Chapter 1

Introduction

1.1 Human Face: An Overview

Face means identity. Face reveals many attributes indicating our age, sex, and race, health and mood. Every human has got his identity, a unique face.

Pablo Picasso asks “Who sees the human face correctly: the photographer, the mirror, or the painter?” and William Shakespeare writes, “God has given you one face, and you make yourself another.” Everyone has his own perspective to analyze face and comes out with his own interpretation. The pocket Oxford dictionary defines the face as “the front part of a person’s head from the forehead to the chin.” Mathematician studies actual dimensions and its relationship whereas artist looks it as a shape, form and proportion. Face is like kaleidoscope, every time it reveals different meaning.

Cave paintings, manuscripts, sketches, illustrations, portraits, sculptures, all speak the development of mankind. These artworks reflect cultural and technological developments. In a cultural rebirth from the 14th through the middle of the 17th century which is called as renaissance, many artists and illustrators made efforts to depict the human face through their creations. We can easily make out pace of the study of human face in the last millennia. From centuries we are documenting our observations and from last 30 years it is at peak.

Human face is more than a changing painting with time, a sculpture with life. It bewitches us with its beauty. Many mathematicians began to analyze beautiful faces based upon evolutionary biology and psychology. In 19th century, Physical anthropology was developed to study the statistical data about the distribution of body dimensions in the population. Mathematical and statistical analysis of human face revealed many obscure details and scientists started investigating formulas for facial beauty. Anthropometry refers to the measurement of the human individual for the
purposes of understanding human physical variation explains the significance of differences in body proportion between populations whose ancestors lived in different environmental settings.

In 18\textsuperscript{th} century, whole world was intrigued by many streams of science. Once of them was Genetics, discipline of biology, the science of heredity and variation in living organisms. Darwin's theory of evolution and Gregor Mendel's study of inheritance are the most revolutionary concepts in the history of mankind. Human faces are ever evolving carrier of pattern and mutating surface. Till 19\textsuperscript{th} century, Human group classification was mainly based on facial features. There are many theories about human races based on skin color, cranial or facial features and hair texture. Some of them are still topic of debate. The 0.1% genetic difference that differentiates any two random humans is still the subject of much debate. In the same period other streams like forensic science, plastic surgery and orthodontics also greatly evolved and added another dimension to the study of human face.

Since last 30 years, Computer science has made phenomenal developments and impacted each and every field. Because of its amazing data processing capability and speed the development pace was exponentially increased. With the help of Computer graphics, virtually every object can be simulated and visualized in 3D environment. Today people are performing anthropometry with three-dimensional scanners to calculate segmental volumes of an individual body scan. There are several examples in entertainment world that computer graphics has achieved ultimate realism. Human face has extremely intricate topology. In Hollywood movies facial modeling, texturing and rendering is done in such a way that audience can not distinguish between fake and photo.

Human face is the nature’s most magical and mysterious surface. It can send messages too elusive for science. Even after all the information is digitized, specific human face modeling requires highest level of artistic and analytical skills. In entertainment industry, visual appeal carries more importance than actual dimensions. This output is
useless for medical industry. Many Medical applications are based on 3D range data scanned by expensive MRI equipments. Various fields operate on different input data and have different requirements. Everyday each field is evolving in different direction. Those inventions are revealing new dimension of human face. Now there is requirement of a flexible and adaptive liaison between all these developed and ever growing streams which will have the compatibility with future technology. Due to this cause the researcher felt need to study the selected topic.

1.2 Motivation

Pablo Picasso says “Are we to paint what's on the face, what's inside the face, or what's behind it?” From centuries many legendary people tried to explicate various aspects of human face, but still it remains unsolved mystery.

There are many other aspects of human face. Most significant are:

i. Tool for living, Biological importance

Biologically, face is the most important multifunctional part of our body.

ii. Tool for communication, impression and expression

Human face is the most favored communication tool inseparably associated with his emotions. The facial impression comes with perception. It is psychological evaluation and look of personality despite of the outer skin. By nature, facial impression is emotional, subjective and synthesis based on personal thoughts and experiences so sometimes it becomes controversial. Facial expression comes from the motions or positions of facial muscles it conveys emotions. The Facial Action Coding System (FACS) developed by Paul Ekman, Wallace V. Friesen, and Joseph C. Hager is a method for measuring facial behaviors.

iii. Tool for identity, Biometric tool for identification
We come in this world with a face and everybody recognizes us with that face. Every person continuously refines his own face recognizing methodology and builds and modifies his own database of human faces in memory. Each brain in this world is an independent system. Based on uniqueness of features many biometric philosophies were developed based on retinal identification, ear Pattern and facial structure. Thus face has become premier tool of identification.

