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Teeth Feature Extraction and Matching for Human Identification Using Scale Invariant Feature Transform Algorithm

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ABSTRACT

Dental biometrics has emerged as vital biometric information of human being due to its stability, invariant nature and uniqueness. Dental radiograph and dental photograph are tools mostly used in biometrics as it provides information about teeth in detail. The proposed system has four main stages as preprocessing, feature extraction, feature matching and finalized recognized person. Preprocessing stage uses conversion and segmentation of quiery input image to make it fesible for feature extraction. Feature extraction uses SIFT algoritham as it extract highly distinctive invariant features which uses for matching purpose. In matching input image is comparatively matched with every image of database and find out the maximum matched features image of person. The system is work for both types of dental images i.e. photograph and radiograph in which two different datasets are required. The required database contains 50 images of dental photographs and 50 images of dental radiographs so experimentation has done on total 100 images and that are taken from Dyanita dental clinic. The proposed system is implemented in Matlab/ R2012a programming tool.

Key words: Dental biometrics, dental photograph, dental radiograph

INTRODUCTION

Teeth are parts of human organ that are not easily decayed and located inside mouth. It has its own characteristics based on a number of distinctive features for each individual tooth. Therefore, teeth based identification is one of reliable tools for human identification. In general, human has 32 teeth and each tooth has five surfaces it means that inside a mouth there are 160 tooth surfaces with various conditions [4]. If we use dental features as a tool of identification, manual matching based on teeth appearance needs a large amount of time and some expertise, therefore computer aided for an identification system is needed. The features of teeth includes properties of the teeth e.g. shape and size of teeth, crown and root morphology, pathology, and dental restorations, periodontal tissue features and anatomical features. During the feature extraction certain salient information of teeth such as contour, artificial prosthesis, shape and size of teeth number of cuspids etc is extracted from dental image i.e. dental photograph and radiograph [9]. In this work the feature extracted is tooth contour and tooth shape because they remains more invariant over time as compared to some other features of teeth and this thing play an important role in dental biometric.

Tooth Anatomy

A tooth (plural teeth) is a small, calcified, whitish structure found in the jaws (or mouths) of many vertebrates and used to break down food. The roots of teeth are covered by gums. Teeth are not made of bone, but rather of multiple tissues of varying density and hardness. A typical healthy tooth has number of layers and its internal structure. Each tooth relates to the gum and surrounding jaw bone. Fig. 1 shows the tooth anatomy. The crown is the part of the tooth that is visible above the gum (gingiva) and neck is the region of the tooth that is at the gum line, between the root and the crown. The root is the region of the tooth that is below the gum. Some teeth have only one roots, for example, incisors and canine (‘eye’) teeth, whereas molars and premolars have 4 roots per tooth.

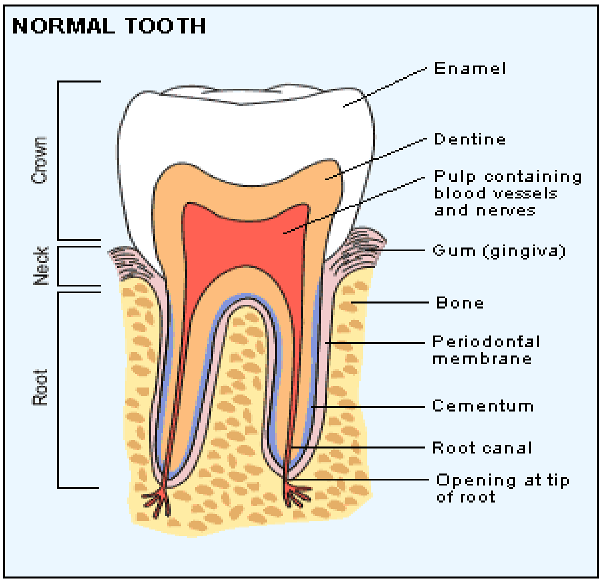


Fig. 1 Tooth anatomy

Dental Photograph

Dental photograph is a pictorial view of teeth structure. It is a image capture by digital camera by stretching upper and lower lips as shown in Fig. 2 It gives the information of teeth structure with tooth contour and tooth size of both upper and lower jaw teeth.

