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Dental Biometrics for Human Identification using Bag of Features

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***Abstract*—** Identification of human, based on dental records is one of the popular and emerging trends in Biometrics. An efficient technique to identify human based on their dental records using bag of features and multi-class Support Vector machine proposed in this paper. The dental images of 34 persons were collected using digital camera. The captured images were pre-processed, and SURF bag of features were extracted using image processing. The extracted SURF features are used to design Multi-class Support Vector Machine for human identification. The accuracy for human identification using dental features of proposed model is 98.85 percent for training data and 97.95 percent for testing data.

***Keywords*—** Dental Biometrics, Bag of Features, Surf Feature, Multi-class SVM

I. INTRODUCTION

A. *Image Processing*

Image processing is a method to convert an image into digital form by performing some operation on it to get some enhanced features or some useful from it. Now a days it is rapid growing technology or field where lots of research work is done in current Trend. Three basic steps required for Image processing they are: First is to importing image with the help of digital photograph or any other scanning device Second is to manipulate or analyze image by image enhancement or any other technique and Third is output of image[1].

There are two types of image processing methods Digital image processing and Analog image Processing. In this paper we focus on digital image processing. Digital image processing is the use of computer algorithms to perform image processing on digital images. Digital image processing has many advantages over analog image processing. It allows a much wider range of algorithms to be applied to the input data and can avoid problems such as the build-up of noise and signal distortion during processing [1].

An image may be defined as two dimensional function f (x,y) where x and y are Spatial coordinates and amplitude f at any pair of coordinates (x,y) is called intensity of the image. When x,y and the amplitude values of f are all finite, discrete quantities, we call the image as digital image [2]. Digital image processing are widely applicable in some of major fields such as :-Image sharpening and restoration, Medical field, Remote sensing, Transmission and encoding, Machine/Robot vision, Colour processing, Pattern recognition, Video processing, Microscopic Imaging, Anisotropic diffusion, Hidden Markov models, Image editing, Image restoration, Independent component analysis, Linear filtering, Neural networks, Partial differential equations, Principal components analysis, Self-organizing maps, Wavelets.

B. *Computer Vision*

Computer vision is an interdisciplinary field that deals with how computers can be made for gaining high-level understanding from digital images or videos [3]. It is a field of computer science that works on enabling computers to see, identify images in the same way as human vision does and then provide appropriate output. It is closely link with artificial intelligence, as the computer must interpret what it sees and perform appropriate actions. Its task include methods for acquiring, processing, and analyzing and understanding digital images and extraction of high dimensional data from real world to produce numerical or symbolic information [3].

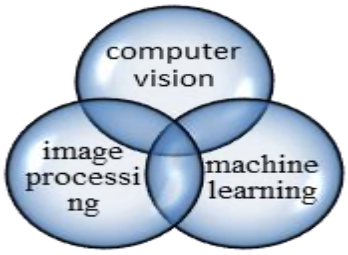

Figure 1: Computer vision relation with image processing and machine learning

C. *BIOMETRICS*

Biometric derived from the Greek word "bios" for life and "metron" for to measure. It is a technology which is used to identify, analyse and measure an individual's physical and behavioural characteristics. Each human being is unique in terms of characteristic which make them different from others. Biometrics system is divided in to two categories: Behavioural biometric system and physiological or physical biometric system [4]. Behavioural biometrics is the field of study related to measure of uniquely identifying and measurable patterns in human beings such as signature password. Physiological or physical biometrics is the field of study related to specific characteristics of humans such as finger prints, iris patterns, face and palm print patterns. Biometrics is the measurement and statistical analysis of people's unique physical and behavioural characteristics. The technology is mainly used for identification and access control, or for identifying individuals who are under surveillance [5].The basic premise of biometric authentication is that every person can be accurately identified by his or her intrinsic physical or behavioural traits

