Visualization of Realistic Human Facial Aging and Human Skin Senility

Azam Bastanfard, Hussein Karam, Hiroki Takahashi, Masayuki Nakajima

Graduate School of Information Science & Engineering

Tokyo Institute of Technology

2-12-1 Ookayama, Meguro-ku, Tokyo, 152-8552 Japan

Tel: 03-5734-2183, Fax:03-5734-2187

{besmel,huss,rocky,nakajima}@img.cs.titech.ac.jp

Abstract: Facial aging (senility) is a representation of difference of human face after passing years. Applications of facial aging are widespread. They include animation, face recognition, entertainment, criminal objects like finding murders after number of years, finding missing people, and it can be used for medical surgery and face reconstruction. This paper presents a new method for creating realistic facial aging based on medical information. The approach discusses facial declination based on the medical face anthropometry, and simulates wrinkle with lighting technique to make realistic senility on the face. The technique produce realistic facial aging. Comparing with other proposed methods our proposed algorithm is easy because it does not need to collect a lot of images. Experimental results demonstrate this approach with a variety of facial senility.

Keywords: Facial Aging, Facial Declination, Wrinkle Simulation, Computer graphics, Face Anthropometry.
1 Introduction

After passing years there is a lot of changing in the face. It can be called as senility of face or facial aging. Facial aging is one of natural phenomena which will be happened in persons face. The observation of details, such as expressive wrinkles, marks of aging, and conversational signals in the speech, is an important feature of understanding human faces. Wrinkles are important for understanding and interpreting facial expression and also a major aspect in determining age. There are two types of wrinkles: expressive wrinkles (particularly relevant to the face) and wrinkles due to the age. Expressive wrinkle also refers as a temporary wrinkles appear on the face during facial expressions at all ages and may become permanently visible over time. As skin changes with age, wrinkles appear and become permanent and more pronounced. Human faces are distinctively individual, and so are the wrinkles on them. This paper focus on visualization of facial aging concentrating on the medical aspect of facial declination and the appearance of wrinkle.

This paper is organized as follows. Section 2, reviews some of the previous work in wrinkle simulation with skin modeling and aging with a discussion of its problems. Section 3 provides a brief summary of medical information which we have used. Section 4 introduces our proposed algorithm for facial declination, wrinkle visualization and aging. Some experimental results with discussion are given in section 5. Finally, conclusion, and direction for future work are discussed in section 6.

2 Previous work and problems

Wrinkle simulation with skin modeling and aging are extremely important in enhancing the realism of human figure models. Varied models are used to simulate skin deformation for different purposes. There are geometric models, physically-based models and biomechanical models using either particle system [27], or continuous system. Park [20,21,9] used geometric parametric model for facial animation. Waters [31] and Thalmann [17] proposed geometric model based on muscle actions of the face. Ishii et al. [11] proposed a geometric model of micro wrinkle which uses a curved surface on a based on a polygon for expressing folds and ridges. Platt [22] proposed a physical tension-net model for facial animation. Terzopoulos [23] and Lee [14] proposed a physically based model using a three layered deformable lattice structure for facial tissue which produce some of the expressive wrinkles during the skin deformation. Walter [32] used a biomechanical model for tissue simulation. Miller [18] generated realistic snake skin using color mapping techniques. Kaufman et al. [13] simulate reptile skin pattern by using the texture synthesis language, which provides tools for defining and generating regular and random texture patterns. Nahas et al. [19] proposed a method for obtaining the skin texture by recording the data of human face.

There have been a few effort for the dynamic model of wrinkles. Viaud et al. [24] have presented a generic hybrid model for the formation of expressive wrinkles, where bulges are modeled as spline segments. Terzopoulos et al. [23] produces some of the expressive wrinkles during the skin deformation. A simplified facial model with a two dimensional lattice skin surface is proposed to simulate expressive wrinkle in facial animation and the aging process [29]. A cloning method and an aging simulation in a family have been proposed in [15]. Another approach have been proposed in [2] to simulate skin aging and wrinkles with cosmetics insight. Some other techniques for facial aging simulation based on morphing technique and caricature theory with averaging face have been proposed in [10], and [3,6] respectively.