Ideal facial reconstruction system should consider all above mentioned aspects of human face and predict a unique facial model that is exact match with fact.

Curious and creative mind raises several questions about Human Face like

a. How it reveals age, race, sex and health?

b. What are those landmarks where son shows some resemblance to father’s or ancestor’s facial pattern? Is there any genetic explanation for this phenomenon?

c. How a layman enjoys caricature and identifies the person although it distorts all the dimensions and breaks all the rules of anatomy?

d. After changing makeup, hairstyle and apparels, how a small kid also can recognize actor?

e. How to draw a portrait of a person whom you have never seen in life?

Likewise there are many queries motivated researcher to study the human face. Like many virtuosos and scientists, researcher was also captivated by study of human face and took relentless efforts to analyze it by drawing portraits and working in computer graphics industry. Researcher got acquainted with many aspects of human face from his gurus, guides and professors. There are many who meliorated the knowledgebase.

Researcher thinks that now it is his moral responsibility to serve mankind. With this only thought in mind researcher embarked the thesis. It is his long cherished wish to
explicate human face into its simple form. This endeavor may reveal mankind a different realm of human face.

Nature’s cipher associated with every Face will be revealed.

1.3 Importance

The whole world population is increasing by every second. It was 6,908,777,549 on 09:23 UTC (EST+5) Mar 29, 2011. ¹ Amazingly each one has got unique face. Although all the faces have same number of features and follow similar structural rules, we can find considerable variation to identify a person. Within approximately 9”x 7”x 8” volume, we can see so many variations. Mathematically, it is possible that there might be some repetition of pattern but still there is no acknowledged formula to prove this. It is important for any mathematician, statistician or student of morphology to find answer for this problem.

Another interesting fact that the hardest part of our body teeth, softest and most flexible part tongue and lips and most reflective parts eyes, all find place in the face. Modeling these parts along with its properties is a great challenge.

The fact that everyday new innovations are being made in all fields of science, every curious practitioner, thinker and philosopher is documenting his experiments and observations. This trend has picked up speed and complexity with the help of computer technology. Human Face related observations can be found in many different streams. The face related information scattered in various fields can be synthesized to form a solution that will address many questions raised over many generations. To navigate through this huge information ocean and extract the required data, one must have know-how of each stream. Keeping up with the flow of information in these fields is a difficult task. In its absence there might be chances that

¹ World Population Index  http://www.census.gov/main/www/popclock.html

Coordinated Universal Time (UTC) is the equivalent of Eastern Standard Time (EST) plus 5 hours or Eastern Daylight Saving Time (EDT) plus 4 hours.
domain from one stream may not be linked in proper sense with appropriate range data across other stream.

Each field has different concepts, processing style and techniques to deal with face study. Medical anatomy is dominated by Latin names on the other hand Mathematics is full of Greek alphabets and symbols. The philosophy of Design pattern in art and computer technology has completely different meaning and application.

Face is made up of hard elements like bone, cartilage surrounded with flexible muscles, nerves, blood vessels along with fat and other tissues. This is wrapped by semitransparent skin and hair. Various applications with different paths address certain issues but because of limitations in philosophy it fails to address some other issues. Although special cases can be addressed, it requires highly developed skills in specialized industry and dedicated time of many experts. Still there is a requirement of a complete modeling and visualization system which will address all these elements in detail. Most of the entertainment related technologies use surface based modeling process whereas most of the medical applications are image based or volumetric analysis based pay least attention to external look and texture. In medical industry, 3D head model expects the accuracy, functionality and natural response so that surgeons can plan a surgery and get realistic feel and feedback before operating actual patient. If one has to reconstruct the face using 3D modeling technique then it has to match with anthropometric dimensions and associate algorithms that mimic functionality. On the contrary, entertainment industry normally works with 3D models having proportionate dimensions and fake textures to get the expected look and feel. It does not require the dimensionally accurate model and physically based rendering all the time. For Game industry, exact biological construction of features is a least concern; it should be low poly and simple so that highest data processing speed can be achieved. It is important to address all the needs of various fields, essentially this multidisciplinary study and system design is a greatest challenge for many professionals.
1.4 Research Statement
Developing Methodologies for Parametric Reconstruction of Human Face in 3D Environment

