Literature Review - 2

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The **primary** research paper I chose for this Literature Review is **"Blending Face Details: Synthesizing a Face Using Multiscale Face Models"**[1] by **S. H. Yoon, J. Lewis and T. Rhee**.

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@ARTICLE{8103313,
author={S. H. Yoon and J. Lewis and T. Rhee},
journal={IEEE Computer Graphics and Applications},
title={Blending Face Details: Synthesizing a Face Using Multiscale Face Models},
year={2017},
volume={37},
number={6},
pages={65-75},
keywords={computer graphics;2D parameter space;3D face mesh;CDMs;MFM;computer graphics;face details;multiscale continuous displacement maps;multiscale face models;nonhuman characters;salient facial features;weighted multiscale detail blending;Computational modeling;Face recognition;Semantics;Shape analysis;Solid modeling;Splines (mathematics);Three-dimensional displays;blendshapes;computer graphics;continuous displacement maps;face modeling;multilevel b-spline;multiscale face model;parameterization},
doi={10.1109/MCG.2017.4031069},
ISSN={0272-1716},
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The **secondary** research paper I chose is **"Practice and Theory of Blendshape Facial Models "**[2] by **John P. Lewis, Ken-ichi Anjyo, Taehyun Rhee, Mengjie Zhang, Frédéric H. Pighin, Zhigang Deng**.

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@inproceedings{Lewis2014PracticeAT,
 title={Practice and Theory of Blendshape Facial Models},
 author={John P. Lewis and Ken-ichi Anjyo and Taehyun Rhee and Mengjie Zhang and Fr{\'e}d{\'e}ric H. Pighin and Zhigang Deng},
 booktitle={Eurographics},
 year={2014}
}
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Now, the reason I chose these papers is 'BlendShapes' is one of the most important concepts in movies and video games. These papers discuss the techniques to model a face in detail.

We can start by discussing how the secondary paper describes it in 2014 and how the primary paper expresses its improvisations of the same concept in 2017.

The secondary paper describes ‘BlendShapes’ as a simple linear model of facial expression, which is a great approach to realistic facial animation. This concept has been used in many Hollywood films and animation films. There are many approaches to model a face in 3d besides BlendShape. Some of them are:

- physically based models, which approximate the mechanical properties of the face such as skin layers, muscles, fatty tissues, bones, etc.
- parametric models, in which custom deformation algorithms defined specifically for the face are Implemented
- approaches using proprietary deformers of commercial packages, such as “cluster deformers”
- generic, low-level meshes driven by dense motion capture
- principal component analysis (PCA) models obtained from scans or motion capture
- and some other hybrid approaches.

Of all these approaches, BlendShapes remain a popular choice due to its combination of simplicity, expressiveness and interoperability.

This approach has been used for lead actors in many movies such as : *The Curious Case of Benjamin Button, King Kong, The Lord of the Rings* etc.

Even when more sophisticated approaches are used to model a face, BlendShapes is used as the base layer because of its simplicity.

Figure : Blendshapes are an approximate semantic parameterization of facial expression. From left to right, a half smile, a smile, and a (non-smiling) open-mouth expression. While the smile and open-mouth expressions are most similar in terms of geometric distance, the smile is closer to the half-smile in parameter distance (distance=0.36) than it is to the open-mouth expression (distance=1.34). Please enlarge to see details.

The above figure clearly explains how BlendShapes are a semantic parameterization. The weights have intuitive meaning for the animator as the strength or influence of the various facial expressions. Other models discussed above such as PCA do not provide this.

This also, for some extent, force the animator to stay “on model”, that is, arbitrary deformations can be avoided. There are two ways to look at this: It could be seen as limiting artist’s power or that it helps ensure that the facial character is consistent even if animated by different individuals.It also enforces a division of responsibility between the character modeler and animator.

