# Construction of 3D Facial Wrinkles using Splines

Ali Mehdi
University of Bradford, UK
amehdi@bradford.ac.uk

Rami Qahwaji
University of Bradford, UK
R.S.R.Qahwaji@Bradford.ac.uk

Hassan Ugail
University of Bradford, UK
H.Ugail@Bradford.ac.uk

Abdullah Mehdi
Princess Sumaya University for Technology, Jordan
mehdi@psut.edu.jo

## ABSTRACT

Facial Aging (FA) is a very fundamental issue as aging, in general, is part of our daily life process. Facial Aging is used in many applications such as security. There are many systems that were implemented for FA using 2D approaches while not many were conducted using 3D systems. Creating a 3D system is much more reliable than the 2D ones as every detail of the face is covered. In this paper, we put the first stone in building our complete 3D Facial Aging system that will overcome the available systems. In this work, we constructed the facial curves (splines) using Maya, which is a very powerful 3D modelling tool. Then with the aid of the Triangulation Algorithm we simplified the facial mesh and eventually, wrinkles were constructed by manipulating the Non-Uniform Rational B-Spline (NURBS) Curves. We have also presented an understanding of the two terms (triangulation and NURBS) and how they work.

Key Words: Facial Aging, Facial Recognition, NURBS, Triangulation.

## 1. Introduction

Facial Aging (FA) is a branch of Facial Recognition (FR) and “the main reason for facial recognition is delivered from the forensic needs to identify victims or suspects” [1]. FR is a remarkable process; the Humans’ brain has the ability and capacity to distinguish between many known and unknown faces with a high speed.

The biggest advantage of using the face (over other parts of the human’s body) in many applications is that the face is always with the person. Moreover, the face carries a magnificent number of features that identify individuals such as gender, emotional state, ethnic origin, age etc, and as mentioned in [2] that it is impossible to find two identical people; even twins have some differences.

FA is used in security, helps identifying missing children and many other applications that are stated in [3], such as a web browser can decide by itself whether the user satisfies the age restrictions to view certain web pages; a vending machine will not sell cigarettes or alcohol to underage people.

Finally, it is very important to study the Facial Aging phenomenon, as it is part of our human nature, and develop various systems and methods in leading to better estimations that are performed by machines. The reliability of the machines depends on how accurate the input systems are.

## 2. Related Work

In the task of automatic age estimation [4], a quantitative analysis of the performance of different classifiers is discussed. The idea was to generate an estimation of the age of a person shown in a face image by designing classifiers that recognize the model-based representation of the unseen face images.

But on the other hand, the work in [5] that was conducted by 'Lanitis' the same author of the previous work, described (using learned age transformations) the effect of facial aging on the face appearance and how it can be clarified presenting some results indicating that acceptable age estimations can be generated for unseen images. The work was based on a statistical face model [6] that allows reversible coding of face images. The author of [4] and [5] seems to be relying on a 2D database that is available online called the FG-NET database [7]. This database is an image database that contains face images of different individuals at different ages. The downside of this database is that there is no consistency in the available images, i.e. some images are presented in black and white and some of them are coloured; some images have busy backgrounds and others are even blurred as well as some subjects in the images are wearing glasses etc. Obtaining very accurate results in such a huge variation of data might not be possible.

Another method for automatic age estimation, called the AGES (AGing pattErn Subspace), was proposed in [3]. In their work, the aging pattern was defined as a sequence of images that represent the aging face, so the idea was to model this pattern. A representative subspace was used to determine the aging pattern for a face image by projecting the image in the subspace so that the face image can then be reconstructed and at the same time the location of that face image in the aging pattern will reveal its age. The AGES method is an interesting work that achieved respectable results based on 2D facial aging estimation.

The method described in [8] uses aging simulation and cloning in a family of four people (father, mother, son and daughter). This work differs from the other works stated in this section due to its approach of using 3D virtual faces that were reconstructed from the four family members by extracting their shapes and textures and mixing them. For mixing 3D heads between the family members, a method was generated to conduct 3D shape interpolation and 2D morphing using triangulation. Then eventually, based on the identification of the feature points, wrinkles within facial animation and aging were created.

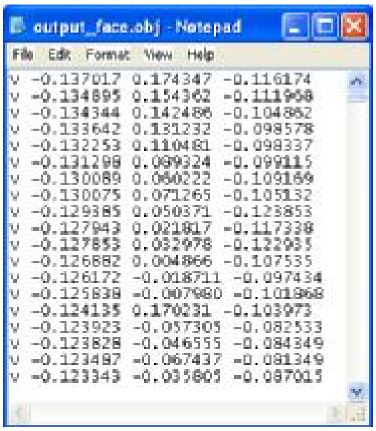
For face aging process, a dynamic model was presented in [9] for simulation. A high resolution face model was considered and expanded with age and hair features. The system focuses on three facets that occur due to aging: changes in the appearance of hair style and shape, wrinkles appearance and the effects of aging on facial components.

