Deven N. Trivedi · Nimit D. Shah
Ashish M. Kothari · Rohit M. Thanki

Dental Image Processing for Human Identification

Springer

Dental Image Processing for Human Identification

Deven N. Trivedi • Nimit D. Shah
Ashish M. Kothari • Rohit M. Thanki

Dental Image Processing for Human Identification

Springer

Deven N. Trivedi
E. C. Department
G. H. Patel College of Engineering and Technology
Vallabh Vidyanagar, Gujarat, India

Ashish M. Kothari
Atmiya Institute of Technology and Science
Rajkot, Gujarat, India

Nimit D. Shah
C. U. Shah University
Wadhwan City, Gujarat, India

Rohit M. Thanki
C. U. Shah University
Wadhwan City, Gujarat, India

ISBN 978-3-319-99470-3 ISBN 978-3-319-99471-0 (eBook)
https://doi.org/10.1007/978-3-319-99471-0

Library of Congress Control Number: 2018967495

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

Biometric systems are used for authentication of a person in many institutions, organization, and agencies. The main reason for use of this system is that it is able to distinguish an authorized person from an unauthorized person. These systems use a person's physical and/or behavioural biometric traits for authentication. These traits can include fingerprints, facial recognition, eye scans (retina, iris), handwritten signatures, voice and speech recognition, and dental characteristics. For a human identification system, these biometric traits must be time-invariant property; otherwise, false acceptance rate (FAR) of the system will be increased.

Recently, dental modalities have played a significant role in human authentication. Disasters, such as plane crashes and car accidents, where the human body is burned due to fire, result in biometric modalities such as facial features, iris, fingerprint, palm print, and hand geometry that can't be obtained easily. Therefore, dental features, which remain unchanged in fire and time invariants, help in identifying a person in this situation. A recent major disaster that presented a challenge was the tsunami in Thailand. In this disaster, many people were killed, including a large number of foreign tourists. In order to assist in the identification of the foreign tourists, the Thai Government set up an organization called Thailand Tsunami Victim Identification (TTVI). In this operation, dental recognition played a large role in identification as compared to the other common forms of biometric modality recognition.

In this book, a dental recognition system based on feature withdrawal and feature comparison is described for person identification. During the feature withdrawal process, dental features such as artificial prosthesis, contour, and number of cupids are extracted from the dental radiographs. Here, tooth contour is used as an extracted feature because they stay more invariant over a long period of time, compared to other tooth features. This system was tested and analysed for two types of dental radiographs in JPG and DICOM® formats. The dental radiographs were obtained from Oroscan at the Shreeji CT Scan Centre (Dr. Batra's student clinic) in Vallabh Vidyanagar, Gujarat, India. In this image database, images are taken of the same person within different time zones. The system was designed using various image processing techniques, such as edge detection, feature matching, contouring with bilinear interpolation, and final matching with appropriate FAR.

Edge detection is a major operation in a dental identification system. This system is analysed using two optimal edge detectors such as Shen-Castan infinite symmetric exponential filter (ISEF) and canny. ISEF is a recursive filter and directly applied to the image. This filter consists of different stages such as the whole image filtered in X and Y direction to generate a binary Laplacian image. Then various operations, such as non-maximum suppression, gradient, hysteresis thresholding, and thinning, are applied to the Laplacian image to obtain edges of the image. Here, the contour coding method is applied to these extracted edges of the dental image to get 20,000 columns of contour values. These values of the dental image are directly used for matching with any dental image. If the same person's dental image is going to match, almost all the columns have the same value. Otherwise, dissimilarity columns are for a different dental image. This system is directly applicable for any post-mortem (PM) and ante-mortem (AM) dental radiograph images.

This origin of this book is based on research work done by Dr. Deven N. Trivedi at CU Shah University. The authors are indebted to numerous colleagues for valuable suggestions during the entire period of the manuscript preparation. We would also like to thank the publishers at Springer, in particular, Michael McCabe, senior publishing editor/CS Springer, for their helpful guidance and encouragement during the creation of this book.

Vallabh Vidyanagar, Gujarat, India — Deven N. Trivedi
Wadhwan City, Gujarat, India — Nimit D. Shah
Rajkot, Gujarat, India — Ashish M. Kothari
Rohit M. Thanki

Contents

List of Figures

List of Tables

Chapter 1
Introduction

1.1 Overview

The word "biometrics" derives from the ancient Greek 'bio', for 'life' and 'metric', that by which anything is measured [1]. A biometric is generally useful for analysing the identity of a person through their physical and behavioural characteristics [1]. Certain physical characteristics of a person are fixed, for example, fingerprints, face, teeth, iris, and DNA. These traits are more or less time-invariant, lasting throughout a person's lifetime [1, 2]. Behavioural characteristics of a person are not fixed, varying with time, for example, speech, signature, keystroke and gait [2].

Biometric characteristics or traits should have the following properties [1]:

- *Universality*: All persons possess different biometric features.
- *Permanence*: The biometric should not vary with time.
- *Collectability*: Biometric acquisition should be straightforward.

Other parameters such as performance, acceptability, exceptional handling and cost are considered for a biometric-based system used in real-time applications [1]. Details of these parameters are given below:

- *Performance*: Efficiency, accuracy, pace, robustness and database needed for implementing practical applications based on biometrics.
- *Acceptability*: The system is approved by its users.
- *Exceptional handling*: A biometric system should be user-friendly.
- *Cost*: The cost that the system incurs for the real-time applications.

D. N. Trivedi et al., *Dental Image Processing for Human Identification*,
https://doi.org/10.1007/978-3-319-99471-0_1

1.2 Biometric Performance Testing and Statistics

The performance of a biometric system can be determined in several ways, and it can be evaluated by three factors [3]:

1. *Technology evaluation*: This factor is associated with different matching algorithms. Here, the results obtained from the various matching algorithms are evaluated. The accuracy of matching algorithms is also calculated.
2. *Scenario evaluation*: This factor is associated with the results of the matching algorithm when operating in a mock environment.
3. *Operational evaluation*: This factor is associated with the overall performance of the system in real time.

Several other statistics are also used for measuring the performance of a biometric system:

- *False acceptance rate (FAR)*: The FAR is sometimes called the false match rate (FMR). It weighs the number of times the system falsely identifies one human with another human. For example, if person A is matched 2 times out of 100 attempts with person B, then the FAR for the system is 0.02. The system with low FAR value is widely used in real-time application [3].
- *False rejection rate (FRR)*: The FRR is sometimes called a false non-match rate (FNMR). It measures the number of times the system falsely rejects a human. For example, if a biometric of a particular human is rejected 5 times out of 100 matches, the FRR for the system is 0.05. If the value of the FRR is low, then the performance of the system is good. The FRR also includes the failure to acquire (FTA) rate, which is the rate the system fails to capture or collect authentic data of a human [3].
- *Performance testing using ROC analysis*: FAR and FRR are reciprocal (inverse) terms. Thresholding should be used according to the type of application, whether, for example, it is forensic, civilian or high security.
- *Thresholding (false acceptance/false rejection)*: In any biometric system a matching score is calculated using two types of matching methods: similarity with actual data and similarity with false or impostor data. An excellent data matching is one in which actual data matching score is high, and an impostor data matching score low for any system. Such a scenario is quite difficult or not possible for any system possible in the real world [3]. Thus, two types of decision are made by a biometric system, one the actual type of matching and the other the impostor type of pairing. For each kind of analysis, there are two possible decision results: true or false. Indeed, four outcomes are possible: (i) genuine data is matched, (ii) genuine data is rejected, (iii) an impostor datum is rejected and (iv) an impostor datum is accepted. Results (i) and (iii) are correct whereas (ii) and (iv) are incorrect. The two data sets are bifurcated by marking some range or employing some threshold [3]. FAR, FRR and the equal error rate (EER) are all employed to identify the accuracy of a biometric system. The EER is simply the threshold level of any system. One can conclude that a system with a low EER can be used for real world applications [3].
- *Receiver operating characteristic (ROC) curve*: In Fig. 1.1, the ROC curve shows that forensic applications have a high FAR value because it is used to find criminal person. Analysis of the system for forensic applications requires more

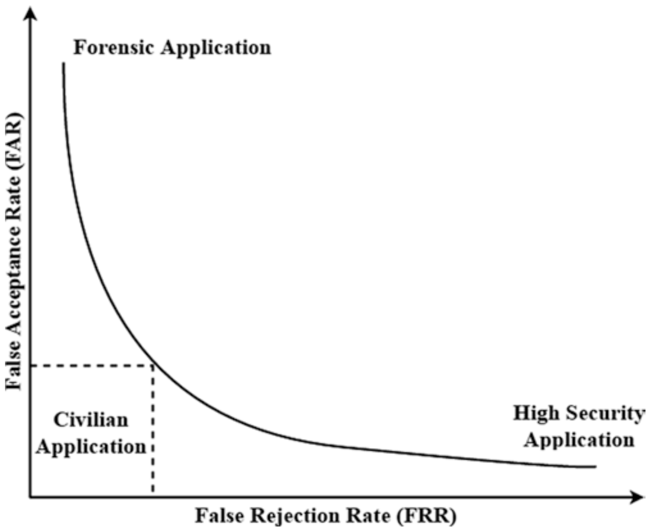


Fig. 1.1 Receiver operating characteristic (ROC) curve

data or more templates for matching humans. In high-security applications, the value of the FRR should be high and FAR should be low. The EER is the point where the FAR and FRR are equal. For civilian applications, EER should be considered and its value be as low as possible [3].

Some qualities of a biometric system should be measured to ensure better performance [3]:

1. The robustness of the system can be measured by the FRR.
2. The distinctiveness of the system can be measured by the FAR.
3. The availability of the system can be measured by the failure to enroll (FTE). FTE is the parameter that helps one understand the failure rate of biometric systems [3].
4. The throughput rate evaluates accessibility. It is the number humans a biometric system will process within a specified time interval [3].
5. Acceptability is evaluated by examining the claimants and surveying the results. By testing the several methods above one can determine which biometric system is better.

1.3 Classification of Biometric Characteristics

Security of biometric data has become the highest concern in global data communications and software development. In real-world applications, no biometric system has foolproof security, and so constant efforts are made to ensure adequate security features are included in the biomatrics system. Some key areas for consideration are data capturing, authentication, feature enhancement and algorithm selection [4].

Biometric data are divided into two major types: physical and behavioural, as shown in Fig. 1.2. Physical biometric data relate to the head, hand, face, iris and dental features. Physical biometric data are time-invariant: they do not change with time. However, in the event of certain calamities or a disaster, only dental biometric information is unchanged compared to all others. Moreover, in cases of antemortem (AM) and postmortem (PM) only information obtained from the physical biomatrix can be used; behavioural biometric data cannot be used.

1.3.1 Behavioural Biometric Data

Behavioural biometrics depend on human psychology. They are time-variant, changing over time. A system based on such data requires a more dynamic design, allowing for a degree of freedom. Behavioural biometric parameter effects include signature verification, keystroke and speaker verification [3].

1.3.2 Physical (Physiological) Biometric Data

Physical biometrics are evaluated by physical traits rather than a behavioural characteristic, e.g. dental, DNA, face, blood vessel pattern in the hand, fingerprint, hand geometry and skull. They are more time-invariant than behavioural biometric data,

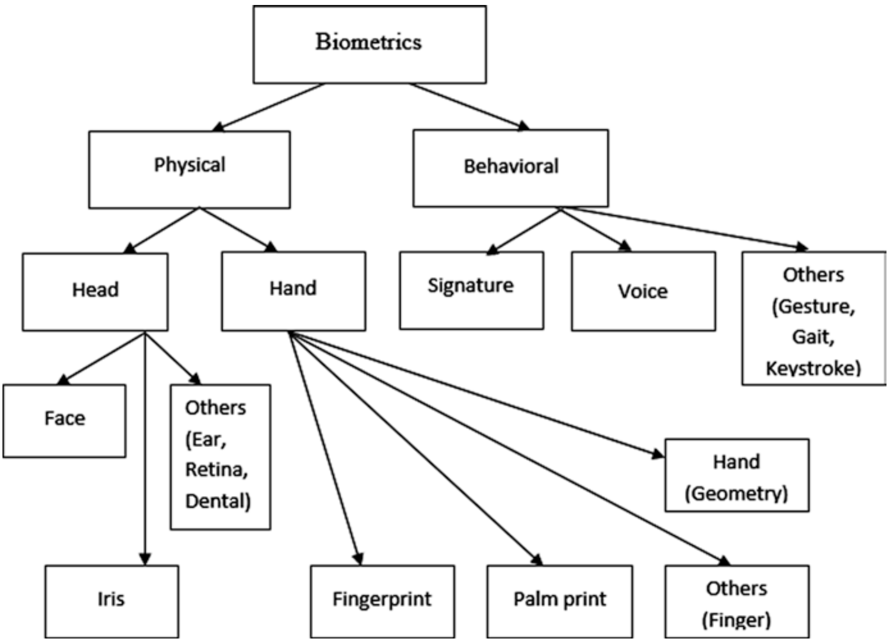


Fig. 1.2 Various types of biometrics

and are thus the best tool for the human identification. These tools have different applications, and each has its advantages and disadvantages. Some physical biometrics are also used for identification of disease. In grave disasters, various physical biometrics like skull and dental biometrics are used primarily for human identification.

Verification is a process of comparing data of one human with its enrolled data, as stored earlier. This system is used in some high-security areas such as banks and airports [3]. Identification is analysed by comparing data of one human with an entire enrolled database of the system. For example, suppose person A is a criminal which is to be identified. For this, the biometric data of person A is matched with the entire stored database of the system. Here, matching is performed one trait at a time.

1.4 The Biometric System Process

The biometric system process has five main stages, which are described below (shown in Fig. 1.3):

1. *Data collection*: Biometric traits in terms of the image captured from a human who seeks to identify him/herself or who the system seeks to identify. If the reference data for a human is not available in the system, then first he/she has to enter their data into the system. This process is known as enrollment. If reference data is already stored, then verification or identification can proceed.
2. *Feature extraction*: After a preprocessing operation, some features are extracted from the biometric image and the features converted to digital data.
3. *System database*: For the enrollment process, digital biometric data is stored in the system database. In the authentication or verification process, where reference data is required, data is acquired from this database.

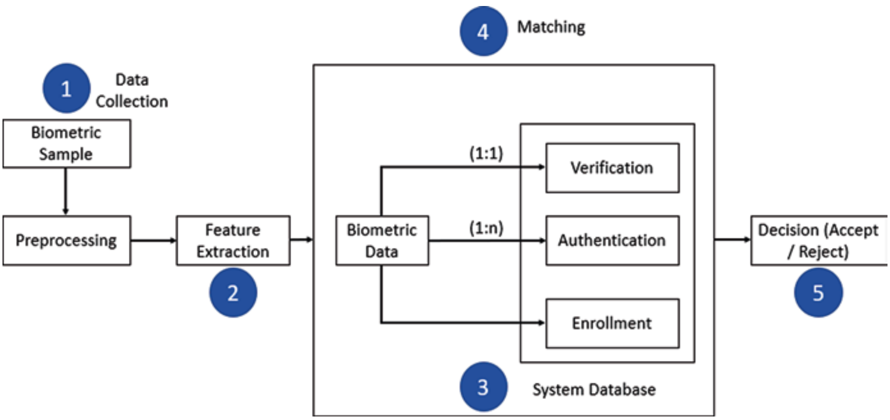


Fig. 1.3 Biometric system process

4. *Matching*: The matching process depends on whether verification or identification performed. In a verification operation, enrolled data are matched one by one to the same human's data. In an identification operation, obtained data are paired with an entire database of the system.
5. *Deciding*: The process of decision is a critical tool in verification or identification. The matching results are stored in tabular form. A human can be identified based on some threshold level [3].

1.5 Dental Modality and Identification System Based on It

Dental modalities are a significant tool in forensic science as well as in identification of persons. Dental patterns are robust and less time-variant, making them an essential feature for the operation. The objective of human identification based on dental modalities is that matching of AM and PM radiographs of a human can easily serve when other patterns are not available for matching. But dental radiographs may be poor quality and irrelevant. Thus, image enhancement is necessary before processing. Dental images are available in various formats including BMP, jpg and DCM.

Dental modalities play an important role in critical situations like natural disasters, vehicle accidents and plane crashes. In dental patterns, some features such as maxilla and mandible are more robust compared to other biometrics, so they are used for human matching. Moreover, sometimes dental processing is also a handy tool in clinical diagnosis. For a diabetic or blood pressure patient, iris matching of same patient gives different results according to sugar level or blood pressure. For the analysis of these types of diseases, dental modalities are used. Dental patterns have certain limitations, mentioned below. Thus, in some cases they are not a good choice for identification.

- *Identification*: AM and PM data should be matched with the authenticating and sufficient database. If some teeth data are missing in the database, the results may come out wrong.
- *Possible identification*: Sometimes features are the same in AM and PM dental images. However, during the capturing of dental images it may be a difference that creates the problem of mismatching the human [3].

The use of a biometric system was recorded even before 1000 years ago. For example, in 500 BCE clay material fingerprints were saved and used as a human mark for business transactions in Babylon. In the 1870s, physical measurements of humans were stored, such as skull diameter, foot size and hand size. So qualitative and quantitative analyses have been done since that time. Facial measurements also have been analysed since the 1920s. After the 1950s, signal processing was introduced, and all biometric systems went in a new direction, incorporating appropriate analyses of facial expression, hand geometry and so on. After the 1980s, some algorithms were developed for better enhancement and segmentation to match actual data. Since the 2000s, computer processing, computer tomography and MRI changed biometric systems. replacing them with new technology, aspects and methodology using appropriate advanced examination. Each day biometric systems emerge that entail new ideas and innovative technology; above all other advantages, these concepts are readily available on the internet.

The primary purpose of forensic dentistry is to identify deceased individuals for whom other traits of biometric identification (hand, skull, fingerprint, iris [5]) may not be available. In forensic dentistry, postmortem dental radiographs are compared against recorded antemortem dental radiographs for identifying a person. Sometimes, the forensics relies on manual records of dental images; comparison is made by forensic experts by observing various features [2, 6]. Some distinctive dental features such as dental restorations, crowns, tooth present/not present, root morphology, pathology, maxilla, mandible and implants are used for identification of human.

Depending on matches and unmatched radiographs, forensics determines a person's identity. The entire process depends on the application. Here, first, images of AM dental radiographs and PM dental radiographs are collected. Then various operations are performed such as enhancement, segmentation and feature extraction on dental radiographic images and the resultant data stored in tabular form. Finally, matching is performed using these tabular data. An example of PM dental radiographs and AM dental radiographs is shown in Fig. 1.4a, b [6]. The design of a dental identification system is done by one of two matching methods: manual or automated.

Nowadays, automated matching is widely used, since it has a fast execution time and better efficiency.

The automated dental identification system comprises two main stages: (1) feature extraction and (2) feature matching [6].

- *Feature extraction*: Here, several feature extraction algorithms are applied to dental images to obtain essential features such as tooth contour, cupids, crowns,

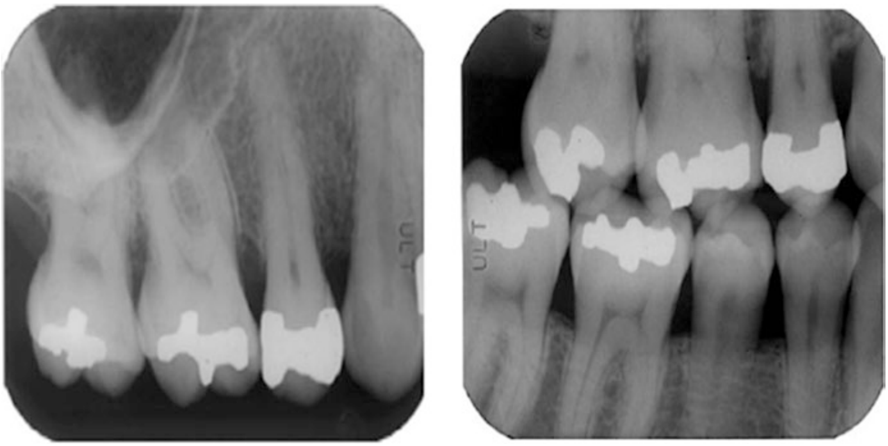


Fig. 1.4 Postmortem (PM) and antemortem (AM) dental radiographs of the same human

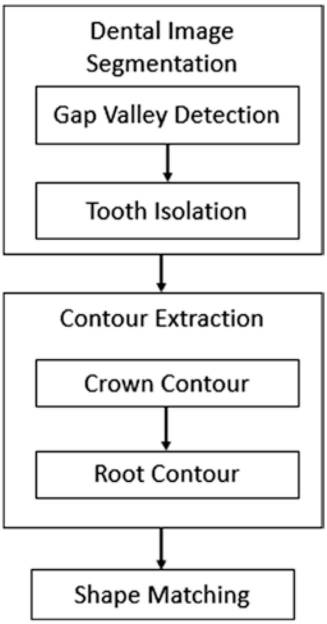
maxilla and mandible. These features are time-invariant. When a dental database is stored in the system database, the enhancement process is performed on dental images before application of feature extraction operation.

- Enhancement is performed if the acquired dental image is of poor quality. The dental identification system is shown in Fig. 1.5. Here, a region of interest (ROI) of the dental image is obtained using a dental image segmentation process. The process consists of two operations such as gap valley detection and tooth isolation. After segmentation of the ROI of the image, edge detection (e.g. ISEF (Infinite Symmetric Exponential Filter)) is applied and edges of the image are obtained. Further, contouring method is implemented on the sides of the images to obtain the contours of the teeth. These contour values are used as features of the dental image.
- *Feature matching*: Here, extracted features of PM images (query image) in terms of digital data are compared with recorded features of AM. Comparison of the function is made using different threshold levels. The performance matrices of FAR, FRR and EER are calculated based on the obtained comparison results. Once the results are received the next step is identification [5].

As discussion indicates, segmentation and contour extraction are critical. The main issue is the quality of the acquired image (as shown in Fig. 1.6). Therefore, a low pass filter should be applied to the image to enhance its quality.

In this book, the dental identification system used is ISEF, which is the optimal edge detector and recursive. Edge detection gives sharp edges of the image. The introduced method has two stages, trait extraction and matching. In the trait extrac-

Fig. 1.5 Process for dental feature extraction and matching



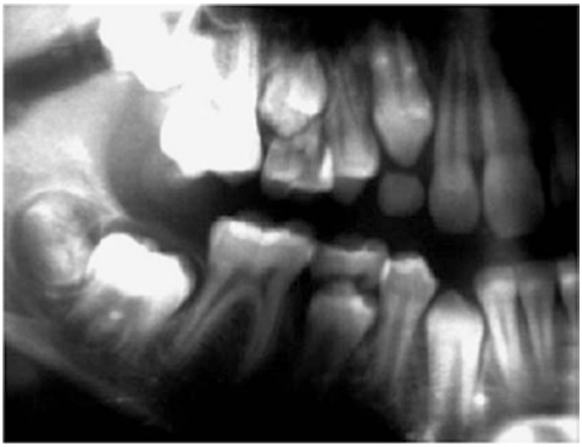


Fig. 1.6 Dental radiograph with poor image quality

tion stage, various operations such as low pass filtering, Gaussian, zero crossing, gradients, thinning and hysteresis thresholding are applied to dental images. After that, the matching stage has three operations: shape enrollment, evaluation of likeness of image and classification of the issue. In shape enrollment, contours of an image are obtained and the distance between them is calculated. The second matching method for dental images is based on crossing areas. Here, the space of contour shapes is taken for matching to improve the accuracy of the system. The contours of an image are a time-invariant quantity. Thus, the Euclidian distance between them is also used for matching [6].

