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Facial Muscle Anatomy Based Approach for Forensic Facial Reconstruction in Sri Lanka

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Abstract—Forensic facial reconstruction is still at its infancy in Sri Lanka and is yet to utilize the advanced technologies of other countries. Hence introducing a more efficient multimedia based technique to the local forensic officials in order to improve the efficiency and the accuracy of the reconstructions is the aim of this study. In contrast to the other mechanisms used for facial reconstruction by others, this paper adopts a novel approach of muscle based facial reconstruction which goes hand in hand with the manual reconstruction process. The adopted process involved, acquiring a 3D model of the skull and digitally sculpting muscles in a 3D environment, followed by adding different facial features to improve identification. The research also encompassed a tissue thickness analysis that is conducted for the first time on Sri Lankans as well as a facial component analysis, both of which were needed to improve the accuracy of the final output. This procedure was attempted on cases of the age category 20-30 and of medium weight. The outputs and the process were evaluated with different parties such as general public, forensic officials, lawyers and CID all of which are to be benefited from this application. The ultimate goal of conducting the study was to understand and overcome the challenges faced in developing this novel application for the Sri Lankan Forensic officials and to establish the first unit for facial reconstruction in Sri Lanka.

Keywords— forensic facial reconstruction, tissue thickness, facial components, digital sculpting, Sri Lankan, muscle-anatomy

I. INTRODUCTION

Upon the occurrence of a natural or a manmade disaster, such as terrorist bombings, mob uprisings, Tsunami, etc... the administrative bodies of a country has to handle piles of *unidentified dead bodies*. And when murder victims plunged deep underground are surfaced years later, even then the administrative bodies have to handle *unidentifiable dead bodies*. In these situations when neither their personal effects nor body tissues can define the identity of the deceased, the investigations are moved on to the facial reconstruction stage. Yet it has to be born in mind that this stage is also known as the facial approximation, because the end result of this process, is a face that would only hold *some resemblance* to the deceased, and will not be the exact face of him/her. Once an approximate is reconstructed it is circulated via digital and paper mediums with hope of a citizen being able to identify it. Upon such identification, the stated identification is verified using DNA, fingerprint or dental records analysis. Hence facial reconstruction is of great use to criminal investigators.

But apart from criminal investigators, facial reconstruction is also used by biological anthropologists in approximating the look of early hominid forms, as well as by archaeologists in verifying the remains of historic figures.

In spite of all these uses, Sri Lanka currently does not adopt any facial reconstruction method. The authors of the paper intended to solve this shortcoming by recommending a manual, 2D or 3D reconstruction method. However around the world, the facial reconstruction process is conducted mostly via manual mechanisms or 3D automated mechanisms. And out of the two even, the manual method has significant disadvantages such as being highly time consuming and requiring expensive resources and human expertise. In contrast to it 3D reconstruction is more cost and time effective. Therefore the authors considered that introducing a computer aided 3D reconstruction method to the Sri Lankan Forensic Scientists would be the best solution.



Fig. 1 Time taken for the manual and 3D techniques for facial reconstruction

A solution for implementing the suggested 3D facial reconstruction in Sri Lanka was developed by the authors in collaboration with the Department of Forensic Sciences in Colombo and Sri Jayewardenepura Universities. One of the leading experts of facial reconstruction in Sri Lanka has assisted the researchers in this study and he is intending to implement the first center for facial reconstruction in Sri Lanka with the developed solution.

The feasibility of implementing such a solution, its effectiveness and the challenges in implementing and developing the application are discussed in this paper.

II. RELATED WORK

Forensic facial reconstruction has been active in the field of forensics from the latter part of the 18th century and it has been practiced using various methodologies over the years. Although the earliest attempts at “reconstruction” were at a very trivial level, those have aided to bring the practice to what it is today.

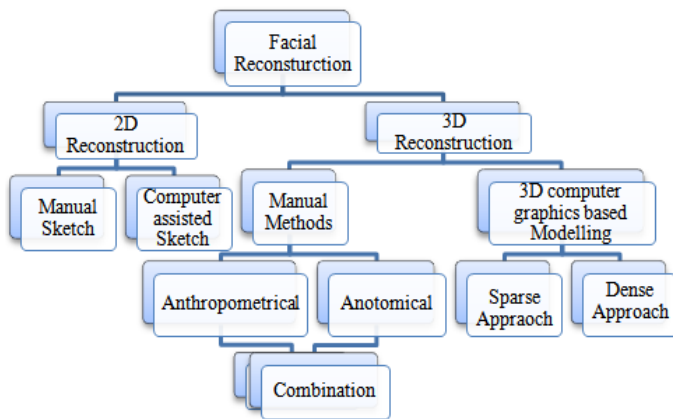


Fig. 2 Types of facial reconstruction

In early years the reconstruction of the face was done manually using clay and a plasticine model of the skull [1]. It is noted in the literature that a reconstruction was done for the popular composer John Sebastian Bach by the German anatomist His in the year of 1895 [2]. He used set of soft-tissue measurements obtained from White German cadavers to construct a three dimensional clay model of Bach. However the human effort and the specific clay and plasticine materials required for reconstruction were costly and the process involved several man hours.

