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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 of scientific examination, comparison, and evaluation of video 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 to reconstruct human faces occluded due to short noise innight-time video clips. A skull database is created with unique skull models with varying shapes, forms and proportions. Human body mathematical model biometric using golden ratio algorithm is proposed and used to find the occluded face proportions. Closure principle of gestalt theory of visual perception is used to fill in the missing parts of a face design and to create a whole faceimage using gan. The proposed model is found to have 50% lesserreduced Median error rate and 20% reduced Stdev than PrNet and10% 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 certain image processing and video processing techniques fail to detect human face from a completely noised frame. The noise occurs due to various reasons such asthe suspects are too far away from the camera location, low resolution images and poor standard (SD) video recordings. Such poor-quality evidences become real challenges in facial recognition and analysis. Forensic facial reconstruction has a vital role in identifying the criminal. In forensic science human face is remade using skeletal remains of a person. Facial Approximation has many procedures and its own pitfalls [15]. Traditional face reconstruction was based on human art [17] skills, using clay materials which essentially required a lot of handwork and creativity. In order to identify a suspect forensic science uses face reconstruction [18] techniques by embedding soft tissues onto a human skull [1-3][37][38].

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Using facial skeleton bones facial appearances are reconstructed using manchester technique by considering the factors of soft tissue thickness and facial muscles [4]. To find similarities between skulls mahalanobis distance is used [5]. Virtual sculpture systems are used in computerized models in 3d face reconstruction. Tissue depth method uses soft tissue depth data in which fine measurements were obtained by the use of needles, x-rays or ultrasound [10,14]. In anatomical tissue method soft tissue depth data is not considered but facial muscles are considered. Reconstruction was done by shaping muscles, glands and cartilage onto the skull layer by layer. Reconstruction of fossilized skulls have been achieved by this method [13]. In combination 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 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. Computerized 2d reconstruction based cranial face reconstruction method uses tissue depth markers on an unidentified skull at various anthropological landmarks, then photographing the skull 3d animation software and virtual sculpture system are used to model the face onto the skull. This method decreases practitioner's 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 facial reconstruction process uses Manchester method on a specific Facial tissue data having multiple classes [26]. Computerized method such as hierarchical radial basis function with mesh template is used to generate surface of the face [27]. To connect the skeletal structure with the overlying soft tissue techniques including 2Dartistic representation, 3D sculptural reconstruction, and computer-generated images are used. The problem of identifying the similarities of skulls is based on mahalanobis distance which is the measurements 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 eye and position of malar tubercle [33,34,35,36][39]. Facial reconstruction has seen major changes over the years with scientific methodologies [28]. Recent researches of facial reconstruction use 2D artistic representations, 3D sculptural techniques and 3D computer generated images [29].

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]. The face reconstruction can be done using a variety of techniques, viz. 3D morphable model-based reconstruction, epipolar geometry-based reconstruction, one-shot learning-based reconstruction, deep learning-based reconstruction, and shape from the 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 instructed with Selective Parameters consisting of skull image, tendons, bones, Face muscles, skin thickness and with Precise Face Metrics algorithm. Selective precise Facemetrics algorithm is created using vetrivian [23] human model design and divine proportions of human body. Precise Facemetrics algorithm is carefully designed to generate exact, accurate, and precise human face model. In Human face reconstruction model tendons, face bones, face muscles, thickness of skin, color, shape are considered as input factors in image form. The set of input factors are used to model human face. The newly modeled face is named as Reference Skull. A HumanskullDB database is created to serve the purpose. The HumanskullDB consists of 500 male and female skull-face images. The database created, HumanskullDB and the Reference Skull is 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 query image. The vgg face2 dataset and generated new Face Image is passed towards 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 is trained. After training the two feature vectors are compared. Feature is maintained as 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. Autoencoder and Latent space is used to find similar images.

