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Facial Index Based 2D Facial Composite Process for Forensic Investigation in Sri Lanka

P. B. Jayasekara[1], L. Sivaneasharajah[1], M. A. S. Perera[1], J. Perera[2], D. D. Karunaratne[1], K. D. Sandaruwan[1], R. N. Rajapakse[1]

[1]University of Colombo School of Computing, Colombo, Sri Lanka
[2]Department of Forensic Medicine and Toxicology, Faculty of Medicine, University of Colombo, Colombo, Sri Lanka
Email: jpeushani@gmail.com, slavendini@gmail.com, slanjalishani@gmail.com, ddk@ucsc.lk, dsr@ucsc.lk, r.n.r@ieee.org, pererajean32@yahoo.com

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Abstract

The "facial composite" is one of the major fields in the forensic science that helps the criminal investigators to carry out their investigation process. The survey conducted by United States Law Enforcement Agencies confirms that 80% of the law enforcement agencies use computer automated composite systems whereas Sri Lanka is still far behind in the process of facial composite with lot of inefficiencies in the current manual process. Hence this research introduces a novel approach for the manual facial composite process, while eliminating the inefficiencies of the manual procedure in Sri Lanka. In order to overcome this situation, this study introduces an automated image processing based software solution with 2D facial feature templates targeting the Sri Lankan population. Thus, this was the first ever approach that creates the 2D facial feature templates by incorporating both medically defined indexes and relevant aesthetic aspects. Hence, this research study is comprised of two separate analyses on anthropometric indices and facial feature shapes which were carried out targeting the local population. Subsequently, several evaluation techniques were utilized to evaluate this methodology where we obtained an overall success rate as 70.19%. The ultimate goal of this research study is to provide a system to the law enforcement agencies in order to carry out an efficient and effective facial composite process which can lead to increase the success rate of suspect identification.

Keywords

Facial Composite, Facial Index, Facial Feature Templates, Sri Lanka

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1. Introduction

In the occurrence of crime incidents, the law enforcement agencies and police officers often depend on eyewitness testimony in order to establish the complete view of the crime situation. Eyewitness testimony is an account given by a victim unfolding the occurrence of a criminal activity [1]. The most prominent usage of the eyewitness testimony is when the investigators are impotent to find a pathway to carry out the interrogation as no threat of physical evidence is found at the scene.

In the event of criminal identification, the way Sri Lanka is analyzing the physical evidences is more similar to a certain extent with international context but still suspect identification through facial composite is far behind than we could ever imagine.

A facial composite is a graphical representation of a human face according to eyewitnesses' description. In order to overcome the current situation in Sri Lanka, an automated image processing based software solution has been introduced which includes 2D facial feature templates created using the anthropometric indices and shapes.

The failure rate of suspect identification through facial composite sketch has been declared as 92.86% in the year of 2014 [2]. The reason may be the failures in manual hand drawing procedure carried out by Sri Lankan forensic sketch artists [2]. When considering the current situation in Sri Lanka, still there are only two forensic artists who have not been given the opportunity of a professional training for drawing composite images [2]. Apart from this, still there's no secondary layer to carry out the job currently done by Sri Lankan forensic artists. This raises questions especially in terms of continuity in a case where forensic artists leave their profession.

However there is several recognized composite sketch software available in the international market such as FACES 4.0, E-FIT which is currently used by CIA, FBI and the US Military [3]. Even though, the data set which has been used in these available software has a vast difference with that of the Sri Lankan facial features. Thus it is not practical to use this software to create composite images of Sri Lankan suspects.

Since Sri Lanka is at its infancy level in facial composition, our attempt is to pinpoint the gap in order to find out the optimum way to automate this traditional procedure by incorporating the information technologies (image processing) and statistical analysis techniques and its related aspects. Since this research proposes a template based composite system, as a first step the need is to construct 2D facial feature templates by analyzing the Sri Lankan dataset. In early studies it was proven that the ability of assessing facial feature appearance has been achieved by anthropometric proportion indices and this has been used for a number of forensic and clinical practices [4]. Additionally, the facial features' shapes have also been identified to figure out the most frequently occurring shapes of Sri Lankan population. Eventually both these indexes and shapes were incorporated in the 2D facial feature template creation.