Fig. 2 Typical dental photograph

Dental Radiograph

Dental radiograph is an intra or oral image that is taken using X-ray radiation. Dental radiograph consists of teeth using X-ray radiation. Dental radiograph consists of teeth, bones and surrounding soft tissues. There are three types of dental radiograph that is commonly used in dentistry that are periapical, bitewing and panoramic as shown in Fig. 3 (a) (b) (c).

(a) **(b)** **(c)**

Fig. 3 (a) Periapical radiograph (b) Bitewing radiograph (c) Panoramic radiograph

The proposed system uses only bitewing radiographs because it gives clear information of shape and contour features of teeth which is used for feature extraction.

EXISTING SYSTEMS

Many authors explored the feature extraction and matching techniques based on dental radiograph in dental biometric and few explored system based on dental photograph. Hong chen and A K Jain uses mixture of Gaussians models to segment teeth and anisotropic diffusion to enhance the images. Matching part contains tooth-level matching, computation of image distances, and subject identification [1], Active contour & skeleton based shape extraction and matching using level set method is implemented by V Pushparaj and U Gurunathan[2], Some uses mathematical morphology for teeth segmentation [3], classification and numbering of dental radiographs for an automated human identification system is implemented by using the binary support vector machine method[4] presents matching of two radiographs based on histogram properties, area of tooth and dental work is done by Sood et al [7]. Extracting some features namely average pixel intensity, length to width ratio and root centre angle to retrieve a closest match this method is implemented by Maurya et al [8]. A semi-automatic contour extraction method is used to address the problem of fuzzy tooth contours caused by the poor image quality [9]; semiautomatic dental recognition using a graph-based segmentation algorithm and teeth shapes features [10]. The teeth segmentation is important part of the system. Normally the teeth are segmented using the pixel neighbourhood based connectivity. The pixel neighbourhood connectivity gives fair results for the dental radiographs [11].

PROPOSED METHOD

The proposed system has mainly four modules: pre-processing, Feature extraction, feature matching and recognized person identification. Pre-processing is done by resizing and rgb2gray conversion. Feature extraction uses morphological operation and sifts feature extraction. Matching is done by using SIFT feature matching algorithm and finally find out the recognized person. Fig. 4 shows the block diagram of the proposed human identification system based on teeth feature extraction and matching. It consists of the following steps

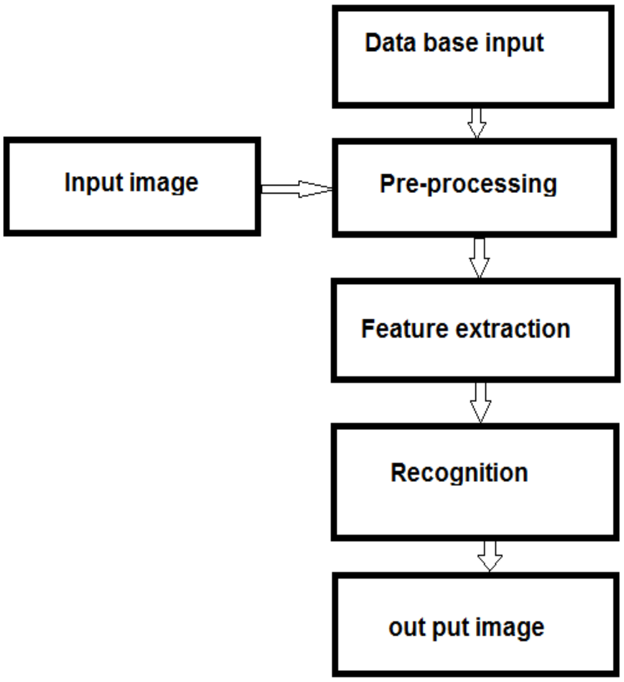


Fig. 4 Block diagram of proposed system

Pre-processing

I. Input image: Here the input images are dental photograph and radiograph in JPEG format are used. First user has to select database type i.e. either dental photograph or radiograph, then input image is selected from that database type for further processing. The input image is then resized to 150*150 in pre-processing step.

(a) **(b)**

Fig. 5 a) Input dental photograph (b) Input dental radiograph

II. RGB to gray conversion: RGB to grey conversion is required for both photograph and radiograph images because the processing takes place on gray scale image. This conversion is carried out by eliminating hue and saturation information while retaining the luminance information of image.

