HANDS AS CHARACTERS: DESIGNING FOR A LARGE SCALE PIPELINE USING LIMITED CHARACTERISTICS

A Thesis

by

FRANKLIN S. CHANCE, IV

Submitted to the Office of Graduate Studies of
Texas A&M University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

May 2007

Major Subject: Visualization Sciences

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Approved by:

Chair of Committee,	Ergun Akleman
Committee Members,	Carol Lafayette
	Gerald Vinson
Head of Department,	Mark Clayton

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ABSTRACT

Hands As Characters: Designing for a Large Scale Pipeline Using Limited Characteristics. (May 2007)

Franklin S. Chance, IV, B.E.D., Texas A&M University

Chair of Advisory Committee: Dr. Ergun Akleman

This thesis concentrates on hands and their production as concerns a larger-scale pipeline with multiple secondary or tertiary characters. It establishes a platform from which many unique hands can be produced from a single, rigged hand. Emphasis is given to automating a large amount of the rigging and sculpting processes through use of high and low-level user interfaces so users of varying skill can use this thesis effectively. Systems for sculpting the hand and animating the hand are created for their own specific purposes and linked together through the interface to create a tool for modeling a new hand from an existing mesh, having the new hand automatically rigged for animation and ready to use with only minor adjustments by the user.

A system is developed conclusively that allows for the efficient mass production of tertiary character assets. Unique hands are quickly and correctly created with the ability to connect them to digital characters. This method can be applied not only to hands, but other parts of characters as well. Eventually full secondary or tertiary characters can be created using this method of production.

To my parents and Jessica

ACKNOWLEDGMENTS

Thanks to my committee and Karthik Swaminathan for the generous help given me throughout this process.

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CHAPTER I

INTRODUCTION

A greeting in many cultures starts with the hands. This could be a wave, a hand position, a gesture or a sign. Some communication with hands needs little translation; a punch or an obscene gesture is often interpreted similarly across cultural boundaries. Often, as with a few other parts of the body, seeing nothing but the hands can lead to judgment of a character before any other communication takes place. They can also lead to revealing preconceived notions; what would be thought of a delicate, petite woman possessing hands to rival those of Andre the Giant?

It seems then that given the importance of hands, especially in the aspect of acting or expression of emotion, that it is obvious the design of hands is an important part of a character. It is difficult to shape them into a defining characteristic, and more difficult still to repeat this process efficiently. The main idea is to be able to produce hands as unique and recognizable characters themselves through a system that ameliorates the process of their sculpting and articulation. This thesis has developed a system able to produce many of these articulated hands that are distinct and unique enough to be considered different characters, so as to be viable in a production pipeline. It accomplishes the construction of a tool, which with little to no training and very little time, a user can produce multiple unique human hands which have the added benefit of nearly complete articulation.

This thesis follows the style and format of *IEEE Transactions on Visualization and Computer Graphics.*

I.1. Challenges in Several Areas

In order to implement a system to demonstrate the approach presented in this thesis, problems in both the sculpting/modeling aspect and the articulation aspect had to be addressed. Structurally, three dimensional computer animation is somewhat similar to stop-motion animation using puppets or clay. The reason behind this has to do with the internal setup of the character. In two dimensional animation, for example, any character can be drawn in precisely the way the artist wishes; characters can stretch to incredible proportions, blow themselves up like balloons, or shrink to a tenth of their normal sizes. Traditional stop-motion artists are more familiar with this process, in that they have had to deal in three dimensions with other mediums such as clay or puppets. This means that many have had to use movable skeletons, or armatures, in order to articulate the character [1]. This type of setup limits the characters range of motion by constricting it only to movement and poses that are feasible based on the armature.

A character setup artist has the job of articulating a digital character so that it can be animated with ease and fluidity. This process entails many things, which can differ slightly depending on the animation pipeline in which the setup artist is working. Most commonly, the setup artist is responsible for the degree and freedom of movement built in to a digital character, as well as the interface needed for the animator to interact with the character. The importance of a good character setup that is easy for the animator to use and understand is paramount. This will allow the animator to concentrate on what the character ideally should do, rather than attempting to coax the character to do what is desired in spite of inherent limitations from the setup process.

Character setup can be a very long and tedious process, especially when the setup of more than one character is required for a project. Many aspects must be considered in the task of articulating a character for animation, and great care must be taken to ensure that all parts of the characters animation setup work together without causing any hindrance to the animation process. When creating the functions and controls for a digital character, one must consider joint placement and orientation, intended range of movement, usability of control interfaces, likelihood of certain types of movement, adaptability of the character to different positions and environments and many other factors that can cause the setup process to take a longer time than many wish to spend perfecting it.

The more advanced the setup, or rig, for a three dimensional digital character, the greater range of motion is possible. In fact, the goal of many character setup artists is to take the functionality of a rig from the idea of a simple armature to the level of a two dimensional animated character, where any pose that can be drawn is possible. This may seem an odd comparison, but having an articulation setup in a 3-D program that has capabilities close to those of a hand-drawn character is a difficult and worthy goal in almost any character setup process.

I.2. Motivation

The reason for creating this system stems from the ever-increasing need to specialize in the computer animation industry. This being the case, many people, students or otherwise, want to focus on different aspects of computer animation such as texturing, lighting or animation to name just a few. In order to showcase one of these aspects to an extreme degree, other steps must be completed first. For example, to show off the ability to texture a digital character, one must first have a digital character to texture. In that vein, this thesis provides the tool to easily create and solve certain sculpting and articulation problems, with hands, that others might not have the knowledge or skill set to deal with, yet still need completed.

CHAPTER II

PRIOR WORK

In any character setup situation there is a balance between the time taken to articulate the character and the level of complexity that the characters rig possesses. Certain setup techniques, such as muscle systems or deformer based setups take longer to complete but often create more accurate character rigs, while vertex influence weighting (assigning the influence of joints on a vertex by vertex basis) is much faster and easier but produces less accurate results. Combinations of different techniques can better each of these approaches where one is deficient. For example, in a system created by Mohr and Gleicher [2], multiple extra joints are added to the skeleton automatically in order to "capture richer skin deformations than the standard linear blend skinning model" (563). Put simply, the more joints there are in a skeleton, the more detailed the skinning or enveloping can become. Even working in this method without the help of Mohrs and Gleichers automated system, the time it takes to set up a character does not drastically increase, yet yields much more desirable results.

Some techniques of character articulation involve more complex methods of skinning rather than more complex skeletons. Pose-space deformation, a technique defined by Lewis, Cordner and Fong [3], requires a less complex skeleton than systems that use simple vertex weighting. This method is defined by using different shapes or poses which are defined by the artist to control specific ranges of deformation after the model has been weighted. The vertices that change position during deformation are interpolated from pose to pose so that every shape has in some way been defined by the artist, much like a blend shape or morph target. While this more complex technique requires additional time to set up and slightly more attributes for a computer graphics program to keep track of, if done correctly it achieves a much more desirable artist-controlled result than normal vertex weighting.

The techniques used in the creation of this project hopefully more closely resemble that of the process defined by Mohr and Gleicher, where a more complicated initial setup will cut down on the time required of the animator to complete the articulation. In addition, the skeleton used for modifying the hand geometry (the modeling skeleton) [4] will have a certain degree of control over the movement and placement of the articulation skeleton in order for the movements of the fingers and palm to pivot in the correct place. It is also important for the transition between the modeling process and the animation process to be smooth, especially to ameliorate the task of making minor adjustments to the hand model.

CHAPTER III

METHODOLOGY

III.1. Defining Hands

Because hands are what this thesis has focused on producing, a way had to be found to create them. The sculpting of a hand is not necessarily a simple matter. The first thing that must happen is to identify what characteristics actually make up human hands, which is what this thesis deals with. Normal human hands all share the same characteristics. They all have four fingers, a palm that ends at a wrist joint, and an opposable thumb. These details aside, however, human hands can be very different in many respects. Hands can have palms, narrow palms, bony fingers, stubby fingers to make a very few distinctions.

Fig. 1. Normal human hands.

In addition to the main characteristics of the hand, such as number of fingers, general shape or palm size, there are many other less noticeable characteristics that hands possess. Each finger has characteristics of its own. Aspects such as pad size, pad bulge, knuckle size, nail length, pad position in all three directions and knuckle prominence are often taken for granted or overlooked when observing the hands.

