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Human Face Reconstruction using Divine Proportions and Gestalt for Occluded Video Face Recovery in Forensic Analysis using Deep Learning

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Abstract*: Forensic video analysis has been used in diverse kind of high-profile cases, global discrepancies, and conflict zones. It is a three-phase process involving the scientific examination, comparison, and evaluation of video evidence in legal matters. Human facereconstruction using deep learning for occluded video face recovery to aid in forensic analysis is the main objective of this paper. Forensic facial reconstruction is a combination of both scientific methods and artistic skill. In this paper, we introduce a method for reconstructing human faces occluded by short noise in nighttime video clips. A skull database is created with unique skull models that vary in shape, form, and proportion. A mathematical model of the human body, utilising the golden ratio algorithm, is proposed and used to determine the proportions of occluded faces. The closure principle of Gestalt theory of visual perception is used to fill in the missing parts of a face design and to create a complete face image using a generative adversarial network (GAN). The proposed model is found to have a 50% lower reduced Median error rate and a 20% lower standard deviation than PrNet, and a 10% lower Mean error rate than 3Dddfav2.

***Keywords*: Forensic, Face Reconstruction, Golden Ratio, Gestalt.**

I. INTRODUCTION

Facial reconstruction is used to rebuild a human face when specific image processing and video processing techniques fail to detect a human face from a completely noisy frame. The noise occurs due to various reasons, such as suspects being too far away from the camera location, low-resolution images, and poor standard-definition (SD) video recordings. Such poor-quality evidence becomes a real challenge in facial recognition and analysis. Forensic facial reconstruction plays a vital role in identifying criminals. In forensic science, a human face is recreated using the skeletal remains of a person. Facial Approximation has many procedures and its pitfalls [15]. Traditional face reconstruction was based on human art [17] skills, using clay materials which essentially required a lot of handwork and creativity. To identify a suspect, forensic science uses face reconstruction [18] techniques by embedding soft tissues onto a human skull [1-3].

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Using facial skeleton bones, facial appearances are reconstructed using the Manchester technique by considering the factors of soft tissue thickness and facial muscles [4]. To find similarities between skulls, the Mahalanobis distance is used [5]. Virtual sculpture systems are used in computerised models for 3D face reconstruction. Tissue depth method uses soft tissue depth data in which the use of needles, x-rays or ultrasound obtained fine measurements [10,14]. In the anatomical tissue method, soft tissue depth data is not considered, but facial muscles are taken into account. Reconstruction was achieved by shaping the muscles, glands, and cartilage onto the skull layer by layer. Reconstruction of fossilized skulls has been achieved by this method [13]. In combination with the Manchester method, both soft tissue thickness and facial muscles are considered. Facial tissue pegs or markers are added on the skull at 90 degrees using a 3mm drill bit. Each peg length represents the mean tissue depth at the anatomical point. The facial tissue depth is determined by age, gender, build, etc. [10,11,12]. This is one of the most accepted methods for facial reconstruction. Computerised 2D reconstruction-based cranial face reconstruction methods use tissue depth markers on an unidentified skull at various anthropological landmarks. Then, 3D animation software and a virtual sculpture system are used to model the face onto the skull. This method decreases practitioners' subjectivity and skill. This is considered to be a fast, efficient and cost-effective method which creates multiple images of the same face quickly and efficiently [6,7,8,9]

For identifying the suspect in forensic crime cases, the facial reconstruction process uses the Manchester method on specific Facial tissue data having multiple classes [26]. Computerized method, such as hierarchical radial basis function with mesh template, is used to generate the surface of the face [27]. To connect the skeletal structure with the overlying soft tissue, techniques such as 2D artistic representation, 3D sculptural reconstruction, and computer-generated images are employed. The problem of identifying the similarities of skulls is based on Mahalanobis distance, which is the measurement of the distance between a point P (standard deviation) from a distribution D(mean) [5]. Sensable technologies provide important skeletal details for facial reconstruction, such as muscle attachment strength, position of the eye and position of the malar tubercle [33,34,35,36]. Facial reconstruction has seen significant changes over the years with scientific methodologies [28]. Recent researches on facial reconstruction use 2D artistic representations, 3D sculptural techniques and 3D computer-generated images [29].

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The technique of superimposition for face reconstruction requires photographic evidence of a suspect [30]. This technique involves using the photograph of a suspect and overlaying it onto a skull to create a reconstructed face [30]. By aligning specific facial features and structures, forensic experts can create an approximation of the suspect's appearance [31]. Face reconstruction can be performed using a variety of techniques, including 3D morphable model-based reconstruction, epipolar geometry-based reconstruction, one-shot learning-based reconstruction, deep learning-based reconstruction, and shape-from-shading-based reconstruction.

