Facial Aging Using Image Warping

Greyce Schroeder[1], **Léo Pini Magalhães**[1], **Ricardo Rodrigues**[2]

[1]State Univ. of Campinas, Brazil (UNICAMP)
Caixa Postal 6101 – 13083-970 – Campinas – SP – Brazil

[2]State University of New York at Buffalo
Buffalo, NY.

{sgreyce,leopini}@dca.fee.unicamp.br, rnr4@cse.buffalo.edu

Abstract. *Image warping is a transformation that maps one image into another, altering its shape. This type of transformation has a wide range of applications in medical imaging and, specially, in entertainment industry. In this paper we present a method for simulating aging on frontal face images altering only the shape of the face. We use a method of warping called Radial Basis Functions (RBF) together with a quantitative model for expressing human aging. The prototype works with images from people with 20 years old up and performs the aging up to 70 years.*

1. Introduction

Aging is an inevitable process and its effects cause major variations in the appearance of human faces. Some aspects of aging are fairly uncontrollable and are largely based on hereditary factors; others are somewhat controllable, resulting from many social factors including smoking, stress and lifestyle, among others. Various practical applications could benefit from an automated aging simulate. Some examples are: capture of wanted fugitive, missing children, age-invariant face recognition.

Our task is to simulate facial aging from images using morphing and warping, which consist of an animation procedure where an image is transformed into another image. The warping process requires two images (source and target) and a set of common features between those images. So, a warping function deforms the source image into the target image. There have been a number of different algorithms proposed for image morphing and the main difference between these algorithms is the way of finding an appropriate warping function between the two given images [Wolberg 1998]. In this work, we use a warping function called Radial Basis Function (RBF) [Arad et al. 1994] for simulating the facial aging process.

The RBF warping method uses two sets of points to specify the features in the images: one in the source image and another in the target image. Since we do not have a target image, we use a numerical model to estimate how each facial feature change along the aging process. These estimated features are then used as target features in the warping. So, there are three main steps that are executed during the aging simulation: i) Some control points are marked (e.g. eyes, nose, mouth, etc); ii) Calculate the displacement of each point according with the desired age; iii) Do the image warping with these points.

2. Modelling Facial Aging

Typical facial age simulation technique can be broken down into two categories. The first uses computer vision techniques, performing age progression via learning schemes and image-based methods. Typically, a machine learning approach is used to model face shape and texture changes. The models are then used to synthesize new images that simulate the age changes

[Gandhi 2004]. The problem with this approach is that it requires a large amount of training samples, which are scarce in this area. The second category uses models of facial aging derived from the face anthropometry theory [Pessa et al. 1999]. The process of aging individuals in this case involves modifying facial appearance using physical measurements obtained by experimentation. Most studies on this category focus only on the textural aspect of aging (e.g. skin texture, wrinkles, etc), not altering the geometry of the face. Therefore, we propose a new method that alter the facial shape that can be used as a complement of texture based models.

For aging model, this work was based in a numerical representation of facial aging process which modifies the shape of the face but not alter the textural aspect. This representation was based in aging parameters represented for points and defined in [Pitanguy et al. 1977]. These points are showed in figure 1A and they allow measure these parameters: height of the forehead; eyelids; palpebral pouches; height and width of the nose; nasolabial fold; central mid face; height of the lips; lateral and central pouches of the face.

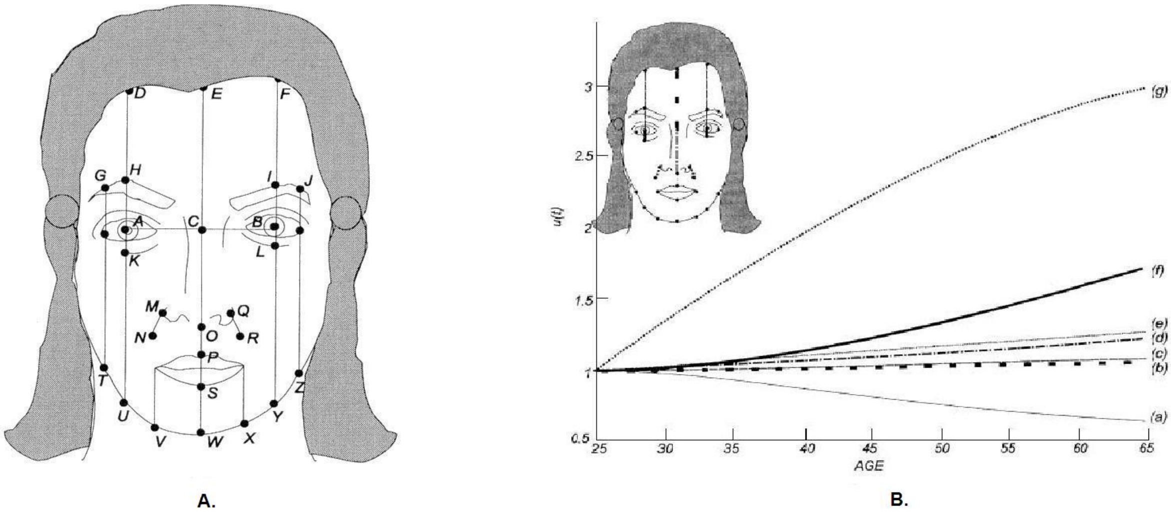

Figure 1. A. Characteristic points defining the facial features. B. General curves [$u(t)$] for (a) the height of the lips; (b) and (c) central and lateral height of the forehead; (d) height of the nose; (e) height of the upper lip; (f) palpebral pouches; and (g) nasolabial fold. From: Pitanguy: Plast Reconstr Surg, Volume 102(1).July 1998.200-204.