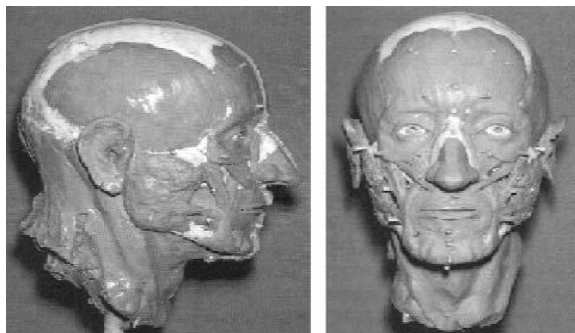


Fig. 3 Facial reconstruction manual technique [1]

This was followed by the two-dimensional facial reconstruction which required ante mortem photographs and the skull as its basis. It also involved an artist sketching the contours of the skull [1], [3], [4].



Fig. 4 Markers applied to a skull copy, contour fitting the markers [1]

Two dimensional reconstructions were followed by the final, and acceptably the best, stage of the evolution of facial reconstruction methods; the reconstruction using computer images/Graphics based methods. This was ranked to be the best available methodology due to its effectiveness, speed and flexibility.

The focus of this study, computer aided 3D reconstruction, has been carried out by different researchers in different ways and each of them has had their own advantages as well as disadvantages. However each of them had to initiate the process by first obtaining the 3D model of the skull. Computed

Tomography (CT) scanning technique [5] was adopted by some while a sequence of photographic skull image frames [5] were used by some to generate the 3D model of the skull. In the more modern researches sophisticated techniques such as Facial Optical Surface Scanners [6], Electro spatial digitizers [7], Cyberwave TM Model Color -3D Scanhead scanners [8] have been used.

Once a 3D model was acquired then it was prepared for the skin building process. According to the literature this was done using two main techniques.

1. Dense Approach
2. Sparse Approach

The dense approach used deformation algorithms where a reference skull model is deformed to match the measurements of the unidentified skull model [9]

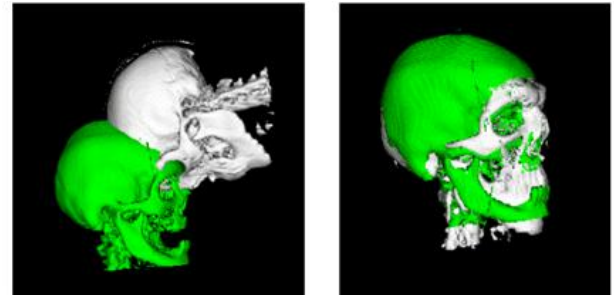


Fig. 5 Aligning the two Skulls: Green skull is the reference model and the white skull is the Subjects' model. The left image shows an initial misalignment and the right image shows the two skulls after the alignment [9]

The second and in fact the most vastly used technique in facial reconstruction studies; the sparse approach, used tissue depth land markers. These landmarks were positioned based on the anthropological data (via CT and MRI head scans) and the number of landmarks to be placed was subjected to change based on the study.

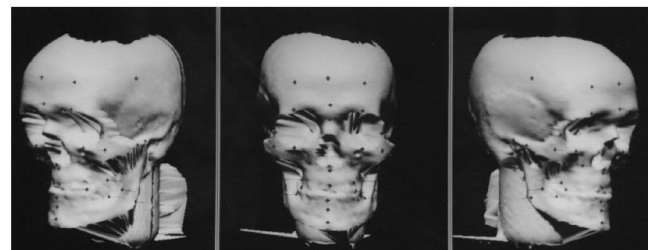


Fig. 6 Skull with landmarks in position [6]

In the sparse method, after placing the landmarks on the skull, the subsequent steps that have to be adopted to complete the reconstruction again has differed based on the research groups and studies.

One such was the method presented by the Professor of Forensic Medical Sciences, Peter Vanezis. He had presented the technique of fitting a facial template to the skull and adjusting that template according to the markers [6]. These templates were stored in databases, categorized based on the skull they were supposed to fit into, and in the reconstruction process the artist had chosen a template that had standard average features and matched best with the subjects' skull anthropologically. This method had been adopted by some other researchers as well, and in all these studies the templates had been collected by taking head scans of a large number of people, as seen in [1] and [6]. But in later studies, it was felt that this approach resulted in a reconstructed face that had a high resemblance to the donors face (templates face) [10], [11]. This was felt to be a major shortcoming since an ideal reconstruction was expected to result in a reconstructed face

that had a resemblance to the deceased and not to the donor. Hence a change in the approach was supported by the forensic community. It resulted in a shift from template based reconstruction on to *skull as the sole basis* reconstruction approach.