1.6 Various Processes Involved in Dental Image Matching

The necessary steps for a human identification system based on dental images are shown in Fig. 1.7. The dental identification system has multiple operations, including image processing, image segmentation, feature extraction and image matching. The details of these operations are given in next subsections.

1.6.1 Image Processing

In a dental identification system, the dental images of humans are taken and are stored in the database of the system. The database of antemortem dental radiographs is used as a registered database. Person identification can be made by comparing postmortem dental radiographs with its enrolled dental radiographs based on several salient features. Background, teeth and bones are the three main parts of dental radiographs. An image of dental radiographs is obtained using a morphological

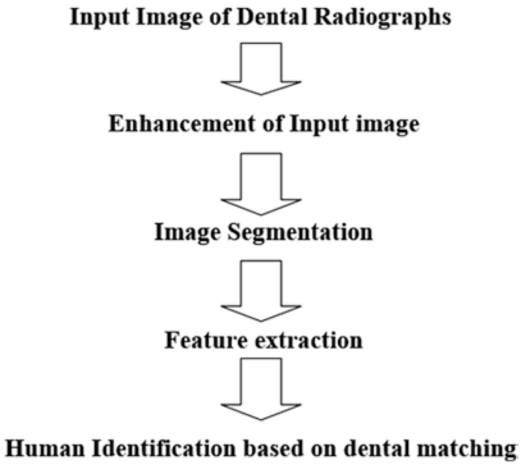


Fig. 1.7 Steps for dental image matching

operation such as a hat transform. The noises present in the images are removed with help of a smoothing operation. The Gaussian low pass filter is used for smoothing of image.

1.6.2 *Image Segmentation*

After a dental image is obtained, segmentation is applied to it to get salient features. For the extraction of features, first a teeth segmentation operation is performed on the dental image. For this, first the flood fill algorithm is applied to the dental image, which can identify the connected area between two teeth. The segmentation of dental image can be done using steps like (a) contour pulling out, (b) gap Valley recognition and (c) tooth isolation.

1.6.3 *Feature Extraction*

The extracted features of the dental query image must be compared with enrolled features of the dental image. The AM and PM images are taken at different times. Therefore, it becomes difficult to compare these two images. So, for this purpose, some subtle features are extracted from the dental images. The various types of feature extraction operations such as affine transformation and shape registration are used for this purpose.

1.6.4 *Image Matching*

Dental image matching can be done in various ways such as (1) matching by intrinsic properties, (2) matching by structure, (3) principle axis matching and (4) method using correlation.

1.7 Dental Identification System

In this system, an AM dental radiograph of person is matched with the PM one based on some salient features. This system is used frequently in incidents like aeroplane crashes, where identification of missing persons is difficult. Dental records are usually stored in AM radiographs in a system's database. The identification system comprises two main steps, dental feature extraction and feature matching [6]. Dental features provide less information than feature matching; it entails false contour, prosthesis, number of cupids and so on. Segmentation and shape are used to extract the dental feature. Contour-based extraction on the edges of the dental image is presented in [6]. Finally, human identification is made if elements of the query PM images match enrolled AM images. The primary flow of human identification system for postmortem dental images and antemortem images is shown in Fig. 1.8 [7].

The first step of the human system is a categorisation of dental image dependent on teeth characteristics in the captured dental image. Dental images are categorised as bitewing, low periapical, upper periapical and panoramic (shown in Fig. 1.9) [7–11]. Bitewing images have characteristics of both jaws of the skull. Periapical

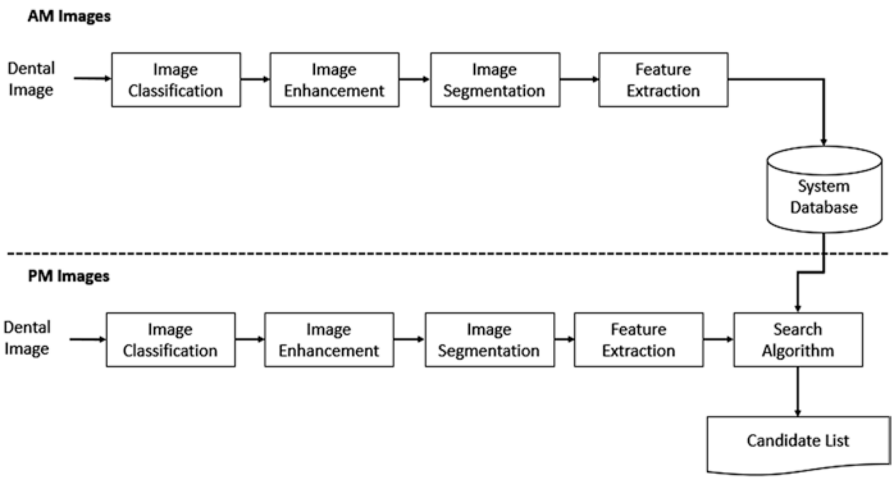


Fig. 1.8 Flow chart for dental image-based human identification system

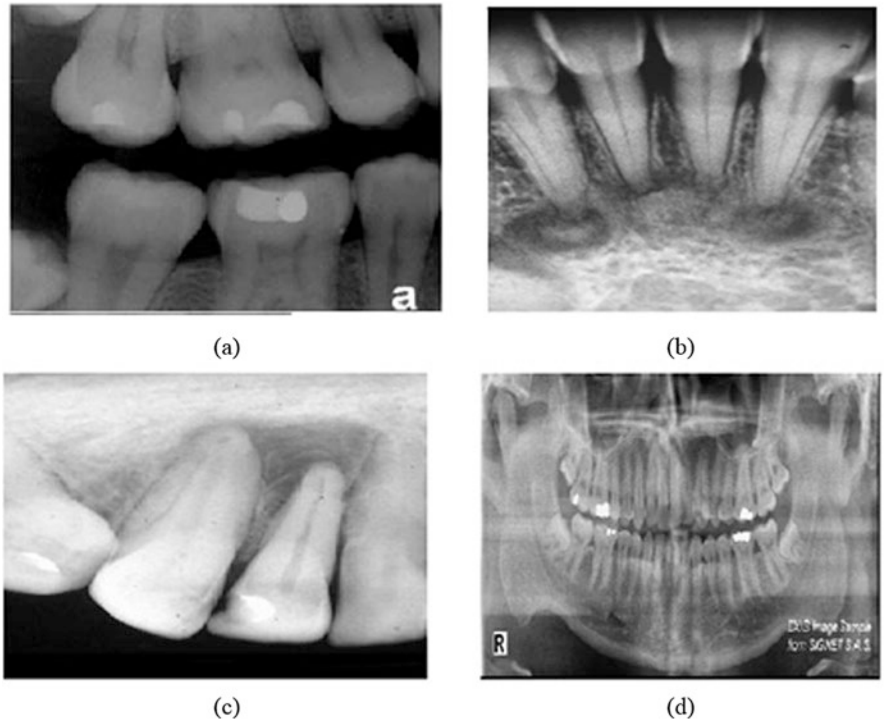


Fig. 1.9 Various types of dental images: (**a**) bitewing, (**b**) low periapical, (**c**) upper periapical and (**d**) panoramic

images have only one jaw, either lower (known as a low periapical image) or upper (known as an upper periapical image). The bitewing image is widely used in all dental image processing [12]. The dental images have three parts: (1) bone area (having average intensity), (2) background area (having lowest intensity) and (3) tooth area (having highest intensity).

Tooth segmentation is done as part of the feature extraction process, where a few specific features of the dental image are obtained. Finally, the characteristics of the antemortem dental image (enrolled image) and postmortem dental image (query image) are compared. For comparison of the PM-AM dental images, the matching distance between features is calculated [13]. Based on the matching distance, a decision about human identification is reached. If the value of the matching distance is low, the indication is that the PM dental image is the best match with AM dental image. The accuracy rate of the algorithm depends on the order contained by the most original AM dental image. The percentage of genuine dental images ranked as first is defined for comparing various algorithms, as follows:

$$\%\mathrm{perf} = \frac{A}{P} \times 100 \tag{1.1}$$

where *A* is number of authentic AM dental images retrieved having rank 1; % perf is performance index, and *P* is number of PM query dental images.

1.8 Book Organization

This chapter briefly discussed the general characteristics of the biometric system, its process and testing parameters. Also, information on dental biometry and the identification system based on it is also described. The rest of this book is organised as follows.

Chapter 2 presents related works on dental image processing available in the literature. This chapter also covers issues in a human identification system. Chapter 3 shows various types of standards for medical images. Chapter 4 gives information and illustrated the mathematics of different image processing algorithms used in the implementation of the dental image-based identification system. Chapter 5 gives a performance analysis of dental image-based identification system using various types of dental images. Chapter 6 concludes the book with several future research directions.

Bibliography

1. Biometrics and Standards (2009). ITU-T Technology Watch Report. http://www.itu.int/dms_pub/itu-t/oth/23/01/T230100000D0002MSWE.doc.
2. Jain, A., & Kumar, A. (2012). Biometric recognition: An overview. In E. Mordini & D. Tzovaras (Eds.), *Second generation biometrics: The ethical, legal and social context* (pp. 49–79). Dordrecht: Springer.
3. Hofer, M. (2007). *Dental biometrics: Human identification based on dental work information*. Brazil: School of Medical Information Technology.
4. Mal, K., & Bhattacharya, S. (2013). Comparative study of different biometric features. *Int J Adv Res Comput Commun Eng, 2*(7), 2776–2784.
5. Jain, A., & Chen, H. (2004). Matching of dental X-ray images for human identification. *Pattern Recognition, 37*, 1519–1532.
6. Chen, H., & Jain, A. (2005). Dental biometrics: Alignment and matching of dental radiographs. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 27*(8), 1319–1326.
7. Zhou, J., & Abdel-Mottaleb, M. (2005). A content-based system for human identification based on Bitewing Dental X-ray images. *Pattern Recognition, 38*, 2132–2142.
8. Shah, S., Abaza, A., Ross, A., & Ammar, H. (2006). Automatic tooth segmentation using active contour without edges. In *The biometric consortium conference, 2006 biometrics symposium: special session on research at the* (pp. 1–6). IEEE.
9. Nassar, D. E. M., & Ammar, H. (2006). A neural network system for matching dental radiographs. *Pattern Recognition, 40*(2007), 65–79.
10. Nazmy, T., Nabil, F., Salam, D., & Samy, H. (2005). Dental radiographs matching using morphological and PCNN approach. In *The international congress for global science and technology* (p. 39). Special Issue of International Journal on Graphics, Vision and Image Processing (GVIP). Cairo.

11. Pushparaj, V., Gurunathan, U., & Arumugam, B. (2012). Human forensic identification with dental radiographs using similarity and distance metrics. In *India Conference (INDICON), 2012 Annual IEEE* (pp. 329–334). IEEE.
12. Nomir, O., & Abdel-Mottaleb, M. (2005). A system for human identification X-ray dental radiographs. *Pattern Recognition, 38*, 1295–1305.
13. Nomir, O., & Abdel-Mottaleb, M. (2008). Hierarchical contour matching for dental X-ray radiographs. *Pattern Recognition, 41*, 130–138.

Chapter 2
Dental Image Matching: A Technical Survey and Potential Challenges

2.1 Technical Survey on Dental Image Matching

In this section, various existing dental image matching algorithms are discussed. These algorithms are based on feature extraction of dental images and comparison of various dental features.

2.1.1 Extraction of Tooth Contour and Matching

Jain et al. [1] have proposed a dental identification system based on dental features. In this system, tooth contour is used as a dental feature. The system has three steps: segmentation of the dental image, contour extraction and shape matching. First, the higher jaw and lower jaw are separated and the tooth is segmented. Then the crown part and the root part are separated. Finally, the corresponding distance between postmortem (PM) and antemortem (AM) dental images is calculated. Here, lesser matching distance is used to improve the matching of the dental image. This system falls short in effectiveness in subsequent phases due to reasons like poor quality of images, dental tooth not completely noticeable or query image partly occluded, natural similarity among tooth shapes of different persons, and different imaging angles of AM images and PM images.

Anil Jain and Hong Chen have suggested the use of dental radiographs for identification [2]. Here, dental features such as contours, the corresponding locations of adjacent teeth and the shape of teeth (bridge crowns and fillings) are used for human recognition. The suggested method is divided into stages such as feature extraction and matching. After these stages, other steps such as shape registration and subject recognition are performed. The algorithm suggested by Jain and Chen is shown in Fig. 2.1 [2].

D. N. Trivedi et al., *Dental Image Processing for Human Identification*,
https://doi.org/10.1007/978-3-319-99471-0_2

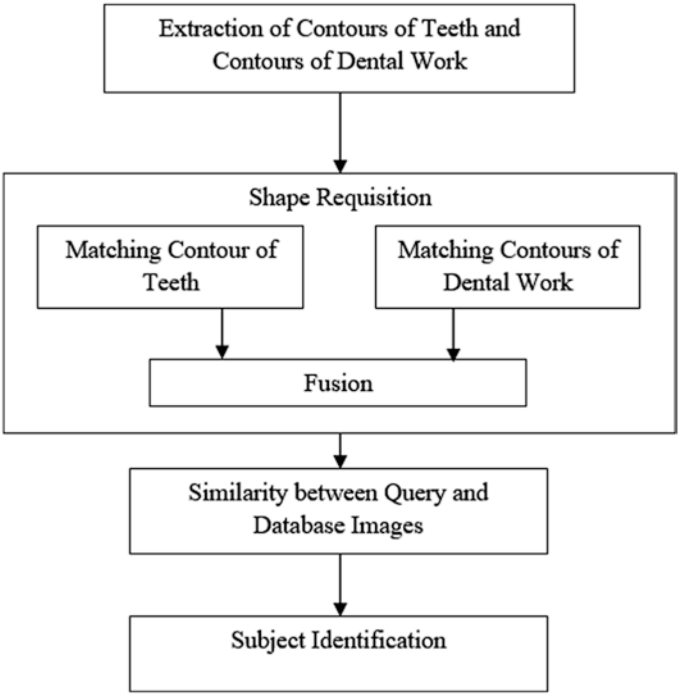


Fig. 2.1 Dental Identification Algorithm indicated by Jain and Chen [2]

2.1.2 Automated Dental Identification System

Around 2006, Hany Ammar [3] and his research team presented the difficulties connected with the PM dental image recognition method. They provided a new protocol for automated dental identification system based on computerised methods. In this system, the dental image is analysed differently by extracting high-level characteristics of the image to speed up the capturing of a probable matching. After that, the low-level characteristics of the image are analysed and dental-to-dental image comparison is used. Ammar and his team suggested a probabilistic model of class-condition densities [4] for feature extraction. Anmar also recommended an adaptive tactic searching method.

In 1997, the Criminal Justice Information Services Division (CJISD) of the FBI developed a dental task force (DTF). The objective of this force was to recover information of missing and unidentified persons based on dental recognition. A dental image repository, referred to as DIR, was used by this task force. The DIR consisted of a computerised dental recognition system with objectives and purposes analogous to that of the automated fingerprint system. This system was fully automated and was used to store dental records [4].

A block diagram of the computerised automated dental identification system (ADIS) is shown in Fig. 2.2 [4]. The DIR is a combination of dental images of humans. These images are stored at the National Crime Information Center (NCIC) and have information such as gender, blood group, etc. The other components of the ADIS system are feature extraction, image retrieval, etc.

Nassar and Ammar offered a tooth categorisation system in Ref. [4], which consists of developing tooth charts. The suggested model proposed by Nassar [4] is given in Fig. 2.3:

- In this model, dental images were matched in two ways based on dental location. Modification in dental images was attained by improvement (grayscale correction), segmentation (object confinement), preregistration (algebraic conversion) and standardised pixel rates.
- After this, the range of obtained information decreased by compression for reducing computation time [4].

2.1.3 Contour Matching

In this section, various matching approaches based on contour are discussed. Nomir et al. [5] have proposed a matching method to eliminate the difficulties in contour matching [6]. In this approach, image enhancement was done by using binarisation process. Then thresholding was applied to the binary image. After thresholding, vital horizontal projection was taken by vertical integral projection on the separated tooth. Contour extractions were done using the Fourier descriptor method and force

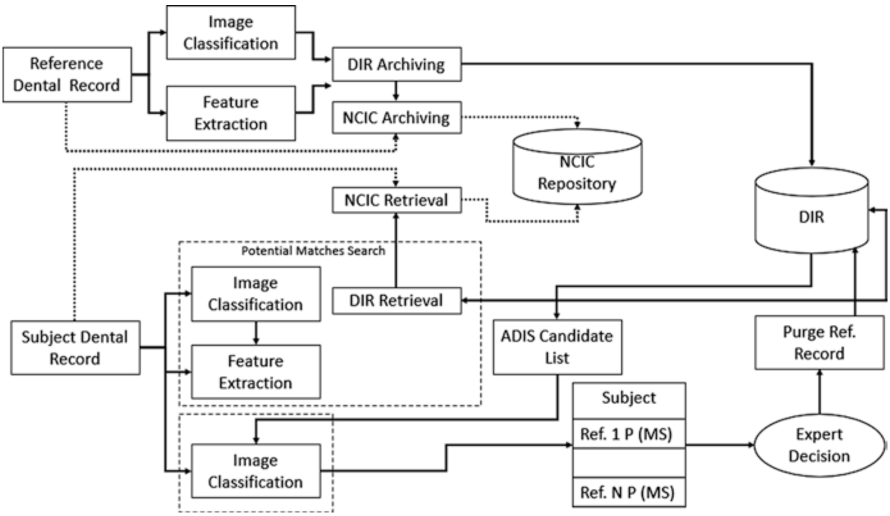


Fig. 2.2 Block Diagram for ADIS Model [4]

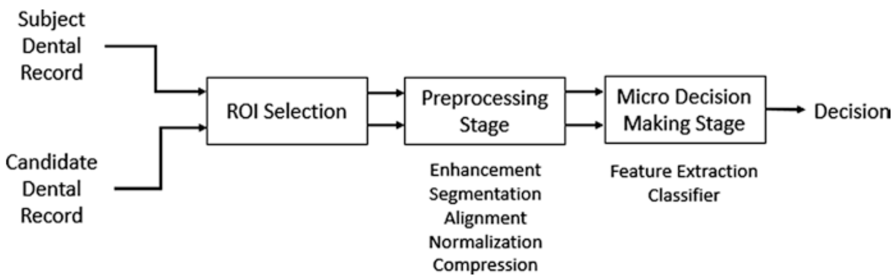


Fig. 2.3 Block Diagram of Dental Image Evaluation suggested by Nassar et al. [4]

field power function. Complete distance (L1 standard) and Euclidean distance (L2 norm) were used for the comparison of dental features. The percentage of recognition (% Perf) of this system is around 86%.

Lin and Lai [7], on the other hand, have suggested a new image enhancement system for dental images. The authors proposed the use of homomorphic filtering to improve illumination in dental images and reduce irregularities. Here, tooth classification was done based on the relative L/W ratio of every pulp, tooth and crown size. However, the suggested model cannot work for poor-quality dental images. This system has an accuracy rate of 94.9% for molar dental images and 95.6% for premolar dental image.

2.1.4 DICOM® Medical Standards and Dental Image Processing Based on It

Around 2010, Bhagat and Antique [8] investigated the Digital Imaging and Communications in Medicine (DICOM®) norm for the distribution and presentation of various types of medical images. This standard comprises explanation on multiple image formats and compression algorithms for medical images. This standard is used by researchers studying the field of medical image processing. This is the most common standard used for scanned images in hospitals.

On the other hand, Sahu and Verma [9] have examined DICOM® for medical images and also described a medical imaging technology known as picture archiving and communication system (PACS®). This electronic system was filmed less information structure for obtaining, storing, transporting and electronically exhibiting medical image. One example of a PACS® project is e-Shshrut Chhavi, which was developed by the Center for Development of Advanced Computing (CDAC), Noida, India. It is handy for any hospital where medical images are used for diagnosis. This system provides features of DICOM® image for investigation of it and information retrieves from it [9]. The Web PACS® system searches for the account data and produces outcome based on existing image information at the time of search [9].

V. Pushparaj et al. [10], meanwhile, discussed about computerised dental identification system. In such system, the tooth contour is used as a feature for matching. This proposed algorithm has five stages. As a beginning step, the dental image is preprocessed. Then the processed dental image is divided into individual teeth using segmentation operation. The contouring of each tooth is done by labelling process. Finally, values of the contours are compared for human matching [10]. Here, space measure is used for better matching. The system is tested using data of 100 dental images, which comprise periapical and bitewing images. The results of this system show that it has a high rate of identification compared to other systems. This system suggested by Pushparaj is shown in Fig. 2.4 [10].

Ajaz and Kathirvelu have proposed a human identification system based on dental features [11] and which consists of three main processing steps: (a) extraction of dental features (crowns, fillings and bridge) using mathematical morphological operations, followed by thresholding; (b) dental code are generated using distance between the adjacent tooth and the angle at which the tooth works are aligned; and (c) matching of the dental code of a PM image with an enrolled code on the database. This system was tested on the basis of data of 30 dental radiograph images. The success rate of this system was around 90%.

Jaffino and Banumathi [12], on the other hand, explained the dental recognition system. The dental image information such as tooth, tooth contours are used for matching purposes. This system was tested using periapical and bitewing dental images. It involves various steps such as preprocessing, feature extraction and matching. The outcomes of this technique are reasonable compared to those of the existing system.

2.1.5 3D Single Tooth Identification

Wong et al. [13] have conducted a study on dental identification system and the development of 3D dental identification system. The 3D dental identification system was used for a dental tooth image where very partial jaws are available.

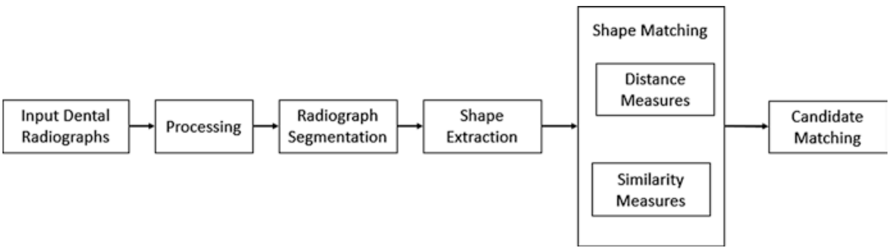


Fig. 2.4 Model indicated by Pushparaj [10]

Two types of single tooth samples, in particular tooth crown segmented from scanned dental casts and an entire single tooth (crown and root) reconstructed from cone beam CT images, were studied. The K-nearest neighbourhood (KNN) classifier was applied for the classification of dental images in terms of the posterior (molar, premolar) and anterior (canine and incisor) tooth types [13]. Then an iterative closest point (ICP) algorithm was applied to match the PM dental image and the AM dental image [13].