Although, we have some techniques for wrinkle simulation with skin modeling and aging, but still now a model based on the complete description of head's anatomy doesn't exist because of its complexity Moreover, there doesn't exist yet a method where the texture image is modified as a function of skin deformation. A physically based approach can offer a better simulation of wrinkle formation, but if it requires geometrical modeling of the wrinkles it may be expensive. Cloning method and aging simulation in a family [15] generate aging wrinkles on the faces of the son and daughter. Although, in this method it is assumed that the daughter has more similar shape feature from her father than from her mother, but more similar color feature from her mother than from her father, with the reverse case for the son. This assumption is not satisfied for all families, because similarity can not recognize in all families. Caricature technique [3,6] suffer from average face dependency and needs a collection of multiple images of different faces to form the average one.

Compared with all of the previous work our approach present a new method for facial aging with wrinkle simulation which is simple because it doesn't need to make an average face and it is possible when we have only one image. In this approach we use medical face anthropometry for making more realistic senility in face.

3 Medical Face Anthropometry

Up to now, little has been done to visualization of aging process. It is quite cumbersome process which is related to the change of physical structure and biological composition in body tissues. The form and values of these change can be measured according to face anthropometry, the science dedicated to the measurement of the human face. From this point of view our idea is derived to simulate facial aging process based on face anthropology[28]. Anthropometry is the biological science of human body measurement. In medicine, quantitative comparison of anthropometric data with patients' measurements before and after surgery furthers planning and assessment of plastic
and reconstructive surgery [12]. Anthropometric evaluation begins with the identification of particular location on a subject, called landmark points, defined in terms of visible or palpable feature (skin or bone) on the subject. Farkas [8] describes a widely used set of measurements for describing the human face. Such measurements uses a total of 47 landmarks of point to describe the face. The landmarks are typically identified by abbreviations of corresponding anatomical terms. For example, the inner corner of the eye which called "en" for endocanthion, while the top of the flap of cartilage (the tragus) in front of the ear is "t" for tragus [28]. Farkas [8] includes some types of facial measurements. In [8] \( e_n - e_z \) refers to the shortest distance between the landmarks at the corner of the eye, \( v - t_r \) refers to the vertical distance between the top of the head and hairline, and \( c_h - t \) refers to the tangential distance from the corner of the mouth to the tragus. In this paper, a similar use of anthropometry for facial aging will be discussed from the medical point of view.

The aging process is slow, relentless and irreversible. It occurs at different rates from individual to individual as well as in each person at any given time. Over time the effects of gravity and the longitudinal pull of muscles cause drooping or sagging of the skin and deeper structures of the cheeks, eyelids, nose, chin, legs etc. from areas of deeper attachment. The result is wrinkles and jowls in the face and cellulite in the extremities. Medical information of facial aging show us all of the features which have variation.

4 Facial Aging Algorithm

Growth and aging processes influence facial shape and structure greatly. The structure and size of bones changes, the skin texture changes, the skin fattens or sags, wrinkles appear, and even muscular activities change in terms of intensity. Three main elements have to be considered in facial aging: aging wrinkles, skin texture variation, and facial shape change. This section shows how to visualize and predict aging accounting for these three elements. We shall explore a new proposed and effective approach for facial aging and wrinkle simulation.

Two proposed methods will be introduced, one of them is for face declination and the other is for simulating wrinkle with lighting technique to make realistic senility on the face. Our idea is derived from the study of the medical face anthropometry mentioned in the previous section.

