Human Frontal Sinus Identification Based on SIFT and Pattern Recognition Techniques-A Hybrid Approach

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Declaration

I certify that this research work titled "*Human Frontal Sinus Identification Based on SIFT and Pattern Recognition Techniques-A Hybrid Approach*" is my own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources it has been properly acknowledged / referred.

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I would like to dedicate this thesis work to
my teachers, family and friends.

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LIST OF ABBREVIATIONS

Abbreviation	Illustration
CT	Computed Tomography
CMH	Combined Military Hospital
CF	Co-Relation Factor
DNA	Deoxyribo Nucleic Acid
DR	Digital Radiography
DIFT	Difference Image Forest Transform
DB	Data Base
DIP	Digital Image Processing
ES	Ethmoidial Sinus
ECG	Electro Cardio Gram
FMR	False Mismatch Rate
FS	Frontal Sinus
FSD	Fourier Spectrum Difference
FD	Feature Descriptor
HD	Histogram difference
HG	Hand Geometry
IM	Image Match
KNN	K Nearest Neighbour
MR	Match Rate
MSCT	Multi Slice Computed Tomography
MRI	Magnetic Resonance Imaging
MS	Maxillary Sinus
PSI	Pixel Similarity Index
RI	Radiographic Image
USG	Ultra Sound Graph

CHAPTER 1: INTRODUCTION

The basic aim of recently developed forensic sciences technologies is to identify persons, deceased bodies and human remains found at a crime scene or accident site by using several suitable and appropriate methods, procedure and techniques. Many different methods had been purposed for personal identification in past using conventional biometrics. With advancement of computer technology various methods were devised based on identify the distinguishing features or peculiar characteristics associated with humans such as finger prints, appearance or their voice. Different visual characteristics such as sex, height, body weight, deformation of the body, old scars had also been used as personal identifiers. In 19^{th} century, the forensic personal identification science got progressions and acceleration became more and popular. In this regards the first documentation of fingerprints was defined in 1823 by Johannes Evangelists Purkinje, a Czech anatomist and physiologist. In 1880, for identification of criminals French Police Officer Alphonse Bertillon developed first anthropometric scientific system which was based on physical measurements [8]. In the same pattern, a useful method for classifying fingerprints was devised by Francis Galton.

In November 1895, Wilhelm Conrad contributed a lot in forensic science development by introducing radiographic images commonly known as X-rays. Human identification had always been challenging. In September 1984, Sir Alec John Jeffreys, British geneticist, developed techniques for DNA fingerprinting and DNA profiling which provided a significant contribution for forensic personal identification [3, 8].

Human identification based on forensic imaging has not lost its impotence and is developing at very high pace .The same techniques are also being used in difficult cases of DNA analysis where identification of relatives, twins, or cases of poorly conserved remains is revealed through DNA matching. The digital imaging techniques such computed tomography (CT), Digital radiography (DR), magnetic resonance imaging (MRI), multi slice computed tomography (MSCT) and ultrasound (USG) has been widespread and is being utilized optimally in disease detection [8]. In the same way digital radiography can be used for analysis of morphological structure of frontal sinus for extraction of prominent features which can lead towards development of application for forensic personal identification [5].

1.1 Radiographic Techniques and Forensic Sciences

The usage of radiographic images in forensic sciences was introduced in 1896 just after one year discovery of x-ray by Prof. Arthur Schuster .A criminal case for identification in which bullets were found inside the head of a victim was to be resolved. It was proposed, the possibility of identification by comparison of radiological images of the frontal sinuses with already held radiographs. The positive identification was achieved and radiographs images became source of identification. The first complete radiological identification by using pneumatic cells of the skull was described by Culbert & Law, in 1927. Today, forensic scientists regularly use radiographic images as part of the normal autopsy procedures and clinical forensic applications [8, 26].

1.2 Radiographic Techniques in Autopsy Procedure

Modern forensic facilities use radiological techniques are part of normal autopsy procedure and at the same time their usage is fairly common and normal routine. The decision of acquiring radiographs images is related to the individual circumstances but normally implemented after the external examination and prior to the dissection. Radiological techniques are great help for providing important clues and determination of cause of death. In the autopsy procedure, radiography is considered as best source of collection of forensic evidences including time and cause of death [41, 42]. Various types of fractures, traumas and soft tissue injuries which cannot be observed through naked eye can easily be identified through radiographic images. The quality of radiographic images and image enhancement techniques has further make the task easier. Moreover analysis process has become more informative reliable and authenticated. Now radiographic images can depict those hidden information which cannot be extracted using normal x-rays. Using advance level applications permanent autopsy records can be created for future references for revaluation or comparison in personal identification. The same can be submitted as evidence to courts. The identification of the ripped, carbonized, Skelton bodies is possible with minimum of efforts specially incase of natural disasters where only few human remain or skeleton is found. In such incidents normal conventional biometrics are destroyed completely making identification process further difficult and time consuming. In such cases DNA matching can be utilized but it is very expensive and in some cases DNA matching samples are not available. Radiographic images are very cheap as compared to DNA matching and can produce reliable results with minimum of efforts [8]. The only problem with radiographic images is their availability in medical record for comparison.

1.3 Forensic Personal Identification Using Radiographic Techniques

Radiographic images had been great advantage to forensic scientists which assisted and benefited them in observing variations in human particular organ shapes, and contours including distinctive patterns of structures [39]. It also helps in detection of various fractures and other unique pathological features which can be utilized to determine the identity. Identification of human based on comparison of ant mortem and postmortem radiographs of frontal sinuses has now been well established procedure among forensic scientists. Many researchers believe and claim to use frontal sinus as an alternative or substitute for fingerprints as frontal sinuses in particular have always been assumed to be different in every person [5].

1.4 Structure of Frontal Sinus

1.4.1 Location of Frontal Sinus

The frontal sinuses are located in the frontal bone above each eye. They make an important contribution to normal forehead contour [8].

Fig 1.1: *Location of Frontal Sinus [8]*

1.4.2 Dimensions and Characteristics of Frontal Sinus

The dimension and general Characteristics of frontal sinus are as under:-

Characteristics	Description
Shape	Frontal sinus is a triangular, pyramid shaped located above each eyes.
Invariability	The structure of frontal sinus can be variable from person to person and its sizes might be different in different populations.
Height	The approximate height of frontal sinus is between 5 and 66 mm and width between 17 and 49 mm.
Interior wall	The interior wall of frontal sinus is the strongest of the sinus walls and its thickness can reach up to 12 mm.
Dipole	In the entire sinus wall, there is dipole which is minimal in the posterior wall and interior wall.
posterior wall	The posterior wall is a plate of thin, compact bone (1-2 mm) whose upper part is vertical.
Drainage	The drainage is located in rear portion of the sinus floor.
Complexity	The frontal sinus frontal recess is complex shaped feature.
Size	The size of the bottom half depends on the dimensions of the frontal recess.

Table 1.1: *Dimensions and Characteristics of Frontal Sinus [42]*

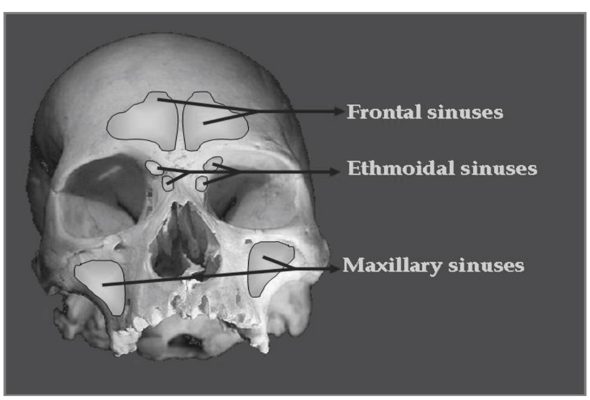


Figure 1.2 *General Structure of Frontal Sinus [8]*

1.4.3 Functions of Frontal Sinus

No definite functions of frontal sinuses have been discovered therefore its functions remain largely unknown [1, 3, 8]. The sinuses have been believed to play numerous roles. The current theories suggest following functions [26, 27]:-

- Humidifying and warming inspired air.
- Assisting in regulation of intra nasal pressure.
- Increasing the surface area of membranes.
- Head Balancing.
- Imparting resonance to the voice.
- Absorbing shock to the head.
- Contributing to facial growth.
- Secreting various secretions.

1.5 Frontal Sinus as Powerful Biometrics

The distinctive and unique features of frontal sinus like shape and size make it most convenient biometrics to be used as identification especially in forensic analysis. The major reasons for declaring frontal sinus as valuable biometric are:-

- The nature of frontal sinus is highly variable. It is different for each individual and also shows variation even among the monozygotic twins [5].
- There is no sign of frontal sinus at the time of birth. At age of two it starts developing and changes are found till the age of twenty years and afterword no change has been observed [40]. Minor changes can be observed at advance age. But as a whole this feature is relatively stable structure during adult life. As its stability period is after twenty years therefore, it is suggested that the radiographs images older than ten years are more reliable for the identification purposes [5].
- The strong bone structure of skull provides natural protection against external environment [2]. It remains intact in human remains where normal conventional biometrics no longer exists. Therefore, it can be considered as reliable and consistent biometrics.

- The radiographic images of individual para nasal are taken commonly for diagnostic purposes. Almost everybody undergo for para nasal radiographs once in his/her life for maintenance of health folder/ record especially in advance courtiers [41].
- Radiographic comparison and matching is permitted due to unique frontal sinus features. The various frontal sinus patterns can be compared using different methods and techniques In the presence of an ante mortem and post mortem radiograph both can be compared to achieve desired personal identification of human [26].
- Frontal sinus is widely accepted as biometrics and its comparison is normal routine method/ procedure in forensic sciences [1, 39, 42]. Various applications can be developed for comparison of the ante mortem and postmortem radiographs of the frontal sinus. The same can be accepted as a reliable method worldwide.
- Finger prints are no longer only means of identification. There is need to explore other biometrics which may provide high level of verification and identification [18]. At present algorithms can be developed in which discrimination of radiographs can simply be achieved by applying pattern matching [41].
- Conventional radiographs are being replaced with digitized radiographs due to significant advancement in radiographic technology [5, 8].
- Digital radiography is an appropriate imaging method for identification of unknown human remains. The advantages of digital radiography is not comparable with conventional radiographs due to following reasons:-
    - Structures can be observed beyond the plane of interest and visualization of small density differences is possible [3].
    - Manipulation of images is easier and region of interest can be evaluated through segmentation.
    - Minor points can e precisely b located and accurate measurements can be made as compared to conventional radiographs. Volumes and

areas can be accurately determined up to desired level of precision [42].

- Identification process can further be improved by creating individual information record such as name, Date of Birth, address etc [39].

1.6 Various Biometrics Comparison

All the currently used biometrics cannot utilize in case of deceased persons as the biometrics are destroyed or may not be available for identification [33]. In such cases we have to rely on non conventional biometrics. The comparison of applicability of biometrics for deceased person is as under:-

Biometrics	Applicability
Finger Prints	×
Iris	×
Voice	×
Face	×
Hand Geometry	×
ECG	×
Ear	×
Gait	×
Teeth	√
Frontal Sinus	√

Table 1.2: *Various Biometrics Comparisons [33]*

CHAPTER 2: LITERATURE REVIEW

2.1 Introduction

The frontal sinus is located in the frontal bone, and consists of paired, irregularly shaped cavities, The frontal sinus initial development stars in 4th month after conception but it is not visible at time of birth[1,5,8]. It begins to develop during the second year of life, reaches its maximum size at the age of twenty, and remains stable through rest of the life. The size and shape frontal sinus is claimed to be unique for each individual and same is affected by genetic and environmental factors [39]. Frontal sinus variations have been reported even for monozygotic twins [40]. The possibility of identifying a person by comparing frontal sinus radiographs was first suggested by Schuler in 1943[8]. The unique distinctive shape and size of frontal sinuses has stimulated several attempts to identify persons by analyzing measurements of the sinuses obtained from radiographic images. A study was carried no identification human skeletal structure using the frontal sinus region as identifier. The proposed methods suggest that the region of interest can be segmented using manual or semi automatic segmentation. The methods have been assessed on numerous numbers of radiographs and produced positive results for identification [6, 7, 9, 43]. The experiment were based on extraction of best features to be used from shape and size of frontal sinus using manual or semi automatic marking of frontal sinus The later methods implemented image foresting transform and shape context /top border algorithm for segmentation of region of interest and matching of frontal sinus .

2.2 Overview

Biometrics is a science of identifying individuals through physiological and behavioral traits [18]. The physiological trait include iris , ears, heart beat(ECG) ,palm print ,fingerprints, retina etc where case behavioral traits can be signature, gaits, keystroke dynamics etc) .

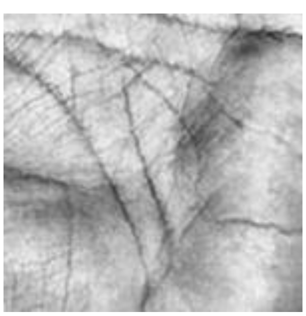


Figure 2.1: *Biometrics on the Basis of Different Traits [18]*

The major advantage of biometrics over normal verification and authentication system is permanent association with concerned individual and consistency. The use of biometrics instead of classical verification and authentication system is increasing at very rapid pace due to distinctive and unique nature and reliability which is inherent as well .For development of applications related to humans in future, biometrics will remain effective and valuable means for ensuring security. They will remain pivotal and essential requirement to access highly confidential and classified data. To become an effective biometric, it must possess certain characteristics which are as under:-

- **Universality:** which means that every person in the universe must have this feature[16].
- **Distinctiveness** that means that there it should be sufficiently distinction between two different individuals[19].
- **Invariability** The feature should be easy to collect and comparable quantitatively to differentiate .It must help to make comparison process easy and avoid conflicts [8].
- **Quality** It must have sufficient quality where distinguished feature can be extracted without difficulty [16].
- **Stability** means that these features are permanent and are not effected by various factors [10].
- **Performance** refers that whether we can achieve desired accuracy, speed and robustness in terms of identification and verification and whether desired identification accuracy can be attained within prescribed time

limits even affected by various environmental factors that affect the identification accuracy and speed [18].

- **Quantitative** It refers whether features can be measured quantitatively [19].
- **Acceptability** It indicates level of acceptance and willingness by people to recognize the biometric as valid identifier in routine life [16].
- **Reliability** reflects how easily biometrics authentication may be compromised by intruder's attempts using deceptive methods [18]. It is also related to false acceptance rate. All above mentioned requirements are desirable and a biometrics may not fulfill or serves these prerequisite of being a biometric feature. However, in practice, it is pretty possible any biometric which satisfies all the above requirements may not applicable as practical biometric system. In general, a practical biometric system requirement may vary depending upon scope and nature of application.

2.3 Classical Verification and Authentication Methods

Two methodologies were mainly used for verification purpose. These are:-

2.3.1 Personal Identification Code Oriented Method

In past for decades this approach was considered as consistent and reliable method but at present there is sharp decrease in importance and significance due to flowing reasons:-

- Strong passwords are difficult to managed and maintained and moreover, passwords can be identified or compromised by using high performing computing systems even high level encryption methods are used [18].
- Complex passwords are very difficult to remember. The problem is further aggravated if mandatory to change passwords after specified periods of time [16].
- Although most of applications compel to have complex password and length more than seven characters yet average human being can not always remember such password and invariably is not violable solution [19]. The

same approach is also known as knowledge based approach as knowledge of password is essential and vital requirement to access different systems.

Figure 2.2: *Identification Based on Personal Identification Code [18]*

2.3.2 Card Oriented Approach

In card oriented approach access or identification is ensured through cards such as smart cards, ID cards and passports etc[17]. This method had been used for number of years to get access to high security zones. The dilemma of this approach is that any person who manages to produce the desired card can authenticate himself to get access of restricted areas so identification merely depends upon holder of card not the individual. Therefore, this approach warrants a quick and responsive blocking mechanism in case of theft or stealing of card. Moreover, safe custody and management of card is another problem and overhead [19].

2.4 General Mechanism of Biometric Systems

Biometric systems generally follow following mechanism:-

2.4.1 Creation of Biometric Data Base

A data base of biometrics is created through various applications. The Data base store all relevant details regarding individuals [16]. The same data base is used to compare biometrics and granting access level for restricted zone or confidential information.

2.4.2 Matching of Biometrics and Grant of Access

In this level biometrics record of individual desire to get access, is compared with the previously stored biometrics record in data base. This type of comparison is made using one to many matching approach. The person will be granted access to the system if his biometrics record matches with any authentic record held in data base. This mechanism is computationally very expensive as all the record in data base must be compared to find the match between input biometrics and database of biometrics record. To implement the mechanism, high end machines are required [23].

