Age Progressive Person-Specific 3D Model for Sri Lanka

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***Abstract*—Face Age Progression is a process of predicting the face of a person with advancing years. Automation of such process with the power of the Computing is one of the huge challenges in the world. This paperexploresautomatic age progression in 3D modelespecially in Sri Lankan context where there is no such model exists in present. To implement this, Person-Specific 3D model is reconstructedusinggeneric model and asingle frontal image instead of using 3D scan or different poses of images. Then 3D modelis deformed according to the extracted person-specific features.Aging approach on 2D image isproposed based on IBSDT method. Age is progressed in Person-specific 3D model using aged 2D image, texture mapping and structural changes in the nasolabial fold area.**

Keywords-Shape Warping, 3D Model, 2D model, Spring Potential Model, Age Progression, IBSDT(Image Based Surface Details Transfer), image normalization, nasolabial

I. Introduction

Aging is perceived by humans depending on the appearance of the face. The previous researches have proved that aging could not be attributed with single factor. It is a combination of habits, life style, working environment and obesity. In each of these categories, aging variesat same age with wrinkle appearance, structure of face changes. SriLankahas different life style, environment and whether conditions. So aging of a person in SriLanka differs from European countries where most of the age progression systemshave developed. Face age progression is mostly used as a forensics tool by law enforcement, and also in the medical field.

3D face models have more accuracy and clarity than using 2D models whenobservingstructural deformation of a face.The existing software for reconstructing3D model from 2D image are mainly done based on the European context, hence they are not suitable to be used in Sri Lankan context due to the difference between geometric face structure of Sri Lankans and Europeans.This paper presents a way tosimulate age progression in the reconstructed 3D model in order to address Sri Lanka related facial changes over aging.

A. Related Work

Limited amount of researcheshave carried outrelated to age progression in 3D models. Reconstructing 3D is focused in Active Appearance Model that is a cost-effective scheme to model 3D faces automatically from images and videosequences [1]. Another 3D reconstruction approach, first constructs a 3D dense morph-able shape model from 3D face scan data. Then it extracts the landmarks from 2D image sequence, finally constructs 3D face model [2]. A 3D face image could also be modeled using a set of 3D face models of different persons in a face database [3].

A Bayesian age difference classifier classifies face images of individuals based on age differences and performs face verification across age progression [4].Designing and evaluating discriminative approaches also use in age progression [5].Age progression is simulated over the different ages using age prototypebased on IBSDT method [8]. To determine age prototype, aging function is implemented using age estimation with SVM approach in which the accuracy of age estimation affected the age progression. This method eliminates the difficulty in getting images of same person at different ages,considering overall age pattern at a particular age group.

B. Problem Statement and Motivation

Country specific age progression is rarely considered by the previousresearches.Aging in 3D model is another research area which increases the clarity of changes in face. Age progression on 2D or age progression in 3D is not yet developed in SriLanka which was the motivation to do this research.

3D models provide an easy way to change the shape of the face using deformation without much effort. A 3D face of a person can be modeled with images of different poses or with a 3D scan of a face. This paper is to reconstructa 3D model with a single frontal face image.The main reason behind this approachisthe practical aspect of this application. Nowadays,lost people due to displacement in SriLanka or missed criminal causes to identify them with their older frontal images in the current context. In such a case, their appearance in 3D could be predicted in the current context by this system only with the frontal image. More tourists are aware of getting SriLankan specific things. So, the aging simulation of well known person in 3D could be used to attract them.

II. Person-Specific 3D Model Reconstruction

The existing template model is modified according to the average depth information of SriLankan faces. Only the significant places such as nose hook area, eye and forehead are deformed in order to generate a generic model for SriLanka. Then generic model is used as a base model for the other processes in reconstructing person-specific model.

To model a 3D face, object “3ds” file structures are used. A “3ds” file contains a series of information that is used to describe details of a 3D scene. The details of 3D scene containas interdependent blocks called Chunks. This research is mainly considered three types of chunks as the three dimensional vertices coordinates, the two dimensional mapping coordinates and the list of polygons that connecting vertex' points [6]. Vertex coordinates and Texture coordinates are illustratedin following figures:

