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ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

RECOGNITION OF MISSING CHILDREN USING FEATURE-BASED METHOD

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ABSTRACT

In this research work, a new system has been proposed to tackle the problem of identifying and recognizing missing children. The skin and non-skin part of the original image has been segregated by using binary operation, then, the face area of skin image has been obtained by using morphological operation. Finally, the feature points (mouth, right nostril, left nostril, right eye and left eye) are located on the face image of missing children of later age. The four triangles are formed by taking the combination of feature points (mouth, right nostril, left nostril, right eye and left eye) of the face images of missing children of later age. The ratios of three sides of all the four corresponding triangles of the two face images of missing child of later and early ages have been calculated. The difference between ratios of sides as well as difference between angles of these four corresponding triangles have been calculated. If the difference between ratios of any two sides and difference between the included angles of anyone of the four corresponding triangles is equal to or less than specified threshold value, then these two face images belong to same child, otherwise not. FG-NET aging database are used to analyze the proposed system. The performance of the proposed system has been compared with the existing system. It has been acknowledged that the proposed system is better and more useful to identify and recognize the missing children from age 1 to age 18 years.

Keywords: *Biometric, Feature Points, FG-NET, Geometrical Transformation, Missing Children*

1. INTRODUCTION

Identification of missing children are an issue across the world that requires much more rigorous and systematic attention than what it is getting at the moment. The main responsibility for locating the missing children lies on Police department. The Police departments in all the states have access to a lot of information on missing children by virtue of the fact that both missing and found children cases have to be reported to the Police. But, there is a big gap in automating auto search and match of both automatically. The problem of missing children is being addressed by various Non-Government Agencies (NGO). Unfortunately, these agencies have different databases using non-standard data format. These unformatted data are not sufficient to make appropriate decision. Moreover, when a child is found after a time gap, it is extremely difficult to search the missing children records and match the child with existing records. Owing to the recent academic, technological and industrial advances, biometric information such as face images can be used successfully to identify some children that have been missing by automatically screening the databases maintained by the NGO's or public data resources available on the Internet. However, when the missing cases exceed years, some photos may either become useless, because of the several natural biometric changes that tend to occur particularly on children faces or may have significant reduction on their signal-to-noise ratio, making the child identification even harder. Moreover, face images of the same child may vary depending on the illumination, profile position, changes in facial expression and other artifacts [1]. Face Recognition Technology (FRT) can be used for identification and recognition of an individual. Good face recognition algorithms and appropriate preprocessing of the images can compensate for noise and slight variations in orientation, scale and illumination. But, the human face is not unique, rigid object. There are numerous factors that cause the appearance of the face to vary. e.g., the facial appearance (age, facial expression, facial hair, glasses, cosmetic etc.) may vary for the same person. The appearance of the face may vary due to illumination, pose, scale and imaging parameters (such as resolution, focus and noise). So, there are still a lot of gap in technology growth in the field of face recognition [2]. An automated intelligent system is required to match an image of the child with the morphed image of the same child after a time gap.

Researcher studied how age differences affect the face recognition performance to identify missing children. Their results show that the aging process does increase the recognition difficulty, but it is less severe than the effects of illumination or expression [3]. A few seminal studies have demonstrated the feasibility of improving face recognition accuracy by simulated aging [4]. There has also been work done in the related area of age estimation using statistical models [5]. Reference [6] shows how a subspace of aging pattern and their representation is composed of face texture and the 2D facial shape; the shape is represented by the coordinates of the feature points as in the active appearance model. Reference [7] shows the evaluation of age estimation of facial image and perform the comparative studies of various methods. In [8], the authors proposed the framework that simulate aging effect on face images to predict how an individual might look in the future or how he/she used to look in the past. Authors have developed age estimation algorithms, namely, PLO (Preserving Locality and Ordinal Information) and semi-PLO, from the learning ordinal discriminate features. PLO preserve both the locality and the ordinal information simultaneously, while, semi-PLO preserve the locality information of the whole training data and the ordinal information of the labeled image set [9]. The hybrid constraint support vector regression (HC-SVR) algorithm for facial age estimation has been proposed by [10]. The authors proposed the appearance-based human face age estimation that combines the shape feature, texture feature, and frequency feature using Active Shape Model (ASM), Radon transform, and Discrete Cosine Transform (DCT) to establish robust adaptive hybrid features for further classification [11]. The author proposed the novel approach which combines the global features extracted by AAM and local features extracted by LPQ to age estimation [12]. The multistage learning system, called grouping estimation fusion (GEF) to estimate the age of human through facial images has been developed by [13]. Authors studied the human ability to analysis the face images across age progression by implemented the face verification and age estimation task. The different facial parts, for example, eye wrinkles, internal face (without forehead area) and whole face (with forehead area) using bio-inspired features (BIF) has been analyzed by [14]. The authors proposed the novel algorithm for recognition of various ages of frontal face image that has four age categories, namely, Pre-processing, facial feature extraction by a novel geometric feature-based method, face feature analysis, and age classification [15]. Authors have proposed the probabilistic approach framework to extract the facial features using both location and texture information [16]. Authors have performed the comparative analysis of various approaches for age estimation, face verification and appearance prediction. In [17], the authors proposed an automatic face recognition system that based on appearance-based features of entire face image. Authors have introduced the various approaches and advancements to identify and track the facial features like, pose variation, occlusion and different lighting condition [18]. The 3D face aging modelling technique to improve the performance of age-invariant face recognition has been proposed by [19]. Authors have proposed an automatic age estimation method, namely, AGES (AGing pattErn Subspace) based on facial aging pattern. The existing models, system performances, algorithms, face aging databases and evaluation protocols in the field of age synthesis and estimation of face images have been surveyed by researchers [20]. The authors proposed the sequence k-nearest neighbor (SKNN) and ranking-KNN to predict the age group and value, respectively [21]. Authors have designed and implemented the face recognition model for age invariant using the scale invariant feature transform (SIFT) algorithm [22]. All the above stated existing systems have failed when the face image of the missing child (e.g. age 6) is matched with that of same child (e.g. age 2). A new system is required which can overcome this problem and useful to match the two images of same child from age 1 to 18.

The objective of the proposed research is to carry out the work to find a technology which can help to identify and recognize the missing children by using feature-based method, e.g., identifying children missing at an early age (1 to 6 years) and found later at the lapse of longer period of time. The proposed system will be useful to identify and recognize the missing children even after a number of years (1 year to 18 years).

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

2. PROPOSED SYSTEM

In order to locate the feature points of the face image, the following steps are:

Step 1: A face recognition algorithm using feature-based method has been applied on the original image. Firstly, the skin and non-skin part of the image have been segregated by using binary operation. Thereafter, the face area has been obtained by generating the binary mask of skin image over the segmented image. The positions of feature points (mouth, right nostril, left nostril, right eye and left eye) of the face image are located by applying the HSI (Hue, Saturation, Intensity) operation on the face area of the image. Note that the early age of child (Figure 1) means that the age of child when he/she had been missed.

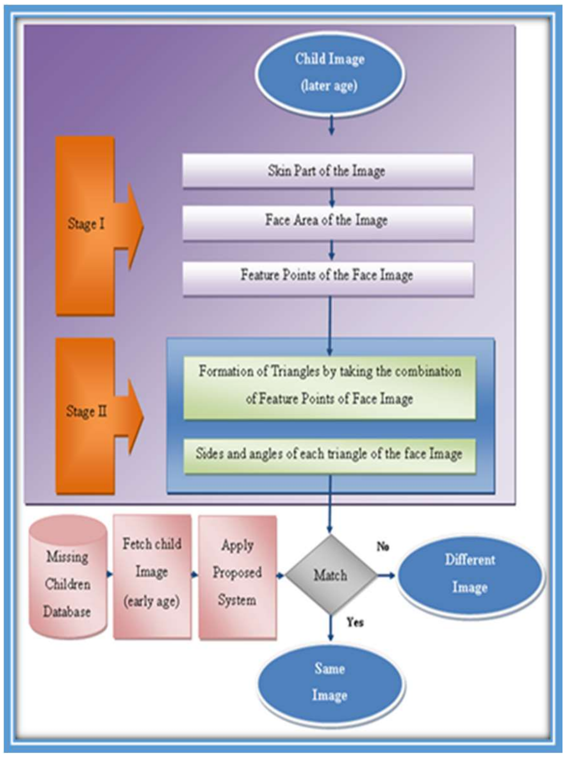

Figure 1: Block Diagram of Proposed System

Step 2: After locating the feature points of the face image, different triangles have been formed by taking various combinations of these feature points of face of child image of early and later age. The sides and angles of each triangle formed by various combinations of feature points have been calculated by using the trigonometry formulas. The difference between ratios of sides as well as difference between angles of these triangles of two face images has been calculated. In order to decide if the given two images are belonging to same child or not, the threshold values have been set for the difference between ratios of sides as well as difference between induced angles of corresponding triangles of two face images. The block diagram of proposed system has been shown in figure 1.