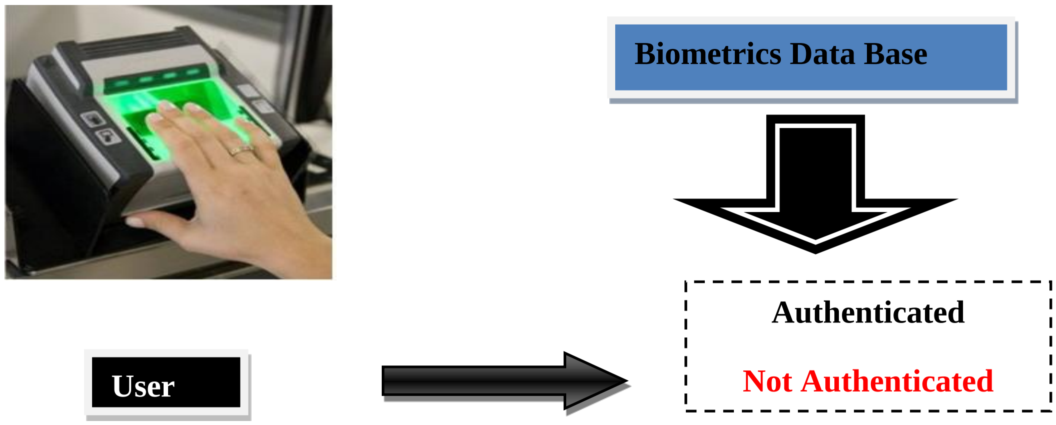


Figure 2.3: *General Mechanisms of Biometric Systems [16]*

2.5 Currently Used Biometrics

2.5.1 Identification Based on Fingerprint

This is the oldest and widely used biometric system which is famous for its accuracy worldwide. Each individual has distinctive ridge patterns and it does not change throughout the life. Fingerprint matching is the most commonly used and least expensive biometric technology due to which it has been incorporated in numerous applications to enhance security [16, 18, 19]. Some of examples are PDA's, laptops and personal computers.

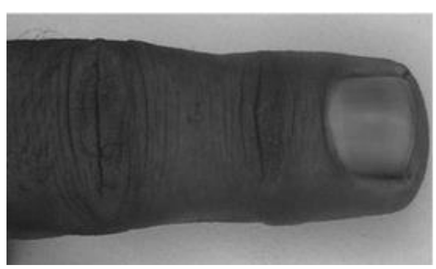


Figure 2.4: *Identification Based on Finger Prints [18]*

2.5.2 Identification Based on Iris

Medically it has been established that the iris is developed during eight months and throughout the rest of life it remains stable [18]. Features like rings, furrows, freckles and corona are used during Iris scanning. Iris has 266 unique spots in iris which are more than any other biometric system [32]. Normal range of unique traits in other biometrics is 13 to 60[18]. The major advantage of using iris as biometrics is that it is naturally protected from environmental hazards like pollution and remains unharmed. Isolation of iris is easier because of its distinct shape in the face to isolate it from rest of the parts of the face. Iris fast and speedy recognition enable it to be used for large scale systems. Moreover texture alteration of iris is very difficult which ensure a stable and reliable security [18]. As the iris scanners are becoming cost effective and affordable, its usage will be amplified in future.

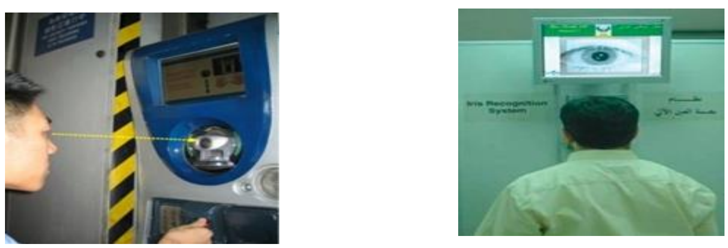


Figure 2.5: *Identification Based on Iris [32]*

2.5.3 Identification Based on Voice

Voice recognition systems have characteristics of being much dynamic as compared to other biometric systems. Voice recognition software is being implemented through various methods. The system incorporate person different speaking styles which lead the system to be very difficult to deceive a system but at same time warrants very advanced algorithms to authenticate this information . Voice is a mixture of behavioral and physiological characteristics [18]. Physiological component is constant but behavioral component can be variant component. For development of reliable voice recognition software, high level programming is pre requisite. Through use of this biometric technology personal authentication is possible remotely or through phone line. The authentication process may be effected due to variation in communication parameters i.e. phone speaker, microphone which may reduce its performance. So, quality of communication channel should be kept at an acceptable level [32].

2.5.4 Identification Based on Face

Identification based on face recognition is becoming more and more popular and common day by day. In this field a lot of research is being carried out and very reliable and accurate face recognition software are commercially available [10]. The focal point of current research is to develop recognition systems that can accurately judge for changes in age and expression of particular face [20]. An advance level research is also being carried out to resolve the issue like use of artificial hair transplant, use of various types of glasses, make up and facial surgery which entirely change outlook. The prime advantage of face reorganization as it can operate remotely by capturing desired images by cameras. The identification can be achieved with interaction. Because of above mentioned these types of systems acceptance increasing sharply and rapidly [10].

2.5.5 Identification Based on Hand geometry

Hand geometry and finger prints are closely related. Hand Geometry is based on analysis and measurement of the shape of the hand [13]. Identifying someone using hand geometry is normally considered as simple and reliable. But in most of countries courts human hand is not considered distinctive and its features are not descriptive enough which can give surety for reliable identification [13]. In hand geometry identification system human hand is scanned for extraction of features, hand geometry and measurements of fingers for verification of an individual. The scanning is carried out using special scanner which has peg on it for proper alignment of hand [13]. In this way hand geometry features or attributes are read and saved effectively. The comparison device compares the geometry of hand with all previous hand attributes in the database and decides about identification of individual. The major drawback or weakness of this approach is that it is not possible to detect weather the person is alive or deceased. Moreover, there is chance to deceive system as two people may have same hand geometry. That is why it is usually combined with some reliable authentication systems for verification and identification.

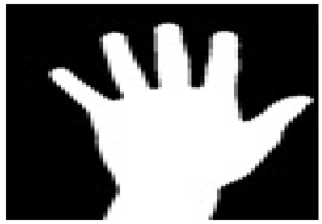


Figure 2.6: *Identification Based on Hand Geometry [13]*

2.5.6 Identification Based on Electro Cardio Gram (ECG)/Heart Sound

Various experiments are being conducted to determine the relationship between various cardiac parameters. The most significant contribution of Electro Cardiac Gram, which can also be used as biometrics.The heart sounds cannot be easily simulated or replicated as compared to other conventional biometrics [14]. It has medically been established that different persons have different cardiac parameter values which suggest use of these parameters as distinguished feature for identification. Preliminary results indicate that an identification rate of up to 96% is achievable by comparing ECG and heart sounds with well preferred parameters [13]. The disadvantage of using approach is that parameter values should not be older than two months and must be collected over a period of two months.

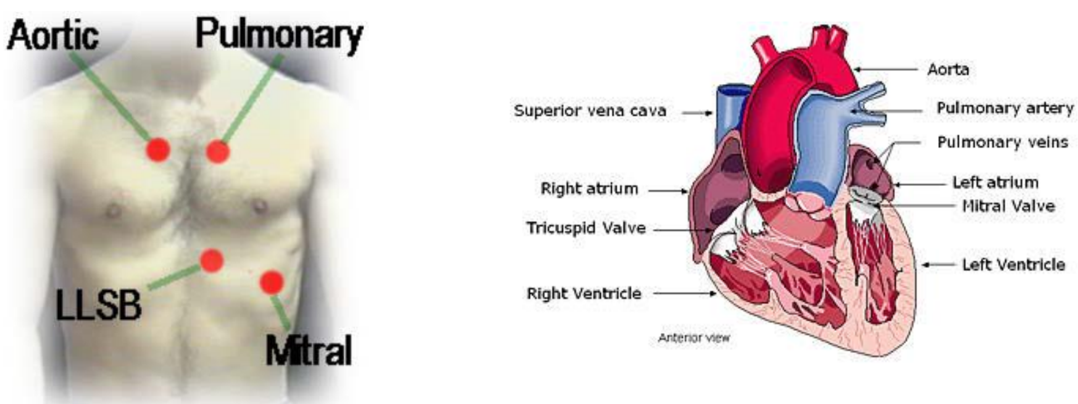


Figure 2.7: *Identification Based on ECG[14]*

2.5.7 Identification Based on Ear

Identification based on ear is new emerging technology. Many researches are being carried out to enhance and improve results of existing methods. Ear images are acquired and region of interest is cropped manually. The distinguished features are extracted and saved in data base. The matching of features is carried out using various methods and match rate up to 95% is achievable using different techniques [17, 24]. In future, this biometrics is like to become more popular due to distinguished ear construction.

Figure 2.8: *Identification Based on Ears [22]*

2.5.8 Identification Based on Gait

Style of walking of an individual is called Gait. Many studies has highlighted this fact that different persons has different gait or walking style [15]. Recognition of a person from their gait is a biometric of increasing interest. All possible walking styles and patron of person are stored as distinguished features. The matching is carried out using classifier .Experimental results shows that 100% match rate is achievable for cases where training and testing sets corresponds to the same walking styles are used, and 90% match rate is achievable in cases when training and testing sets do not correspond to the same walking styles [15].

Figure 2.9: *Identification Based on Gait [15]*

2.5.9 Identification Based on Teeth and Dental

Many researchers have purposed human identification method based on matching the contours of teeth and the shapes of dental works. For matching of contour of teeth and shape of dental work, radiographic images are mandatory requirement [21]. Using this biometrics as identifier matching rate of 100% is being claimed using different methods [21, 34]. The other advantage of this biometrics is applicability in forensic applications where few human remains are found to identify unrecognized or unidentified bodies.

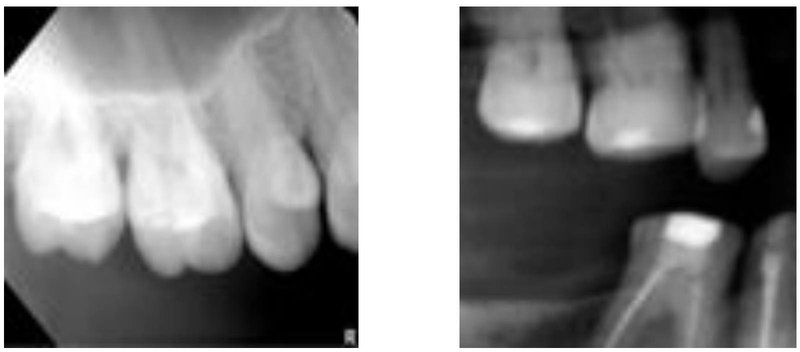


Figure 2.10: *Identification based on Teeth and Dental [21]*

2.5.10 Identification Based on DNA

DNA is the genetic material of a cell. The chromosomes inside the nucleus of the cell are made of DNA [32]. It is the material in cells that stores the inherited characteristics that make up our bodies. In forensic science, DNA testing is one of the best methods to identify a victim or victims. DNA can be obtained from human remains or other sources. To identify the individual DNA sample obtained from human remains found at the disaster or accident site are matched with DNA sample already known to be from the victim or the victim's relatives. Thus, for DNA based identification samples collection is necessary, to be obtained/ collected either from personal items, prior medical specimens or from family members victim[18]. This method is commonly used for deceased persons or where limited or a few human remains are found. In future, DNA matching will be very common procedure for human identification.

Figure 2.11 *Identification Based on DNA [32]*

2.6 Importance of Frontal Sinus Radiographs for Human Identification

Identification of human beings is possible through various methods and procedures. The most common and widely adopted method is through finger prints [19]. The subject method is applicable only if soft tissue of finger print is preserved. However, when the corpse has been decomposed or converted into skeleton, the normal identification biometrics cannot be utilized [3]. In such situation we have to rely on non conventional biometrics such as contour of teeth, shape of dental work or DNA analysis [21]. In this regards, medical documentation specially can be great help and can substantially improve the chances of identification of corpses initially declared as unrecognizable/unidentified. Followings are some of the cases in which human remains were correlated and compared to the identity missing persons. In all cases ante mortem and post mortem radiographic images of frontal sinus (skull) were analyzed using different methods and techniques for identification. Moreover, now days the quality of radiographic images have improved tremendously thus allowing development of very consistent and reliable applications for human identification based on images of human skull, which is normally not destroyed or damaged [8].

2.6.1 Case Study-1

In December 2006, few human remains (skeleton) were found in a patch of woodlands. During forensic analysis it was revealed that many of the remaining bones ulna, ribs, vertebrae etc were found fractured. The signs of trauma were also visible on skull. Only the upper portion was relatively preserved, while face bones were found fractured and detached from their joints. Preliminary analysis discovered that the corpse was having characteristic traits of an adult woman. As per Police investigation tentative victim was woman of 30 years of age who had been missing since May 2006.Durning investigation it was also revealed that she got injured at the age of 8 and remained under clinical and medical treatment till she was

25.The forensics team was provided number of radiographic images to disclose and determine whether the remains belonged to the missing women. Two radiographic images of frontal sinus taken from 1989 and 1993 (Figure 2.12 A&B) were compared with radiographic image of the skull remains taken during post mortem in 2006 (Figure 2.12 C).The distinctive pattern of frontal sinus was used to compare the images to resolve the issue. This study case shows that frontal sinus pattern is unique and remains preserved even elapse of considerable time where normal conventional biometrics are destroyed and cannot be utilized for identification purpose[4]. The human skull decomposition time is very long thus biometrics related to skull can be utilized even after considerable time has passed [1]. The change in frontal sinus pattern shape and size is minimum enabling and declaring it as strong biometrics for forensic analysis [3, 37].

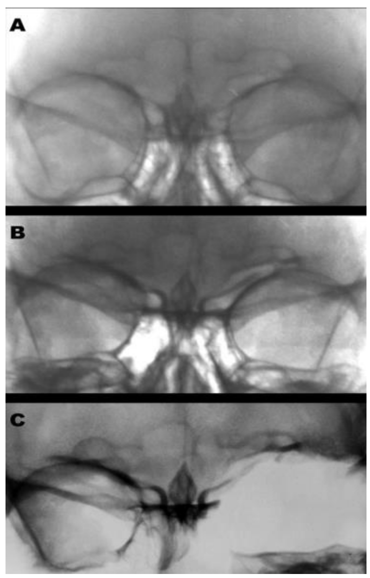


Figure 2.12: *Comparison of Images of the Victim's Frontal Sinus, in 1989(A), 1993(B), and Post-Mortem in 2006(C) [5].*

Following are few case study findings:-

- The frontal sinus cavities are located between internal and external layer of the frontal bone.
- Their radio graphical evidence can be observed at age of 5-6 and it is fully developed at age of 20[5, 39].
- The frontal sinus is absent in only 4% of the population and shows distincti-ve variations in shape, area, and symmetry [2].

- The unique and distinctive shape area and symmetry of frontal sinus plays pivotal role to make it an important parameter to determine gender segregation and also allow us to use for identification.
- The quality controlled radiographic images taken through adequate technique are essential for good forensic practices and analysis.
- The morphological analysis frontal sinus revealed the identity of missing women. The quality radiographic images taken during her treatment when she was alive enabled her positive identity .The image enhancement technique in which brightness and contrast were adjusted to allow improved contour visualization, was used for comparison of radiographic images. The results from the comparison between the ante mortem images taken before and post mortem after the victim death indicated that there was very minor slight variation in frontal sinus pattern. Apart from using radiographs in identifying frontal sinus trauma and diseases, the same can be effectively used in morphology visualization and analysis to reveal the identity of unidentified and unrecognized corpse [39].

2.6.2 Case Study-2

This male victim was burned in a hotel fire and his body was beyond recognition. The postmortem dental examination revealed that previous cleft palate surgery of victim teeth was carried out in near past.

Figure 2.13: *Case 2: Ante Mortem Radiographic Image obtained several months before the Victim's death. The complete extent of the frontal sinus is well represented [4].*

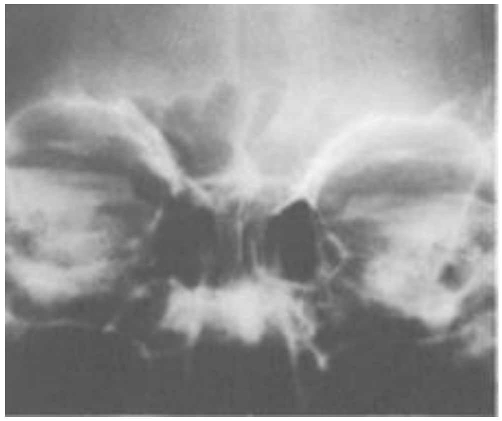


Figure 2.14: *Case 2: The post mortem radiographic image of the victim, the outline shape of the frontal sinus, can easily be observed [4].*

The radiographic images showed some distortion due to burning. Victim got his treatment from nearby medical center where cleft palate surgery was performed. From hospital record and files a radiographic image of victim was found which was taken two years back during subject surgery. The both radiographic images were compared and his positive identification was made on the basis of frontal sinus outlines and dental restorations. Although the victim was completely burnt but slight and minor variation in frontal sinus outline were observed. This case study proves that frontal sinus pattern is not adversely affected in burnt cases where all other biometrics is completely destroyed and cannot be used for identification [4, 34].