In the research done by Davy et al [11] rather than using reference images from a database, the skull was used as the sole base and NURBS curves were used to create elliptical cross sections which were then used as the base of the face.



Fig. 7 Facial reconstruction manual technique [11]

Another study that used the skull as sole basis approach, has utilized 3dsmax and the software's inbuilt scripting functionality for reconstruction. They have used mesh calculations to produce the reconstructed face. [3] (Figure 8)

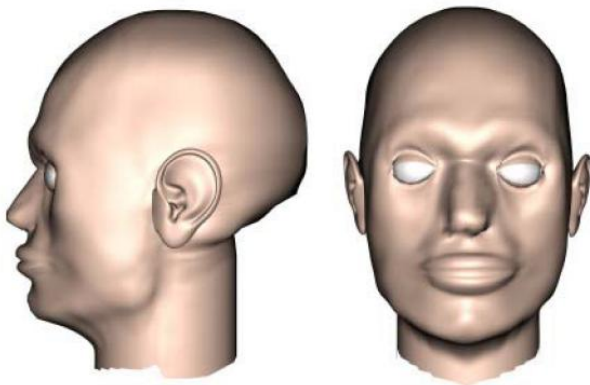


Fig. 8 Reconstructed face of the research of [3]

Facial features such as eyes, eyebrows, nose and lips were added as the final step. In most of the previous studies the facial features of living humans were acquired by digitizing faces of the subject and then placing those facial components on the reconstructed face [12]

Although several studies point out that adding facial features when no actual information is available would increase the possibility of identification, it is argued by some that additional facial features should be kept as minimum as possible due to the reason that additional features would mislead the identification.

III. METHODOLOGY

The developed solution involved a framework with a set of processes and tools. This framework is described as phases in this third section of the paper, and in each phase the tools and techniques that were used for the process are described.

Test cases to reconstruct faces were obtained in two samples. One was the sample of skulls belonging to solved forensic cases that were acquired from Sri Jayewardenepura and Karapitiya Medical Faculties. Photographs of the each of the deceased were also acquired to be compared with the reconstructed final 3D face. The second sample was CT scan patient data. Scan data of patients who had come for head scans

were used with the permission from hospital authority and a DICOM viewing software (CT scan image viewing software) was used to extract a the skull and the patients actual face via the 3D surface rendering function of the editor for evaluation purpose.

Ideally when an *unknown skull* is found, the following process will have to be carried out, with a pre-requisite stage and four main steps as follows.

Pre-requisite: Forensic Analysis of the Skull of the deceased Person

- Step 01 : Capturing the 3D model of the skull
- Step 02 : Placement of Landmarks
- Step 03 : Digitally Sculpting the Face
- Step 04 : Adding Facial Components

Pre-requisite: Forensic Analysis of the Skull

This stage was performed when no prior knowledge on the owner of the skull was present, which would be the case in any unidentifiable dead body. And in such instances this analysis was performed to determine certain information about the deceased person from the skeletal remains of the dead body. A forensic medical expert extracted the following details from the skeletal remains.

- General age category (Normally an assumption in a bracket of 5-10 years would suffice)
E.g. 25-30 years
- Sex

These identified features assisted the reconstruction process in step 02.

A. Step 01: Capturing the Skull

As the first step, the 3D model of the skull was acquired. Out of the two schools of thought that were mentioned in the related work, using the *skull as the sole base* of the reconstruction technique was used by the researchers, and hence acquiring a fairly accurate model of the skull was of paramount importance.

To capture the real life skull samples the Vivid 910 3D scanner of Konica Minolta™ (Figure 9) was used. This was mainly due to the reason that it was already been used to generate models of human components in the Medical Field.



Fig. 9 Our set up of acquiring the 3D model of the skull with the Vivid 910 3D Laser scanner at University of Colombo

After the 3D models were acquired using the 3D Scanner, it was observed that most of the test skulls were fractured and damaged. Nevertheless this was not an unexpected dilemma since most the human remains unearthed after years would be in a dilapidated stage.

However this status of the skulls rendered it hard to conduct an accurate reconstruction. Hence it was required to make certain rectifications to the 3D models of the skulls. A 3D editing software application was utilized in this stage to successfully rectify the acquired 3D models. (Figure 10 [a, b]).