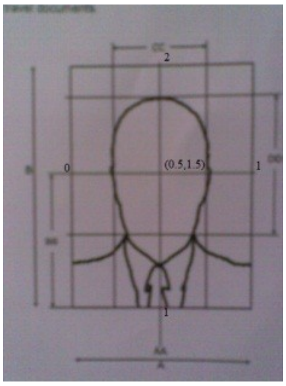


Figure 2: vertex coordinate

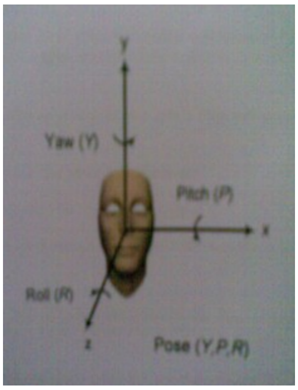


Figure 1: Texture Coordinate

A. 3D Model Deformation

The feature point's locations are differed according to the geometric structure of the face. So, generic 3D model is deformed to generate person-specific 3D model. Since the 3D model is constructed as vertices and polygons, the position of particular vertex point along with neighborhood is changed to deform the model. The deformation is divided into two main parts as vertex mapping and vertex modification. Comparing the generic model with input images, to find the new values of critical vertex points are done by vertex mapping. In the vertex level modification, the relative effect on the neighborhoodis considered due to movement of the specific vertex. The translation or amount of moving is larger in close vertices. It gradually decreaseswhen the distance from the original increases.

The movements of the neighborhood are different near each feature component such as nose, mouth, and eyes. The movement of neighborhood near nose is larger compare to the movement near eyes. Considering these facts, the spring potential model is used to deformthe 3D model.

B. Spring Potential Model

When a spring is compressed or expanded, it creates a force opposite to the direction where the original force is applied. This force is mathematically equated by the following formula:

$F = -k*Dx$ ……………….Eq.1

$Dx = Xc-Xi$………………..Eq.2

where k is the elasticity coefficient. Dx is the distance from original vertex (Xc) to target vertex (Xi). A spring with bigger k is stiffer as it creates a larger force from its inertial state. Spring with a smaller k is more flexible as it creates a smaller force from its inertial state.

A set of fixed points are placed in di, i=1, 2...n for every dimension of the information space. A point p in the space is considered for a given 3D object. n number of springs with the constant stiffness are attachedK>0to p. The other ends of the springs are named pi, i=1, 2...n. Consider n more springs from pi to di with the stiffness Ki for i= 1, 2… n. The points pi, i=1, 2...n are free and movable. The points di, i=1, 2….n are fixed. Then balance of this spring system is calculated when the vertex point p is moved [7]. Following figure is illustrated this scenario:

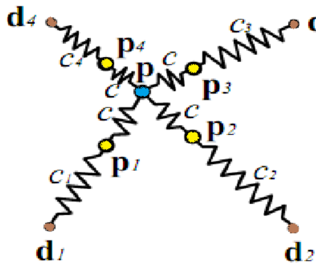


Figure 4:The spring potential model for a 3D object

This model can be applied to deform the face with its feature points. Following figures illustrate the deformations of nose of our 3D model.

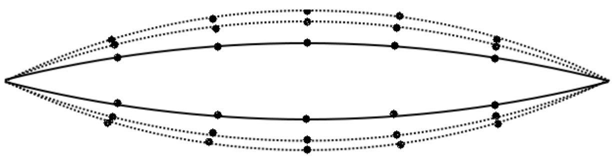
Compressed Nose Normal Nose Expanded Nose

Figure 3: Deformation of nose

Linear interpolation is used to expand and to compress face features linearly through horizontal and vertical axis. Two known points are given by the coordinates as fixed face point (x0,y0) and movable face point (Xn, Yn). Then movable face point is changed to (Xn+1, Yn+1). The linear interpolation is used to calculate how many points that between y0 and yn+1 are changed according to amount of change happenedto movable point. For a value x in the interval, the value y along the straight line is given from the following equation:

$(y-y0)/(x-x0)=(yn-y0)/(xn-x0)$ ……… Eq.3

To find the deformed vertical points, Vertical curve fitting is used over face features especiallyfor mouth and eye. As in the following figure, vertex points are expanded outwardwhen mouth is larger. The displacements of levels are reduced



according to the spring theory, as the levels increase from the first level.

C. Texture Mapping in 3D Model

Each vertex in the 3D model is interconnected with the texture coordinate of the image(x, y coordinates of image). For a given image, the critical texture coordinates are derived from critical points' selection.Then remaining points' texture

Figure 5: interpolation of vertical curves of mouth

coordinates are calculated using spring potential method that explained in the previous section.

III. Age Progression In 3D Model

The overall age progression is divided into two major parts such as structural changes in 3D model and in-texture changes on 2D image. The structural deformation is in the area of nasolabial fold. In-texture variation is applied to overall face area corresponding with actual age group by the appearance of wrinkles. The following figure depicts how our main components are integrated together.

