Muscle-based Facial Animation

GRADUATE PROJECT REPORT

Submitted to the Faculty of
the Department of Computing Sciences
Texas A&M University-Corpus Christi
Corpus Christi, Texas

in Partial Fulfillment of the Requirements for the Degree of
Master of Science in Computer Science

by

Wei Wang
Spring 2010

Committee Members

Dr. Scott King
Committee Chairperson

Dr. John Fernandez
Committee Member

Dr. David Thomas
Committee Member
ABSTRACT

The goal of this project is to create a muscle-based facial model which can be used to generate realistic facial animation. Maya software was used to set up the facial muscles, and attach them to the facial geometry so that changing the muscle parameter values will deform the shape of the facial model. To create smooth animation, one can change the contractions of each muscle resulting in a changing face. A Maya plug-in was created to control all the muscle parameters.
# TABLE OF CONTENTS

Abstract ........................................................................................................................................ ii

Table of Contents ......................................................................................................................... iii

List of Figures .............................................................................................................................. vi

List of Tables ................................................................................................................................ vii

1. Background and Rationale ........................................................................................................ 1

1.1 Computer Facial Animation .................................................................................................. 1

1.1.1 History .............................................................................................................................. 1

1.1.2 Speech Animation ........................................................................................................... 2

1.2 Previous Work ....................................................................................................................... 3

1.2.1 Shape-based Facial Animation ........................................................................................ 3

1.2.2 Motion Capture ................................................................................................................. 3

1.2.3 Physically-based Facial Model ........................................................................................ 4

1.3 Talking Head ......................................................................................................................... 4

1.4 Maya Software ...................................................................................................................... 6

1.4.1 cMuscle System .............................................................................................................. 7

1.4.2 Maya API .......................................................................................................................... 8

2. System Overview .................................................................................................................... 10

2.1 Facial Model ......................................................................................................................... 10

2.2 User Interface ...................................................................................................................... 11

2.3 Speech Animation ............................................................................................................... 12

3. System Implementation .......................................................................................................... 14
LIST OF FIGURES

Figure 1.1 Cartoonish and Realistic Talking Heads ......................................................... 2
Figure 1.2 Talking Head System .................................................................................... 5
Figure 1.3 Animation Tracks ....................................................................................... 6
Figure 1.4 Different Maya Models ................................................................................ 6
Figure 2.1 Muscle-based Facial Model ........................................................................ 10
Figure 2.2 Relationship between this Project and Talking Head ................................. 12
Figure 3.1 Facial Muscles [DEA Picture Library] ....................................................... 15
Figure 3.2 R_LEV_SUP Muscle Parameter ................................................................ 16
Figure 3.3 Simulation of Facial Muscles ..................................................................... 17
Figure 3.4 Muscle Parameter Attributes in Maya Muscle Builder .............................. 18
Figure 3.5 Muscle Spline Deformer Shape .................................................................. 19
Figure 3.6 Points on the Skin Controlled by Down_lip ............................................... 20
Figure 3.7 Sticky Bind Distance for orb_oris muscle .................................................. 21
Figure 3.8 Muscle Controllers ..................................................................................... 23
Figure 3.9 Slider Bar in Talking Head ......................................................................... 24
Figure 3.10 Slider Bar in Maya .................................................................................... 25
Figure 3.11 Set Muscle Parameter L_LEV_SUP to be 1.00 ........................................ 26
Figure 4.1 Facial Model with Different Expression .................................................... 28
Figure 4.2 Keyframes from Speech Animation Generated by the Project ................... 30
Figure 4.3 Comparison between Our Model and Talking Head Model ....................... 31
Figure 5.1 The Facial Deformation at a Fixed Time t ................................................... 32
LIST OF TABLES

Table 3.1 Muscle Parameters in Talking Head ............................................................ 16

Table 3.2 Muscle Controller Corresponding to the Muscle Parameters ......................24
1. BACKGROUND AND RATIONALE

This project creates a muscle-based facial model and applies speech animation to it. To build a realistic muscle-based facial model, Maya software is used to create complex 3D graphics. To synchronize speech animation with the deformation of the face model, the Talking Head system was used to provide the changing values of the muscle parameters.

1.1 Computer Facial Animation

As computer science and technology develop quickly, computer facial animation is widely used in many fields, such as animation, film, education, and human computer interaction. This section introduces the properties of computer facial animation.

1.1.1 History

As an individual subject of computer graphics, computer facial animation started in the early 1970s. It involved 2D facial animation, and used the transformation of 2D facial images. As the old films and animations, this kind of facial animation always requires a large number of pictures to create one motion. Nowadays, the 2D technique is not sufficient to support good performance for realistic and flexible facial animation. Compared with 2D animation, a 3D facial model offers a more powerful and skillful way to create computer facial animations. The first 3D facial animation was developed by Parke [1972]. Different methods are used to build 3D models and generate facial motion. The traditional techniques include shape/morph targets,
skeleton-muscle systems, bones/cages, motion capture of points on the face and knowledge based solver deformation. The skeleton-muscle approach is used for this project. Further introduction is given in the following section. Based on these different 3D animation methods, some realistic facial models and animations are provided as shown in Figure 1.1.

