A Study into Rigging Concepts and Techniques

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Abstract

This report presents a body of research into rigging and character setup. We will look at some of the key research areas of this field, the human body and the tools and technologies used to bring characters to life. It is not the aim of this report to present a new method of rigging, nor make a comparison between existing techniques, this report demonstrates an understanding into the process of rigging a character and, later, how the principles and techniques discussed can be implemented.

Keywords and Definitions

Industry	Refers to the visual effects and animation industry
Skinning	The process of binding a character mesh to a joint skeleton and refining the deformation of the mesh by painting skin weights.
Joint Skeleton	Refers to joint hierarchies used to drive characters.
VFX	Visual Effects abbreviation.
Vertex	A vertex is the point at which two or more lines meet. In a 3D package a vertex can be found in the corners of a polygon.

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1. Introduction

For an audience to engage with, and believe in, a character said character needs to move, deform and react in a realistic and believable manner. Achieving this involves putting the character through a series of processes; design, modeling, texturing, rigging, skinning and finally animation, until the character has been through these stages of production it is nothing more than a concept. This is outlined by *Miller, Arikan, Fussell, (2010).*

This project will focus on the rigging and skinning stages of character creation. Creating a character rig is a two step process; First, an articulated skeleton of joints needs to be created; Second, a series of controls needs to be created giving an animator control of the skeleton. Once the rig has been created the character mesh needs to be bound and weighted to the skeleton, a process referred to as skinning.

The intention of this project is to investigate the various different approaches to character setup and to produce a series of example rigs demonstrating the projects understanding of the process as a whole. Although considerable research into rigging will be conducted, this project is not presenting a new approach to, or comparing existing approaches to rigging. It is however, demonstrating how some of the different principles and techniques can be implemented.

This report is broken down into various sections; first building background knowledge by looking into related research work conducted in the field of character rigging, a biological look into the human body and finally some technical information presenting some of the different tools used to create character rigs and to skin characters. Following this, an overview of some practical development work that has been conducted alongside the research is presented. Finally a conclusion puts forward the intended outcome of this project.

2. Related work

The art of rigging has been the subject for vast amounts of research aiming to simplify aspects of, and in some cases, all of the process from skeleton creation through to skinning and painting muscle weights. Although this project is not introducing a new technique or system for simplifying the process, it is important to introduce some of the history of the subject area to put this project into context.

2.1 Automated rigging systems

One of the largest areas of interest within the context of rigging is how parts of the rigging process, and in some instances the whole process, can be automated to reduce the time needed to set up characters ready for animation. Researchers Miller, Arikan and Fussell (2010) have been developing a system by which a character can be rigged and skinned in a matter of seconds. This system, Frankenrigs, utilizes a database of existing rigs to find the best matches to suit a target character. Lakakwar, (2009) has also been developing techniques to speed up the rigging process, unlike the Frankenrigs system, Lakakwar's approach is a script based method; when the script is run two GUIs (Graphical User Interface) appear that allow the user to interactively setup the skeleton, controls and bind the mesh to the skeleton shown in Figure 1. Other systems for automated rigging have been developed such as Rig-o-matic (Baskin 2007), The Setup Machine (Anzovin, R, et al 2008) and ZV Auto Rig (Dominici, No Date).

Although these systems can aid during the rigging process, all of them need human interaction and fine tuning even after the target character has been through the specific system. Frankenrigs is by far the most automated process however even this system is not guaranteed to produce a fully functional rig that is ready for animating. Some of these systems, such as Rig-o-matic, do very little to speed up the process of skeleton creation and even after you have used the script you are still left with the tasks of skinning the character and setting up controls.

It is clear that some progress has been made over recent years in automating the rigging process, but no system has yet been created that can truly automate the process and achieve the same results as a rigging technician can produce from scratch.

2.2 Skinning methods

Creating a skeleton for a character is only one step of the rigging process. Possibly the most time consuming, tedious and demanding aspect of the process is attaching the geometry to the skeleton, a workflow which is often referred to as skinning; as discussed by Gain, et al (2007), Miller, et al (2010) and vimyargentina (2011). This process has been advanced and developed over the past decade to try and achieve the most realistic skin deformation possible. The three main approaches to skinning that have emerged are Skeletal-Subspace Deformation (SSD), Animation Space and Multi-Weight Enveloping (MWE) each with their advantages and disadvantages highlighted by Gain, et al (2007).

SSD is the most commonly used approach, smooth-bind in Maya for example, and works by linearly combining the results of each individual vertex transformed rigidly with each bone it is close to. Simply put, the vertices closest to a joint will be deformed more than those further away from a joint when it is transformed or rotated. Although this method is the most popular SSD has one obvious downfall documented by Cordner, et al (2000). If a joint is transformed or rotated to an extreme the mesh will begin to lose volume as it follows the joint, as illustrated in Figure 2; this can take vast amounts of time to override during the skinning process.