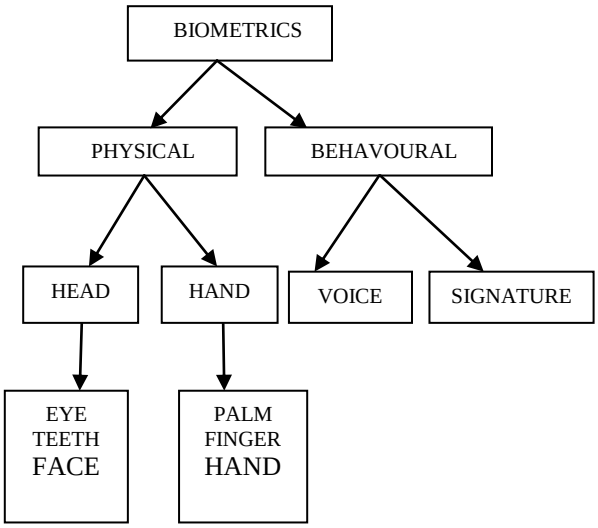

Figure.2. Biometrics Classification

D. *DENTAL BIOMETRICS*

Dental biometrics is a technology which is used to identify person based on their dental appearance. It is an efficient technique which helps to identify person. In 1193 Jai Chand, last raja of Kanauji dead body was discovered with the help of his dental condition.[6] Human Identification based on dental information was first observed in Roman Empire when Nero's mother Agripina ordered to kill loilla paulina who was later identified by her dental caries and bad dental condition [6]. The first treatise of human identification based on dental records was done in 1857, by Dr Oscar Amoedo Valdes who applied a dental based identification technique to identify disaster victim in Paris. After his work human identification based on teeth is accepted worldwide. During last decades human identification based on dental records was extremely used to identify victims in massive disasters such as 9/11 terrorist attack in New York and tsunami in Asia.

Table.1. Comparison of various Biometric Identifiers

BIOMETRIC IDENTIFIER	UNIVERSALLTY	DISTINCTIVENESS	PARMANENCE	COLLACTABLITY	PERFORMANCE	ACCEPTABLITY	CIRCUM VENTION
DNA	H	H	H	L	H	L	L
EAR	H	M	H	M	M	H	M
FACE	H	L	M	H	L	H	H
FACIAL	H	H	L	H	M	H	L
FINGER	M	H	H	M	H	M	M
GAIT	M	L	L	H	L	H	M
HAND	M	M	M	H	M	M	M
HANDVEIN	M	M	M	M	M	M	L
IRIS	H	H	H	M	H	L	L
ODOR	L	L	L	M	L	M	M
RETINA	H	H	M	L	H	L	L
SIGNATURE	L	L	L	H	L	H	H
VOICE	M	L	L	M	L	H	H
DENTAL	H	H	H	M	H	M	M

Above table 1 illustrates the comparison of various Biometrics identifiers with Dental Biometric techniques among various parameters. Where H is High, M is Medium and L is Low.

Dental Biometrics has many advantages in certain scenarios where other methods fail such as:-

- Tooth are made of hardest substance in human body i.e. enamel which does not decay easily
- Tooth does not burn or melt at 1100 degree temperature
- Tooth does not decay easily or in cases where person badly burnt or disfigured in accident.

- Human teeth structure can vary person to person even if person belong to hereditary relation their teeth structure are different
- Tooth size, tooth contours and shapes, distance between teeth, and crowns, fillings, are various parameters which vary person to person.
- It is also used to calculate age of person based on their tooth structure [7].

E. *Forensic Odontology*

"Forensic odontology" is derived from Latin, meaning a forum or where legal matters are discussed. Forensic odontology is the application of dental knowledge to those criminal and civil laws that are enforced by police agencies in a criminal justice system [6].

Forensic dentists are involved in assisting investigative agencies to identify recovered human remains in addition to the identification of whole or fragmented bodies; forensic dentists may also be asked to assist in determining age, race, occupation, previous dental history and socioeconomic status of unidentified human beings [8].