This system was tested using a dental image that has a 3D single tooth. The system was tested on 50 PM tooth crowns, 200 AM tooth crowns, ten entire PM single teeth and 100 whole AM single teeth. Two classification schemes were used: two-class and four-class schemes for single-tooth crown identification and complete tooth identification. In the 2-class plan, the anterior (incisor or canine) and posterior (molar or premolar) types of teeth were used, while in the 4-class scheme, the incisor, canine, molar and premolar teeth were used.

For tooth crown identification, the 2-class classification has 96% accuracy, with 76% Rank-1 identification accuracy and maximum identification accuracy of 96% at Rank 1. In contrast, 88% classification accuracy is achieved in the 4-class scheme, with a lower Rank-1 precision of 68% and lower maximum efficiency of 88% at Rank 1. However, the 4-class plan is twice as fast as the 2-class scheme. For incomplete single-tooth (both crown and root) identification, the 2-class classification accuracy attained is 90% accuracy, with 80% Rank-1 identification accuracy and maximum identification accuracy of 90% at Rank 3 [13]. On the other hand, the classification accuracy is 80% in the 4-class scheme, with a lower Rank-1 precision of 70% and lower maximum efficiency of 80% at Rank 2. Here, the 4-class plan is also twice faster than the 2-class plan [13].

Marin et al. [14] have described a recognition system based on various processes such as tooth contour detection, segmentation, and 3D reconstruction. In this system, the features are extracted from dental conical topographies. Automatic contour detection starts by filtering the dental image using adaptive threshold method. The applied approach is innovative for contour detection because it exploits the domain knowledge of particular shape of each tooth (incisor, canine, premolar, molar). The region of interest (ROI) in the tooth is established, and tooth contour is determined using possible edge directions [14]. The overall accuracy of this system is 81.76% [14].

Rajput and Mahajan [15], on the other hand, have studied dental recognition system for the investigation of crimes. The system was developed using PM and AM dental radiographs. This system was also tested using photographic dental images. Here, contour and skeleton-based shape extraction methods were used. The method with binary and Gaussian filtering was used for extraction of the outline of the tooth. Here, the inclusion of both dental radiographs and photographs are improved investigation effects for a dental image database. This work offered a review of a new system for identification of missing persons in mass disasters using data based on dental X-ray images of PM and AM [15].

2.1.6 Modern Image Modalities

Al-Saleh et al. [16] have explored various image models such as multi-detector computed tomography (CT), magnetic resonance imaging (MRI) and positron emission tomography (PET) for showing both soft tissue and skeletal features in dental images. Here, a tool for dental listing was utilised for optimising the arrangement of images. Padmapriya et al. [17], meanwhile, have explored an online information distribution concept for dental image matching, which provides security to distributed dental images.

2.2 Issues in Human Identification System

After studying human identification system based on biometrics, the many disadvantages of these biometric modalities (which are used in identification) are discussed in this section.

Biometrics is a tool of identification that has been broadly used in many applications. A biometric identification system is based on physical characteristics. Dental biometrics has emerged as a vital tool for providing biometric information of human beings on account of its stability, invariant nature and uniqueness. It utilises dental biometric photograph and dental biometric radiograph for human identification. The dental image provides information about a person's teeth, including tooth contour, the relative position of neighbouring teeth and shapes of dental biometric work like crowns, fillings and bridges.

A biometric identification system is based on physical features such as the face, palm print, fingerprint, the eyes (iris, retina) and DNA. However, many of these features are only suitable for antemortem identification, that is, when a person to be identified is still alive. They cannot be used for postmortem identification, especially in cases of body decay or severe body damage caused by fire or collision. Due to this, dental biometrics plays an essential role in human identification and postmortem identification. Whenever a big disaster happens, identifying a person using other biometrics is a big issue as all other biometrics have time-variant characteristics. The face, fingerprints, palm prints, and the eyes are more time-variant biometrics than dental biometrics. They can be damaged during big disasters.

Some points are discussed below regarding biometric issues.

2.2.1 Biometric Modalities

1. *Fingerprint recognition*: ridges and furrows are an essential part of a person's fingerprint. The uniqueness of a fingerprint can be observed through ridges and grooves. For many years, fingerprint identification has been perceived as an

innovative recognition technique. It is accessible, relevant and the oldest method used. Every person has a unique pattern of fingerprints; identical twins have different patterns of fingerprints.

Problems in fingerprint recognition: an artificial material (wax) finger can be made and created easily. Also, skin damages like scars and cuts are big obstacles to this recognition technique.

2. *Face recognition*: the face has many features such as the nose, lips, eyebrows, eyes, ears and chin. All these are essential for the recognition of the location and shape of the face. Face recognition is very user-friendly, accessible and a reliable method. It has two modalities [18]: (a) facial metric and (b) eigenface. In facial metric, the shape and location are measured by the distances between the nose, lips, ears, chin. Different facial parts (e.g. distances between the nose, pupils or jaw) are measured. In eigenfaces, the whole facial image is analysed as 'canonical faces are observed by the weighted combination' [19].

   Problems in face recognition: the face has variant traits. However, when it comes to twins, their facial attributes are not unique. Additionally, due to different expressions, proper identification cannot made with this technique. Lightning is also a significant issue.

3. *Iris recognition*: the iris is a part of eye which connects with a pupil, lens, and some fibres and also controls the pupil. According to lightning, iris acts as a diaphragm and some strength of light is focused. Iris texture is formed in the early life of human called morphogenesis. After formation, throughout the entity, its remain stable.

   Today's biometric systems mostly rely on the iris. The colour of the iris is the colour of the eye, so it is an essential part of the eye. Every human has a different iris colour and texture. The iris is captured by camera technology that produces infrared illumination. Sometimes blood pressure and diabetes are reasons why the colour of the iris turns to grey [18].

   Problems in iris recognition: scanners are expensive, and image quality changes depending on the scanners. For this technique to work, user cooperation is essential. Finally, the colour of the iris changes due to diabetes and blood pressure.

4. *Hand geometry*: this recognition method includes measuring the thickness, length, width, surface area and overall structure of the hand bone. A person's hand geometry does not change over a period of time. Thus, it is an efficient tool for matching. Hand geometry system consists of two methods [18]: (a) contact based and (b) contact-less based. In contact based, the hand should be placed on a flat surface and hand image captured by cameras. In contact-less-based, neither pegs nor a platform is required for hand image capturing.

   Problems in hand geometry recognition: it is not unique and not adequate for children. Rings, arthritis, etc. may also pose a challenge.

5. *Retina scan*: the pattern of the blood vessels at the back of the eye is unique from person to person and from eye to eye. The retina is observed through an infrared light source and not by normal light. Blood vessels can absorb infrared energy faster than can other tissues. Through the blood vessel pattern of the

retina, matching could be simple and easy due to its uniqueness. However, a person's cooperation during the performance of the technique is necessary as focus would be required on certain areas for a few seconds. Coherent source of illumination and coupler are needed to read the blood vessels [18].

Problems in retina scan recognition: this method explores a person's medical information (e.g. hypertension, diabetes), thus causing privacy concerns. It is not user-friendly. Diseases influence measurement accuracy.

6. *DNA recognition*: DNA is person's genetic material. Every single person has a different DNA. There are various sources of DNA. DNA patterns can be collected from a person's nails, saliva, blood, hair and others. After collecting DNA, samples are processed and segmented by size. Then comparison of DNA samples with other DNA samples is made. This process, however, is not fully automated and is not user-friendly [18].

   Problems in DNA recognition: private information is shared. It requires large storage. It is not a fully automated system. It is not user-friendly and is very costly.

7. *Signature*: it is a depiction of a person's name, surname, or nickname on documents. It can be used as proof for the identity of a person. Signature is widely used and accepted in governments, non-governmental organisations (NGOs) and legal transactions as proof of identification. In forensic science, all facts relating to a criminal are explored during the process of signature matching. For the authentication of a person, mostly banks are used for obtaining signature specimen.

   Problems in signature recognition: any professional fraudster would be able to reproduce fake signatures. Based on psychology, a person's signature changes from time to time. And due to a person's medical or emotional condition, signature might be broken.

8. *Keystrokes*: this method examines how a person types on the keyboard. It includes the pace, pressure and style of release of a person. Keystrokes change from person to person [18].

   Problems in keystrokes: timing patterns change, as well as pushing and releasing. The system can also depend on the hardware.

9. *Voice recognition*: it explores the vocal features that produce speech. It does not concern sound and pronunciation of the speech. The vocal properties depend on the dimensions of the nasal cavities, vocal tract, mouth and some other speech-processing behaviour of the human body. This has three different types [18]. (a) Text-dependent systems: the enrolled user is requested to say a phrase or word that was already spoken by the user. Then it is compared with the stored samples. (b) Text-prompted systems: from the pre-recorded data of the system, the user has to repeat a word or read a word. (c) Text-independent systems: without text, some sounds are produced and enrolled and query sound is matched. Words and text are not used to match, only phonetic sounds.

   Problems in voice recognition: noise intrusion from the environment and size of the database are some examples. Also, voice quality changes when a person is suffering from cold or because of emotional conditions.

2.2.2 Usefulness of Dental Modality

On 26 December 2004, a big disaster occurred (tsunami) around the Indian ocean, and more than 5000 people were killed by the earthquake [20]. Thailand was the country most affected.

In the southern part of Thailand, around 100 resorts were damaged, and about 2000 of those killed were foreigners. To deal with the situation, the Tahi government established a team of expert from all over the world. The task of this disaster management team was to identify the 5000 dead bodies. Within a short time after the disaster, around 1500 dead bodies were identified and released to their families. Identification of the bodies was carried out on the basis of physiological traits, witness testimonies and other reliable evidence. On 12 January 2005, the Thailand Tsunami Victim Identification (TTVI) operation was formally carried out by the Thai government. The countries' military officers and experts all joined efforts to resolve the situation.

The key takeaways from the TTVI operation are enumerated below [20]:

- Its purpose is to collect data relating to the physical traits of the dead victims, to collect earlier data from their families and to match all biometric traits.
- Multimodal analysis was done.
- The Thai forensic had very little data of the physical traits of their people.
- North America and the UK had 90% database of their people.
- Dental biometrics was the most powerful tool for identifying the dead bodies.
- Fingerprints and information on the iris were not obtained from the bodies.
- Around 46% of the bodies were identified by their dental traits.

The TTVI committee used various methods for obtaining the biometrics of the people who died or went missing because of the tsunami. These methods are as follows:

- *Dead bodies*: with the aid of more than 20 countries and 500 dentists, dental biometric evidence was obtained from the recovered bodies. International authorities initially presumed that many of the dead bodies were foreigners. After a thorough investigation by the Thai team, they were able to calculate how many of the dead bodies were Thai and how many were foreigners. All the victims' dental biometrics were collected and stored in one database and then processed. Early data of the dead victims were also saved and verified by the verification team. After the entire verification process, some of the dead bodies were identified.
- *Missing persons*: police agencies of various countries collected the dental biometrics of the victims. All of the process was organised by Interpol. The Thai government asked the victims's family to provide dental biometric records from clinics and hospitals and then submit to the TTVI. Simultaneously, the Thai dental biometric council distributed missing person data lists to all dental biometric authorities and gathered authentic records of patients who were on their records.

- *Dental biometric identification process*: the Thailand government used the Disaster Victim Identification (DVI) international software to do analysis based on the dental images of the victims. The information collected is recorded on the Interpol DVI antemortem and postmortem forms.

The TTVI committee also conducted a survey on the problems encountered during the process of analysing the victims' biometrics. The robustness property of teeth makes used for person identification by the forensic department. The teeth of the human body can better withstand any damage compared to other body parts. In cases of disasters like a tsunami, it has been proved that dental biometric records are more reliable than other physiological tools. Moreover, in those bodies where the skull was not damaged, dental biometric records were available. The availability of dental biometric records proved that in critical situations, identification can be made.

In most countries, adequate dental biometrics was available, whereas in some countries, it was not. But not all the tooth records were used for identification. Only those that contained the required traits were matched. While Europe and America had a high percentage of dental biometric records, thus proving that it could be a primary tool for the identification of victims, other countries showed either insufficiency in collecting biometric data or lack of awareness regarding science and technology. Based on the analysis of its expert team, the Thai government did not have proper dental trait records. Whatever treatment was done on patients, records did not contain information like treated tooth/teeth, missing tooth/teeth, implantation material used, etc. [20]. Within first four months after the disaster, a survey came out with the following information [20]:

- Most dead bodies were released by identifying their dental records.
- Due to severe damage to the body, iris and fingers were missing.
- Dental record processing is secure and less pricey than others.
- Because the Thai government did not have dental records, it used DNA for matching, and it was too costly and time-consuming.
- Fifty percent of the Thai dead bodies needed DNA.
- Only 10% of bodies needed DNA matching in Europe and North America, so analysis done by these countries was less expensive and time-consuming.
- The Thai people lacked dental care awareness, so the government needed to work harder to resolve this issue.
- It had been proved by the report of the TTVI that dental traits were more reliable and easy to use in a disaster situation.
- Countries like the UK and the USA had a towering rate of antemortem, so they paid less money for the survey.
- Thailand and other Asian countries had some dental records, but they were not presented in proper format, teeth were missing and treatment information was not clear.
- The Canadian team used advanced technology like the internet, leading to the identification of all the Canadian victims.

- All the Asian countries did not perform professional work relating to biometric records.
- Dental biometrics is an essential tool in disasters for recognising a person.
- Record keeping of biometrics must be improved so records can be used successfully.

After doing a survey on the use of dental biometric data in today's world, it is concluded that human recognition based on dental images is the most effective tool for human identification in many organisations and in worse disaster conditions such as tsunamis, earthquakes, etc.

2.3 Proposed Human Identification System Based on Dental Modality

After a survey on the different human identification systems based on dental modalities, this book suggests the use of dental-image-based identification system to overcome some of the limitations of the existing identification system. This system is implemented using dental feature extraction and contour value comparison. A block diagram of the proposed human identification system based on dental modality is shown in Fig. 2.5.

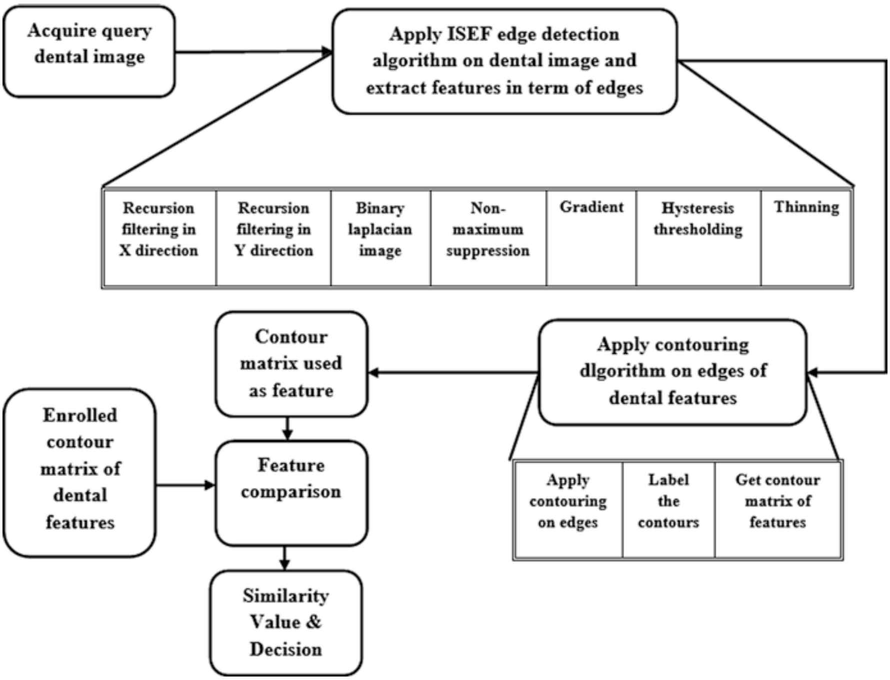


Fig. 2.5 Proposed Human Identification System based on Dental Modality

This identification system used advance standardised DICOM® images. Subsequently, a variety of segmentation algorithms are used to obtain dental features form dental biometric image. Different dental features (maxilla, mandible, tooth contour) of the human being are taken out, and detection is executed by comparing the corresponding trait symbols of PM descriptions with those of AM descriptions.

In this system, tooth contours are used as a dental feature. A semi-regular contour withdrawal method is used to deal with unidentifiable tooth contours caused by low image quality. This method involves three stages: contour matching, pixel classification and radiograph segmentation.

Bibliography

1. Jain, A., & Chen, H. (2004). Matching of dental X-ray images for human identification. *Pattern Recognition, 37*, 1519–1532.
2. Chen, H., & Jain, A. (2005). Dental biometrics: Alignment and matching of dental radiographs. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 27*(8), 1319–1326.
3. Ammar, H. H., Abdel-Mottaleb, M., & Jain, A. (2004). Towards an automated dental identification system (ADIS). In *Biometric authentication* (pp. 789–796). Berlin, Heidelberg: Springer.
4. Nassar, D. E. M., & Ammar, H. H. (2006). A neural network system for matching dental radiographs. *Pattern Recognition, 40*, 65–79.
5. Nomir, O., & Abdel-Mottaleb, M. (2008). Hierarchical contour matching for dental X-ray radiographs. *Pattern Recognition, 41*, 130–138.
6. Lira, P. H., Giraldi, G. A., & Neves, L. A. (2009). Panoramic dental X-ray image segmentation and feature extraction. In *Proceedings of V workshop of Computing Vision*. Brazil: Sao Paulo.
7. Lin, P. L., & Lai, Y. H. (2009). An effective classification system for dental bitewing radiographs using entire tooth. *WRI Global Congress Intell Syst, 4*, 369–373.
8. Bhagat, A. P., & Atique, M. (2010). Medical images: Formats, compression techniques and DICOM image retrieval a survey. In *Devices, circuits and systems (ICDCS), 2012 International Conference on* (pp. 172–176). IEEE.
9. Sahu, B. K., & Verma, R. (2011). DICOM search in medical image archive solution e-Sushrut Chhavi. In *Electronics computer technology (ICECT), 2011 3rd international conference on* (Vol. 6, pp. 256–260). IEEE.
10. Pushparaj, V., Gurunathan, U., & Arumugam, B. (2012). Human forensic identification with dental radiographs using similarity and distance metrics. In *India conference (INDICON), 2012 annual IEEE* (pp. 329–334). IEEE.
11. Ajaz, A. and Kathirvelu (2013). Dental biometrics: computer-aided human identification system using the dental panoramic radiographs. In Communications and signal processing (ICCSP), 2013 international conference on (pp. 717–721). IEEE.
12. Jaffino, G., Banumathi, A., Gurunathan, U., & Jose, J. P. (2014). Dental work extraction for different radiographic images in human forensic identification. In *Communication and network technologies (ICCNT), 2014 international conference on* (pp. 52–56). IEEE.
13. Wong, Y. S., Zhong, X., Lu, W. F., Foong, K. W. C., & Cheng, H. L. (2015). An approach for single-tooth classification and identification. In *Industrial electronics and applications (ICIEA), 2015 IEEE 10th conference on* (pp. 1698–1702). IEEE.
14. Marin, I. Pavaloiu, I., Goga, N., Vasilateanu, A. and Dragoi, G. (2015). Automatic contour detection from dental CBCT DICOM data. *In E-health and bioengineering conference (EHB), 2015* (pp. 1–4). IEEE.

15. Rajput, P. V., & Mahajan, K. J. (2016). Review on dental biometric in human forensic identification. *Int Res J Eng Technol, 3*(4), 1685–1688.
16. Al-Saleh, M. A., Alsufyani, N. A., Saltaji, H., Jaremko, J. L., & Major, P. W. (2016). MRI and CBCT image registration of temporomandibular joint: A systematic review. *J Otolaryngol Head Neck Surg, 45*(1), 30.
17. Praveenkumar, P., Priya, P. C., Thenmozhi, K., Rayappan, J. B. B., & Amirtharajan, R. (2016). Convoluted Rubik's encoded quantum polarized-a secure DICOM image. In *Computer communication and informatics (ICCCI), 2016 international conference on* (pp. 1–5). IEEE.
18. Kaur, G., & Verma, C. K. (2014). Comparative analysis of biometric modalities. *Int J Adv Res Comput Sci Softw Eng, 4*(4), 603–613.
19. Sirovich, L., & Kirby, M. (1987). Low-dimensional procedure for the characterization of human faces. *J Opt Soc Am, 4*(3), 519–524.
20. Petju, M., Suteerayongprasert, A., Thongpud, R., & Hassiri, K. (2007). Importance of dental Records for Victim Identification Following the Indian Ocean tsunami disaster in Thailand. *Public Health, 121*(4), 251–257.

Chapter 3
Analytical Study of Edge Detection Algorithms and Contouring Algorithm

3.1 Various Edge Detection Algorithms

In this section, different edge detection algorithms are discussed. These algorithms are used in the presented dental identification system and are used for the detection of the edge features of dental images.

Edge detection is one of the most common operations used in image analysis. There are many algorithms available in the literature for enhancing and detecting edges compared to any other single subject. A comparison of the various types of edge detection algorithms is provided in Table 3.1 [1]. Based on the comparison, it is shown that Shen-Castan (ISEF) edge detector algorithms perform better than other edge detection algorithms Fig. 3.1.

Edge detection of the image using various edge detection algorithms is given in Fig. 6.1. The results show that canny edge detection works better than other types of edge detection algorithms. The test image is taken from the standard image database of the University of California [2].

3.2 Canny Edge Detection Algorithm

In this section, a mathematical description is provided and the use of canny edge detection algorithm is explained. This edge detection algorithm uses a filter whose response is Gaussian distribution [3]. The reaction of the one-dimension Gaussian filter is shown in Eq. (3.1):

$$G(x) = e^{-\frac{x^2}{2\sigma^2}} \tag{3.1}$$

D. N. Trivedi et al., *Dental Image Processing for Human Identification*,
https://doi.org/10.1007/978-3-319-99471-0_3

Table 3.1 Comparison of Various Edge Detection Algorithms

Edge Detection Algorithm	Advantages	Disadvantages
Classical (Sobel, Prewitt, Kirsch, etc.)	Simplicity, detection of edges and their orientations	Sensitive to noise and inaccurate
Zero Crossing (Laplacian, Second Directional Derivative)	Detection of edges and orientations Having characteristics in all directions	Responding to some of the existing edges and sensitive to noise
Laplacian of Gaussian (LoG) (Marr-Hildreth)	Finding the correct places of edges, testing a wider area around the pixel	Malfunctioning at corners, curves and the grey-level intensity function varies, not finding the orientation of edge because of using the Laplacian filter
Gaussian (Canny, Shen-Castan)	Using probability for finding the error rate, localisation and response Improving the signal to noise ratio Better detection, especially in noise conditions	Complex computations, false zero crossing and time-consuming
Coloured Edge Detectors	Accurate and more efficient in object recognition	Complicated and complex computations

The reaction of the two-dimension Gaussian filter is given in Eq. (3.2), and the characteristic of this filter is shown in Fig. 3.2:

$$G(x,y) = e^{-\left[\frac{x^2+y^2}{2\sigma^2}\right]} \tag{3.2}$$

The canny edge detection algorithm specifies three issues:

- *Error rate*: edge detection by the algorithm should be very sharp and specific. It only responds to edges in ways that edges should not be missed.
- *Localisation*: the distance between the edge pixel found by the algorithm and the actual edge pixel should be as less as possible.
- *Response*: the algorithm should not find multiple edges where only a single side is there.