After some years, these points are displaced due to aging process. Measuring these displacement in a group of select people, is possible to estimate how these points change along the years. In [Leta 1998] the authors define a general aging curve $u(t)$ for each parameter. The study was conducted on a group of 40 women, photographed at two different ages, at least 5 years apart. The curve $u(t)$ was approximated by two consecutive second-order polynomials with the possibility of an inflection point, which was made possible through the least squares method. This methodology gives the parameter of the two polynomials for a given inflection point at a certain age. The figure 1B shows some curves obtained. For more details consult [Leta 1998].

3. Radial Basis Function

Considering an image as a 2D object and a finite domain of a plane with a grey level (or color) associated with each point, a warping of an image is a transformation of the plane to itself, and the grey level values are transformed according to the transformation of their associated coordinates. Given two set of n control points pairs $\{\vec{p_i}, \vec{q_i}\}$, where $\vec{p_i} = (x_i, y_i)$ is the coordinate of a feature in the source image and $\vec{q_i} = (u_i, v_i)$ is the corresponding point of the same feature in the target image where $i = 1, ...n$, our goal is to get a mapping function between both images that describes the spatial relationship between these corresponding control points and provide a interpolation of this mapping at intermediate points. One way of solving this interpolation problem is to define the mapping function as a linear combination of radially symmetric basis functions, each centered on a particular anchor point [Arad et al. 1994].

A RBF spatial transformation in 2D is composed of two mapping functions: $u_i = f_x(x_i, y_i)$ and $v_i = f_y(x_i, y_i)$. Each of the mapping functions can be decomposed into a global component and a local component. Although the two components are distinct they are evaluated almost simultaneously, giving rise to a single transformation. This decomposition enables a family of transformations to be defined where, if desired, the influence of each control point can be controlled. Given n corresponding control point pairs, each of the two mapping functions of the RBF has the following general form:

$$\begin{array}{l} f_x(\vec{p_i}) = \alpha_1 + \alpha_2 x + \alpha_3 y + \sum_{i=1}^{n} a_i g(r), \\ f_y(\vec{p_i}) = \beta_1 + \beta_2 x + \beta_3 y + \sum_{i=1}^{n} b_i g(r) \end{array} \tag{1}$$

where r is the euclidian distance between two points and $g(r)$ is a basis function. Common choices for basis functions include the Thin-Plate Spline (TPS), Gaussian, Multiquadric (MQ) and Shifted-LOG. In this work we utilize the Gaussian function given by $g(r) = e^{(-r_i^2/\sigma)}$. These parameter σ allows to control the local deformation around each control point. The coefficients α_0, α_1, α_2, β_0, β_1, β_2, a_i and b_i ($i = 1, ..., n$) in equation (1) need to be find in order to determine the mapping functions in x and y. This coefficients will be used for mapping the remainder image pixels using the base function. For this it is necessary to solve the linear system in equation (2). A similar linear system can be derived for finding the coefficients for $f_y(\vec{p_i})$.

$$\begin{cases} f_x(x_i, y_i) = \alpha_1 + \alpha_2 x + \alpha_3 y + \sum_{i=1}^{n} a_i g(r_i) \\ \sum_{i=1}^{n} a_i = 0 \\ \sum_{i=1}^{n} a_i x = 0 \\ \sum_{i=1}^{n} a_i y = 0 \end{cases} \tag{2}$$

The first equation in the system assures that the interpolating surface is smooth while the other equations assure an almost linear behavior of the RBF when evaluated far from the control points. The linear system can be rewrite in matrix:

$$\begin{bmatrix} g(r_{11}) + \lambda & g(r_{12}) & \cdots & g(r_{1n}) & 1 & x_1 & y_1 \\ g(r_{21}) & g(r_{22}) + \lambda & \cdots & g(r_{2n}) & 1 & x_2 & y_2 \\ \vdots & \vdots & \ddots & \vdots & \vdots & \vdots & \vdots \\ g(r_{n1}) & g(r_{n2}) & \cdots & g(r_{nn}) + \lambda & 1 & x_n & y_n \\ 1 & 1 & \cdots & 1 & 0 & 0 & 0 \\ x_1 & x_2 & \cdots & x_n & 0 & 0 & 0 \\ y_1 & y_2 & \cdots & y_n & 0 & 0 & 0 \end{bmatrix} \begin{bmatrix} a_1 & b_1 \\ a_2 & b_2 \\ \vdots & \vdots \\ a_n & b_n \\ \alpha_1 & \beta_1 \\ \alpha_2 & \beta_2 \\ \alpha_3 & \beta_3 \end{bmatrix} = \begin{bmatrix} u_1 & v_1 \\ u_2 & v_2 \\ \vdots & \vdots \\ u_n & v_n \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} \tag{3}$$