1.1.2 Speech Animation

Current research on speech animation is mostly focused on animation instead of modeling. The technique which is popularly used is keyframing. Similar to the technique used in 2D animation, a lot of key frames are created to support any changes on the face. Although some successes have been achieved in the computer animation field, the keyframing method has some limits. One is that keyframing does not provide speech-synchronized animation. If using keyframing to synchronize speech, then the speech has to be broken into phonemes and then converted into pictures which become the keyframes. But there are some differences for the same phoneme on emphasis, duration and influences from neighbor phonemes [King 2001]. To solve this problem, our project uses a different technique which concentrates on
the modeling and changes based on the facial model.

1.2 Previous Work

There are many different approaches which implement realistic facial animation. Related works with three different types of techniques are introduced in this section. Actually, for most of the projects, multiple techniques are combined together for the implementation. The facial animation created belongs to the physically-based facial model.

1.2.1 Shape-based Facial Animation

This technique is also known as blend-shape facial animation. It includes modeling the facial geometry of key facial expressions, and then blending the different sub geometries. It is still widely used for films and entertainment fields for facial expressions. The most famous sample using the blend-shape technique is Gollum in the film *The Lord of the Rings*. There are two features of shape-based facial animation. One is that much manual work is needed for the facial model. The other is that the change between two different blend shapes is linear. Early work like [JTDP 2006] is based on this type of technique. [DCFN 2006] introduces how to animate popularized 3D blend-shape face models by mapping facial motion capture data spaces to 3D blend-shape face spaces.

1.2.2 Motion Capture

Motion capture is usually combined with blend-shape based facial model to generate smooth animation, such as [LD 2008]. Firstly, the data is recorded by the cameras or other devices. Then the captured data is converted into a 3D facial model.
Finally the animation is generated based on different data. Different methods are used to capture the data and change it from 2D to 3D. [CB 2005] describes a method for creating expressive facial animation by extracting information from the expression axis of a speech performance. The main difficulties of motion capture are the quality of the data which may include vibration as well as the retargeting of the geometry of the points. [PL 2006] examines different techniques for retargeting a recorded facial performance onto a digital face.

1.2.3 Physically-based Facial Model

Physically-based facial model simulates tissues, bones, skin and muscles as a real human to provide animation. It is very powerful for creating realism. But the complexity of facial structures makes the model creation difficult and expensive. In this project, Maya provides the muscle system for muscle contractions and skin deformation. It is discussed in detail in Section 1.4. [SNF 2005] simulates the facial musculature, passive tissue and underlying skeletal structure for an anatomically accurate model. The data is acquired from a real human. [SSRF 2006] presents a physically-based facial model for speech simulation.

1.3 Talking Head

Talking Head [King 2001], shown in Figure 1.2, is partially involved in the project. Its muscle parameters are used to set up similar muscle parameters on Maya. The speech animation data is acquired from Talking Head.

This section gives a brief overview of the Talking Head system. It is a conversational agent running on Linux. It provides a human computer interface,
which is able to talk with the user. The process is to accept the input text from the keyboard, give an appropriate reply based on the current conversation, and translate it into speech. Talking Head consists of several subsystems with different functions. They coordinate to provide both audio and visual components for speech animation.

To make Talking Head look like a real human, different parts are created, which make up the whole facial model. The parts related to the speech-synchronized animations are: the geometry facial model images, the high deformable model of the lips, the parameters and variables used to control the movement of the lips, the jaw, and the muscles. In this project, similar methods were used to control the contractions of the muscles, and movements of the jaw.

Talking Head system records speech animation data for each parameter at every time frame. As shown in Figure 1.3, different colored curves indicate the changes of different parameter values over time. The researcher acquired the points on each curve through Maya API and simulated the same speech piece in the demo.
To achieve realistic facial animation and ease the effort, Maya software is applied to get good 3D modeling and animation. It is a popular, integrated node-based 3D software, which is widely used in film, visualization, and computer and video games. Maya allows the developer to create NURBS (non-uniform rational basis spline), polygons or subdivision surfaces to build up the facial model [Maya 2008]. It also has its own bones and muscles system which is useful for the modeling. One sample of Maya model created by subdivision surfaces is shown in Figure 1.4. The left is the model with the texture, the middle one shows the wireframe, and the right model shows the bones inside.
Maya offers an API to combine with third-party software. Both MEL (Maya Embedded Language) and C++ are available to use. The project depends on this feature of Maya. By implementing Talking Head in Maya, the system can benefit from the flexible and realistic facial modeling. The methodology for implementation is presented in the following section.