The rest of this paper is organized as follow: Section 3 discusses an overview of the implementation procedure. Section 4 presents the practical approach along with the results and finally section 5 highlights the conclusion and future work.

## 3. Overview of Implementation Procedure

The input files that are used in this work are 3D object files which have the extension (.obj) and the dimensions (x, y and z). The OBJ file format is also a text file format [10], which means that they can be manipulated using text editors, see figure 1 which shows a sample of an obj file opened in 'Notepad'. However, the object files may also have the extension (.mod), if they are in binary format [11].

The first column is the x positions, the second column is the y positions and the third column is the z positions of the vertices.



```
v -0.137017 0.174347 -0.116174
v -0.134895 0.154362 -0.111968
v -0.134344 0.142486 -0.104862
v -0.133642 0.131232 -0.098578
v -0.132253 0.110481 -0.098337
v -0.131298 0.089324 -0.099115
v -0.130089 0.060222 -0.109169
v -0.130075 0.071265 -0.105132
v -0.129385 0.050371 -0.123853
v -0.127943 0.021817 -0.117338
v -0.127853 0.032978 -0.122935
v -0.126882 0.004866 -0.107535
v -0.126172 -0.018711 -0.097434
v -0.125838 -0.007980 -0.101868
v -0.124135 0.170231 -0.103973
v -0.123923 -0.057305 -0.082533
v -0.123828 -0.046555 -0.084349
v -0.123487 -0.067437 -0.081349
v -0.123343 -0.035805 -0.087015
```

Figure 1 – Sample obj file structure opened in Notepad

The obj file that is used in this work is a complex file that has many vertices and a huge mesh, thus the work has to be started by simplifying this input data. The reason of simplifying the mesh is to have more control over the face. A method for simplifying such file will be conducted in Maya. The method involves creating curves on the face then extracts their control points using Maya plug-ins (explained in section 4.1). Once the control points have been generated, a triangulation algorithm will be applied to connect each point to its neighboring ones to form the simplified mesh that represents the face model (more details about the triangulation algorithm are also presented in section 4.1).

For wrinkles formation, the curves will be manipulated accordingly and the whole process of extracting the control points will be repeated to generate a new aged face image. The flow chart below explains this process:

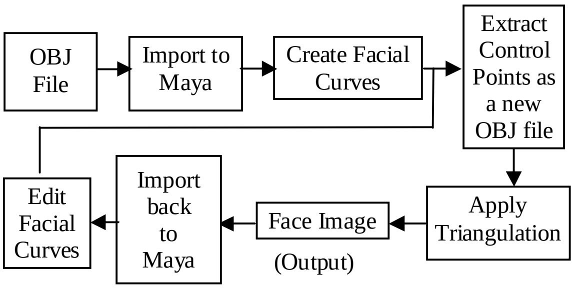


Figure 2 – Implementation process

The curves are of type (NURBS) which are explained in details in section 4.2 of this paper. NURBS curves are easy to control and manipulate and Maya handles the NURBS curves very well which is why it was chosen. The curves will be manipulated as follow: First, location of some common wrinkles will be chosen, then the curves will be manipulated in the x,y,z directions based on our understanding of the NURBS curves and their properties. After manipulating the curves, the control points will be extracted as explained above and the whole process will be repeated as shown in Figure 2 to have a new aged face.

This method will be adopted for its simple procedure that will prove first, the understanding of the steps involved in the method and second, it will prove the possibility of generating wrinkles manually by only changing the magnitudes of the control points of the curves.