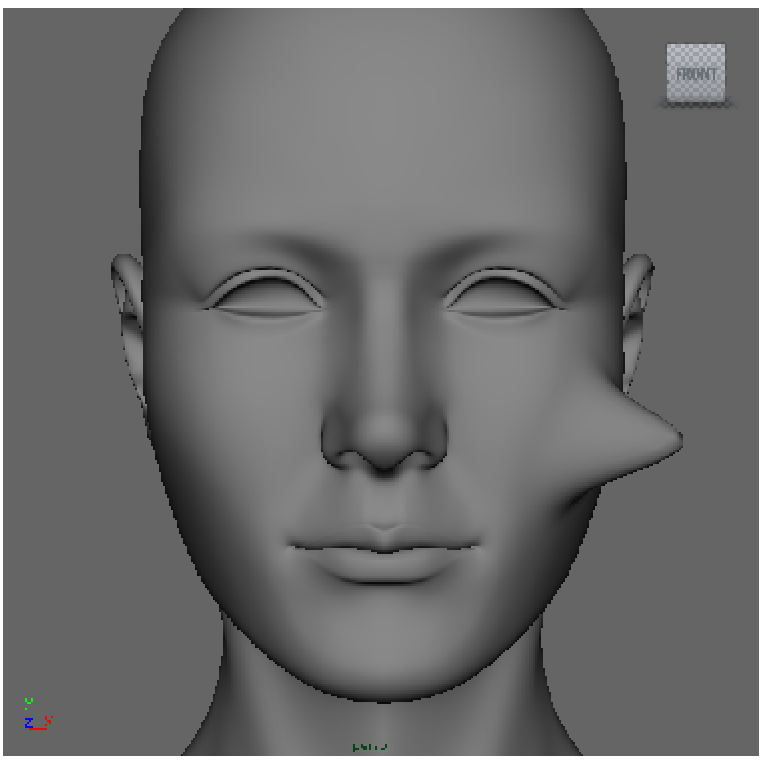

Figure : Blendshapes prevent the artist from making “improper” edits such as this.

BlendShapes ensure that mistakes like this figure does not happen as explained in the above paragraph.

Coming to the math of this concept, we can view this as a simple vector sum. Consider a facial model composed of $n = 100$ blendshapes, each having $p = 1000$ vertices, with each vertex having three components x, y, z. By “unrolling” the numbers composing each blendshape into a long vector b_k in some order that is arbitrary but consistent across the individual blendshapes **like the figure below**

$$\begin{bmatrix} f_{1x} \\ f_{1y} \\ f_{1z} \\ f_{2x} \\ f_{2y} \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ \vdots \\ f_{pz} \end{bmatrix} = \begin{bmatrix} x & x & \cdots & x \\ y & y & \cdots & y \\ z & z & \cdots & z \\ x & x & \cdots & x \\ y & y & \cdots & y \\ \vdots & | & \cdots & | \\ \mathbf{b}_1 & \mathbf{b}_2 & \cdots & \mathbf{b}_n \\ | & | & \cdots & | \\ | & | & \cdots & | \\ | & | & \cdots & | \\ | & | & \cdots & | \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}$$

The blendshape model is expressed as

$$f = \sum_{k=0}^{n} w_k b_k$$

or using matrix notation

$$f = Bw$$

Where f is the resulting face, in the form of a 3000x1 vector, B is a m=3000x100 matrix. Thus blendshapes can be considered simply as adding vectors. This linear algebra viewpoint will be used to describe various issues and algorithms.

Since blendshapes are linear models, there are some limitations as well. Linear Interpolation is one of the limitations of blendshapes i.e, if two weights are not in an affine combination, the movement is constrained to a plane. Some other issues are lack of orthogonality and the fact that blendshape models are not unique.

Let’s see how these **limitations are addressed in our primary paper.**

The primary paper discusses the benefits of blending of multiscale details from different face models. We have established in the discussion of our secondary paper that creating realistic 3D face models is important and challenging task in computer graphics. 3D facial models in games and movies require details such as wrinkles, pores, and more. Recent technology has made acquiring all these details possible. Creating a 3D face model from scratch is considered highly laborious and time consuming task, even for a skillful artist.

In entertainment applications such as movies and games, many characters are imaginary so they cannot be done by automatic modeling. So, there is a need for simple, understandable blending model which the authors discuss in this paper.