The parameter λ showed in the matrix diagonal is used for approximating the position of the control points in the interpolation (i.e. $u \approx f_x(x, y)$ and $v \approx f_y(x, y)$). The higher the value of λ, the smoother is the deformation. If $\lambda = 0$ we have an exact interpolation transformation (i.e. $p_i = q_i$, $i = 1, ..., n$).

4. Results and Conclusion

Figure 2 shows the simulation of a facial aging from 20 years to 60 years with $\sigma = 30$ e $\lambda = 1$. The frontal region is limited by the eyelids and the forehead control lines and the distance between these limits enlarges with forward aging. In nasal region is observed an enlargement of its contour. The orolabial region is defined by 2 horizontal control segments bounding the upper and lower lips and the lips become thinner. The mental region have 8 control segments, that define the low limit of the face and descend with aging. The image (c) shows the inicial points, the control points defined for aging curves and the mapped points for the radial basis function.

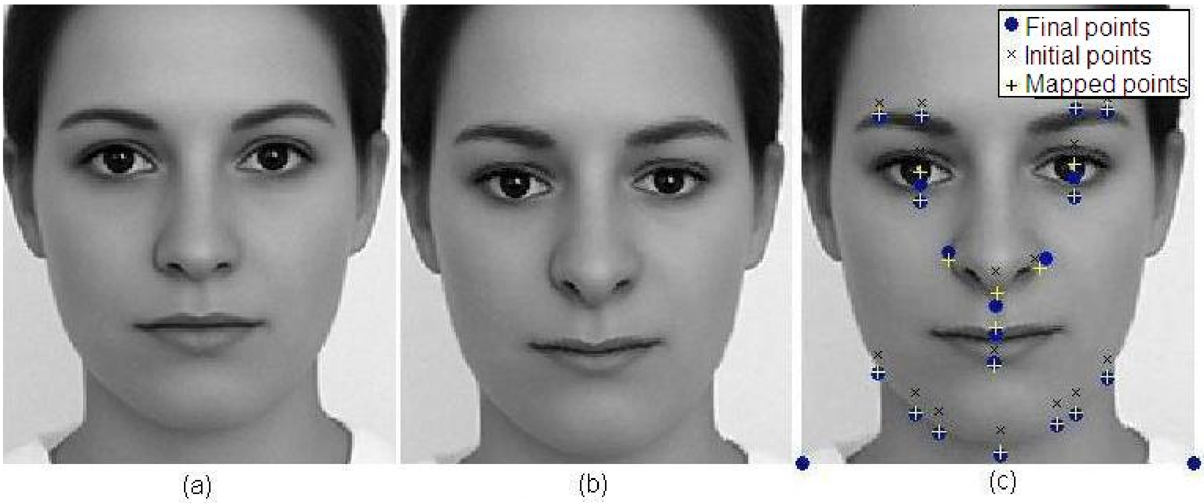

Figure 2. Simulation of aging from 20 to 60 years ($\sigma = 30$,$\lambda = 1$). (a) original image; (b) aged image (c) aged image with control points.

In the present work we manipulate facial images using aging curves that allows measure the displacement of some points in the face with the aging. In order to get more realistic results it would be necessary the use of textural aging methods as a complement, which is the natural continuity of this work.

References

Arad, N., Dyn, N., Reisfeld, D., and Yeshurun, Y. (1994). Image warping by radial basis functions: Application to facial expressions. *Computer Vision, Graphics, and Image Processing. Graphical Models and Image Processing*, 56(2):161–172.

Gandhi, M. R. (2004). A method for automatic synthesis of aged human facial images. Ph.d. thesis, McGill University.

Leta, F. R. (1998). Modelagem matemática e simulação gráfica do envelhecimento facial. Ph.d. thesis, PUC Rio.

Pessa, J., Zadoo, V., Yuan, C., Ayedelotte, J., Cuellar, F., Cochran, C., K.L.Mutimer, and Garza, J. (1999). Concertina effect and facial aging: nonlinear aspects of youthfulness and skeletal remodeling, and why, perhaps, infants have jowls. *Plastic and Reconstructive Surgery*, pages 635–644.

Pitanguy, I., Quintaes, G., Cavalcanti, M., and Leite, L. (1977). Anatomia do envelhecimento da face. *Bulletin of Plastic Surgery No 40*, 67:385–390.

Wolberg, G. (1998). Image morphing: a survey. *The Visual Computer*, 14(8/9):360–372.