## 4. Practical Approach

### 4.1 Simplifying the OBJ file

The following image is the original obj file. Notice the huge number of triangles that this image contains:

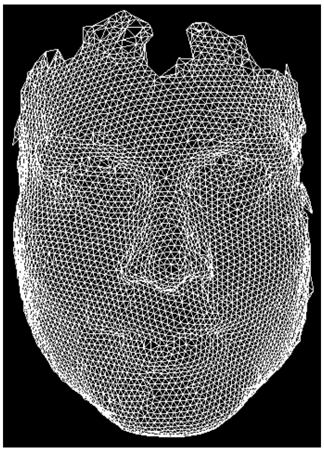


Figure 3 – The original obj image

The procedure of simplification is tackled in two stages; first, we extract the control points of drawn curves on the face and second, we triangulate the generated points to form a mesh. The original obj file was opened in Maya environment and the number of curves that were drawn on the face was decided to be 54 for the simple reason that the more curves drawn on the face the more control we get over constructing the wrinkles:

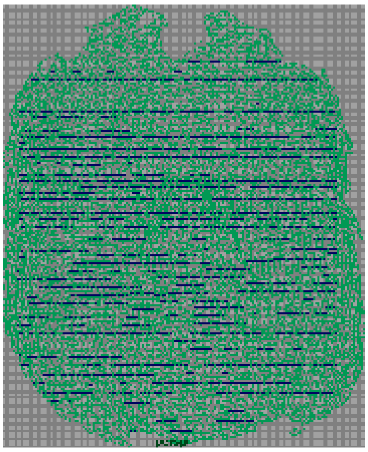


Figure 4 – Fifty four curves were created on a 'Live' face

The following figure shows the resulting facial curves that were constructed using the 54 curves.

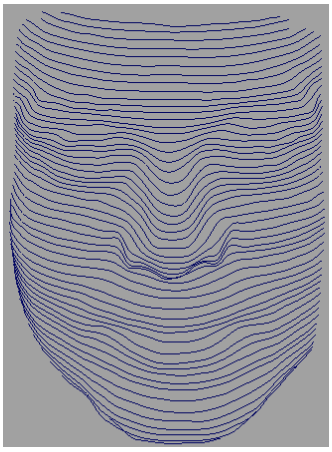


Figure 5 – Facial curves

To extract the control points i.e. to generate the cloud points of this face, a Maya Plug-in is used. Basically, Maya Plug-in searches for the control points of each curve then extracts them in a separate folder. The process is as follow: The algorithm considers the drawn curves and generates a surface on Maya scene. Every object in the Maya scene is a DG (Dependency Graph) node, that has an input and output [13]. Hence, to access the components of these objects (e.g. in our case, vertices of the curves) we need to process the nodes hierarchy to reach the object of interest.

Having done the above process, now the points can be extracted. Figure 6 shows the process of the points extraction followed by Figure 7 that presents the extracted cloud points.

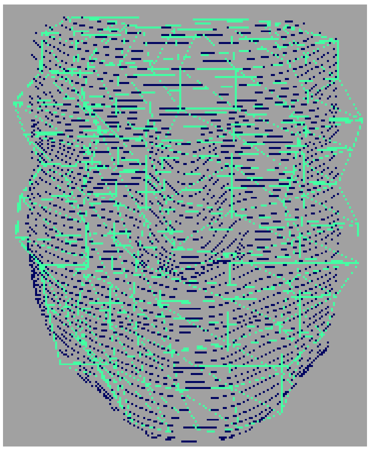


Figure 6 – Points extraction process

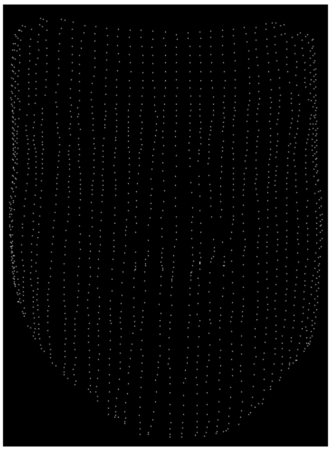


Figure 7 – The extracted cloud points

The cloud points don't give enough information about the facial features; therefore, the triangulation algorithm has to be implemented.

The triangulation was devised by Boris Delaunay in 1934 [14]; every three points generate a triangle (providing that they are not on a straight line). The circumcircle (the circle that contains all the vertices of the triangle) must not contain any other vertex; otherwise the Delaunay triangulation condition will not be met. Figure 8 (which was copied from [14]), shows a Delaunay triangulation in a space with the circumcircles.

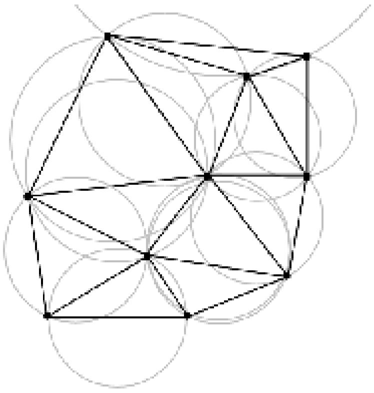


Figure 8 – Delaunay triangulation

Moreover, triangulation can be applied on every simple polygon with a number of vertices *n* [15]. Our triangulation approach is incremental, i.e. it looks for the nearest three points and joins them together to form a triangle then it moves to the next set and so on until we have a complete mesh that covers the face. Figure 9 illustrates the face after applying the triangulation method to it.