2.6.3 Case Study-3

The local fire department discovered victim body from an apartment. After observing nature of fire, damage caused to body and condition of body was suspected that it was a murder case. The body identification was extremely difficult due to condition of body. The authorities decided to use radiographic comparison method to reveal the identity. A comparison of ante mortem radiographic image located from local hospital and radiographic images obtained during autopsy produced positive result of identification. During comparison frontal sinus were compared to resolve the issue. The study suggests that distinctive and unique shape and size of frontal sinus remains unchanged in spite of 100% burning of body. The bone structure of frontal sinus is least effected by external environment thus enabling shape and size be considered as powerful identity descriptor for deceased persons [3, 36].

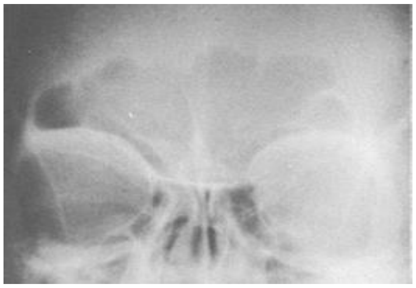


Figure 2.15: *Case 3: Ante Mortem Radiographic Image of the victim showing considerable size and shape of frontal sinuses [4].*

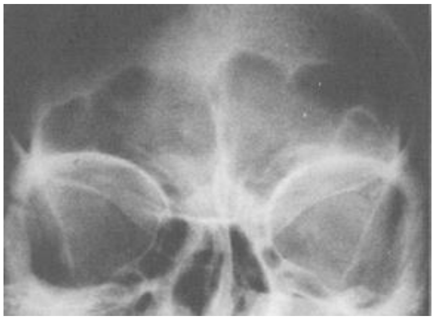


Figure 2.16: *Case 3: Post mortem Radiographic Image of the victim showing similar size and shape of frontal sinuses [4].*

2.6.4 Case Study-4

The body of female was found in northern Indiana River after her disappearance. At the same time, eight miles west of the site of discovery of the first body, another nude male body was discovered. The person was reported missing for last ten days. The both bodies were in advance state of decomposition and could not be recognized or identified. Due to condition of bodies, visual comparison was not possible. The both bodies had similar wound on chest making identification process further difficult and confusing. Both bodies were positively identified by dental works and frontal sinus outline comparison using radiographic images. The police arrested her husband as suspected murderer and after twenty days, the alleged husband of the female victim confessed both killings.

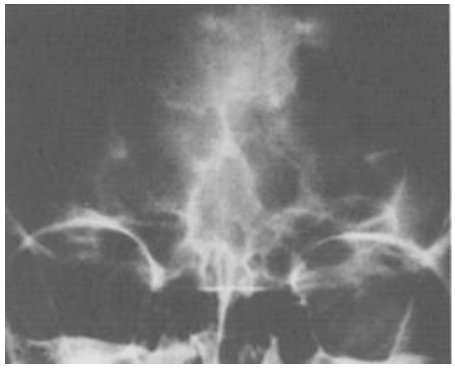


Figure 2.17 *Case 4: Radiograph Image obtained six years before the victim's death, showing distinctive and unique shape of Frontal Sinus [4].*

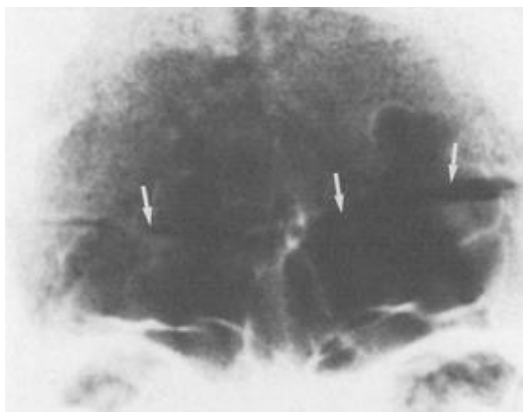


Figure 1.18: *Case 4: Postmortem Radiographic Image of victim showing outlines characteristic of Frontal Sinus [4].*

2.6.5 Case Study-5

A few human remains and skeleton of an individual who had been reported missing from an extended care facility were found several months after his disappearance. The positive identification of individual was achieved by comparison of the radiographic images taken at the state hospital six years prior to his disappearance and radiographic image taken during autopsy.

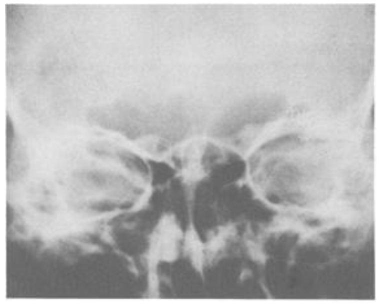


Figure 2.19: *Case 5: Ante Mortem Radiographic Image taken six years before disappearance of victim [4].*

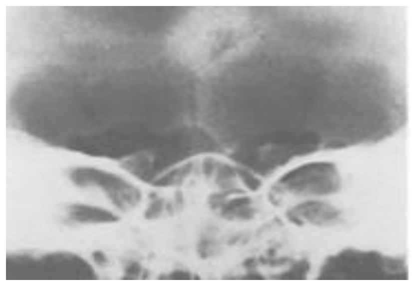


Figure 2.20: *Case 5: Postmortem Radiographic Image of the decomposed body showing similarity of frontal Sinus [4].*

Although the radiographic image comparison is very effective means of identification but may involve difficulties. The finding and collection of ante mortem and postmortem records may be very time consuming if standard procedure for maintenance of medical record is not being adopted or adhered to. The families sometimes may not know the names of medical and dental practitioners where decedent was receiving medical care. As search of ante mortem record may take considerable time, postmortem records must be obtained as soon as possible with special care. Till the time ante mortem data is unknown and being discovered, the postmortem data collection must be comprehensive, and should include a complete autopsy, radiographic images of skull and dental radiographs. It must be ensured that post mortem skull radiographs are obtained prior to opening of the head to avoid the possible saw cut on frontal sinus outlines to preserve its shape [3].

The maintenance of skull radiographs in medical records is normally overlooked but these radiographs are vital source of ante mortem records. Their importance is further increased in case of non availability of conventional ante mortem dental records. In general, these radiographs are also source of providing supporting information such as previous trauma, and surgery. Moreover, facial bone structure visible in radiographs can make comparison process more authenticated and reliable. These bone structure can also be source of extraction of additional features for comparison, specifically, cranial and facial structures visible in the various types of radiographs [25]. The advancement of radiographic image technology which is becoming very common now a day can help in utilization of numerous features for comparison with appropriate ante mortem and postmortem radiographs of some same structures. The enhanced capability of such radiographs is great assistance to depict structures which are often unique to the individual. The potential and capability of radiographs images has not yet been fully explored or utilized. Although forensic experts can determine race and sex by observing structural variations in the skull but very limited attention or research has been carried for utilizing of cranial and facial structures specially teeth and frontal sinuses for identification purpose. The unique features of frontal sinus can be extracted to act as identity descriptor to resolve complex cases in addition to conventional biometrics [26].

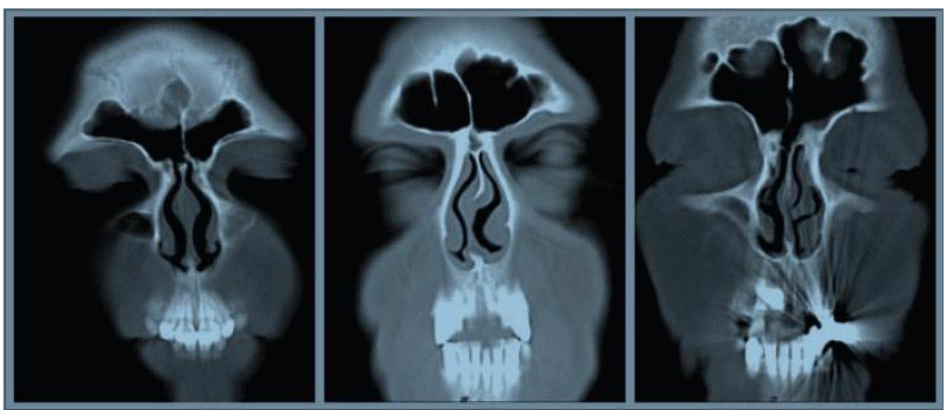


Figure 2.21: *Variations in Shape of Frontal Sinus [5]*

The summary of investigation is as under:-

- The frontal sinus is irregularly shaped feature which is located in the frontal bone and consists of paired cavities.
- The function of sinus has not yet been precisely defined medically [1].
- Its development stars at creation of fetus but no well defined

shape can be observed or visible at time of birth. It begins to develop during the second year of life, reaches its maximum size at the age of twenty, and remains stable and unchanged rest of the life [4, 39]

- It has been proven medically that pattern of frontal sinus is unique and distinctive for each individual. Moreover, its pattern largely depends on genetics and surrounding environment [44].
- It has also been established that frontal sinus is unique for monozygotic twins as well[5,39].
- Many case studies highlight that morphological analysis was used to identify missing persons, burnt cases and unidentified/unrecognized bodies by comparing ante mortem and post mortem radiographs[4].
- The distinctive and unique pattern of frontal sinus suggests that it can be used as strong and powerful biometrics in addition to other available biometrics[3,36]. The advancement in digital radiographs where they can be manipulated and analyzed for disease detection can effectively be utilized for development of consistent and reliable application for personal identification.
- The identification of human by extracting various features of frontal sinus like area, perimeter, width, height, Circularity, ferret has been suggested[9,42] but it involves very precise segmentation of frontal sinus thus more prone to human error.
- A method can be devised based on this hypothesis that unique and distinctive frontal sinus will produce unique and distinctive sinus features. The features can be extracted by applying a particular technique. The unique sinus features can be compared later through various methods for identity.

2.7 Various Methodologies Based on Sinus Recognition for Human Identification

Not much research has been carried to use frontal sinus as biometrics due its complexity. The determination of frontal sinus shape is extremely difficult owning to its complex bone structure. In most of the cases the visual and manual comparison had been used for identification purpose [4, 35]. Mainly three methodologies with adequate results were found where identification has been achieved through manual segmentation, extraction of feature, comparing feature or using image foresting and transform/top border algorithm [6, 7, 9, 42].

2.7.1 Mathodology-1 Frontal Sinus Recognition for Human Identification using Manual Segmentation

The method was experimented on fifty two radiographs. The method involves following steps:-

2.7.1.1 Manual Segmentation and Features Extraction

In manual segmentation image is edited using software Serif Photo plus, to obtain the shapes of the frontal sinuses. The paint brush tool is used to draw a new layer over the original image specifying shape of frontal sinus. The shapes were manually drawn and points describing shape of frontal sinus were extracted directly from the upper layer. To ensure effectiveness of methods the manual segmentation was carried out under the supervision of a radiologist.

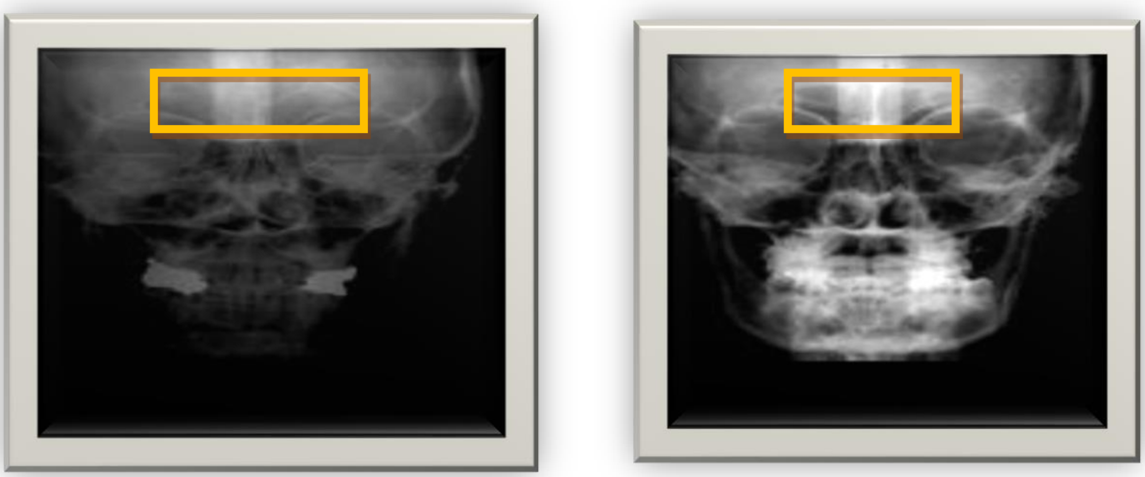


Figure 2.22: *Manual Segmentation and Features Extraction [42]*

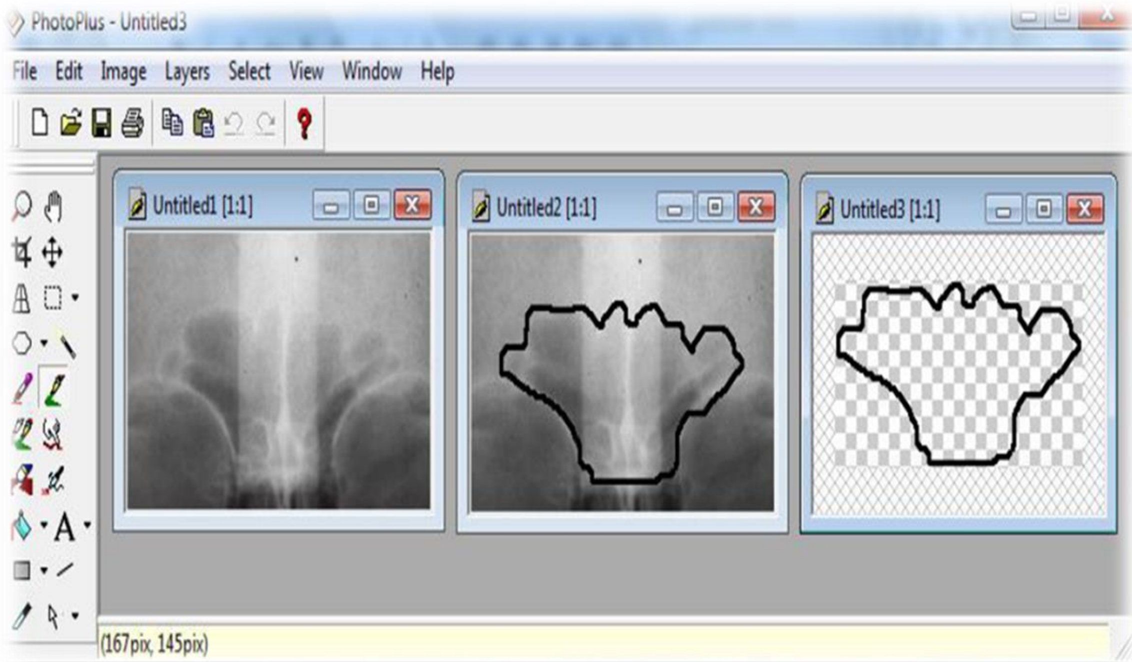


Figure 2.23: *Manual segmentation of frontal sinus using photo plus[42]*

From frontal sinus shape flowing features are extracted:-

- **Area:** The area is calculated in number of pixels from the frontal sinus shape.
- **Perimeter:** The perimeter is calculated in number of pixels from the frontal sinus shape.
- **Width:** The width is defined as the smallest rectangle enclosing the frontal sinus shape in number of pixels.
- **Height:** The height is defined as the smallest rectangle enclosing the frontal sinus shape in number of pixels.
- **Circularity:** The circularity of the frontal sinus shape is given by 4π (area/perimeter). A value of 1.0 indicates a perfect circle. As the value approaches to 0.0, frontal sinus takes the shape of elongated polygon.
- **Feret's Diameter:** it is defined as the longest distance between any two points along the frontal sinus shape in number of pixels. The same is also known as the caliper length.

2.7.1.2 Feature Data Base A data base containing records of extracted features (shape descriptors) for each radiographic image is created. The record matching is carried out during matching process of frontal sinus.