II. PROPOSED METHODOLOGY

A. Human Face Reconstruction Model

Human face reconstruction model is an idiosyncratic model designed using Blender [32], Gans [21], Human Skull DB, using FASTAI, PYTHON, and TENSORFLOW. The Blender is equipped with Selective Parameters, which include a skull image, tendons, bones, Face muscles, and skin thickness, and utilises the Precise Face Metrics algorithm. A selective, precise Facemetrics algorithm is created using Vetrivian [23] human model design and divine proportions of human body. The Precise Facemetrics algorithm is carefully designed to generate an exact, accurate, and precise human face model. In Human face reconstruction models, tendons, face bones, face muscles, skin thickness, colour, and shape are considered as input factors in image form. The set of input factors is used to model a human face. The newly modelled face is named the Reference Skull. A HumanskullDB database is created to serve the purpose. The HumanskullDB consists of 500 images of male and female skulls. The database created, HumanskullDB and the Reference Skull are passed as inputs to the generator module network of Generative Adversarial Network (GANs) [21]. The generator network generates a set of new Face Images. A Region-Based Human Face Database (Vgg face2[20]) is used for verifying the face image against the query image. The VGG Face2 dataset and the generated new face image are passed through the proposed identical dual Network (IDN) for comparison. Two CNNs are used. One to train the new Face Image and another CNN to train RHFDB. The new face image and an image from RHFDB are trained. After teaching, the two feature vectors are compared. The feature is maintained as a constant input. N-1 comparisons are performed for each image in the RRFHDB. At each instance, a pair of images is trained via CNN [16, 25]. Two feature vectors are produced. Generated feature vectors are stored in VECDB [22] vector database. Autoencoders and latent spaces are used to find similar images.

B. Vetrivian-Human Model: Proportions Suggested by Leonardo Da Vinci

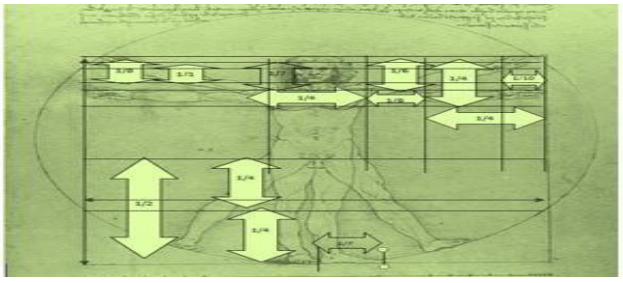

Fig. 1. Vetrivian-Human Model

C. Proposed Precise Facemetrics Algorithm Based on Divine Proportions

Read the gender and colour of a person as GENDER, COLOR
Read the total height of a person as HEIGHT
Assign the length of the outspread ARMS=HEIGHT
Calculate the length of the hand:
Hand = (1* height) / (10*1)
Calculate the length of the hairline to the bottom of the chin:
HARLNTOCHN= (1* height) / (10*1)
Declare the length of the bottom chin to the top of the head as B.OTCHNTOHEADTOP.
Calculate BOTCHNTOHEADTOP = (1* height) / (8*1)
Declare face points:
FP1: throat pit to below the nose
FP2: from below the nose to the top of the eyebrows
FP3: top of eyebrows to hairline
FP4: hairline to top of head
FP5: from the throat pit to Adam's apple
FP6: Adam's apple to below the nose
The length of the face = (FP2 + FP3 + FP6)
The width of the face = (length of face/1.618)
Left tip of eyebrow to the right tip of eyebrow = FP2 * 1.618
From tip of eyebrow to between the eyes = 2 * FP2/1.618

D. Humanskull DB database(Skull And Face Points)

Fig. 2. Skull And Face Points

The HumanskullDB database includes head muscles, face sinews, and frontal, lateral, and anterior views of superficial and deeper facial muscles, skin thickness maps, female face maps, and micro-needling depth chart images. The database consists of 500 images.

E. Human Face Database (RRHFDB)

Digiface [19] dataset is used for facial verification against the query face image. The dataset contains 1.2Million face images with factors of pose and age. There are 110000 identities. The dataset is categorised by region in our project.

Fig. 3. Digiface dataset

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F. Identical Dual Network (IDN)

In an Identical dual network, two CNNs are used. One to train the new Face Image and another CNN to train VGGFace2 [20]. The new face mage and an image from VGGFace2 are trained. After training, the two feature vectors are compared. The feature vector of the query image is maintained as a constant input. N-1 comparisons are performed for each image in VGGFace2. At each instance, a pair of images is trained via CNN [16, 25]. Two feature vectors are produced. Generated feature vectors are stored in VECDB [22] vector database. Autoencoders and latent spaces are used to find similar images. The similarity metric is used to find the closeness of the image.

G. Vecdb Vectordatabase

This is a temporary database to store the feature vector generated for the query image and the feature vectors created for the photos present in VGGFace2 [20] dataset.