(a) (b) (c) (d)

Fig. 6 (a) Input dental photograph (b) Gray scale image of dental photograph (c) Input radiograph (d) Gray scale image of dental radiograph

III. Segmentation

In teeth segmentation each tooth is segmented in rectangular region using mathematical approach like noise filtering, the holding to isolate the teeth from background. In this there are four steps as, specify colour rang, intensity and hue map, create binary image from hue intencity map and return binary image. This will give segmented teeth image as shown below Fig. 7.

(a) (b) (c)

Fig. 7 (a) Input dental photograph (b) Grayscale image of dental photograph(c) Segmentation of photograph

(a) (b) (c)

Fig. 8 (a) Input dental radiograph (b) Grayscale image of dental radiograph (c) segmentation of radiograph

Feature Extraction

Feature extraction uses scale invariant feature transform to extract SIFT key points from input image and compare with database images for feature matching. Scale invariant feature transform is an algorithm in computer vision to detect and describe local features in images. Here, it uses skeleton image to extract highly distinctive features. There are four main steps of SIFT feature extraction.

I. Scale-space Extreme Detection

This is the stage where the interest points, which are called key points in the SIFT framework, are detected. For this, the image is convolved with Gaussian filters at different scales, and then the difference of successive Gaussian-blurred images is taken. Key points are then taken as maxima/minima of the Difference of Gaussians (DoG) that occur at multiple scales. Specifically, a DoG image $D(x,y,\sigma)$ is given by

$$D(X,Y,\sigma) = L(X,Y,K_i\sigma) - L(X,Y,K_j\sigma) \quad (1)$$

Where $L(x,y,k\sigma)$ is the convolution of the original image $I(x,y)$ with the Gaussian blur $G(x,y,k\sigma)$ at scale $k\sigma$, i.e.

$$L(x,y,k\sigma) = G(x,y,k\sigma) * I(x,y) \quad (2)$$

Hence a DoG image between scales $K_i\sigma$ and $K_j\sigma$ is just the difference of the Gaussian-blurred images at scales $K_i\sigma$ and $K_j\sigma$. For scale space extrema detection in the SIFT algorithm, the image is first convolved with Gaussian-blurs at different scales. The convolved images are grouped by octave (an octave corresponds to doubling the value of σ and the value of K_i is selected so that we obtain a fixed number of convolved images per octave. Then the Difference-of-Gaussian images are taken from adjacent Gaussian-blurred images per octave.

II. Key point Localization

After scale space extrama are detected the SIFT algorithm discards low contrast key points are then filters out those located on edges. Scale space extrema detection produces too many key points candidates, some of which are unstable. The next step in the algorithm is to perform a detailed fit to the nearby data for accurate location, scale, and ratio of principal curvatures. This information allows points to be rejected that have low contrast (and are therefore sensitive to noise) or are poorly localized along an edge.

III. Interpolation of Nearby Data for Accurate Position

First, for each candidate keypoint, interpolation of nearby data is used to accurately determine its position. The initial approach was to just locate each keypoint at the location and scale of the candidate keypoint. The new approach calculates the interpolated location of the extremum, which substantially improves matching and stability. The interpolation is done using the quadratic Taylor expansion of the Difference-of-Gaussian scale-space function, with the candidate keypoint as the origin. This Taylor expansion is given by:

$$D(X) = D + \frac{\partial X^{T}}{\partial X} + \frac{1}{2} X^{T} \frac{\partial^{2} D}{\partial X^{2}} X \tag{3}$$

Where D and its derivatives are evaluated at the candidate keypoint and $x = (x, y, \sigma)$ is the offset from this point. The location of the extremum, $\hat{X}$, is determined by taking the derivative of this function with respect to x and setting it to zero. If the offset $\hat{X}$ is larger than 0.5 in any dimension, then that's an indication that the extremum lies closer to another candidate keypoint.