MWE (Phillips, Wang, 2002), by contrast, further develops the SSD formula and results in each vertex having twelve weights to each influencing joint. This gives six times the amount of control over each vertex than SSD offers, an example of the difference between SSD and MWE can be seen in Figure 3. This added control over vertex's adds another level of complexity to the setup of MWE and could mean that some of the twelve weight controls available may be missed and cause issues with deformation during animation.

Finally, Animation Space (Merry, Marais, Gain, 2006), tries to find common ground between SSD and MWE by giving more control than SSD per vertex but not going to the same lengths as MWE and offering four weight points of control per vertex. However, again this added complexity and control adds more time to the implementation of this approach an the possibility for vertices to be overlooked.

Regardless of which skinning method is chosen each approach requires time and perseverance to successfully complete the skinning process.

2.3 Muscle systems

The area of human anatomy has been a point of interest in computer graphics since the 1970s (Scheepers, et al 1997) by those striving to replicate the intricacy and complexity of the human body presented later in the report (section 3). One of the key ideas within this field is that of creating muscles and, as a result, realistic deformation of a characters skin. Principle research in this field by {Wilhelms, 1997) and (Gelder, Wilhelms, 1997) looks into how muscles can be modeled and integrated into a character as they are in real life. This idea of modeling and connecting the different muscles that would be found within a character or creature is a mammoth task, the complexity of a humans muscle system is discussed in section 3.2. If the time is available then of course it would be beneficial to produce a muscle system to deform a characters skin, however, time constraints will not always allow for this luxury.

Implementing a muscle system into a workflow is no easy task. FOAM Digital, an educational VFX initiative set up at the University of Portsmouth, have expressed a desire to include a muscle system in their pipeline whilst talking to McMahon, (2012). McMahon indicates that the production pipeline currently in place at FOAM Digital is built around that of industry giants Weta Digital. Weta's work to date includes VFX blockbusters such as Avatar, Prometheus, Tintin and District 9 not to mention the recently released The Hobbit. The work Weta completed on The Hobbit, discussed by Duncan, (2012) included the use of muscle systems to bring characters such as the Goblins, and of course Gollum, to life with the help of motion capture data. This shows that muscle systems are used in industry, but can take time to implement into the pipeline of a character.

As well as creating physical muscles that deform the skin of a character, Gleicher, Mohr, (2003) have produced an alternative method for producing realistic muscle deformation. This system uses a base skeleton and example posses of the mesh to generate new joints that will solve extreme deformation volume loss issues, as discussed in section 2.2.This approach is significantly less memory intensive for a computer compared to that of modeling and simulating muscle influences on skin. This system is an automated skinning approach but with more consideration and focus on the quality of deformation produced.

3. Biological research

To create a believable character on screen it is important to understand the biology which brings each of us to life. The art of rigging a character is nothing more than creating a skeleton to control body parts, and attaching a characters mesh to it. To achieve the most accurate and believable range of movement for that character a working knowledge of the different systems involved is key.

3.1 The human skeleton

The human skeleton is the frame upon which the rest of our body is built, it is tough, flexible and protects vital organs. Although the precise number of bones in an adult skeleton various from person to person, on average, 206 different bones make up the skeleton *(Baggaley, 2000).* The skeleton can be divided into two major sections, The Axial Skeleton and The Appendicular Skeleton. The Axial skeleton is the name given to the bones which form the skull, rib cage, vertebral column and sternum. The Appendicular skeleton is the name given to the bones of the arms and legs, clavicle, scapula and the pelvis. Understanding how the skeleton is broken up into these section can inform how different sections of a digital skeleton can be separated into independent hierarchies.

When we refer to a digital skeleton we are not in fact referring to bones, we are actually talking about joints. In the human skeleton a joint is the point at which two different bones meet and the skeleton articulates. Joints are classified by the range of movement each can produce, this is determined by the shape of articular cartilage surfaces and the way they fit together, a list of these can been seen in Figure 4. Transferring this knowledge to a digital skeleton is the first step in creating a believable character rig.

3.2 The human muscle system

The human muscle system works with the skeleton and produces the forces which maintain our posture and allow us to move. Muscles usually attach to one bone and stretch across a joint to attach to another bone, when the muscle contracts it pulls the bones and creates movement. Tendons, fibrous chords of connective tissue, attach muscles to bones. A detailed look at the inner working of the muscles can be found in the sketchbook which accompanies this report. There are over 600 muscles in the human body *(Baggaley, 2000)*, connected through intricate overlapping layers.