Forensic dentists are responsible for six main areas of practice:

- Identification of found human remains
- Identification in mass fatalities
- Assessment of bite mark injuries
- Assessment of cases of abuse (such as child, spousal or elder abuse)
- Civil cases involving malpractice
- Age estimation

F. *Dental Anatomy*

Dental Anatomy is a field of Anatomy which deals with study of human tooth structure .It is also a taxonomical science that deals with naming teeth & structures of teeth shown in Figure 3 [9].A Tooth (Teeth) is a small calcified whitish structure found in the jaws (mouth) for breaking food. Tooth formation begins before birth. Teeth are not made of bones but it is made of various types of tissues, enamel etc. Teeth are hardest substance in human body. Different parts of teeth are shown in figure 4 [9].

1 CROWN: It is top part of tooth that we normally see.
2 GUMLINE: In this Gumline tooth and gums are met.
3 ROOT: It is a part of tooth which is embedded in bone.
4 ENAMEL: It is outermost layer of teeth which is hardest substance found in human body.
5 DENTIN: It is next layer of tooth found after enamel.
6 PULP: It is the soft tissue found in the centre of teeth where nerve tissues are present.

Usually there are 20 primary (Baby) teeth and 28 to 32 permanent teeth, last 4are third molars or wisdom teeth each of which may or may not grow in. Fig (a) shows that there are 16 teeth found in maxilla (upper jaw) and 16 found in mandible (lower jaw) [8]. There are four types of teeth they are:

1) INCISORS: sharp chisel shaped front teeth (4 upper and 4 lower) used for cutting.
2) CANINES: they are called cuspids because of their shapes like cusps, used for tearing food.
3) PREMOLAR: these teeth have two cusps shape for tearing and grinding.
4) MOLARS: These teeth have many cusps on their biting surface and use for grinding food.

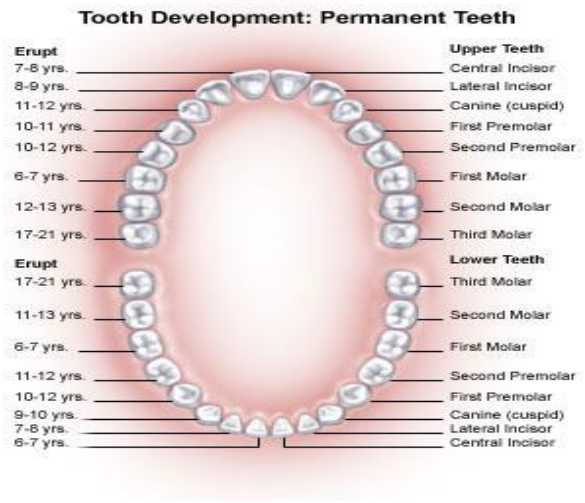

Figure.3. Tooth Anatomy

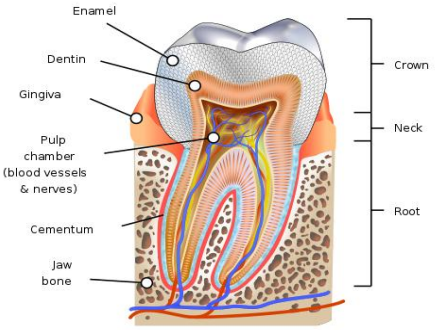

Figure.4. Structure of tooth.

(Rest of the paper is organized as follows, Section I contains the introduction of Image processing, Computer vision, Biometrics, Dental Biometrics and Forensic odontology, Section II contains literature review of the related work of Previous authors in this Field, Section III contain explain the methodology with flow chart, Section IV describes results and discussion, Section V concludes research work with future directions).