Fig. 2. Palm of a human hand.

These are characteristics which all normal human hands possess, yet are represented differently. That is to say, for example, pad sizes can be larger or smaller and fingers may be longer or shorter.

Knowing that hands have all these attributes in common, it makes sense that every hand created by this thesis must have these characteristics as well. This also brings about the conclusions that when hands are created by a user and this thesis, those characteristics must be either created from scratch or present to begin with. Because the approach of this thesis is to create a tool to be used by users of varying skill levels, it seems that creating these characteristics every time the tool is used to sculpt a hand is a needlessly complex task. Therefore, the preferred method to accomplish the sculpting in this thesis is to use a basic neutral mesh containing all the necessary, modifiable characteristics of a normal human hand.

So then, in this thesis the creation of hands means more specifically the re-sculpting of hands. Because the hands produced by this thesis are not modeled from scratch, a very mutable hand mesh must be created. Changeable, in this context, refers to a characteristic that allows parts and features of the hand mesh to be moved around and re-sculpted, yet still retain the traits that make it recognizable and above all, functional, as a human hand. When one looks at the final goal, which is to produce multiple unique and articulated hands, one must realize that the topology of the hand mesh must be such that no matter the degree of deformation, it must also retain the characteristics that make it unique. For example, when the knuckles are sculpted, there must be enough vertex information in that area to obtain the desired shape without adding any extra geometry. This limitation comes from the fact that each hand created must have the exact same number of vertices and faces in order for the sculpting and articulation process to work.

III.2. What Must Hands Do?

The mesh used for the neutral hand in this thesis must have several characteristics present to be successful as a model from which to sculpt successive hands. First of all, it must have the general shape of a human hand; that is, four fingers, one opposable thumb, and a normal human palm.

This hand must also contain enough geometry in certain key areas such that modification in those areas will still preserve its form and function. This means, simply put, that however a knuckle is modified in position, size or shape, it must

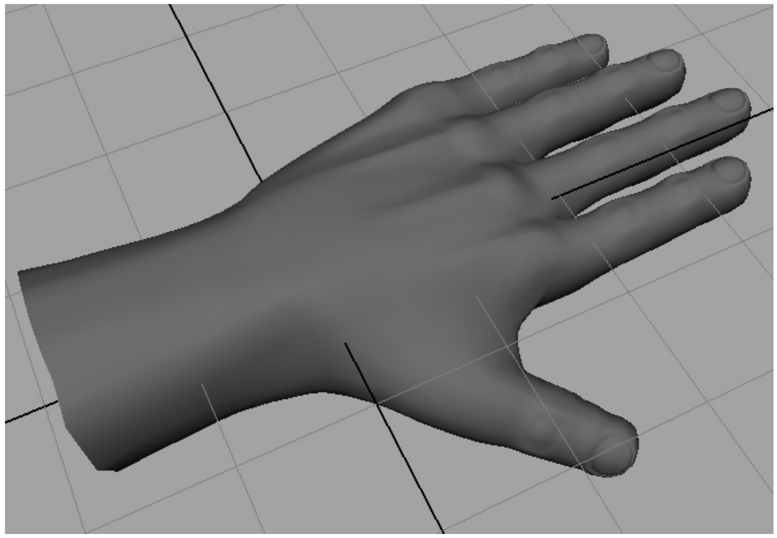

Fig. 3. Computer model of a human hand with normal features.

still look and perform like a knuckle in both form and function. The geometry used for knuckles, specifically, is important due to their function in a human hand. An "eye-shape" mesh (see Fig. 4) is used to define the geometry on the knuckles because of the inherent ability for this type of shape to open and close. The mesh pivots at the actual center of the joint inside the finger, deforming the skin in the same manner as a real human hand.

Other geometric considerations are taken into account such as the positioning of the fingers. The fingers are positioned straight ahead, along the hand's main axis. The reason for this is the ease of articulation that this provides. Because the fingers are oriented along a common axis, modifying the length, width and depth of the fingers and features of the fingers becomes much easier. As for the thumb, it is oriented in a more natural position based on the motion that is most common to that digit; that of rotating towards the pinky finger. The articulation of this is more difficult because of the fact that the bones do not lie along the x, y or z axis, but much more desirable because of deformation issues that arise when the thumb is wrenched

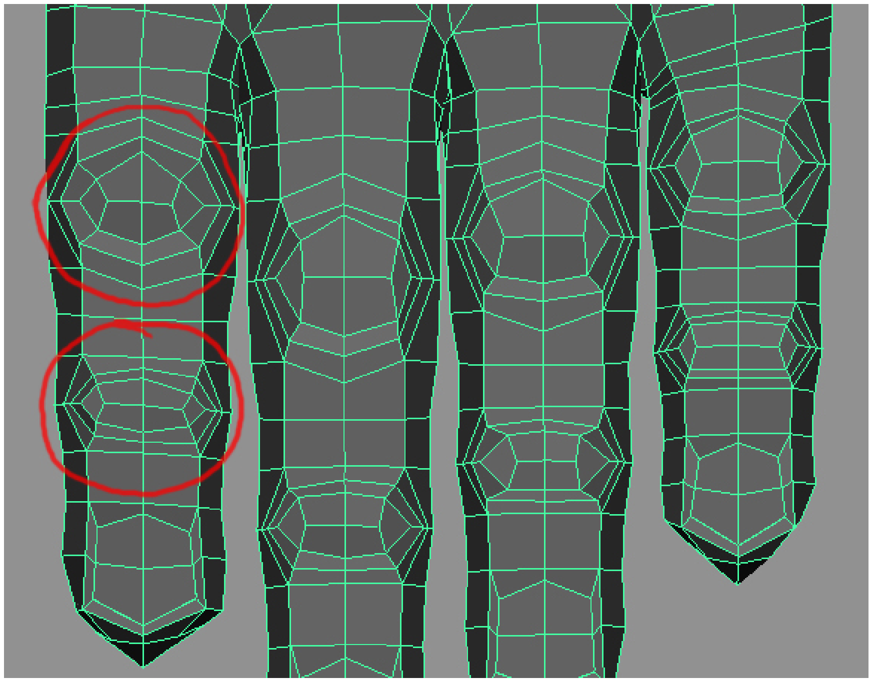

Fig. 4. Eye-shaped geometry applied to knuckles on a model of a human hand.

towards a parallel or perpendicular axis to that of the fingers.

For instance, if the thumb is sculpted to where it lies along an axis parallel to the fingers, the geometry representing the joining of the thumb to the palm of the hand will be too concentrated to easily prepare it for articulation or sculpting.

In much the same manner that the hand has to be created, it must be allowed to move. The same type of issue arises when one thinks of the manner to implement the articulation of the hand; whether the rigging of the hand should take place from scratch every time a new hand is created, or whether the rig should be modified from an existing hand and applied to the new hand. Articulating the hand is also a complicated process, but where the processes of the articulation and sculpting in this approach differ is that while the user wants to directly control the model of the hand, the rigging should be largely automatic. To make articulation automatic saves much time in production and training. However, because each hand sculpted by the thesis