If we take a closer look at one section of the muscle system, the arm for instance, Peck, (1979) indicates there are around 33 muscles in one arm alone. Figure 5 shows the complexity of these muscles. It is this complexity in structure that makes reproducing a muscle system for a digital character very challenging. This complexity also justifies why it is not always possible to include a muscle system within a production pipeline as discussed in section 3.3.

3.3 The human skin

The human skin comprises of two main layers, the dermis and epidermis. The top layer, epidermis, is made up of thin layers of plate-like-cells layered on top of one another. The deeper dermis layer is made up of fibrous and elastic tissue, this layer houses blood vessels, nerves, fibers, hair follicles and sweat glands (Simblet, 2001). The skin defines the boundary of our being and houses all of the systems which form the human body. As the skeleton and muscle systems work inside the skin, it is made to deform and move with the underlying systems.

In a digital sense, the mesh of a character becomes the skin when it is bound to a joint skeleton through the skinning process (section 5.2), until this happens the character is nothing more than a statue.

4. Technical background

Building successful rigs is dependent on creating various elements such as joints, constraints, IKHandles and controls together with the execution of tasks including skinning and painting skin weights. Each of these stages come together to form a characters rig. Understanding which elements and techniques to employ when, and for what reason, is integral to the creation of successful character rigs. Having this grounding knowledge also ensures that any of todays range of 3D applications could be used to build the rig as the underlying principles of creating character rigs are the same throughout.

This section will present some of the various tools and utilities available in Autodesks Maya software typically used to build character rigs. Maya has been chosen in this case because it is considered an industry standard piece of software used by giants of the animation/visual effects world including Double Negative (DNeg), as presented by Paul Franklin, Co-Founder DNeg, during a British Kinematograph Sound and Television Society talk (Monday 3rd December 2012) into the visual effects Paul, and his team at DNeg, delivered for Christopher Nolans The Dark Knight Rises (2012). Other studios working with Maya include Weta Digital, Framestore and The Moving Picture Company (MPC).

4.1 Tools and utilities

As this project continues to delve deeper into the world of rigging, and begins to present rigging tests and practical research, it is important to clarify the meanings and use of the tools being used.

4.1.1 Joints

Joints are created to emulate joints in a physical skeleton. When creating joints, it is vital that consideration is given to where a character is going to need to articulate. Poor joint placement will result in poor deformation later in the rigging process.

4.1.2 Forward and Inverse Kinematics

Kinematics is the study of human and animal movement (Winter, 2009). Forward kinematics, in terms of animation, is a method of animating by which an animator moves each joint of a skeleton one by one to create movement. Inverse Kinematics is described by (Baerlocher, 2001) but can be simplified to solving the complexities of aligning joints to exact positions during a given task, for example, moving the hand to touch an object. Manually moving each arm joint from the shoulder down takes considerable time and accuracy, inverse kinematics calculates the correct position of joints for you.

4.1.3 IKHandles

IKHandles add Inverse Kinematic animating options, for an animator, to a character. Typically IKHandles will be added to arm and leg joint chains to speed up the positioning of these limbs during animation.

Behind an IKHandle lies a mathematical algorithm, or IK solver, which computes the rotation values for all of the joints in a joint chain controlled by an IKHandle (Autodesk, 2013)). By default, Maya loads four different IK solvers;

• Single Chain IK solver (ikSCsolver)
• Rotate Plane IK solver (ikRPsolver)

• Spline IK solver (ikSplineSolver)

• Human IK solver (hikSolver)

Each of these solvers drives an IKHandle of the same name, and although each handle has a different solver, all IKHandles feature two standard components, Handle Vector and Handle Wire. The Handle Vector is a line drawn from the start joint, of the IK chain, to the end joint (Figure 6). This line is used by the IK solver as its rotate plane. The Handle Wire is a line which passes through each joint in the IK chain (Figure 6).

The more complex ikRPsolver consists of a number of additional controls which can be seen in Figure 7 and Figure 8. These additional controls give the animator more refined control of the effected joints. These additional controls can, however, increase the time needed to implement this IKHandle.

4.1.4 Constraints

Constraints allow you to limit an objects movement and constrain [its] position, rotation and scale (Autodesk, 2012). Constraints are integral to a successful rig and understanding the different functions of each constraint available is key.

4.1.4.1 Point Constraint

A point constraint will constrain the position of one object to another. Depending on how this constraint is set up, the driven object can be made to snap to the position of the driving object.

4.1.4.2 Aim Constraint

The aim constraint is used to lock the orientation of the driven object to face the driving object.

4.1.4.3 Orient Constraint

The orient constraint will match the orient of a driving object to one or more driven objects.

4.1.4.4 Scale Constraint

The scale constraint works in the same way as the orient constraint with one difference, instead of constraining the orient, the scale constraint constrains the scale of an object to its driving object.