Therefore, to create these templates, in the first place a preliminary study was done with 140 undergraduate students (both male and female) aged 20 - 25 to find out the anthropometric proportion indices measurements of eyes, nose, upper vermilion, lower vermilion and these facial feature shapes of Sri Lankans.

Furthermore, this research also consolidates a detailed rule set based decision support system to filter the most possible facial feature templates according to eyewitness description. Thus the incorporation of Information Technology into the Sri Lankan facial composite process will be a guide to a more accurate and efficient suspect identification procedure with the help of more advanced facial composite process. Hence we have taken the very first step to provide Information Technology based solution for facial composite process in Sri Lanka.

2. Related Works

The "Facial composite" process has a very long history where it evolved from manual composition to computer based facial composition solutions. The entire facial composite evolution can be categorized into four [5] generations. In the beginning of 1911 [5], the first generation came up with the manual facial composite process where the sketch artist converted the eyewitness description into a hand drawn facial image based on their own impression [5]. This manual process is still prevailing in certain countries as the only technique in compositing the culprits face image. The second generation of the facial composite techniques was known as "Mechanical Systems" [5] such as Identikit and Photo fit which used the idea of facial composite by manually synthesizing the individual facial feature templates to get the ultimate image. "Identiti Kit" was a mechanical system for a facial resemblance which made up on 568 facial features drawn on transparent acetate sheets [5].

The "Photo fit" was developed in three versions in order to cover the population of male Caucasian, female Caucasian and male Afro Asian [6]. The overall design of the photo fit was a book format which contains thin paper strips along with an index list.

The third generation evolved with the software solutions where the individual facial feature templates are composited with the help of the computer technology [5]. E-FIT is unique and innovative computer based facial composite software which emerged in this third generation to carry out the holistic composite which ultimately creates near photo realistic and color image of the suspect based on eyewitness testimony [7] [8].

Finally, the fourth generation of facial composite system has been evolved with the concept of genetic algorithm [7] where the eyewitness needs to select the whole face rather than combining the individual facial feature [5]. "EvoFit" was one such system which was initiated in mid stage of 1990's. A 25% to 60% of world leading composites have been constructed using EvoFit which seems more accurate than the previous systems used by law enforcement authorities [9]. However EvoFit differs from other solutions as EvoFit carried out a genetic algorithm in synthesizing facial proportional aspects where the need was to integrate genetic recombination and mutation operators to create the best likeness face [9]-[11].

From 1990, feature based selection method was used for most of the composite software solutions. The products such as FACES, Mac-a-Mug Pro are commonly used software by the United States [12]. Similarly as EvoFit, FACES was also used by thousands of law enforcement agencies including FBI and CIA [12]. Generally it consists of features like eyes, mouth, nose, eyebrows, lips, mouth lines, tattoos and scars.

The entire aforementioned computer based software systems such as EFit, EvoFit and Faces increase the efficiency of traditional manual methods. Since almost all these international composite systems were developed targeting the facial features of foreign people, these are not feasible to utilize these software systems in Sri Lanka [2].

Facial Feature Analysis

Anthropometric proportion indices have been used in a considerable number of facial analysis studies conducted for various facial feature types and different races in several fields such as medicine, forensic, plastic surgery. Previous researches related to numerical measurements of facial feature analysis have done similar calculations with the use of medically accepted facial indexes using anthropometric soft tissue landmarks [13].

According to the literature, different formulas have been stated for Facial Index, Nasal Index, and Eye Index. A similar anthropometric calculations was applied in the upper and lower vermilion index calculations as there were no such formulas were defined for these two indexes.