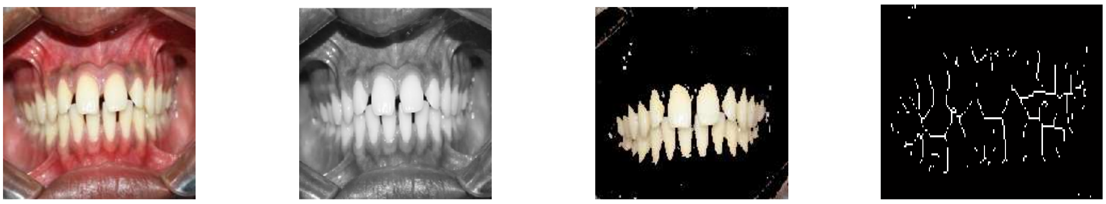
IV. Orientation Assignment

In this step, each keypoint is assigned one or more orientations based on local image gradient directions. This is the key step in achieving invariance to rotation as the keypoint descriptor can be represented relative to this orientation and therefore achieve invariance to image rotation. First, the Gaussian-smoothed image at the key points scale is taken so that all computations are performed in a scale-invariant manner. For an image sample at scale , the gradient magnitude, , and orientation, , are pre-computed using pixel differences:

$$m(x, y) = \sqrt{(L(x+1, y) - L(x-1, y))^{2} + (L(x, y+1) - L(x, y-1))^{2}} \tag{4}$$

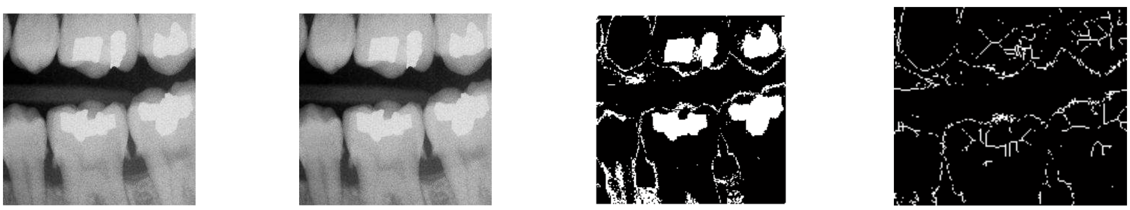
$$\theta(x, y) = a\tan 2(L(x, y+1) - L(x, y-1), L(x+1, y) - L(x-1, y)) \tag{5}$$

The magnitude and direction calculations for the gradient are done for every pixel in a neighbouring region around the key point in the Gaussian-blurred image L In this step output image of pre-processing step is converted to binary and morphological operation is apply on it to extract SIFT features as shown below.



(a) (b) (c) (d)

Fig.9 Photograph of (a) Input dental (b) Grayscale image (c) segmentation (d) skeleton morphology



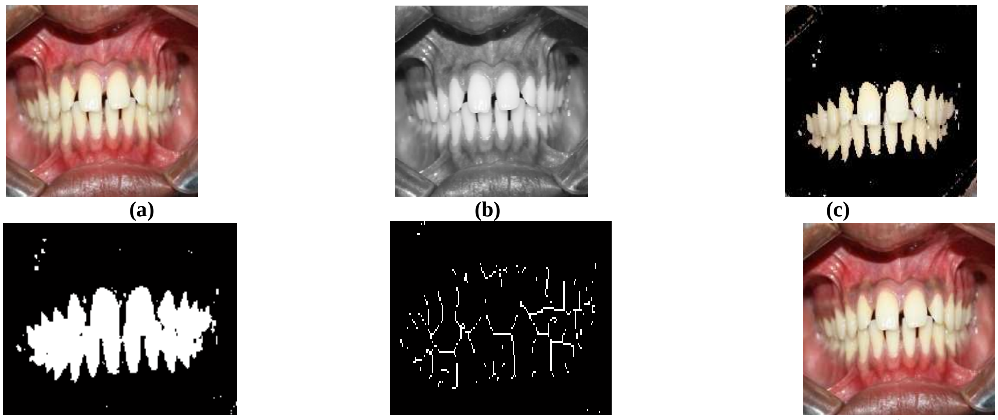
(a) (b) (c) (d)

Fig. 10 Radiograph of (a) Input dental (b) Grayscale image (c) segmentation (d) skeleton morphology

Feature Matching

In feature matching, key points found in feature extraction step are used for matching of database image with input image on the basis of their distratio and thresholding. For image matching and recognition, SIFT features are first extracted from a set of reference images and stored in a database. A new image is matched by individually comparing each feature from the new image to this previous database and finding candidate matching features based on Euclidean distance of their feature vectors. If Euclidean distance is 0.8 times less than secondary least euclidean distance then two feature points are match. After repeated experiment when distratio=0.65, there reflect matching points and remove mismatch points in addition the matching ratio is the best. More match points help to achieve high accuracy; this is calculated by using following formula.