It has been observed from various studies that eyes are the most important source of information to locate the identity of human being because the other features of face may be easily located with the help of precise location of eyes [23]. Two nostrils are the two dark regions present in the nose area and the mid-points of two nostrils can be easily located on the face area. The mouth can be easily located by finding the position of mouth corner and lip line. However, the other features (eye brows, nose tip, chin etc.) are not considered because it is very difficult to locate the precise position of eye brows due to large variations in the case of small child. The precise location of nose tip and chin are very difficult to identify due to low resolution of images.

2.1 Algorithm of Proposed System

The algorithm of the proposed system contains following two phases:

2.1.1 Phase 1: Algorithm for face recognition using feature-based method

1. Read the RGB (Red, Green, Blue) image of child (later age).
2. Detect the skin part of the image by applying binarization operations.
3. Locate the face area by generating the binary mask of skin image over the image.
4. Obtain the feature points for mouth, nostrils and eyes.
5. Calculate the position of the mouth based on the image's hue and saturation.
6. Calculate the position of left and right nostrils based on the image's hue and saturation.
7. Detect both pupils from the image of left and right eye based on the image's hue and saturation.

2.1.2 Phase 2: Algorithm to match child image against the missing children database

1. Generate the four triangles by taking the combinations of distinct feature points of mouth, right nostrils, left nostril, right eye and left eye of the face area of the image.

2. Obtain the sides and angles of each triangle by using trigonometry formulas.
3. Fetch another image of child (early age) from the missing children database.
4. Match the sides and angles of each triangle of child image (later age) with same child image (early age) from missing children database.
5. Calculate the difference between ratios of sides as well as difference between angles of each triangle of both child images. If the difference between ratios of any two sides and difference between included angle in anyone out of the corresponding four triangles of both child images is less than specified threshold value, then it belongs to same child, otherwise not (Note that the threshold values have been chosen to separate in the case of ratio of sides and difference between included angles).

3. WORKING OF THE PROPOSED SYSTEM

The working of the proposed system has been explained as under:

3.1 RGB Image

The RGB image of child (later age) of size 256 × 256 has been taken as shown in Figure 2.

Figure 2: Original Image

3.2 Skin Color Image

The next step is to detect the skin part and non-skin part (hair, hand, window pane etc.) of the image so that the foreground image can be segregated from the background image to detect the face present in the image. The next step is to convert the RGB color space into YC_bC_r, here, Y is the luminance component and C_b and C_r are the blue-difference and red-difference chroma components respectively. The values of C_b and C_r have been set by conducting the experiments in MATLAB environment on the image dataset and are obtained from RGB color space. The value of C_b and C_r is given in equations (1) and (2) respectively.

$$C_b = 0.148 * R - 0.291 * G + 0.439 * B + 128 \quad (1)$$

$$C_r = 0.439 * R - 0.368 * G - 0.071 * B + 128 \quad (2)$$

The experiments have been conducted to find out the range of values of C_b and C_r. The value of C_b and C_r is calculated for every pixel in the skin image. If the value of C_b and C_r satisfies the equations (3) and (4) respectively, then the pixels are considered skin color, otherwise, they are non-skin color.

$$125 \leq C_b \leq 210 \quad (3)$$

$$125 \leq C_r \leq 205 \quad (4)$$

The output of given image is the binary image that contains 1's in the skin part and 0's in the non-skin part of the image. The detected skin pixels of the image may be discontinuous due to lighting effects that lead to miss skin pixels or due to the presence of non-skin face features like the eyes and eyebrows etc. To make the process continuous, the white isolated pixels are removed which have lower value than the specified threshold. The resultant skin image has been shown in Figure 3.

Figure 3: Skin Image

3.3 Face Image

The skin color segmentation generates a binary mask with the same size of the image. However, some non-skin pixels may appear similar to skin pixels (e.g. clothes, wall etc.) which can be easily removed by using morphological operations [24]. The small holes can be filled by using region filling operation and boundary extraction and the final face output image is shown in Figure 4.

Figure 4: Face Image

The next step is to calculate the bounding boxes of interest for mouth, nose and eyes. These boxes can be generated with the help of face geometry performed by Viola-Jones algorithm [25]. The 5×4 matrix of bounding boxes of face, mouth, right eye, left eye and nose has been calculated and has been shown in the first, second, third, fourth and fifth row of the matrix (equation (5)) respectively.

$$\begin{bmatrix} 172 & 173 & 172 & 173 \\ 69 & 180 & 69 & 43 \\ 129 & 128 & 52 & 43 \\ 38 & 125 & 57 & 36 \\ 77 & 159 & 60 & 33 \end{bmatrix} \quad (5)$$

3.4 Mouth Extraction

Before carrying out mouth extraction process, the mouth itself has to be located within the face area. The mouth templates are used to determine possible mouth locations and thereafter, the possible regions are analyzed with the anthropometric location of the mouth to mark the position of a mouth region [26]. The extraction of mouth has been shown in Figure 5.

Figure 5: Mouth

The co-ordinates of center of mouth are located as shown in equation (6).

$$(\mathrm{mm}_1, \mathrm{mm}_2) = (39, 25) \quad (6)$$

3.5 Nose Extraction

The nose is a point in the face area with the highest symmetry and high luminance values. The nostrils of nose are two dark regions surrounded by the skin which is lighter in color and is located by the connectivity of components of the binary image of face. The midpoint of two nostrils of nose image is relatively stable and can be used for the face recognition. After getting the accurate position of the midpoint of two nostrils, the region of nose area can be easily defined as shown in Figure 6 (a). The right and left nostril are obtained from the nose image by calculating the position of left corner, right corner and mid-point of the nose image as shown in Figures 6(b) and 6(c) respectively.

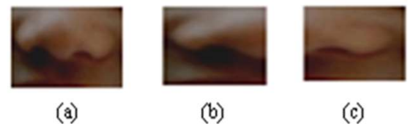

Figure 6: (a) Nose, (b) Right Nostril, (c) Left Nostril

The co-ordinates of centers of right and left nostrils are located as shown in equations (7) and (8) respectively.

$$(\mathrm{rrn}_1, \mathrm{rrn}_2) = (22, 19) \quad (7)$$

$$(\mathrm{lln}_1, \mathrm{lln}_2) = (24, 47) \quad (8)$$

3.6 Eye Extraction

The iris of the eye is a circular dark region and it can be easily identified. The position of the pupil and the iris radius is estimated with binary eye images. The image is eroded to increase the separation between the connected regions. The connected component is the measurement of distance between two binary pixels of the image. The height and the width of the biggest connected component and its center coordinates of eye image are to be calculated. For right eye, the inner eye corner is the left most point of the contour and outer eye corner is the rightmost point of the contour. For left eye, rightmost point over the contour becomes the inner corner and leftmost point becomes the outer corner. Both right and left eye have been shown in Figures 7 (a) and 7 (b) respectively.