4.1 Facial declination

Facial declination is a kind of deformation, which add realism to face modeling. For realistic deformation warping [25] is a good approach. It is a branch of image processing that redefines the spatial relationship between points in an image. As people become older, their faces are subject to many changes. For instance, skin elasticity decreases and the skin also thins. Dermal papillae become blunted with loss of rite pegs so the skin is more easily abraded. Facial and other fat atrophies is absorbed. The head undergoes a global remodeling that effects a marked increase in the size of the face relative to cranium. Wrinkles, creases, bags, and wattles are developed in response to biomechanical stresses like gravity, characteristic facial expression, and facial postures. Progressive changes in skin texture and hair color, as well as loss of hair (balding) also occur with advancing years. Each of these characteristics can be said to provide perceptual information about a person's age precisely because each is produced by a continuous changes resulting from physical and biomechanical stresses occurring throughout the lifespan [16].

The idea for the facial declination algorithm is based on the way of integrating such items in order to indicate the age of a person with other aging artifacts. In our approach we divide the given face into three balance regions. The first region is from the hairline to the eyebrows, the second region is from the eyebrow to the lower end of the nasal area, The third region is from the upper lip to the chin. Figure 1, illustrates such balance. Each region contain some facial landmark points measurements obtained from the medical face anthropometry discussed in section 3.

Based on medical aging process classification discussed in section 3, and with advancing years or aging this balance will be change. For example the hair-line will have receding, and because of bending and stretching in cartilage, nose, ears and other features have declination too, which in turn affects the overall appearance of the face. Such change will be a function of some threshold which is given in terms of age, sex, weight, and other parameters. For instance, there is some threshold for hair receding [7], or there is some coefficient for cartilage growth with aging [4,8,12,26,30]. The process of our algorithm can be summarized as follows. First, landmark points measurements or features of the given face are determined using medical face anthropometry. Second, we divide the face into its three balance regions. Third, we choose one region including some feature which will be declinate. In such step, we determine declination ration which is feature changing ratio to age, and declination scale will be declination ratio by feature. Fourth, after taking a new declination scales, we have
height and weight for face feature which give us new coordinate of face.

4.2 Wrinkles Visualization

The process of aging is a complex one. It depends not only on the structure of the initial face but also on many aspects of one's life, including climatic, psychological and other parameters. The complexity of facial aging is due mainly to the fact that there is no unique model integrating all primary and secondary effects perceived on a face: each particular aspect requires specific modeling (facial animation, wrinkles, speech, etc.) and all aspects intersect each other in a complicated manner. Therefore, face declination algorithm which described before can't only give us the impression of aging process. The visualization of wrinkle due to facial expressions and aging add realism to facial aging, especially with advancing years.

Wrinkles are an extremely important contribution for enhancing the realism of the human figure models. It is also important for understanding and interpreting facial aging and also an aspect in prediction of age. This section focuses on wrinkle visualization based on face anthropometry with two aspects: texture with lighting technique. Skin changes with age, wrinkles emerge and become pronounced. Wrinkles depend on nature of skin and muscle contraction. The skin consist of three layers: the epidermis, dermis, and hypodermis. It is observed that the general appearance of skin and the wrinkles are determined by the combined effect of the three layers. From this point of view, wrinkle formation process will be given in terms of multilayer composition of some texture pattern with lighting of a given particular face [33]. Patterns for wrinkles are represented in texture images. Different skin surface details and their deformations are stored in texture images. The wrinkle formation information modifies the corresponding synthetic wrinkle pattern texture image. The method uses texturing function to perform a small perturbation on the normal direction before using it in the intensity calculations. Therefore, realistic wrinkle simulation is the appearance of two concepts: casting light and texturing as shown in figure 2.