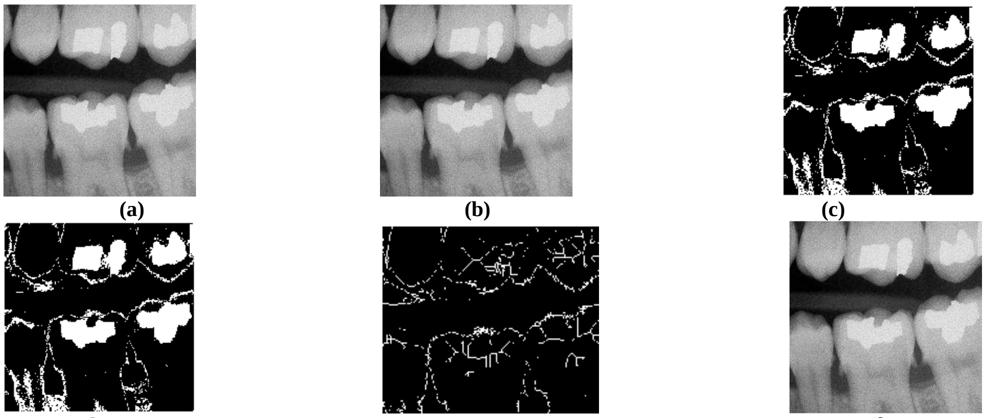
$$E(x, y) = \sqrt{\sum_{i=0}^{n} (x_i - y_i)^{2}} \tag{6}$$



(a) (b) (c)

(d) (e) (f)

Fig. 11 Photograph of (a) Input dental (b) Grayscale image (c) Segmentation (d)Binary image (e) Skeleten morphology (f) Recognised person's dental



(a) (b) (c)

(d) (e) (f)

Fig. 12 Radiograph of (a) Input dental (b) Grayscale image (c) Segmentation (d)Binary image (e) Skeleten morphology (f) Recognised person's dental

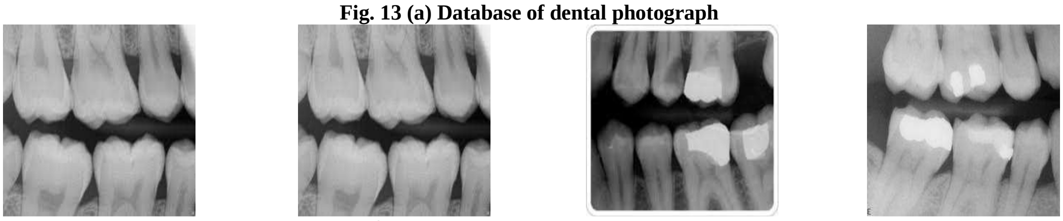
EXPERIMENTATION

Database

We have taken the database containing Dental photograph and dental radiograph of 50 persons from Dnyanita dental clinic, Aurangabad. All these images are of size 256*256 and are in JPEG format. In this photograph images are capture by canon digital camera of 16 megapixels with 25mm wide angle lens and 10x optical zoom while radiographs are taken from digital X-ray machine. Some images from the database are shown in following Fig. 13.

Arpita **Anand** **Anirudha** **Amol**

Fig. 13 (a) Database of dental photograph



Abhishek **Alfiya** **Bhagyashri** **Priti**

Fig. 13(b) Database of dental radiograph

System requirements

The proposed module requires computer system with Hardware specified with Intel (R) Core i3 – 2.53 GHz, 3GB RAM and 250GB Hard disk. Software requires windows7 Operating system, Matlab 2012 Programing tool with Version 7.9.

Experimental Results

The experiment is done on 50 person's dental photograph and 50 person's radiograph i.e on all 100 dental images. Experimentation for photograph and radiograph is same but their matching ratio and matching time is differing. The output results of 20 people's are shown below. It contains 10 photograph and 10 radiograph results.

Experimental results of dental photograph

The system is tested by using 50 dental photographs and obtained the reading and calculations of every image. Out of those result of 10 sample photographs are mention in below table 1.