The implementation steps for the canny edge detection algorithm is as follows [1, 3, 4]:

- Read in the image to be processed, I.
- Create a 1D Gaussian mask G to convolve with I. The standard deviation of this Gaussian is a parameter for the edge detector.
- Create a 1D mask for the 1st derivative of the Gaussian in the x and y directions, G_x and G_y. The same value is used as in step 2.
- Convolve the image I with G along the rows to give the x component image I_x and down the columns to provide y component image I_y.

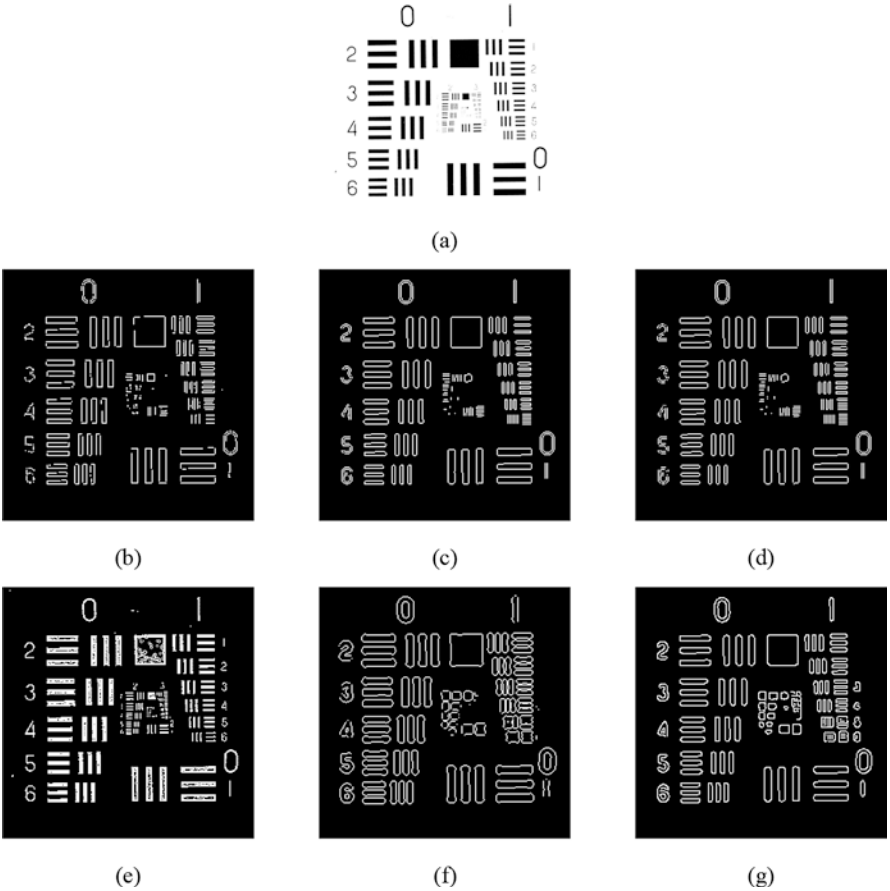
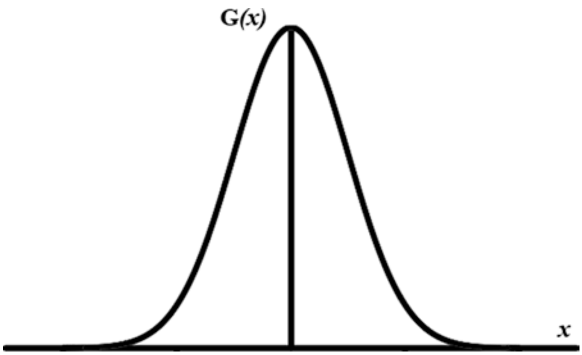


Fig. 3.1 Results of Edge Detection Algorithms (**a**) Original Image (**b**) Roberts Edges (**c**) Sobel Edges (**d**) Prewitt Edges (**e**) Laplacian Edges (**f**) Log Edges (**g**) Canny Edges

Fig. 3.2 Characteristics of Canny Edge Detection Algorithm



- Convolve I_x with G_x to give I'_x, the x component of I convolved with the derivative of the Gaussian, and convolve I_y with G_y to provide i with $'_y$.
- To know the result for this, combine x and y components. The magnitude of the effect is computed at each pixel (x, y):

$$P(x,y) = \sqrt{I'_x(x,y)^2 + I'_y(x,y)^2} \tag{3.3}$$

Some issues such as bandlimiting, sensitivity to noise and inaccuracy are associated with canny edge detection algorithm when it is applied to images. These limitations are overcome by the Shen-Castan edge detection algorithm [5]. This algorithm is also known as ISEF edge detection algorithm.

3.3 Shen-Castan (ISEF) Edge Detection Algorithm

Canny's edge detector defined optimality concerning a specific set of criteria. While these criteria seem reasonable enough, there is no compelling reason to think that they are the only possible ones. That implies that the concept of optimality is a relative one and that the existence of a better (in some circumstances) edge detector than Canny's is a possibility. ISEF works recursively so that sharp edges can be found. The striking problem in edge detector is avoided by gradient and threshold [5]. However, the analysis of edge detection yields a different function to optimise: namely, suggest minimising (in one dimension) [5]:

$$C_N^2 = \frac{4\int_0^\infty f^2(x)\,dx \cdot \int_0^\infty f'^2(x)\,dx}{f^4(0)} \tag{3.4}$$

That is, the function that reduces C_N is the optimal smoothing filter for an edge detector. The optimal filter function is given in Eq. 3.5, and the characteristics of ISEF are shown in Fig. 3.3. This filter function is known as infinite symmetric exponential filter (ISEF) function:

$$f(x) = \frac{p}{2} e^{-p|x|} \tag{3.5}$$

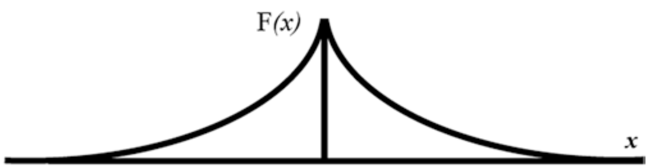


Fig. 3.3 Characteristics of ISEF Edge Detection Algorithm

Shen and Castan maintain that this filter gives a better signal to noise ratios than Canny's filter and provides better localisation [5]. The designing of Canny's algorithm depends on optimal filter with Gaussian response. On the other hand, Shen and Castan used the optimal filter directly. It could also be due to a difference in the way the different optimality criteria are reflected in reality.

On the other hand, Shen and Castan do not address the multiple response criteria, and as a result, it is possible that their method will create spurious responses to noisy and blurred edges. 2D ISEF is given in equation below:

$$f(x,y) = a \cdot e^{-p(|x|+|y|)} \tag{3.6}$$

This can be applied to an image in much the same way as the derivative of the Gaussian filter, as a 1D filter in the x-direction, and then in the y-direction. However, Shen and Castan gave a realisation of their filter as one-dimensional recursive filters. While a detailed discussion of recursive filters is beyond the scope of this book, a quick summary of this specific case may be useful [6]. The filter function f in Eq. 3.5 is a real, continuous function.

$$f(x,y) = \frac{(1-b)b^{(|x|+|y|)}}{1+b} \tag{3.7}$$

The steps in ISEF edge detection algorithm are shown in Fig. 3.4. Figure 3.4 shows how seven stages are sequentially applied to any input images, and after gradient, hysteresis thresholding is used to eliminate striking problems, which means avoiding disconnected edges or connecting edges that are removed by noise or processing. According to gradient and changing in thresholding, disconnected edges are to be connected. The details of each stage are given in the next subsections [5].

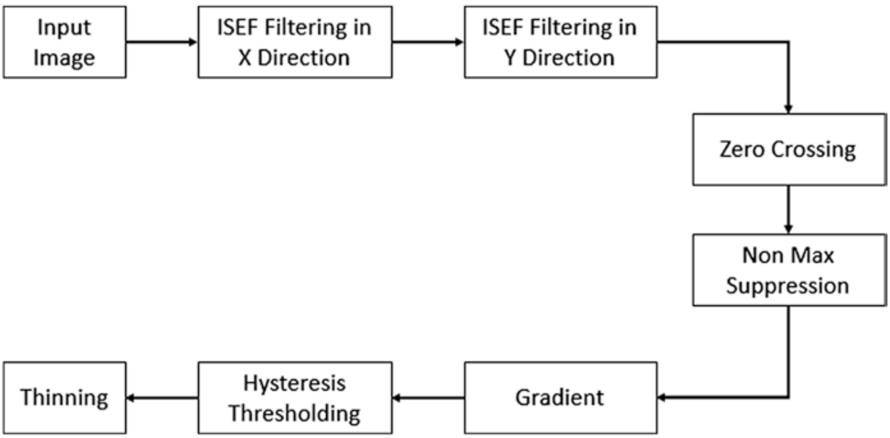


Fig. 3.4 Steps for ISEF Edge Detection Algorithm

In this edge detector, first, recursive filtering in the x-direction is done, and provided as $r[i, j]$:

$$\begin{aligned}
y_1[i,j] &= \frac{1-b}{1+b} I[i,j] + b y_1[i, j-1], j = 1 \ldots N, i = 1 \ldots M \\
y_2[i,j] &= b \frac{1-b}{1+b} I[i,j] + b y_1[i, j+1], j = 1 \ldots N, i = 1 \ldots M \\
r[i,j] &= y_1[i,j] + y_2[i, j+1]
\end{aligned} \tag{3.8}$$

with the boundary conditions:

$$\begin{aligned}
I[i,0] &= 0 \\
y_1[i,0] &= 0 \\
y_2[i, M+1] &= 0
\end{aligned} \tag{3.9}$$

Then filtering is done in the y-direction, operating on $r[i, j]$ to give the final output of the filter, $y[i, j]$:

$$\begin{aligned}
y_1[i,j] &= \frac{1-b}{1+b} I[i,j] + b y_1[i-1, j], j = 1 \ldots N, i = 1 \ldots M \\
y_2[i,j] &= b \frac{1-b}{1+b} I[i,j] + b y_1[i+1, j], j = 1 \ldots N, i = 1 \ldots M \\
y[i,j] &= y_1[i,j] + y_2[i+1, j]
\end{aligned} \tag{3.10}$$

with the boundary conditions:

$$\begin{aligned}
I[0,j] &= 0 \\
y_1[0,j] &= 0 \\
y_2[N+1, j] &= 0
\end{aligned} \tag{3.11}$$

The use of recursive filtering speeds up the convolution significantly. In the ISEF implementation at the end of the chapter, filtering is performed by the function ISEF, which is called $ISEF_{Vert}$ for filtering of the rows and $ISEF_{Horiz}$ for filtering of the columns. The value of b is a parameter for the filter and is specified by the user. All of the work at this point computes merely the filtered image. Edges are located in this image by finding zero crossings of the Laplacian, a process similar to that undertaken in the Marr-Hildreth algorithm. An approximation to the Laplacian can be obtained quickly by merely subtracting the original image from the smoothed image. That is, if the filtered image is S and the original is I, the smoothed image is obtained using the below equation:

$$S[i,j] - I[i,j] \approx \frac{1}{4a^2} I[i,j] * \nabla^2 f(i,j) \tag{3.12}$$

The resulting image $\boldsymbol{B} = (\boldsymbol{S} - \boldsymbol{I})$ is the band-limited Laplacian of the image. From this, the binary Laplacian image (BLI) is obtained by setting all of the positively valued pixels in B to 1 and all others to 0; this is calculated by the C_N function computable in the ISEF source code provided. The candidate edge pixels are on the boundaries of the regions in BLI, which correspond to the zero crossings. These could be used as edges, but some additional enhancements improve the quality of the edge pixels identified by the algorithm. The first improvement is the use of false zero-crossing suppression, which is related to the non-maximum suppression performed in the Canny approach. Zero crossing is there, at the place of an edge pixel with the second derivative of the filtered image. The minimum or maximum gradient is available at the edge. Positive zero crossings at the second derivative alter sign from positive to negative, and it is called a negative zero crossing if it changes from negative to positive. Positive zero crossings are allowed for a positive gradient and negative zero crossings for a negative gradient. All additional zero crossings are unspecified to be fake (spurious) and are not measured to communicate to an edge. In situations where the original image is very noisy, a standard thresholding method may not be sufficient. The edge pixels could be threshold using a global threshold applied to the gradient, but Shen and Castan suggest an adaptive gradient method.

A window with fixed width W is centred at candidate edge pixels found in the BLI. If this is indeed an edge pixel, then the window will contain two regions of different grey level separated by an edge (zero-crossing contour). The best estimate of the gradient at that point should be the difference in level between the two regions, where one area corresponds to the zero pixels in the BLI and the other corresponds to the one-valued pixels. Finally, a hysteresis thresholding method is applied to the edges. This algorithm is the same as the one used in the Canny algorithm, adapted for use on an image where edges are marked by zero crossings. The two single edge detectors examined in this book are the Canny operator and the Shen-Castan method. An excellent way to end the discussion of edge detection may be to compare these two approaches against each other.

The two methods may be summarised as follows: the Canny algorithm convolves the image with the derivative of a Gaussian then performs non-maximum suppression and hysteresis thresholding. The Shen-Castan algorithm convolves the image with the Infinite Symmetric Exponential Filter, computes the binary Laplacian image, suppresses false zero crossings, performs adaptive gradient thresholding and finally also applies hysteresis thresholding. Both algorithms offer user-specified parameters, which can be useful for tuning the method to a particular class of images. The user-defined parameters in algorithms are sigma (standard deviation) $0 <= b <= 1.0$ (smoothing factor), high hysteresis threshold, low hysteresis threshold and width of the window for adaptive gradient thinning factor.

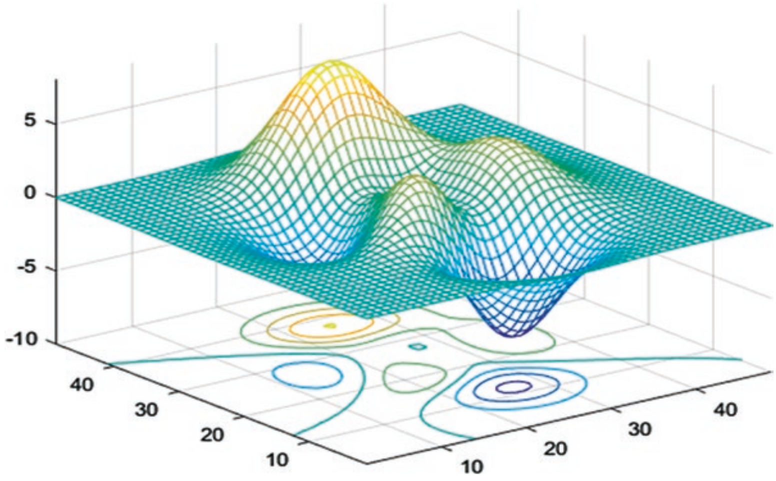


Fig. 3.5 Contour Heights and Project on Surface

3.4 Contouring Algorithm

Contour is a curve that can specify the difference of two successive values of any matrix. When all the values of an image data matrix are connected, some patterns are generated. Contour is also a curve that is created by isolines, and it is dependent on matrix pixel's value of any image. According to the difference between the pixels value, the height of the contour will vary as shown in Fig. 3.5.

The contouring algorithm first decides which contour levels to draw. Based on the specified level of contour, contours are established. If the user is not defined, then the software itself will set the value of 20 contour levels, which shall be divisible by 2 or 5. The contouring algorithm treats the input matrix Z as a frequently spaced grid, with each part linked to its adjacent neighbours. The algorithm verifies each pixel in matrix which are adjacent and make comparison between them to generate matrix with different contour values. If pixels have different values, they are interpolated by values and points are marked. After the completion of this process, all interpolated points are connected to make a contour curve. In all available literature on contouring studied [7, 8], it is indicated that contouring is a simple and practical method, as described below:

- It obtains the image.
- It pertains to edge detection algorithm
- It pertains to image contouring
- It labels the contours
- For comparison, feature of the contour matrix is used.

How bilinear interpolation works in contouring algorithm is described as follows: any matrix of 5×5 where every pixel has adjacent pixels in x-direction and

y-directions is used. Then insertion is done precisely, as shown in a graphical way in Fig. 3.6 below:

$$
\begin{aligned}
I_{20.2,14.5} &= \frac{21-20.2}{21-20}\cdot 150.5 + \frac{20.2-20}{21-20}\cdot 128.5 = 146.1 \\
I_{20,14.5} &= \frac{15-14.5}{15-14}\cdot 91 + \frac{14.5-14}{15-14}\cdot 210 = 150.5 \\
I_{21,14.5} &= \frac{15-14.5}{15-14}\cdot 162 + \frac{14.5-14}{15-14}\cdot 95 = 128.5
\end{aligned}
\tag{3.13}
$$

Here, the matrix only has the values 0 and 1, as shown in Table 3.2. So interpolation will be done at 0.5 but where adjacent pixels' value is being changed in x-direction and y-directions. The interpolation point is marked by a dot, all the dots are connected and one pattern is to be done by comparing them. This is a 5 × 5 matrix only (shown in Fig. 3.7). But in real image processing, the size of the image will be 512 × 512 matrix, and so many contours are to be made.

Another 10 × 10 matrix is taken to better explore how contours should be plotted using bilinear interpolation. Here also whenever pixel values are being changed in the x-direction, y-direction points are marked. Suppose a value between 3 and 4 is changed, location is marked at 3.5, according to the bilinear interpolation theory. Similarly, all the pixels should be checked and relevant points marked, then all aspects are to be connected. Our contours are made for a 10 × 10 matrix (shown in Fig. 3.8).

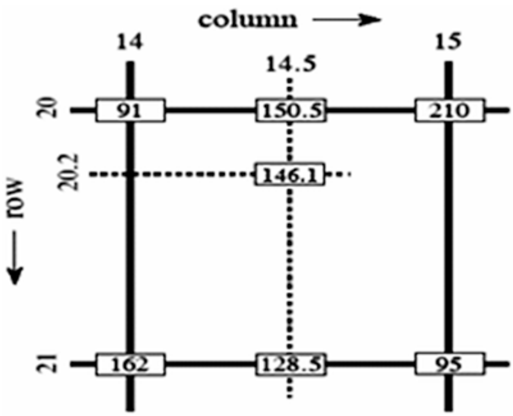


Fig. 3.6 Graphical Representation of Bilinear Interpolation

Table 3.2 Sample Values of 5 × 5 Matrix

	1	2	3	4	5
1	0	1	0	0	0
2	0	0	0	0	1
3	0	0	1	0	0
4	0	0	1	0	1
5	0	1	1	1	0

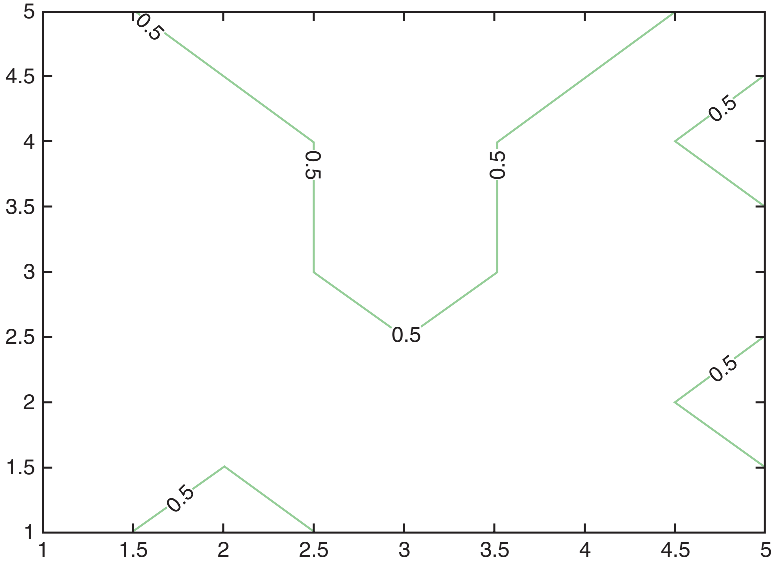


Fig. 3.7 Contouring of 5 × 5 Matrix

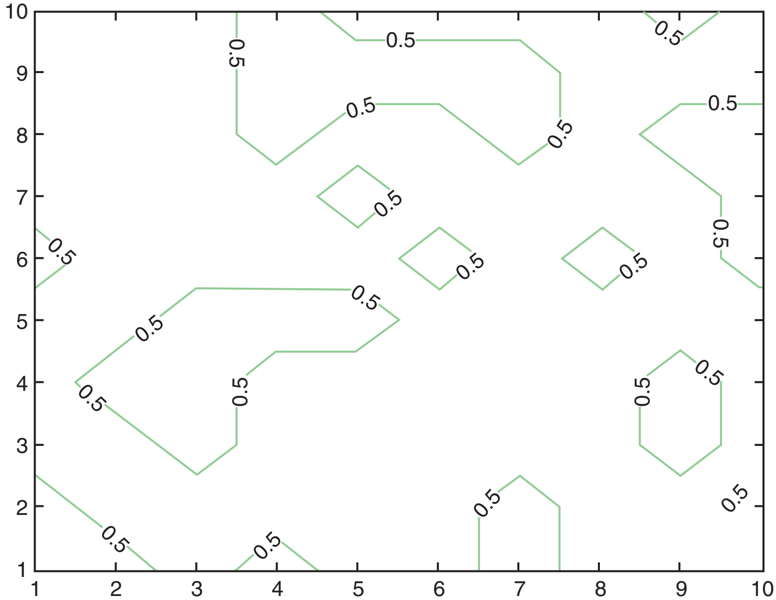


Fig. 3.8 Contouring of 10 × 10 Matrix

3.5 Graphical User Interface

A graphical user interface (GUI) [9] is a graphical display that contains pop-up menu, interactive buttons and a variable component that can directly interface with another graphics without using commands and text in MATLAB [10]. In GUI, sometimes the user does not have any technical information about the task or project, although it can be accomplished by the end user. The GUI components may be list box menus, push buttons, toolbars, radio buttons and sliders. The user can explore data in graphs, histograms and tabular-related attributes. The GUI contains below features:

- It has an axis component
- A pop-up menu explores different data set related to various MATLAB functions.
- Various text components are available to be restored in the pop-up menu or buttons
- Multiple buttons give different level plots: contour, surface and mesh.

If the user wants to design any GUI, the user needs to determine (1) what the user wants it to do, (2) how the user should interact with it and (3) what components are required. Then the user must decide what technique that the user wants to use to create a GUI. MATLAB enables the user to develop GUIs programmatically or with GUIDE, an interactive GUI builder [10]. It also provides functions that simplify the creation of standard dialogue boxes. The technique the user choose depends on user experience, user preferences and the kind of GUI that the user wants to create.