Figure 7: (a) Right Eye, (b) Left Eye

The co-ordinates of center of right and left eye are located as shown in equations (9) and (10) respectively.

$$(\mathrm{rre}_1, \mathrm{rre}_2) = (45, 30) \quad (9)$$

$$(\mathrm{lle}_1, \mathrm{lle}_2) = (9, 20) \qquad (10)$$

3.7 Feature Points Extraction

The next step is to calculate the feature points (mouth, right nostril, left nostril, right eye and left eye) of face image with the center co-ordinates of right nostril, left nostril, right eye and left eye images and bounding box of face image. The 5×4 matrix of bounding boxes of face, mouth, right eye, left eye and nose (as obtained in equation (5) in section 4.3) is again shown in equation (11).

$$\begin{bmatrix} \text{Face} \\ \text{Mouth} \\ \text{Left Eye} \\ \text{Right Eye} \\ \text{Nose} \end{bmatrix} = \begin{bmatrix} X(1,1) & X(1,2) & X(1,3) & X(1,4) \\ X(2,1) & X(2,2) & X(2,3) & X(2,4) \\ X(3,1) & X(3,2) & X(3,3) & X(3,4) \\ X(4,1) & X(4,2) & X(4,3) & X(4,4) \\ X(5,1) & X(5,2) & X(5,3) & X(5,4) \end{bmatrix} \qquad (11)$$

$$= \begin{bmatrix} 172 & 173 & 172 & 173 \\ 69 & 180 & 69 & 43 \\ 129 & 128 & 52 & 43 \\ 38 & 125 & 57 & 36 \\ 77 & 159 & 60 & 33 \end{bmatrix}$$

The feature points of mouth of face image are calculated from equation (11) and centre co-ordinates (39, 25) of mouth image (equation (6)) as shown in equation (12).

$$\begin{aligned} T1 &= X(2,1) + \mathrm{mm}_1 = 69 + 39 = 108 \\ T2 &= X(2,2) + \mathrm{mm}_2 = 180 + 25 = 205 \end{aligned} \qquad (12)$$

The feature points of right nostril of face image are calculated from equation (11) and centre co-ordinates (22, 19) of right nostril image (equation (7)) as shown in equation (13).

$$\begin{aligned} T3 &= X(5,1) + \mathrm{rrn}_2 = 77 + 19 = 96 \\ T4 &= X(5,2) + \mathrm{rrn}_1 = 159 + 22 = 181 \end{aligned} \qquad (13)$$

The feature points of left nostril of face image are calculated from equation (11) and centre co-ordinates (24, 47) of left nostril image (equation (8)) as shown in equation (14).

$$\begin{aligned} T5 &= X(5,1) + \mathrm{lln}_2 = 77 + 47 = 124 \\ T6 &= X(5,2) + \mathrm{lln}_1 = 159 + 24 = 183 \end{aligned} \qquad (14)$$

The feature points of right eye of face image are calculated from equation (11) and centre co-ordinates (45, 30) of right eye image (equation (9)) as shown in equation (15).

$$\begin{aligned} T7 &= X(3,1) + \mathrm{rre}_1 = 129 + 45 = 174 \\ T8 &= X(3,2) + \mathrm{rre}_2 = 128 + 30 = 158 \end{aligned} \qquad (15)$$

The feature points of left eye of face image are calculated from equation (11) and centre co-ordinates (9, 20) of left eye image (equation (10)) as shown in equation (16).

$$\begin{aligned} T9 &= X(4,1) + \mathrm{lle}_1 = 38 + 9 = 47 \\ T10 &= X(4,2) + \mathrm{lle}_2 = 125 + 20 = 145 \end{aligned} \qquad (16)$$

The feature points of face image calculated from equations (12), (13), (14), (15), and (16) are shown in Table 1.

Table 1: Feature points of face image

Mouth (M)		Right Nostril (N_1)		Left Nostril (N_2)		Right Eye (E_1)		Left Eye (E_2)	
T1	T2	T3	T4	T5	T6	T7	T8	T9	T10
108	205	96	181	124	183	174	158	47	145

The feature points of face are represented on the face diagram as shown in Figure 8.

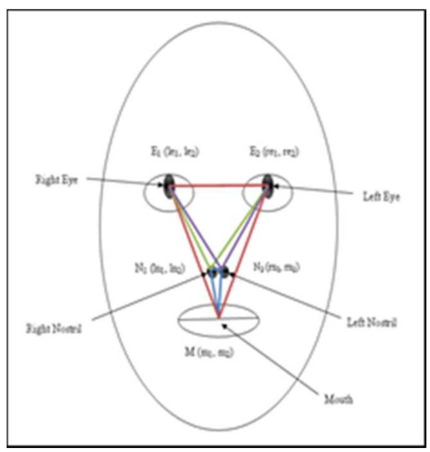

Figure 8: Feature Points of Face Image

The four different triangles have been obtained by combining these feature points of face image and the result of feature points of face image is shown in Figure 9.

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

Figure 9: Feature Extraction of Face Image

4 FORMATION OF SIDES AND ANGLES OF A TRIANGLE

The next proposed step is to obtain the sides and angles of four triangles.

4.1 Sides and Angles of a Triangle

The co-ordinates of four triangles (figure (8)) have been shown in equation (17).

$$\begin{aligned}
&\text{Triangle}_1\ (\Delta_1) \\
&= [\text{M}(108,205), \text{N}_1(96,181), \text{N}_2(124,183)] \\
&\text{Triangle}_2\ (\Delta_2) \\
&= [\text{M}(108,205), \text{E}_1(174,158), \text{E}_2(47,145)] \\
&\text{Triangle}_3\ (\Delta_3) \\
&= [\text{N}_1(96,181), \text{N}_2(124,183), \text{E}_1(174,158)] \\
&\text{Triangle}_4\ (\Delta_4) \\
&= [\text{N}_1(96,181), \text{N}_2(124,183), \text{E}_2(47,145)]
\end{aligned} \tag{17}$$

The sides and angles of these triangles have been calculated using the trigonometry formula and shown in Table 2.

Table 2: Sides and angles of triangles

Triangles	Sides (mm)	Angles (Degree)
Δ_1	28.07 26.83 27.20	62.59° 58.06° 59.35°
Δ_2	127.66 85.56 81.02	100.02° 41.30° 38.68°
Δ_3	127.66 85.87 55.90	127.17° 32.41° 20.42°
Δ_4	127.66 60.80 81.32	127.27° 22.27° 30.46°

5 PERFORMANCE EVALUATION OF THE PROPOSED SYSTEM

After calculating the sides and angles of the triangles formed on the face image, the next step is to evaluate the performance of proposed system by taking the images of children from FG-NET (Face and Gesture Recognition Research Network) aging database [27]. In FG-NET aging database, few images of various children from age 1 to age 18 are not available (e.g. ages of X child are 1, 3, 4, 7 and so on) due to which only available images of children over various ages have been taken.

5.1 Feature Points of Images

To elaborate the proposed system, the images of child-1 of various ages are shown in Figure 10.

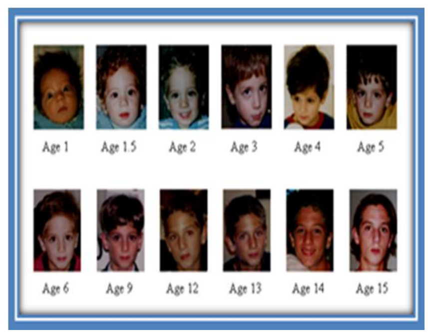

Figure 10: Images of Child-1 of Various Ages

Initially, the distinct feature points of face images of child-1 of various ages are located as shown in Table 3 (See Annexure 1). The images of child-2 of various ages are shown in Figure 11.

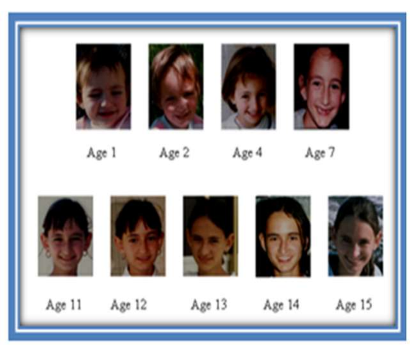

Figure 11: Images of Child-2 of Various Ages

The distinct feature points of face images of child-2 of various ages are shown in Table 4. (See Annexure 2).