1.4.1 cMuscle System

cMuscle System (Maya Muscle System) has become an extension plug-in suite for Maya since 2008. It provides high-quality muscle deformation, and allows the user to create life-like skin animation [Techniques 2009]. Maya muscle system consists of three different components: capsule, muscle and bone, which enable sophisticated simulation results. In this project, all these three components need to be generated first to form the basis of the facial animation.

The bone, which is known as joint in the facial model, can be generated using the traditional Maya tools, then additional commands to modify their positions, shapes and sizes. They make up the skeleton system, which is the foundation of the muscle mechanism. Usually the only movement of the joints is rotation, which can create some limited facial motions.

The capsule object appears at the origins of the muscle. Some of them have simple translation movements, and some of them have no movement. The major roles of them are indicating the position of the muscle. Capsule is usually bound with the spline deformer control of the muscle, which changes the shape of the muscle when moving.
The muscles are generated based on the capsule and bones. Their shapes and sizes can be adjusted to apply better performance. To control the facial model precisely, the researcher put all the muscles and joints in a correct hierarchy in order to manage their influences between each other.

1.4.2 Maya API

As powerful 3D computer graphics software, Maya is able to provide extended and customized applications depending on different requirements of the users. Usually artists work in Maya by using its GUI (Graphical User Interface), such as the menus, the buttons, and the dialog boxes shown visually [Gould 2003]. In fact, developers work in Maya in another way. They complete the tasks by programming through the API (Application Program Interface), using either MEL or C++.

C++

The core of the Maya software is written in C++. It allows a developer to extend Maya by using the C++ API, for instance, to create additional classes besides the original ones Maya has. Since C++ is a powerful object-oriented programming language, it is used to improve the functions of Maya.

However, Maya also provides its own script language MEL (Maya Embedded Language), which has all the programming functionality needed. The C++ interface does not contain everything the MEL interface has, and vice versa. Thus, C++ and MEL are usually selected to develop Maya depending on the specific scenarios [Gould 2003].
MEL

In this project, MEL script is used more frequently, since it offers the required programming functionality. The following part introduces the basic attributes of MEL and how they will be used.

MEL, which is Maya Embedded Language, is a specific programming language used in Maya. Its structure and syntax are simpler than C++, which makes it more accessible for the Maya developer. MEL is an interpreted language that is executed immediately after writing a command. This attribute makes it run slower than the compiled language, such as C++. The result of each line is shown right after executing, which makes it easy to test and check errors.

For this project, two steps need to be done during MEL programming. One is to create accurate facial motions based on the specific conditions. The researcher used MEL to control the movements and relationships of the muscle parameters in order to create facial motions on the existing head model. The other step is to generate the graphical user interface based on the functionality created. The visual interfaces, such as slider, may give a better application for the users.
2. SYSTEM OVERVIEW

The project uses Maya as a platform to implement the facial animation system based on a muscle-based facial model. In this chapter, we give an overview of the entire project and how it can be managed. Section 2.1 talks about the work on the facial model and related muscles. Section 2.2 shows different user interfaces created through Maya API. Section 2.3 introduces how to combine the muscle-based facial model with the animation acquired from Talking Head.

2.1 Facial Model

Realistic speech animation requires an appropriate facial model that can represent a large number of needed mouth shapes. This highly deformable facial model is based on the changes of the muscles and bones. The final project consists of the muscles, the lips, the bones, and the skin as shown in Figure 2.1.

![Figure 2.1 Muscle-based Facial Model](image)

The skin in this facial model is a polygonal object. The original facial geometry is obtained from reference. As shown above, it has good performance on the
simulation of a real human head with lots of manual work. Deformer command is used for the geometry to make the skin controlled by points instead of surfaces or edges. The bones and muscles are built up using the Maya muscle system. They attach to the facial geometry so that transformation on the muscles and bones deform the facial geometry. The lip is considered as two muscles with specific motions in the project.

2.2 User Interface

For virtual character animation, the facial geometry deformation is complicated and diverse based on different face expressions. In this case, using a small number of controls to change a large number of local regions on a deformable surface is important. Some previous works are presented in [FKY 2008] and [SMND 2008]. In this project, multiple user interfaces are created using both MEL and C++, which include the controller, the slider bar and the plug-in.

The controller is based on the Maya GUI. The method to create such controller for facial animation is widely used in films and games. For each facial motion, several changes on the muscles and bones may be needed to deform the skin specifically. The controller envelopes these muscle behaviors to generate one face shape. The slider bar is using MEL script only. It can complete the same work as the controller does. The advantage of the slider bar is that it provides a visible dialogue window for the user. The animation plug-in combines C++ and MEL for implementation. C++ is used to apply the script command and read data information from Talking Head system. More details are discussed in Section 3.4.
2.3 Speech Animation

The implementation of speech animation based on the facial model is related to Talking Head. In Figure 2.2, Talking Head consists of an animation model and a facial model. The animation model acquires phoneme information from Festival, which is an external speech synthesis system. The animation model generates muscle parameter values in a .tha file and sends it to the facial model. Speech animation is created by combining the deformation of the facial model and the audio file from Festival. This project builds a muscle-based facial model that can be used instead of the facial model in Talking Head system.