Table -1 Experimental Results of Dental Photograph

Sr no	Name of person	Input image size	Threshold value	No. of iteration	Key points		Match points	Mismatch points	Matching ratio	Matching time (sec)
1	Aishwrya	522x338	0.035	60	316	316	316	00	100%	6
2	Ajinkya	256x147	0.035	60	226	1174	187	39	83%	7
3	Amol	256x125	0.035	60	243	2441	181	62	75%	8
4	Anand	387x216	0.035	60	528	528	528	00	100%	6
5	Anirudha	397x213	0.035	60	318	344	256	56	80%	4.5
6	Anju	583x308	0.035	60	358	358	358	00	100%	5
7	Arpita	948x411	0.035	60	155	157	155	00	100%	4
8	Arundati	256x94	0.035	60	278	344	252	26	91%	5
9	Arushi	591x248	0.035	60	309	391	274	25	90%	4
10	Datta	867x420	0.035	60	444	702	379	75	86%	5

Similar to this all 50 photographs are process and find out their results, from this average matching ratio and average matching time is calculated.

$$\text{Average matching ratio} = \frac{Sum\ of\ all\ matching\ ratio(\%)}{total\ no.of\ images} = \frac{4629\%}{50} = 93\% \quad (7)$$

$$\text{Average matching time} = \frac{Sum\ of\ all\ matching\ time(sec)}{total\ no.of\ images} = \frac{286.9}{50} = 5.6\ \text{seconds} \quad (8)$$

Graphical Representation of Key points and Match Points in Dental Photograph

In experimental result of dental photograph, total key points in every image, match points and mismatch points are calculate to obtain matching ratio. From these relations between key points and match point of input image and database image is study and represent in Fig. 14. In this figure Red Square indicate matching points while blue is for total key points of image. If there is all matches with key point then it reflect only match point due to overlapping of red and blue dot. This is for images 1,4,6,7 here all key points are match.

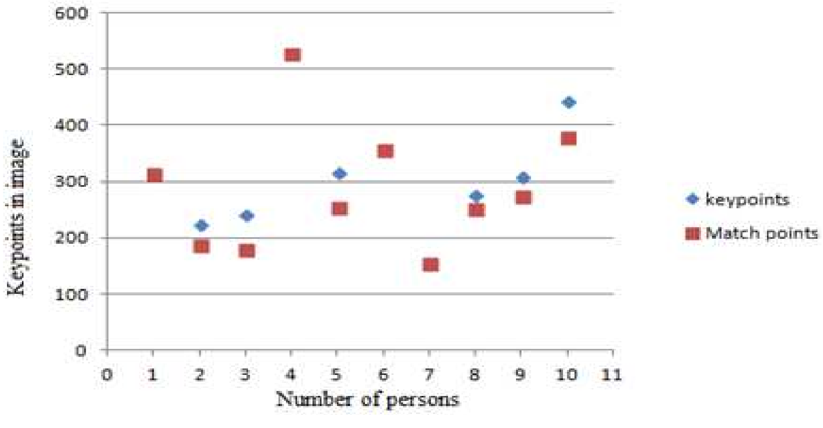


Fig. 14 Key points and match key points in dental photograph

Experimental Results of Dental Radiograph

The system is tested by using 50 dental radiographs and obtained the reading and calculations of every radiograph image. Out of those result of 10 sample radiographs are mention in below table 2.

Similar to this all 50 radiographs are process and find out their results, from this average matching ratio and average matching time is calculated.

$$\text{Average matching ratio} = \frac{Sum\ of\ all\ matching\ ratio(\%)}{total\ no.of\ images} = \frac{4566\%}{50} = 91\% \quad (9)$$

$$\text{Average matching time} = \frac{Sum\ of\ all\ matching\ time(sec)}{total\ no.of\ images} = \frac{47.6\ sec}{50} = 0.95\text{seconds} \quad (10)$$