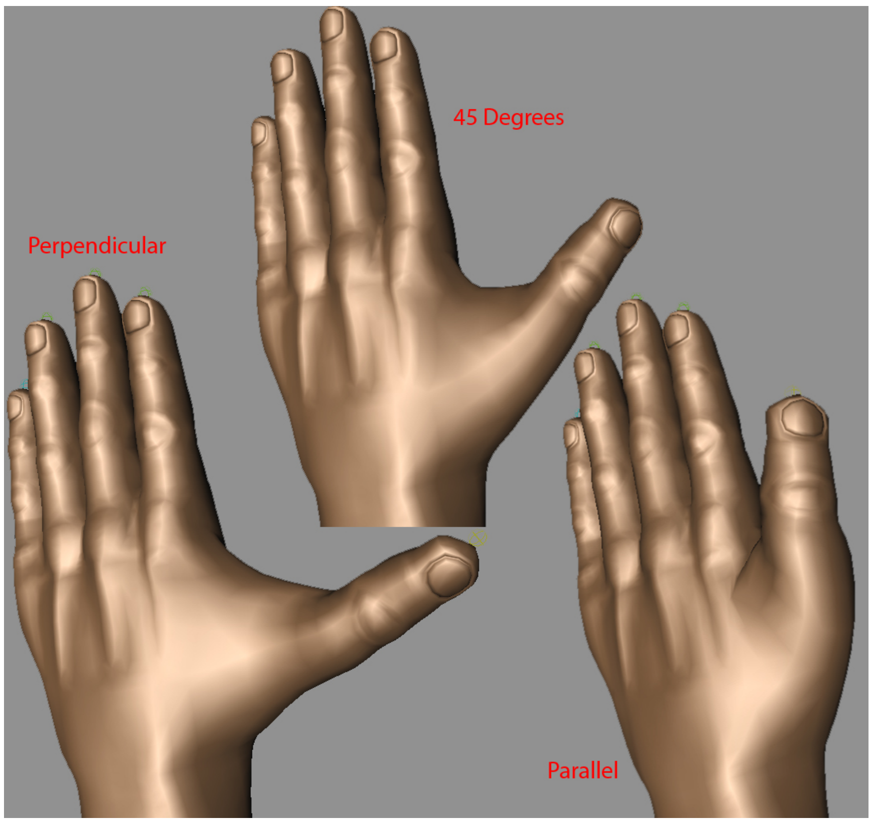

Fig. 5. Positions of the thumb along multiple axis.

has the propensity to differ in its form as applies to bone, muscle and fat, the hand needs very specific rigging in order for it to deform properly.

Because of this complexity in rigging, especially concerning the uniqueness of the hand, the complexity of the system that would fully articulate the hand increases dramatically. Instead, a better solution presents itself in that the automatic rigging takes place to a certain extent, and the user provides the final touches concerning the unique aspects of the hand. Also, given that there are two distinct processes, modeling and articulation, as well as two distinct manners of implementation, manual and automatic, it follows there should be two different systems to control them.

In this thesis, there is a separation in the systems that drive the deformation of the hand while it is being sculpted, and the systems that drive its function as a character's hand, i.e. its articulation. This is because the system that is used to sculpt the hand has physical representation in a real hand, but not necessarily muscular; meaning that many attributes of the hand will need to be modified when sculpting the mesh, but are not directly modified when animating the hand. An example of this would be the size or prominence of the bones in the back of the palm. On some hands these bones will be much more noticeable than others, so there must be a way to control their size in order to have added depth in the sculpting process. However, whatever is used to control this attribute should not be used in the system that drives the hand's animation, as one does not normally flex bones.

The other side to this problem is that, while the systems that control the sculpting and the animation of the hand must be separate, they must still be bound to each other in a specific way. For instance, if a hand is sculpted that dramatically increases the length of the index finger and the sculpting system does what it must by making the finger longer yet leave the parts that control the hand's articulation behind, the finger will no longer be able to bend and flex at the correct places, seeing as the geometry that represents the knuckles has moved past the scope of the system that drives the knuckles' motion.

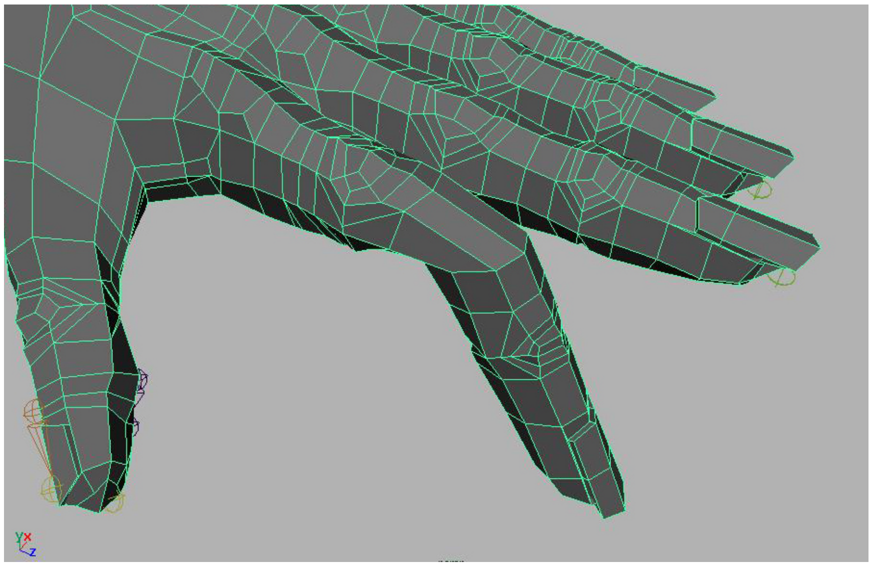

Fig. 6. Incorrect pivot location on the index finger due to the finger's increase in length.

Because of this, during some operations of the sculpting of the hand, the system controlling the hand's articulation must be made to follow the sculpting of the hand, such as changing the width or length of the hand, or the width and length of the fingers.

The systems created, while taking these problems into consideration, will be similar to each other yet fundamentally different in their function. While some operations can feasibly be carried out by either system, others must be the sole focus of only one. An example of this is scale, especially as it pertains to fingers. For instance, assume perhaps that the system used to sculpt the fingers might be based on the same type used to articulate the hand. Systems that articulate digital characters are almost always based on a hierarchy where much of the time transformations are inherited from higher to lower items. Because these are based on a hierarchy, where each successive link in a chain inherits the transformations of the previous deformer, performing an operation such as increasing the scale of the first knuckle on the index finger would increase the scale of all successive knuckles in the chain.

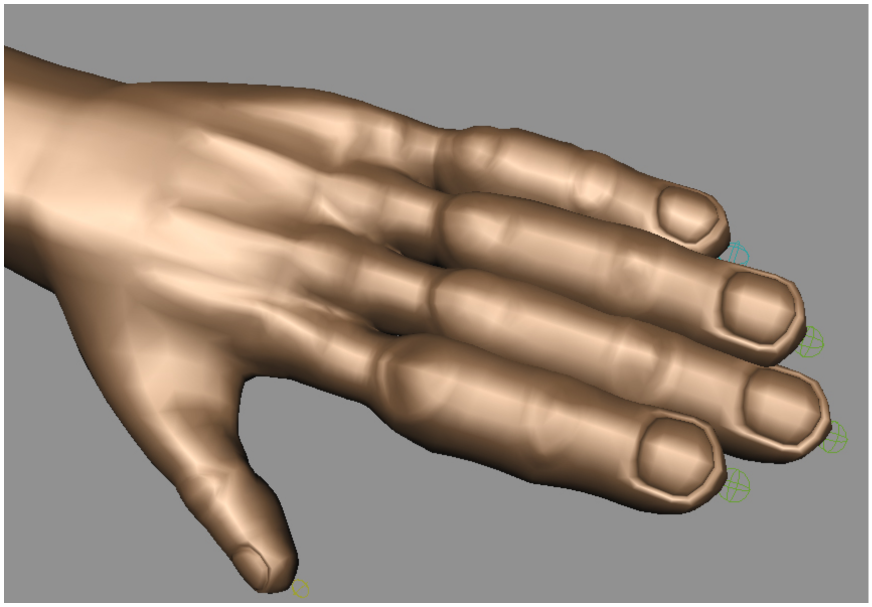

Fig. 7. Increasing the scale of only the middle knuckles in a joint hierarchy. The successive joints inherit the transformations of joints higher in the hierarchy.

This is not desired due to the necessity of having to constantly modify values lower in the hierarchy. By having transformations carried to successive parts of the hierarchy, in order to have, for example, a large middle knuckle and small fingertip, one would need to "counter-sculpt" the shapes of successive deformers if they were not desirable.

III.3. User Interaction

Making a tool such as this necessitates a way for the users to interact in an easy, simple manner. However, lessening the complexity of the interface sometimes carries with it the problem of taking some of the ability to prescribe detail away. The simpler an interface, the harder it becomes to include more complex operations. Given these circumstances, an interface with many levels of detail is necessary to ensure that users of varying skill can use the system in its entirety. Less skilled users may want a very simple user interface with controls and operations that do most of the work for them. An example of this would be an option that says "Big or Small" and sculpts the hand to a "Big" or "Small" shape based on pre-set values. More skilled or more detail driven users may want more specific controls so that the ability to define almost every part of the hand independently from every other part is not lost. For instance, they would have the ability to grow the length of the index fingernail by a certain amount, while leaving every other attribute alone. This level of user would still be able to, and most likely would want to use the high-level interface as a starting point, but would continue from what was sculpted based on pre-set values to something more unique. Allowing users of the tool to choose level of detail is a main concern of this thesis so that using it will be desirable to more potential users.