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ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

5.2 Sides and Angles of Triangles of Face Image

The sides and angles of face images of child-1 and child-2 of various ages have been shown in Table 5 and Table 6 respectively (See Annexure 3 and Annexure 4).

5.3 Similarities between Two Triangles

The face images of child being compared at various ages to establish the similarities among them if the triangles formed on the face images are identical based on the specified threshold value. The similarities between two images of same child can be established by checking the difference between ratios of two sides as well as differences between included angles in anyone out of corresponding four triangles. In order to check the triangles formed on both the images under consideration are similar, the ratios of sides of all the corresponding four triangles of child-1 of age 1 with age 1.5, age 2, age 3 … etc. are calculated and shown in Table 7. Here, $Ratio_1$ represents the ratios of sides of Δ_1 of child-1 of age 1 with age 1.5, age 2, age 3 … etc. Similarly, others Ratio's correspond to other triangles have been shown (See Annexure 5). Similarly, Table 8 shows the ratios of sides of all the corresponding four triangles of image of child-2 of age 1 with age 2, age 3, age 4 … etc. (See Annexure 6). The difference between ratios of sides (denoted by R) of all the corresponding triangles of age 1 with age 1.5, age 2 … etc. are shown in Table 9. Similarly, the difference between angles (denoted by D) has been calculated. The values of R's and D's are used to find the similarity between two triangles of different images. The values of R's and D's of child-1 have been shown in Table 9. The values of R_1 of Δ_1 are obtained by calculating the difference between $Ratio_1$ of child-1 of age 1 with that of age 1.5, age 2, age 3 … etc. Similarly, the values of D_1 of Δ_1 are obtained by calculating the difference between angles of child-1 of age 1 with that of age 1.5, age 2, age 3 … etc. Here, $Ratio_1$ represents the ratios of sides of Δ_1 of images of a child. Similarly, the values of R's and D's of other triangles have been calculated. The values of R's and D's have been obtained from table 7 and table 5 respectively (See Annexure 7).

Similarly, the values of R's and D's of child-2 have been shown in Table 10. The values of R's and D's have been obtained from Table 8 and Table 6 respectively (See Annexure 8). The next step is to calculate the values of d_1 which are obtained from the values of R's in Table 9. It has been observed that the smallest values of R's (i.e. R_1, R_2, R_3 and R_4) in all the four triangles are obtained by taking the difference between the other two values of R's. The smallest value of R's in anyone out of the four triangles is represented by d_1. The values of d_1 indicate the similarity between the two sides of corresponding triangles of the images of child-1 over various ages. In ideal case, the value of d_1 is equal to 0; the two sides of the corresponding triangles are exactly equal. Therefore, the values of d_1 should be closer to zero for better results. The values of d_1 present in one of the four triangles of images of various ages have been shown in Figure 12.

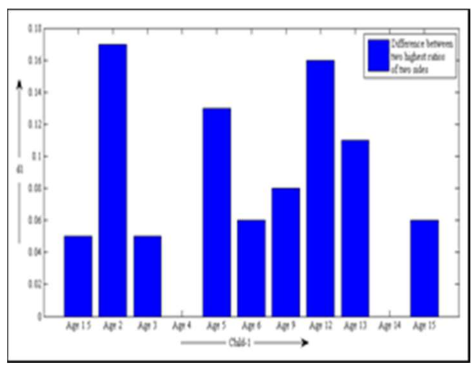


Figure 12: Difference Between the Two Highest Ratios of Two Sides of Anyone out of the Corresponding Four Triangles of Images of Child-1 of Age 1 with Age 1.5, Age 2, Age 3, … Age 16

The value of d_1 of child-1 image for age 1.5 is obtained from Δ_3 of Table 9. Similarly, other values of d_1 of child-1 image of ages 2, 3, 4, 5, 6, 9, 12, 13, 14 and 15 have been obtained from $\Delta_3, \Delta_3, \Delta_2, \Delta_2, \Delta_1, \Delta_4, \Delta_2, \Delta_3, \Delta_2$ and Δ_1 respectively. This clearly shows the similarity between two larger sides of triangles. Similarly, the values of d_2 are obtained from the values of D's (Table 9). The values of d_2 are calculated by taking the difference between angles of anyone out of the corresponding four triangles of two face images of child-1 of

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

various ages. In ideal case, the value of d_2 is 0; two angles of corresponding triangles are exactly equal. Therefore, the value of d_2 should be closer to zero for better results. It has been observed that the smallest values of D's (D_1, D_2, D_3 and D_4) in all of the four triangles are obtained by taking the difference between other two values of D's. The smallest value of D's in anyone out of the four triangles is represented by d_2 and same as shown in Figure 13.

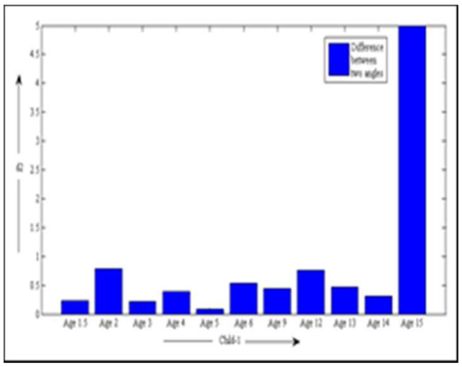


Figure 13: Difference between the Two Angles of Anyone out of the Corresponding Four Triangles of Images of Child-1 of Age 1 with Age 1.5, Age 2, Age 3, ... Age 16

The same triangles (as in the case of d_1) have been considered to take the values of d_2. The value of d_2 of child-1 image for age 1.5 is obtained from Δ_3 of Table 9. Similarly, other values of d_2 of child-1 image of ages 2, 3, 4, 5, 6, 9, 12, 13, 14 and 15 have been obtained from $\Delta_3, \Delta_3, \Delta_2, \Delta_2, \Delta_1, \Delta_4, \Delta_2, \Delta_3, \Delta_2$ and Δ_1 respectively. This clearly shows the similarity between two angles of two corresponding triangles. For better understanding of the proposed system, another case of child-2 of various ages has been taken. The values of d_1 and d_2 (in case of child-2) are shown in Figure 14 and Figure 15 respectively which have been obtained from Table 10.

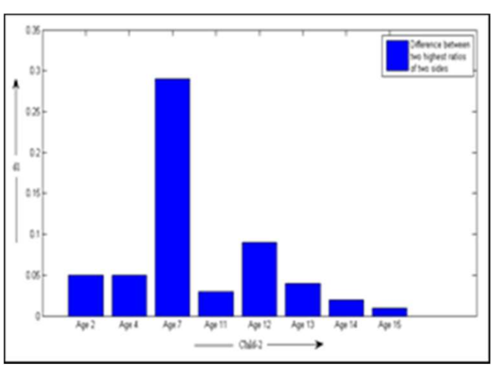


Figure 14: Difference between the Two Highest Ratios of Two Sides of anyone out of the Corresponding Four Triangles of Images of Child-2 of Age 1 with Age 2, Age 4, ... Age 15

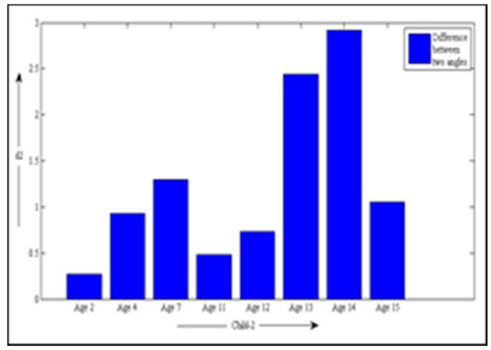


Figure 15: Difference between Angles of anyone out of the Corresponding Four Triangles of Images of Child-2 of Age 1 with Age 2, Age 4, ... Age 15