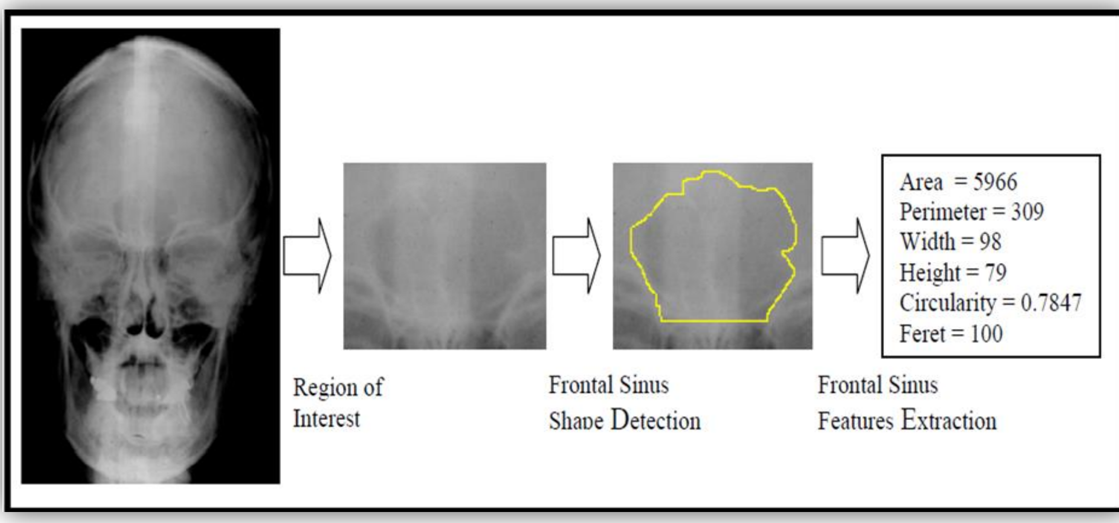


Figure 2.24: *Frontal sinus shape descriptors[42]*

Image	Total Dimension	Area	Perimeter	width	Height	Circularity	Feret's Diameter
Imag1	335x 452	4827	355	133	56	0.48104	133
Imag2	363 x 567	5966	309	98	79	0.78470	100

Table 2.1: *Frontal Sinus Shape Descriptors Data Base [42]*

2.7.1.3 Matching of Frontal Sinus

The matching process involves matching input features area, width, height, circularity with data base features records through query. For each matching of data base features, a score is calculated proportional to the feature vectors distance. The closet feature record is used to determined possible match of frontal sinus.

2.7.1.4 Experimental Results Analysis

The two radiographs of the same individual were obtained in different moments at least one year apart .The first image was considered as the ante mortem radiograph and the second one was considered as the post mortem radiograph. The proposed method was evaluated on following frontal sinus features area, width, perimeter, height, circularity and feret's Diameter.

2.7.2 Mathodology-2 Frontal Sinus Recognition Based on Image Foresting Transform Algorithm

The methods involve following steps:-

2.7.2.1 ROI Segmentation using Differential Image Foresting Transform Algorithm (DIFT)

The algorithm involves following steps:-

- The get general pattern of frontal sinus shape the segmentation process stars by marking initial pixels called seeds.
- The function cost of the path is determined which is the difference between the gray levels of the pixels.
- The similar gray levels will have lower value of function as compared to gray level with more difference. Due to similarity of gray levels pixels will tend to connect themselves to a smaller path. In this way the similarity of gray level can determine shape and size of frontal sinus.
- The pixel intensities I (p) represent two seeds , one selected inside and the other selected outside the ROI .

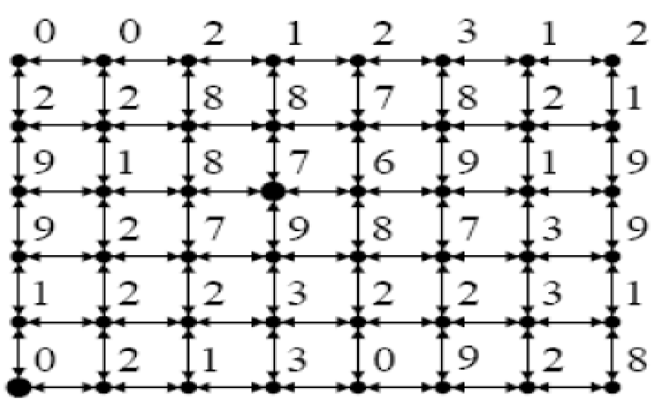


Figure 2.25: *Matrix of a gray level 2D Image with Neighborhood [9]*

The minimum cost path is obtained using the cost function:-

$$\mathbf{C\ (p,q) = I(q) - I(p)} \ldots\ldots\ldots\ldots\ldots\ldots (2.1)[6]$$

Where I (p) is the intensity of a pixel and I(q) is the intensity of its predecessor pixel.

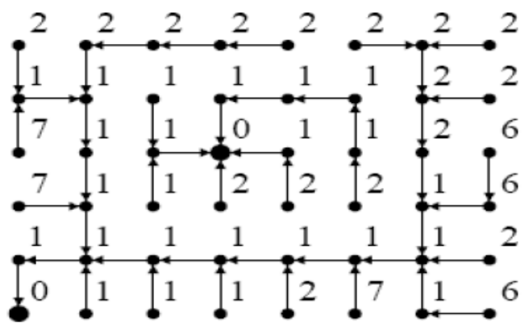


Figure 2.26: *Minimum Cost Path Forest obtained from Figure 2.25[9].*

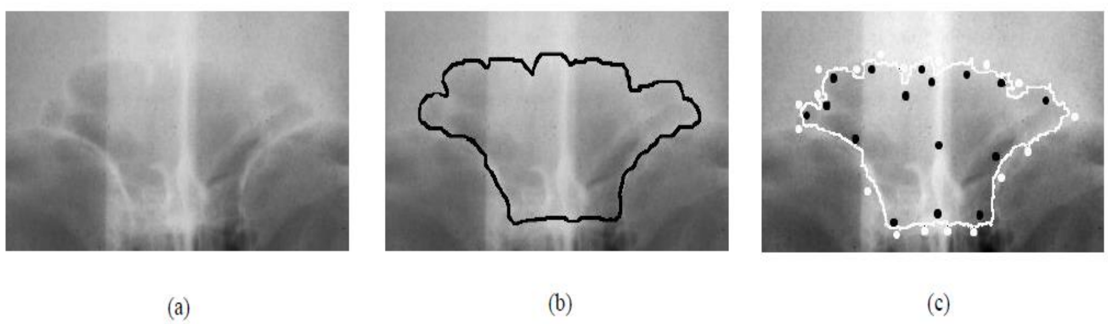


Figure 2.27: *(a) Radiograph Image of a frontal sinus (b) Manual segmentation of the frontal sinus (c) segmentation using DIFT algorithm [6]*

More seeds can be added by user inside or outside the ROI and repeat the algorithm in case of non-precise segmentation.

2.7.2.2 Frontal Sinus Features Extraction

In order to extract the features that can describe and uniquely identify a frontal sinus shape, the shape context method was used .It involves following steps:-

- The shape context is a descriptor of various shapes and pattern.
- The similarity measurement between two objects is computed as

minimum cost of alignment among the points of their shapes.

- Darker the position in the histogram, greater is the occurrence of points of the shape in that angle and distance.

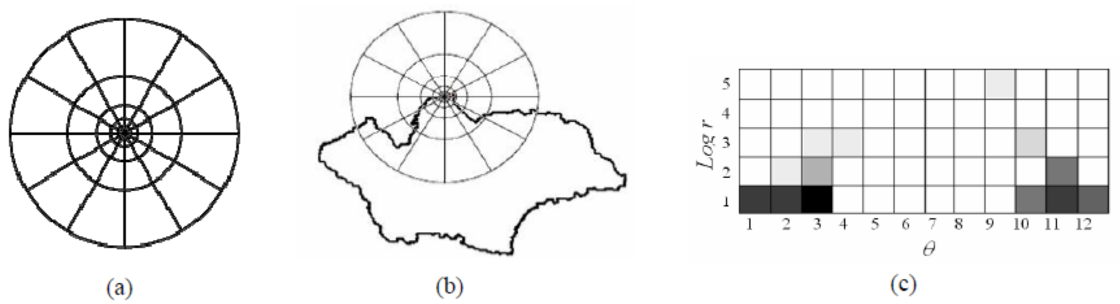


Figure 2.28: *Matching of Frontal Sinus [6]*.

2.7.2.3 Frontal Sinus Matching

To determine similarity between two frontal sinuses function minimum cost of alignment has been calculated. The function is computed using descriptors of the shape context for every pixel and corresponding pixel. Lower the function value, larger the similarity grade between the frontal sinuses. For any pixel pi and pj, function is determined as under:-

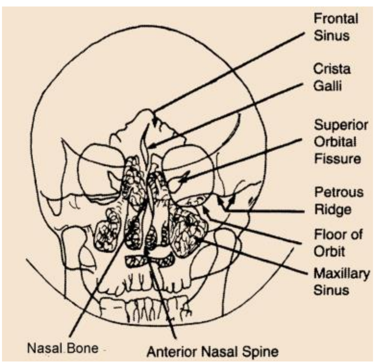
$$C_{ij} = \frac{1}{2} \sum_{k=1}^{K} \frac{\left[h_i(k) - h_j(k)\right]^2}{h_i(k) + h_j(k)} \qquad \text{..........(2.2)[6]}$$

where *Cij* denotes matching cost between pi and pj, hi (k) and hj(k) denote the normalized histograms of pi and pj respectively, and K represents the quantity of bins of the histogram.

CHAPTER 3: RADIOGRAPHIC VIEWS AND DATA ACQUITION

3.1 Introduction

To diagnose injuries, fractures birth defects and other diseases radiographic images are used. To ensure radiation safety, Skull x-ray exposure is kept minimal and at the same time x-ray equipment and procedures are precisely monitored. The patient will have to sit upright in a chair. The posture helps to demonstrate air-fluid levels within the sinuses. The location of is behind the patient. The x-ray tube is adjusted in front of the patient which can be moved to allow for various positions and views. A patient may also be instructed to move his or her head at various angles and positions.



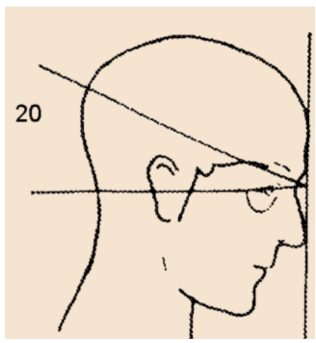


Figure 3.1: *Basic Skull Projections [47]*

3.2 Slandered Positions of Sinus Radiographs

The various radiographic positions used to study paranasal sinuses are:

- Occipito-mental view (Water's view)
- Occipital-frontal view (Caldwel view)
- Submento-vertical position (Hirtz position)
- Lateral view
- Oblique view 39 Degrees oblique (Rhese position)

3.2.1 Occipito Mental view

This is the most common view taken to study the paranasal sinuses .This is also known as the Water's view. The radiographic base line tilted to an angle of 45 degrees to the horizontal. The patient sits at the position making the sagittal plane vertical. The radiological beam is horizontal and is centered over a point 1 inch above the external occipital .

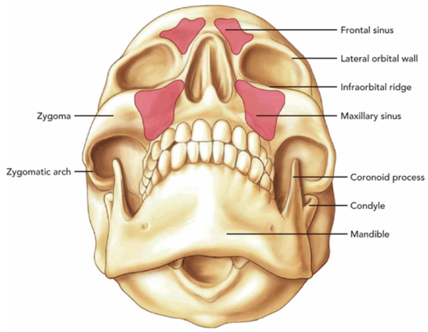


Figure 3.2: *Occipito Mental view [48]*

3.2.2 Occipito Frontal view (Caldwell view):

This view is also known as the frontal sinus view. This position is ideally suited for studying frontal sinuses. To get view the patient is made to sit in front of the film with the radiographic base line tilted to an angle of 15 - 20 degrees upwards.

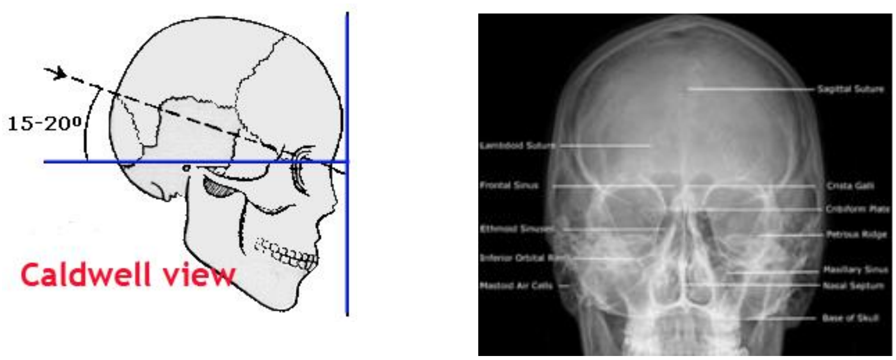


Figure 3.3: *Occipito-frontal view*

Caldwell can further be divided into Facial - PA (Caldwell) 15Â° and Facial - PA (Caldwelll) 25Â° - 30Â°.Its characteristics are as under:-

Facial - PA (Caldwell) 15°

Name of projection	**Facial - PA (Caldwell) 15°**
Area Covered	Orbital Rim, maxillae, nasal septum, zygomatic bones and anterior nasal spine
Pathology shown	Fractures, neoplasms and inflammatory processes of the facial bones
Radiographic Anatomy	Facial Bones Radiographic Anatomy
Orientation	24 x 30 cm Portrait
Film / Screen Combination	Regular
Bucky / Grid	Moving or Stationary Grid
Filter	No
Exposure	75 kVp 20 mAs
FFD / SID	100cm
Central Ray	CR angled caudad 15° and centre to exit at the nasion
Collimation	Outer skin margins of facial bones
Respiration	Suspended

Table 3.1 *Facial - PA (Caldwell) 15°[47]*

Skull - PA (Caldwelll) 25Â° - 30Â°

Name of projection	Skull - PA (Caldwelll) 25° to 30°
Area Covered	Greater and lesser sphenoid wings, frontal bone, superior orbital fissures, frontal and anterior ethmoid sinuses, superior orbital margins, crista galli, foramen rotundum adjacent to each inferior orbital rim and ebtire superior orbital fissure
Radiographic Anatomy	Skull Radiographic Anatomy
Orientation	24 x 30 cm Portrait
Film / Screen Combination	Regular
Bucky / Grid	Moving or Stationary Grid
Filter	No
Exposure	75 kVp 20 mAs
FFD / SID	100 cm
Central Ray	CR directed to exit at the level of the nasion CR 25° - 30° degrees caudad
Respiration	Suspended

Table 3.2 *Skull - PA (Caldwelll) 25Â° - 30Â°* [47]

3.3 Data Set Acquisition

3.3.1 Acquisition of Radiographic Images

Individual Para Nasal Sinus (PNS) radiograph is primary requirement. The biggest challenge was collection of data (frontal sinus images) as no such data set of frontal sinus is available on internet. CMH Rawalpindi and Nishtar Hospital Multan were approached for provision of data. 160 frontal sinus radiograph images of 80 individuals (2 x radiographs per individual) were acquired. Nishtar Hospital Multan referred Al Furqan Radiology Lab which provided 45 x images in jpg format with no patient details.CMH Rawalpindi provided the data in special software Rogan DELFT which has own data base . 35 x images have been exported from Rogan DELFT data base. The age of individual is more than twenty years.