This thesis' approach was to produce a series of unique hands of a singular topology using a working system that facilitated the construction of an easy to use hand setup for multiple digital characters. The series of hands are unique and distinct enough to be recognizable as distinct characters themselves, and not only in comparison to the other hands; the hands are identifiable based on only the characteristics they possess, and not in context with any other hand. In addition, the hands created with this system have to go through only a minimal additional setup process in order to keep them able to be animated correctly.

CHAPTER IV

IMPLEMENTATION

In order to model the geometry of the hand, Alias Maya 7.0 was used. Maya includes a very well constructed modeling tool with the ability to easily perform geometric mesh construction and subdivision operations. It was chosen both for its familiarity and its availability. A polygon surface was also chosen as the method of creating the hand due to the ease of construction and the simplicity in deforming such a surface using tools provided by Maya.

Construction of the hand presented somewhat of an artistic and technical challenge considering that the hand must contain geometry such that the modification of which would be simple, yet still retain its definitive characteristics. Simply put, the hand must include just the right level of detail so that the sculpting of its features does not overly distort its geometry, whether it is stretched or pinched.

The hand was designed with movement in mind. Movement in this manner does not mean simply the bending of a finger at a knuckle, but also means that the movement of certain features of the hand to different places on the hand or to different sizes must be taken in to account. The fingertips for example needed to have enough geometry built in so that they would be able to move in all three axis of orientation as well as the ability to scale in different directions. In addition to this, features like knuckles were designed with the eye-shape geometry to facilitate their ease of movement and deformation.

The animation system was created for the hand in a very straightforward manner, using Mayas joint and bone articulation system. In order for conventional rigging and animation to be possible with this tool, there needed to be this system of "joints and

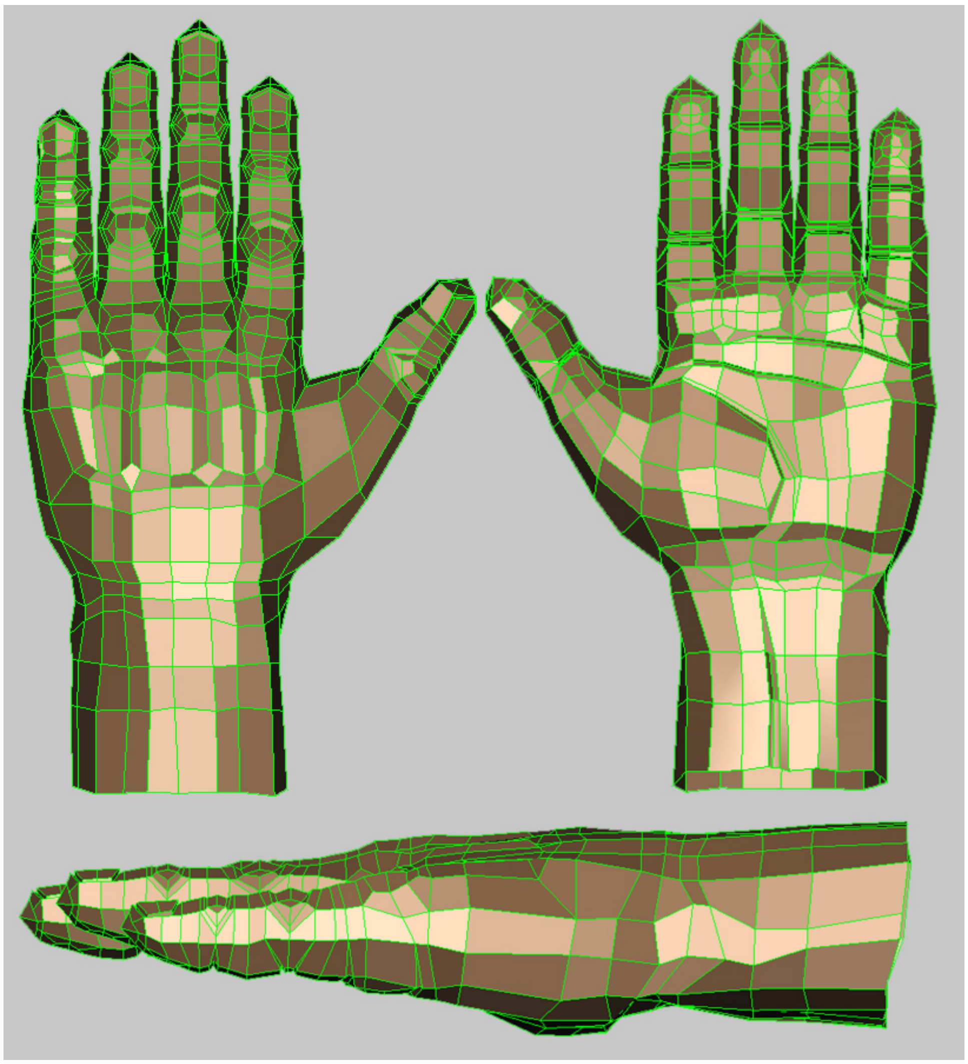

Fig. 8. The top, bottom and side orthographic views of the digital hand.

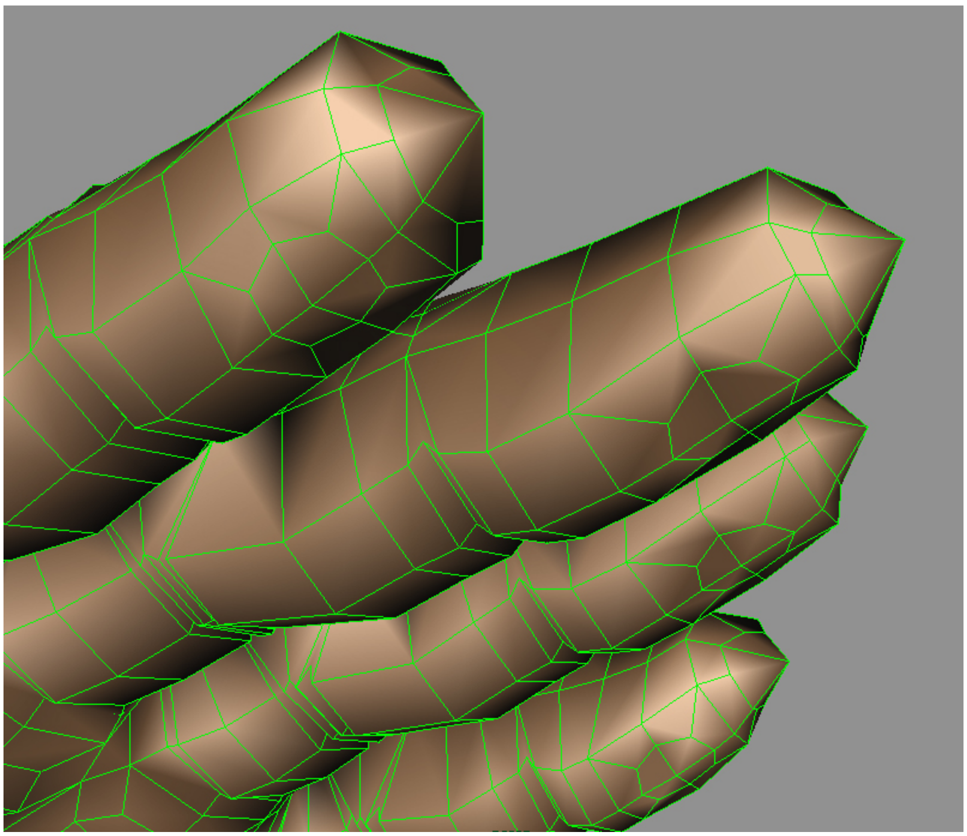

Fig. 9. Wireframe geometry of the fingertips.

