Cloning and Aging in a VR Family

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Abstract

Face cloning and animation considering wrinkle formation and aging are an aspiring goal and a challenging task. This paper describes a cloning method and an aging simulation in a family. We reconstruct a father, mother, son and daughter of one family and mix their shapes and textures in 3D to get virtual persons with some variation. The idea of reconstruction of a head is to detect features from two orthogonal pictures, modify a generic model with an animation structure and use an automatic texture mapping method. It is followed by a simple method to do 3D-shape interpolation and 2D morphing based on triangulation for experiments of mixing 3D heads between family members. Finally, wrinkles within facial animation and aging are generated based on detected feature points. Experiments are made to generate aging wrinkles on the faces of the son and the daughter.

1. Introduction

Are you curious of your face when you are getting old? We introduce our cloning and aging experiments of a family. We reconstruct every member of a family and then abstract the father's aging features and mix with other members of the family, assuming that his children resemble his aging. Three main elements have to be considered in facial aging: aging wrinkles, skin texture variation, and facial shape change. In this paper, we show how to simulate and predict aging accounting for these three elements. We consider first a face reconstruction method from orthogonal picture data, then an interpolation of heads in 3D with texture metamorphosis, and finally wrinkle generation.

1.1. Review

There are various approaches to reconstruct a realistic person using a Laser scanner [4], a stereoscopic camera [1], and an active light stripper [6]. There is also an approach to reconstruct a person from picture data [3][7]. However most of these approaches have their limitation for practical usage due to restrictions from commercial products (such as a camera) for the input of face data.

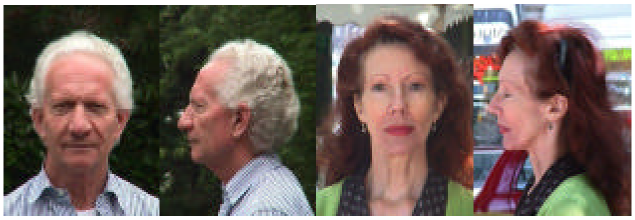
The techniques for metamorphosis, or "morphing", involve the transformation between 2D images [8][11] and one between 3D models [9][10] including facial expression interpolation. Most methods for image metamorphosis are complicated or computationally expensive, including energy minimization and free-form deformation.

There are a few efforts for facial wrinkle simulation. Viaud et al. [14] have presented a geometric hybrid model for the formation of expressive wrinkles, where bulges are modeled as spline segments. There are also physically based facial animation models, where some wrinkles appear as the outcome of the skin deformation [15][16]. A dynamical wrinkle simulation system has also been developed, combining the physically based skin deformation with texture modeling of wrinkles [13]. However, the present models do not provide a way to automatically generate wrinkle patterns on each individual face based on the its features.

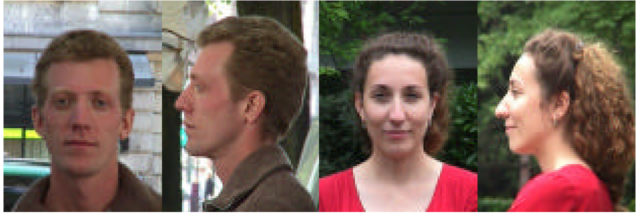
In Section 2, we introduce a fast modeling method to reconstruct an individualized head, by modifying a generic head. In Section 3, an automatic texture mapping method is described in detail including texture generation and fitting processes. Then Section 4 is devoted to image morphing based on triangulation. In Section 5, we present a wrinkle generation method, which is based on facial anatomy information abstracted from feature points. Then our experiments for aging simulation in a family are shown in Section 6. Finally, a conclusion is given in Section 7.

2. Face modeling for individualized head

In this section, we present a way to reconstruct a head for both animation and wrinkle generation.



(a) Father (b) Mother



(c) Son (d) Daughter

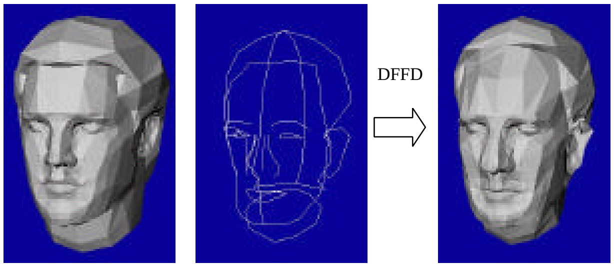
Figure 1: Family pictures for cloning and aging.