Table -2 Experimental Results of Dental Radiograph

Sr no	Name of person	Input image size	Threshold value	No. of iteration	Key points		Match points	Mismatch points	Matching ratio	Matching time (sec)
1	Abhishek	217x160	0.035	60	147	147	147	00	100%	1.1
2	Akash	256x175	0.035	60	40	47	5	35	13%	1
3	Alfiya	266x189	0.035	60	59	59	59	00	100%	1
4	Amar	256x175	0.035	60	39	39	39	00	100%	0.7
5	Amit	256x181	0.035	60	70	71	30	40	43%	0.9
6	Amol	256x169	0.035	60	44	44	44	00	100%	0.8
7	Arati	266x189	0.035	60	80	80	80	00	100%	1.1
8	Archana	225x170	0.035	60	147	147	147	00	100%	1.2
9	Arushi	259x194	0.035	60	49	49	49	00	100%	0.8
10	Aryan	256x213	0.035	60	70	70	70	00	100%	1.1

Graphical Representation of Key Points and Match Points in Dental Radiograph

In experimental result of dental radiograph, total key points in every image, match points and mismatch points are calculate to obtain matching ratio. From these relations between key points and match point of input image and database image of radiograph is study and represent in Fig. 15.

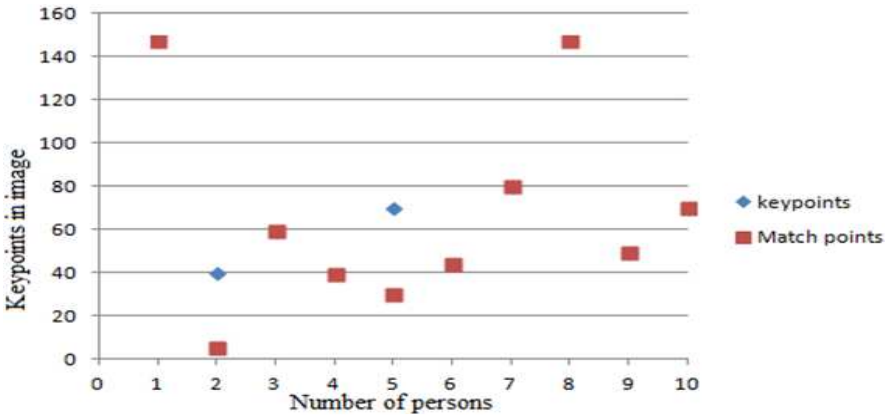


Fig. 15 Key points and match key points in dental radiograph

SYSTEM COMPARISION

In this proposed system is compared with some of the existing systems, most of them are work only on dental radiograph and one system namely contour based tooth shape matching and skeleton based tooth shape matching uses both dental photograph and radiograph. These systems are comparing on the basis of two parameters that are matching accuracy and matching time as shown in table 3.

Table -3 Comparisons with Existing Systems

Ref. no.	Name of the author	Technology used	Matching accuracy		Matching time(sec)	
			Dental photograph	Dental radiograph	Dental photograph	Dental radiograph
2	Vijaykumari Pushparaj, Ulaganathan Gurunathan	counter based tooth shape matching	80.9%	87%	6	12
		Skeleten based tooth shape matching	78.5%	83.3%	6	12
4	AnnyYuniarti, Anindhita Sigit Nugroho, Bilqis Amaliah	Classification and numbering system of dental radiograph	--	91.6%	--	--
5	Martin L. Tangle, Chastine Fatichah, Fei Yan, Janet P. Betancourt	Classification of periapical radiograph based on multiple probabilistic attribute	--	84.51%	--	--
17	Nourdin Al-sherif, Ayman Abaza, HanyAmmar	Tooth contour extraction based on guided SIFT descriptor	--	74%	--	7
	Proposed system	SIFT feature extraction and matching	93%	91%	5.6	0.95

The systems are comparing on the basis of techniques used and their accuracy and time. Its graphical representation is shown in Fig. 16 and Fig. 17. Fig. 16 shows comparison based on dental photograph whereas Fig. 17 shows comparison based on dental radiograph.