II. Related Work

In 2017 G. Jaffino, A.Banumati, Ulaganathen Gurunathan, J.Prabin Jose proposed Texture Based person Identification using Dental radiograph and photograph in forensic odontology. They used Buterworth High pass filter in Enhancement technique, Bite viewing radiograph using Spline Isolation, Missing tooth detection in Segmentation, Moments Feature Extraction in Feature Extraction, For matching they use K-NN classification & Texture based, Fuzzy classification based matching . As a result they create an efficient algorithm with 93% accuracy [10].

In 2015 Soma Datta & Nabendu Chaki proposed Person identification technique using RGB based Dental images. They used De noising winner filter in Enhancement technique, Watershed & snake Algorithm used in Segmentation, ROI Extraction such as volume, size, area in Feature Extraction, They propose an effective technique but its result is not 100% [11].

In 2015 Dipali Rindhe & Ganesh Sable proposed Teeth Feature Extraction and matching for human identification using scale invariant Feature Transform Algorithm. They used good quality of image in JPEG Format in Enhancement technique, Thresholding in Segmentation, SIFT Algorithm in Feature Extraction, for matching they use Feature Based on Eucledian distance. As a Result their methods give better matching rate for identification [12].

In 2014 Vijaya Kumari pushparaj, Ulaganathen Gurunathan, Banumati Arumugan proposed a Victim Identification with Dental Texture images and Morphological operations. They used good quality of radiograph and photograph in Enhancement technique, Missing Tooth Identification and spline isolation in Segmentation, contour Extraction used for Feature Extraction, For matching they used Binary (svm) Contour Based Matching. As a Result This Method outperforms other methods in terms of Computation time & hit rate [13].

In 2013 Amina khatra presented pattern recognition and computer vision stand point, the problem of person identification based on dental records can be viewed as an image matching and retrieval problem. Development of Eigen value or Eigen vector based dental radio graphs information database that can be combined with principal component analysis for further optimizing the feature database [14].

In 2012 Shubhangi C.Dighe & Revti Shriram proposed a Preprocessing, Segmentation and Matching of dental radiograph used in Dental Biometrics. They used Histogram equalization in Enhancement technique, Extraction of ROI in Segmentation, Thresholding in Feature Extraction, For matching they used Difference between radiograph based on dental work, mode, median, skewness &kurtosia , Control point selection of tooth contour. As a result their Method gives direct visualization of matching or not matching & unsatisfactory for two blurred image [4].

III. Methodology

The method consists of three basic steps shown in Figure 5. First, photograph of teeth were captured using digital camera. It was pre-processed to extract unique SURF features by use of feature extractor. These extracted features are used in Multi-class SVM for classification of human.

A. Pre-processing

This is the first basic step or fundamental step of image processing. In this step we work on the dental image which is captured by our digital camera. First we crop the dental image into fixed size then we resize the image. We have done all this process to all the image of various persons.

B. Feature Extraction

Feature extraction a type of dimensionality reduction that efficiently represents interesting parts of an image as a compact feature vector. This approach is useful when image sizes are large and a reduced feature representation is required to quickly complete tasks such as image matching and retrieval. In this process we extract Features by the use of SURF feature extraction Technique SURF stands for Speed-up robust features. It is painted local feature detector or descriptor. It is used for object recognition, image classification and image registration. It is partly inspired by Scale invariant feature transform (SIFT) descriptor. SURF is several times faster than SIFT and is more robust against different image transformation than SIFT. It is used locate and recognize objects, people or faces to reconstruct 3D scenes to track objects and to extract point of interest [15].