The main steps of cloning are: detect 2D feature points on the two images, obtain 3D position of feature points, and modify a generic model with a geometrical deformation. The feature detection is processed in a semiautomatic way using the structured snake method with some anchor functionality [7].

Figure 2 shows normalized pictures with scaling and translation to visualize them in the feature points space. It also shows detected features in red points and lines, which will be used for automatic wrinkle generation later.

Figure 2: Size and position of two pictures are changed after normalization. Feature points in red color are overlaid on the image.

Then two 2D position coordinates in the front and side views, which are the (*x*, *y*) and the (*z*, *y*) planes, are combined to be a 3D point. We use front (*y*) value as priority values and side (*y*) values are used only when front (*y*) values are not available. This helps to prevent certain problems like closed eyes in a side image of a mother in **Figure 1**. Dirichlet Free Form Deformations (DFFD) [5] are used to get new geometrical coordinates of a generic model adapting to the detected feature points. The control points for the DFFD are feature points detected from the images. As shown in **Figure 3**, the head does not have a large number of points, which is useful to accelerate animation speed. To get a realistic looking face, we use an automatic texture mapping, which is described in below section.



A generic model

Feature lines obtained from two 2D images

An individualized head

Figure 3: Modification of a generic head with detected feature points.

3. Automatic Texture mapping

Texture mapping is useful not only to cover the rough matched shape, but also to get a more realistic colorful face.

The detected feature points are used for automatic texture mapping. The main idea of texture mapping is that we get an image by combining two orthogonal pictures in a proper way and then give correct texture coordinates of every point on a head.

3.1. Texture generation

The process of texture generation ha two main steps. First geometrical deformation step is performed to combine front and side views and second the multi-resolution image mosaic is processed to remove boundary effects.

A front view is kept as it is and a side view is deformed to be connected to the front view. We define a set of feature lines keeping original on a front view between two feature lines, which are red lines in **Figure 4**. There is a corresponding feature line on a side image. We deform the side image to transform the feature line to the corresponding one on the front view.

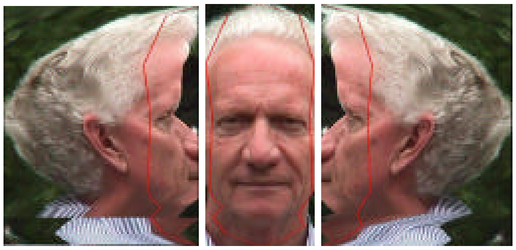


Figure 4: The three images are after deformation, ready for merging.

We use the side view for the right view and deform it with transformation to match to the right feature line on the front image. For a left image, we flip a side image across to the vertical axis and deform it with relation of the left feature line on the front image. The resulted three images are shown in **Figure 4**.

The three resulting images after deformation are merged using pyramid decomposition method using the Gaussian operator[2]. We utilize REDUCE and EXPAND operators to obtain the G_k (Gaussian image) and L_k (Laplacian image) and merge three L_k images on each level on any given curves, which are feature lines for combination. Then the merged images P_k is augmented to get S_k, which is the result for each level obtained from P_k and S_{k+1}. The final image is S_0.

Figure 5 shows the whole process of the Multi-resolution technique to merge three images while **Figure 6** shows an example from level 3 to level 2.

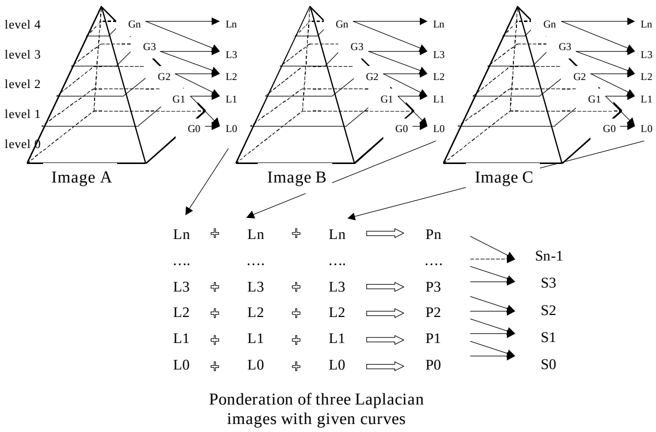


Figure 5: Pyramid decomposition and merging of three images.