As stated in previous studies facial index [14], eye index [6] nasal index [6] [13] [15] [16] can be defined as follows;

$$\text{Facial index} = \frac{\text{Facial Height} \times 100}{\text{Upper Facial Width}} \tag{1}$$

$$\text{Eye index} = \frac{\text{Eye Width} \times 100}{\text{Eye Height}} \tag{2}$$

$$\text{Nasal Index} = \frac{\text{Nose width} \times 100}{\text{Nose height}}. \tag{3}$$

Research conducted in [17] has identified that in certain faces upper vermilion values differ from lower vermilion values based on the person's facial type and shape whereas in certain faces the height of the upper vermilion equals to the height of the lower vermilion [18]. Considering these facts it is essential to have two separate formulas for the calculation of upper vermilion index and lower vermilion index.

$$\text{Upper vermilion Index} = \frac{\text{Mouth Width} \times 100}{\text{Upper Vermilion Height}} \tag{4}$$

$$\text{Lower vermilion Index} = \frac{\text{Mouth Width} \times 100}{\text{Lower Vermilion Height}} \tag{5}$$

3. Methodology

Mainly, the proposed solution consists of two steps which need to be carried out to create an ultimate composite image. They are Pre requirement stage and Building composite image.

3.1. Pre Requirement Stage

As the pre requirement stage of our proposed process, the 2D facial feature templates were created based on the analysis of two relevant parameters known as facial feature indices and facial feature shapes. Henceforth the index measurements of facial features were taken to obtain the size whereas the available shapes of main facial features of Sri Lankan people were considered to obtain the shapes in the process of template creation.

3.1.1. Facial Feature Template Creation

The dataset which consists of 140 frontal standard facial photographs of undergraduate students comprising both male and female between 20 to 25 age categories, were captured in order to create the facial feature templates. The same standard environment setup was used to provide a similar condition (frontal view, neutral expression, daylight condition, same distance from camera to personal object) for the entire process of capturing photographs.

This research study has focused only on main facial components and subsequently the 2D facial feature templates have been created for eyes, nose, mouth and face. These templates were created using the results obtained from the two sub studies carried out for index analysis and facial shape analysis of Sri Lankans. Since the weight of a person can affect the width and height of the facial features, the collected data set was categorized based on the weight categories using BMI (Body Mass Index) values, as BMI can be used to screen for different weight categories.

3.1.2. Index Measurement of the Facial Features

In the creation of facial feature templates, it was required to carry out an in-depth analysis of facial features. Even though there have been initial studies conducted with regard to facial indices in Sri Lanka [19]-[21], the index analysis hasn't been conducted for Sri Lankans for all the indexes required in this study. According to the literature, numerical analysis of the linear measurements and proportional indices were carried out for main facial features of the targeted subjects through anthropometric soft tissue landmarks as shown in **Figure 1** [17].

The facial feature detection library, Luxand Face SDK was used for the facial feature detection from facial photographs as it is comparatively more reliable and accurate over manual measuring techniques and other related tools. Using such libraries would overcome inefficiencies related to the manual measuring techniques such as subjectivity and high time consumption. Subsequently the distance between the feature points and the indices were calculated via the Java based tool stated above. Initially, the facial feature index formulas which are mentioned in the literature review were used to measure the index values of each facial feature. Subsequently they were classified further into different categories as shown in **Tables 1-5** in order to obtain a more accurate categorization. Once after classifying each facial feature, the width and height of these facial features were measured in millimeters and the average value of these measurements were calculated to decide the most possible width and height to represent the whole data set for each category.

Table 1. Average eye index, average width and average height along with the eye classifications for both male and female.

Eye classification	Eye index range		Eye index mean		Eye width mean		Eye height mean	
	Male	Female	Male	Female	Male	Female	Male	Female
Narrow	<274.99	<249.937	255.95	228.94	7.46 ±0.44	7.26 ± 0.66	2.88 ± 0.22	3.10 ± 0.22
Medium	275 - 325.1	250 - 293.999	296.91	272.59	7.44 ± 0.51	7.25 ± 0.49	2.51 ± 0.28	2.69 ± 0.22
Wide	>325.29	>294	341.37	326.32	7.44 ± 0.68	7.56 ± 0.33	2.13 ± 0.21	2.31 ± 0.14

Table 2. Average nasal index, average width and average height along with the Nasal classifications for both male and female.

