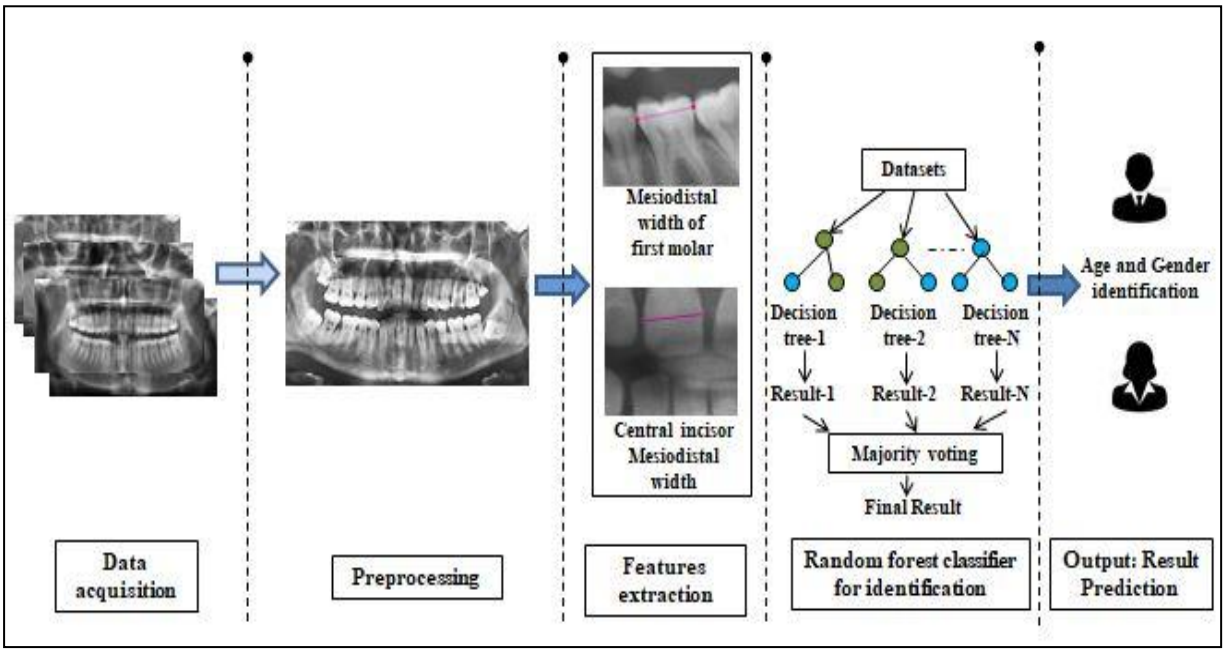

Figure 7 **Gender and Age Assessment System Using OPG Of Teeth**

System using Random Forest Classifier (RFC). Random forest algorithm works on basis of decision tree mechanism. Outcome of each decision tree may lead to over fit the training data, but using random tree this problem can be avoided. Final results are classified based on the majority of voting. RFC is a powerful classification algorithm in image processing field that will produces results with high accuracy.