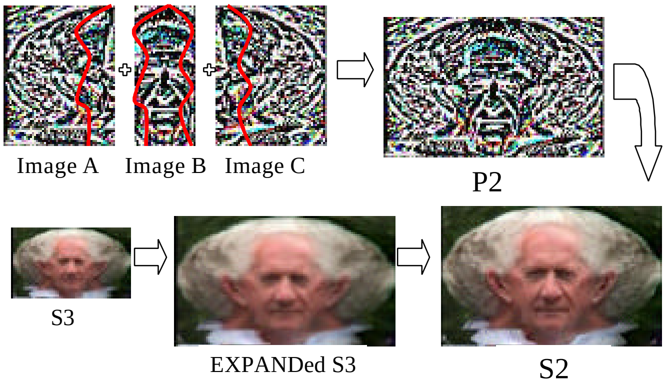


Figure 6: The process from level 3 to level 2.

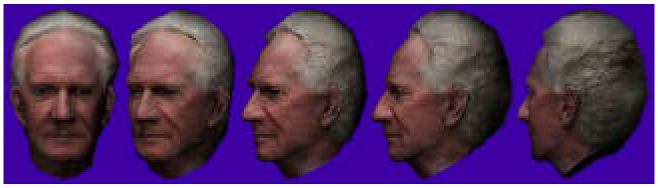
This Multi-resolution technique is very useful to remove boundaries between the three images. Images of the eyes and teeth are added automatically on top to obtain full eyeball and teeth images as shown in **Figure 7**.

3.2. Texture fitting

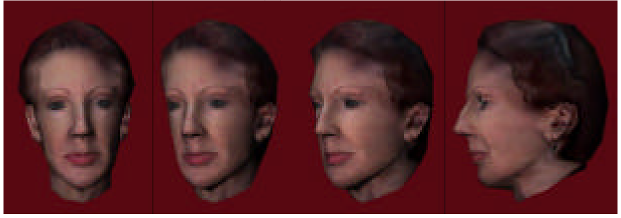
To give a proper coordinate on a combined image for every point on a head, we first project an individualized 3D head onto three planes, the front (*x*, *y*), the left (*y*, *z*) and the right (*y*, *z*) planes. With the information of feature lines, which are used for image merging in above section, we decide on which plane a 3D-head point on is projected. The projected points on one of three planes are then transferred to one of feature points spaces such as the front and the side in 2D. Then they are transferred to the image space and finally to the combined image space. The eyes and teeth fitting process are done with predefined coordinates and transformation related to the resulted texture image size, which is fully automatic after one process for a generic model.

Figure 7: Texture coordinates overlaid on texture image.

The final texture fitting on a texture image is shown in **Figure 7**. Brighter blue points are feature points, others are non-feature points, and the triangles are a projection of triangular faces on a 3D head.



(a) Father



(b) Mother

(c) Son

(d) Daughter

Figure 8: Snapshots of a reconstructed heads of a family in several views.

Since we use a triangular mesh for our generic model, the texture mapping result from efficient triangulation of the texture image as the generic model does. This resulting triangulation is used for 3D-image morphing in below section. **Figure 8** shows several views of the reconstructed heads out of sets of two pictures in **Figure 1**.

4. 3D merging of two persons

We merge two head shapes and their two texture images to get one in-between head. Our reconstruction method makes it possible to perform morphing between two persons through 3D-shape interpolation based on the same topology and 2D morphing for texture images to get an intermediate 3D-head[12].

4.1. Intermediate shape

Every head generated from one generic model shares the same topology and has a similar characteristic for texture coordinates. Then the resulting 3D shapes are easily interpolated using a simple linear interpolation of three coordinates of each point on a head.

4.2. 2D image metamorphosis based on triangulation

We need two items to obtain intermediate texture mapping. First 2D linear texture coordinate interpolation is performed and image morphing follows. Parts of image, which are used for the texture mapping, are triangulated by projection of triangular faces of 3D heads as shown in **Figure 7**. With this information for triangles, Barycentric coordinate interpolation is employed for image morphing. Each pixel of a triangle of an intermediate image has a color value, which is decided by mixing color values of two corresponding pixels on the two images. Three vertexes of each triangle are interpolated and the pixel values inside triangles are obtained from interpolation between two pixels in two triangles with the same Barycentric coordinate. To obtain smooth image pixels, bilinear interpolation among four neighboring pixels is processed.

We vary the morphing ratios a and b where $a + b = 1$ to show a dynamic morphing. **Figure 9** illustrates intermediate heads between the father and the daughter.