4.1.4.5 Parent Constraint

The parent constraint matches the position, translation and rotation of a driven object to a driving object. This constraint forces the driven object to act as a child of the driving object as if they were part of the same hierarchy. Using this constraint instead of using a hierarchy keeps the two objects separate.

4.1.4.6 Pole Vector Constraint

Usually used during the setup of IKHandles, this constraint causes a pole vector to move to and follow a target object, or control. The implementation of the pole vector constraint prevents IKHandles, namely the ikRPsolver, from unexpectedly flipping during animation.

4.1.5 Controls

Controls are usually created from ‘curves’ and act as easy to select objects which control all aspects of the underlying skeleton. Constraints are used to tie the controls to their respective joint or handle. Controls also act as a hub for custom attributes to be collected and made accessible for the animator.

4.2 Skin binding - Skinning

We have already introduced the different skinning methods available (section 2.2) such as Skeletal Subspace Deformation (SSD). Let us now take a look at the skinning process through a piece of 3D software, Maya, and present the options available.

4.2.1 Smooth Bind

Smooth bind in Maya uses the SSD method to bind a character mesh to a joint skeleton. It offers three variations on the SSD method which are detailed below.

4.2.1.1 Classic Linear

Classic Linear uses the basic SSD algorithm to bind the mesh, an example of this can be seen in FIgure 9. The method of skin binding results in the classic pitfalls of the SSD method (section 2.2).

4.2.1.2 Dual-Quaternions

This method of skin binding uses a more sophisticated version of the SSD algorithm, the result can be seen in Figure 10.

4.2.1.3 Weight Blended

The weight blended option allows for both classic linear and dual-quaternions to be used based on a weight map that is painted before the bind is executed.

4.2.2 Rigid Bind

The rigid bind, unlike smooth bind, does not have any variations on the method. The rigid bind option will bind a mesh to a joint skeleton and only allow each vertex to be effected by one joint. This bind method results in very sharp deformation, illustrated in Figure 11.

4.2.3 Interactive Bind

The interactive bind option available in Maya offers a more intuitive approach to the smooth binding process. It allows you to select any one of the three methods of smooth binding, and use interactive capsules to make adjustments (Figure 12). Once general adjustments have been made using the interactive capsules fine tuning can be done with the paint skin eight tool.

4.3 Technical background conclusion

This section has presented some of the different tools and techniques available in Maya for the creation of character rigs. It is important for this information to be presented at this stage to help put the future work of this project into context. Because we have taken time to look at this technical information we can refer back to it when evaluating the rigs produced later in this project.

As highlighted at the beginning of this section (section 4) Maya is often the application of choice for the industry and as such future practical work produced will be completed using this application.

5. Practical development

So far during this project a lot of time has been dedicated to researching the subject area of rigging and giving the project a contextual background. Alongside this research practical test and development work has been conducted to clarify understanding in the topics discussed and to put principles and techniques researched into practice. This development work will help to inform the future work this project will encompass.

5.1 Skeleton creation

As discussed throughout this project, the skeleton is the underlying mechanism which drives a character. Ensuring a reliable and considered skeleton can be created is integral to the success of this project going forward. During the practical development that has been conducted so far skeleton creation has been a big focal point. Two characters have been used to test and implement some different skeleton creation approaches, these can been seen in Figures (13 and 14).

Creating these test skeletons has highlighted some techniques and practices which will be employed in future skeletons, but also some areas for further development. The method adopted, during this development work, for creating the skeleton, was the broken hierarchy approach. A broken hierarchy breaks each section of the skeleton up into separate joint chains. Building a skeleton in this way meant that changes could be made quickly and without effecting the rest of the skeleton. it was also found that this approach enabled efficient mirroring of joint chains to minimize the work load.

One drawback to the broken hierarchy method is that care must be taken when creating the controls for the skeleton. As this method consists of several separate joint chains, for them to work as a complete skeleton each section must be connected through constraints (section 4.1.4) to controls. Although this is not a major issue, it is one that if not considered could cause issues later on during the rigging process.

As well as adopting the broken hierarchy approach to skeleton creation, other useful techniques were found to add efficiency and continuity to the skeleton. The first technique was to ensure consistent joint orientation throughout the skeleton. This attention to detail keeps the direction of joint rotation consistent making life easier for the animator, and the rigger, during the control setup stage. The second technique is even more straightforward, maintaining a naming system for each joint. Sticking to a consistent naming system ensures joints can be mirrored and renamed without having to rename every joint saving huge amounts of time. Finally, but possibly most importantly, test the skeleton throughout the creation process. Cutting up the mesh, parenting the sections to their respective joints and constraining the skeleton together enables the skeleton to be tested. If joints are in the wrong place, testing the skeleton in this manor will highlight this before time is spent binding the mesh to the skeleton and possibly even painting skin weights.