Nasal classification	Nasal index range		Nasal index mean		Nasal width mean		Nasal height mean	
	Male	Female	Male	Female	Male	Female	Male	Female
Narrow	<86	<82.999	83.54	78.04	9.38 ± 0.90	8.44 ± 0.58	11.40 ± 0.88	10.80 ± 0.90
Medium	86.1 - 99.2	83 - 91.999	94.84	88.24	9.54 ± 0.71	8.65 ± 0.59	10.39 ± 0.84	9.90 ± 0.67
Wide	>99.3	>92	102.69	94.49	9.80 ± 0.68	9.23 ± 0.64	9.62 ± 0.89	9.64 ± 0.58

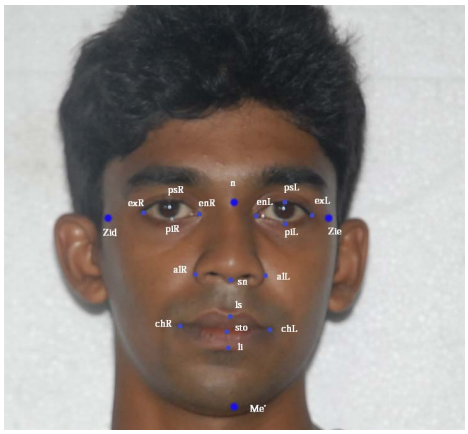


Figure 1. Anthropometric soft tissue landmarks [3] Nasion (n), subnasale (Sn), Alare (alL/R), endocanthion (enL/R), exocanthion (exL/R), palpebraleinferius (piL/R), palpebralesuperius (psL/R), cheilion (ch), labialesuperius (ls), labialeinferius (li), stomion (sto), right zigion (Zid), Menton (Me).

Table 3. Average Upper Vermilion (U.V) index, average width and average height along with the upper vermilion classifications for both male and female.

U.V classification	U.V index range		U.V Index mean		U.V width mean		U.V height mean	
	Male	Female	Male	Female	Male	Female	Male	Female
Narrow	<594.1	<808.999	514.13	1487.95	12.06 ± 0.95	11.75 ± 1.05	2.33 ± 0.31	1.87 ± 0.32
Medium	594.2 - 789.8	809 - 1191.999	686.94	897.92	12.67 ± 1.04	11.59 ± 0.65	2.07 ± 1.53	1.30 ± 0.1
Wide	>789.9	>1192	879.49	630.97	12.63 ± 1.08	11.81 ± 0.98	1.49 ± 0.34	0.79 ± 0

Table 4. Average Lower Vermilion (L.V) index, average width and average height along with the Lower vermilion classifications for both male and female.

L.V classification	L.V index range		L.V index mean		L.V width mean		L.V height mean	
	Male	Female	Male	Female	Male	Female	Male	Female
Narrow	<443	<444.999	430.37	396.71	12.35 ± 1	3.05 ± 0.29	2.87 ± 0.34	2.94 ± 0.31
Medium	443.1 - 553.1	445 - 535.9	541.11	484.06	47.54 ± 1.03	11.25 ± 2.44	2.36 ± 0.26	2.98 ± 2.04
Wide	>553.2	>536	648.46	586.96	13.37 ± 0.84	12.07 ± 2.83	1.95 ± 0.29	2.00 ± 0.20

Table 5. Average face index, average width and average height along with the face classifications for both male and female.

Face classification	Face index range		Face index mean		Face width mean		Face height mean	
	Male	Female	Male	Female	Male	Female	Male	Female
Narrow	<79.9	<77.9	76.49 ± 2.82	75.39 ± 1.64	178.04 ± 12.80	168.59 ± 10.21	227.34 ± 15.35	216.34 ± 14.60
Medium	80 - 88.9	78 - 82.9	84.29 ± 2.49	79.76 ± 1.44	174.64 ± 8.85	166.18 ± 8.89	242.27 ± 17.32	220.36 ± 13.75
Wide	> 89	>83	91.99 ± 2.42	84.93 ± 1.97	174.69 ± 9.59	168.42 ± 11.22	243.40 ± 28.24	233.86 ± 12.59

4. Results

The results of the eye, nasal, upper vermilion, lower vermilion and face index analysis of each facial feature are presented in **Tables 1-5** respectively. As the main outcome of this analysis, average values of index, height and width were calculated. The below mentioned mean values of width and height were used to construct the 2D facial feature templates.

4.1. Commonly Available Shapes of Facial Features

Since there are no other studies conducted on facial feature shapes for Sri Lankan context, shape categorization has been conducted based on aesthetic aspects with the help of the domain experts' knowledge. Therefore, two domain experts in the aesthetic field were consulted to classify the facial feature shapes.