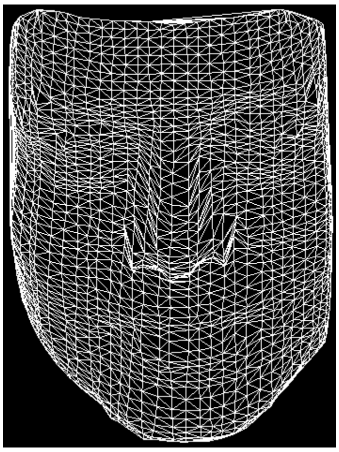


Figure 9 – The triangulated face

As can be seen that this face contains far less mesh than the one illustrated in Figure 3.

Once the new triangulated face is generated, we then import it back to Maya to smooth it and shade it to have a finalised face model that will be used as the basis of our experiments.

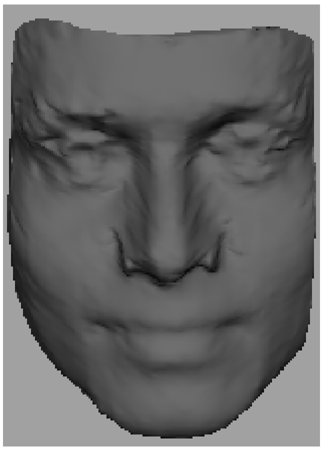


Figure 10 – The finalised face image

## 4.2 Manipulating the NURBS Curves

NURBS stands for Non-Uniform Rational B-Spline [16][17]. Non-Uniform means that some control vertices affect a larger region of the curve than others [18] (see Figure 11). Rational is pointing out that the NURBSs are based on a ratio of sums of polynomials which allocates each control point to a weight [16]. B-Spline is Basis Spline and the word 'Basis' was taken from an equation called 'Basis Function'. The basis function equation works out the weight of a given control point [16].

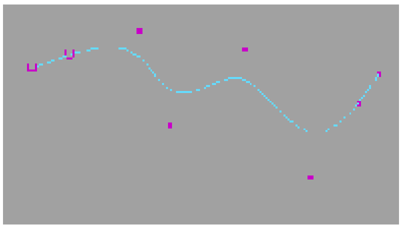


Figure 11 – A simple curve with its control vertices

The closer the vertex to the curve, the more influence it has on it.

In our work, the curves were constructed in a very high accuracy so that the vertices are very close to the curve resulting in all the vertices have all the influence on the curve, Figure 12 shows a section of the first 4 curves in our model with the control vertices:

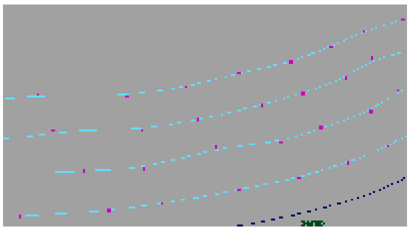


Figure 12 – Control vertices in our model

To prove the idea of manipulating the facial curves will result in the appearance of wrinkles, we chose some parts of the face to apply the wrinkles on. The following wrinkles were constructed (refer to [reference 12, Appendix A, P24] and Figure 13 for the medical terms): transverse frontal lines, transverse nasal line, inferior orbital grooves, nasolabial furrows, oromental grooves and mentolabial groove.

To manipulate the curves, we used their control points which are highlighted in Figure 13. We constructed each wrinkle individually by manipulating the x,y,z positions of the control points manually.

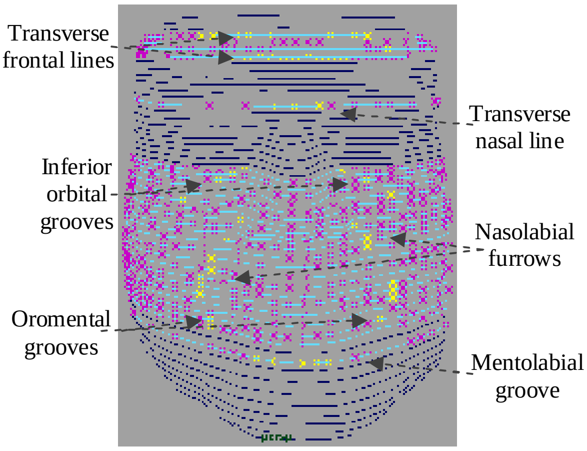


Figure 13 – The points that were manipulated

Referring to the flow chart in Figure 2, we extracted the whole control points again using Maya plug-ins then triangulated those points to obtain the aged model. Figure 14 presents a comparison between our simplified model and the aged one.