In this book, presented human identification system based on dental images are implemented using GUI in MATLAB and generate results are covered in the Chap. 5. The GUI of the human identification system based on dental images is shown in Fig. 3.9.

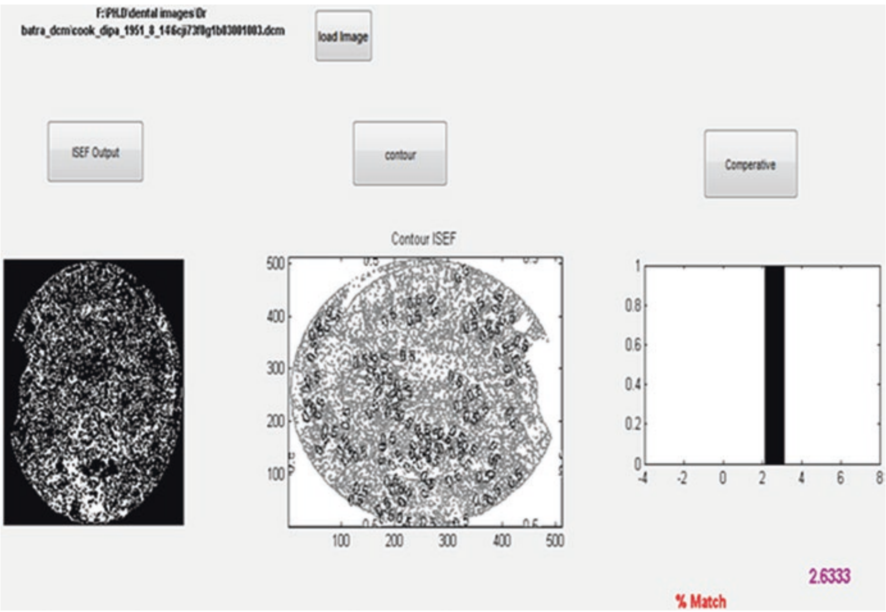


Fig. 3.9 GUI of Human Identification System based on Dental Images

Table 3.3 Sample Values of 10 × 10 Matrix

	1	2	3	4	5	6	7	8	9	10
1	1	1	0	1	0	0	1	0	0	0
2	1	0	0	0	0	0	1	0	0	1
3	0	0	1	0	0	0	0	0	1	0
4	0	1	1	0	0	0	0	0	1	0
5	0	0	1	1	1	0	0	0	0	0
6	1	0	0	0	0	1	0	1	0	1
7	0	0	0	0	1	0	0	0	0	1
8	0	0	0	1	0	0	1	0	1	1
9	0	0	0	1	1	1	1	0	0	0
10	0	0	0	1	0	0	0	0	1	0

Bibliography

1. Pithadiya, K., Modi, C. K., Chauhan, J. D., & Jain, K. R. (2009). Performance evaluation of ISEF and Canny edge detector in acrylic fibre quality control production. In *Proceedings of National conference on innovations in Mechatronics*. IME.
2. Weber, A. G. (1997). The USC-SIPI image database version 5. *USC-SIPI Report, 315*, 1–24.
3. Canny, J. (1987). A computational approach to edge detection. In *Readings in computer vision* (pp. 184–203).
4. Rong, W., Li, Z., Zhang, W., & Sun, L. (2014). An improved CANNY edge detection algorithm. In *Mechatronics and Automation (ICMA), 2014 IEEE International Conference on* (pp. 577–582). IEEE.
5. Shen, J., & Castan, S. (1988). Edge detection based on multi-edge models. In *Real-time image processing: Concepts and technologies* (Vol. 860, pp. 46–54). International Society for Optics and Photonics.
6. Purushotham, S., & Anouncia, M. (2009). Enhanced human identification system using dental biometrics. In *Proceedings of the 10th WSEAS International Conference on NEURAL NETWORKS* (pp. 120–125). World Scientific and Engineering Academy and Society (WSEAS).
7. Sandberg, B., Chan, T., & Vese, L. (2002). A level-set and Gabor-based active contour algorithm for segmenting textured images. In *UCLA Department of Mathematics CAM report*.
8. Meng, X., Nandagopal, T., Li, L., & Lu, S. (2006). Contour maps: Monitoring and diagnosis in sensor networks. *Computer Networks, 50*(15), 2820–2838.
9. Lefkowitz, H. M. (2000). *U.S. Patent No. 6,091,417*. Washington, DC: U.S. Patent and Trademark Office.
10. Moore, H. (2017). *MATLAB for engineers*. New York, US: Pearson.

Chapter 4
DICOM® Medical Image Standard

4.1 Introduction

In the early days of the 1990s, Picture Archiving and Communication Systems (PACS®) played a vital role in the field of medical imaging. In medical applications, PACS® along with image representation tools were used to extract essential information from medical images. These tools were designed and developed to help all stakeholders use data better. In 1993, however, Digital Imaging and Communications in Medicine (known as DICOM®), a new standard with advanced features, was introduced, one which ensured that all the information was readily available [1, 2].

DICOM® is a standard that helps various image processing processes, whereas PACS® is an electronics system mainly used to acquire data from medical images. DICOM® plays a crucial role in the full medical imaging report and in the determining results, whereas PACS® provides access to medical images and augments the storage capacity of the system. At any instance, when a patient, a doctor or experts want to share or explore images or parts of images, they can efficiently use any modalities of an archive database by DICOM® standards. In hospitals, all expert personnel use this standard to enhance and authenticate standards for medical information [2].

The information model for mapping a real-world medical examination can be divided into four processes namely acquisition, learning, sequencing and imaging as shown in Fig. 4.1 [2]. Per the DICOM® standard, all these images are stored in a database with specific tags. When a search is carried out on web pages, DICOM® tags are useful to explore any detailed information (patient ID, disease, age, etc.)

DICOM® image standards have the following attributes [1–3]:

- Patient-level information: In this tag, all patient information (name, birthdate, sex, weight, etc.) is stored, and when needed, it can be explored.

D. N. Trivedi et al., *Dental Image Processing for Human Identification*,
https://doi.org/10.1007/978-3-319-99471-0_4

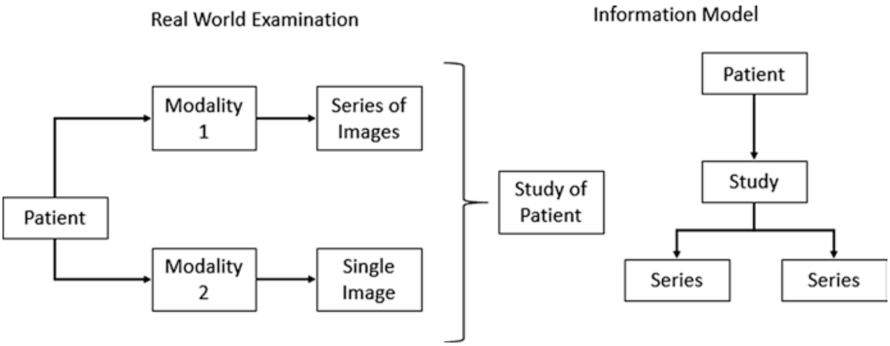


Fig. 4.1 Mapping real-world examination to information model

- Study-level information: In this tag, all detailed information about unique identifiers (UIDs) (doctor, examination report, etc.) is stored.
- Series level information: Series instance UID is an important key; a patient's series is stored at a specific level, modality, body part examination, and date/time information.
- Image level information: In this tag, image resolution, image size, and capturing date and time is stored.

The next three hierarchical inquiry/get back in sequence models are defined in the DICOM® standard.

1. Tolerant root
2. Knowledge root
3. Enduring/revise root

At the Tolerant Root level, the user must specify the nature of the query and its characteristics.

All patient-level information and DICOM® tags are associated with another level of information. Patient-level information attributes can be a primary tool as given in the table, which has information regarding patient history, the profile of the concerned doctor and other necessary details.

Series level information explores the category to be analysed in so far as it concerns standards and communication. This level is mainly used by doctors, experts and patients to obtain information as and when required.

Revision point is below patient level and has attributes associated with the study level. All lower level attributes are dependent on higher level attributes. So, anyone can have information about the image, but first they would have to go through the patient level and study level information [2].

4.2 Benefits of Using the DCM4CHE DICOM® Archive

A toolkit called JDICOM, written in the Java programming language responding to user needs in 2000, developed for understanding of DICOM® medical image [4]. The lead developer was convinced by the popularity of the new toolkit to form a fully attributed DICOM® archive. This project provides end users with an open source DICOM® database and integrates all the tools with the common standards of Integrating the Healthcare Enterprise (or IHE, another associated healthcare enterprise). DCM4CHE covered all feasible exercises and developed a tool combined for research, testing and creating an authentic environment for associated projects and persons [1]. The DCM4CHE project has grown to have some fruitful aspects like [1]:

- Creating a transparent environment
- Providing steady progress
- Giving a concrete database
- Allowing for healthy sharing with administrators and researchers
- Integrating vendors and experts.

4.3 Modern Improvements in Standards for Cooperative Digital Anatomic Pathology

The idea of Cooperative Digital Anatomic Pathology treats the way information technology and image processing can better facilitate workflow for anatomic pathology information pathology (APIS). The main attributes of this system are that it incorporates image information with information technology, and web technology to resolve diagnosis and laboratory drawbacks. This system can be very fruitful when used in concert with IHE, medical practitioner, lab technician and digital imaging researcher. Every year, in Europe and America, IHE performs various operations:

- It finds various drawbacks while executing of patient detail.
- It provides sufficient attributes during sharing data.
- It comprises image data for doctors and researchers.
- It lets data is used at the machine level and for the practitioner.
- It digitalizes information and sets it to the standard.
- It can change according to healthcare requirements.
- It is regularly updated.
- It is low cost and easily adopted.
- Its execution guide is built on HL& CDA.
- It gives a structured report of digital imaging with whole slide images.

The various tools for the DICOM® image standard are described below [1]:

1. *DICOM® Supplement 122:*

   This tool has the following features:

- Explores multi slide mechanism
- Provides microscopic imaging
- Correlates with different samples of images
- Describes adequate DICOM® features
- Can facilitate gathering of proper information like a sample's detailed features
- Patient's full discrimination in many slides with a different view
- Provides every sample's various dimensions
- Differentiates container ID and sample ID
- Allows correlation of DICOM® samples with HL7 v2 SPM slice and the HL7 v3 replica field information model [4]

2. *DICOM® Supplement 145:*

   This tool is useful for the following features:

- Full slide view different from conventional; images can be stored and explored.
- Proper access to large size of image volume.
- Generally, image browser can display a small part of the image at any instant; to overcome any technical drawbacks, remedies are provided.
- Stores slides on PACS®.

4.4 Dental Image Database

The presented DICOM® dental image database was collected from Dr. Batra (Student Clinic), Vallabh Vidyanagar, Gujarat, India. They provide two types of dental images, .jpg format and DICOM® format. In.jpg format, images are subtypes such as 8-bit depth (DB1) and 24-bit depth (DB2) as shown in Fig. 4.2. In DICOM® format, only one type of image, 16-bit depth (DB3), is available as shown in Fig. 4.3. The same features of this dental image database are given in Table 4.1.

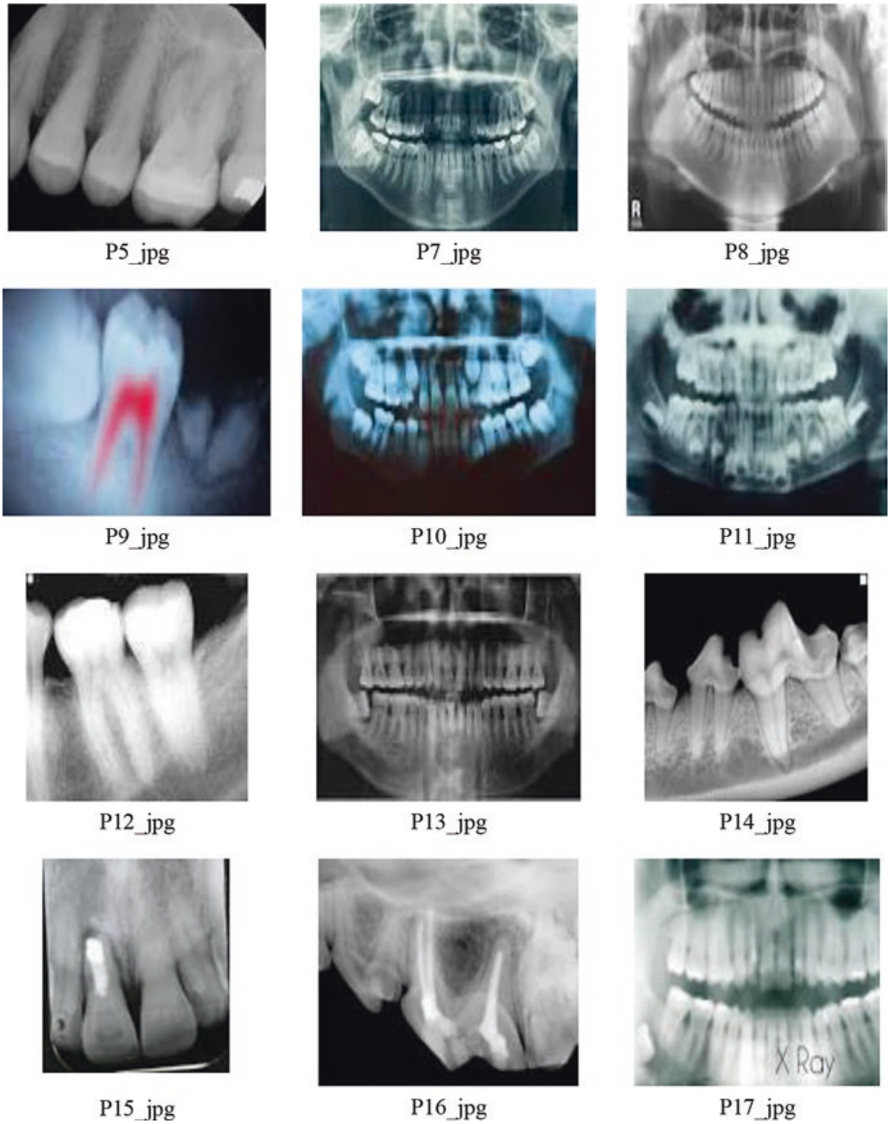


Fig. 4.2 Dental Images from Database DB1 and DB2

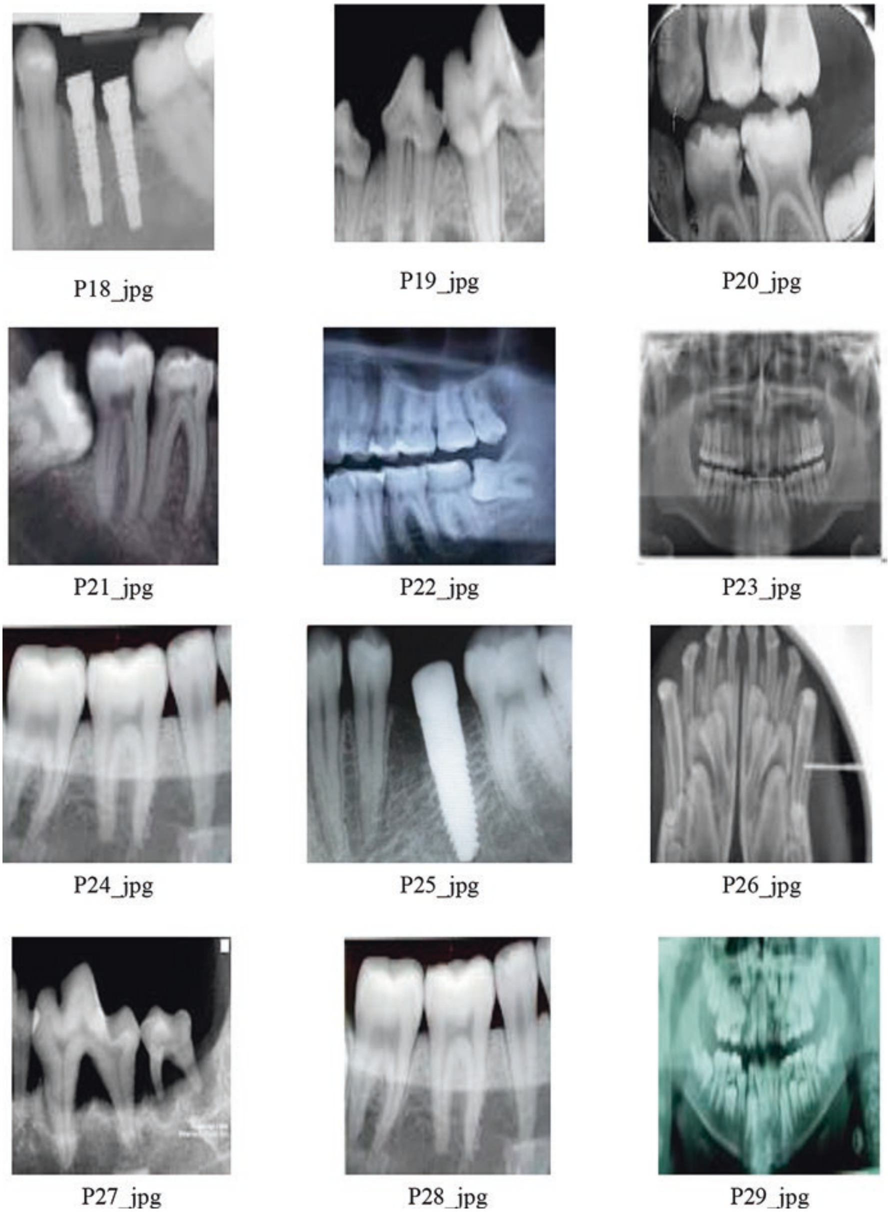


Fig. 4.2 (continued)

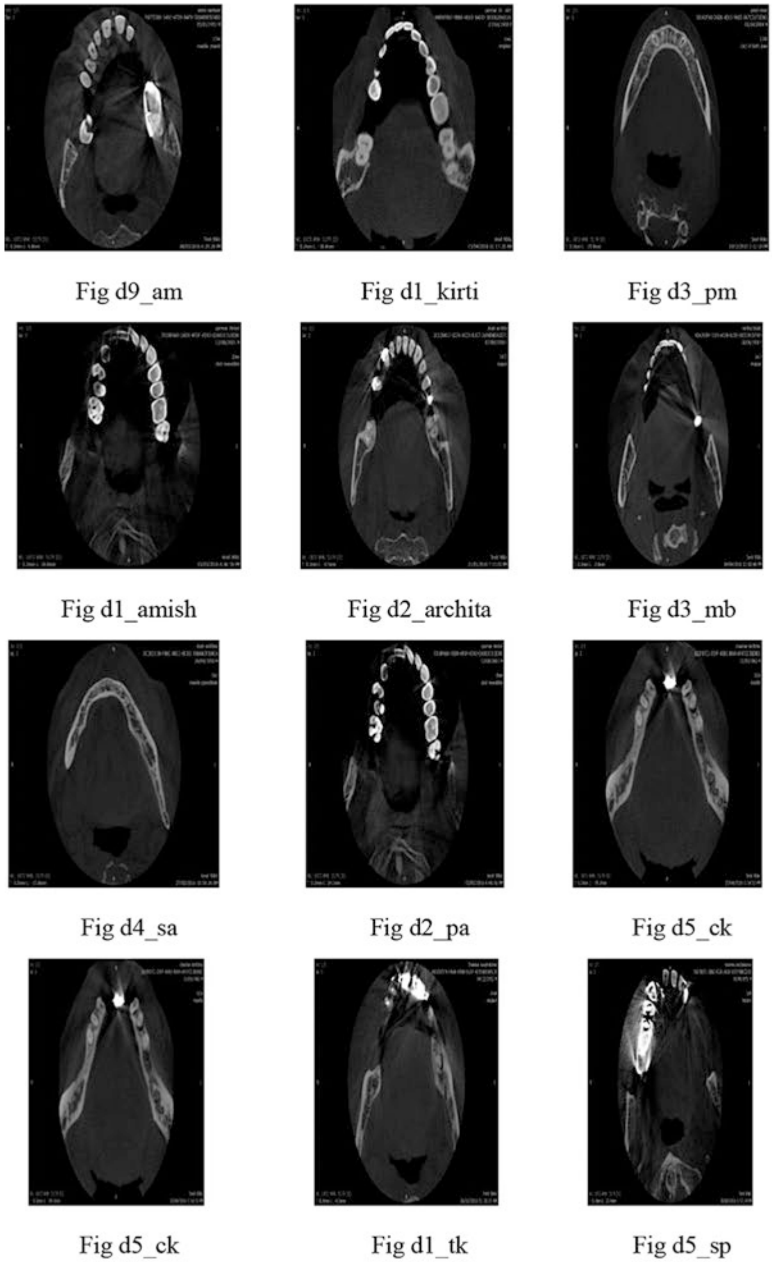


Fig. 4.3 Dental images from Database DB3

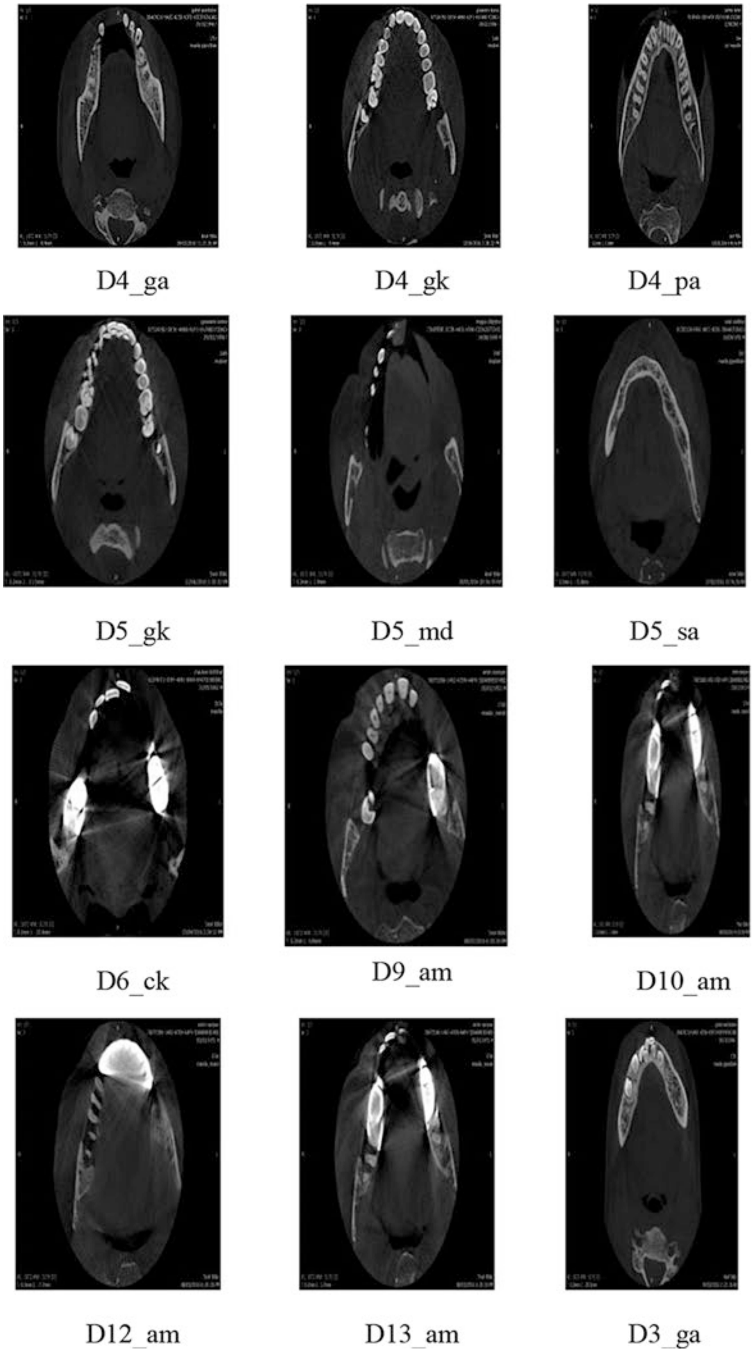


Fig. 4.3 (continued)

Table 4.1 Features of dental image database

Database	Format	Source	Image Size	Bit Depth	Width × Height
DB1	Jpg	Dr. Batra	335 KB	8	1300 × 912
DB2	Jpg	Dr. Batra	60–70 KB	24	600 × 800
DB3	DICOM®	Dr. Batra	513 KB	16	512 × 512

Bibliography

1. Warnock, M. J., Toland, C., Evans, D., Wallace, B., & Nagy, P. (2007). Benefits of using the DCM4CHE DICOM archive. *J Digit Imaging, 20*(1), 125–129.
2. Sahu, B. K., & Verma, R. (2011). DICOM search in medical image archive solution e-Sushrut Chhavi. In *Electronics Computer Technology (ICECT), 2011 3rd International Conference on* (Vol. 6, pp. 256–260). IEEE.
3. Chen, H., & Jain, A. K. (2005). Dental biometrics: Alignment and matching of dental radiographs. In *Application of Computer Vision, 2005. WACV/MOTIONS'05 Volume 1. Seventh IEEE Workshops on* (Vol. 1, pp. 316–321). IEEE.
4. Daniel, C., Macary, F., Rojo, M. G., Klossa, J., Laurinavičius, A., Beckwith, B. A., & Della Mea, V. (2011). Recent advances in standards for collaborative Digital Anatomic Pathology. *Diagnostic Pathology, 6*(1), S17. BioMed Central.