![Diagram of Speech Animation](image)

Figure 2.2 Relationship between this Project and Talking Head. Our facial model can be driven by the talking head animation model in place of its facial model.

The muscle-based facial model shown in Figure 2.2 acquires muscle parameter changes from the animation model. The program in Talking Head is modified and recompiled to print the data. This output data from the animation model is listed in a particular MEL script format. The specific plug-in created by the researcher is used to
read the generated MEL file. After input, the speech animation will be created by setting the appropriate values to the muscle parameters at different times. Besides Talking Head, the speech data can also be gained from other sources or even set by users. Thus, the facial model is easy to be extended.
3. SYSTEM IMPLEMENTATION

This section demonstrates the implementation of the project in detail. The goal of the entire project is to build a muscle-based facial model and apply speech animation on Maya platform. For this work, the researcher focused on creating a muscle-based facial model through Maya API. There are three steps needed: firstly, based on the existing facial geometry, one adds muscle system to it. Secondly, attach the muscles to the facial geometry such that changing the muscle parameter values will deform the geometry. Finally, apply the speech data from Talking Head to generate facial animation. In addition, friendly user interfaces, such as slider bar and plug-in, are provided for the user to control the facial motions.

3.1 Adding Muscles to the Facial Geometry

The facial geometry works as the basis of this project. The original model is a polygonal object. Deformer MEL command was applied on it to control the deformation of all the geometry points.

To add animations to the fixed facial geometry, muscles and bones need to be created. The muscles on the face of a real human are shown in Figure 3.2. To simulate realistic facial animation, each point on the face may be controlled by more than one muscle or several bones at the same time.
The project creates the muscle/skeleton system, and control the muscle behaviors based on MEL scripting. The researcher concentrated on the muscles around the mouth, which control the speech behaviors of human. The specific muscles and bones have the same functions as the muscle parameters in Talking Head. By MEL scripting, the final muscle-based deformation facial model is more accurate and less influenced by the artistic skills of the developer.

### 3.1.1 Setup Muscle System

As a great 3D software, Maya offers skeleton and muscle mechanisms (cMuscle system) in order to support good simulations of human behavior. To generate facial animations through the Maya API, multiple bones and muscles need to be created in the head first. As shown in Figure 3.1, there are a lot of muscles which control the speech animation and the facial expression. [Olsen 2007] shows a possible sample of muscles generating facial expression.

![Figure 3.1 Facial Muscles [DEA Picture Library]](image)
In this project, the muscles needed for setup are related to the nineteen muscle parameters used in Talking Head, which are listed in Table 3.1.

<table>
<thead>
<tr>
<th>No.</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>OPEN_JAW</td>
<td>Moves jaw downward</td>
</tr>
<tr>
<td>1</td>
<td>JAW_IN</td>
<td>Moves jaw backward</td>
</tr>
<tr>
<td>2</td>
<td>JAW_SIDE</td>
<td>Moves jaw lateral</td>
</tr>
<tr>
<td>3</td>
<td>ORB_ORIS</td>
<td>Contracts lips, making mouth opening smaller</td>
</tr>
<tr>
<td>4</td>
<td>L_RIS</td>
<td>Left Risorius - Moves left corner towards ear</td>
</tr>
<tr>
<td>5</td>
<td>R_RIS</td>
<td>Right Risorius - Moves right corner towards ear</td>
</tr>
<tr>
<td>6</td>
<td>L_PLATYSMA</td>
<td>Left Platysma - Moves left corner downward and lateral</td>
</tr>
<tr>
<td>7</td>
<td>R_PLATYSMA</td>
<td>Right Platysma - Moves right corner downward and lateral</td>
</tr>
<tr>
<td>8</td>
<td>L_ZYG</td>
<td>Left Zygomaticus - Raises corner up and lateral</td>
</tr>
<tr>
<td>9</td>
<td>R_ZYG</td>
<td>Right Zygomaticus - Raises corner up and lateral</td>
</tr>
<tr>
<td>10</td>
<td>L_LEV_SUP</td>
<td>Left Levator labii Superior alaeque nasi</td>
</tr>
<tr>
<td>11</td>
<td>R_LEV_SUP</td>
<td>Right Levator labii Superior alaeque nasi</td>
</tr>
<tr>
<td>12</td>
<td>DEP_INF</td>
<td>Depressor labii Inferioris</td>
</tr>
<tr>
<td>13</td>
<td>DEP_ORIS</td>
<td>Not used</td>
</tr>
<tr>
<td>14</td>
<td>MENTALIS</td>
<td>Moves lower lip upward</td>
</tr>
<tr>
<td>15</td>
<td>L_BUCCINATOR</td>
<td>Moves left corner lateral</td>
</tr>
<tr>
<td>16</td>
<td>R_BUCCINATOR</td>
<td>Moves right corner lateral</td>
</tr>
<tr>
<td>17</td>
<td>INCISIVE_SUP</td>
<td>Moves upper lip backward</td>
</tr>
<tr>
<td>18</td>
<td>INCISIVE_INF</td>
<td>Moves lower lip backward</td>
</tr>
</tbody>
</table>