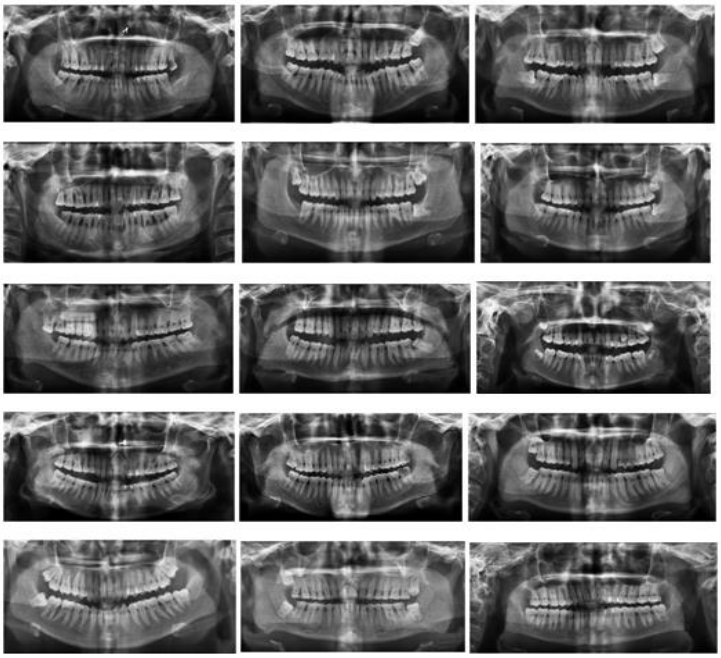

Figure 8 **Datasets Collected from College of Dental Science, Davangere**

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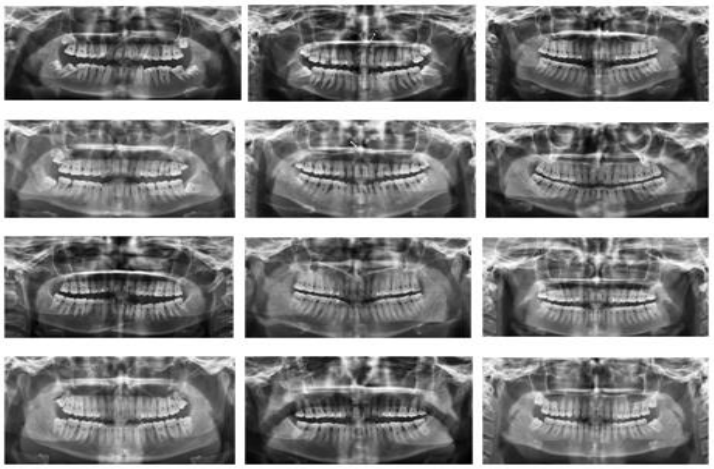

Figure 9 Datasets Collected from Bapuji Dental College & Hospital, Davangere

A few dataset samples that were collected from dental colleges were illustrated in Figures 8 and 9. These visuals were acquired in Tagged Image File Format (TIFF).

5. Experimental Results and Discussions

A database was created for this automated system so that one can determine a person's gender based on their age using only an Orthopantomogram (OPG) of their teeth as input. Gathering datasets of dental images proved to be a significant challenge during our research. Since medical images aren't readily available publicly and those obtained from internet sources can't be relied upon, we collaborated with various dental colleges. Through proper procedures and academic agreements, we obtained 1142 OPG images. Our model first preprocesses the input image by eliminating any noise that might have been captured during image acquisition. Additionally, it enhances the brightness and quality of the image. We implemented our prediction system using Python programming language, utilizing the Python Image Library (PIL) for image enhancement. The output of this stage is an improved version of the original image, as illustrated in Figure 10.

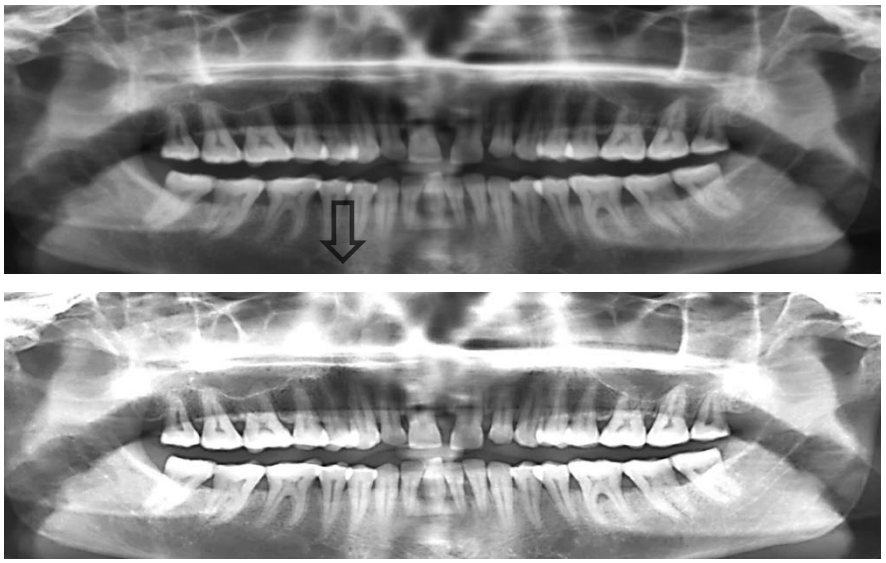

Figure 10 Result of Preprocessed Image

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5.1 Edge Detection Using Canny Edge Detection Algorithm

Image segmentation involves dividing images into various segments, with the primary purpose being the localization of objects and image boundaries. In our approach, we utilized the Canny detection algorithm to identify the edges of teeth, facilitating precise predictions of age and gender by our model. The Canny edge detection method consists of five steps, which we applied to detect edges in dental panoramic radiographs (OPG). Figure 11 illustrates the results of employing the Canny edge detection technique on an OPG image in our study.