The values of d_1 and d_2 (Figures (14) and (15)) of child-2 image for ages 2, 4, 7, 11, 12, 13, 14 and 15 have been obtained from Δ_4, Δ_4, Δ_3, Δ_2, Δ_2, Δ_3, Δ_3 and Δ_2 respectively. The values of d_1 are used to calculate the threshold value ($Threshold_1$) of the triangles in the image. The values of d_2 are used to calculate the threshold value ($Threshold_2$) of the triangles in the image. The purpose of $Threshold_1$ and $Threshold_2$ are used to determine the identification and recognition of a child image of various ages. From the above Figures (12) and (13) as well as from the Figures (14) and (15), it has been concluded that if the difference between ratios of sides is less than or equal to 0.17 and difference between included angles is less than or equal to 1.30˚ in anyone of the corresponding four triangles of child image, then the images belong to same child, otherwise not. In other words, the threshold values have been chosen 0.17 and 1.30˚ in case of difference between ratios of sides and difference between angles respectively. i.e.

$$\text{Threhold}_1 \leq 0.17 \text{ and Threhold}_2 \leq 1.30^{\circ} \quad (18)$$

If the face images of two children satisfy equation (18), then the images belong to same child, otherwise not. The threshold values ($Threshold_1$ and $Threshold_2$) are used to determine whether two images belong to same child or not. The study has been carried out on 15 images of each 80 children (total 1200 images) from FG-NET aging database. It has been concluded that the similarity of same children over various ages of

Journal of Theoretical and Applied Information Technology
15th April 2018. Vol.96. No 7
© 2005 – ongoing JATIT & LLS

ISSN: 1992-8645 www.jatit.org E-ISSN: 1817-3195

FG-NET aging database has been found 78.95%. Similarly, ratios of sides of corresponding triangles of child-1 image with that of child-2 (different children) over various ages have been shown in Table 11. The various ages of child-1 have been compared with that of child-2. In these two datasets of different children, almost same age group has been taken (See Annexure 9). The values of R's and D's of different children of various ages have been calculated as shown in Table 12 (See Annexure 10). The values of d_1 have been shown in Figure 16 which is obtained from Table 12.

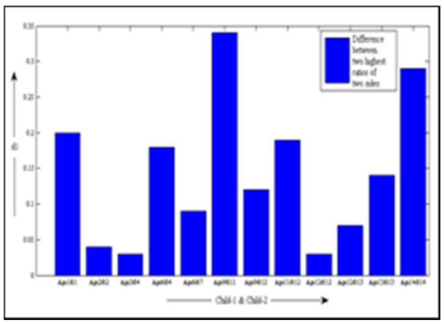
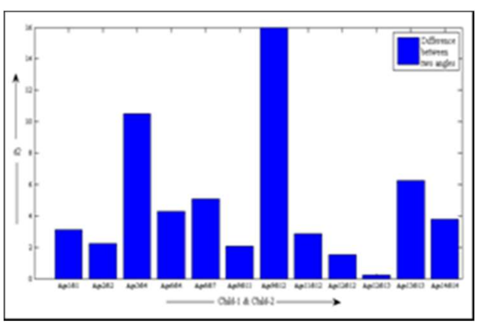


Figure 16: Comparison between the Ratios of Two Sides of Corresponding Four Triangles of Child-1 with that of Child-2 over Various Ages

The values of d_2 have been shown in Figure 17 which is obtained from Table 12.



Fi ... en of Child-1 with that of Child-2 over Various Ages

The values of d1 and d2 (Figure 16 and Figure 17) of (child-1 & child-2) images for various ages (1&1, 2&2, 3&4, 6&4, 6&7, 9&11, 11&12, 12&12, 12&13, 13&13 and 14&14) have been obtained from Δ_3, $\Delta_1, \Delta_3, \Delta_1, \Delta_2, \Delta_1, \Delta_2, \Delta_3, \Delta_2, \Delta_3, \Delta_3$ and Δ_2 respectively. The same threshold values (i.e. 0.17 for difference between ratios of sides and 1.30˚ for difference between included angles as in case of same child) have been taken to verify the similarity between images of different children of various ages from the image dataset. It has been concluded that the similarity between two images of different children is found 8.33%. It has been further concluded that the accuracy of the proposed system is 83.87% in both cases (same child and different children).

6 COMPARATIVE STUDY OF PROPOSED SYSTEM WITH EXISTING SYSTEM

Face recognition accuracy is limited by the large intra-class variations caused by factors such as pose, lighting, expression and age. The researcher performed the age progression on the face image of different children of various ages. The face images of 10 different children (age 1) are matched with corresponding face image of same children of ages 2, 3, 4, 5, 7, 8, 9, 10, 11 and 12 which are shown in Table 13. 'Y' stands for match child and 'N' stands for mismatch child (See Annexure 11). The 10 images of each 10 different children over various ages have been taken to compare the accuracy of proposed system with the existing system proposed by Yu Liang et al. It has been concluded that the accuracy of the proposed and existing system is found 81% and 78% respectively. It has been analyzed from various studies that the identification accuracies of different approaches could not be directly compared due to the differences in the databases used, number of subjects used and the underlying face recognition methods used for evaluation. Usually, the larger the number of subjects and the larger the database variations in terms of age, pose, lighting and expression, the smaller the recognition performance improvement due to the aging process.

7 CONCLUSION AND SUGGESTIONS FOR FUTURE WORK

In this research work, a new technology using feature-based method has been presented which is useful to identifying and recognizing the missing children. A face recognition algorithm using feature-based method has been applied on the given image to locate the position of feature points (mouth, right nostril, left nostril, right eye and left eye) of the face image of missing child. After locating the feature points of the face image, different triangles have been formed by taking various combinations of these feature points of face image of child of early and later age. The sides and angles of four triangles formed by various combinations of feature points have been calculated by using the trigonometry formulas. The difference between ratios of sides as well as difference between angles of the corresponding four triangles of two face images has been calculated. In order to decide if the given two images belonging to same child or not, the threshold values have been set for the difference between ratios of sides and difference between included angles of corresponding triangles of face image. If the difference between ratios of sides is less than or equal to 0.17 and difference between included angle is less than or equal to 1.30˚ in anyone of the corresponding four triangles of child image, then it belongs to same child, otherwise not. The study has been carried out on 15 images of each 80 children (total 1200 images) from FG-NET aging database. It has been concluded that the similarities among the same children over various ages are obtained 78.95%. The same dataset has taken to calculate the similarities among different children of various ages and similarities are found 8.33% in case of different children. The accuracy of the proposed system is obtained 83.87% in both cases. The proposed system is further compared with the existing system and the accuracy of proposed and existing system is obtained 81% and 78% respectively. In short, the proposed system is found far better to identify and recognize the missing children.

For future work, the image of the missing child can be matched against the missing child database which may have more than 50000 images. The proposed system can be modified for different face angles and pose illumination variations. The proposed method can be further modified by using multiple 3D face models. The computation of age from 1 year to 80 years in the presence of eye patches, dark glasses, other occlusions and shadowing effects needs to be explored. A possible future development of this work is the generalization to images with unconstrained background and with partial occlusion like beard and spectacles.

ACKNOWLEDGEMENT

The first author (R.K.) is grateful to the Management, the Dean, the HOD and all staff members of Faculty of Graduate Studies and Research, Botho University, Gaborone, Botswana for their valuable support. The work of the second author (A.M.) was supported and encouraged by the Management, the Director, the Dean and the Principal of Nehru Institute of Technology, Coimbatore, India.