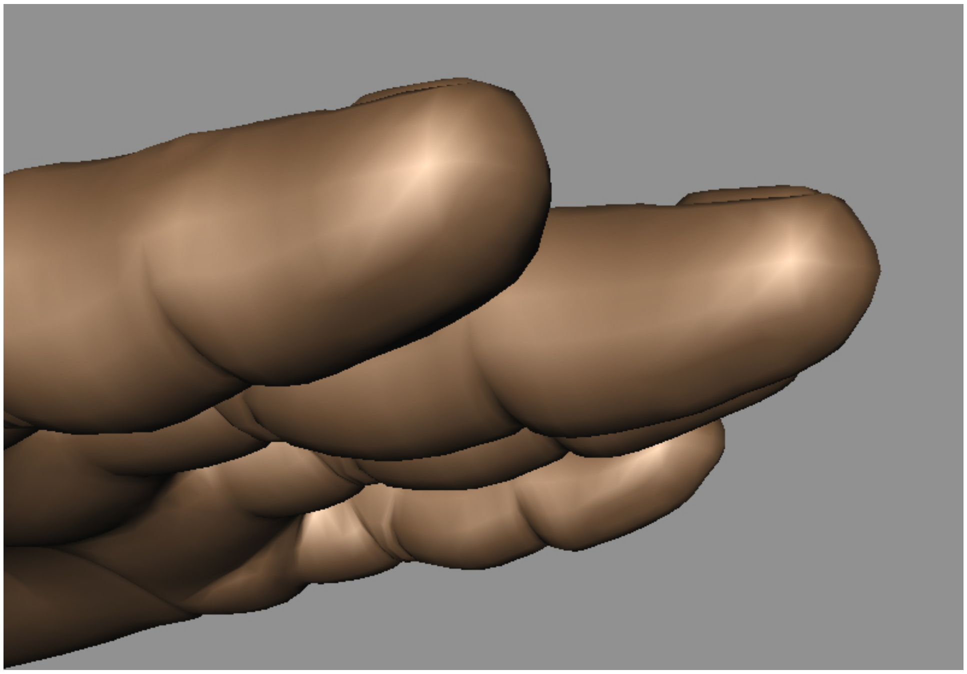

Fig. 10. Smoothed geometry of the fingertips.

bones" that allow for the deformation of the different parts of the hand. By joints and bones, this thesis refers to the system of deformers used by Alias' Maya software to drive the deformations on a geometric mesh. These joints and bones were placed inside the mesh of the hand much like bones and joints in a normal human hand. The main difference in the mechanics of this computerized hand and a real hand is that not all muscles, joints or bones that exist in a real hand have to be present in its digital counterpart. It is perfectly possible and in many cases, desirable, to lessen the complexity of the mechanics of real creatures when represented in a computerized world. The reason for this is that real creatures are extraordinarily complicated, and the visual benefit in the physical correctness of a digital character is often negligible.

Creating the articulation system was a straightforward matter given these previous considerations. Joints were placed at all the joints in the hand, including the wrist. A joint was placed in the center of the hand to act as a stationary root to

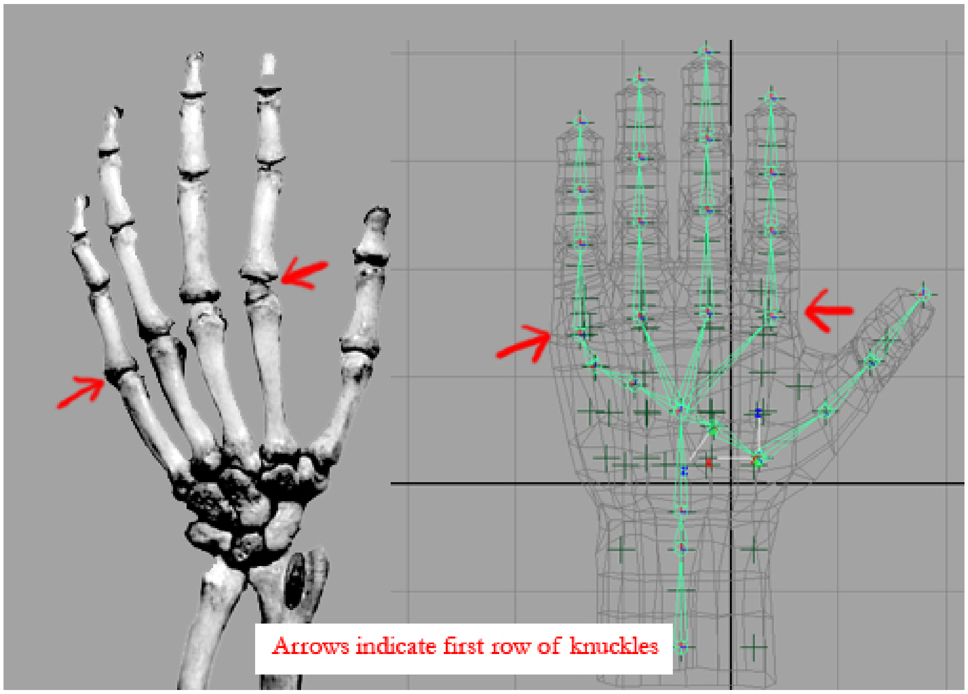

Fig. 11. Real bone structure vs. digital bone structure.

anchor the fingers, and a series of joints was placed on the axis between the thumb and pinky in order to assist the gripping motion available to hands with an opposable thumb.

All other joints in the hand were placed with a secondary purpose in mind; once the hand is sculpted and finalized, a small amount of tweaking is necessary in some cases to ensure the proper performance of the hand. These extra secondary joints are available for that purpose, and can be controlled using driven keys (a command that consists of a driving object and a driven object, the driven objects value dependant on the set values of the driving object), expressions (usually commands, like scripts, often mathematical in nature that do not use set values like driven keys) or scripts. The geometry was then weighted (each vertex given influence on its behavior by one or more of the joints) carefully, so that it could move as correctly as possible given the original hands geometry. These weights were then exported for later use in creating

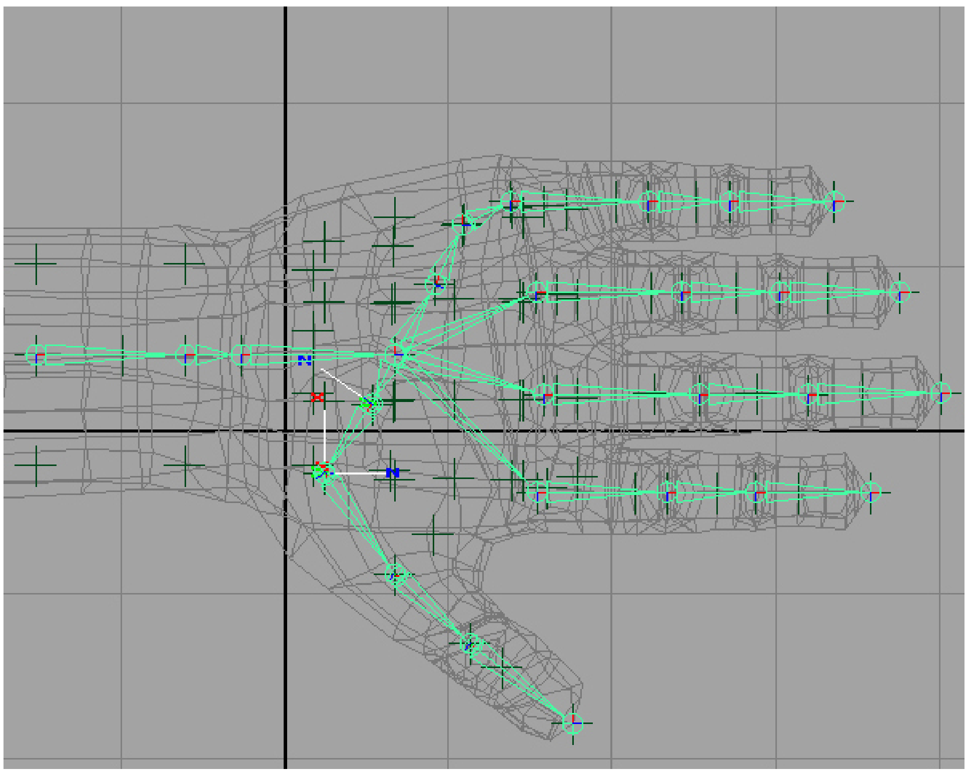

Fig. 12. Articulation skeleton for a digital hand, designed to mimic the workings of an opposable thumb.