Chapter 5
Analytical Study of Human Identification System Based on Dental Images

5.1 The Flow of Human Identification System Based on Dental Images

This section discusses designing the flow of human identification system based on dental images. This identification system is designed and implemented using the ISEF edge detection algorithm and the contouring algorithm. This system uses two design flows for the identification of humans, which are given in Fig. 5.1.

In the first design flow, human identification and matching can be done based on the extracted edges of the dental image. In the second design flow, on the other hand, human identification and matching can be done based on the contour values of the extracted edges of the dental image.

5.2 Performance Evaluation Parameters for Human Identification System

In this section, the equation and description on the performance evaluation of human identification system are provided. The performance of the presented dental identification system can be evaluated by false acceptance rate (FAR), false rejection rate (FRR), receiver operating characteristics (ROC) curve and equal error rate (EER) [1–3]. These rates are a function of threshold. The value of rates is obtained by operating the presented dental identification system at various threshold values.

D. N. Trivedi et al., *Dental Image Processing for Human Identification*,
https://doi.org/10.1007/978-3-319-99471-0_5

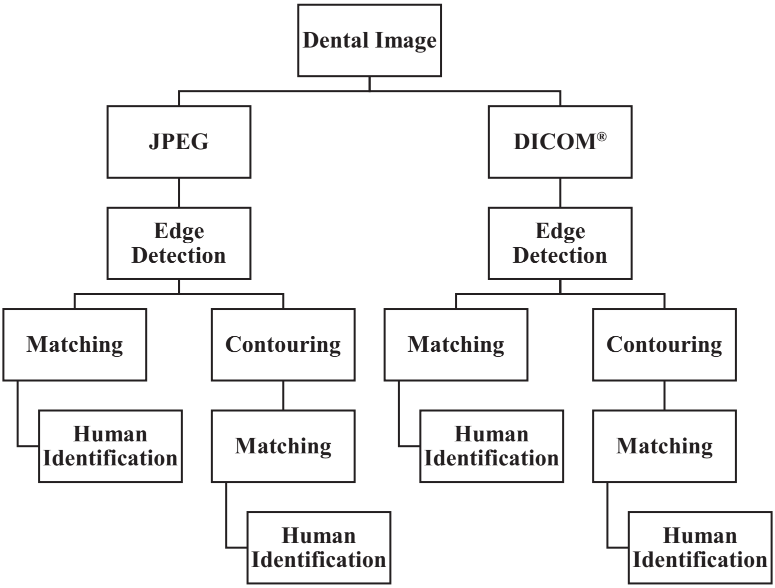


Fig. 5.1 Design Flow of Human Identification System based on Dental Images

5.2.1 False Acceptance Rate (FAR)

False acceptance occurs when an individual template is matched with another enrolled template. This is also known as false match rate (FMR) [1]. The false acceptance rate (FAR) is calculated using below Eq. 5.1 [3].

$$FAR = \frac{\text{No.of Matching Score} \le \text{Selected Threshold}}{\text{Total No.of Matching Score}} \tag{5.1}$$

Where, *FAR* = false acceptance rate and *Matching Score* = similarity score between query biometric image and its closest match biometric image in database.

5.2.2 False Rejection Rate (FRR)

A false reject occurs when an individual template is not matched with its own enrolled template. This is also known as false non-match rate (FNMR) [1, 2]. The false rejection rate (FRR) is calculated using below Eq. 5.2 [3]:

$$FRR = \frac{\text{No.of Matching Score} > \text{Selected Threshold}}{\text{Total No.of Matching Score}} \tag{5.2}$$

Where, *FRR* = false rejection rate and *Matching Score* = similarity score between query biometric image and its closest match biometric image in database.

5.2.3 Receiver Operating Characteristics (ROC) Curve

This curve is obtained by calculating the values of FAR and FRR for each tested threshold. It plots a curve for the FAR versus the FRR. This curve gives a trade-off between FAR and FRR values at various thresholds. This curve is also giving a trade-off between the system's performance and security.

5.2.4 Equal Error Rate (EER)

It is the value on ROC curve where error rates FAR and FRR have the same value (i.e. FRR = FAR). It is mostly used for comparison of biometric systems. The equal error rate (EER) is calculated using below Eq. 5.3 [3]:

$$\mathrm{EER} = \frac{\mathrm{FAR\ Selected\ Threshold} + \mathrm{FRR\ Selected\ Threshold}}{2} \tag{5.3}$$

where *EER* = equal error rate, *FAR* = false acceptance rate and *FRR* = false rejection rate.

FAR, FRR and EER play an important role when designing a dental identification system for any particular application. When a dental identification system design is for high-security applications, then FAR must be as low as possible compared to FRR. When the dental identification system design is for forensic applications, then FRR must be as low as possible compared to FAR. EER is used when the dental identification system design is for civilian applications.

5.3 Dental Image Processing on Authenticate Database

In this book, two types of dental image database, such as jpg and DICOM®, are used for analytical study and for the analysis of human identification system. In this section, dental image processing for both matching design flows shown in Fig. 5.1 is performed using jpg dental images.

The dental image processing flow is as per illustrated below. Here, ISEF edge detection [4] is applied to the input dental image to obtain edges of the dental image. The results of ISEF edge detection on the dental image is given in Figs. 5.2, 5.3, 5.4, 5.5, 5.6 and 5.7. In Figs. 5.2, 5.3, 5.4, 5.5, 5.6 and 5.7, the resultant images obtained at each stage of the ISEF edge detection algorithm are shown.

Fig. 5.2 Original Dental Image

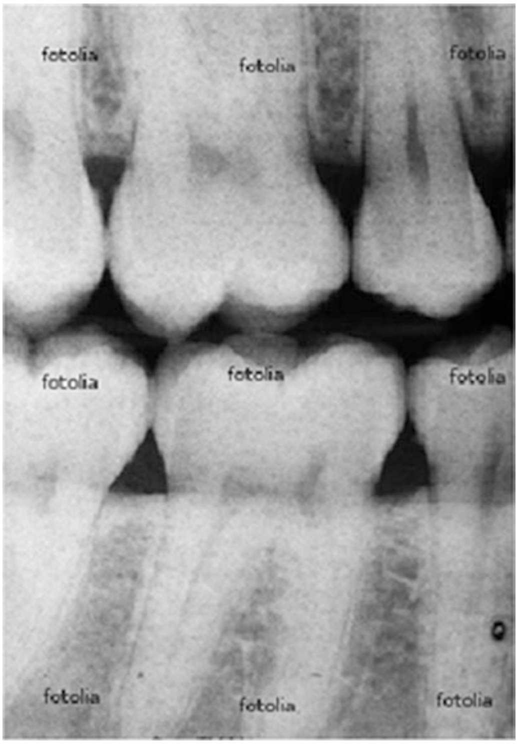


Fig. 5.3 Filtered Image in X Direction

Fig. 5.4 Filtered Image in Y Direction

After obtaining edges of the dental image using ISEF edge detection, contouring algorithm [5, 6] is applied to edges of the dental image to obtain contour values of edges of the dental image. The results of the contouring on edges of the dental image are given in Figs. 5.8, 5.9 and 5.10.

5.3.1 Human Identification Based on Dental Features

This section examines human identification based on dental features. For human identification, two dental images of the same person or different persons are compared, and based on the results of the comparison, a decision will be made. Here, two types of matching, matching using edges of the dental image and matching using contour values of edges of the dental image, are performed.

5.3.1.1 Results for JPG Dental Image Database

For the analysis of the presented dental identification system, two dental images of the same person are taken from the dental image database. Here, the P34 dental image of a person is matched with the same person's P35 dental image with screw

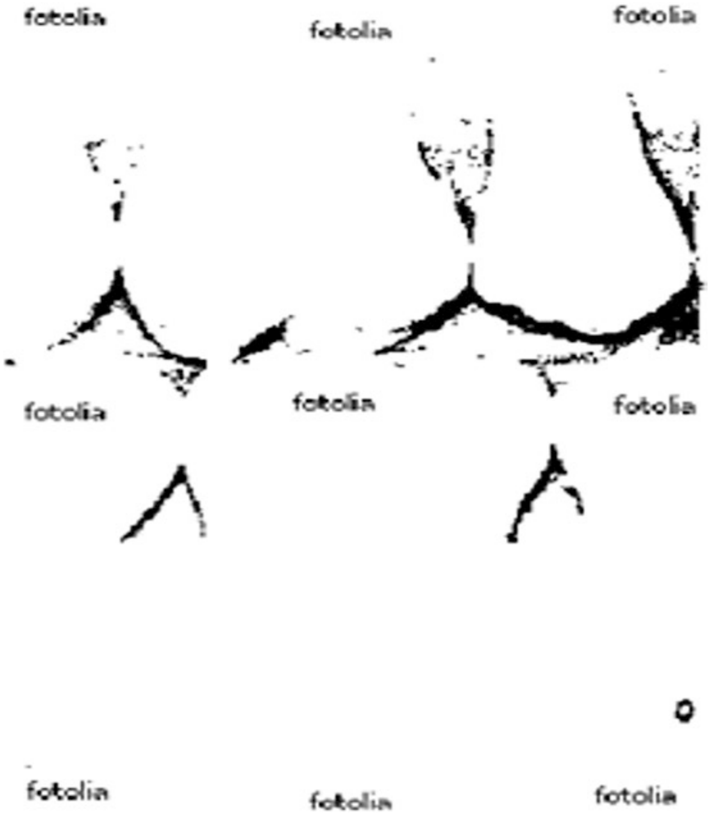


Fig. 5.5 Binary Laplacian Image

taken after 5 years. Here, P indicates patient information. These query dental images (QEs) are shown in Fig. 5.11 and 5.12, respectively.

The edges of these two dental images are obtained using ISEF edge detection algorithm. Then matching of these two images is performed by comparing the values of their edges. The results of the matching are shown in Table 5.1, where the value of the edges of the P34 dental image is compared with that of the dental images of different patients.

For matching of the dental image, the thresholding is applied on matching percentage to obtain comparison chart. The chart is presented in Fig. 5.13, which shows that the matching between P34 and P34 dental images and between P34 and P35 dental images results in a positive value and all other matching values are negative. This indicates that this approach can be used for the identification of a person based on dental features. Here, dental features are edges of dental images.

The matching of a person can be done using the edges of the dental images, but the system threshold value in this case is near 99%. This value is too high. According

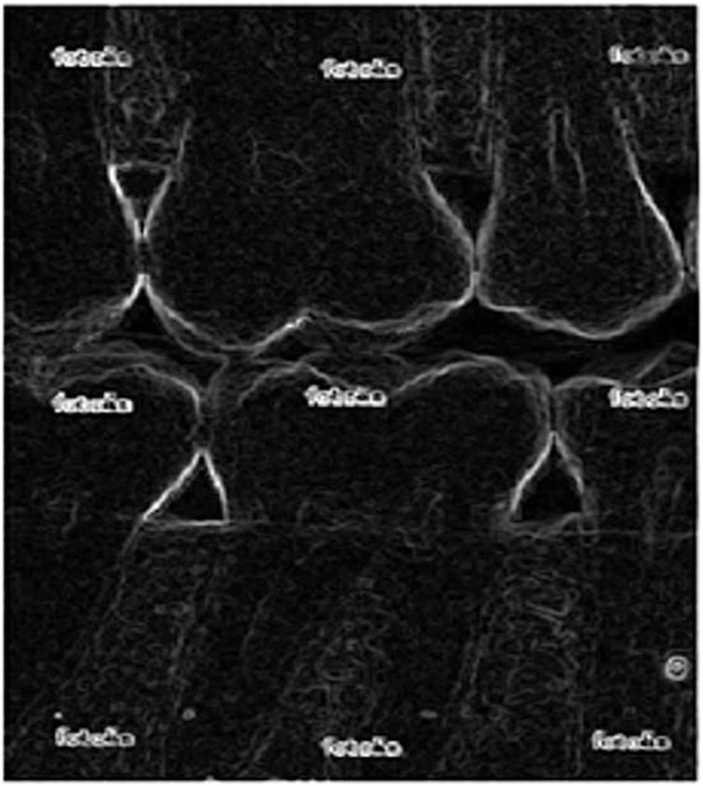


Fig. 5.6 Resultant Image after Gradient Operation

to the literature on human identification system [1, 2], the system threshold should be as low as possible. Because edge detection matrix matching only analyses individual pixels, it is not concerned with adjacent pixels. This is also a problem in many existing techniques [2], where researchers do matching by pixels to pixels, edge detection, eumelanin distance, chain codes and various algorithms. But still, they do not have any proper algorithm that can specify adjacent pixel format.

So to overcome the limitations of some existing systems, contouring algorithm is used in this presented system, which can apply to a matrix of edge detection and some derived patterns (contours). These patterns (contours) are directly matched with another dental image matrix for the matching of a person.

The output of the contouring algorithm on the original P34 dental image and the P35 dental image is shown in Figs. 5.14 and 5.15, respectively. The edges of the P34 dental image and the P35 dental image are shown in Figs. 5.16 and 5.17, respectively, after application of the ISEF edge detection algorithm. The output of the contouring algorithm on the edges of the P34 dental image and the P35 dental image is shown in Figs. 5.18 and 5.19, respectively.

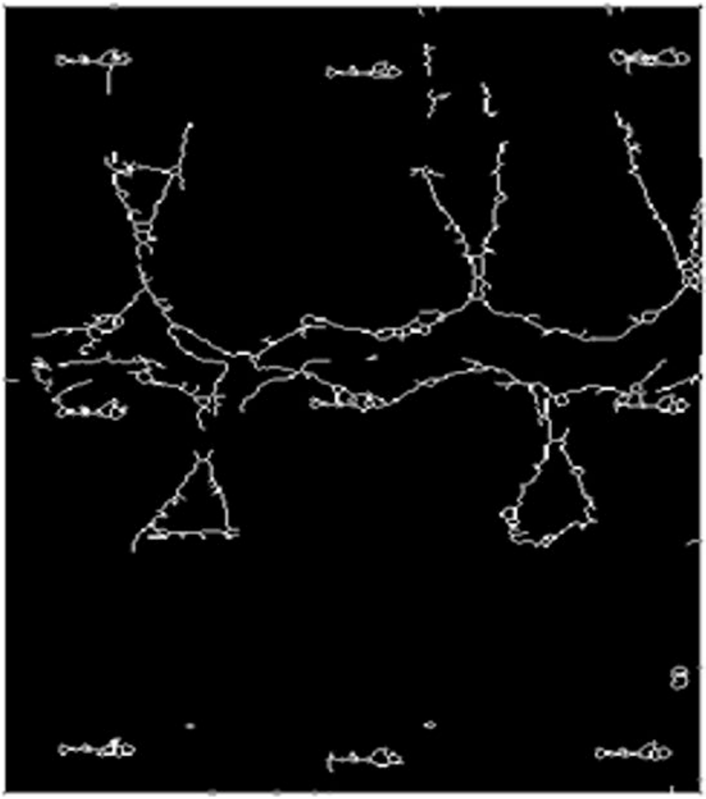


Fig. 5.7 ISEF Edges of Dental Image

Here, ISEF edge detection algorithm and contouring algorithm are applied to different dental images taken from a jpg database. The resultant images are shown in Figs. 5.20, 5.21, 5.22, 5.23, 5.24 and 5.25.

The contour values of the edges of the dental images mentioned in Figs. 5.10 and 5.12 are obtained using contouring algorithm on the edges of this dental image. Then matching of these two images is performed by comparing the contour values of the edges of these two images to obtain threshold values. The results of the matching of the dental images are given in Table 5.2, where contour values of the edges of the P34 dental image are compared with query dental images (QEs) of different patients. The table shows that the result of matching of the P34 dental image with other dental images is less than 75%, which indicated that this presented system can be used for identification based on dental features. The comparison chart on the percentage matching of the P34 and P51 dental images with other dental images on the database is shown in Fig. 5.26.

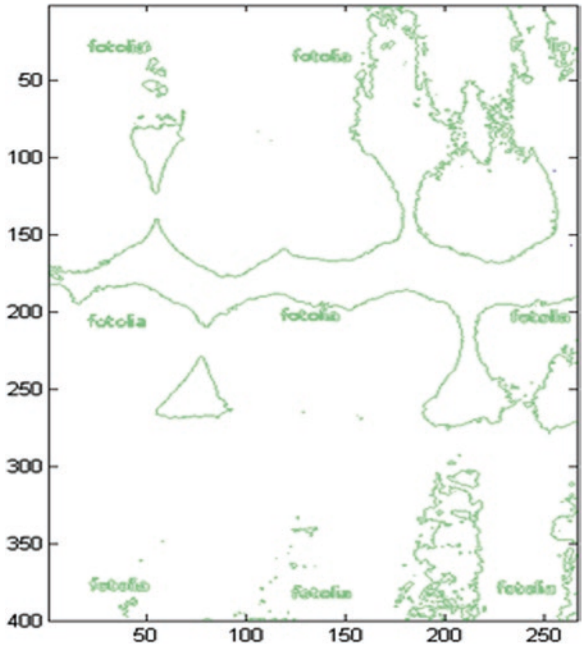


Fig. 5.8 Contouring of Original Dental Image

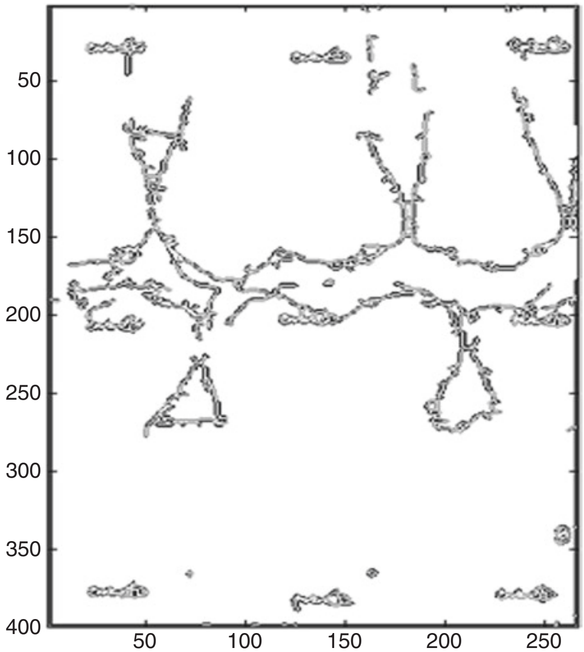


Fig. 5.9 Contouring of Edges of Dental Image

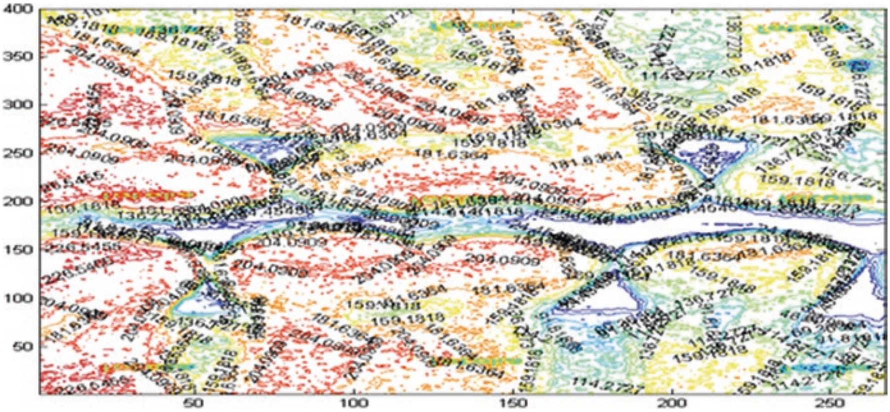
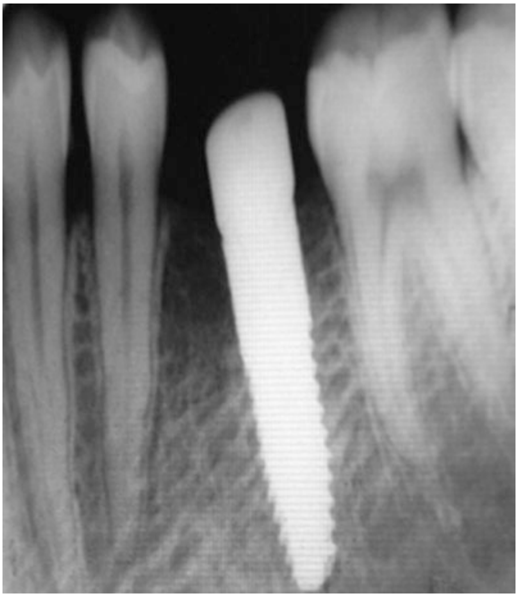


Fig. 5.10 Labeling of Contour Values for Original Dental Image

Fig. 5.11 P34 Dental Image with Screw



5.3.1.2 Results for DICOM® Dental Image Database

This presented dental identification system is also tested using DICOM® dental images. The application of ISEF edge detection algorithm and contouring algorithm on DICOM® dental images is shown in Fig. 5.27.