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

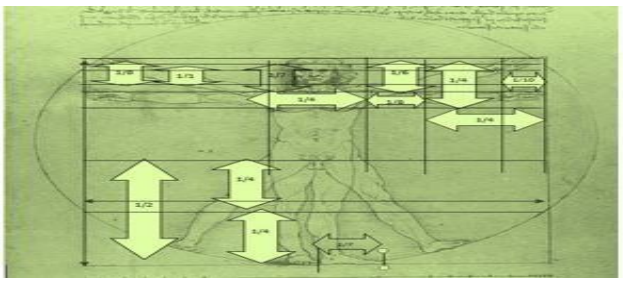

Fig. 1. Vetrivian-Human Model

C. Proposed Precise Facemetrics Algorithm Based on Divine Proportions

Read the gender and color of a person as GENDER, COLOR
Read the total height of a person as HEIGHT
Assign length of the outspread ARMS=HEIGHT
Calculate the length of hand:
  Hand = (1* height) / (10*1)
Calculate the length of hairline to the bottom of the chin:
HARLNTOCHN= (1* height) / (10*1)
Declare length of bottom chin to the top of head as BOTCHNTOHEADTOP
Calculate BOTCHNTOHEADTOP = (1* height) / (8*1)
Declare face points:
FP1: throat pit to below nose
FP2: below nose to top of eyebrows
FP3: top of eyebrows to hair line
FP4: hair line to top of head
FP5: from 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

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 are part of HumanskullDB database. 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 categorized region wise in our project.

Fig. 3. Digiface dataset

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F. Identical dual Network (IDN)

In 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 is trained. After training the two feature vectors are compared. The feature vector of query image is maintained as constant input. N -1 comparisons are performed for each image in the 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. Autoencoder and latent space is used to find similar images. The similarity metrics 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 images 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:

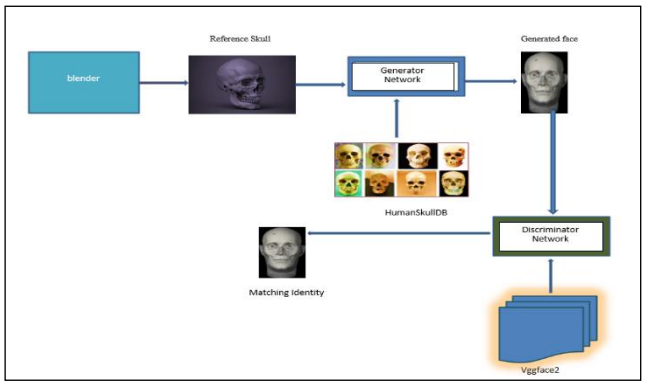

Fig. 4. Human Face Reconstruction Model

III. RESULT

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

Fig. 5. HumanskullDB

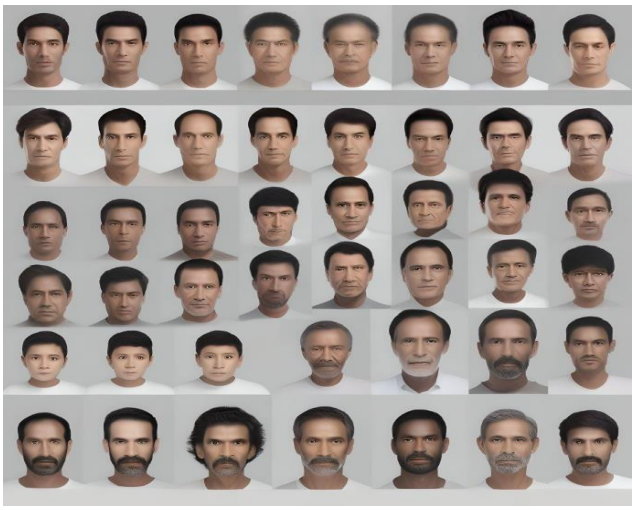

Fig. 6. New Faces Generated

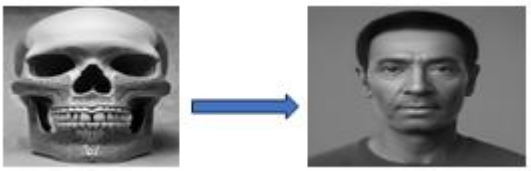

Fig. 7. References kull and Matching Image

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 Stdde. Reconstruction Error

IV. CONCLUSION

Forensic facial reconstruction using deep learning techniques and blender is implemented successfully in this paper. Reconstructing human faces which are occluded due to short noise in night-time video clips is demonstrated inthis paper.

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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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