Table 3.1 Muscle Parameters in Talking Head

Some of the muscle parameters in the table are replaced by the controls of the lip muscles in this project. For instance, the R_LEV_SUP is represented as the control shown in Figure 3.3. The simple behavior of this muscle is to move the right part of the upper lip upward.

Figure 3.2 R_LEV_SUP Muscle Parameter

Some parameters are generated as Maya muscles, like ORB_ORIS, L_LEV_SUP.
and R_LEV_SUP. ORB_ORIS is divided into three parts to make better control of the skin deformation. The rest of the muscle parameters, such as OPEN_JAW, JAW_IN and JAW_SIDE are linked with the mouth_down bone. The entire skeleton and muscle system is shown in Figure 3.4.

Figure 3.3 Simulation of Facial Muscles

3.1.2 Muscle Controls

In this project, some muscle controls play significant roles in the animation, especially the controls of the upper and lower lips. The control of the muscle is shown as the yellow wire cube in Figure 3.4. The quantity of the controls for each muscle is specialized by the function of the muscle. For the muscles such as ORB_ORIS, there are only three controls for each of them. The two end controls attached to the capsules implement simple translate motions, and automatically control the behavior of the middle control. To generate more complex animation, the number of controls for the two lip muscles increases to five.

Some constraints between the controls are defined to create realistic and flexible contractions of the muscles. Different types of constraints are provided in Maya with different effects. Parent constraints are always used in this project with limitation of
the influence weights. These constraints add realism to the facial animation, such as the little rotation of the lips while pouting to pronounce /u/.

### 3.1.3 Modify Muscle Shapes

For all the muscles created, besides their different behaviors, each of them has its individual shape. Before connecting the muscles to the skin, the muscle shapes need to be modified to make them behave in an expected way.

Three types of muscle shape need to be modified, the default shape, the squashing shape, and the stretching shape. First when creating the muscle, its fundamental shape is defined. There are two different cases in this project: the three muscles indicated orbicularis oris are created as NURBS objects by hand. They look like three small boards above the upper lip. Their shapes can be customized before converting to muscles. The other muscles are created by Muscle Builder automatically with limited changes of the traditional muscle shapes. Both types of muscles can be modified by attributes after applying the spline deformer, as shown in Figure 3.5.

![Figure 3.4 Muscle Parameter Attributes in Maya Muscle Builder](image-url)
In this project, the muscles attributes that need to be modified are the squashing and stretching shapes. As shown in Figure 3.4, first the end control of the muscle is dragged to decide when the muscle is squashing and when it is stretching. Then Set Current as Squash and Set Current as Stretch are used to fix the squashing and stretching positions. The Stretch Volume Presets gives a basic set of the squashing and stretching extents. For the facial muscles, Small type is always applied.

![Figure 3.5 Muscle Spline Deformer Shape](image)

The Muscle Builder only sets the basic muscle attributes, which are not sufficient to simulate accurate animation. To improve the contraction of the muscle, its squashing and stretching shapes need to be modified by hand. Muscle Spline Deformer Shape allows specific changes of the muscle shape in its squashing and stretching positions. In Figure 3.5, the state -1 indicates the squashing shape, and the state 1 indicates the stretching shape. Maya generates linear transformation of the muscle shape between these two states and the default state. The linear transformation leads to non-linear deformation of the skin.

**3.2 Attaching the Muscle System to the Facial Model**

To make the muscle system deform the facial geometry precisely, the behaviors
of the points on the skin need to be managed by painting weights for every point. For a realistic facial model, the exact value of each point when it is influenced by a specific bone and muscle needs to be known. Maya offers weight mechanism to achieve these influences for the points.

3.2.1 Connect Muscle System with the Facial Geometry

After generating the muscles and bones, the researcher bound the specific bone or muscle with the selected points on the face by using the command - connect muscle objects. To implement this, the points can be put into different clusters when binding with a specific bone or muscle. Figure 3.7 displays the points controlled by Down_lip muscle on the skin. Only colored points are influenced by this muscle. The different color indicates different control extents. Red means fully controlled by Down_lip, while other colors mean the points are also controlled by the other muscle objects.