Above all the results are processed on DICOM® dental images which are captured on same angles and portion (e.g. maxilla and mandible). The maxilla and mandible are the strongest part among any dental biometrics and is less time variant than

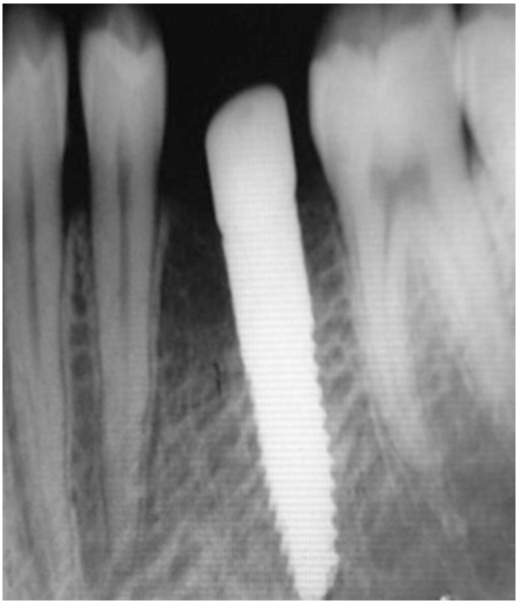


Fig. 5.12 P35 Dental Image after 5 Years with Screw

other biometrics. So it can be an authentic tool when human identification is done using dental features.

In Table 5.3, the dental images of 11 persons are processed and matched with other images, and then the average was taken. Here, the D9_Am image is considered as a query image and D9_Am is compared with all other dental images, including a D9_Am image.

5.3.2 Performance Evaluation of Presented Dental Identification System

In this section, the performance evaluation of dental identification system based on ISEF edge detection algorithm and contouring algorithm is given. The performance of this system is evaluated using various parameters such as FRR, FAR and EER. For the calculation of these parameters, around 110 dental images are taken from the DICOM® dental database. The FRR and FAR values of the presented dental identification system are tabulated in Table 5.4.

Based on values in Table 5.4, plot FRR/FAR vs. Threshold curve and receiver operating characteristics (ROC) curve for presented dental identification system based on dental features are shown in Figs. 5.28 and 5.29, respectively. Equal error rate (EER) is a point on the FRR/FAR vs. threshold curve shown in Fig. 5.29 where FAR and FRR have the same value. The EER value of this system is around 0.105.

Table 5.1 Matching of Dental Images based on Edges of it

Fig.	Maximum pixel	Match	Mismatch	Percentage%	TH 99% (Per.- Th)
p34-p34	687354	687354	0	100	1
p34-p35	656502	653117	3385	99.4844	0.4844
p34-p1	161000	147848	13152	91.8311	−7.1689
p34-p2	200000	167517	32483	83.75	−15.25
p34-p3	200000	188758	11242	94.379	−4.621
p34-p4	187500	171994	15506	91.7301	−7.2699
p34-p5	393216	375835	17381	95.5798	−3.4202
p34-p6	307200	302043	5157	98.3213	−0.6787
p34-p8	187500	172385	15115	91.9387	−7.0613
p34-p9	307200	302882	4318	98.5944	−0.4056
p34-p10	178000	172767	5233	97.0601	−1.9399
p34-p11	178000	173521	4479	97.4837	−1.5163
p34-p12	178000	173532	4468	97.8499	−1.1501
p34-p14	81200	77785	3415	95.7943	−3.2057
p34-p15	204282	180,884	23,398	88.5462	−10.4538
p34-p16	124416	109360	15056	87.8987	−11.1013
p34-p17	362414	357538	4876	98.6546	−0.3454
p34-p20	132908	128369	4539	96.5849	−2.4151
p34-p21	75900	70282	5618	92.5982	−6.4018
p34-p22	165120	160691	4429	97.3177	−1.6823
p34-p24	480000	448822	31178	93.5046	−5.4954
p34-p25	93450	88774	4676	94.9963	−4.0037
p34-p26	105679	100802	4877	95.3851	−3.6149
p34-p27	131520	124687	6833	94.8046	−4.1954
p34-p28	106800	98278	8522	92.0206	−6.9794
p34-p29	36186	30924	5262	85.4585	−13.5415
p34-p30	36100	34422	1678	95.3518	−3.6482
p34-p31	153450	148099	5351	96.5129	−2.4871
p34-p32	3939840	3527668	412172	89.5384	−9.4616

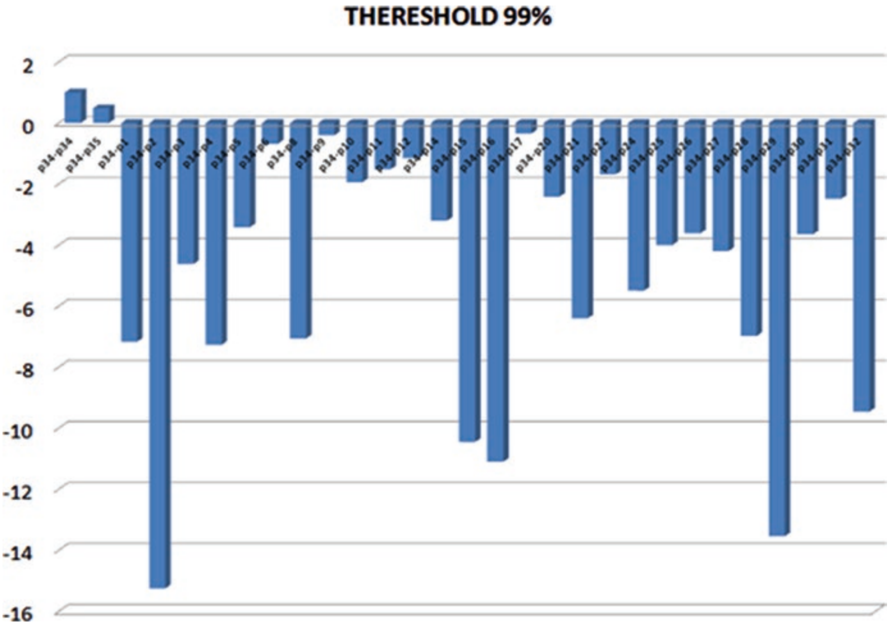
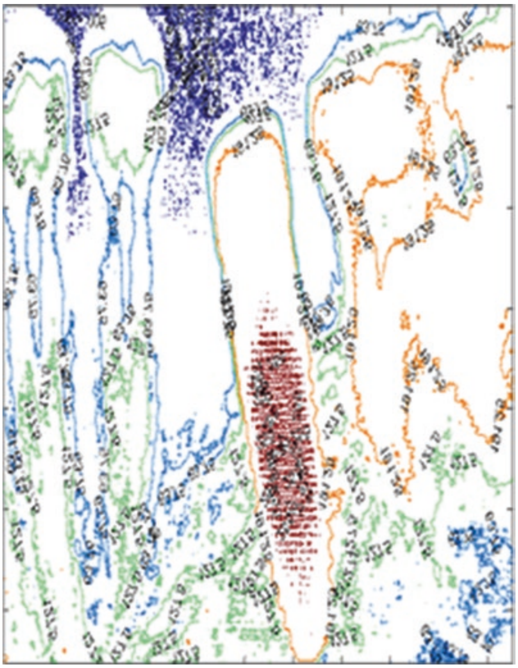


Fig. 5.13 Comparison Chart for Dental Image Matching

Fig. 5.14 Contour Values of Original P34 Dental Image



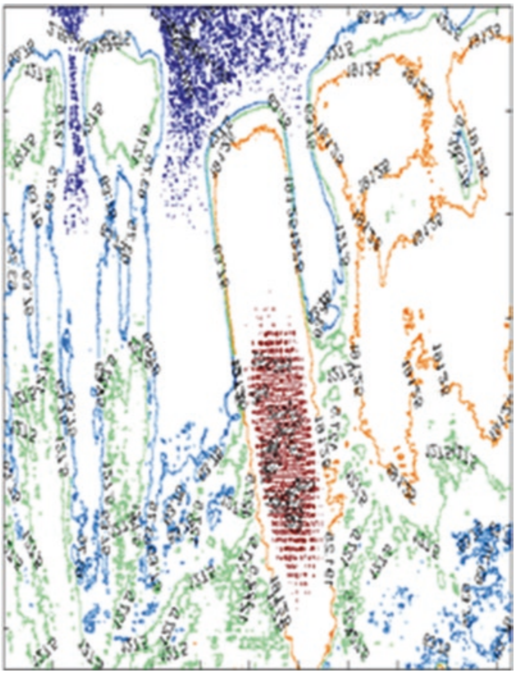


Fig. 5.15 Contour Values of Original P35 Dental Image

Fig. 5.16 Edges of P34 Dental Image

Fig. 5.17 Edges of P35 Dental Image

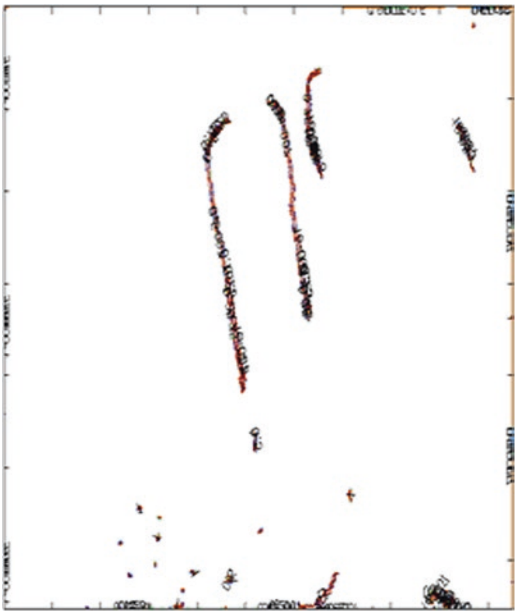
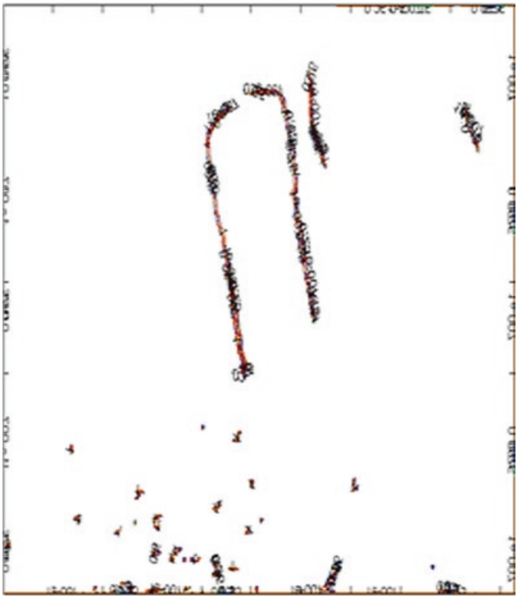
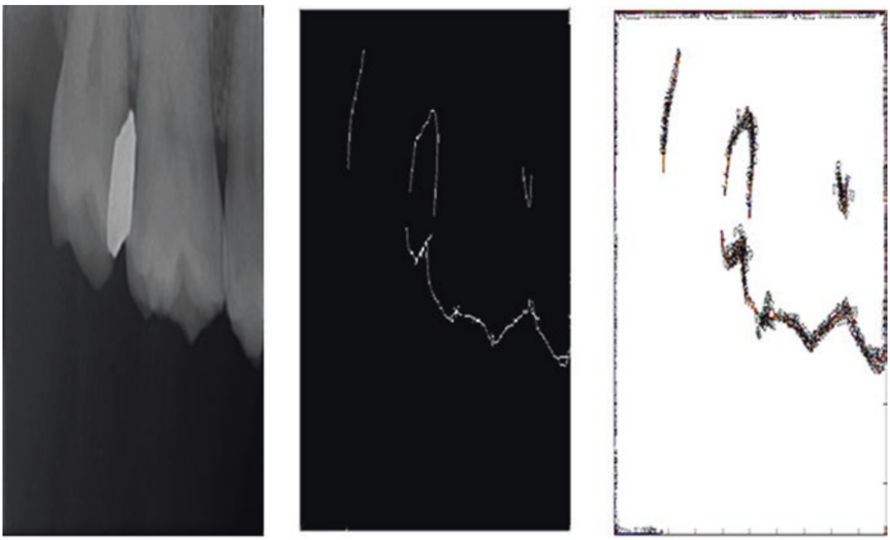


Fig. 5.18 Contour Values of Edges of P34 Dental Image

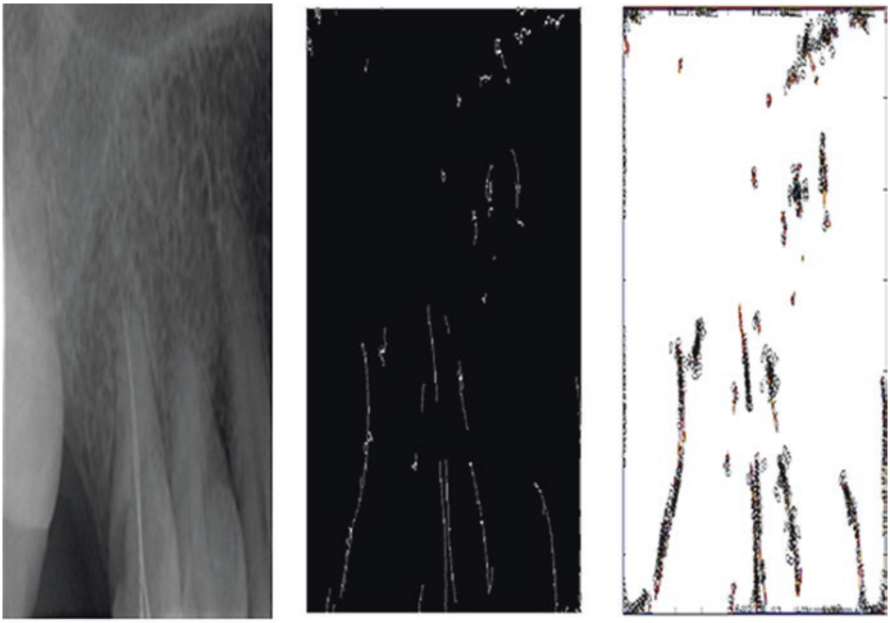
Fig. 5.19 Contour Values of Edges of P35 Dental Image





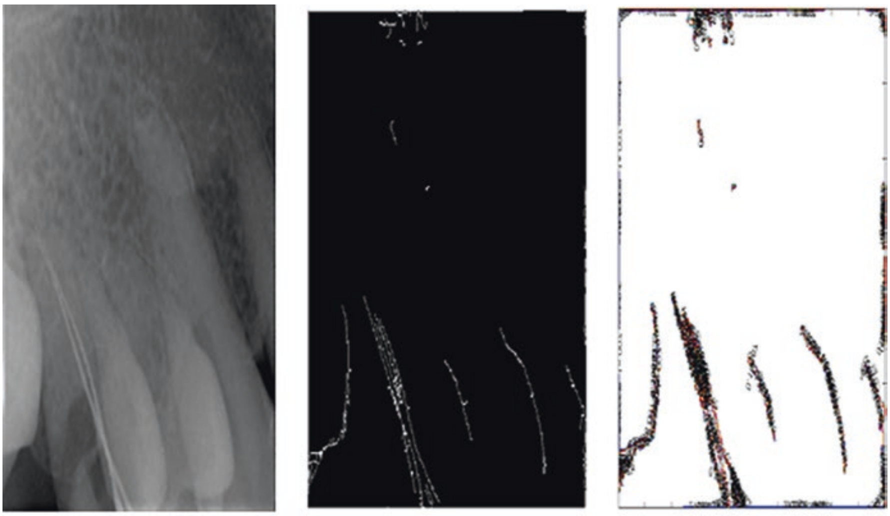
(a) (b) (c)

Fig. 5.20 (**a**) Original Dental Image (**b**) Edges of Dental Image (**c**) Contour Values of Edges of Dental Image



(a) (b) (c)

Fig. 5.21 (**a**) Original Dental Image (**b**) Edges of Dental Image (**c**) Contour Values of Edges of Dental Image



(a) (b) (c)

Fig. 5.22 (**a**) Original Dental Image (**b**) Edges of Dental Image (**c**) Contour Values of Edges of Dental Image

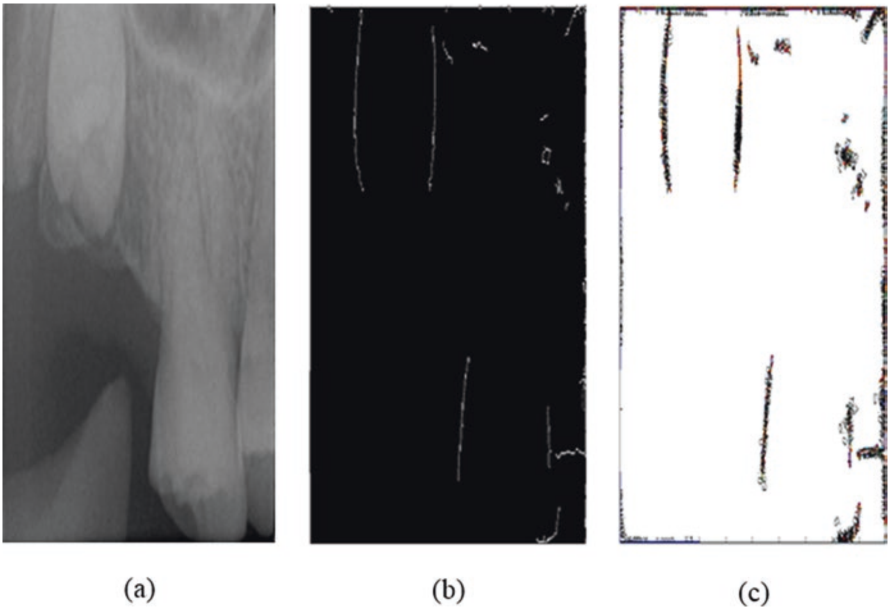


Fig. 5.23 (**a**) Original Dental Image (**b**) Edges of Dental Image (**c**) Contour Values of Edges of Dental Image

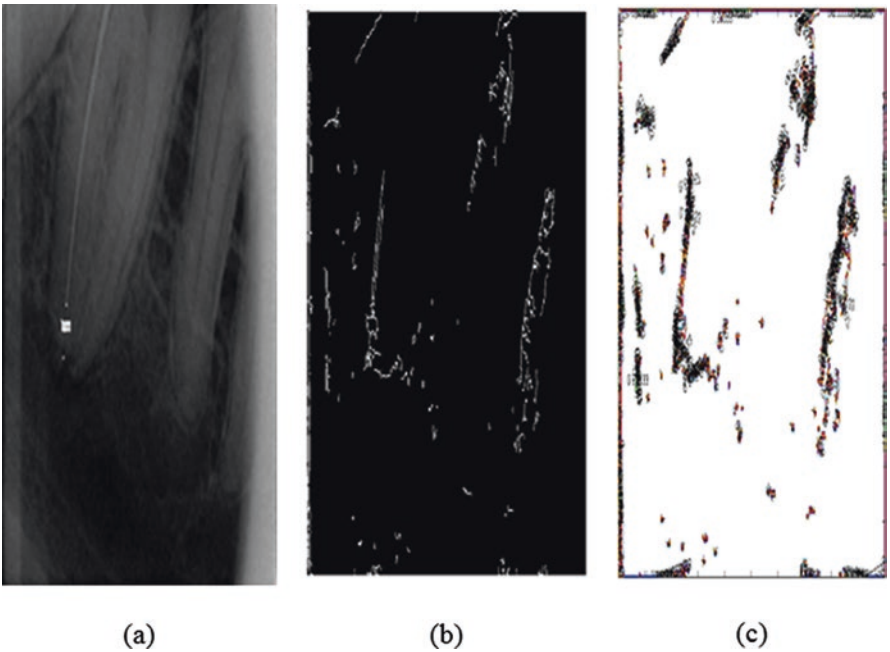
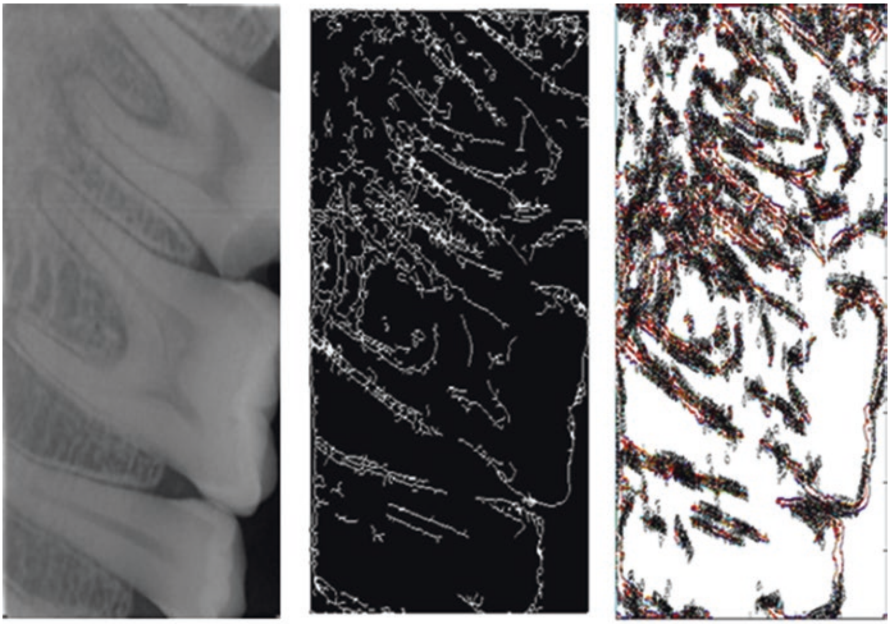


Fig. 5.24 (**a**) Original Dental Image (**b**) Edges of Dental Image (**c**) Contour Values of Edges of Dental Image



(a) (b) (c)

Fig. 5.25 (**a**) Original Dental Image (**b**) Edges of Dental Image (**c**) Contour Values of Edges of Dental Image