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ANNEXURE 1

Table 3: Feature points of face image of child-1 for various ages

SN	Image	Mouth M		Right Nostril N_1		Left Nostril N_2		Right Eye E_1		Left Eye E_2	
1	Age 1	72	146	64	128	84	127	111	111	35	110
2	Age 1.5	67	156	81	155	98	153	144	137	40	119
3	Age 2	46	82	40	75	55	71	72	63	31	62
4	Age 3	124	199	84	182	120	157	153	136	51	129
5	Age 4	112	216	103	187	133	173	164	162	57	144
6	Age 5	70	149	52	128	87	127	109	116	60	114
7	Age 6	66	138	62	122	77	124	93	113	59	105
8	Age 9	68	200	91	147	104	150	161	123	61	128
9	Age 12	56	111	45	97	62	95	81	91	42	79
10	Age 13	67	109	49	96	66	102	93	92	33	83
11	Age 14	107	211	94	180	134	182	172	154	49	134
12	Age 15	59	119	55	105	69	103	80	80	50	86

ANNEXURE 2

Table 4: Feature points of face image of child-2 for various ages

SN	Image	Mouth M		Right Nostril N_1		Left Nostril N_2		Right Eye E_1		Left Eye E_2	
1	Age 1	67	156	81	155	98	153	123	125	41	119
2	Age 2	97	202	90	166	103	153	123	152	79	139
3	Age 4	64	134	58	120	79	121	93	112	42	91
4	Age 7	84	193	89	180	112	181	142	152	78	156
5	Age 11	122	236	103	211	133	210	194	191	97	151
6	Age 12	93	163	70	129	93	130	116	105	43	114
7	Age 13	110	201	97	177	125	177	146	164	64	137
8	Age 14	86	196	75	180	114	171	135	135	29	146
9	Age 15	52	96	45	84	57	83	86	81	38	74

ANNEXURE 3

Table 5: Sides and angles of triangles for face image of child-1 of various ages

SN	Image	Δ_1 Sides	Δ_1 Angles	Δ_2 Sides	Δ_2 Angles	Δ_3 Sides	Δ_3 Angles	Δ_4 Sides	Δ_4 Angles
1	Age 1	20.03 19.70 22.47	56.24° 54.86° 68.90°	76.01 52.40 51.62	93.88° 43.46° 42.66°	76.01 31.39 51.87	130.22° 18.38° 31.40°	76.01 49.98 34.13	128.29° 31.07° 20.64°
2	Age 1.5	17.12 14.04 31.15	1.44° 1.18° 177.38°	105.55 79.31 45.80	112.26° 44.06° 23.68°	105.55 48.70 67.23	130.44° 20.56° 29.00°	105.55 65.52 54.56	122.77° 31.47° 25.76°
3	Age 2	15.52 9.22 14.21	79.89° 35.78° 64.33°	41.01 32.20 25	90.71° 51.73° 37.56°	41.01 18.79 25.63	134.24° 19.16° 26.60°	41.01 34.18 15.81	104.14° 53.91° 21.95°
4	Age 3	43.83 43.46 42.19	61.53° 60.66° 57.80°	102.24 69.35 101.14	70.72° 39.87° 69.21°	102.24 39.12 74.47	125.44° 18.16° 36.40°	102.24 82.93 62.43	88.22° 54.17° 37.62°
5	Age 4	33.11 30.37 47.85	43.27° 38.95° 97.78°	108.50 74.97 90.60	81.30° 43.08° 55.63°	108.50 32.89 81.35	139.58° 11.34° 29.09°	108.50 65.92 62.97	114.65° 33.52° 31.83°
6	Age 5	28.02 23.71 27.80	65.34° 50.26° 64.40°	49.04 51.09 36.40	65.71° 71.72° 42.57°	49.04 24.60 29.97	127.73° 23.37° 28.90°	49.04 51.42 14.04	72.42° 91.75° 15.83°

7	Age 6	15.13 16.49 17.81	52.19° 59.44° 68.37°	34.93 36.80 33.73	59.18° 64.78° 56.04°	34.93 19.42 26.17	98.94° 33.31° 47.75°	34.93 32.28 17.26	83.82° 66.75° 29.43°
8	Age 9	13.34 57.78 61.61	12.30° 67.24° 100.46°	100.13 120.74 72.34	55.93° 87.31° 36.76°	100.13 63.07 48.30	127.56° 29.96° 22.48°	100.13 74 35.51	128.73° 35.21° 16.06°
9	Age 12	17.12 17.81 17.09	58.71° 62.73° 58.55°	40.80 32.20 34.93	74.97° 49.27° 55.76°	40.80 19.42 25.61	129.45° 21.56° 28.99°	40.80 36.50 18.25	90° 63.44° 26.56°
10	Age 13	20.88 24.70 7.07	50.11° 114.83° 15.06°	60.67 31.06 42.80	109.42° 28.88° 41.70°	60.67 28.79 38.08	129.75° 21.40° 28.85°	60.67 47.17 18.39	130.14° 36.46° 13.40°
11	Age 14	40.05 33.62 39.62	65.71° 49.91° 64.38°	124.62 86.45 96.40	85.74° 43.78° 50.48°	124.62 47.20 97.62	114.16° 20.22° 45.62°	124.02 82.22 64.35	115.94° 36.39° 27.67°
12	Age 15	14.14 14.56 18.87	47.95° 49.87° 82.19°	30.59 44.30 34.21	43.56° 86.06° 50.38°	30.59 25.50 25.50	73.74° 53.13° 53.13°	30.59 35.36 19.65	59.74° 86.56° 33.69°

ANNEXURE 4

Table 6: Sides and angles of triangles for face image of child-2 of various ages

SN	Image	Δ_1		Δ_2		Δ_3		Δ_4	
		Sides	Angles	Sides	Angles	Sides	Angles	Sides	Angles
1	Age 1	17.12 14.04 31.15	1.44° 1.18° 177.38°	82.22 64.01 45.22	96.13° 50.72° 33.15°	82.22 37.54 66.37	100.95° 26.63° 52.43°	82.22 51.61 53.82	102.48° 37.80° 39.72°
2	Age 2	18.39 36.67 49.37	17.99° 38.01° 124°	45.88 56.36 65.52	43.42° 57.60° 78.98°	45.88 20.03 27.79	146.88° 13.80° 19.32°	45.88 35.85 29.16	89.18° 51.37° 39.45°
3	Age 4	21.02 15.23 19.85	72.28° 43.64° 64.08°	55.15 36.40 48.30	79.91° 40.52° 59.57°	55.15 16.64 47.63	108.23° 16.66° 55.12°	55.15 35.90 33.12	106.01° 38.73° 35.26°
4	Age 7	23.02 13.93 30.46	45.76° 25.76° 108.55°	64.13 71.03 37.48	63.96° 84.36° 31.68°	64.13 41.73 42.20	99.64° 39.90° 40.45°	64.13 59.94 26.40	86.78° 68.95° 24.27°
5	Age 11	30.02 31.40 28.23	60.17° 65.16° 54.67°	104.92 84.91 88.60	74.38° 51.20° 54.42°	104.92 63.89 69.11	104.09° 36.20° 39.71°	104.92 93.17 60.30	83.32° 61.88° 34.80°
6	Age 12	23.02 4.04 33	34.08° 92.49° 53.43°	73.55 62.39 70.01	67.21° 51.45° 61.34°	73.55 33.97 52.50	114.87° 24.77° 40.36°	73.55 51.89 30.89	123.39° 36.08° 20.53°
7	Age 13	28 27.30 28.30	60.45° 56° 61.55°	86.33 51.62 78.81	79.92° 36.07° 64.01°	86.33 24.70 72.95	114.99° 15.03° 49.98°	86.33 50.70 51.86	114.66° 32.25° 33.09°
8	Age 14	40.03 19.42 37.54	82.75° 28.77° 68.48°	106.57 78.24 75.82	87.52° 47.18° 45.30°	106.57 41.68 88.60	103.87° 22.31° 53.82°	106.57 75 57.20	106.66° 42.40° 30.94°
9	Age 15	12.04 13.89 13.93	51.29° 64.20° 64.51°	48.51 37.16 26.08	98.67° 49.23° 32.10°	48.51 29.07 21.02	150.71° 17.05° 12.24°	48.51 41.11 12.21	120.81° 46.71° 12.48°

ANNEXURE 5

Table 7: Ratios of sides of corresponding four triangles of images of child-1 of age 1 with age 1.5, age 2, age 3 … age 13

SN	Image	Δ_1	Δ_2	Δ_3	Δ_4
		$Ratio_1$	$Ratio_2$	$Ratio_3$	$Ratio_4$
1	Age 1.5	1.17 1.40 0.72	0.72 0.66 1.13	0.72 0.64 0.77	0.72 0.76 0.63