Skeletons can be created in a matter of minuets, but after practicing this step in the rigging process it is clear that the more time and attention to detail taken at this stage, the more successful the character will be once fully rigged.

5.2 Control system

Following on from practical development of the skeleton, different types of controls have also been investigated and tested at this stage of the project. The control system, if created correctly, should be the only aspect of the rig the animator needs to interact with, getting this part of the rig correct is key to its success.

It was discovered during the development of control systems that creating unique, but consistent shapes, for each of the controls produced an easier to understand rig. One example of this is to clearly differentiate between IK (Inverse Kinematics) and FK (Forward Kinematics) (section 4.1.2) controls. As well as this, the shapes should also try to define what the control is controlling. It is very easy to create circle and cube shapes for every control, however, it may not be clear from this which part of the character the control is effecting. A primary example of this is the shape of the hand controls, taking the time to create a shape which represents the hand makes the control stand out and easily recognizable for the animator.

As well as creating controls for the character, it was found that creating custom controls, to give the animator more control over the rig itself. was hugely beneficial to the efficiency of the rig. Having an IK/FK switch, for instance, allowed for controls not being used to be hidden thus simplifying the appearance of the rig for the animator. Custom attributes were also found to be a useful way of adding greater control. The hand is a good example of where custom controls can be used. Custom sliders could be set up allowing the animator to quickly pose the hand without having to animate each finger individually.

5.3 Practical development conclusion

The practical development work conducted so far has been invaluable in highlighting successful and unsuccessful techniques for character rig creation. This starting point will inform the future work of this project by ensuring best practices', discovered by the development work, are adhered to. Although not all areas of the rigging process have been covered by this development work the initial stages have been tried and tested and, as a result, more time can be allocated to the more demanding stages in the future work as these initial stages should be relatively simple to complete.

6. Research Conclusion

So far, this report has presented a discussion into rigging concepts and techniques, a brief look at the human body as well as some technical information looking into how rigs are created. It is clear from these findings that rigging and character setup is a crucial stage within the industry and one that is constantly evolving and adapting to meet new challenges posed by new characters.

As a result of these findings this project will take this information and produce a series of rigged characters demonstrating some of the different principles and techniques discussed. These examples will not be used to determine which method or technique is most successful, nor will they be presenting a new method of rigging; quite simply, they will show case this projects understanding of the rigging process and how a range of different characters can go through the process.

Looking forward, future work will also develop understanding in some of the more technical areas of rigging. The research presented in this report indicates that a knowledge of programming may be beneficial for a rigging artist. As discussed in (section 2.1) the automation of the rigging process can significantly reduce the amount of time required for each rig. Unfortunately, this approach to rigging requires considerable knowledge of programming and mathematics. Although the future work of this project is not dependent on such knowledge, allocating time towards the development of these skills is something that may influence the rigs produced.

The principles and techniques discussed throughout this report are integral to the creation of successful characters. Understanding them is only the first step, the implementation of these principles and techniques into a range of successful character rigs will underpin the knowledge gained to date.

7. Evaluation Introduction

With good grounding knowledge of character rigging principles and techniques obtained through the research presented thus far, the remainder of this report focuses on the practical work conducted as a result. These evaluative sections sit alongside the contextual research, often referring back for clarification, and not only tie all areas of this project together but also show how the project continued to develop throughout.

We will begin by evaluating a cartoon character style rig discussing the process and the complications that arose during the rig development. Next, a brief reflection on the progress of the practical work and how the practical work evolved. Finally, we evaluate a muscle system and discuss the difficulties the project faced whilst developing the system. Further research into programming and muscles systems is also presented before final conclusions are reached.

8. Cartoon Character Rig

Looking at the rig created, and the video documentation of the process, it is safe to say a substantial amount has been learnt about the rigging process. This first character was always intended to be a chance to refine current knowledge of rigging, as well as put elements of the contextual research into practice, while tackling a relatively straight forward character. Upon reflection, the character was not as simple as first thought and required more time than was expected. In the context of the project this is not however a drawback. The more complex nature of the character highlighted various elements of the rigging process which, for the most part, had been overlooked or under estimated. This section will discuss these issues in detail.