The framework of the algorithm is derived from lighting and texture mapping. The approach has the following steps. First, landmark points measurements or features of the given face are determined using medical face anthropometry. Second, the face is divided into its three balance regions. Third, darken with a certain amount the color of initial skin texture to give the impression of wrinkle depth. Fourth, with some chosen region, the synthetic texture patterns are combined with the given face to form wrinkle in such region due to facial animation or aging. Finally, change the luminance and coloration of the given particular face to give impression for the wrinkles and other aging artifacts. In what follows, we will discuss some mathematical notions our algorithm used. The prime component in the calculation of the intensity of a picture elements is the direction of surface normal at the picture elements. To calculation the surface normal we first examine the derivative of the surface definition functions. Let us represent a point on a surface by a vector P where

$$\vec{P} = [x(s, t), y(s, t), z(s, t)]$$

The partial derivatives of these functions form two new vectors which we call $\vec{P}_s$ and $\vec{P}_t$. These two vector are tangent to the surface, their cross-product form the axes, $\vec{P}_s \times \vec{P}_t$. Since each is tangent to the surface, their cross-product forms the normal at $\vec{P}$. Thus,

$$\vec{N} = \vec{P}_s \times \vec{P}_t$$

The normal vector perturbation is defined in terms of a function which give the displacement of the irregular surface from the ideal smooth one. We will denote this function to be bump map B. On the wrinkled patch the position of a point is displaced the direction of the surface normal by an amount equal to the value of B. We can displace point $\vec{P}$ by adding to it the normalized normal scale by a selected bump-map value B. Thus, the new position vector can then be written as:

$$\vec{P}' = \vec{P} + \frac{B\vec{N}}{|\vec{N}|}$$

Blinn [1] showed that a good approximation to the new normal $\vec{N}'$ is

$$\vec{N}' = \vec{N} + \frac{B_u(\vec{N} \times \vec{P}_1) - B_v(\vec{N} \times \vec{P}_2)}{|\vec{N}|}$$

Where $B_u$ and $B_v$ are partial derivative of selected bump map entry B with respect to the bump map parameterization axes, u and v. $\vec{N}'$ is normalized and substituted for the surface normal in the illumination equations. Note that only the partial derivative of the bump map are used in equations and finite difference can be used to compute $B_u$ and $B_v$.

Figure 3 illustrates that reflected intensity depends on the illuminated surface type, where $\vec{L}$ is the light, $\vec{P}_1$ and $\vec{P}_2$ are any given two points, which have $\vec{N}_1$ and $\vec{N}_2$ as their normal vectors based on the type of the surface. On a flat surface, all point have the same normal, and the result intensity will be constant in all points. However, if the surface is not flat the normal vector will vary as resulting reflected light intensity. Directional Light creates with a light intensity. Light
vector has three dimensions, and illustrated how the third dimensions axis is perpendicular to the images and pointing toward the viewer.

![Figure 3: Directional light in flat and non flat surface](image)

5 Experimental result

Several visualizations for facial aging have been performed based on our proposed algorithm. Figure 4 shows some facial aging without wrinkle visualization. It uses face declination algorithm. Figure 5 presents another facial aging with wrinkle visualization. Figure 6 demonstrates a visualization of facial aging which includes both face declination and wrinkle appearance with advancing years.

![Figure 4: Facial declination results](image)

![Figure 5: Wrinkle visualization results](image)

![Figure 6: Facial aging visualization](image)

6 Conclusion and future work

The modeling and rendering of wrinkle simulation with skin modeling and aging are very important for human figure modeling because it greatly enhance the realism.

In this paper, we have presented a new and effective technique for facial aging visualization via two proposed methods using medical face anthropometry. It has wide applications for example this method can be used as a stimuli in psychological investigations into the representation of faces in human memory, criminal objects like finding murders after number of years, finding missing people, and it can be used for medical surgery and reconstruction of face. The method proposed is easy because it does not need to collect a lot of images and it is local. By local, we mean that wrinkling effects caused by deformations are confined the deformed areas.

In the future work, we would like to extend our algorithm for facial aging animation with fractal theory. Fractal theory has the property of self-similarity which is similar to the aging process. This technique will allow us more real-time performance and realistic aging animation.

References