1.5 Explanation of terms used in Research Statement
1.5.1 Developing Methodologies
Development of any new system opens many options of vast data collection from various sources, conceptualizing methods. Methodologies term used in proposed title can be explained as “the systematic set of methods that can be applied to achieve desired results.” The set of methods should promote strong collaborative system with dynamic gathering of requirements. In the current context methodology involves phase wise development plan that demonstrates the flexible way to deal with multidisciplinary information. The proposed methodology is analogous to rapid application development process, by virtue; it quickly and interactively visualizes the results in 3D environment.

1.5.2 Parametric
The term parameter, which originates in mathematics, has a number of specific meanings in various other fields such as statistics and computer science. In the proposed title parametric terms used in the sense of parametric equations, are methods of defining a function using parameters. Technically, it determines a range of variations and especially a factor that restricts what can result from a process or policy. It can be called as "a limit or boundary." Any attribute is linked to mathematical parameters that establish the limits of other variables. Although there are many other non technical meanings of parameter, in this proposed thesis researcher refers term parameter to its technical sense "limit," though the precise meanings of the two words differ.

1.5.3 Reconstruction of human face:
Reconstruction of human face is referred as the scientific art of building the face onto the skull for the purposes of individual identification (Wilkinson C, 2004)
1.5.4 3D environment:
It is referred to three dimensional space and depth.

1.6 Research Objective
The main objectives are as follows

i. Surface modeling of human face in 3D environment

ii. Deal with streams which interact with Human Face like anthropology, forensic science, physiology and 3D modeling.

iii. System should be able to work with very minimal input like verbal description or very precise input like anthropometric dimensions of an individual.

iv. Deliver the 3D data which can be readily imported in various 3D environments

v. Output of the system should be easily be verified and tested

1.7 Assumptions
In the proposed system of reconstruction of human face researcher planned phase wise development process which is based on the inferences and findings of few scientist and artists. The assumption made to derive and establish constraints of 3D human facial model in different phases is given below:

i. In AdarshMudra phase (Section 3.6.7); to derive the dimensions and proportions of facial features of generic Indian, researcher followed the guidelines of male features proportions published by Avard Fairbanks.

ii. In AdarshMudra phase (Section 3.6.7), the ideal measurements, proportion and relationship of facial features is based on Leonardo da Vinci's Facial Third Formula.
iii. The constraints set in the Mudra (Section 3.6.1) and PurnaMudra (Section 3.6.2) phase conform to the survey and critical findings of Indian Anthropometric Dimensions by Debkumar Chakrabarti

iv. In Jeevak phase (Section 3.6.8), to derive the facial skin displacement from skull the calculation of tissue depth is based on critical findings of Facial soft tissue thickness in northwest Indian adults Forensic Science International, Volume 176, Issue 2, Pages 137-146 by D. Sahni, Sanjeev, G. Singh, I. Jit, P. Singh

While deriving the facial features from skull researcher will follow the facial approximation techniques which come along with its own limitations. The parts of facial features near to bone like forehead, nose bridge, cheekbones will have better prediction but the eyebrows, eyes, nasal tip, ear and lips will be predicted from genetics information may not be perfect in dimension.

1.8 Hypothesis
Research Hypothesis: The proposed research study has following directional and null hypothesis.

i. Directional Hypothesis (H1):
The anthropometric dimensions of bony facial features of the reconstructed 3D facial model using proposed system (Section 3.6) should fit within 5% tolerance of the anthropometric dimensions of the target human face.

ii. Null Hypothesis (H0):
The anthropometric dimensions of the reconstructed 3D facial model using proposed system may not fit within 5% tolerance of the anthropometric dimensions of the target human face.

1.9 Methodology of the Proposed Research
Explanation of methodology of proposed study in brief:
i. Gathered study of Human face in various streams (Section 2.2)

ii. Analyzed each one and extracted needed information

iii. Drawn need and requirements from various fields

iv. Decided scope of the project

v. Phase wise development to handle complexity of the subject (Section 3.6)

vi. Ideated new concepts like Vyaktirekha and Jeevak (Section 3.6.8)

vii. Experimented various techniques and derived the most suitable path

viii. Analysis of data and validation of results

For more details please refer section 3.2 and 3.3.