![Figure 3.6 Points on the Skin Controlled by Down_lip](image)

In Figure 3.6, when Down_lip moves downward, the colored points also move downward based on their weights. Although the animation in the sample is very simple, it gives the basic concept for the project. When multiple bones and muscles
are created, the behavior of one point will be influenced in a more complex way. Accurate control of each point is significant to generate the realistic facial animation.

### 3.2.2 Set Weight Values

Maya allows each point in the deformer to have different weight values for different bones and muscles. The range of the weight value is from 0 to 1. For instance, if the weight of point1 is 0 for muscle1, then it does not move when muscle1 is moving. The weight value describes the extent of the point influenced by the changing muscle parameters.

The researcher used some features of Maya muscle mechanism to improve the weight values assignment. One is picking up the appropriate painting tool as needed, for instance, setting the weights of the points to be symmetrical with the x plane. This avoids some distortion of the facial model, and saves the unnecessary painting effort. Switching painting mode from Replace to Smooth, Set Weight Flood also get good results to assign weights.

The other way to improve the painting is using the command – Visualize Sticky Bind Distance for Selected MuscleObject. It creates a visible ball to show the range of skin which is influences by the exact muscle or bone. Painting weight outside the ball may cause distortion and return warning as shown in Figure 3.8.

![Figure 3.7 Sticky Bind Distance for orb_oris muscle](image.png)
Another way for precise weight value is to assign weight for a specific point. This method is too complicated to apply in the entire project, but it is useful to fix the distortion. The Component Editor lists the weight values of all the points controlled by each muscle and bone so that incorrect weight can be detected. And in the Component Mode, each point can be selected and set specialized weight value.

The accurate weights for each point generate realistic and flexible facial animations in the muscle-based deformable model. And it is also important for the combination with Talking Head.

3.3 Deforming the Facial Geometry with Muscle Parameters

The Talking Head system generates basic facial animations for the lips and the face based on the changes of the muscle parameters listed on Table 3.1. This method is applied in Maya to benefit from the speech animation provided by Talking Head. In this section, it introduces how to control the muscle parameter values to deform the facial model, and how to apply the facial animation from Talking Head to Maya. We create the same muscle parameters corresponding to the ones used in Talking Head. And we set attributes to them based on the data provided by Talking Head through Maya API.

3.3.1 Muscle Controllers

As discussed in Section 3.1, not all the muscle parameters in Talking Head are created as muscles in the project. Although one can generate different facial shapes with the model, we still need to create relationships between the existing muscle system and Talking Head. Thus the controllers, which corresponding to all the muscle
parameters in Table 3.1, are created. The result is shown in Figure 3.8. For instance, the blue cube with the axis in the figure is cJaw. The attribute cJaw.translateY related to OPEN_JAW parameter in Talking Head.

![Figure 3.8 Muscle Controllers](image)

The creating controller method is widely used in traditional Maya facial animation. It translates each face deformation to the controller and provides the user a clear view of the changes. One controller can be bound to several muscles or bones using Set Driven Key command. For each controller, first all the muscles or bones which it controls are selected, and record their default positions by setting driven key. Then the capsules or controls are moved to deform the facial geometry as needed, and change the related controller attribute. Another driven key is set to generate linear transformation between the two states. At last, Smooth skin deformation will be created for each controller. This method allows each muscle to have its individual behavior instead of setting influences between them. It is easy to add more muscles and extend the system.

Some results are displayed in Table 3.2. Parameter is the corresponding muscle parameter in Talking Head. One attribute of the controller relates to one parameter. It
envelops several changes of the different muscles or bones for one simple motion.

<table>
<thead>
<tr>
<th>Controller</th>
<th>Attribute</th>
<th>Parameter</th>
<th>Muscles/Bones</th>
</tr>
</thead>
<tbody>
<tr>
<td>cJaw</td>
<td>translateY</td>
<td>OPEN_JAW</td>
<td>Mouth_down</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Up_lip</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Down_lip</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Orb_oris/L_orb_oris/R_orb_oris</td>
</tr>
<tr>
<td></td>
<td>translateZ</td>
<td>JAW_IN</td>
<td>Mouth_down</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Up_lip</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Down_lip</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Orb_oris/L_orb_oris/R_orb_oris</td>
</tr>
<tr>
<td></td>
<td>translateX</td>
<td>JAW_SIDE</td>
<td>Down_lip</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Mouth_down</td>
</tr>
</tbody>
</table>

Table 3.2 Muscle Controller Corresponding to the Muscle Parameters

Since all the muscle parameter values in Talking Head are changing from 0 to 1 (Except JAW_IN and JAW_SIDE are from -1 to 1), the related controller attribute changes are in the same range. This makes the use of speech simulation values from Talking Head to be easy and direct.