The same 140 frontal photographs were used to detect the different shapes of Sri Lankan people's facial features. All the 140 photographs were inspected by the domain experts in aesthetic field Mr. Winnie Hettigoda, the Senior lecturer, of multimedia art Faculty of Visual Art in University of the Visual and Performing Arts and the forensic artists at Criminal Records Division in Sri Lanka categorized the different shapes of facial features.

During the classification process the two domain experts were able to identify 6, 10, 8 and 7 types of shapes for face, eye, nasal and mouth respectively for males. Similarly 6, 8, 8 and 7 types of shapes for face, eye, nasal and mouth were identified respectively for females. **Figure 2(a)** and **Figure 2(b)** represent the identified shapes for each facial feature along with their frequency percentage for male and female correspondingly.

4.2. Building Composite Image

A facial feature template based composite system was implemented to computerize the manual hand drawn facial composite process to enhance the efficiency of the current manual process. The created 2D facial feature templates were then added to the system afterwards the facial composite process will be take place at this stage with the help of the eyewitness description. Subsequently an interface has been implemented to derive the facial feature templates and each type of templates will be shown in different tabs in composite software system from which the eyewitness can select the appropriate facial feature templates to produce the ultimate suspect's face.

5. Evaluation

Face pool comparison and resemblance techniques were carried out as the evaluation methods for this study. The evaluation was conducted only for male category as the facial feature templates were constructed only targeting male indices and shape categories. As shown in **Figure 3**, the face pool technique was conducted with 75 responded where they were asked to participate in the online survey. **Table 6** illustrates the results of 06 test cases which were obtained from the face pool comparison conducted via the aforementioned online survey.

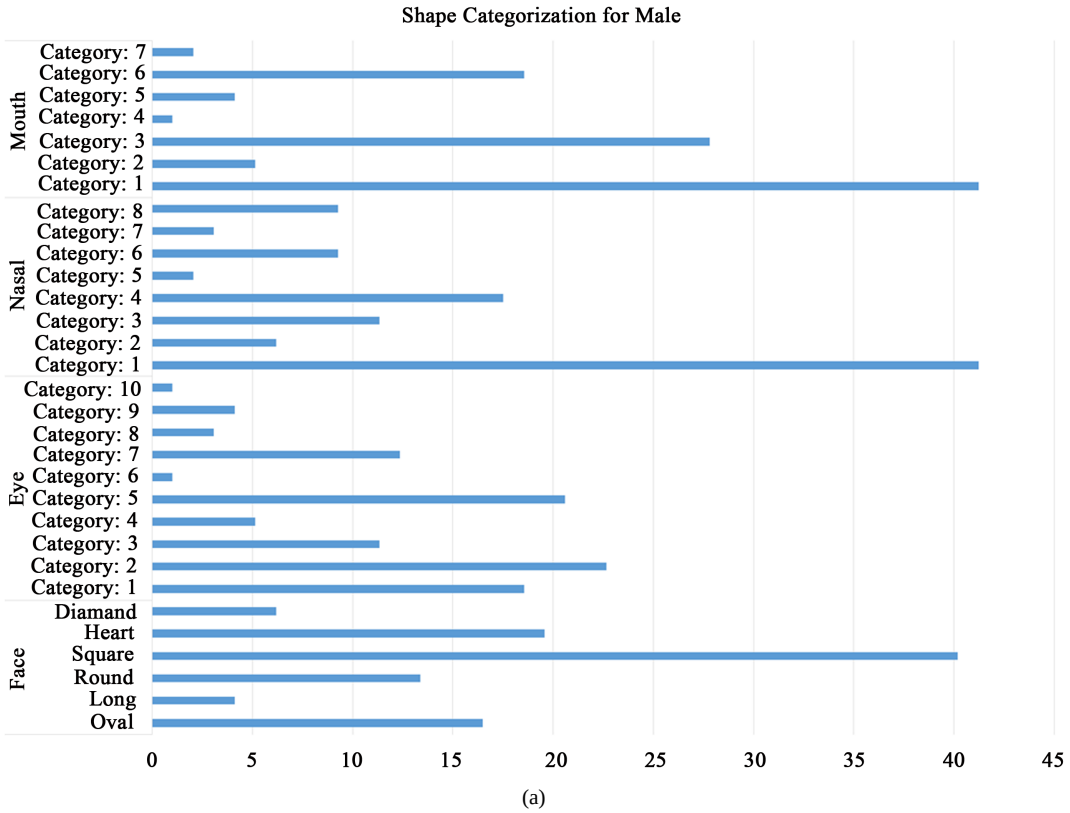
As the second evaluation method the resemblance evaluation technique was conducted via online survey with 51 respondents. As shown in **Figure 4** the respondents were asked to rate the resemblance rate of the each feature in the composite image with the original image. The options suggested for the rating was Very Similar, Similar, Average, Slightly Similar and Not at all which range from 5 to 1 were in order to analyze the evaluation results. **Table 7** illustrates the results of 04 test cases which were obtained from the resemblance evaluation which conducted via the aforementioned online survey.