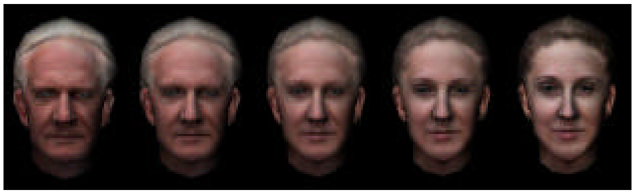
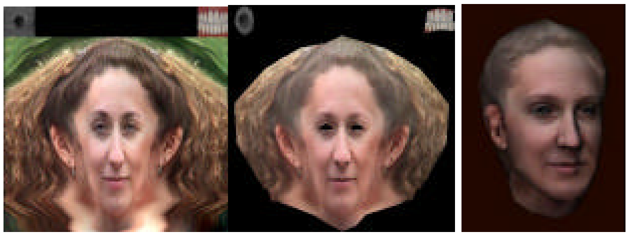
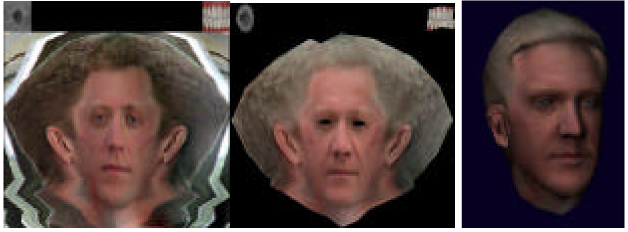


Figure 9: Intermediate heads in 3D between the father and the daughter.



(a) Daughter



(b) Son

Figure 10: The children are mixed with their father. The left two images are their original texture images and middle images are mixed with their father. Right heads show the results of mixing.

It is also possible to set different ratios for shape mixing and image mixing. **Figure 10** gives some examples of shape and image mixing with different ratio. We think the daughter has more similar shape features from her father than from her mother, but more similar color features from her mother than from her father. For the son, it seems it is reverse. Since the aging features on the mother's texture is not obvious, it is not very useful to utilize mother's texture to make children's looking older. We experiment with their father by mixing shape and image, but without losing their own geometrical characteristics and female/male characteristics. The daughter is mixed 20% for shape with the father and image 30%. For the son, shape is mixed 25% and image 40% with his father.

5. Anatomically guided aging simulation

Wrinkles hold significant characteristics on a human face, they are extremely important in enhancing the realism of facial simulation. Two types of wrinkles appear with facial animation: expressive wrinkles and wrinkles due to age. Expressive wrinkles appear on the face during expressions at all ages and may become permanently visible over time. Facial skin changes with age: more lines and wrinkles emerge and the general appearance and texture of the facial skin become pronounced and rough. Permanent visible wrinkles are one of the major age indications of a person. In this section, we describe a methodology to simulate facial aging taking into account wrinkle dynamics, facial shape and skin details.

5.1. Physically based wrinkle generation from facial feature points

We have developed a system to allow the users to design and generate dynamic wrinkles with facial animation and aging [13]. A three-layered structure is employed by a physically-based facial simulation model, which consists of a skin layer, a connective tissue layer and a muscle layer as shown in **Figure 11**.

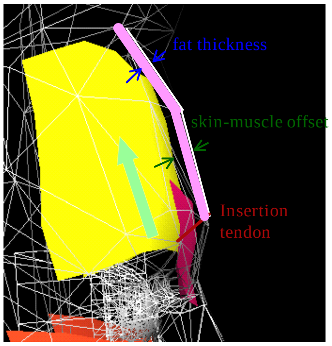


Figure 11: Three-layered structure

Facial muscles are mainly designed as B-spline patches according to the nature and direction of muscle fibers. Connective tissues are simulated as a layer of springs between the skin and the muscle layer. The deformation of skin is motivated by the simulated muscle layer and decided by a biomechanical model.

The design of muscles and wrinkles follows the general facial tissue anatomy. Wrinkles are produced corresponding to the facial skin movement controlled by muscle contractions. While one parameter direction of a muscle patch approximates the muscle fiber orientation, intuitively, the transverse parameter dimension indicates the potential wrinkle locations with skin deformation.

The feature points for 3D-face cloning provides not only informations to reconstruct the face shape but also anatomy locations of each individual face. The anatomy locations abstracted from feature points can be used for the muscle construction and the wrinkle pattern generation. We have developed algorithms to automate the muscle and wrinkle design process using the feature points of 3D facial cloning.