Table 5.2 Comparison of P34 Dental Image with Other Dental Images

Image	Threshold <100	Threshold <200	Threshold <300	Threshold <400	Threshold <500
P34	100	100	100	100	100
P35	70	95	99.33	99.45	99.66
Q1	29.30	43.79	60.80	62.80	69.00
Q2	30.57	44.50	63.00	63.66	63.66
Q3	22.40	45.12	67.00	67.26	68.45
Q4	25.66	40.70	61.00	61.23	65.50
Q5	18.00	35.00	48.00	54.00	54.00
Q6	24.40	38.86	63.70	63.70	63.70
Q7	25.10	39.40	64.60	64.60	65.80
Q8	27.87	44.26	69.10	69.10	75.66
Q9	21.23	35.00	58.26	59.66	61.00
Q10	29.30	38.86	58.50	61.76	66.37
Q11	30.10	39.40	68.70	68.70	68.70
Q12	28.40	44.26	61.88	68.00	68.00
Q13	25.66	44.50	58.51	58.51	58.51
Q14	27.00	45.12	61.60	65.00	69.40
Q15	24.70	40.74	62.10	63.30	68.80
Q16	25.10	35.00	66.20	69.76	74.20
Q17	27.89	38.89	61.67	61.67	61.67
Q18	21.43	39.40	66.33	66.79	66.79
Q19	29.30	43.79	55.21	55.21	55.21
Q20	30.10	44.50	52.00	52.00	52.00
Q21	22.50	45.12	65.00	65.00	65.00
Q22	25.00	40.70	63.88	66.23	70.23
Q23	21.00	35.00	50.26	50.67	58.00
Q24	24.40	38.86	59.88	59.88	62.00
Q25	25.10	39.78	49.65	49.65	58.77
Q26	27.87	44.26	68.10	68.10	74.10
Q27	21.23	23.45	49.45	54.34	65.55
Q28	29.30	38.86	50.43	53.70	60.00
Q29	29.10	33.40	55.00	59.90	61.27
Q30	29.40	44.26	62.71	62.71	71.60
Q31	25.66	44.50	59.96	63.40	68.30
Q32	27.00	35.00	54.44	58.30	58.30
Q33	24.70	29.86	57.00	61.60	64.00
Q34	25.56	39.40	60.12	64.20	72.35
Q35	29.30	40.12	59.00	59.44	61.12
Q36	28.44	41.70	58.44	60.44	60.44
Q37	22.40	35.10	56.26	56.70	56.70
Q38	25.66	38.00	64.09	65.29	71.00
Q39	21.00	39.40	57.26	57.26	62.38
Q40	24.00	44.20	67.00	67.00	67.00

(continued)

Table 5.2 (continued)

Image	Threshold <100	Threshold <200	Threshold <300	Threshold <400	Threshold <500
Q41	25.23	35.00	58.34	64.10	64.10
Q42	27.34	32.25	65.26	65.26	67.49
Q43	21.23	39.40	51.33	55.87	55.87
Q44	29.30	44.26	66.21	67.21	67.21
Q45	30.10	44.50	56.26	56.78	62.33
Q46	28.40	45.12	50.21	60.45	65.56
Q47	25.66	40.70	53.45	55.00	59.45
Q48	23.00	35.00	67.70	69.00	72.00
Q49	24.70	38.86	49.70	49.70	57.76
Q50	25.10	39.40	68.10	69.10	74.30
Q51	27.89	43.79	62.34	62.34	68.26
Q52	27.43	44.50	58.85	59.00	62.18
Q53	29.30	45.12	57.32	57.32	57.32
Q54	30.10	40.70	53.33	57.60	57.60
Q55	21.50	35.00	60.10	62.15	62.15
Q56	25.26	38.40	65.54	65.70	68.10
Q57	21.00	39.40	67.10	67.10	71.35
Q58	24.40	44.26	50.23	55.44	62.58
Q59	25.10	35.00	57.60	57.60	65.00
Q60	27.87	33.55	51.33	57.00	63.23

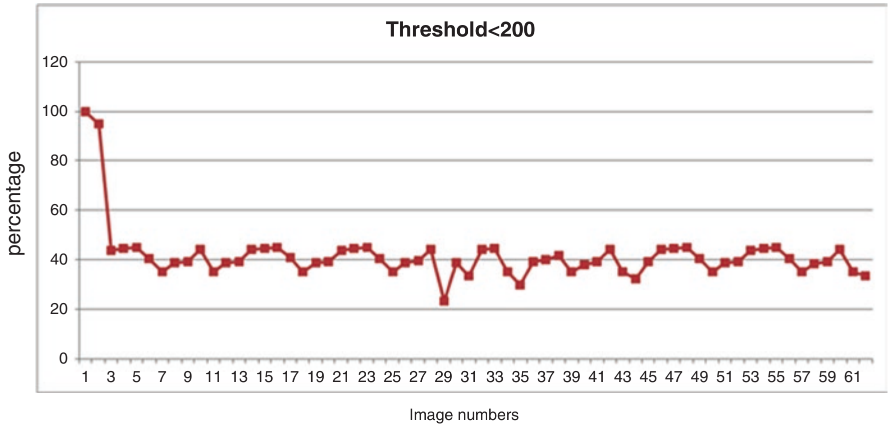


Fig. 5.26 Comparison Chart of Percentage Matching of P34 Dental Image with Other Dental Images of Database

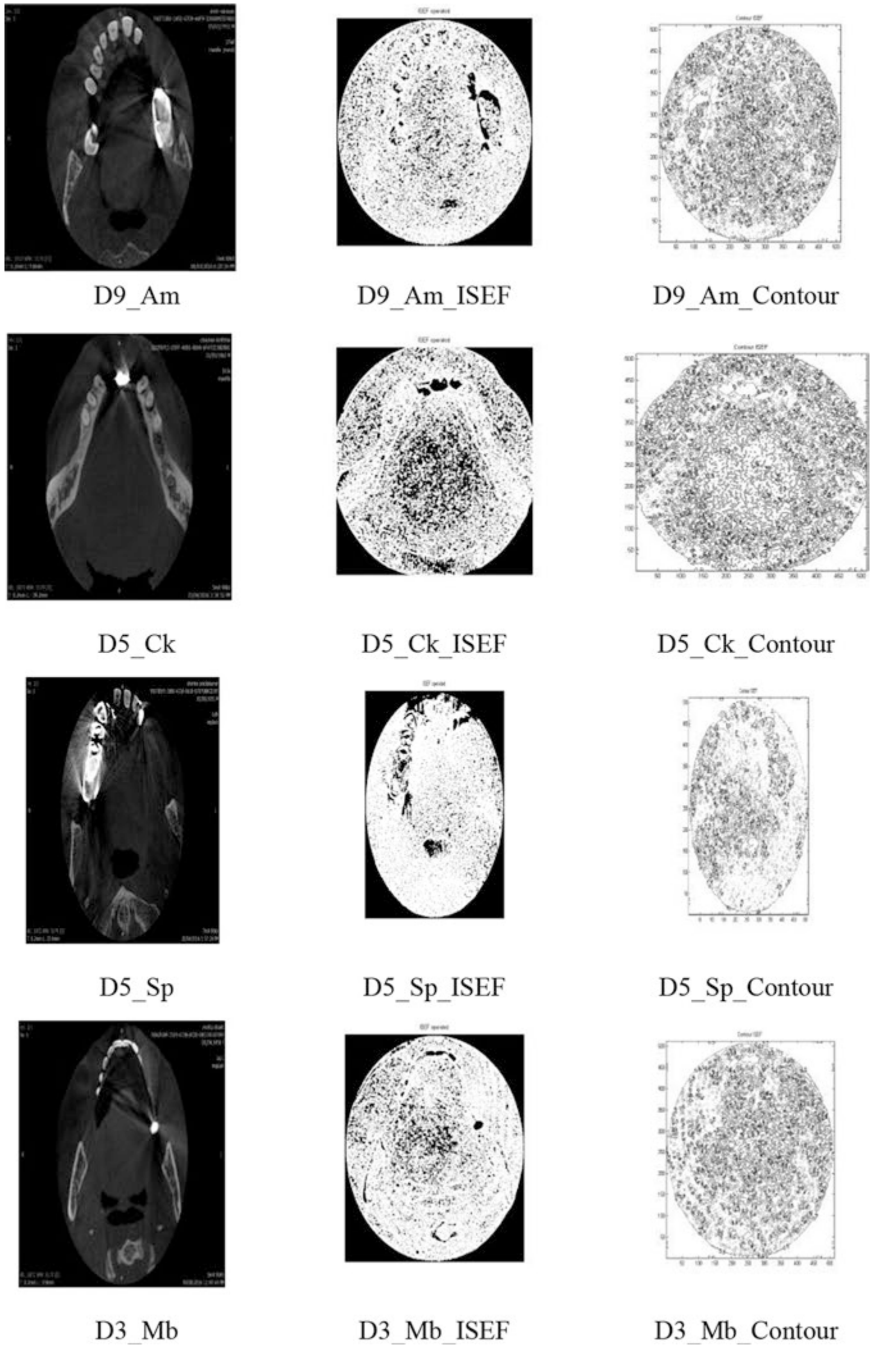


Fig. 5.27 Various DICOM® Dental Images with Results of ISEF Edge Detection and Contouring

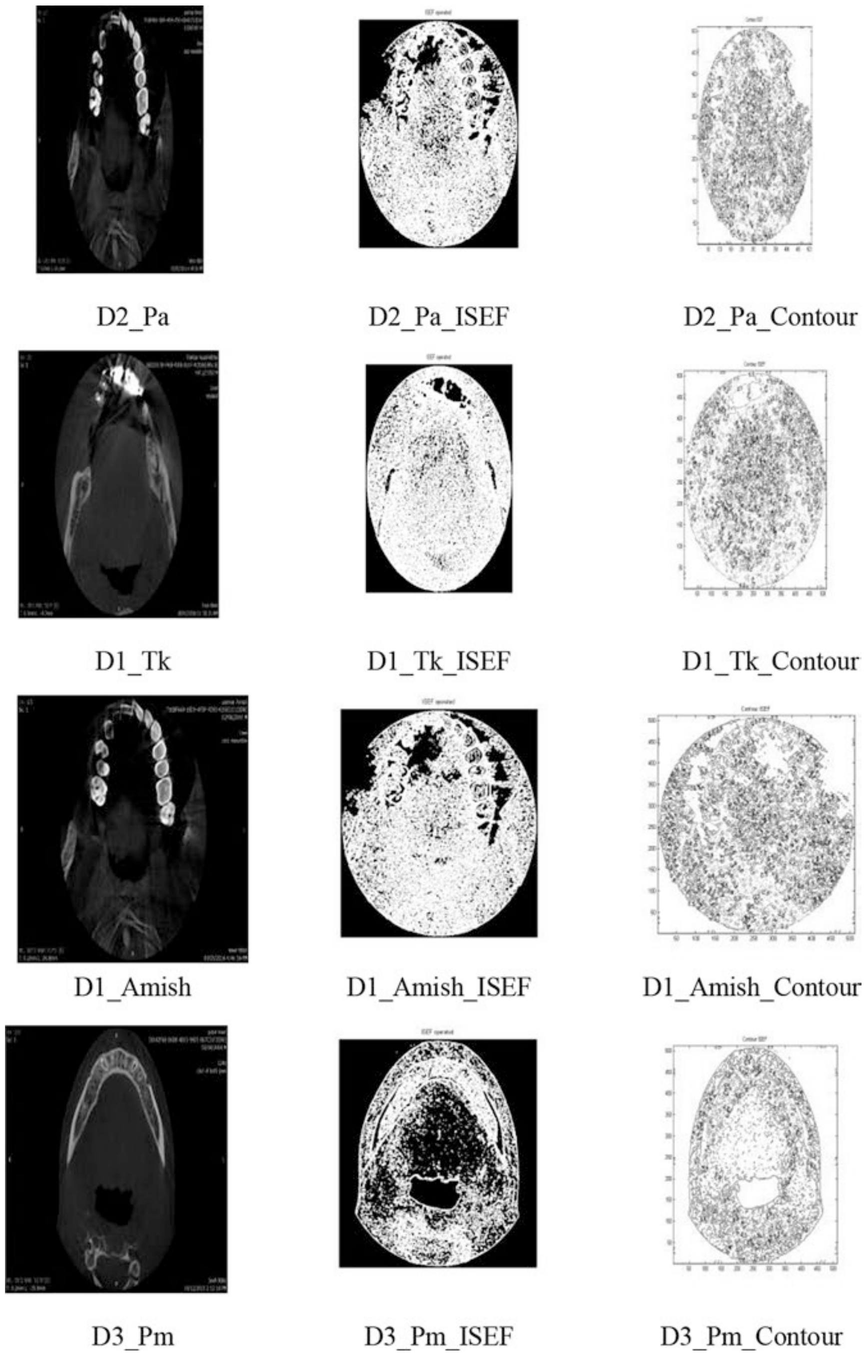


Fig. 5.27 (continued)

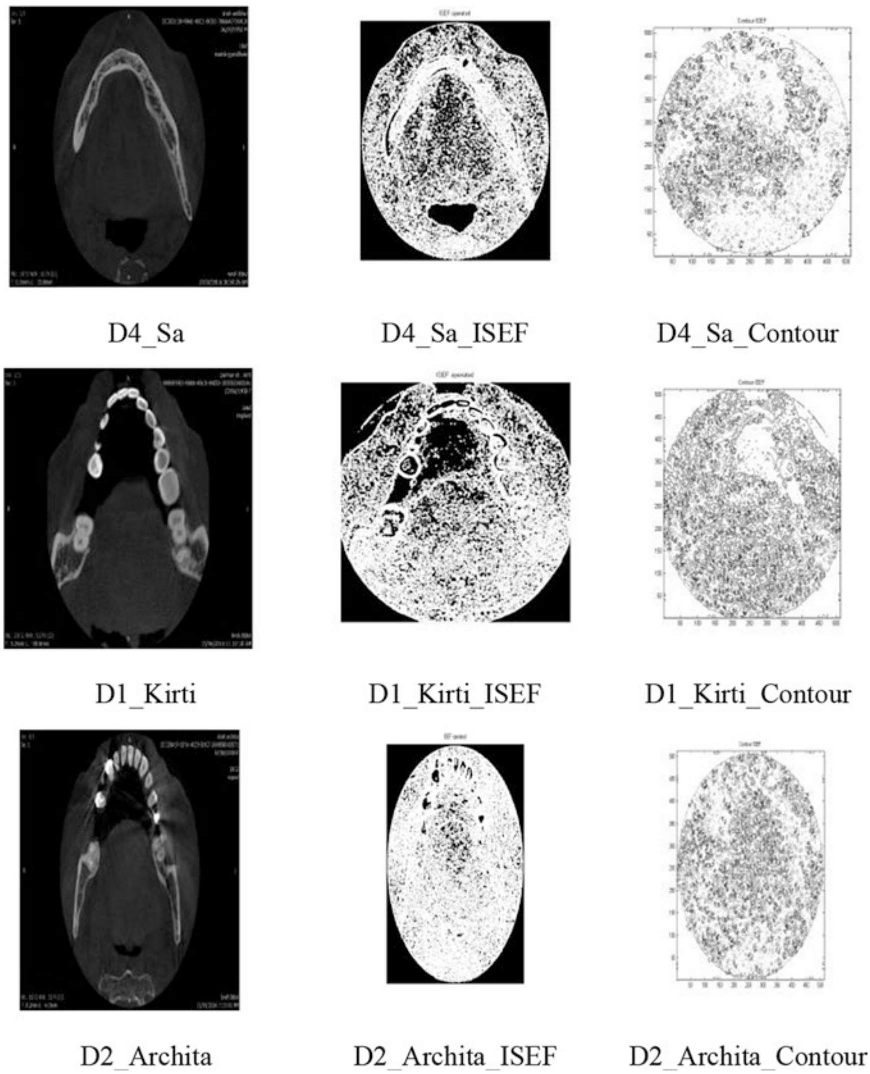


Fig. 5.27 (continued)

Table 5.3 Average Matching of Contour Values of DICOM® Dental Images

DICOM® Dental Image	Matching Percentage of Contour Values of Images
Am	78
Ck	12
Sp	62
Mb	58
Pa	65
Tk	63
Amish	58
Pm	67
Sa	54
Kirti	08
Archita	64

Table 5.4 FRR and FAR for Presented Dental Identification System

Threshold	FRR	FAR
85	1	0
80	0.2	0.07
70	0.1	0.15
60	0.1	0.24
50	0.1	0.35
40	0	0.55

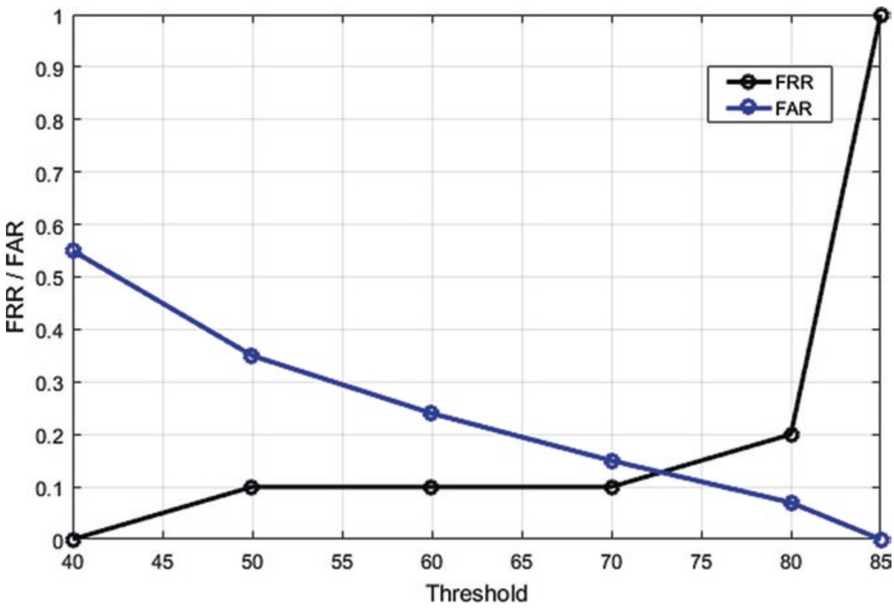


Fig. 5.28 FRR/FAR vs. Threshold Curve for Presented Dental Identification System

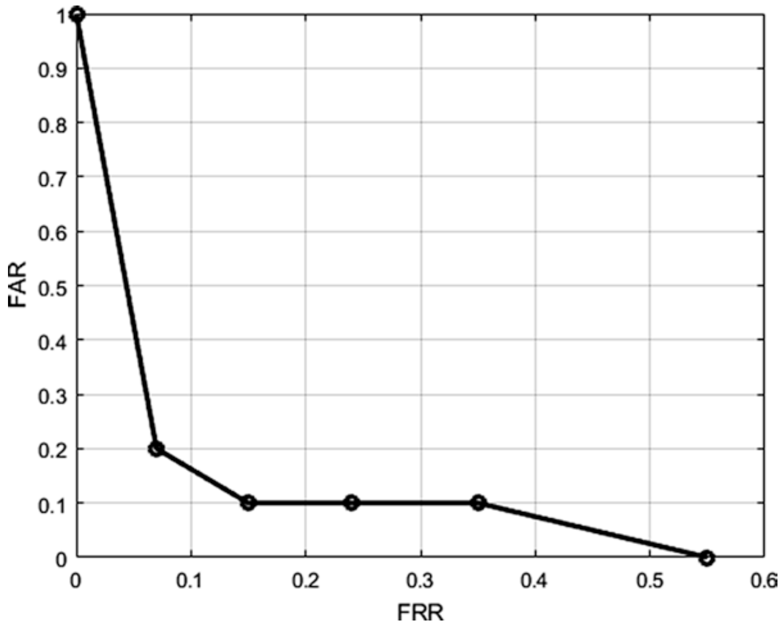


Fig. 5.29 ROC Curve for Presented Dental Identification System

Bibliography

1. Biometrics Testing and Statistics (2006). National Science and technology council (NSTC) Report, August. Available: www.biometrics.gov/documents/biotestingandstats.pdf
2. Jain, A., Ross, A., & Prabhakar, S. (2004). An introduction to biometric recognition. IEEE transactions on circuits and Systems for Video Technology, special issue on image and video based. *Biometrics, 14*(1), 4–20.
3. Giot, R., El-Abed, M., & Rosenberger, C. (2012). Fast computation of the performance evaluation of biometric systems: Application to multibiometrics. *Future Generation Computer Systems, 1*, 1–30.
4. Shen, J., & Castan, S. (1988). Edge detection based on multi-edge models. In *Real-time image processing: Concepts and technologies* (Vol. 860, pp. 46–54). International Society for Optics and Photonics.
5. Sandberg, B., Chan, T., & Vese, L. (2002). A level-set and Gabor-based active contour algorithm for segmenting textured images. In *UCLA Department of mathematics CAM report*.
6. Meng, X., Nandagopal, T., Li, L., & Lu, S. (2006). Contour maps: Monitoring and diagnosis in sensor networks. *Computer Networks, 50*(15), 2820–2838.

Chapter 6
Comparative Comparison and Future Challenges for Human Identification System

6.1 Comparison of Presented Human Identification System with Existing Systems

Edge detection is one of the most commonly used operations in image analysis and feature extraction. Since edge detection is the initial step in object recognition, it is necessary to know the differences between edge detection algorithms. In this book, the classification of various commonly used edge detection algorithm is given. Then ISEF algorithm has been applied to various dental images, and lastly tooth contouring was presented. The contouring algorithm is applied to original dental radiographs and ISEF-edge-detected dental radiographs to obtain contour values of more than 70000 columns. Out of these values, only 20000 nos. of columns are used in the presented dental identification system.

The various contour labels are applied to ISEF-edge-detected dental images, and according to those labels, various contour columns are obtained. These results are directly applicable to any postmortem (PM) and antemortem (AM) dental radiographs. If every digit in a column is nearly equal, then both radiographs refer to the same person. Otherwise, both the radiographs refer to different persons. Subjective evaluation of images showed that under noisy conditions, ISEF is a better algorithm.

As per discussion, P34 dental image from jpg database matches all other dental images, and results show that the matching of P34 dental image and P35 dental image is 70%, while another dental matching is less than 31%. For DICOM® dental image, D9_Am dental image is taken and is compared with 110 DICOM® dental images of various persons. The results have an average 82% matching for the same person and average 20–65% matching for other persons.

Table 6.1 shows a comparison of the presented human identification system with the existing system, identifying various features. The comparison shows that the presented system performs better than the existing system.

D. N. Trivedi et al., *Dental Image Processing for Human Identification*,
https://doi.org/10.1007/978-3-319-99471-0_6

Table 6.1 Comparative Comparison of Human Identification Systems

Features	Existing System	Presented System
Type of biometric system	Mostly fingerprints, iris	Dental
Type of edge detection techniques	Canny, Sobel	ISEF
Type of matching algorithm	Euclidian distance, direct matching, chain code etc.	Contouring (bilinear interpolation)
Types of database	Jpg	Jpg and DICOM®
Matching tool	A single tooth or entire image (adjacent pixels are not considered)	Maxilla or mandible only (more time-invariant tool, adjacent pixels are considered)
Case study	Not mentioned	All the case (person) records are matched and real time
Source of database	Internet	Authenticate (Dr. Batra)
Percentage of matching	Not mentioned	65–80%
FAR	0.04–0.09	0.01–0.03
Applications	Only civilians (in disaster not applicable)	Civilians, forensic and high security

6.2 Future Challenges

In this book, dental image processing for human identification system is presented. This system is implemented using ISEF edge detection algorithm and contouring algorithm. This system is tested using various types of dental database such as jpg and DICOM®. The results show that the presented system is effective for human identification based on dental features. The future scope of this system will include a hardware implementation of this system and also the application of ISEF edge detection algorithm and contouring algorithm on iris or bone radiographs for the identification of human diseases or for patient diagnosis.

Index

D. N. Trivedi et al., *Dental Image Processing for Human Identification*,
https://doi.org/10.1007/978-3-319-99471-0