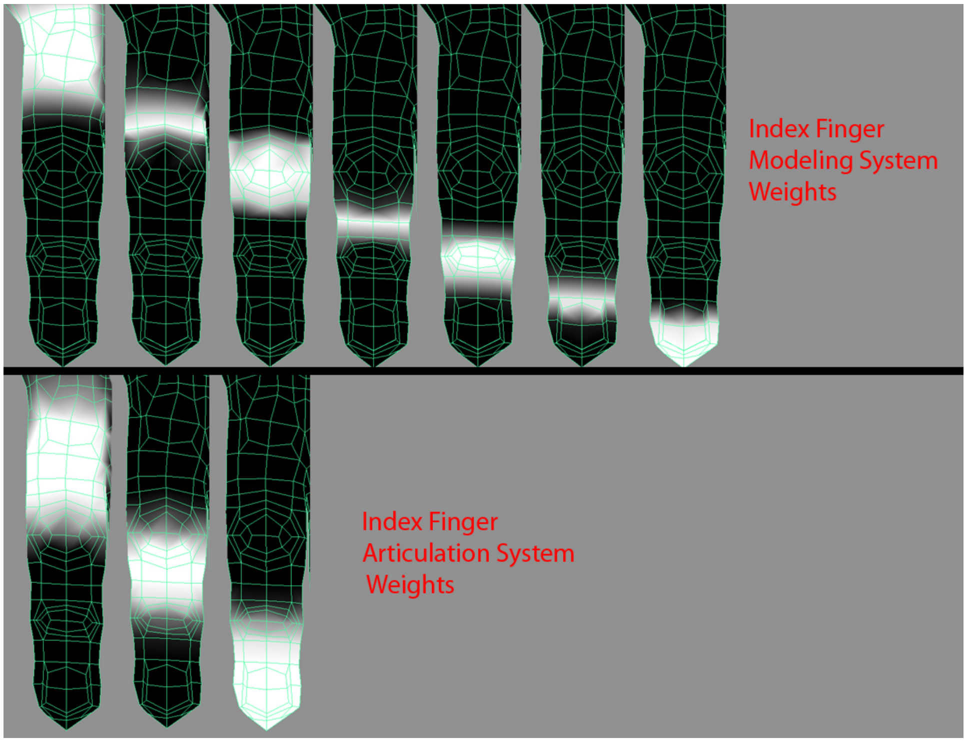

Fig. 13. Comparison of skin weighting between modeling system and articulation system.

new hands.

The sculpting system was created using some of the same techniques, but in a very different manner. In effect, the sculpting system included the entire articulation system, but with a key difference. The articulation system was there, but weighted differently than it was for animation, because its purpose was instead the modification of the hand geometry in a sculpting fashion rather than a fashion that allowed the hand to move normally.

Originally, the entire sculpting system was constructed using joints as well, but that type of construction had a significant flaw due to the way vertex influence is calculated in Maya. Once joints are bound to a piece of geometry in Maya, a skin cluster node is created. This node is an object in the program that contains the weight information for all the joints that the geometry has been bound to. After this has been done, the same piece of geometry cannot be bound to another set of joints. Therefore, the binding would have had to take place all at once, to every joint in the articulation system as well as every joint used solely for the sculpting of the hand. This might not sound undesirable at first, but a problem arises in that when modifying weights in the same skin cluster node, the weights on each vertex can only amount to a value of 1, which is something that makes creating the sculpting system very difficult. For instance, a vertex might be part of many features of a hand, such as modifying the length of a section of finger, modifying the width or height of that same section, modifying the bulge of the pad of that finger or the pads position on the finger itself. Many times, these values need to be modified independently of any other value, and in the case of using joints to do this, influence must be taken away from one joint to add to another.

This problem was overcome using another deformer provided in Maya called a cluster deformer (Figure 14).

These are deformers which allow a user to control vertices with varying amounts of influence, which in Maya's "relative" mode do not pass on transformations down the hierarchy, meaning it is possible to modify a cluster at the base of the finger and have that operation independent of a modification at the tip, even though the cluster at the tip is farther down the hierarchy. Two more important differences between clusters and joints are as follows: first, that clusters are based on a world coordinate system and cannot be oriented in the same manner as joints, and second, that each clusters vertex membership set (the vertices in the hands geometry that are affected by the cluster) is contained, along with the degree of influence the cluster exerts, in a separate skin cluster node from the single skin cluster node that contains the influence of all the joints.

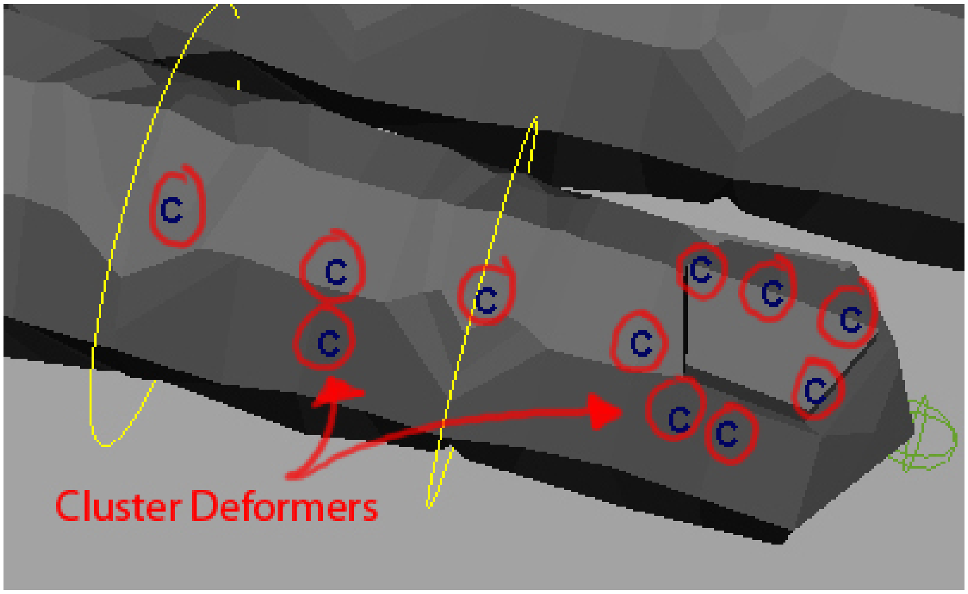

Fig. 14. Cluster deformers in Maya.

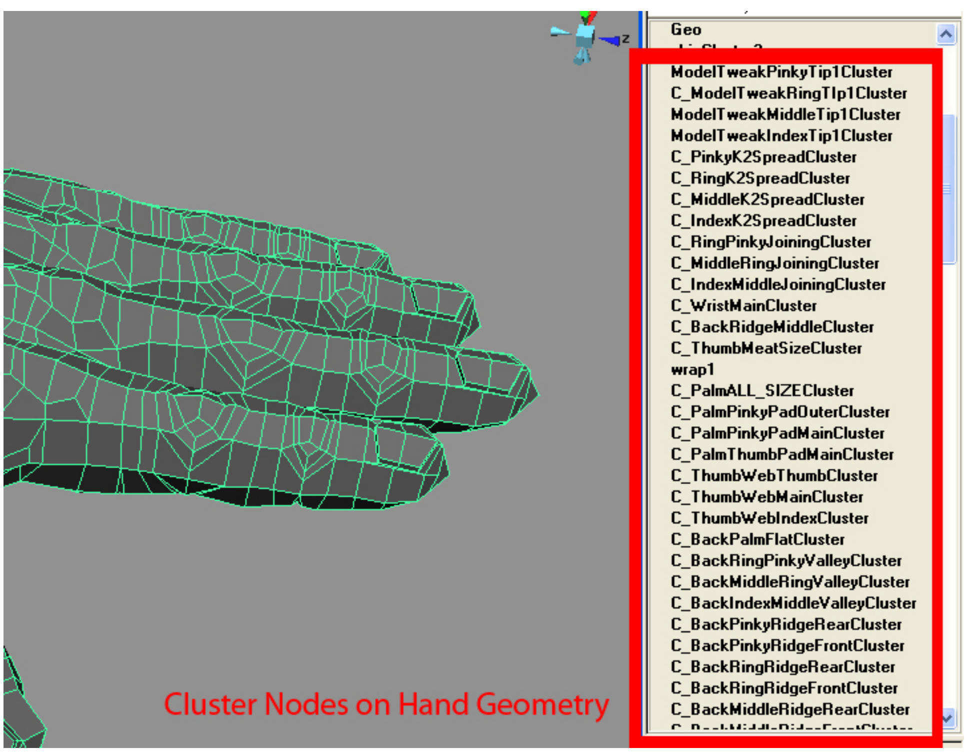

Fig. 15. Some cluster nodes affecting the geometry of the digital hand.