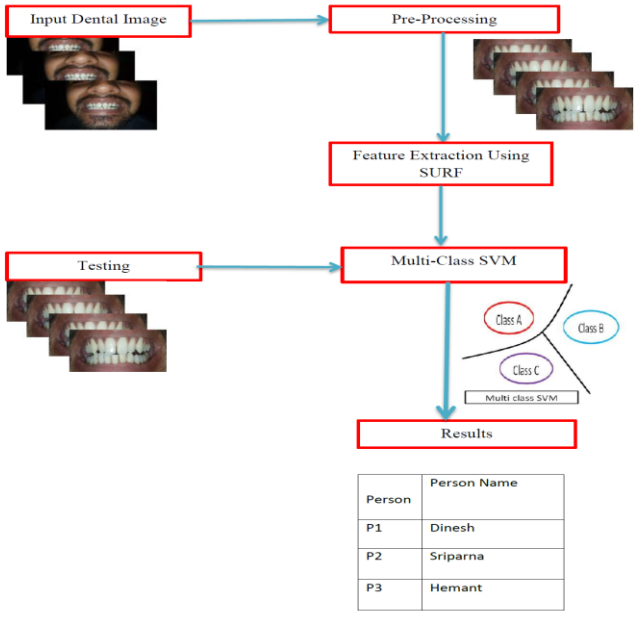

Figure.5. Flow chart of Methodology

Surf Algorithm is used because of its powerful attributes including Scale invariance, translation invariance, lighting invariance, contrast invariance and rotation invariance [16].

Surf Algorithm consists of 4 main parts:

- Integral image generation
- Interest point detection
- Descriptor orientation assignment (optional)
- Descriptor Generation

Integral image is used by all subsequent parts of algorithm to significantly accelerate their speed. Equation "(1)" shows integral image [17].

1 (1)

Surf uses blob detector based on Hession matrix to find point of interest. Surf uses determinant of Hession matrix as a measure of local change around point and also for selecting scale [18].

Given a point p=(x, y) in an image I, the Hessian matrix H(p, σ) at point p and scale σ, is:

$$H(p,\sigma) = \begin{pmatrix} lxx(p,\sigma) & lxy(p,\sigma) \\ lyx(p,\sigma) & lyy(p,\sigma) \end{pmatrix} \quad (2)$$

Where lxx (p, σ) is the convolution of the second-order derivative of Gaussian, with image I(x, y) at point x.
Interest points can be found at different scales, partly because the search for correspondences often requires comparison images where they are seen at different scales.

The goal of a descriptor is to provide a unique and robust description of an image feature, by describing the intensity distribution of the pixels within the neighborhood of the point of interest. Most descriptors are thus computed in a local manner; hence a description is obtained for every point of interest identified previously.

In order to achieve rotational invariance, the orientation of the point of interest needs to be found. By comparing the descriptors obtained from different images, matching pairs can be found.

Four basic steps are followed to extract SURF bag of features [19].

Step 1: Divide or split the dataset in to two parts, that is First is Training set and second is Testing Set. In this we can use the ratio of training and testing set as 60:40, 70:30, 80,20 and 90;10.

Step 2: Since it is a Supervised learning , so it is better to keep a mapping of image so that which image belongs to what classification label

Step 3: Extract Features from training image dataset. For Feature Extraction we can use (SURF or SIFT). In our method we use SURF.

Step 4: Final step is codebook Generation. It is used as a Dictionary that registers equivalent mappings between features and their description in the object.

C. Classification

In This Phase Multi-class SVM used .It is used to classify multiple Class objects where various objects belong to more than two or more classes [20]. Multiclass SVM aims to assign labels to instances by using support vector machines, where the labels are drawn from a finite set of several elements. The main approach for doing so is to reduce the single multiclass problem into multiple binary classification problems [21].
There are two types of Multiclass SVM:

- One versus all
- One versus one

Classification of new instances for one versus all case is done by winners takes all strategy, in which classifiers with highest output function assigns the class. For one versus one approach, classification is done by a max wins voting strategy in which every classifier assigns the instance to one of the two classes, then the vote for the assigned class is increased by one vote, and finally the class with the most votes determines the instance classification [22]. Multi-class SVM categorization is shown in figure 6.