2	Age 2	1.29 2.14 1.58	1.85 1.63 2.07	1.85 1.67 2.02	1.85 1.46 2.16
3	Age 3	0.46 0.45 0.53	0.74 0.76 0.51	0.74 0.80 0.70	0.74 0.60 0.55
4	Age 4	0.61 0.65 0.47	0.70 0.70 0.57	0.70 0.95 0.64	0.70 0.76 0.54
5	Age 5	0.72 0.83 0.81	1.55 1.03 1.42	1.55 1.28 1.73	1.55 0.97 2.43
6	Age 6	1.32 1.19 1.26	2.18 1.42 1.53	2.18 1.62 1.98	2.18 1.55 1.98
7	Age 9	1.50 0.34 0.37	0.76 0.43 0.71	0.76 0.50 1.07	0.76 0.68 0.96
8	Age 12	1.17 1.11 1.32	1.86 1.64 1.48	1.86 1.62 2.03	1.86 1.37 1.87
9	Age 13	0.96 0.80 3.18	1.25 1.69 1.21	1.25 1.09 1.36	1.25 1.06 1.86
10	Age 14	0.05 0.59 0.58	0.61 0.61 0.54	0.61 0.67 0.53	0.61 0.61 0.53
11	Age 15	1.42 1.35 1.19	2.48 1.18 1.51	2.48 1.23 2.03	2.48 1.41 1.74

ANNEXURE 6

Table 8: Ratios of sides of corresponding four triangles of images of child-2 of age 1 with age 2, age 4, age 7, ... age 15

SN	Image	Δ_1	Δ_2	Δ_3	Δ_4
		$Ratio_1$	$Ratio_2$	$Ratio_3$	$Ratio_4$
1	Age 2	0.93 0.38 0.63	1.79 1.14 0.69	1.79 1.88 2.39	1.79 1.44 1.85
2	Age 4	0.81 0.92 1.57	1.49 1.76 0.94	1.49 2.26 1.39	1.49 1.44 1.63
3	Age 7	0.74 1.01 1.02	1.28 0.90 1.21	1.28 0.90 1.57	1.28 0.86 2.04
4	Age 11	0.57 0.45 1.10	0.78 0.75 0.51	0.78 0.59 0.96	0.78 0.55 0.89
5	Age 12	0.74 0.34 0.94	1.12 1.03 0.65	1.12 1.11 1.26	1.12 1.00 1.74
6	Age 13	0.61 0.51 1.10	0.95 1.24 0.57	0.95 1.52 0.91	0.95 1.02 1.04
7	Age 14	0.43 0.72 0.00	0.77 0.82 0.60	0.77 0.90 0.75	0.77 0.69 0.94
8	Age 15	1.42 1.01 2.24	1.70 1.72 1.73	1.70 1.29 3.16	1.70 1.26 4.41

ANNEXURE 7

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Table 9: Difference between ratios of sides as well as difference between angles of all the corresponding four triangles of images of child-1 of age 1 with age 1.5, age 2, … age 16

SN	Image	Δ_1		Δ_2		Δ_3		Δ_4	
		R_1	D_1	R_2	D_2	R_3	D_3	R_4	D_4
1	Age 1.5	0.23	54.80°	0.06	18.38°	0.08	0.23°	0.04	5.52°
		0.68	53.68°	0.13	0.60°	0.13	2.18°	0.14	0.39°
		0.45	108.48°	0.05	18.98°	0.05	2.41°	0.10	5.13°
2	Age 2	0.85	23.65°	0.23	3.17°	0.18	4.03°	0.39	24.15°
		0.56	19.08°	0.44	8.27°	0.35	0.78°	0.70	22.83°
		0.29	4.57°	0.21	5.10°	0.17	4.81°	0.31	1.31°
3	Age 3	0.00	5.30°	0.01	22.96°	0.06	4.77°	0.14	40.07°
		0.08	5.80°	0.25	3.59°	0.11	0.22°	0.06	23.09°
		0.08	11.10°	0.23	26.55°	0.05	5.00°	0.20	16.98°
4	Age 4	0.04	12.97°	0.00	12.58°	0.25	9.36°	0.06	13.64°
		0.18	15.91°	0.13	0.39°	0.32	7.04°	0.22	2.45°
		0.14	28.88°	0.13	12.97°	0.06	2.32°	0.16	11.20°
5	Age 5	0.12	9.10°	0.52	28.17°	0.27	2.49°	0.58	55.87°
		0.02	4.60°	0.39	28.26°	0.45	4.99°	1.46	60.67°
		0.09	4.50°	0.13	0.09°	0.18	2.50°	0.88	4.81°
6	Age 6	0.13	4.05°	0.75	34.70°	0.56	31.27°	0.63	44.47°
		0.07	4.58°	0.11	21.32°	0.37	14.93°	0.43	35.68°
		0.06	0.53°	0.65	13.38°	0.19	16.35°	0.20	8.79°
7	Age 9	1.16	43.94°	0.33	37.95°	0.26	2.66°	0.08	0.44°
		0.02	12.38°	0.28	43.85°	0.58	11.58°	0.29	4.14°
		1.14	31.57°	0.05	5.90°	0.32	8.92°	0.20	4.58°
8	Age 12	0.06	2.48°	0.23	18.91°	0.25	0.76°	0.49	38.29°
		0.21	7.87°	0.16	5.81°	0.41	3.18°	0.50	32.36°
		10.14	10.35°	0.39	13.10°	0.16	2.41°	0.01	5.93°
9	Age 13	0.16	6.12°	0.43	15.54°	0.16	0.47°	0.19	1.85°
		2.38	59.97°	0.48	14.59°	0.27	3.02°	0.80	5.40°
		2.22	53.84°	0.95	0.95°	0.11	2.55°	0.60	7.24°
10	Age 14	0.09	9.47°	0.00	8.14°	0.06	16.05°	0.00	12.35°
		0.02	4.95°	0.07	0.31°	0.13	1.84°	0.07	5.32°
		0.07	4.51°	0.07	7.82°	0.08	14.22°	0.07	7.03°
11	Age 15	0.06	8.29°	1.30	50.32°	1.25	56.48°	1.07	68.54°
		0.16	5.00°	0.33	42.59°	0.80	34.75°	0.32	55.49°
		0.23	13.29°	0.98	7.73°	0.45	21.73°	0.75	13.05°

ANNEXURE 8

Table 10: Difference between ratios of sides as well as difference between angles of all the corresponding four triangles of images of child-2 of age 1 with age 2, age 4, … age 15

SN	Image	Δ_1		Δ_2		Δ_3		Δ_4	
		R_1	D_1	R_2	D_2	R_3	D_3	R_4	D_4
1	Age 2	0.55	16.54°	0.66	52.71°	0.08	45.94°	0.35	13.30°
		0.25	36.84°	0.45	6.88°	0.51	12.83°	0.41	13.57°
		0.30	53.38°	1.10	45.83°	0.60	33.10°	0.05	0.27°
2	Age 4	0.11	70.84°	0.27	16.22°	0.77	7.29°	0.05	3.54°
		0.65	42.46°	0.82	10.20°	0.86	9.98°	0.19	0.93°
		0.76	113.30°	0.56	26.41°	0.10	2.69°	0.13	4.47°
3	Age 7	0.26	44.32°	0.38	32.17°	0.38	1.30°	0.42	15.70°
		0.01	24.51°	0.31	33.65°	0.67	13.27°	1.18	31.15°
		0.28	68.83°	0.07	1.47°	0.29	11.97°	0.77	15.45°
4	Age 11	0.12	58.73°	0.03	21.74°	0.19	3.15°	0.23	19.16°
		0.66	63.98°	0.24	0.48°	0.37	9.57°	0.34	24.08°
		0.53	122.70°	0.27	21.26°	0.18	12.71°	0.11	4.92°
5	Age 12	0.40	32.64°	0.09	28.92°	0.01	13.93°	0.12	20.92°
		0.60	91.31°	0.38	0.73°	0.16	1.86°	0.75	1.72°
		0.20	123.94°	0.47	28.19°	0.15	12.07°	0.63	19.20°
6	Age 13	0.10	59.01°	0.29	16.21°	0.57	14.04°	0.07	12.19°
		0.59	56.81°	0.67	14.65°	0.61	11.60°	0.02	5.55°
		0.49	115.82°	0.38	30.86°	0.04	2.44°	0.09	6.64°
7	Age 14	0.30	81.31°	0.04	8.61°	0.13	2.92°	0.08	4.19°
		0.11	27.58°	0.22	3.53°	0.15	4.31°	0.25	4.59°