Figure 3.4: *Samples of Radiographs*

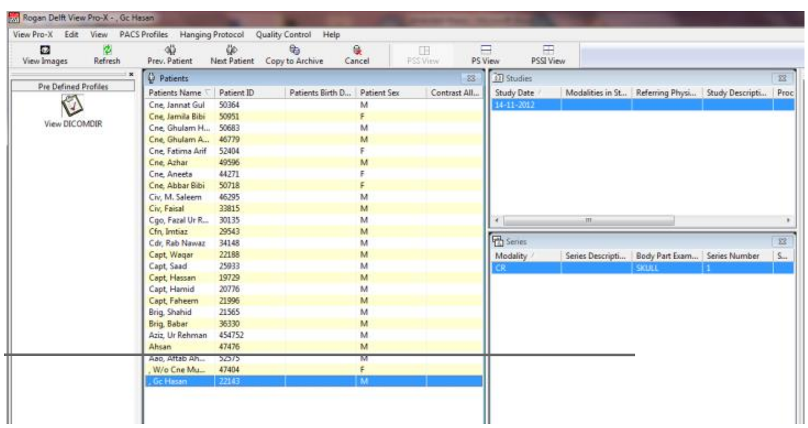


Figure 3.5: *Rogan DELFT Data Base*

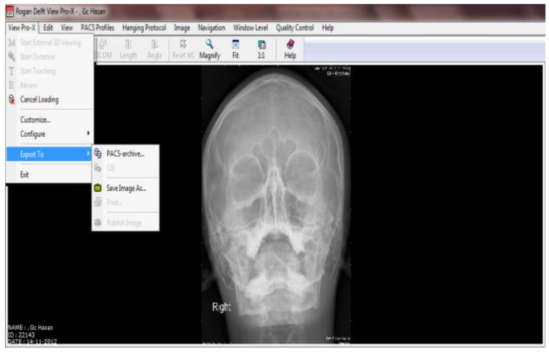


Figure 3.6: *Acquisition of Radiographs from Rogan DELFT Data Base*

3.3.2 Acquisition of ROI

The frontal sinus acquisition has been carried out in two steps:-

3.3.2.1 Radiographic Image Enhancement

The function of x-ray camera sensors is to accrue charge which is reflected as larger pixel intensity proportional to the amount of x-ray illumination. The illumination depends on the quality of the x-ray beam and the object being imaged. In case of high density area, object will permit less x-rays and ultimately less x-rays reaches to sensors. The higher density areas will appear darker as outcome. When beam passes through low density areas, its strength will not get reduced and the image will appear brighter as sensors will accrue more charge comparatively. The overall quality of the radiograph merely depends upon on two factors, characteristics of the sensors and the amount of x-ray absorption by sensors. Too less illumination causes the image to appear darker and of low contrast. More illumination results greater contrast and produces better quality images, with a larger difference between pixel intensities corresponding to bones and the background. However, too much illumination will reduce the quality of image considerately. To improve the quality of radiograph images of frontal sinus, the images were converted to gray scale images. The images have been enhanced using contrast stretching transformation. The minimum pixel value is set to 0, and the maximum pixel value to the largest possible intensity is set to 255.

3.3.2.2 Segmentation

Segmentation of Segmentation of region of interest is performed by selecting nose tip as pivot point. The size of segmented image has been standardized as 200 x 150 pixels as maximum size of frontal sinus of Asians is about 200 x 150 pixels [44].The semi-automatic extraction of exact shape and marking of frontal sinus has only been achieved due to extremely complex pattern of frontal sinus[6, 9, 43]. The frontal sinus has been acquired by cropping region of interest automatically. The image database has been created for experiment.

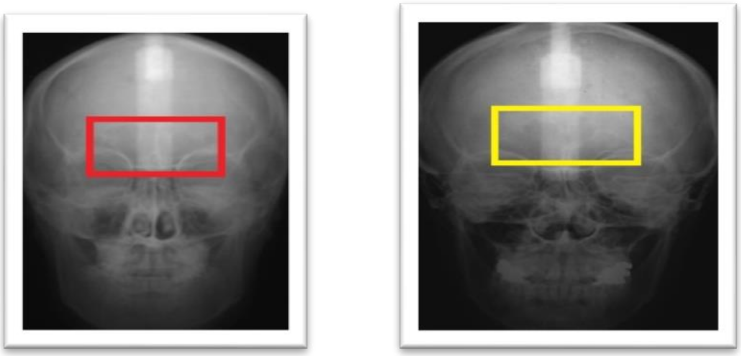


Figure 3.7: *Radiograph Images obtained from the data set used in the experiments. Different individuals have different frontal sinus shape patterns.*

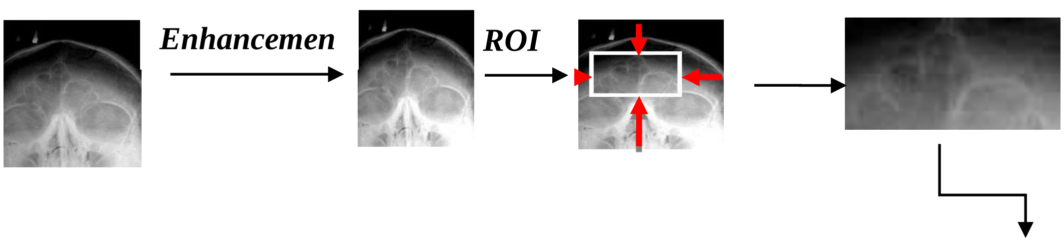
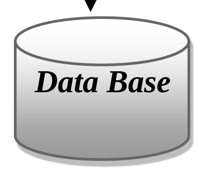


Figure 3.8: *Frontal Sinus Acquisition*



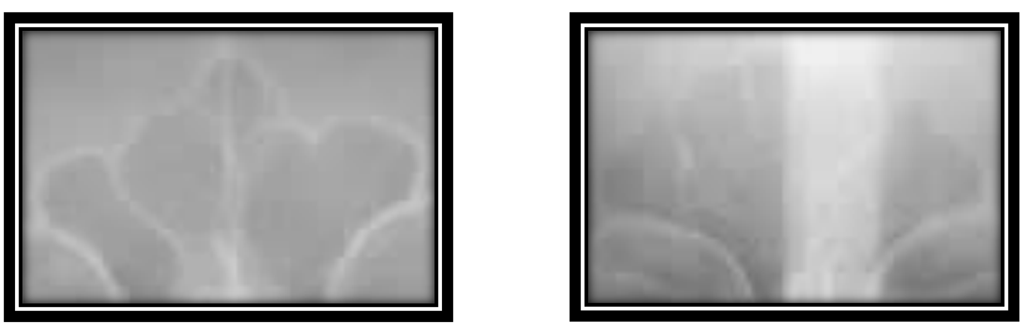


Figure 3.9: *Dataset of ROI*

CHAPTER 4: PROPOSED METHODOLOGY

4.1 Introduction

The suggested novel methodology for human identification is based on frontal sinus recognition using scale invariant feature transform descriptors and pattern recognition techniques. Thorough medical analysis and investigations has establish this fact that the radiographic pattern of frontal sinus is highly variable distinctive and unique for every person irrespective of gender. Many methods based on biometrics such as fingerprint, face, iris, and retina have been used for person identification. The same biometrics loses their importance in case of deceased persons or unrecognized/ unidentified dead bodies. This phenomenon suggests use of other biometrics such as the frontal sinus patterns, obtained from digital radiographic films for person identification. The proposed methodology has been compared with previously implemented methods which involves manual identification, Identification based on shape context and top border detection method. The proposed methodology produced better results of frontal sinus identification even with rotational distortion due to movement. Moreover, in case of prevailing security environments, the same methodology can effectively be utilized for forensic personal identification for crime investigation for unrecognized/ unidentified dead bodies.

The frontal sinus is irregularly shaped feature which is located in the frontal bone and consists of paired cavities. The function of sinus has not yet been precisely defined medically. Its development starts at creation of fetus but no well-defined shape can be observed or visible at time of birth [1,5, 8]. It begins to develop during the second year of life, reaches its maximum size at the age of twenty and remains stable and unchanged rest of the life. It has been proven medically that pattern of frontal sinus is unique and distinctive for each individual. Moreover, its pattern largely depends on genetics and surrounding environment [1,44]. It has also been established that frontal sinus is unique for monozygotic twins as well [39]. Many case studies highlight that morphological analysis was used to identify missing persons, burnt cases and unidentified / unrecognized bodies by comparing ante- mortem and post-mortem radiographs [4, 5]. The distinctive and unique pattern of frontal sinus suggests that it can be used as strong and powerful biometrics in addition to other available biometrics. The advancement in digital radiographs where they can be manipulated and analyzed for disease detection can effectively be utilized for development of consistent and reliable application for personal identification. The human identification based on frontal sinus by extracting various features like area, perimeter, width, height, circularity, ferret, shape context and detection of the top /bottom border of the frontal sinus has been suggested [6, 9, 43] but it involves expert radiologist for segmentation of frontal sinus as well are variant to scale and rotation thus more prone to errors. This suggested hybrid methodology is based on reduction of potential match images using normalized mean square distance, extraction of feature matrixes from SIFT , further reduction using pearson co-relation, and matching/class separation using fishers linear discriminant. The proposed methodology has been derived from digital imaging processing and pattern recognition techniques. The method involves reduction of potential images by comparing normalized square root mean distances and applying pearson co-relation on image features matrixes derived from SIFT Each frontal sinus image represents a distinctive class. Accurate sinus matching has been achieved by applying fisher linear discriminant.

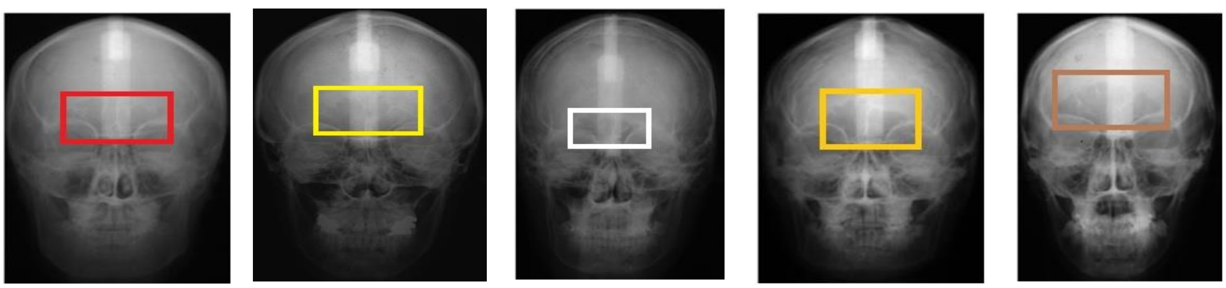


Figure 4.1 *Radiograph images obtained from the data set used in the experiments. Different individuals have different frontal sinus shape patterns.*

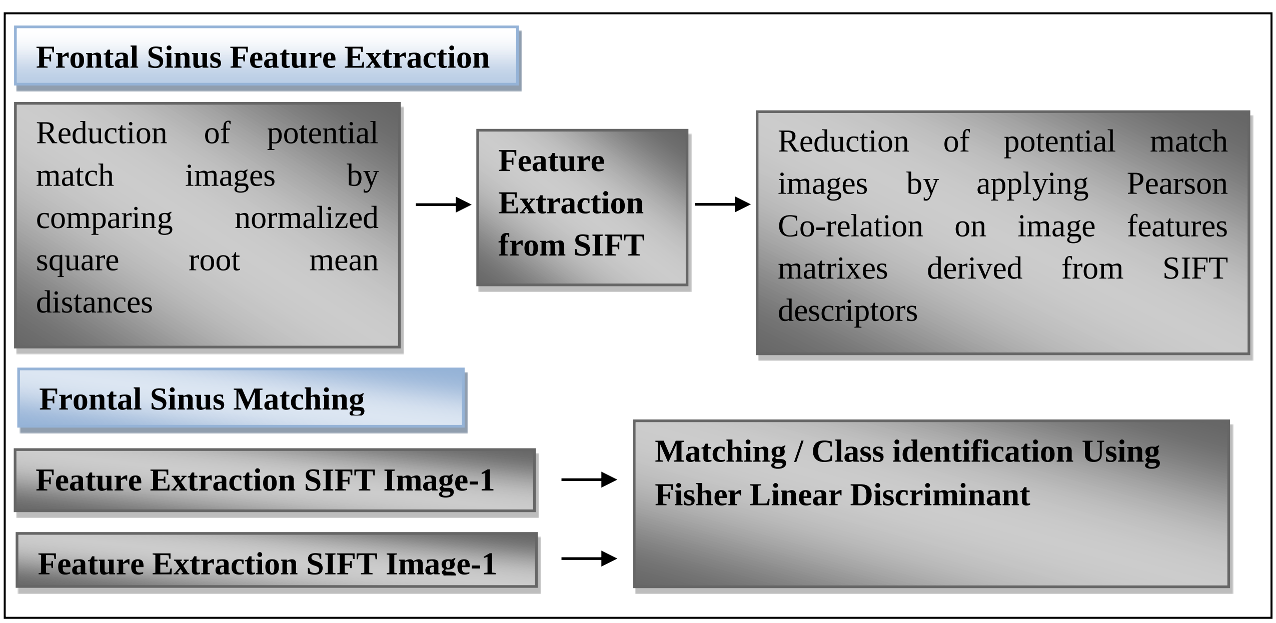


Figure 4.2: *Proposed Architecture*

4.2 Acquiring of Radiographic Images

The frontal sinus identification methodology proposed was assessed on a set of 160 frontal sinus radiograph images of 80 individuals (2 x radiographs per individual).The age of individual is more than twenty years.

4.3 Frontal Sinus Data Set Acquisition

The frontal sinus acquisition has been carried out in two steps:-

4.3.1 Radiographic Image Enhancement

The function of x-ray camera sensors is to accrue charge which is reflected as larger pixel intensity proportional to the amount of x-ray illumination. The illumination depends on the quality of the x-ray beam and the object being imaged. In case of high density area, object will permit less x-rays and ultimately less x-rays reaches to sensors. The higher density areas will appear darker as outcome. When beam passes through low density areas, its strength will not get reduced and the image will appear brighter as sensors will accrue more charge comparatively. The overall quality of the radiograph merely depends upon on two factors, characteristics of the sensors and the amount of x-ray absorption by sensors. Too less illumination causes the image to appear darker and of low contrast. More illumination results greater contrast and produces better quality images, with a larger difference between pixel intensities corresponding to bones and the background. However, too much illumination will reduce the quality of image considerately. To improve the quality of radiograph images of frontal sinus, the images were converted to gray scale images. The images have been enhanced using contrast stretching transformation. The minimum pixel value is set to 0, and the maximum pixel value to the largest possible intensity is set to 255.

4.3.2 Segmentation

Segmentation of region of interest is performed by selecting nose tip as pivot point. The size of segmented image has been standardized as 204 x 152 pixels as maximum size of frontal sinus of Asians is about 200 x 150 pixels [44].The semi-automatic extraction of exact shape and marking of frontal sinus has only been achieved due to extremely complex pattern of frontal sinus[21, 22, 23]. The frontal sinus has been acquired by cropping region of interest automatically. The image database has been created for experiment.

4.4 Frontal Sinus Matching

The matching process involves five steps:-

4.4.1 Generalized Matching/Extraction of Potential Match Images

The difference matrix is matrix of size 3 x n. The first row is obtained by subtracting test image from database images. If images are same, then ideally resultant sum of difference of two images is zero. First row of difference matrix comprises of absolute value of sum of difference of test image and all database images. The second row of difference matrix is obtained by subtracting fourier transform (FFT) spectrum of test image and database images. If images are same, then principally resultant sum of difference of fourier transform (FFT) spectrum of two images is zero. Second row of difference matrix comprises of absolute value of sum of difference of fourier transform (FFT) test image and fourier transform (FFT) all database images.