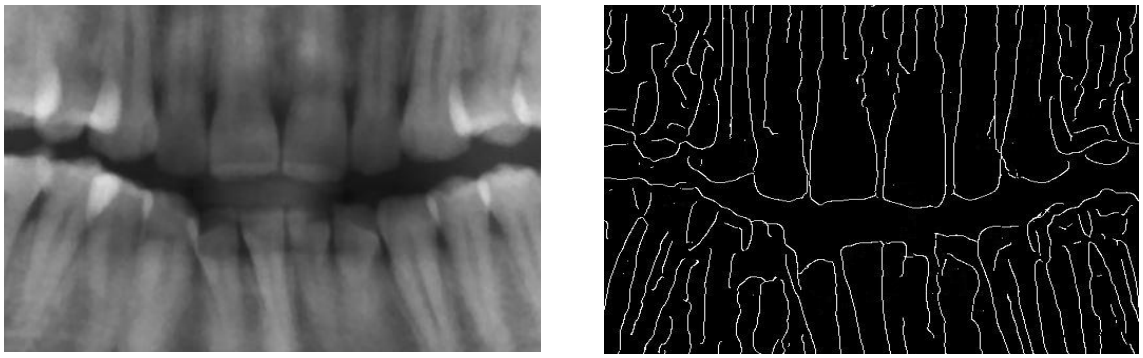

Figure 11 Detection of Edge in Teeth Image Using Canny Edge Detector

Steps In Edge Detection Using Canny Edge Detection Algorithm:

1. **Conversion of image based on Gaussian filter.**

Sigma = 1.5, G Kernel size (5 X 5)

2. **Gradient Calculation.**

Horizontal filter KX and Vertical filter KY

Ix=filters.convolve(image, Kx)

Iy=filters.convolve(image, Ky)

3. **Non max suppression:** To achieve thin edges

angle = A * 180 / np.pi

angle[angle<0] += 180

4. **Double Threshold**

high_Threshold=image.max( ) * highThresholdratio;

low_Threshold= high_Threshold * hlowThresholdratio;

5. **Tracking edge based Hysteresis**

Low_T = Low_T * max(max(b-w))

High_T = Low_T * max(max(b-w))

Scatter graph plot for prediction of human based on teeth OPG is shown in Figure 12. In our present study, we have analyzed important features from teeth images that establish the identity of human. Experimental results are plotted using scatter graph that can be examined easily.

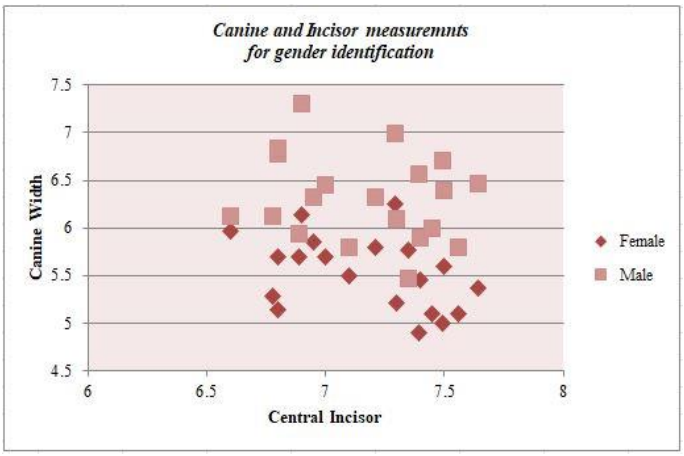

Figure 12 Scatter Graph for Prediction Based on Measurements of Canine and Central Incisor

Human prediction based on the features of teeth by measuring canine width and central incisor width is depicted using scatter graph as shown in Figure 13 and prediction based on measurements of mandible and maxillary canine and canine index is depicted using scatter graph as shown in Figure 13. The average feature parameter values in male are more compared with female gender.