8.1 How did it go?

The initial development work completed on the first character rig went smoothly and no major issues arose. It was not until work began on the IK/FK arm setup that problems began to surface. It became clear early on during this stage of the rig creation that something was not right with some of the joint placement in the arms, along with the orientation of the joints. Setting up an IK/FK arm system involves using three separate joint chains, one to act as the bind chain, another will have an IKHandle attached and the final chain will have FK controls setup. Whilst working through this process it was found that the IKHandle could not be attached correctly. It is expected that once an IKHandle has been attached to an arm chain that the handle, when transformed, will cause the arm to bend inwards replicating the movement of the elbow. However, due to the placement of the arm joints the IKHandle was causing the arm to bend downwards (see video 4 for an example). It was not clear, at first, why this was happening and this issue brought the project to a stand still. Various attempts were made to solve the problem, the first of which was to alter the direction of the pole vector controlling the direction of the bend, more detail on IKHandles including the pole vector can be found in section 4.1.3. However each time the pole vector was moved so too was the arm. Next, the IKHandle was detached to attempt to move the pole vector once more without it affecting the arm. With the IKHandle detached the pole vector could be moved successfully, however as soon as it was re connected the arm snapped to a new position. It became clear that the issue must have something to do with the position of the arm joints. The arm chain did not have any real distinctive angle for the IKHandle to interpret other than pointing downwards. For this reason the arm chain was deleted and re created with a distinctive forward orientation in an attempt to inform the IKHandle as to which direction it should be bending in. This final attempt was successful in resolving the issue with the IKHandle.

The issue discussed with the IKHandle highlights the importance of the practical development work conducted as part of the contextual report. Rigging methods, such as dissecting the character geometry and parenting each section to its relative joint (discussed in section 5.1), allowed for the issues regarding the arm snapping to be spotted quickly as in some instances the movement was minimal and may not have been spotted until much further into the rigging process. Another key practice adopted as a direct result of the practical development work was that of the broken hierarchy approach to the joint skeleton creation. The broken hierarchy approach, discussed in section 5.1, allowed for the arm to be deleted and re created with ease and, most importantly, without having any effect on the rest of the joint skeleton.

Developing the character rig introduced several new tools and utilities not previously considered in section 4, Technical background, that were integral to the completion of the character rig. These include locators, set driven keys and blend colour utility nodes. Not considering and introducing these tools and utilities until during the practical work is one of contributing factors for the extra time needed to complete the character rig. It is true, however, that this character fulfilled its intended purposes of refining current rigging knowledge while serving as a platform to implement existing knowledge. The new tools and utilities used to implement features such as IK/FK switch and reverse foot setup, show that the practical work progressed the projects knowledge of rigging.

One area of rigging which was not practiced during section 5 was the skinning stage of the rigging process. Considerable research into the area of skinning was conducted and a good working knowledge of the process was established. This knowledge did not however prevent issues from happening during the skinning process, and in fact, the lack of previous experience executing the process inevitably led to significant amounts of time being taken to resolve these issues. The main issue that surfaced during the skinning process was that of painting accurate skin weights. For the purpose of speed the model was purchased, this meant however that the nature of how the model was made was foreign to the project. Whilst painting skin weights vertices were frequently being missed and causing irregular and unexpected skin deformation. It was not clear for some time as to why this was happening, altering painting methods and even re binding the skin several times did nothing to resolve the issue. Eventually, it was discovered that the problem was being caused due to layers of mesh on top of each other. These layers were making it near impossible to ensure all vertices were being included when painting a specific area. To solve the issue the geometry was detached from the joint skeleton and dissected into each individual garment. Once dissected each section could be bound and weighted individually ensuring that all vertices were weighted correctly. Looking back at it, this approach makes complete sense when dealing with a character wearing layers of clothes, but, having never worked through the skinning process this was not obvious at the outset. Taking the time to truly understand a character before jumping into the skinning process is something which will be adopted for future rigs without question.

8.2 Cartoon character rig conclusion

Looking back at the cartoon character rig and taking all the issues into consideration it is evident that the rig fulfilled its intended purpose. Although the rig is not completely finished enough knowledge was gained from working through the process that there was no need to continue. The project scheduled four weeks for the rig to completed and it was becoming clear that the setbacks and complications that arose meant that for the rig to be completely finished would have taken a lot longer than was available. This being the first rig for the project it was critical that the time schedule was adhered to, falling behind at this early stage would have almost certainly prevented some of the later work from being completed.

9. Change of direction for practical work

After reflecting on the cartoon character rig and discussing the issues that arose during the process, the decision was taken to alter the direction of the remainder of the project. Originally the practical aspect of the project was destined to produce three rigged characters of varying difficulty and technique; this was altered and would now deliver one developmental character rig, putting many of the areas discussed in the contextual research into practice, alongside an arm rigged with a muscle system.

A huge area of research in the contextual report was that into the area of muscle systems within character rigging and the human anatomy. This research is the main reason for the change to the project. Attempting to deliver three character rigs was always ambitious for the project, and the reality of that ambition came to head during the process of rigging the first character. As discussed in section 8, elements of the process took longer than expected or where overlooked in terms of their complexity to execute. Continuing in the original direction would potentially have resulted in none of the character rigs being fully finished, or alternatively the rigs that were delivered did not put all areas of contextual research into practice. It is for these reasons that the decision had to be taken to ensure this was not the case.