1.10 Techniques of Research

i. Observation: Observations were made during the demonstration of 3D reconstruction human face software. (Section 3.6.7.1.1)

ii. Collection: Facial reconstruction software was demonstrated and feedback was collected and reviewed. (Section 6.2)

1.11 Tools of Research

i. Questionnaire: By asking various professionals to record their reactions towards reconstruction of 3D human face. (Section 7.1)

ii. Opinionnaire: Opinionnaire was designed by the researcher and opinions were taken from various professionals. (Section 7.2)
1.12 **Scope of the Project**

i. The derived 3D head model will be useful for developing 3D medical tutor interactively showing and scientifically explaining each facial part and as a base model for head anatomy research.

ii. Any person having some forensic inputs will be able to render 3D human face without any artistic skills. The system would act as an application for forensic reconstruction of human face from skull.

iii. The Police and security system may use this system for visualizing missing people or criminals. The system can also be used for building library of 3D face models of criminals.

iv. The 3D face model can be used as character asset library to produce 3D animated movies and 3D games. The system will help to deliver fast and accurate 3D human face model. Entertainment Industry will enjoy this as one of the option for replacement of time consuming and highly skilled human face modeling process.

1.13 **Limitations**

i. Focus restricted to reconstruct normal facial features.

As explained in the chapter, facial features start forming from gestation and keeps on growing till adult stage. Ideally human grows predictably and proportionally and the same will be observed in human face. This is taken as the basic assumption of the proposed system.

ii. Facial feature malformation caused by any reason is not considered.

Unnatural growth and accidents modifies and some times distorts the facial shape and proportion. Various surgical changes may help to get a better shape. Abnormal facial features are defined in chapter 3.1.2, Facial dismorphology. Simulation of these
distorted features needs to be addressed individually as the variation is unpredictable. While developing the proposed system researcher will not be considering these abnormal facial features.

iii. Proposed system is focused only on male adult real personalities of Indian origin.

Anthropometry makes it clear that all the facial features have continuous growth till age adult age and from there onwards graphs almost settle down.

iv. Facial Expressions lies out of the scope of the proposed system.

Facial expression is a complex, composite deformation of the features because of various facial muscular actions. Expression is generated by varying intensity of stretching and squashing of facial muscles. Neutral expression can be explained as the form and shape of facial topology when facial muscles are at rest. Although facial expression reveals emotion, mood and ideas, it is a temporary action and does not change facial topology permanently. Hence researcher decided to exclude the study and implementation of facial expression. The proposed thesis is confined to facial reconstruction with neutral expression.

v. Facial hair is not under consideration.

Facial hair can improve attractiveness and can change the look drastically. It can hide blemishes or scars. Skin has minute hair all over but visible facial hair can be seen as eyebrows, eye lashes, scalp hair, beard or moustache and hair on ear. Facial hair reflects genetic condition, age, health, skin condition, surgical changes. Hair loss generally associated with age alters the hairline, hair density and clump arrangement. Hair care involves many techniques such as hair coloring, styling and hair extensions. Hair growth and hair care continuously modifies many hair attributes like hair length, thickness, curling, shining and hairline. As there are already hundreds of established hair styles, hair style module can be developed independently to adorn facial model.
Although hair occupy vast volume and change look of a person, they cannot be considered as the permanent feature. Hence researcher has decided to validate the derived methodology on a hairless head.

vi. Proposed system is focused on exterior facial surface for reconstruction.

As explained in chapter, face is made up of bone, muscles, cartilage, soft tissues, blood vessels and many other nerves covered by skin. Dental arrangement, cartilage, soft tissues and other internal details plays an important role to displace skin and to get its final form. The visual representation of internal details is very difficult and not required in 3D environment rather its impact is important and should be taken into consideration. Hence researcher decided that internal facial details will be represented in terms of its parameters. The proposed design is may be extended to adopt rules set by orthodontics and forensic odontology.

vii. Skin with general shading attributes will be assigned to facial model in 3D environment.

Skin is full of complex patterns with humongous variations. Facial skin reveals variable thickness, color shade patterns, oily skin patterns. Skin’s thin, soft, flexible nature generates many temporary and permanent wrinkles and fold patterns. As our main focus is to reconstruct human face 3D model and not texture exaction from photo or to show realistic look of a person we will simply assign general shading attributes to 3D facial model.