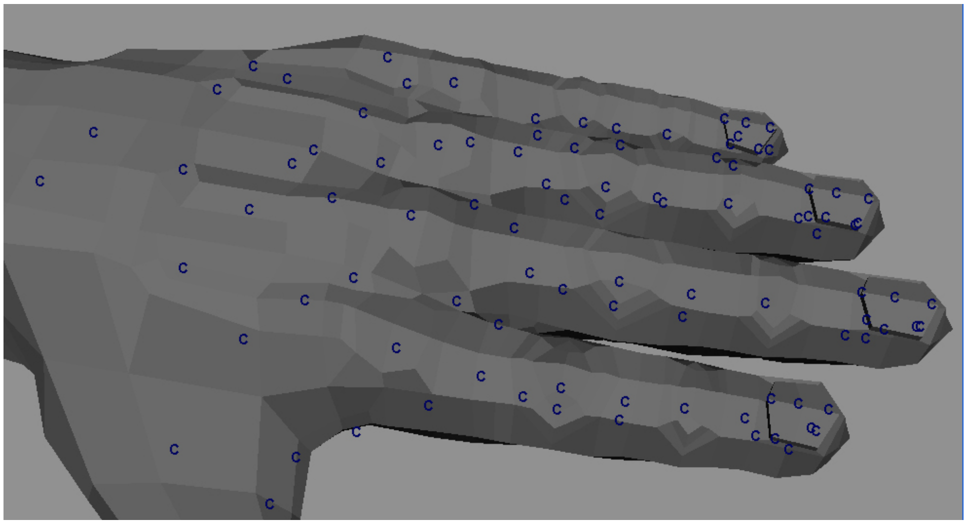

Fig. 16. All of the cluster nodes that affect the digital hand.

This allows many degrees of influence from different cluster deformers to be applied to a single vertex along with the influence of the joints, and because of the information of the clusters being contained in multiple nodes, the influence on a single vertex could amount, effectively, to much more than a value of 1.

The sculpting system set up in this manner gave a single vertex, no matter its position in the hands mesh, the ability to be fully influenced by whatever operation is needed. So, because of these reasons, many clusters were created which represented different operations of sculpting the hand, such as PinkyPadBulge1 (the bulge of the pad on the last section of the pinky finger) or PinkyPad2PosZ (the position of the pad on the middle section of the pinky finger along the Z axis). Creating all of these clusters provided a high amount of detail to the sculpting system, making the entire process much more robust.

After the hand was created, the interface with which the user was to control it had to be designed and put in place. The interface is contained in two parts; a high level and a low level interface. The manner of control for these interfaces is different,

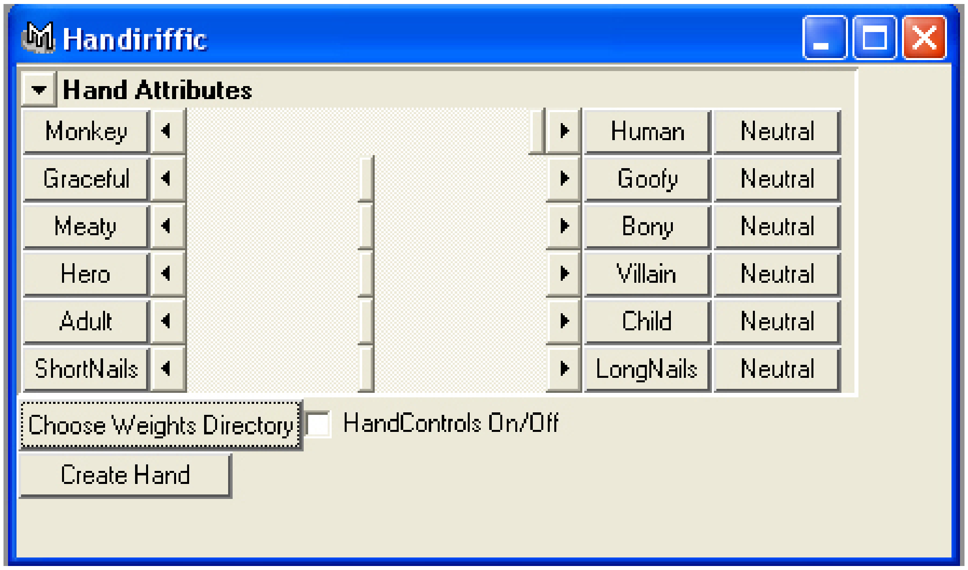

Fig. 17. The user interface created with Maya's MEL (Maya Embedded Language).

because of the difference in complexity of the level of detail. The high-level interface, that is, the interface that controls many operations at once, is scripted using Mayas MEL (Maya Embedded Language) scripting language. In MEL lies a comprehensive tool able to modify, with a great deal of control, every aspect of the Maya program. The idea behind the user interface is that hands will be able to be sculpted and articulated quickly without a great deal of micromanagement. Only as operations become more and more specific will the user need to activate the attributes attached to the physical controls in Maya, which comprises the bulk of the low level interface, in order to achieve the desired result.

The high level MEL user interface consists of general descriptive attributes that can be modified by the user. These attributes should consist in relatively opposite pairs, such as "Graceful or Goofy" or "Adult or Child". By modifying these attributes, the hand can be sculpted by adjusting values representative of the character of the hand rather than minute concrete values given to sections of the hand's geometry.

The user, in this way, would be able to control how "graceful" the hand is, rather than attempting to create a "graceful" look by modifying values such as finger length, palm width, nail length and so on. This high level interface also has the option of turning on and off the low level interface, so both can be available at the same time.

This system is achieved by simply integrating the low level interface in to the high level one. The low level interface is comprised chiefly of curves drawn in three-dimensional space parented to the sculpting hierarchy in Maya. These curves are named accordingly, such as "IndexSection1Control" and so on. Each of these curves has attached to them a series of custom attributes that, through either direct connections or driven keys, modifies either the joint or cluster deformers which in turn modifies the geometry of the hand. These consist of controls for sections 1, 2 and 3 of all four fingers, the thumb, the back of the hand, the palm of the hand, and the hand as a whole.

Driven keys were chosen as the vehicle to attach the interfaces together. A null object (an object with only rotation, position and scale information) was created in the hierarchy of the scene, and given custom attributes that match those of the high level interface.

To set the driven keys, these new attributes were chosen as the drivers, and the physical controls of the hand (the low level interface) were chosen as the driven objects. The hands were then sculpted in such a manner, using the low level interface, that the driven keys could be set to extreme positions representing the opposite ends of the attributes given to the null object and high level interface. For example, the attribute of the null object reading "GracefulToGoofy" was set at its maximum "Graceful" value, sculpted using the low level interface to be the embodiment of a graceful hand, and the key was then set. Then, the value was set to "Goofy" and the process was repeated accordingly. This was repeated for all attributes given