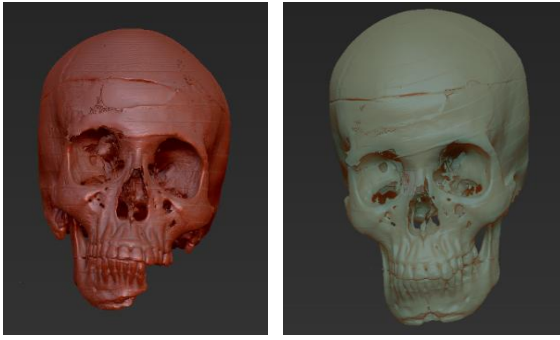


Fig. 10(a) Test skull with half of the jaw missing (b) After applying the symmetry modifier in a 3D editing software

B. Placing Landmarks

Once the 3D model of the skull was obtained, the next step was to define anatomic and physiognomic points, known as landmarks, on the 3D model of the skull (Figure 11). Other studies on facial reconstructions have each used a differing number of landmarks, and hence the number of landmarks the researchers of this study used was optimized to suit in to their method.

The length of each of these landmarks was determined by the soft tissue thickness of the facial area in which the landmark was placed. Since such data was not available on Sri Lankans, an independent research on the facial soft tissue thickness of the Sri Lankan people was also carried out by the researchers using personal computer based Magnetic Resonance Imaging (MRI) and Computed Tomography (CT) images and its results are mentioned in section IV, Analysis Results.

In the course of the research it was found that the facial tissue thickness of a person differs based on age, sex, weight and race. Yet when Sri Lanka is taken in to consideration, all Sri Lankans can be classified in to the broad category of Caucasoid. Therefore in measuring tissue thickness data, the race category was exempted but data was gathered based on the age, sex and weight categories.

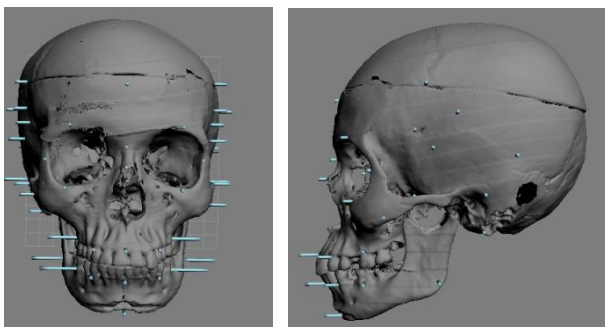


Fig. 11 The skull model with the tissue thickness landmarks (Case 01)

For this study tissue thickness data obtained from a sample of people who were similar to the deceased in terms of Age and Sex (as identified in the pre-requisite stage) was considered.

For instance, in the first case study it was assumed that the deceased was a medium weight female of the age category 20-30. Thus the tissue thickness data gathered from people belonging to those specifications were used. And by using MRI and CT images of the sample group, tissue thickness depths for each of those anatomical landmarks (Figure 12) were measured. Head/Sinus scans (without the patient identification details) obtained from medical institutions were used for this purpose.

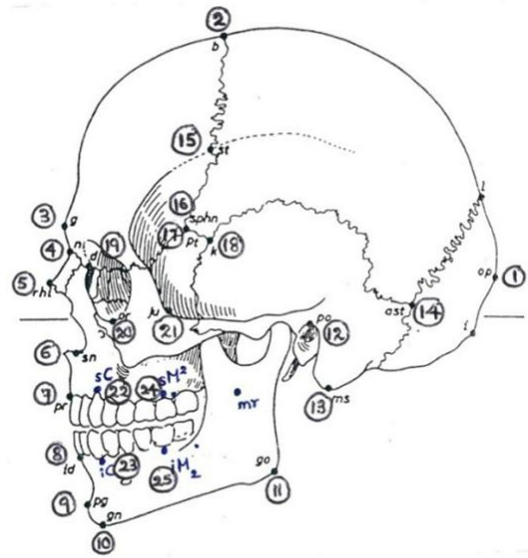


Fig. 12 Lateral view of the skull showing landmarks from 1-25

By using those depth values, the height of the tissue thickness landmarks placed on the model were then adjusted.

(Note: This study was carried out as a proof of concept for the people belonging to the Medium weight category. Hence forensic cases where the deceased was of a medium weight were chosen. Therefore tissue thicknesses were also gathered from a sample of people belonging to the medium weight category).

C. Digitally Sculpting the Face

As with all the other human organs, the face is also constructed with a complex structure of muscles that forms the basis of the skin layer. The method that was used in the research was to reconstruct these muscles on the skull and to generate the skin based on those muscles.

Several techniques were tried out and it was decided to use the ZBrush™ software for the muscle reconstruction. This was due to the reason that it was digital sculpting software hence there would be a direct map between the manual reconstruction (sculpting) and the usage of this technique. Based on the knowledge gathered on the human anatomy, the muscles were constructed.