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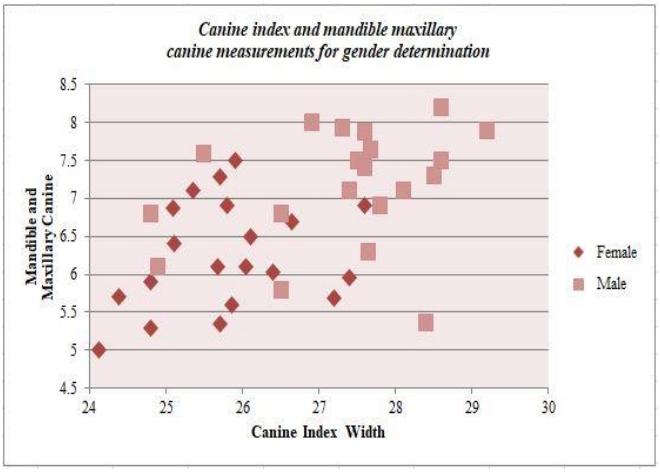

Figure 13 Scatter Graph for Prediction Based on Measurements of Mandible and Maxillary Canine Width and Canine Index Width

Conclusion and Future Scope

The current experimental investigation reveals discernible disparities in gender identification based on certain dental features. Notably, male mandibular canine width surpasses that of females. Moreover, across various parameters, male teeth consistently exhibit greater dimensions than their female counterparts. The devised formula demonstrated high efficacy, achieving a remarkable 94% prediction accuracy. This study successfully aligns experimental outcomes closely with ground truth values, fulfilling the predictive objective without human intervention. This novel model holds promise for applications in forensic science, streamlining identification processes. Our research simplifies the complexities associated with digital radiograph analysis, facilitating a more effortless approach. Future endeavors could expand upon this by pinpointing additional significant dental characteristics and standardizing them across datasets. Beyond teeth, this methodology could extend to other anatomical features such as skulls and limb bones, enhancing age and gender estimation capabilities. To enhance accessibility, development of user-friendly web or smartphone applications is recommended for broader utilization.

References

[1]. Cameriere R, Ferrante L, Cingolani M (2006) “Age estimation in children by measurement of open apices in teeth”. Int J Legal Med 120(1):49–52

[2]. Omar A, Azab S. “Applicability of determination of gender from odontometric measurements of canine teeth in a sample of adult Egyptian population”. Cairo Dent J 2009; 25:167-80.

[3]. Anton Sklavos, Daniel Beteramia, Seth Navinda Delpachitra, Ricky Kumar. “The panoramic dental radiograph for emergency physicians”. Emerg Med J;36:565–571. 2019

[4]. Saloni, Pradhuman Verma, Princy Mahajan, Ankush Puri, Sukhleen Kaur and Sakshi Mehta. “Morphometric analysis of mandibular ramus: A panoramic study”. Indian Journal of Dental Research, Volume 31, Issue 3, May-June 2020

[5]. Poornima Vadla, R. Surekha, Guttikonda Venkateswara Rao, G. Deepthi, Sayani Naveen and Chippalapally Arun Kumar. “Assessing the accuracy of Cameriere’s Indian-specific formula for age estimation on right and left sides of orthopantomogram”. Egyptian Journal of Forensic Sciences. 10:9, 2020

[6]. Alime Okkesim and Sezen Erhamza. “Assessment of mandibular ramus for sex determination: Retrospective study”. Craniofacial Research Foundation. August 2020

[7]. Domenico Dalessandri, Ingrid Tonni, Laura La_ranchi, Marco Migliorati, Gaetano Isola, Luca Visconti, Stefano Bonetti and Corrado Paganelli. “2D vs. 3D Radiological Methods for Dental Age Determination around 18 Years: A Systematic Review”. Applied Science. 10, 3094. Apr 2020

[8]. Stella A and Dr Thirumalai Selvi. “Age assessment automation tool using VBA with OPG”. International Journal of Scientific & Technology Research Volume 9, Issue 01, January 2020

[9]. Ashima Bali Behl, Salvina Grewal, Kavisha Bajaj, Parvinder Singh Baweja, Gurpreet Kaur and Pavita Kataria. “Mandibular

International Research Journal on Advanced Engineering and Management
https://goldncloudpublications.com
https://doi.org/10.47392/IRJAEM.2024.0084
e ISSN: 2584-2854
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Issue: 04 April 2024
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Ramus and Gonial Angle—Identification Tool in Age Estimation and Sex Determination: A Digital Panoramic Radiographic Study in North Indian Population". Journal of Indian Academy of Oral Medicine & Radiology, Vol. 32, Issue 1. January-March 2020

[10]. Vanessa M Andrade, Rocharles C Fontenele, Andreia CB de Souza, Casimiro AP de Almeida, Andrea CD Vieira, Francisco C Groppo, Deborah Q Freitas and Eduardo D Junior. "Age and sex estimation based on pulp cavity volume using cone beam computed tomography: development and validation of formulas in a Brazilian sample", Dentomaxillofacial Radiology 48, 2019