H. Ges Talt Design of Principles

Closure property of Gestalt [24] principle is applied in this project with the perception of human brain filling missing parts of an occluded face and in face reconstruction to build complete face of human being.

I. Reference Input Files

- Head muscles, face sinews, frontal, lateral and anterior view of superficial muscles and deeper muscles of face, skin thickness-map, female face map and micro-needling depth chart images.
- Precise Facemetrics algorithm based on divine proportions.

J. Proposed Human Face Reconstruction Model:

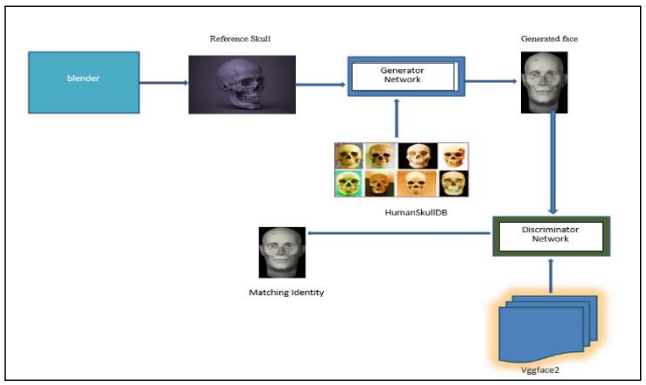

Fig. 4. Human Face Reconstruction Model

III. RESULT

The reference skull is designed using Blender software, based on visual testimonials from the human body of suspects or victims, if found. The designed skull and humanskullDB are passed as inputs to the generator. Based on the inputs, the generator model identifies patterns in the input data and generates a new set of faces. The generated new set of faces is stored in an array data structure and processed one by one, for similarity against VGGface2 [20] dataset to find asuitable match towards the query image.

Fig. 5. HumanskullDB

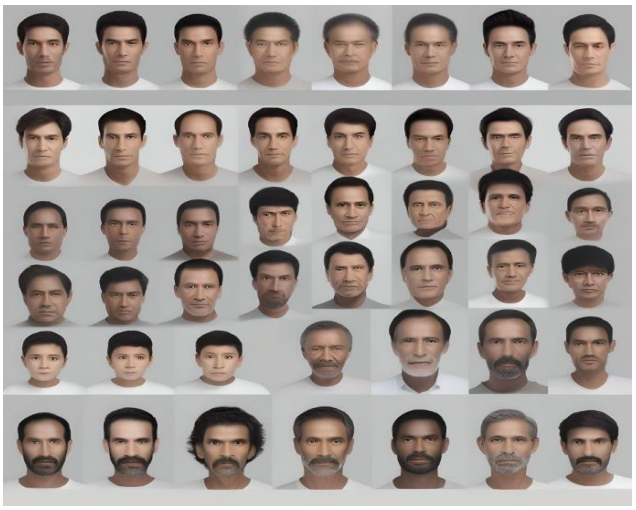

Fig. 6. New Faces Generated

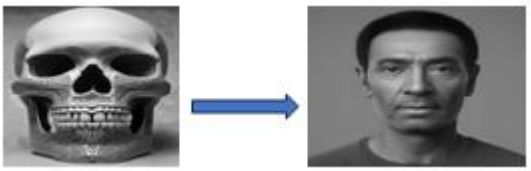

Fig. 7. References Kull and Matching. Image

Table I: Comparing the Performance with BenchmarkModels:

Rank	Model	Mre (mm)	Mre(mm)	Sde (mm)
1	Ours	0.80	0.78	0.45
	Mica	0.90	1.11	0.92
2	Focus	1.04	1.49	0.92
3	Deca	1.09	1.54	1.10
4	Deep3d-facerec on pytorch	1.11	1.53	1.18
5	Pixie	1.18	1.53	1.21
6	Deng 2019	1.23	1.57	1.25
7	Ringnet	1.21	1.59	1.29
8	Flame template	1.21	1.57	1.31
9	Dib2021	1.26	1.89	1.31
10	Ynergynet	1.27	1.98	1.31
11	3Dddfav2	1.23	2.33	1.31
12	Umdfa	1.52	1.87	1.39
13	Prnet	1.50		1.57

Median, Mean and Std. Reconstruction Error

IV. CONCLUSION

Forensic facial reconstruction using deep learning techniques and Blender is implemented successfully in this paper. This paper demonstrates the reconstruction of occluded human faces in nighttime video clips.

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Using the skull database which has unique skull models with varying shapes, forms and proportions and proposed human body mathematical model biometric using golden ratio algorithm remaking the occluded face with divine proportions using closure principle of gestalt theory of visual perception to complete the missing parts of a face structure was achieved with reduced error rates in Median Reconstruction Error-0.80, Mean Reconstruction Error-0.78 and Stddev Reconstruction Error-0.45 compared to benchmark models.

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Authors Contributions	All authors have equal participation in this article.

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