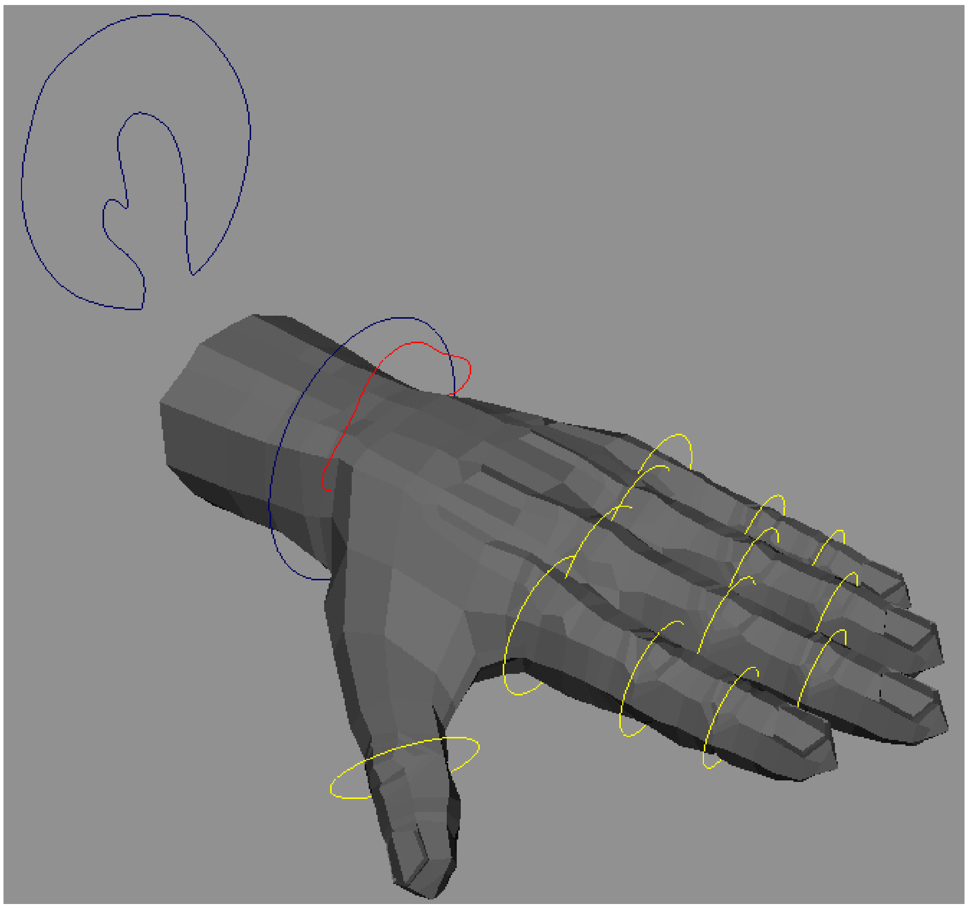

Fig. 18. The control curves associated with the low-level interface.

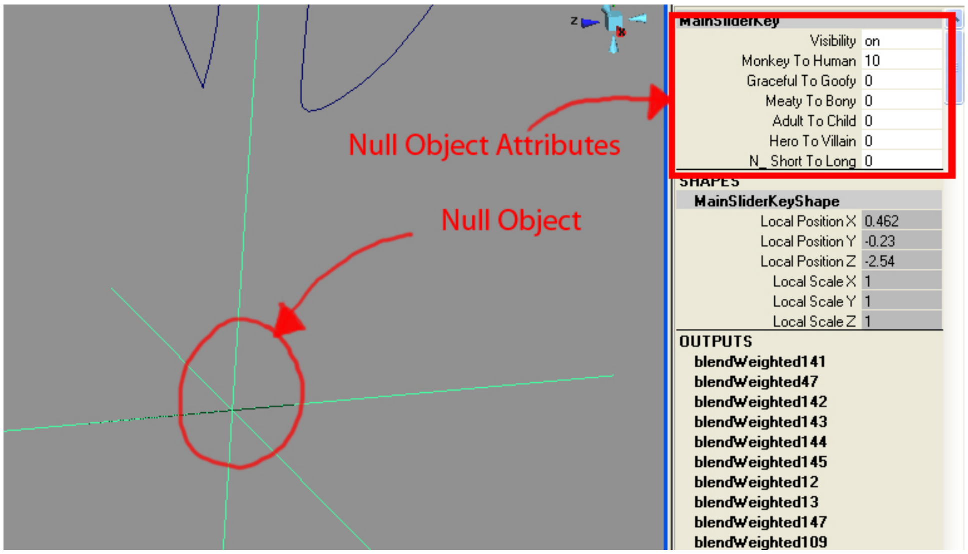

Fig. 19. The null object in Maya with its associated attributes.

to the null object and high level interface, and the two systems were thus linked together. The MEL user interface controlled the null object attributes, which in turn controlled values of the low level interface, making the system more simple and user friendly. With both levels of interaction with the tool, using the MEL Menu or physical controls, the user is able to solve design problems without ever having to directly modify the hand geometry.

CHAPTER V

CONCLUSION

The hands that are created from the neutral hand geometry are unique, as far as the desire of the user is concerned, and automatically articulated to a large degree. The approach focused on user-controlled sculpting with the option of automatic articulation as a secondary objective. Making an automatic rigging system to its fullest extent was not the intention of this thesis; rather, the articulation of the hand must be included, but the sculpting system is treated as the more important aspect because it is evident that the style and shape of the created hand will drive its final style of articulation because of the change in geometry. Each hand created with this tool will need a small amount of additional work to be truly well-articulated. The reason for this, simply put, is that fat hands and skinny hands do not move and deform in the same manner. The amount of fat, bone, muscle and sinew present in hands (this applies to many parts of the body) greatly affects how parts of the hand move.

Operations such as removing or adding fingers stray from the main idea as well. Of course, hands exist with less or more than the normal number of fingers, but such an operation extends beyond the scope of this problem. For instance, creating hands with Ectrodactyly (a congenital deformity of the hands) or hands missing fingers is completely different than, say, creating a hand that was once normal but has had a finger (or more) removed. There are many abnormalities that can be sculpted into a normal human hand mesh, but that is an entirely different type of problem. Allowing geometry to be added to the hand mesh makes for a much more complicated problem and solution, and is outside the scope of this project.

This thesis succeeds as a tool for producing hands quickly and efficiently. It is limited in scope to a very specific function, that being hands, although its method can be applied to other aspects of digital character creation. The setup time for such a process is considerable, but worth completing in the long run given the task of producing multiple digital characters.

CHAPTER VI

FUTURE WORK

The end goal of a well constructed setup system is to complete as much of the setup process as possible, without sacrificing the ability to customize, yet be endlessly repeatable. This would mean that a very thorough hand rig system might include automatic musculature creation [5], or a physically based control rig such as an automatic grasping setup [6]. However, the complexity of the process increases twofold because of these options; for everything added to the articulation setup, it must also be controlled and dealt with by the modeling setup. Because hands involve some of the most complicated setup processes in creating a digital character, the automation of more advanced controls and abilities is very difficult, but rewarding if done correctly. Some automatic setup programs include minimal hand setup purely for the reason that more comprehensive rigs take much more time to create, and are not always desirable unless a specific shot or render is focused on the hand itself. A viable and thorough setup in the future would include more advanced rigging techniques as well as an advanced user interface to make the complicated rig easy to use.

In addition, the application of this method to more if not all parts of a digital character could serve to create a total system for character production. Being able to apply my method to all parts of a character mesh would be a large task, yet be invaluable to production pipelines where multiple digital characters are needed. In addition, being able to concentrate more on the articulation aspect would be very helpful, especially the level of detail possible as well as level of automation.

REFERENCES

[1] P. Lord and B. Sibley, *Creating 3-D Animation: The Aardman Book of Filmmaking,* Harry N. Abrams, Inc., New York, NY, 1998.

[2] M. Gleicher and A. Mohr, "Building Efficient, Accurate Character Skins from Examples," in *ACM Transactions on Graphics.*, vol. 22, no. 3, pp. 562-568, July 2003.

[3] M. Cordner, N. Fong, and J.P. Lewis, "Pose Space Deformation: A Unified Approach to Shape Interpolation and Skeleton-driven Deformation," in *Proceedings of the 27th Annual Conference on Computer Graphics and Interactive Techniques,* pp. 165-172, 2000.

[4] K. Swaminathan, "Crowd Modeling: Generation of a Fully Articulated Crowd of Characters," M.S. Thesis, Texas A&M University, 2005.

[5] M. Pratscher, P. Coleman, J. Laszlo, and K. Singh, "Outside-In Anatomy Based Character Rigging," in *Proceedings of the 2005 ACM SIGGRAPH/Eurographics Symposium Computer Animation.*, pp. 329-338, 2005.

[6] N. Pollard, and V. Zordan, "Physically Based Grasping Control from Example," in *Proceedings of the 2005 ACM SIGGRAPH/Eurographics Symposium Computer Animation*, pp. 311-318, 2005.

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