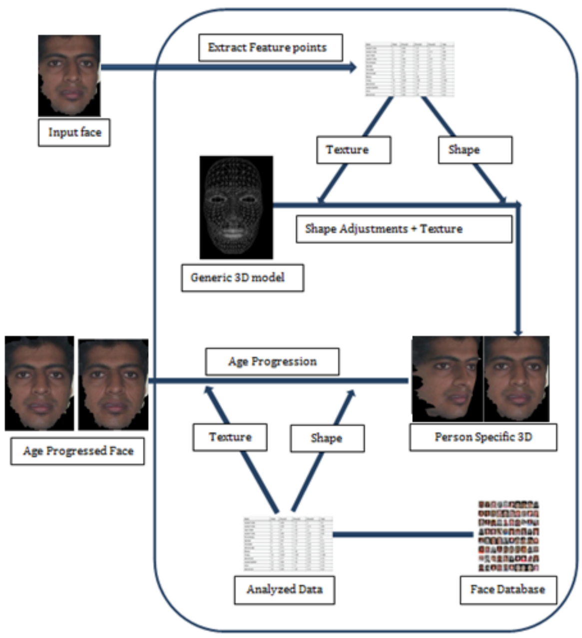


Figure 6: Our Overall Approach

A. In-texture changes to 2D images

The appearance of wrinkle in the face areas such as forehead, nasolabial fold and around eye are considered in this approach. The overall wrinkle observed in the face is transferred from one image to another image using the below explained method called IBSDT.

IBSDT (Image Based Surface Details Transfer)

The IBSDT [8] is a method to transfer geometric details from one surface to another. IBSDT is independent from the surface reflectance properties. So when transferring details, reflectance would be preserved. The intensity ratio between two images istransferredto new image through simple image operations.

$$\hat{I}_2 = \frac{I_1}{\bar{I}_1}\bar{I}_2; \qquad \text{..................Eq.4}$$

$$\bar{I}(p) \equiv \sum_{q\in\Omega(p)} w(q)I(q) \qquad \text{..................Eq.5}$$

In which Ω (p) is the neighborhood of coordinate p, w (.) is the kernel function of a Gaussian smoothing filter, here onwards it is referred as sigma. A Gaussian filter with a user supplied sigma is usedto obtain Ī1 and Ī2. Sigma controls how much geometrical smoothing is applied to the surfaces of I1and I2. Sigma also determines the scale of the surface details to be transferred.

Preprocessing

To create the prototype of a particular age, face database of particular age group is used. The images are in different lightening conditions andin different sizes, since the images were collected from different places. So, the normalization process is carried out to bring those images into illumination invariance and same size, toimprove accuracy as a result of eliminating unexpected results.Normalizationconsists of two steps as image warping and histogram matching.

i. Automatic Feature Detection

The significant control points are detected from the input face using Haar-Cascade algorithm. This algorithm is modified to provide correct results when no feature component found in the face such that the algorithm could handle the face with default points. Control points are adjustable by the user when detected points show considerable different from template image's control points.This approach uses 23 control points which is selected based on ICAOstandards [10].

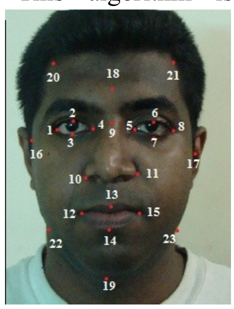


Figure 7: Control Points in template Image

ii. Image warping

The face images were collected from various places such as Internet, friends andhospitals. The variation in resolution and shape of those images are normalized by image warping. So a base image from the databaseis chosen to bring entireimages into one template which reduces the overhead in further image analysis related to age progression. To warp the database images, system uses 23 features points of given image. The image warping process is implementedusing Matlab functions[9]. First it finds the matrix that could be used as a tool to convert the database images' feature points to base points. Then the matrix is applied for all pixel values to get warped images.Threshold resolution is considered to retain wrinkle details in aging process.

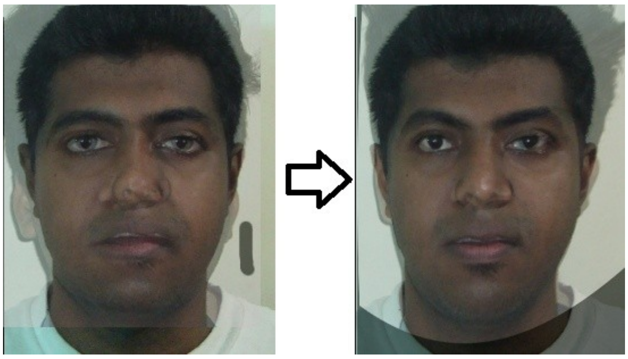


Figure 8: Warped Image

iii. Histogram matching

This area focuses on bringing images into illumination invariance. The images are transformed to the same dynamic range by histogram matching. Since images in the database are with negligible shadows, simple histogram matching is enough to normalize them.

Prototype generation

Age prototype generation is carried out based on IBSDT [8] along with aging parameter estimation approach. In order to avoid unrealistic noises in the age prototype, curve of eye and mouth are extractedbefore generating the prototype. So that, wrinkle could be transferred except from eye and mouth.