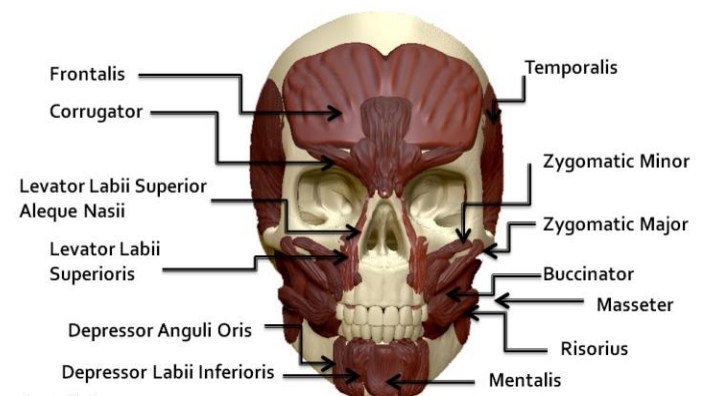


Fig. 13 The initial stage of the skull after applying muscles based on human facial anatomy

The thicknesses of each of these muscles were determined by the landmarks placed in the earlier stage. Each muscle was “inflated” or “trimmed”, “polished” until the thickness specified by the landmarks was achieved.



Fig. 14 The different stages of the reconstruction procedure (Case 02-Male/20-30)

The next step involved reconstructing facial components such as the mouth. The lip height was determined based on the teeth size and the thickness was determined by the landmarks close to the Orbicularis Oris (lip) muscle.

After the face is reconstructed, the addition of different facial components based on user requirement (broad, narrow noses) was incorporated at a later stage in the research. Yet some basic foundation had to be laid on the face in order to add different components later. Therefore the construction of the basic muscles was followed by the construction of more complex facial components such as eyes and nose in a basic level.

The dilemma faced in constructing these components was that all the facial components were supposedly created from cartilages. Therefore unlike the other muscles, the bone structure could not be used as the sole basis for these constructions. The eye itself was constructed as three muscles and the eye ball (namely Orbicularis Oculi, Palpabrel and Orbital) and the only guideline to be followed was that the eyeball had to be behind the eye socket. Once the eyes were created, the mouth had to be realigned with relation to its width because the end position of the lips had to be in line with the position of the eye ball (Figure 15 (a)). The nose was constructed by following the rule that once a line is drawn connecting the starting and end points of the nasal cavity, the distance from that line to the back of the cavity is equal to the distance that the nose would protrude from the skull (Figure 15 (b)).

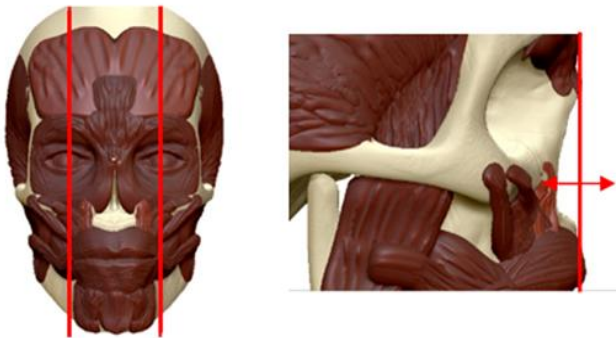


Fig. 15(a) The lip position based on the eye ball (b) The nose position based on nasal cavity

The final step in face building was to apply skin on top of all the muscles. A technique called “remesh all” facilitated this function in ZBrush™. After the skin was applied, the face was edited to get the underlying muscle effects and the structure, using tools available in ZBrush™.



Fig. 16 The Intermediate model created using the muscular structure (Case 01)

D. Adding Facial Components

A realistic appearance for the reconstructed face was to be obtained by modelling the facial features such as eyes and noses appropriately. Yet data on different types of eyes and noses was not available since such an analysis had not been conducted on Sri Lankans as yet. Therefore a separate facial feature analysis was carried out on Sri Lankans and the result of this analysis is in the analysis results section.

Based on the analysis the most common dimensions of the facial features were discovered and by using these values, facial components (different sizes and shapes) of the highest frequency among the target group were added to the 3D model to improve the possibility of identification. (Refer Table I, II in Analysis Results section)



Fig. 17 The Final model of the process (Case 01)

Even though eyes and nose were added to the face, adding different hair styles for the reconstructed face was disregarded since it tends to change the appearance of the final outcome drastically which might also render an output unidentifiable to the deceased persons relatives.

The addition of different combinations of facial features on to the reconstructed face resulted in generating a considerable amount of different facial models, which could subsequently increase the percentage of the identification of the deceased.

IV. ANALYSIS RESULTS

A. Tissue Thickness Analysis

After the tissue thickness analysis it was found that a considerable difference exists between the facial soft tissue thicknesses of Sri Lankans and other races. Hence applying tissue thickness values of other countries to a Sri Lankan skull model would result in inaccurate approximations.

During the comparisons it was also observed that Sri Lankans have differing facial soft tissue thickness depths at the

areas of beneath Chin, Gonion, Sub M2 (Below the second mandibular molar) and Supra M2 (Above the second maxillary molar).