Table 6. Results of the face pool comparison and the highlighted cell depicts the correct image along with its percentage.

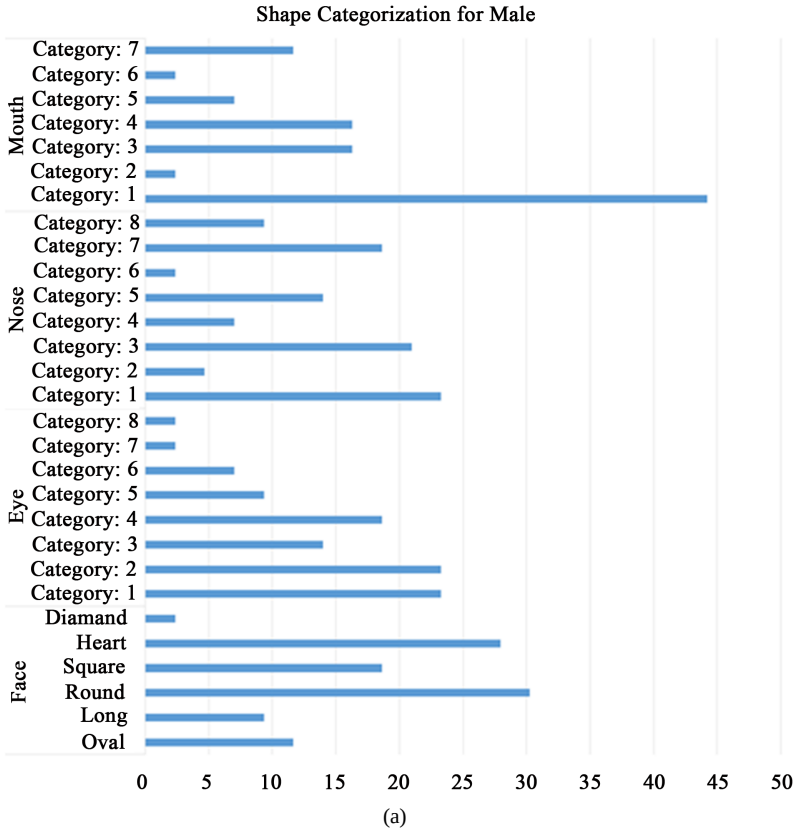
Image No	Test Case 1	Test Case 2	Test Case 3	Test Case 4	Test Case 5	Test Case 6
Image 1	13%	0%	**72.7%**	6.1%	0%	0%
Image 2	13.3%	12.1%	9.1%	6.1%	18.2%	**81.8%**
Image 3	4%	**69.75%**	12.1%	12.1%	18.2%	0%
Image 4	**78.7%**	12.1%	6.1%	**72.7%**	18.2%	6.1%
Image 5	2.7%	6.1%	0%	3%	**45.5%**	12.1%

Table 7. Results from the resemblance rating evaluation.