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		0.40	108.80°	0.18	12.15°	0.02	1.39°	0.17	8.77°
8	Age 15	0.41 1.22 0.81	49.85° 63.02° 112.87°	0.02 0.01 0.03	2.54° 1.49° 1.05°	0.40 1.86 1.46	49.76° 9.58° 40.18°	0.44 3.15 2.71	18.33° 8.90° 27.24°

ANNEXURE 9

Table 11: Ratios of sides of corresponding four triangles of child-1 image with that of child-2 over various ages

SN	Child 1	Child 2	Δ_1	Δ_2	Δ_3	Δ_4
			$Ratio_1$	$Ratio_2$	$Ratio_3$	$Ratio_4$
1	Age 1	Age 1	0.86 0.93 1.33	1.25 1.09 1.40	1.25 1.05 1.82	1.25 0.95 2.82
2	Age 2	Age 2	0.84 0.25 0.29	0.48 0.33 0.45	0.48 0.26 1.03	0.48 0.42 0.70
3	Age 3	Age 4	2.09 2.85 2.13	1.51 1.21 2.25	1.51 0.95 1.54	1.51 1.60 1.95
4	Age 6	Age 4	0.72 1.08 0.90	0.81 1.44 0.65	0.81 2.00 0.52	0.81 1.29 0.46
5	Age 6	Age 7	0.66 1.18 0.59	0.72 0.80 0.89	0.72 0.93 0.60	0.72 0.84 0.63
6	Age 9	Age 11	0.45 1.84 2.18	1.51 1.14 0.75	1.51 0.87 0.67	1.51 0.83 0.55
7	Age 9	Age 12	0.58 1.41 1.87	1.78 1.65 0.95	1.78 1.82 0.92	1.78 1.61 1.11
8	Age 11	Age 12	0.43 0.68 0.92	0.60 1.24 0.57	0.60 1.03 0.40	0.60 0.79 0.43
9	Age 12	Age 12	0.74 0.43 0.52	0.58 0.50 0.47	0.58 0.50 0.47	0.58 0.70 0.51
10	Age 12	Age 13	0.61 0.65 0.60	0.31 0.32 0.44	0.31 0.21 0.37	0.31 0.33 0.33
11	Age 13	Age 13	0.75 0.91 0.25	0.49 0.24 0.64	0.49 0.27 0.63	0.49 0.38 0.50
12	Age 14	Age 14	1.00 1.73 1.06	1.51 1.92 1.21	1.51 4.59 1.22	1.51 1.72 1.05

ANNEXURE 10

Table 12: Difference between ratios of sides as well as difference between angles of all the corresponding four triangles of face images of child-1 with child-1 over various ages

Sr. No.	Child 1	Child 2	Δ_1		Δ_2		Δ_3		Δ_4	
			R_1	D_1	R_2	D_2	R_3	D_3	R_4	D_4
1	Age 1	Age 1	0.07 0.40 0.47	56.35° 38.62° 94.97°	0.15 0.31 0.16	8.18° 12.14° 3.96°	0.20 0.77 0.58	31.57° 3.10° 28.46°	0.30 1.87 1.57	17.54° 7.68° 25.22°
2	Age 2	Age 2	0.59 0.04 0.56	61.91° 2.24° 59.67°	0.15 0.12 0.04	21.57° 25.11° 3.53°	0.22 0.77 0.55	14.92° 10.32° 25.24°	0.07 0.28 0.22	4.98° 15.49° 10.51°

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3	Age 3	Age 4	0.77 0.73 0.04	10.75° 17.02° 6.27°	0.29 1.04 0.75	27.83° 11.12° 38.95°	0.56 0.59 0.03	34.60° 10.51° 24.09°	0.10 0.35 0.45	27.04° 11.19° 15.85°
4	Age 6	Age 4	0.36 0.19 0.18	20.09° 15.80° 4.29°	0.63 0.80 0.16	23.00° 49.02° 26.02°	1.19 1.49 0.30	14.85° 39.46° 24.61°	0.48 0.83 0.35	33.14° 52.64° 19.50°
5	Age 6	Age 7	0.53 0.60 0.07	6.43° 33.75° 40.18°	0.08 0.09 0.17	9.19° 5.21° 3.98°	0.21 0.34 0.13	9.55° 17.78° 8.23°	0.11 0.20 0.09	19.73° 24.80° 5.07°
6	Age 9	Age 11	1.40 0.34 1.74	47.87° 2.08° 45.79°	0.37 0.39 0.76	25.16° 4.77° 29.94°	0.64 0.20 0.84	100.89° 42.45° 58.44°	0.68 0.27 0.96	106.10° 64.39° 41.71°
7	Age 9	Age 12	0.83 0.46 1.29	21.78° 25.25° 47.03°	0.12 0.70 0.82	18.94° 15.97° 34.90°	0.05 0.90 0.85	77.06° 20.72° 56.35°	0.17 0.50 0.66	58.59° 32.85° 25.74°
8	Age 11	Age 12	0.25 0.24 0.49	14.96° 25.69° 40.65°	0.64 0.68 0.03	29.06° 54.37° 25.31°	0.44 0.63 0.19	29.31° 32.19° 2.87°	0.19 0.36 0.16	31.75° 37.01° 5.27°
9	Age 12	Age 12	0.31 0.08 0.23	24.64° 29.76° 5.12°	0.08 0.03 0.11	12.52° 1.51° 11.01°	0.09 0.02 0.07	22.04° 6.31° 15.73°	0.13 0.19 0.07	12.54° 15.68° 3.14°
10	Age 12	Age 13	0.04 0.05 0.01	1.74° 4.74° 3.01°	0.02 0.11 0.13	18.30° 2.24° 20.53°	0.09 0.16 0.07	0.23° 10.36° 10.59°	0.03 0.01 0.02	12.05° 8.90° 3.15°
11	Age 13	Age 13	0.16 0.66 0.50	10.34° 56.84° 46.50°	0.25 0.40 0.15	10.79° 30.05° 19.27°	0.23 0.36 0.14	6.25° 16.07° 9.82°	0.11 0.12 0.01	36.41° 26.84° 9.57°
12	Age 14	Age 14	0.73 0.68 0.06	17.04° 21.14° 4.10°	0.41 0.70 0.29	3.79° 15.08° 18.87°	3.08 3.36 0.28	4.45° 19.05° 23.50°	0.21 0.67 0.46	11.58° 5.59° 17.16°

ANNEXURE 11

Table 13: Matches of 10 different children (age 1) with corresponding same children of various ages (existing system)

	Child1 (Age1)	Child2 (Age1)	Child3 (Age1)	Child4 (Age1)	Child5 (Age1)	Child6 (Age1)	Child7 (Age1)	Child8 (Age1)	Child9 (Age1)	Child10 (Age1)
Age 2	Y	N	Y	Y	N	Y	Y	Y	N	Y
Age 3	Y	Y	N	Y	Y	N	Y	Y	Y	N
Age 4	Y	N	Y	N	Y	Y	N	Y	Y	Y
Age 5	Y	Y	Y	Y	N	Y	Y	N	Y	Y
Age 7	N	Y	Y	Y	Y	Y	Y	Y	N	Y
Age 8	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y
Age 9	Y	Y	N	Y	Y	Y	Y	N	Y	Y
Age 10	Y	Y	Y	N	Y	N	Y	Y	Y	Y
Age 11	Y	Y	Y	Y	Y	Y	N	Y	Y	N
Age 12	N	Y	Y	N	Y	Y	Y	N	Y	Y
Accuracy (Existing System)	80%	80%	80%	70%	80%	80%	80%	70%	80%	80%
Accuracy (Proposed System)	80%	90%	80%	90%	80%	70%	90%	80%	80%	70%