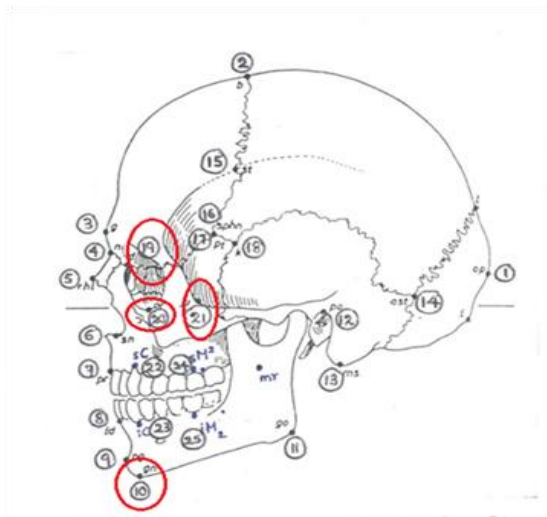


Fig. 18 Areas of differing tissue thickness in Sri Lankans as compared with the data in other regions

B. Facial Feature Analysis

The facial feature analysis resulted in the most common nasal and eye indexes. For this analysis a sample of 426 (290 males and 136 females) of the age category 20-30 was used and the sizes and shapes of the most commonly occurring facial components were devised. In obtaining the measurements of each facial component a photo editing and measuring software was used and in it, the human error rate was also calculated to improve the accuracy of measurements.

1) *Nose Analysis:* Using the photographs of the sample group the nasal index was calculated using the following formula.

$$\text{Nasal Index} = \frac{\text{Nose width} * 100}{\text{Nose height}}$$

After which the indexes were categorized as narrow medium and broad and the most frequent N.I for each of the categories were devised. (Table I)

TABLE I
THE MOST FREQUENT NASAL INDEX

Nose Categories	Most frequent N.I (Male)	Most frequent N.I (Female)
Narrow	100	80
Medium	103	100
Wide	136	104

2) *Eye Analysis:* Same technique was followed to measure variations in the eyes. (Table II)

$$\text{Eye Index} = \frac{\text{Eye width} * 100}{\text{Eye height}}$$

TABLE II
THE MOST FREQUENT EYE INDEX

Eye Categories	Most frequent E.I (Male)	Most frequent E.I (Female)
Narrow	300	257
Medium	355	300
Broad	733	400

V. CHALLENGES FACED

As a research that explored an area that had hitherto not been addressed by any researcher in Sri Lanka, this research had

resulted in testing researchers’ perseverance and commitment in many stages. The scope of research had to be kept strictly in mind since most of the pre-requisites of the research were not fulfilled by other researchers in that area.

For the facial tissue thickness analysis data had to be gathered from several private and governmental hospitals where the researchers had to spend time getting familiarized with the CT and MRI scanning machines, access to which wasn’t granted easily.

Once access was granted to the tissue thickness data, it was found out that most of the patients who apply for brain scans were between the age ranges of 40-60. And yet the test skulls the forensic officers had been able to supply the researchers with were all from the age category of 20-30. Hence it had required extensive effort from researchers to gather tissue thickness data belonging to this group. Another challenge they had faced with was the manner brain scans were conducted. In order to have minimal effect to the patients from the rays emitted during a scan, most of the brain scans had not included a complete head scan, and hence the Mandible (jaw bone) was missing from most of them. Therefore researchers had to search for brain scan data that included the Mandible, in all the hospitals they had access to.

In obtaining photographs for facial feature analysis and tissue thickness data, the researchers were hassled by ethical issues as well. In order to overcome this predicament, consent was obtained from each individual to use their photograph for research purposes and since the tissue thickness data didn’t involve any patients’ personal information, permission was granted by hospital administrations to use the data for the research purpose.

VI. EVALUATION

The forensic facial reconstructions are conducted with the ultimate intention of constructing a face that will be identifiable by the deceased person’s relatives. Hence a reconstruction has to be mainly *identifiable* and have a *resemblance* to the deceased. Two methods of evaluations were conducted to evaluate these features in the reconstructed faces, one for real life skulls sample other for CT scan patient sample.

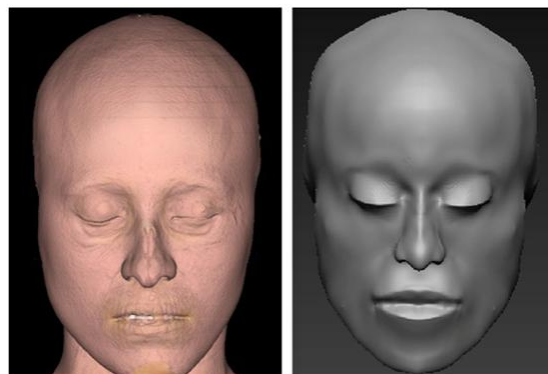
- Resemblance Rating System
- Face pool Comparison

The reconstructed face also has to be *similar* to the deceased. This feature was evaluated using another two methods of evaluations.