The Accuracy of Aging Parameter

Aging parameter isderived from original IBSDT strategy. Sigma in IBSDT decides how much geometric information to transfer from one image to another. Since the age is controlled by the appearance of wrinkles on the face, the wrinkles transferred from one image decides accurate amount of wrinkle of particular age group. The simple ratio checking through mean and variance of age prototype with the actual age group would increase the accuracy of age prototype. It is carried out inthe following manner:

$$R_p = I_p/\bar{I}_p \quad R_a = I_a/\bar{I}_a \ldots\ldots\ldots\ldots\ldots\ldots \text{Eq.6}$$

Where R_p, R_a are ratios of prototype and actual image respectively. And I_p, I_a, $\bar{I}_p$, $\bar{I}_a$are normal convention stated as in Eq.4

The above accumulated ratio of mean, variance between prototype and actual image, wereobserved with changing sigmavalue. Then mean difference and variance difference were calculated. Sigma value was obtained when mean difference and variance differentstarted to differ from zero. Threshold of sigma was defined to increase the accuracy since not much difference between imagesat lower sigma value. So, sigma was taken as above 0.5 by analyzing the pattern of mean and variance.

A. *Structural changes in 3D model*

Facial skeleton changes morphologically with aging through decreasing in volumedue to compression in bones. One of the significant changing areas is the eye socket. Along with aging, the eye sockets become wider and longer. The bones in the middle part of the face also tend to change

Figure 9: The skull of a person between the ages of 20 and 40 (left), the skull of a person over 65 (right).

considerably. Reductions in the angles of the brow, nose, upper jaw bones, decrease of the length and height of the lower jaw[11] contributes to the variation in aging.

The 3D model is deformed using Spring Potential model to address these structural changes with aging. The anatomical values of human face structure were used to define changes happening with aging in the 3D model.

IV. RESULTS AND DISCUSSIONS

The following figure illustrates the generated person-specific 3D model with 30 degree angle left, right and straight view:

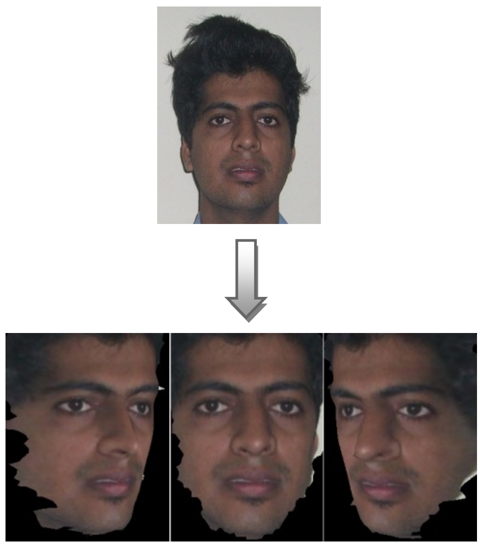


Figure 10: 3D view

The aged 3D model from the actual image at age 80 shows below:

Actual Images Age 80 Images

Figure 11: Age Progressed 3D model

The following figure depicts how the mean difference and variance difference between prototype and age group images is changing with varying sigma value at age 50. According to the graph, sigma is chosen as 0.7.

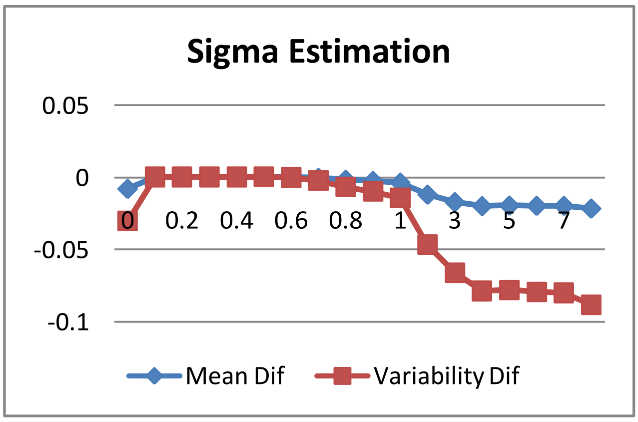


Figure 12: Age Prototype at age 50

Future Improvements

More focus could be given to consider depth information of 3D model in which different models could be used to represent different depth. It could bedeveloped through different poses of images. Then the appropriate model could be chosen within different generic models based on the information gathered from single 2D image where advance image processing techniques could be used to extract the depth information from the frontal image.

Establishing Neural networks mechanisms or Support Vector Machines, to learn the aging function would further increase the accuracy of aging process. So further training with images could predict accurate aged image. Focus on other components such as hair, ear and eyebrow of aging would lead to more realistic age progressed images.

Acknowledgment

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