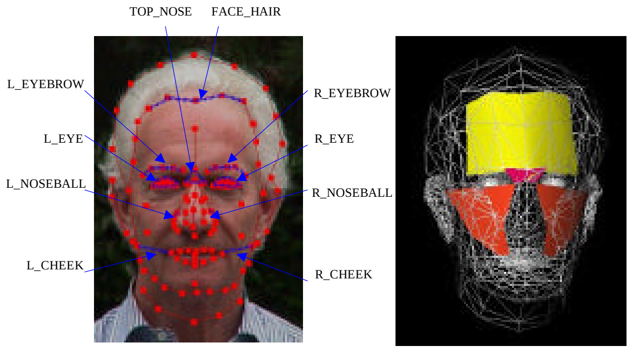


Figure 12: Automatic muscle construction and wrinkle generation with feature points

The feature points used for muscle construction and finally wrinkle generation are displayed in the left side of **Figure 12** with blue dash-dot lines. The feature points corresponding to certain anatomy positions on a face are selected and interpolated in order to obtain rectangular point meshes that form B-spline muscle patches of individual face automatically. The feature points are also used to locate contour lines or some wrinkle lines directly. Four muscle clusters constructed automatically from feature points are shown in the right side of **Figure 12**. The forehead muscles are constructed using the FACE_HAIR, L_EYEBROW and R_EYEBROW feature points. The squeezing muscles are formed based on three TOP_NOSE feature points. The L_EYE, L_CHEEK and L_NOSEBALL features points are selected and interpolated to construct the muscles on left cheek, while the R_EYE, R_CHEEK and R_NOSEBALL feature points are used to form the muscles on right cheek. Wrinkles are located transverse to the muscle fiber direction. We also locate some wrinkle lines directly from the feature points by forming B-spline curves corresponding to some anatomy positions. Contour lines on cheeks are built based on the position of NOSEBALL and CHEEK. Wrinkles around eyes (frog feet) are located according to the EYE feature points.

To validate the feature abstraction process for wrinkle generation, we apply these algorithms on the family example. **Figure 13** shows the synthetic wrinkle patterns that are generated on the father's face, which are close to the locations of the real aging wrinkles. This gives the first evidence to the relevance of our wrinkle abstraction process. Since every face is reconstructed using the same feature definition and from the same generic model, the algorithms can be generalized to create wrinkle patterns from one face to another face. **Figure 13** also shows the synthetic wrinkle patterns on the mother's face.

Figure 13: Wrinkle lines generated from relation among feature points.

The next step is to simulate aging wrinkles on the faces of the children. After the generation of wrinkle patterns on a 3D-face model, wrinkle lines are mapped to 2D-texture image to form their bulge shape **Figure 14**. The shape of expressive wrinkles and aging wrinkles varies at different locations of the face and with different individuals. Nevertheless, a further analysis of wrinkle shape illustrates a general form with a narrow inward furrow accompanied with an outward bulge. We employ a wrinkle shape function composed of several piecewise functions. The width of the inward furrow and the outward bugle and their heights are specified and adjusted to obtain natural wrinkle shape.

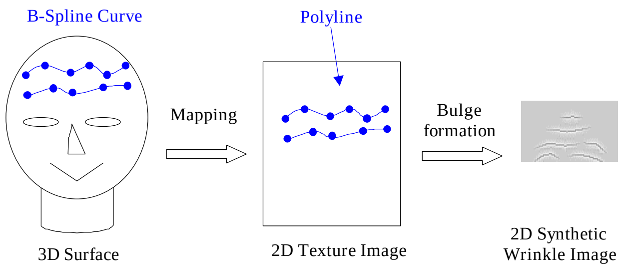


Figure 14: The process to generate synthetic wrinkles.

The dynamic wrinkles are formed by computing the wrinkle heights using the strain measures of 3D facial skin deformation. A linear plasticity model is used to simulate skin aging[17], which is applied to wrinkle formation in our model. The aging wrinkle height linearly depends on the sum of deformation within load duration. The height information modifies the corresponding synthetic wrinkle texture image. The wrinkle rendering are represented by several layers texture mapping combined with synthetic texture images and real photos.**Figure 15** shows various intensities on parts of aging wrinkles.

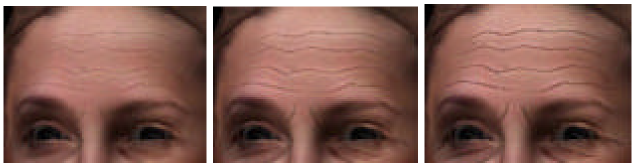


Figure 15: Aging wrinkles of various intensities.