- Photogrammetric Analysis
- Morphing Software to Superimpose

A. Resemblance Rating System

The CT scan patient sample was evaluated under this method and an online survey was used for it.



Actual Photograph of the Patient

Reconstructed 3D model of the face

Fig. 19 Online Survey created for Resemblance Rating System

The reconstructed face was placed alongside the 3D face given by the CT image editing software and the respondents were asked to rank the resemblance of the two on a scale of 0-100. Results obtained for some cases were as follows.

TABLE III
SOME RESULTS OF THE RESEMBLANCE RATING SYSTEM EVALUATION

Case Number	Similarity			
	Overall Face	Outer Contour	Mouth	Nose
Case 3	97%	92%	45%	100%
Case 4	89%	79%	91%	98%

B. Face Pool Comparison

This evaluation method was conducted for the sample of real life skulls that had the deceased persons photograph. An online survey was conducted where respondents were requested to select the photograph that is most similar to the reconstructed 3D model, out of a range of photos which included the diseased person's actual photo as well.

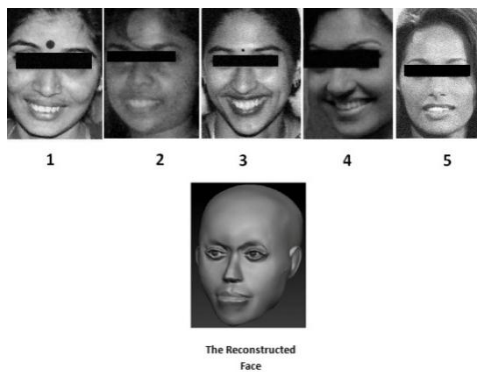


Fig. 20 The online survey created with a pool of faces for respondents to choose from

It should be noted that it is practically impossible for the process of facial reconstruction to result in a face that is 100% similar to the deceased. In the practical context it is not needed either. The relatives of the deceased will be on the lookout for any news regarding him/her and if reconstructed images are somewhat similar to the person and are published in the media they will present them to identify the corpse.

Thus the this survey was not created to compare the actual photo of the deceased with the 3D model, but rather to observe the ability of the general public to identify the actual photo of the deceased out of the list of other photos provided of similar people.

TABLE IV
THE RESULTS OF FACE POOL COMPARISON

Case Number	Photo 1	Photo 2	Photo 3	Photo 4	Real Photo
Case 1	14%	9%	6%	19%	52%
Case 2	7%	15%	12%	22%	44%

C. Photogrammetric Analysis

This evaluation method was adopted to measure the *similarity* between the reconstructed and real faces. In this, the distance between specific facial components in the model and the actual photograph were measured and compared. The chosen components were the standard components that are always used in the photogrammetric analysis. The logic behind this technique was that if the reconstruction process was of high accuracy the difference ratio between the facial

components of the real life image and the modelled image would be less.

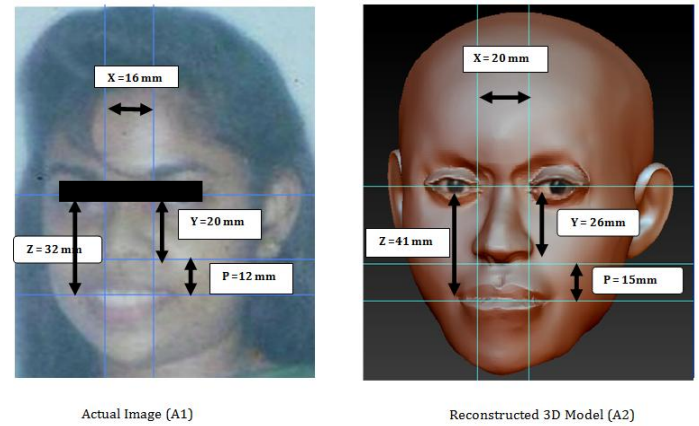


Fig. 21 Photogrammetric Analysis

In figure 21, X refers to the distance between the starting point of two eyes closest to the nose, Y refers to the distance between that same point in a eye to the end point of nose, Z refers to the distance between eye and mouth and finally P refers to the distance between mouth and nose. The results acquired by measuring the distance between these components in some of the reconstructed faces are in the table V.

TABLE V
RESULTS OF THE PHOTOGRAMMETRIC ANALYSIS

Case Number	X	Y	P	Z
Case 1	0%	10%	8.33%	3.125%
Case 2	3.33%	*	*	8.78%
Case 3	0%	10%	10%	3.33%
Case 4	14.28%	3.44%	18.18%	25%

*Unable to obtain clear values

D. Morphing Technique

Another evaluation was done using free morphing software which is known as Free Morphing 2.1. The software was used to identify the differences existing between the ante mortem photograph of the deceased (source image) and the 3D model reconstructed (target image). This method is closely related with superimposition technique which is commonly used to identify missing people when an ante mortem photograph of the deceased is present.