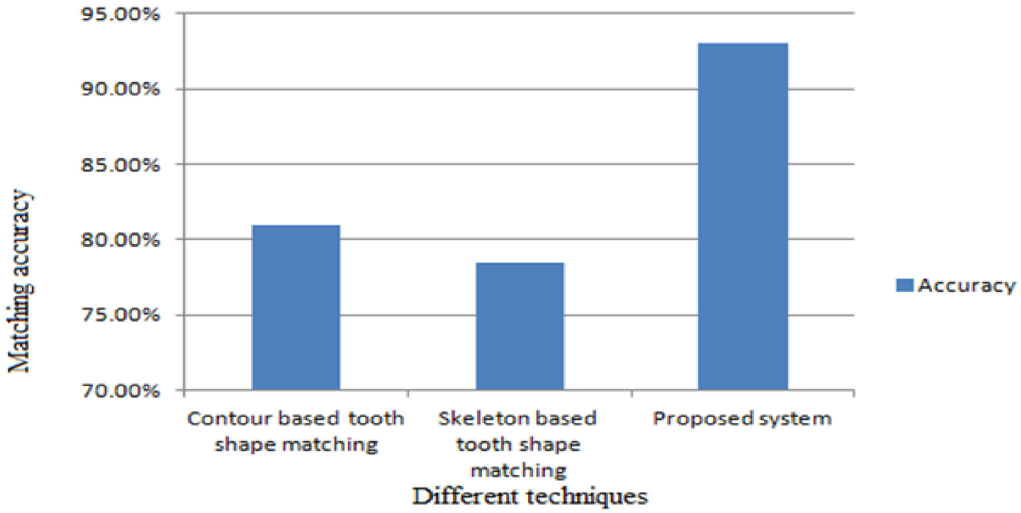


Fig. 16 Comparison with existing system based on dental photograph

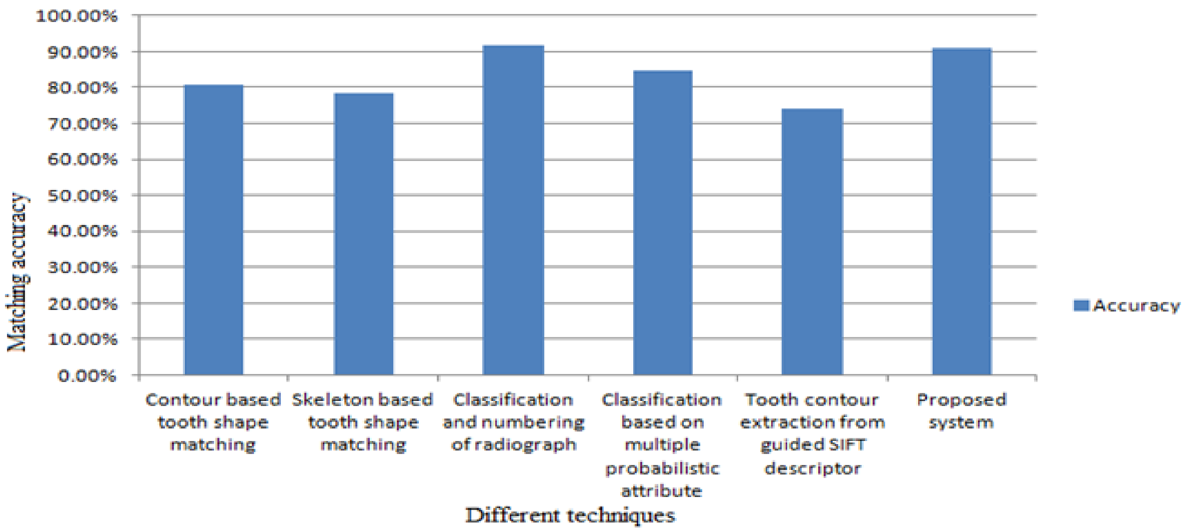


Fig. 17 Comparison with existing systems based on dental radiograph

CONCLUSION

From this work it can be concluded that the proposed method performs well and work for both images i.e. dental photograph and radiograph. In physical biometrics generally parameters like fingerprint, palm print, iris and retina, face are used for identification but teeth are also a good biometric solution for human identification due to its stable and unique features. The proposed system requires less computational time and an automated approach is used to extract and match the teeth features. In this system, teeth have been segmented by using thresholding in photograph and radiograph, from this segmented teeth skeleton is obtain by applying morphological operation. Invariant features are extracted by using scale invariant feature transform algorithm which uses descriptors and match this features of input image and database image by SIFT matching algorithm. Dental radiograph gives better matching rate and require less matching time as compare to dental photograph while photograph is easily available than radiograph, still both images are better for human identification. In future work, the million order dataset can be selected and dental image identification can be done on larger dataset. With increased size of dataset various issues such as uploading data, managing feature set, increased execution time of matching algorithms etc. can be considered. More image features can be extracted for better identification.

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