To obtain third row of difference matrix, the histogram of test image and database images are subtracted. If images are same, then ideally resultant sum of difference of two images histogram is zero. Third row of difference matrix comprises of absolute value of sum of difference of histogram test image and histogram all database images. The difference matrix is generated as under:-

$$\textbf{Difference Matrix} = \begin{pmatrix} Id\,(i,j) & Id\,(i,j+1) & \ldots\ldots & Id(i,n-1) & Id\,(i,n) \\ FS(i+1,,j) & FS(i+1,,j+1) & \ldots\ldots & FS(i+1,n-1) & FS(i+1,n) \\ Hd(i+2,j) & Hd(i+2,,j+1) & \ldots\ldots & Hd(i+2,n-1) & Hd(i+2,n) \end{pmatrix}$$

$i=1, 2, 3 \qquad j=1, 2, 3,4,5\ldots\ldots n$

The normalized root mean square distance D(i) of test image and all images is determined from difference matrix as under:-

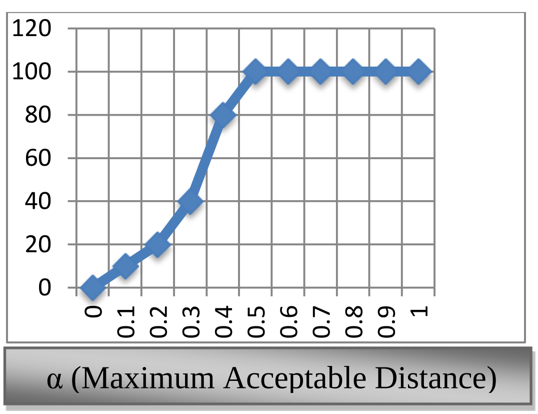
$$D(i) = \sqrt{\frac{(Id)^2 + (FS)^2 + (Hd)^2}{id + Fsd + Hd}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.1)$$

$i=1, 2, 3\ldots\ldots n$

To filter out potential images for matching, The normalized root mean square distance D(i) is compared with maximum acceptable root mean square distance (α).The value of α was determined through estimation. The performance of the human identification was evaluated on a database 2 x sets) containing two radiograph images of 80 individuals each, totaling 160 images. The two radiographs of the same individual were obtained with age limit of 20 years. The first image was considered as anti-mortem radiograph and the second one was assumed as the post-mortem radiograph. The algorithm of generalized match is as under:-

```
For i=1          i=i++
Find difference matrix of sinus test image and database images;
Compute normalized root mean square distance D(i) of test image and all database images;
If D (i) < α
"Image selected for further processing" Else "Image not selected "End
```

The result analysis shows that **maximum acceptable distance (α)** value is estimated as 0.5.The value has been derived through hit and trial method .Such value has been deduced which ensures no potential match image is missed out. The chances of missing potential match image is more at lower value of α but stabilizes at 0.5.The success result of potential match image for various value of α for generalized match is as under:-



(α)	Result (%)
0.2	20
0.4	40
0.5	**100**
0.6	100
0.6	100
0.9	100

Figure 4.3 *Optimum Value of* α (Maximum Acceptable Distance)

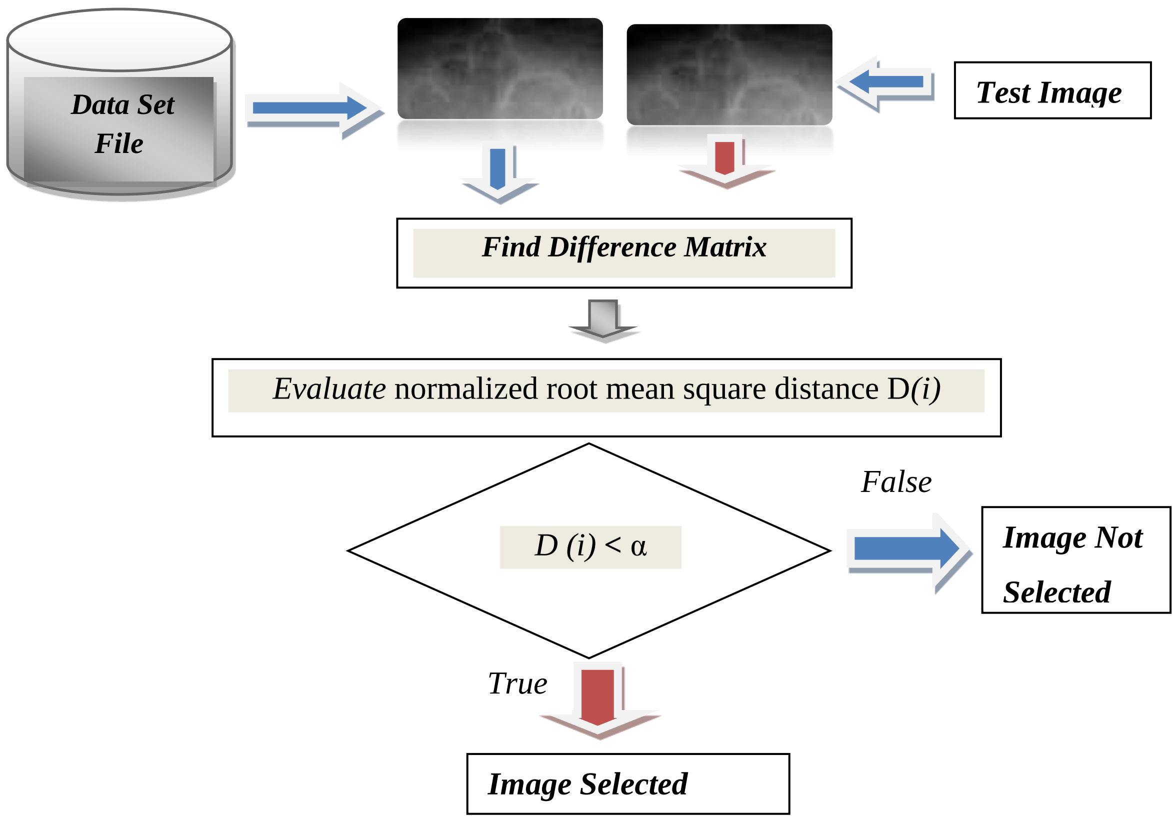


Figure 4.4: *Generalized Matching/Extraction of Potential Match Images*

4.4.2 Feature Extraction Using SIFT and Creation of Feature Matrix

SIFT Descriptors a method for extracting distinctive invariant features from images that can be used to perform reliable matching between different views of an object. The extracted features are invariant to image scale and rotation and ensure reliable matching in spite of addition of noise, and change in illumination. Single feature can be correctly matched with high probability against a large database of features as the features are highly distinctive and unique. The same approach can be used for object recognition in addition to matching various images. By using this approach distinctive feature commonly named as descriptors can extracted which are invariant to scale and rotation. Instead of matching image, the descriptors are matched by applying Euclidian distance. Image matching is a fundamental aspect of many problems in computer vision, including object or scene recognition from multiple images. This approach provide solution which is aims at that image features that have many properties that make them suitable for matching differing images of an object or scene. The features are invariant to image scaling and rotation, and partially invariant to change in illumination. These key points or descriptors are well localized in both the spatial and frequency domains thus reducing the probability of disruption by noise. Large numbers of features can be extracted from typical images. As these features are highly distinctive this allows a single feature to be correctly matched with high probability against a large database of features, providing a basis for image matching or object recognition. Although the radiographic images are taken with particular posture yet there is chance of rotation variance due to movement of patient .The major stages of computation used to generate the set of image features are Scale Space Selection,Scale-Space Extrema Detection, Key point Localization ,Outline Rejection ,Orientation assignment, Local Image Descriptor.

4.4.2.1 Scale Space Selection

Gussian filter with various values of sigma is applied to built scale space.

$$L(x,y,\sigma) = G(x,y,\sigma) * I(x,y)$$

Where $G(x,y,\sigma) = \frac{1}{2\pi\sigma^2} e^{-(x^2+y^2)/2\sigma^2}$ ……………..(4.2)

The LoG is obtain by Subtraction :

$$D(x,y,\sigma) = (G(x,y,k\sigma) - G(x,y,\sigma)) * I(x,y)$$

$$= L(x,y,k\sigma) - L(x,y,\sigma) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4.3)$$

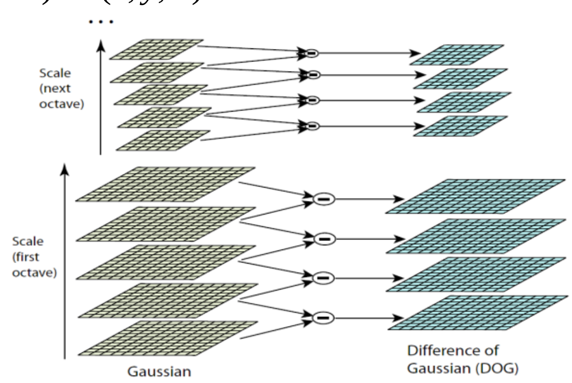


Figure 4.5: *Scale Space Contruction[45,46]*

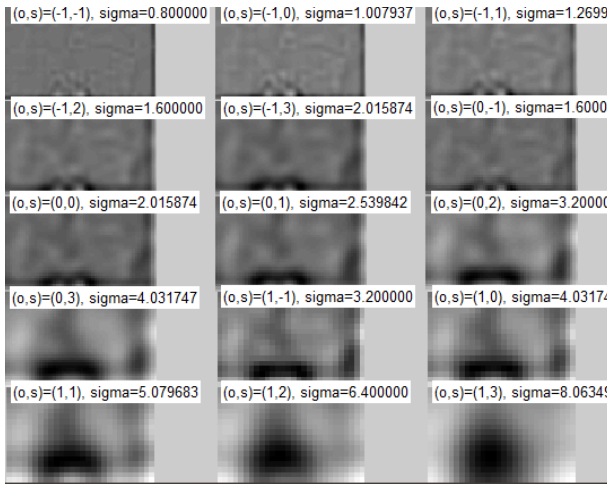


Figure 4.6: *Application of Gussian Filter with various values of Sigma*

To obtain the next level octave the image is down sample by factor of 2 and same procedure is repeated the with starting value K^2 σ. The third level octane is obtained by further down sample image by factor of 2 and repeat the same with starting value K^4 **σ** .For sinus identification three level octane and scale of 3 has been used.Following intial value of k and sigma have been assumed:-

Sigma=1.6 and k=√2

The DoG is Close approximation to scale-normalized Laplacian of Gaussian. $\sigma^2\nabla^2 G$

We know that Diffusion equation is given as under:

$$\frac{\partial G}{\partial \sigma} = \sigma \nabla^2 G \qquad \text{……..(4.4)}$$

Approximate $\partial G/\partial\sigma$:

$$\frac{\partial G}{\partial \sigma} \approx \frac{G(x,y,k\sigma) - G(x,y,\sigma)}{k\sigma - \sigma}$$

$$\frac{G(x,y,k\sigma) - G(x,y,\sigma)}{k\sigma - \sigma} \approx \sigma \nabla^2 G$$

$$G(x,y,k\sigma) - G(x,y,\sigma) \approx (k-1)\sigma^2 \nabla^2 G \qquad \text{……..(4.5)}$$

When D has scales differing by a constant factor it already incorporates the σ^2 scale normalization required for scale-invariance.Keypoints are detected using scale-space extrema in difference-of-Gaussian function D.

4.4.2.2 Selection of Scale-Space Extrema

Key point is point which is invarient to scale and rotation.To find out Gaussian images are detected by comaring a pixel(marked with X) to its

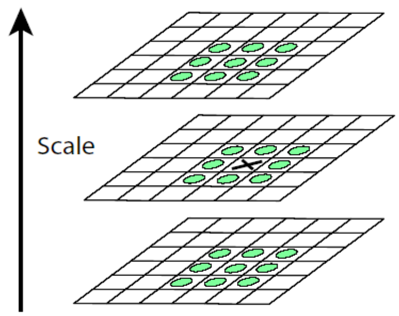


Figure 4.7: *Maxima and minima of the difference-of-Gaussian.[45,46]*

26 neighbours in 3x3 region at the currentand adjacent scales(marked with circle(Figure). In this way many Key point are found.

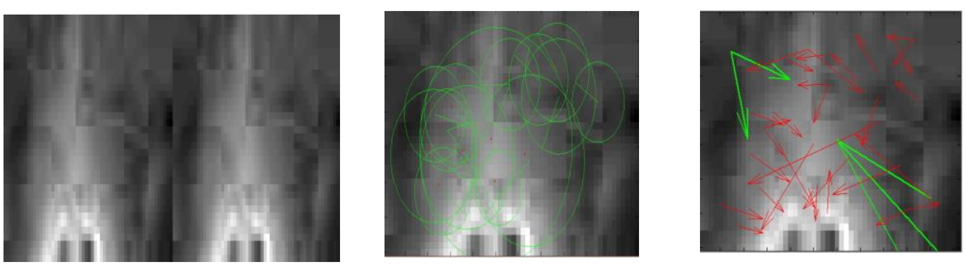


Figure 4.8: *Generation of Key Points*

4.4.2.3 Accurate Key Point Localization

All key points are not required to be selected as some may be poorly localized. To reduce and eliminate poorly localized key point *taylor* series expansion of DoG, D is used.3D quadratic function is fit to the local sample points .Start with Taylor expansion with sample point as the origin with following expression:-

$$D(\mathrm{X}) = D + \frac{\partial D^T}{\partial \mathrm{X}}\mathrm{X} + \frac{1}{2}\mathrm{X}^T \frac{\partial^2 D}{\partial \mathrm{X}^2}\mathrm{X} \qquad \ldots\ldots\ldots(4.6)$$

where $\mathrm{X} = (x, y, \sigma)^T$

Take the derivative with respect to *X*, and set it to 0, giving

$$\frac{\partial D}{\partial X} + \frac{\partial^2 D}{\partial X^2}\hat{X} = 0 \qquad \ldots\ldots(4.7)$$

$\hat{X} = -\frac{\partial^2 D^{-1}}{\partial X^2}\frac{\partial D}{\partial X}$ is the location of the keypoint

Value of D(x) at minima/maxima must be large | D(x) > threshold. In this case key point less than .03 is not selected and is thrown.

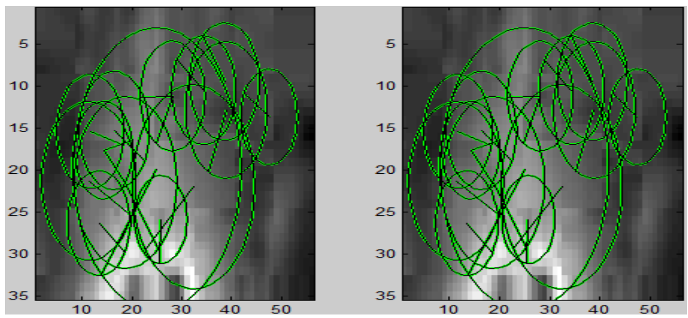


Figure 4.9: *Accurate Key Point Localization*

4.4.2.4 Outline Rejection

Poorly defined peaks are thrown out using ratio of principal curvatures. The Principle curvature is low along edge and is high across edge. To Compute hessian matrix.

$$H = \begin{bmatrix} D_{xx} & D_{xy} \\ D_{xy} & D_{yy} \end{bmatrix}$$

$$Tr(H) = D_{xx} + D_{yy} = \lambda 1 + \lambda 2 \qquad \ldots\ldots\ldots\ldots(4.8)$$

$$Det(H) = D_{xx}D_{yy} - (D_{xy})^2 = \lambda 1 \lambda 2$$

Remove outliers by evaluating:

$Tr(H)^2 / Det(H) = (r+1)^2 / r \qquad r = \lambda 1 / \lambda 2$ Eliminate if r > 10

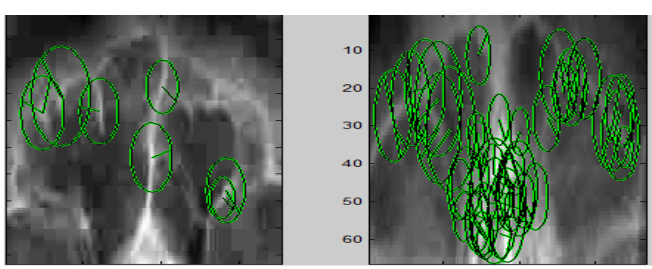


Figure 4.10: *Outline Rejection*

4.4.2.5 Orientation Assignment

To achieve rotation invariance, compute central derivative, gradient magnitude and direction of L(smooth image at the scale of key point(x,y).

$$m(x,y)=\sqrt{(L(x+1,y)-L(x-1,y))^2+(L(x,y+1)-L(x,y-1))^2}$$
$$\theta(x,y)=a\tan 2((L(x,y+1)-L(x,y-1))/(L(x+1,y)-L(x-1,y)))$$ ……*Equation 4.9*

Create weighted direction histogram in neighbor hood of a key point (8 Bins).weights are gradient magnitude. Select peak as direction of key point.

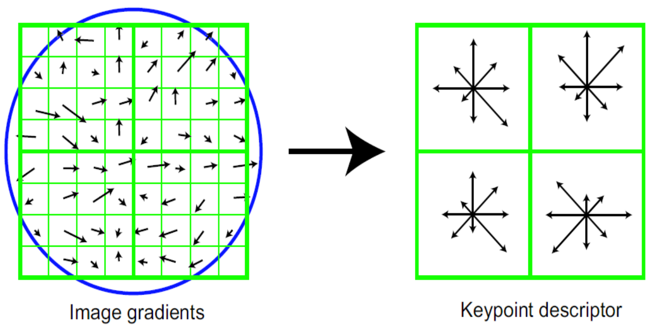


Figure 4.11: *Orientation Assignment*

4.4.2.6 The Local Image Descriptor

Descriptor has 3 dimensions (x,y,θ).Compute relative orientation and magnitude in 16 x 16 neighbourhood at key point. 16 histogram with 8 bins put together ,128 long vector is shift discriptor.Position and orientation of each gradient sample rotated relative to keypoint orientation.

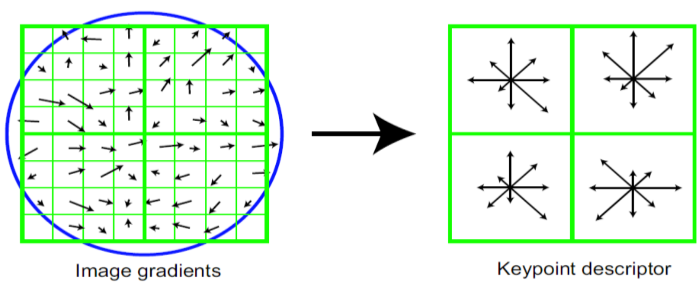


Figure 4.12: *Generation of Shift Discriptor*

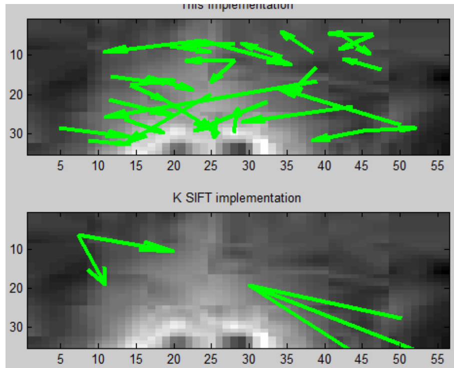


Figure 4.13: *Frontal Sinus Shift Descriptor*

4.4.3 Reduction of Potential Match images using Pearson Co-Relation

There are several types of correlation coefficient but commonly used is Pearson's correlation or Pearson correlation for determination of correlation coefficient in linear regression. For example we want to compute the value of the correlation coefficient from the following table:-

Subject	Age x	Glucose Level y
1	43	99
2	21	65
3	25	79
4	42	75
5	57	87
6	59	81

Table 4.1: *Data Set for Correlation Factor Calculation[32,51]*

Step 1: Use the given data, and add three more columns: xy, x^2, and y^2.