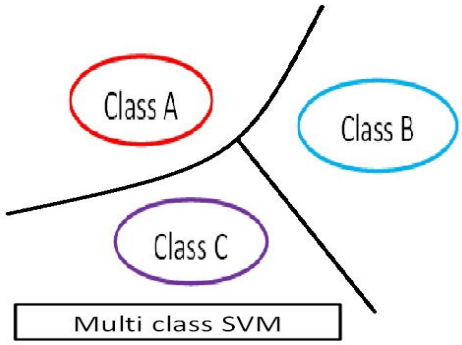

Figure.6. Multi-Class SVM Categorization of Different Class

IV. RESULTS AND DISCUSSION

All the work is implemented on a system having configuration of 8GB RAM with Intel I7 Core processor. For making a system which identify person based on dental records there are dental image of 35 persons is collected with the help of digital camera. The collected dental images consist of both males, females at the age of 23 to 60. For each person we have collected 20 dental photographs at certain distance with different angles.

For training and testing there are 4 parameters through which calculated our result.

For Training and Testing 4 parameters are :-

- 60% of this data will be used as training data and 40% data will be used as test data.
- 70% of this data will be used as training data and 30% data will be used as test data.
- 80% of this data will be used as training data and 20% data will be used as test data.
- 90% of this data will be used as training data and 10% data will be used as test data.

Out of these parameters we calculate our best results with less time intervals.

Table.2. Results of proposed methodology

Sample size		Avg. Execution time	Training accuracy	Testing accuracy
Training %	*Testing %*			
60	40	7.45 sec	99.4%	97.6%
70	30	7.54 sec	99%	97.8%
80	20	7.46 sec	98.6%	98.2%
90	10	7.66 sec	98.4%	98.2%
Average accuracy of Training and Testing			98.85	97.95

In above table 2 illustrates the results of Dental biometrics system where our data set is divided into training and testing samples then, ratio of training and testing samples was used to calculate the accuracy of training set as well as testing set.

First, dataset of 60 % training sample and 40 % of testing sample are taken; as a result it gives accuracy of 99.4% in training accuracy and 97.6% testing accuracy with 7.45 sec execution time.

Second, dataset of 70 % training sample and 30 % of testing sample are taken; as a result it gives accuracy of 99% in training accuracy and 97.8% testing accuracy with 7.54 sec execution time.

Third, dataset of 80 % training sample and 20 % of testing sample are taken; as a result it gives accuracy of 98.6% in training accuracy and 98.2% testing accuracy with 7.46 sec execution time.

Fourth, dataset of 90 % training sample and 10 % of testing sample are taken; as a result it gives accuracy of 98.4% in training accuracy and 98.2% testing accuracy with 7.66 sec execution time.

After comparing all these training and testing accuracy results of training and testing sample ratio of 80% training and 20% testing samples gives best results with 98.6 training accuracy and 98.2% testing accuracy with best execution times that is 7.46 sec.

In below table 3, illustrates the comparison of our proposed method with Some Existing methods. In our proposed system we used Dental Photographs. In this table proposed method is compared with other method that uses dental photographs where proposed method for testing is shown which gives 98.2% accuracy.

Table.3. Comparison with existing methods

Technology Used	Matching accuracy	
	Dental photograph	*Dental radiograph*
Counter based tooth shape matching [13]	80.9%	87%
Skeleton based tooth shape matching [13]	78.5	83.3%
Classification and numbering system of dental radiograph [23]	NA	91.6%
K-NN classification & Texture based, Fuzzy classification based matching [10]	NA	93%
Absolute and Euclidean distance matching [24]	NA	66.7
SIFT Feature Extraction and matching [12]	93%	91%
Proposed method	98.2%	NA

V. CONCLUSION AND FUTURE SCOPE

The proposed work can be analyzed in terms of feasibility and accuracy so identifying a person based on Dental appearance is act as a Confirmatory tools for identifying any individuals, as dental biometric having various advantages among other biometric systems. The Method proposed here gives better results with more than 97% accuracy in testing and more than 98% accuracy in training. Our main Challenge and Future work in Dental Biometric system for human Identification is to deal with poor quality of images, Teeth overlap, teeth shape change consideration due to ageing

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