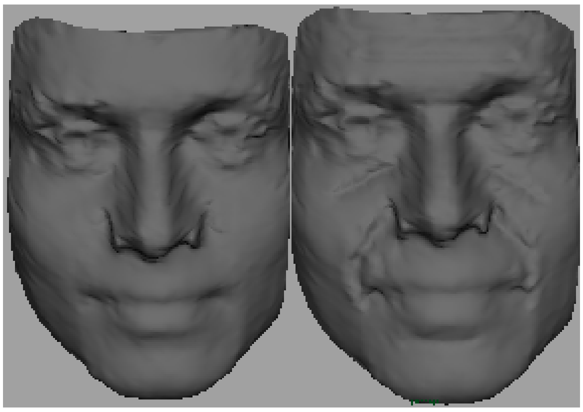


Figure 14 – Comparison between the two models

## 5. Conclusion & Future Work

Based on our results we have shown that by changing the values of the control points of the facial curves, wrinkles will appear. This is an important fact as it will be used in the next step to improve our results by creating an automated system and conduct the experiments on multiple faces. Texture will also be applied on the faces to gain better observation. To automate the system, Matlab codes will be generated to allow us changing the magnitude of the control points automatically by feeding the values to the program. Then, by the use of 3D equations we will generate 6 aged faces increasing in 10 years spans.

## *References:*

[1] Clement, J. G. and Marks, M. K. "Computer Graphic Facial Reconstruction", Published by Elsevier, USA, 2005, pp. 3-5.

[2]http://www.tgdaily.com/content/view/33676/113/, Date of last visit 05/09/2007

[3] Geng, X.; Zhou, Z. H.; Zhang, Y.; Li, G. and Dai, H. "Learning from facial aging patterns for automatic age estimation". Proceedings of the 14th annual ACM international conference on Multimedia. ACM New York, NY, USA, 2006, pp. 307-316.

[4] Lanitis, A.; Draganova, C. and Christodoulou, C. "Comparing Different Classifiers for Automatic Age Estimation". IEEE Transactions on Systems, Man, and Cybernetics, Part B, Volume 34, 2004, pp. 621-628.

[5] Lanitis, A.; Taylor, C. J. and Cootes, T. F. "Towards Automatic Simulation of Aging Effects on Face Images". IEEE Transactions on Pattern Analysis and Machine Intelligence, Volume 24, 2002, pp. 442-455.

[6] Edwards, C. J.; Lanitis, A.; Taylor, C. J. and Cootes, T. F. "Statistical Models of Face Images – Improving Specificity". Published by Elsevier Science, Image and Vision Computing, Volume 16, 1998, pp. 203-211.

[7]http://www.fgnet.rsunit.com/index.php?page=filename, Date of last visit 18/03/2008.

[8] Lee, W. S.; Wu, Y. and Magnenat-Thalmann, N. "Cloning and Aging in a VR Family". IEEE Virtual Reality, 1999. Proceedings. pp. 61-68.

[9] Suo, J.; Min, F.; Zhu, S.; Shan, S. and Chen, X. "A Multi-Resolution Dynamic Model for Face Aging Simulation". IEEE Conf. CVPR. 2007.

[10] http://www.royriggs.com/obj.html, Date of last visit 08/12/2007.

[11] http://jmath3d.aspirine.org/doc/obj_spec.pdf, Date of last visit 16/12/2007.

[12] Albert, M.; Ricanek, K. and Patterson, E. "The Aging Adult Skull and Face: A Review of the Literature and Report on Factors and Processes of Change". Published by UNCWTR01, 2004.

[13] Adams, M.; Miller, E. and Sims, M. "Inside Maya 5", 1st Edition. Published by New Riders,2003.

[14]http://en.wikipedia.org/wiki/Delaunay_triangulation, Date of last visit 01/07/2008.

[15] Lamot, M. and Zalik, B. "An Overview of Triangulation Algorithms for Simple Polygons". IEEE International Conference on Information Visualization, 1999. Proceedings. pp. 153-158.

[16] Gould, D. A. "Complete Maya Programming", 2nd Edition. Published by Elsevier Inc, USA, 2005.

[17] Maestri, G. "Maya at a Glance". Published by Sybex Inc, USA, 2005.

[18]http://devworld.apple.com/dev/techsupport/develop/issue25/schneider.html, Date of last visit 05/07/2008.