Subject	Age x	Glucose Level y	xy	x^2	y^2
1	43	99			
2	21	65			
3	25	79			
4	42	75			
5	57	87			
6	59	81			

Table 4.2: *Correlation Factor Calculation step 1[32,51]*

Step 2: *Multiply x and y together to fill the xy column. For example, row 1 would be 43 × 99 =* ***4,257****.*

Subject	Age x	Glucose Level y	xy	x^2	y^2
1	43	99	4257		
2	21	65	1365		
3	25	79	1975		
4	42	75	3150		
5	57	87	4959		
6	59	81	4779		

Table 4.3: *Correlation Factor Calculation step 2[32,51]*

Step 3: *Take the square of the numbers in the x column, and put the result in the x^2 column.*

Subject	Age x	Glucose Level y	xy	x^2	y^2
1	43	99	4257	1849	
2	21	65	1365	441	
3	25	79	1975	625	
4	42	75	3150	1764	
5	57	87	4959	3249	
6	59	81	4779	3481	

Table 4.4: *Correlation Factor Calculation step 3[32,51]*

Step 4: *Take the square of the numbers in the y column, and put the result in the y^2 column.*

Subject	Age x	Glucose Level y	xy	x^2	y^2
1	43	99	4257	1849	9801
2	21	65	1365	441	4225
3	25	79	1975	625	6241
4	42	75	3150	1764	5625
5	57	87	4959	3249	7569
6	59	81	4779	3481	6561

Table 4.5: *Correlation Factor Calculation step 4[32,51]*

Step 5: *Add up all of the numbers in the columns and put the result at the bottom (Σ) .*

Subject	Age x	Glucose Level y	xy	x^2	y^2
1	43	99	4257	1849	9801
2	21	65	1365	441	4225
3	25	79	1975	625	6241
4	42	75	3150	1764	5625
5	57	87	4959	3249	7569
6	59	81	4779	3481	6561
Σ	247	486	20485	11409	40022

Table 4.6: *Correlation Factor Calculation step 5[32,51]*

Step 6: *Use the following formula to work out the correlation coefficient.*

$$r= \frac{\sum_{i}^{m}(\mathbf{xi}-\mathbf{xm})(\mathbf{yi}+\mathbf{ym})}{\sqrt{\sum(\mathbf{xi}-\mathbf{xm})^2}+\sqrt{\sum(\mathbf{yi}-\mathbf{ym})^2}} \text{.................... (4.10)}$$

From our table following data can be worked out:-

$\Sigma x = 247$ $\Sigma y = 486$ $\Sigma xy = 20{,}485$ $\Sigma x2 = 11{,}409$ $\Sigma y2 = 40{,}022$

n is the sample size, in our case = 6

Correlation coefficient(r) = 6(20,485) – (247 × 486) / [√ [[6(11,409) - (247^2)] × [6(40,022) – 486^2]]] =0.5298

The range of the correlation coefficient is from -1 to 1. Since our result is 0.5298 or 52.98%, which means the variables have a moderate positive correlation. Pearson's correlation coefficient, r, is also widely used in statistical analysis, pattern recognition, and image processing. Applications for the latter include comparing two images for the purposes of image registration, object recognition, and disparity measurement. The correlation coefficient is used for security applications such as surveillance, treaty verification, and tamper detection using security seals, and tagging. Typically, the correlation coefficient is used to compare two images of the same object or scene, taken at different times. The r value indicates whether the object has been altered or moved. In theory, we would obtain an r value of 1 if the object is intact and a value of less than 1 if alteration or movement has occurred. In practice, distortions in the imaging system, pixel noise, slight variations in the object's position relative to the camera, and other factors produce r value less than 1, even if the object has not been moved or physically altered in any manner. In most of cases, typical r values for two digital images of the same scene, one recorded immediately after the other using the same imaging system and illumination, range from 0.95 to 0.98. Usually there needs to be an empirical definition of a threshold r value that indicates dissimilarity. In other words, it is necessary to determine the minimum r value needed to conclude with confidence that the image is unchanged. For several applications for which we are familiar, the chosen threshold values for r range from 0.30 to 0.85, depending on the application.

All descriptors are considered as distinctive features of specific frontal sinus. The further reduction of the number of potential images have been achieved by applying pearson correlation coefficient on feature matrixes obtained from SIFT descriptors. The range of pearson correlation coefficient is from -1 to 1 and is defined as under [33]:-

$$r= \frac{\sum_{i}^{m}(\mathbf{xi-xm})(\mathbf{yi+ym})}{\sqrt{\sum(\mathbf{xi-xm})^2}+\sqrt{\sum(\mathbf{yi-ym})^2}} \quad \textit{[32,51]} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.11)$$

where xi is the value of the ith feature in feature matrix a, yi is the value of the ith feature in feature matrix b, xm is the mean feature values of feature matrix a,ym is the mean feature values of feature matrix b. The correlation coefficient has the value r=1 if the two features matrixes are absolutely identical, r=0 if they are completely uncorrelated, and r=-1 if they are completely anti-correlated [33].All images having correlation factor greater than 0.5 are considered for matching and rest are discarded.

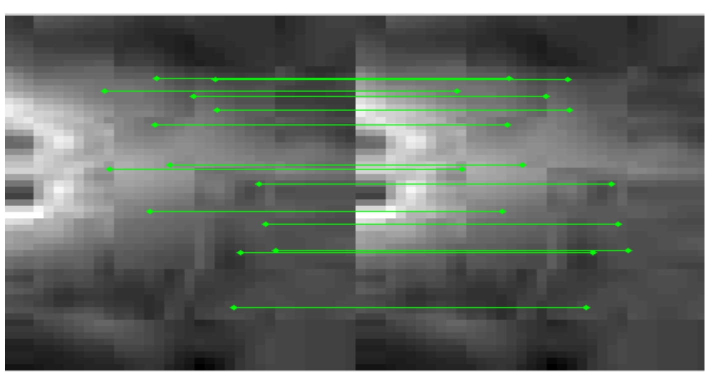


Figure 4.14: *Reduction of Potential Match images using Pearson Co-Relation*

4.4.4 Frontal Sinus Matching Based On Fisher Linear Discriminant Analysis

The 16 histogram with 8 bins put together ,128 long vector is SIFT descriptor .All the descriptors are divided into set of 128 points of two dimensions.

Each image is considered a distinctive class. The class separation has been achieved using FLD. Let reduced feature vector of image a is ***(X1, Y1), (X2, Y2), (X3, Y3), (X4, Y4)………… (Xm, Yn)*** and image b is **(X1, Y1), (X2, Y2), (X3, Y3), (X4, Y4)…………… (Xm, Yn)**

The data points of corresponding reduced feature vector of images are put tougher. If feature reduced feature vector of test image and database image forms two separate classes, the images are not identical. If they form only one class, it is same image.

Fisher Linear Discriminant Analysis looks for a line that maximizes the separation of classes. In order to find the optimum projection we need to express J(w) as an explicit function of w. We define measure of the scatter in multivariate feature space x, which are scatter matrices.

$$\mathbf{Si} = \sum_{k \in Di}^{n} (\boldsymbol{x} - \boldsymbol{mi})(\boldsymbol{x} - \boldsymbol{mi})^{t} \quad \textit{[49,51]} \ldots\ldots\ldots\ldots\ldots\ldots (4.13)$$

The matrix S_B is "between class scatter" and S_W is "withi class scatter". Fisher criterion in terms of Sw and S_B is as under:-

$$\boldsymbol{J(w)} = \frac{\boldsymbol{w^t S_B W}}{\boldsymbol{W^t S_w W}} \quad \textit{[49,51]} \ldots\ldots\ldots\ldots\ldots (4.14)$$

If test image and database image forms two separate classes, the images are not identical. If they form only one class, it is same image.

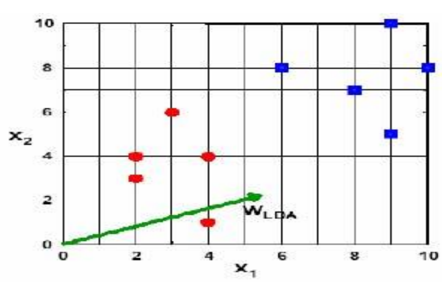


Figure 4.16: *Class Separation from Reduced Features Vectors [50,51]*

The matching /class identification algorithm is as under:-

Extract SIFT Descriptors of test Image and Database Image
Apply FLD for Creation of classes
Only one class identified "Identical Images "Else "Non Identical Images "End

CHAPTER 5: RESULT ANALYSIS

5.1 Experimental Results

The performance of the proposed frontal sinus procedure described in Section 4, for human identification was evaluated on a database (2 x sets) containing two radiograph images of 80 individuals, totaling 160 images. The two radiographs of the same individual were obtained with age limit of 20 years. The first image was considered as anti-mortem radiograph and the second one was assumed as the post-mortem radiograph. For generalized matching to prevent against missing of potential image, experiments were carried out to estimate the value of α (Maximum Acceptable Distance) using normalized mean square root distance through estimation. Then, sequence of genuine and impostor frontal sinus matching experiments were carried out. The result obtained for various value of α (Maximum Acceptable Distance) and probability of obtaining correct image is as under:-

Maximum Acceptable Distance (α)	**Success (%)**
0.1	0.2
0.2	0.3
0.3	0.4
0.4	0.5
0.5	**0.6**
0.6	0.7
0.7	0.8
0.8	0.9
0.9	1.0

Table 5.1: *Determination of Optimum Value of* α (Maximum Acceptable Distance)

The best result of the experiments, *of* α (Maximum Acceptable Distance) was estimated as 0.5.

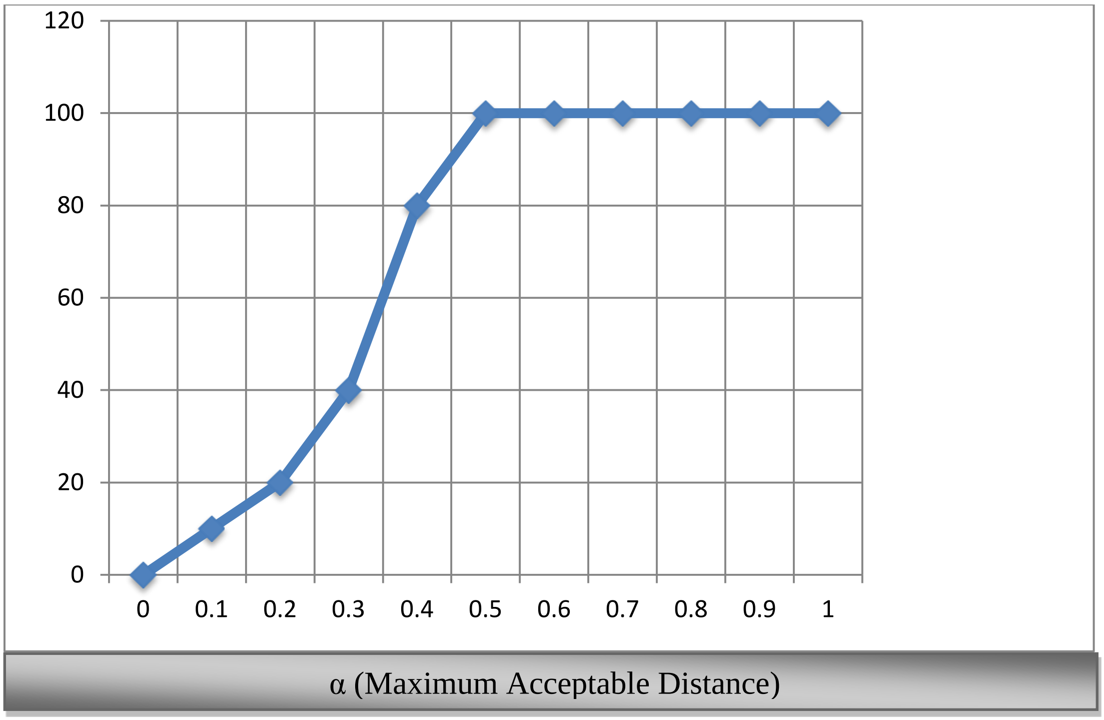


Figure.5.1: *Optimum Value of* α (Maximum Acceptable Distance).

A analysis was carried out to find rotation variation in acquiring radiographic images The maximum variation in rotation in acquiring of radiographic images observed is as under:-

No of Radiographic Images	Axis	Rotation						
		5°	10°	15°	20°	25°	30°	35°
180	X-axis	95	5	3	2	-	-	-
	Y axis	70	3	1	1			

Table 5.2: *Rotation Variation during Radiographic Image Acquisition*

For matching of frontal sinus, the results have been compared with other techniques which involve:-

- Histogram Matching
- Fourier Transform Subtraction
- Image Matching using Pearson Correlation Factor
- SIFT for feature extraction and Matching using Euclidian Distance
- SIFT for feature extraction and matching with K nearest neighbor classifier

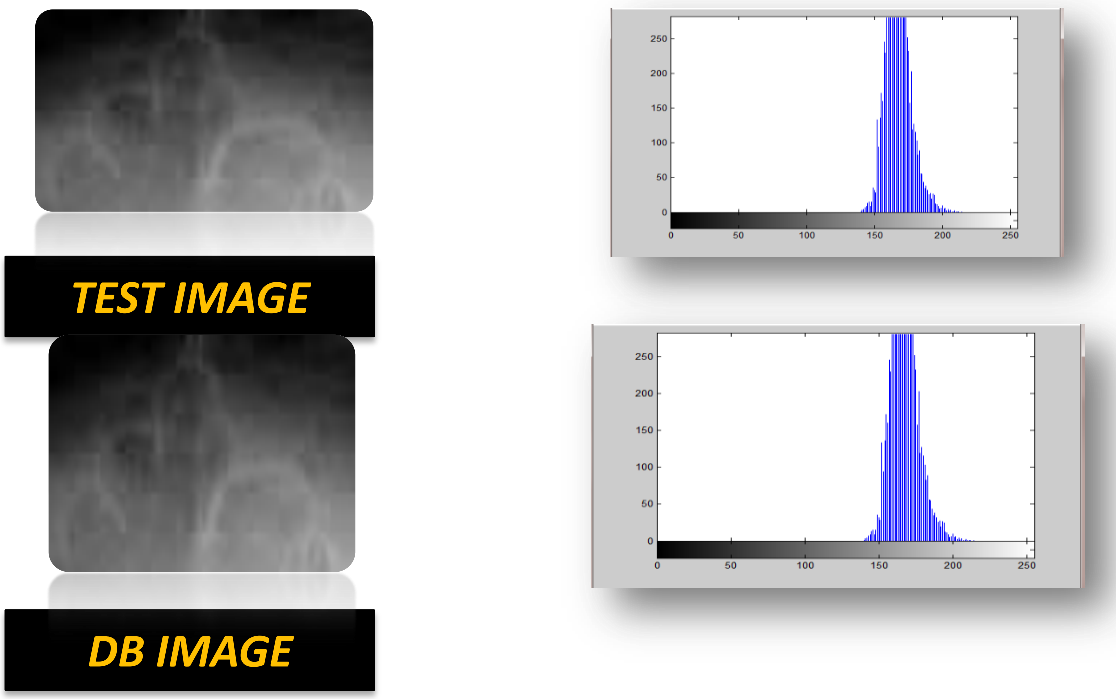
- SIFT for feature extraction , feature matching using Pearson co-relation
- Quaternion technique with maximum average correlation height filter.

5.2 Image Similarity Methods Result Analysis

The images were rotated up to 40 degree x-axis-axis and both to evaluate effectiveness of various methods.