The image sequence (Figure 22) generated by the software for a given source and target image clearly shows how the facial features and the contours of the face, morphs from one to another. By identifying the intermediary transformation stages the authors were able to verify the soft tissue alignment and to observe if there were any obvious errors.



Fig. 22. Image Sequence Generated by the Morphing Software for the given source image and the target image

Thus it is evident that all the evaluation methods adopted to measure the *identifiability* and *similarity* resulted in positive feedback.

VII. DISCUSSION

Since 3D scanners are not commonly available, it was found that using CT images of the skull can also be used as a viable option to generate a 3d models. The advantage of this method is that since the CT scanner possesses the capability to capture details precisely, the resulting model would be of very high accuracy and detail. The DICOM output of the CT scanner was imported in to an image processing application dedicated to DICOM images [Osirix-viewer] and the 3D model was obtained.

The proposed semi-automated methodology of reconstructing based on facial muscles; especially in the field of computer based 3D reconstruction is a novel approach.

The literature stated that the manual reconstruction method resulted in a natural looking output but lacked in efficiency and expertise. Further it was found from the course of this research that a fully automated technique would be more efficient compared to the manual technique. But the output due to the process being fully automated resulted in an unrealistic final model. Thus it was decided to use a semi-automated technique by combining the advantages of both the manual and fully automated techniques. This methodology automates the steps of the reconstruction process where inefficiencies occurred in the manual process (E.g. Creating a plasticine mould of the skull, Sculpting muscles manually using modelling clay). Since the manual reconstruction is done mostly by modelling the facial muscles on a model of the skull, the authors were of the opinion that having a direct map between this technique and the computerized 3D reconstruction process would result in a more natural looking output. Thus muscles were sculpted manually in a digital environment which unlike in the fully automated process resulted in a more natural realistic output.

Since all four evaluations gained positive results as well, reconstructing the face using the muscle based anatomy approach was proven to be reliable and accurate to a sufficient extent. The following problems were addressed by this research.

TABLE VI
SPECIFIC PROBLEMS ADDRESSED BY THIS RESEARCH

Problem	Solution
Lack of Tissue thickness data of Sri Lankans	Tissue Thickness Analysis
Lack of facial features differences data on Sri Lankans	Facial Feature Analysis
Expert technical knowledge on facial reconstruction process	3D sculpting based simplified process
High Cost of exiting solutions	699\$ software cost
Time Constraint	4-5 Hours

After the cost analysis was done it was quite apparent that the solution presented was feasible especially in monetary terms. The cost of the software used, amounts to \$699 and that compared with the systems used in other countries is a very low cost solution. The time consumed was also considerably less when compared with the manual technique. Furthermore the expertise in 3D modelling would not be an issue either due to the reason that to a 3D modelling artist the muscle sculpting learning curve would be substantially short. Comprehensive manuals and documentation have been created by the research team.

VIII. FUTURE WORK

Several areas can be pointed out in to which this work can be taken forward to. One such significant area is to incorporate

this system to the national missing people database. If implemented, then the reconstructed face could be compared with those in the database for a positive identification. The same technique of facial recognition which was used in the evaluation stage of this project could be used for this purpose.

This can also be extended to be used by the archaeologists as well. If a method could be determined to unearth the tissue thicknesses of the excavated human remains, the same framework that has been suggested by the researchers to rebuild the faces of modern man can be adopted to build the faces of our ancestors as well. And hence a realistic face could be given even to the Balangoda Man himself.

IX. CONCLUSION

Although facial reconstruction using computer technologies is widely used in developed countries it is still used at the prefatory level in Sri Lanka. And the aim of this research is to introduce these technologies to the forensic experts who are yet to move away from the manual clay based reconstruction techniques.

A substantial amount of researches have been carried out in the area of facial reconstruction, but reconstructing via the usage of facial muscles, especially in the field of computer based 3D reconstruction are rare. Further it aided to produce a more natural looking face. Hence reconstructing the face using a semi-automated muscle based anatomy approach is proven to be reliable and accurate.

Facial approximations for the 20-30 age group and medium weight cases were produced by this research. The outputs were successful and thoroughly evaluated using accepted evaluation techniques. For the process, optimized tissue thickness landmarks and an accepted facial muscle anatomy based model were used. Although the research was performed on certain age and weight groups this process would be scalable to any other age/weight groups as well (given that the tissue thickness data for all those groups are collected.)

Thus it was concluded that implementing a national unit for facial reconstruction, which would adopt this procedure would be a very timely act for the island

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