3.3.2 Slider Bar

In Figure 3.9, the slider bar in the left gives a direct view of the changes of each muscle parameter value. Drag the slider bar leads to specific deformation on the right facial model. Figure 3.9 shows the deformed facial geometry when the parameter L_RIS equals to the value 1.00.
To compare the same motion between Talking Head model and our facial model, the similar slider bar is built using MEL script. It works as a user interface shown in Figure 3.11. Either moving the slider or editing the attribute value will get related facial deformation.

![Slider Bar in Maya](image)

**Figure 3.10 Slider Bar in Maya**

The main function in MEL used to implement the slider bar includes two parts. One is creating the slider window. The other is calling the function to build each slider. The sub functions are using the same MEL command `attrFieldSliderGroup`. For the attributes of this command, the step value is set to be 0.01 so that the increment equals to the one in Talking Head. The min and max values limit the range of the slider to be 1, which is also the same as Talking Head. (The range of the slider is 2 for JAW_IN and JAW_SIDE parameters.)

### 3.3.3 Muscle Plug-in

The changes of the muscle parameter can be implemented not only by the user interface, but also using MEL. The script – `setAttr “para” value` changes the value of
the muscle parameter (para). It is useful to create the facial animation plug-in. Figure 3.11 shows the result of the facial model after setAttr “cllevsup” 1.00. In comparison, the Talking Head facial deformation after setting L_LEV_SUP to be 1.00 is displayed on the left.

Figure 3.11 Set Muscle Parameter L_LEV_SUP to be 1.00

For speech animation, Talking Head calls one function KeyframePosition(t) to record all the muscle parameter values at the moment t. A continuous animation is generated based on a changing t value and the related muscle parameter values. We read the animation data from Talking Head and set animation frames for each t value.

A plug-in is created using C++ for setting muscle parameter values in Maya. The major function looks like setFrame( para, number, value, time ), while para indicates the name of the parameter, number is the number of the parameter in Talking Head system, value is the given value between 0.00 and 1.00 (from -1 to 1 in particular cases), and time is the time information on the animation bar. The MEL script setAttr, currentTime and setKeyframe are combined in this plug-in. To save the time and cost of animation rendering, the researcher only put the translate information of the
attributes in each key frame. The final plug-in allows the user to set specific attributes as key frame at any time. It provides the basis to generate speech animation by reading files from the Talking Head system.

3.4 Speech Simulation

As discussed in Section 2.3, Talking Head provides a set of data for each muscle parameter to generate speech animation. To apply the data in Maya, there are two methods can be used to modify the code in Talking Head. One is acquired the data from Tracks.iv file directly. Tracks.iv enumerates all the data for speech, including the muscle parameter numbers, values and time information. The specific data need to be picked up and changed into Maya command format.

Instead of refining the data from Tracks.iv, the data is read from a higher level function in CallBacks.C file. This file calls _showKeysPts[p]->_point.setValue(index, t, val, 0); to set values for each muscle parameter. The code is modified to print the required animation values in a text file. The results are shown in a fixed format setFrame –n –t –v to match the Maya plug-in which is discussed in Section 3.3. Only three flags are needed since the parameter name –p is replaced by parameter number –n in Talking Head.

After executing all the MEL command in the generated file, a smooth animation with a large number of keyframes is got. The Talking Head wave file is added to the time bar to make the results look better. The output movie file shows a smooth facial animation with matched sound.
4. RESULTS

In this section, the researcher demonstrates the results of the project. They include the muscle-based facial model, the user interface and the animation. The first part shows the deformable model describing the capabilities of the muscle system. The second part presents a sample animation. Finally, the researcher compares this model with the Talking Head model.

4.1 Results from the Facial Model

For a facial model, it is important to show different emotions. Four basic facial expressions are displayed in Figure 4.1 with specific muscle parameter changes from the slider bar.

![Figure 4.1 Facial Model with Different Expression](image)

The four shapes of the model shown above indicate the model is happy, unhappy,
shocked, and angry. Because the model is focused on the deformation of the skin
around the mouth, some expressions may look fake. Further work with the muscles
for the eyes and face will make it more realistic.

4.2 Facial Animation Results

The animation for the project is implemented by a MEL script generated from
Talking Head animation system. A piece of the MEL command is listed:

```
setFrame -n 28 -t 0.333333 -v 0.027467;
setFrame -n 29 -t 0.333333 -v 0.000000;
setFrame -n 30 -t 0.333333 -v 0.064362;
setFrame -n 31 -t 0.333333 -v 0.000000;
setFrame -n 32 -t 0.333333 -v 0.000000;
setFrame -n 33 -t 0.333333 -v 0.000000;
setFrame -n 34 -t 0.333333 -v 0.000000;
setFrame -n 16 -t 0.366667 -v 0.160526;
setFrame -n 17 -t 0.366667 -v -0.000000;
setFrame -n 18 -t 0.366667 -v 0.000000;
setFrame -n 19 -t 0.366667 -v 0.112466;
```

For instance, setFrame -n 28 -t 0.333333 -v 0.0027467 means set DEP_INF
parameter value to be 0.0027467 at time 0.333333 second. The keyframes of a sample
speech animation is shown in Figure 4.2.