BlendShapes is a simple but powerful concept. **The main goal of this paper is designing faces, rather than facial expression (which is the goal of our secondary paper).** One obvious semantic parameterization is parts-based decomposition, in which a face is designed by selecting the desired eye, nose and mouth shapes and then blending them together. In this paper, the author presents a novel approach to synthesize a new 3d face model using weighted blending of multiscale details across different faces including human and nonhuman characters **as seen in the figure below**

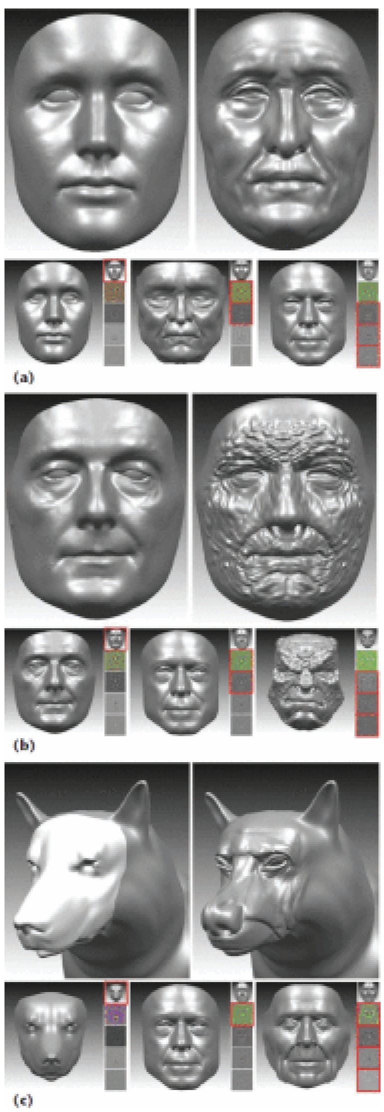

Figure .
Synthesizing a face model using multiscale face models (MFMs): (a) A base face (top left) and a synthesized new face model (top right) using weighted blending of bottom faces. The selected multiscale continuous displacement maps (CDMs) are outlined in red. We also show examples of the detail transfer (b) From a monster and human to another human face and (c) From two humans faces to a dog face.

Recent advancements in technologies makes it possible to capture high-resolution 3D face geometry such as wrinkles and pores. The model proposed by authors lets the artist interactively define semantic correspondences across faces and scales.

Now let’s discuss the algorithm the authors proposed briefly. The first step in creating a multiscale model from a given 3D face model M is to find its parameterization P on a unit domain [0, 1] x [0, 1]. **This is where our secondary paper comes into play**. The parameterization is clearly explained in our secondary paper. BlendShapes gives weighted semantic parameters, which are very useful in modeling to very fine details like smile, wrinkles and pores. We discussed above in the secondary paper about the limitations of blendshapes. Since blendshapes are linear, interpolation is always a problem. **The primary paper eliminates these limitations** by decomposing into a multispace continuous displacement maps (CDMs). Each multiscale face model (MFM) represents face details from coarse to fine scales while providing full correspondences across CDMs. MFMs provide full correspondences across both scales and faces. Using blendshapes, user can interactively synthesize a new face model while blending multiscale details across faces even in highly different shapes.

This proposed approach provides considerable power, while providing natural interactions for the artist: the contributions of various scales can be directly specified, and facial features such as salient wrinkles can be interactively marked to enhance the correspondence across faces. Because our system can incorporate new face scans and models as they become available, it becomes more powerful with additional use.

The authors produced wide range of results including human and non human faces. The authors also discussed about smooth transition from human to non human faces. They have added a lot to blendshapes which were discussed in our secondary paper to achieve this accuracy.

The authors took the feedback from 10 professional studio artists asking them to rate this model on the range of 1-5. They have received a pretty good mean score of 4 out of 5. There are lot of improvements that can be made to this model. An obvious extension would be local region blending. The region outside the face can be blurred using Gaussian function.

To conclude this review of both papers,we can say that the secondary paper explained the concept of blendshape which is used to model facial expressions in 3D. The primary paper, using the concepts explained in the secondary paper, improved the process of modeling a face in 3D from scratch. The concepts explained in secondary paper is highly used in current industries(both movies and games). The primary paper is fairly new and we can expect it to be more useful in industries and academics in the coming days.