Features	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Face	Similar 47.4%	Similar 31.6%	Similar 42.1%	Average 42.1%	Similar 36.8%	Similar 37.3%
Eye	Similar 42.1%	Very Similar 36.8%	Similar 47.4%	Similar 47.4%	Average 36.2%	Similar 47.4%
Nose	Similar 36.8%	Similar 21.1%	Similar 42.1%	Similar 47.4%	Slightly similar 31.6%	Similar 35.3%
Mouth	Average 47.4%	Similar 31.6%	Average 47.4%	Average 47.4%	Slightly similar 42.1%	Average 33.3%



(a)



(a)

Figure 2. (a) Facial feature shape categorization for Male (b) Facial feature shape categorization for female.

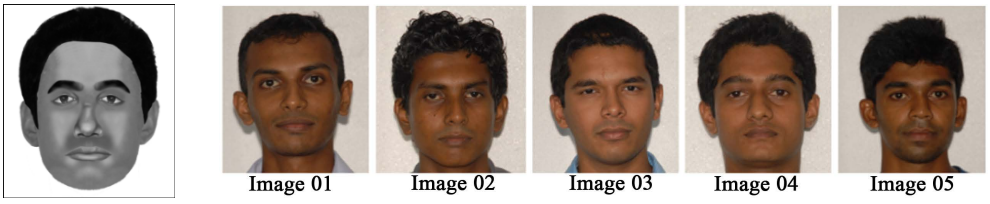


Figure 3. (a) The composite image generated created for the Test Case 01 face pool evaluation; (b) The image list created for the Test Case 01 face pool evaluation.

Figure 4. The composite image and the original image of the provided Test Case 1.

6. Discussion

The overall success rate which obtained from this research study was 70.19% for the 6 test cases whereas the success rate of the prevailing international software gives 60% [22]. Since the accuracy level of the proposed approach could reach to the success rate of available international software, it is obvious that this solution can be used in the identification of suspects through facial composite in Sri Lanka.

According to the evaluation phase, test cases 1, 2, 3, 4 and 6 have taken the higher accuracy rate than the success rate gain from international software solutions. In the proposed solution, the facial feature templates were constructed using the medically defined indexes which were ideal for Sri Lankan people and the aesthetic aspects were also considered when placing the facial templates for the ultimate composite image. These well accepted measurements and aesthetic aspects were put together in constructing facial composite image via this process. Therefore this has become one major reason behind the highest accuracy rate achieved from the proposed process.

However case study 5 has obtained the lowest result as 45.5% and it clearly depicts that this attained success rate is lower than the average success rate which was derived from the proposed process. Moreover the results obtained from the resemblance evaluation shows face, eye features of composite image of case 5 were presented high equivalence rate whereas the features that presented a low equivalence were nose and mouth. Hence it is obvious that the nose and mouth features were the major causes which mislead the audience to select the wrong person for case study 5. And the root cause for this mismatching nose and mouth templates were selected to construct this composite image because only limited nose and mouth shapes were identified from the process as our data set was 140 and it was not enough to represent the whole population. But still this drawback can be eliminated, if the same procedure was applied for large dataset and as a result more nose and mouth shapes can be identified through the shape classification method as mentioned in section “Commonly available shapes of facial features”.

The present study has been able to establish an efficient facial composite process for Sri Lankans which can achieve a considerable amount of high success rate. Therefore the findings and the results of this study will definitely helpful in the forensic science and will eliminate the drawbacks in suspect identification via facial composite.

7. Conclusions

In the field of forensic science, the facial composite plays a major role in the process of tracking down the criminal

when there is no physical evidence found from the crime incident. Henceforth the facial composite image becomes one of the major clues in the investigation procedure.

The study introduces an automated image processing based composite software solution which includes 2D facial feature templates created for the first time targeting the local population to eliminate the inefficiencies in the current manual facial composite procedure in Sri Lanka.

Since these 2D Facial Features templates have been created targeting Sri Lankan context, the analysis of facial feature variations of Sri Lankans were required before creating these facial feature templates. Therefore two major sub researches have been carried and the results obtained from these sub studies were incorporated to construct the 2D facial features templates needed to carry out the proposed facial composite process.

The study conducted was evaluated with face pool and the resemblance techniques and obtained 70.19% accuracy indicating that this proposed process has a significant impact on dramatically increasing the success rate of the facial composite comparative to the prevailing success rate. Hence this computerized system will significantly improve the existing manual process and benefit professionals involved in the criminal justice process mainly police and crime investigators and ensure justice for the victimized person.

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