5.2.1 Image Similarity Using Histogram Matching

The image similarity was found using image histograms. If images are same, then ideally resultant sum of difference of two histogram is zero.



$$IHD = H(test) - H(file)$$

Figure 5.2: *Histogram Matching Using Image histogram Difference*

5.2.2 Image Similarity Using Image Fourier Transform Subtraction

The image similarity was found using image Fourier transform subtraction. The matching is observed by subtracting test image Fourier transform from data base images Fourier transform. If images are same, then ideally resultant sum of difference of two images is zero.

$$FSD = FS(test) - FS(file)$$

Figure 5.3: *Image Fourier Transform Subtraction*

The difference of Fourier transform was obtained by subtracting Fourier Transform (FFT) of test image and data base images spectrum. The comparison parameters were calculated as under:-

MSE21 = mean (abs(X2-X1). ^2)) *NMSE21 = MSE21/sqrt (MSE10*MSE20)*

MSEi0 = mean (abs (X (i)-mean(X (i). ^2)} ………….(5.1)

Where X1=FFT Test SS *X2=FFT Data Base*

5.2.3 Image Similarity Using Pearson's Co-Relation Factor

The range of the correlation coefficient is from -1 to 1.For digital images, the Pearson correlation coefficient is defined as under:

$$r = \frac{\sum_i (x_i - x_m)(y_i - y_m)}{\sqrt{\sum_i (x_i - x_m)^2}\sqrt{\sum_i (y_i - y_m)^2}} \quad \text{………….(5.2)}$$

where x is the intensity of the ith pixel in image 1, y is the intensity of the ith pixel in image 2, x m is the mean intensity of image 1, and ym is the mean intensity of image 2. The correlation coefficient has the value r=1 if the two images are absolutely identical, r=0 if they are completely uncorrelated, and r=-1 if they are completely anti-correlated, for example, if one image is the negative of the other. The r value indicates whether the object is similar or not. Ideally value of is 1 if both images are same bur for practical purpose due to various factor its value cannot taken as 1.To find out similarty of gfrotal sinus, images having correlation factor 0.95-0.98 has been considered as similar images. The results observed for various value of rotation are as under:-

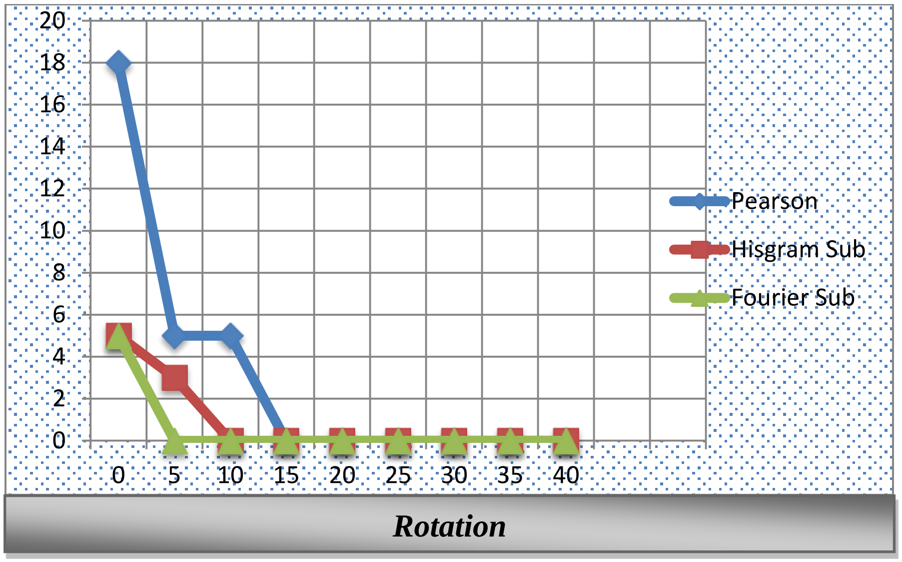


Figure 5.4: *Match Rate (MR) for various values of Rotation*

5.2.4 Matching Using SIFT Descriptors and KNN Classifier

SIFT Descriptors a method for extracting distinctive invariant features from images that can be used to perform reliable matching between different views of an object. The extracted features are invariant to image scale and rotation and ensure reliable matching in spite of addition of noise, and change in illumination. Single feature can be correctly matched with high probability against a large database of features as the features are highly distinctive and unique. The same approach can be used for object recognition in addition to matching various images. By using this approach distinctive feature commonly named as descriptors can extracted which are invariant to scale and rotation. Instead of matching image, the descriptors are matched by applying Euclidian distance. Image matching is a fundamental aspect of many problems in computer vision, including object or scene recognition from multiple images. This approach provide solution which is aims at that image features that have many properties that make them suitable for matching differing images of an object or scene. The features are invariant to image scaling and rotation, and partially invariant to change in illumination. These key points or descriptors are well localized in both the spatial and frequency domains thus reducing the probability of disruption by noise. Large numbers of features can be extracted from typical images. As these features are highly distinctive this allows a single feature to be correctly matched with high probability against a large database of features, providing a basis for image matching or object recognition. Although the radiographic images are taken with particular posture yet there is chance of rotation variance due to movement of patient .All descriptors are considered as distinctive features of specific frontal sinus and database has been created.

Descriptor No	K	Class
1	9	**FS2**
2	9	**FS1**
3	9	**FS1**
3	9	**FS1**
4	9	**FS3**
5	9	**FS2**
6	9	**FS1**
7	9	**FS1**
8	9	**FS1**
9	9	**FS2**
3	9	**FS3**
10	9	**FS3**

Table 5.3: *Trg Set for Classifier*

KNN classifier has been used for frontal sinus identification and matching. Each frontal sinus can be considered as distinctive class. The Euclidean distance of test image features to feature data base features is calculated to decide upon particular class or frontal sinus. The distance is measured as under:-

$$\mathrm{d}(\mathbf{p},\mathbf{q}) = \mathrm{d}(\mathbf{q},\mathbf{p}) = \sqrt{(q_1-p_1)^2 + (q_2-p_2)^2 + \cdots + (q_n-p_n)^2} = \sqrt{\sum_{i=1}^{n}(q_i-p_i)^2}. \quad \ldots\ldots\ldots\ldots\ldots\ldots(5.3)$$

Descriptor No	**Descriptor (128 Long)**				**Class**
1	12	124	77	………………55	FS1
2	22	43	77	………………87	FS1
3	20	233	77	………………45	FS1
3	123	289	77	………………33	FS1
4	177	4	77	………………31	FS1
5	156	44	77	………………29	FS1
6	120	44	77	………………75	FS2
7	12	124	77	………………36	FS2
8	22	43	77	………………31	FS2

Table 5.4: *KNN Classifier Implementation*

The results observed for various value of rotation after applying KNN classifier on SIFT descriptors and Pearson correlation on descriptors matrix are as under:-

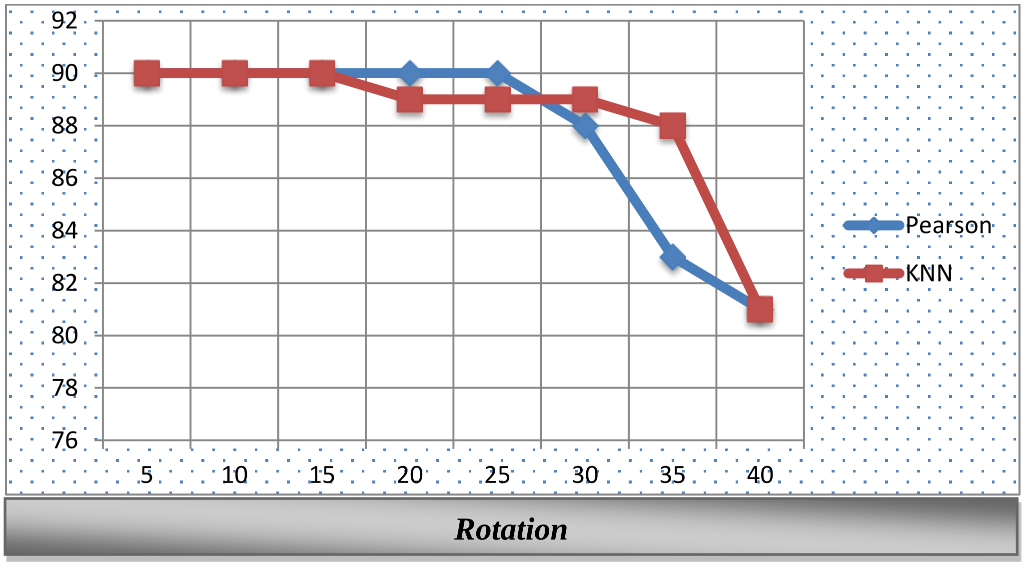


Figure 5.5: *Match Rate (MR) for various values of Rotation (Pearson/KNN)*

As already mentioned above that maximum variation in rotation observed is 20 degree x-axis or 20 degree y-axis or both, match rate has been compared of various methods for rotation 20 degree x-axis or 20 degree y-axis or both which is as under:-

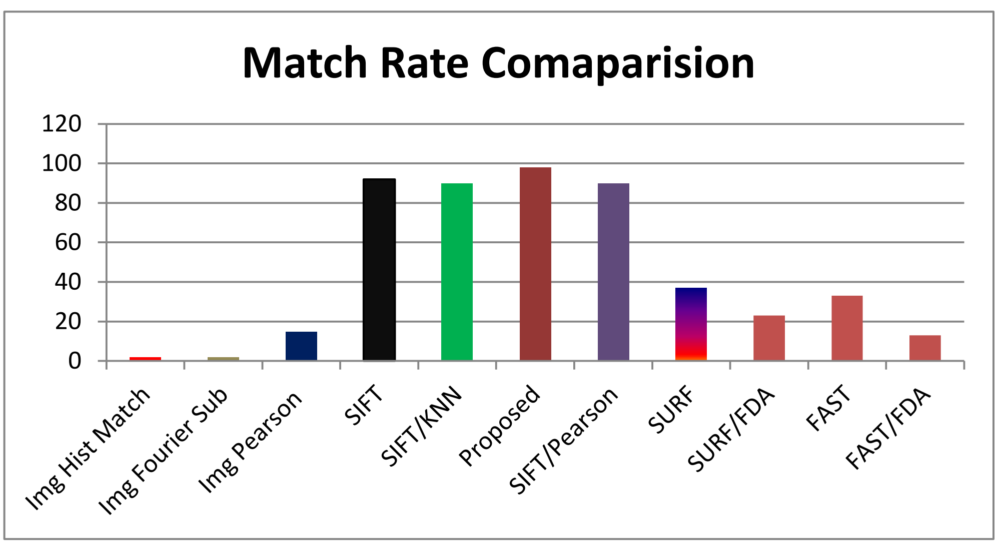


Figure.5.6: *Match Rate (MR) for various Methods Rotation 20 ^{o}*

The under mentioned experiment results for various values of rotation **5 ^{o}- 40 ^{o}** indicates that **proposed method** shows less variation as compared to other methods.

Ser	Method	Rotation							
		5°	**10°**	**15°**	**20°**	**25°**	**30°**	**35°**	**40°**
1	Histogram Matching	2%	0%	0%	0%	0%	0%	0%	0%
2	Image Subtraction	2%	0%	0%	0%	0%	0%	0%	0%
3	Image matching Using Pearson Correlation Factor	15%	5%	0%	0%	0%	0%	0%	0%
4	SIFT for feature extraction and Matching using Euclidian Distance	92%	91%	92%	92%	92%	91%	89 %	89 %
5	SIFT for feature extraction and Matching with KNN classifier	90%	90%	90%	90%	89%	89%	89 %	88 %
6	**Using SIFT for feature extraction , Class Separation / Identification with FLD**	**98%**	**98%**	**98%**	**98%**	**98%**	**96%**	**95 %**	**92 %**
7	SIFT for feature extraction , Feature matching using Pearson Co-Relation	90%	90%	90%	90%	90%	88%	83 %	81 %
8	SURF	23%	21%	21%	19%	17%	15%	13 %	11 %
9	SURF/FDA	13%	11%	9%	9%	5%	1%	1%	1%
10	FAST	13%	11%	9%	8%	1%	1%	1%	1%
11	FAST/FDA	10%	9%	8%	5%	1%	1%	1%	1%

Table 5.5: *Match Rate for various values of Rotation*

5.3 Result Comparison Previous Work

The proposed method has also been compared with previously implemented methods which involves manual identification, Identification based on shape context and top boarder detection method. The proposed methods produced better results of frontal sinus identification even with rotation variation due to movement.

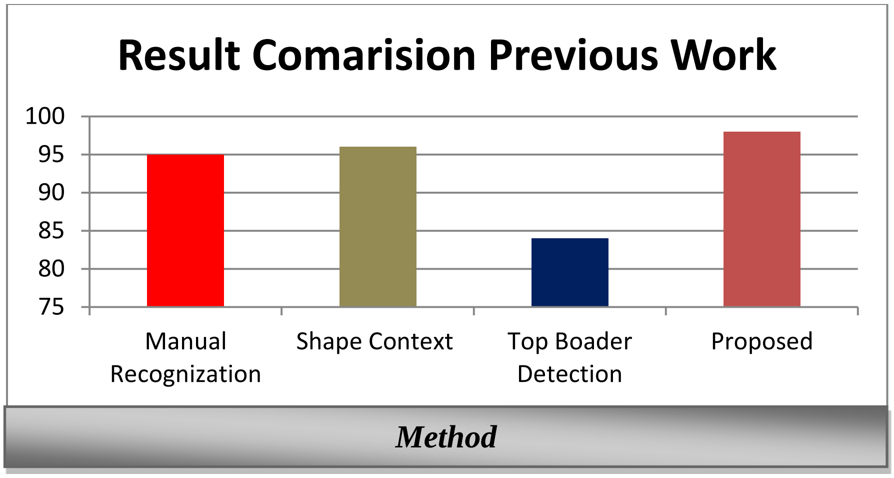


Figure.5.7: *Result Comparison Previous Work [6,9,43]*

CHAPTER 6: CONCLUSION AND SCOPE OF FUTURE WORK

6.1 Overview

The frontal sinus is an effective biometrics for deceased persons. Although it is unique and distinctive but extraction of its correct shape is extremely difficult due to its complex structure. A limited research on this subject is available as marking of its extent and comparison involve a lot of difficulties. Moreover, methods require domain expert (Radiologist) to mark extent and limit of frontal sinus. The understanding of interior and posterior structure of frontal sinus is another hurdle. The most of methods related to matching of frontal sinus involve visual and manual analysis by comparing radiographs images. The quality of radiographic images have improved tremendously in last decade and now normal X-rays have been replaced by DR where they can be manipulated for enhancement and extraction of prominent features. Effective digital image processing and pattern recognition techniques can be used to solve complex problems which ensure minimizing human intervention to produce authenticated results.

6.2 Conclusion

Due to non compliance of rules and regulations, every day many incidents like short-circuiting in factories are reported .In this regards, most recently in Buldia Town tragedy more than three hundred people lost their life. The dilemma of incident is that after lapse of many months bodies were temporality buried being un-identified and unrecognized. Moreover, after suicidal attack many un-identified and unrecognized human remains are left behind. The structure of skull is such that normally it is not destroyed. As frontal sinus is naturally protected, more research must be carried out to device effective methods and applications for human identification. In the same way complex cases of blind murdered can be resolved efficiently if human remains are identified well in time. The previous methods for frontal sinus shape construction and matching produced good result but they involve more human intervention. The aim of proposed method is to reduce human intervention for frontal sinus matching. The proposed method for frontal sinus recognition using SIFT algorithm produced admirable results in our experiments.

These results were better than those reported earlier where area, width, and Feret’s diameter were used as feature descriptor or DIFT algorithm was implemented [6, 9, 43]. The success of the proposed method is due to effectiveness of extraction of feature descriptors which can be matched to determine identity. The experimental results substantiate that proposed method can effectively be used as an alternative for human identification in forensic applications.

6.3 Scope of Future work

Nothing is perfect in this world. There is always room for improvement. In proposed method SIFT techniques have been used for frontal sinus matching. Semi automatic segmentation of image was carried which required to be done automatically. The method is effective for variable radiographic posture of same radiographic viewview .The summary of future work is as under:-

- To reduce human intervention, the segmentation of ROI can be carried out automatically.
- The method produce excellent result for particular radiographic view *Caldwell view* (frontal) or *Occipito Mental view* (Laying View).A method should be worked out to find match if radiographic images of any view are available.

The proposed methodology for frontal sinus recognition using scale invariant feature transform descriptors and pattern recognition techniques produced admirable results in our experiments. These results were better than those reported earlier where area, width, and Feret's used as feature descriptor, shape context method and top/bottom border detection method. The proposed methodology can effectively be used where conventional biometrics are lost. The same method can also be used for identification of unidentified dead bodies and solving criminal cases. The method produced excellent result for particular radiographic view *Caldwell view* (frontal) or *Occipito Mental view* (Laying View).For future research, method should be worked out to find match if radiographic images of any view are available.

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[18] Biometrics of Next Generation: An Overview

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