The new direction of the project, looking into rigging an arm with a muscle system, ensures all elements of the contextual research are put into practice. The new direction also allows for more time to be dedicated to producing the rig, and as a result, should produce a rig to a much higher standard. Developing and experimenting with muscles is the direction the contextual research was always pointing towards and allowing for more time to be spent working on a muscle system, by changing the direction of the project, backs this idea up and really builds on the work conducted so far in the project.

10. Muscle system

Developing a muscle system has been a very challenging process and looking at the rig created the process has been completed with varying levels of success. A great deal has been learnt about character rigging through this process and this next section of the report will discuss the process and present the many challenges and complications that arose along with how they were overcome.

As discussed in section 9 after completing work on the first character rig it became clear that the original aims for the practical work would not be feasible to complete within the time remaining. Looking at the muscle system created it is clear that this move to refine the practical work at this stage was the right choice. Even after refining the project the muscle system created is far from perfect and, by all accounts, far from finished; this is not to say however that it did not fulfill its purpose in putting the contextual research into practice. Although having a fully completed muscle system would have been nice, it became clear after working on the rig for several weeks that in fact more was being understood about the process through the various failed attempts than would have been learnt if nothing had gone wrong, and as such, the completion of the rig became some what irrelevant to the success of the project.

10.1 How did it go?

The first issue that arose during the muscle system development was that of where each of the muscles would connect to the joint skeleton. It soon became clear that some extra joints needed to be built into the skeleton to enable muscles to sit in the correct place inside the character geometry. Although extra joints needed to be used it was important to consider the overall functionality of the skeleton which meant finding a balance between having enough joints to allow for accurate placement of the muscles along with the overall functionality of the skeleton with extra, and somewhat, unusual joints. Understanding the human skeleton was key in determining where extra joints should be added and as such significant time was spend referring back to section 4 of the contextual report.

After experimenting with extra joints it became clear that the only way to ensure muscles could be implemented accurately was by having a physically accurate skeleton model to attach the muscles to. This seemed a logical step in theory, however, working with a skeleton model threw up a new issue. The muscle tools in Maya work by attaching either end of the muscle to a joint, this however means that muscles cannot easily be attached directly to the skeleton model. To overcome this issue each individual bone of the skeleton model was attached to the relevant joint, this meant that muscles could be attached to the underlying joints while using the accurate skeleton model as a reference for muscle placement.

With the joint skeleton developed it was time to begin creating muscles. Maya offers a variety of options for the creation of muscles. Initial work used the simple Muscles/Simple Muscles/ Muscle Builder (see Figure 15); although effective for some muscles, such as the bicep, these tools did not offer enough control to build some of the more complicated muscles such as the pectorals. After experimenting with the muscle builder the decision was taken to move to the more sophisticated Muscle Creator tools (see Figure 16). The muscle creator allowed for a wider range of muscle shapes to be created as well as the ability to re sculpt the muscle at any time. Although the muscle creator offered good flexibility achieving the correct shape for some of the larger muscles was very challenging. Frequently, the ends of the muscle shape collapsed in on themselves which caused odd deformation. The muscle creator is a powerful tool and was successful, however, it is clear from working with the tool that it has limitations. That being said, the muscle system created using the muscle creator can be considered a success.

The process of connecting the muscle objects together and painting skin weights proved to be the most demanding and challenging aspect of the muscle system development. The process begins with applying the cMuscleSystem node to the character geometry; this however does not weight the geometry to the joint skeleton. For the joint skeleton to work with the geometry it must be converted from joints to capsules then connected to the geometry through the muscle objects menu (see Figure 17). Even after this has been completed weights must be painted manually from scratch using the paint muscle weight tool (see Figure 18). It was found while working through this process that a smooth bound skin (see section 4.2) can be converted to a muscle system. Not only does this convert the geometry it converts all joints to capsules and transfers skin weights from the smooth bind to the cMuscleSystem node. Adopting this workflow saved large amounts of time during the development of the muscle system. Connecting muscles to the system, however, has to be done manually and will have no effect on the geometry until weights are painted. It was at this stage that issues with painting weights surfaced and slowed the progress of the project.

Painting skin weights is a laborious process as discussed throughout much of the contextual report. Working through the process of painting weights for each muscle it became clear that the paint muscle weight tool is very delicate. Whilst working on specific muscles great care had to be taken to ensure each vertex was being affected 100% by something. If this was not the case the vertex would be weighted to any available joint and resulted in poor deformation.