In Maya, there are 24 frames every second. The keyframe of animation can be
set in real time, which means the frame rate can be less than 1. The animation in
Figure 4.2 is captured from a 3 second movie with more than one hundred frame
images. The displayed frame range is from 1 to 24. The researcher derives one image
for each frame. Batch render command is use to generate a large number of images
from animation.
4.3 Comparison with Talking Head

This section compares the model with the Talking Head model with same muscle parameter changes. The results are shown in Figure 4.3.
There are six pairs of models listed in Figure 4.3. The changing muscle parameters are OPEN_JAW, JAW_IN, ORB_ORIS, R_RIS, L_PLATYSMA, and L_ZYG. The left one is our facial model deformed by Maya muscle system. The right one is the related face shape in Talking Head system.
5. FUTURE WORK

This work creates the muscle-based facial model. The desired skin deformation is implemented by controlling certain muscle parameters in Maya. The animation data provided by Talking Head is applied to generate the speech animation through Maya API. It is based on the plug-in described in Section 3.3.

For further work, some distortion will be fixed to make the weights painting to be more accurate. Inner mouth needs to be modeled for realism. More muscles need to be added to the current muscle-based facial model in order to create the facial expression and get better animation results.

5.1 Fix Distortion on the Facial Model

In the project, one needs to set the values to several muscle parameters at one fixed moment. For instance, Figure 4.1 shows a particular facial deformation at time t.

![Figure 5.1 The Facial Deformation at a Fixed Time t](image)

Although there is no distortion for each muscle parameter value changing currently, it is hard to ensure that there will be no distortion in further animation since more than one parameters are changed. Thus we need to fix the weight painting after
more animations applied.

Another point is that current facial deformation is focused on the lips and the skin around it. To improve the performance of the muscle-based facial model, more accurate weight values need to be set to the points on the skin. For example, modifying the point weights controlled by each muscle generates the nasolabial fold during animation.

5.2 Inner Mouth

As shown in Figure 4.1, the final animation sometimes seems not so realistic. It is not caused by the skin deformation, but lack of the inner mouth. For a real human, the tongue and teeth play important roles in speech. The pronunciations of all the vowels and consonants need to be complete with the inner mouth.

Some work has been started to apply the existing teeth model to the facial model. Because the teeth model is different from the muscle system, one needs to set relations between them. Further work will be focused on controlling motions of the teeth model by the mouth_down bone. A recommended is to generate the tongue model to get more realistic animation. Since the animation of the tongue is more complex than the muscles in the model. One can create the tongue as a NURBS object, which is easy to be controlled by points and edges. Similar work is presented in [King 2001].

5.3 More Muscles for Further Facial Animation

The muscles in the model are the fundamental ones needed for speech animation. In further research, more muscles are needed to improve the current speech simulation,
and get extended results such as facial expressions. The method to setup additional muscles is the same, which implements the individual behavior of each muscle and makes outside controller for the specific muscle parameter.

The muscles around the lips are generated for the current facial animation. Actually, other muscles on the face are also used when one in talking in real life. To improve the performance of the project, more muscles are needed such as the muscles around the eye and the brow. These additional muscles will make the speech animation more realistic and flexible.

The expression is an important feature to make a facial model look like real. The muscles which create the speech animation are different from the ones generated the facial expressions. Thus, one can easily add another specialized muscle system for expression, which is separated from the speech animation system. The expression muscles will deform the skin individually, or combine with the previous muscles. In this way, the muscle-based facial model can provide the speech animation in different moods. It will reduce the distance from the simulation to realistic speech.
6. CONCLUSION

This project is focused on generating a muscle-based facial model. To implement the model, the researcher set up the muscle system that can deform the face geometry. It consists of the muscles, the bones and the lip. Each muscle component in the model is related to a specific muscle parameter in Talking Head system. Based on the deformable model, controllers were added to all the muscle parameters and a user interface was written through Maya API to manage the face deformation. By acquiring speech data from Talking Head, facial animation was applied to the facial model.
ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Scott King, for his great help on my research. I appreciate his work on the Talking Head system, which provided significant methods and data for my project. And the original facial geometry is based on his face.

I thank my supervisor, Dr. John Fernandez, for his support of my research work. I thank the members of my dissertation committee, Dr. John Fernandez and Dr. David Thomas, for their time, suggestions, and reading of the report.

I would like to thank Alexis Angelidis who provided the highly deformable facial geometry. I thank Sarah Spafford for her teeth model, which is useful for the future facial model. I thank Anh Tuan Do for his help of the Talking Head system. I would like to thank all the members in our lab and my classmates. They provided the good research environment and shared their ideas in academic field.
BIBLIOGRAPHY AND REFERENCES