6. Experiments

Besides the appearance of aging wrinkles, the aging process also includes the change of face shape and the variation of skin textures. Until now, we have not done a detailed study on the facial growth with age. As a part of study for aging, we have mixed man and woman models in same generation to compare the general shape differences at different ages.

Figure 16 shows characteristics of the old on the left side and the young on the right side.

Figure 16: The left is 50% mixed between the father and the mother and the right 50% between the son and the daughter.

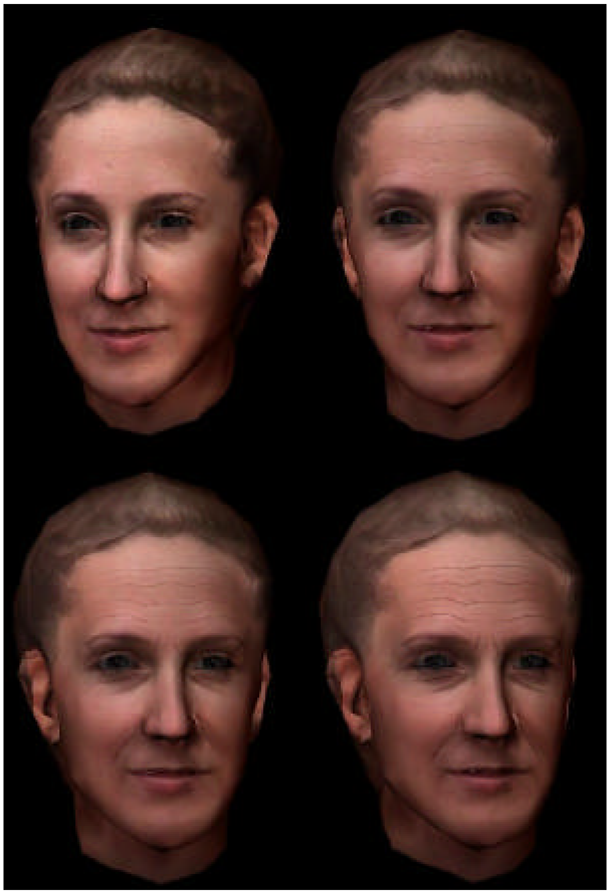


Figure 17: Aging process of the daughter.

Figure 18: Aging process of the son.

Real photos capture all skin details holding age indication. To achieve the realistic look of the aged faces of the children, a slight texture morphing (10% - 40% from the old) is applied to the photos of children to the parents' photo. We also take account of a slight modification (10% - 15% from the old) of head shape by mixing the young with the old. The synthetic aging wrinkles are mixed with the modified photo images.

Figure 17 and **Figure 18** shows the aging simulation examples of the daughter and the son. Every modified head from a generic model shares the same animation structure [18]. We do some simple expressions on an aged face of the son. **Figure 19** shows a result of one expression of the son.

Figure 19: Expression wrinkles on an aged face of the son in the right side. The left-up image is the father's expression while left-bottom image is the son's expression.

7. Conclusion

We introduce a method of aging simulation showing an experiment inside a family. The wide usage of features is also described in this paper, covering shape reconstruction, texture image generation, and design of wrinkle and muscle. We combine several methods to get realistic aging looking. First, we reconstruct two generations using a fast head modeling method with commercial product input, two orthogonal pictures under reasonably good light condition. This shows the processes of modifying a generic model for shape acquirement and producing texture images using a Multi-resolution technique. To get overall color and shape changes, 3D-head interpolation with 2D-image metamorphosis based on triangulation is used. Then muscle and wrinkle design follows automatically utilizing feature information obtained for reconstruction. Skin deformation employs biomechanical model and parameter values. Wrinkles and other details of the skin are designed on texture images. The superimposed wrinkles on a head result into realistic aging wrinkle generation.

The facial reconstruction and animation system based on range data input would give more detail shape. Moreover, actual medical data and biomechanics of facial tissues with finite element analysis would offer the foundation for wrinkle formation and growth. However, it would be far too expensive to simulate this at an interactive rate. Our biomechanical model is suitable for applications that require acceptable accuracy and an interactive display. Further analysis for aging process such as parameters of shape and skin color changes is ongoing research topic.

8. Acknowledgment

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