10.2 Further Research

Alongside working on the rig, continued research has been conducted into the area of muscle systems. It was becoming clear that the approach adopted by the project to create and implement a muscle system could not be the way it was completed in industry. Looking back at section 3.3 of the contextual report it seemed wise to investigate the work WetaDigital completed on The Hobbit: An Unexpected Journey further. It was this investigation that uncovered the Tissue system Weta use to implement muscle systems into their character rigs. Tissue has recently been recognized at The Academy's Scientific and Technical Awards with a Technical Achievement award. In an fxguidetv video two of Tissue's developers James Jacobs and Simon Clutterbuck discuss some of the technology and mathematics behind the system; another video available on WetaDigital's youtube channel gives a slightly more straightforward explanation as to what the system is. Tissue is a physically-based character simulation framework which allows for the creation of anatomically correct muscle, fat and skin systems for virtual characters. The system built by Tissue is driven by key framed animation, motion capture data or even a combination of both. The idea of Tissue is to utalise computers to do a lot of the hard work for riggers, speed up the process and ultimately, produce the most realistic and believable characters possible.

Looking at all of the research presented in both the contextual report and here in the evaluation it is safe to say that a Rigging TD would not be expected to sit and build a custom muscle system from scratch. The implementation of a muscle system for only the arm of a character took the best part of 6 weeks of the project and the result is only a rigged shoulder and upper arm. Although with more time an accomplished system could be created, the approach used during this project is certainly not best practice.

11. Programing

One conclusion drawn from the contextual research was that programming knowledge is a fundamental skill for a Rigging TD to posses, and although not essential, was an area for development during the practical side of this project. It was planned that some programming would be completed once a week, and for a time this was the case. However, as the project pushed forward and issues began to occur with the character rigs the decision was taken to put the programming on hold. Upon reflection, this was the correct decision; the amount of complication with the cartoon character rig and the subsequent refinements to the rest of the project work indicates that there was simply not enough time to incorporate the programing development. This is not say however that the programming work completed was a waste of time, quite the opposite. The programming development completed, in the first couple of weeks of the practical work, confirmed the projects desire to move towards more technical rigging solutions in the future. This desire is also confirmed by the research conducted into the award winning Tissue system, discussed in section (10.2).

The power of programming and technical knowledge is clear and it would be in the projects best interests to move forward with more technical investigation work in the future. Having produced a bespoke muscle system and taking all of the issues that arose into consideration it is clear that more technical knowledge would have benefit the outcomes of the practical work.

12. Legal and Ethical Issues

When completing any digital media work it is imperative to consider legal and ethical issues surrounding the work. The work conducted by this project raises only one issue which will be discussed in this section.

The only issue raised by the work of this project is that of intellectual property. Each of the character models used by this project were not created by the project. Instead, each was purchased through either www.turbosquid.com or through 3D Artiest Magazines. It has been important for the project to state throughout that this is the case to ensure it is in compliance with copyright laws as outlined by the Intellectual Property Office (2010).

Although the only issue raised by the work of this project is that of copyright, other ethical issues could influence the future work of the project. If future work looked into using actors to provide motion capture data to test character rigs, for example, then consent must be given by the actors before capturing any data. The actors consent should also cover their agreement for their movements to be used in animation that could, potentially, be seen by hundreds of people. If consent is not given by actors formally then the work has no right to use any data captured from that actor.

13. Conclusion

Looking at the body of work presented in this evaluation it is clear that the practical side of the project has been a success. The idea of the practical work was to implement the research conducted into rigging examples which clarify the projects understanding of the various rigging concepts and techniques required to produce functional rigging solutions. The initial cartoon character rig demonstrates many of the concepts and techniques discussed throughout the research as well as introduces new tools and utilities integral to the creation of successful rigs. The muscle system work delves much deeper into rig creation and begins to demonstrate techniques employed by the industry as well as highlight how intricate and advanced industry rigs become.

Now that both the contextual research and practical work is complete, it is fair to say that overall this project has achieved what it originally set out to. This project has dived head first into the world of character rigging and successfully presented a well rounded body of research with relevant rigging examples which clearly demonstrate the knowledge gained by the project. The rigging examples also demonstrate the projects ability to overcome complications and use the research conducted to solve the issues.

Looking forward, there is still a vast amount of research and practical work to be completed, primarily, that of gaining a working knowledge of programming languages. For this project to truly push boundaries and compete with research being conducted within the industry, it is clear that a more technical direction must be taken. Many of the issues discussed throughout the evaluative sections of this report could easily have been averted with the aid of programming. Other areas for future investigation include that of motion capture. Coupling muscle systems with motion capture would allow for real-time testing to be completed and would unquestionably result in more accurate rigs. This project is a good starting point for this future work and it will be interesting to see how the project will progress.

Appendices

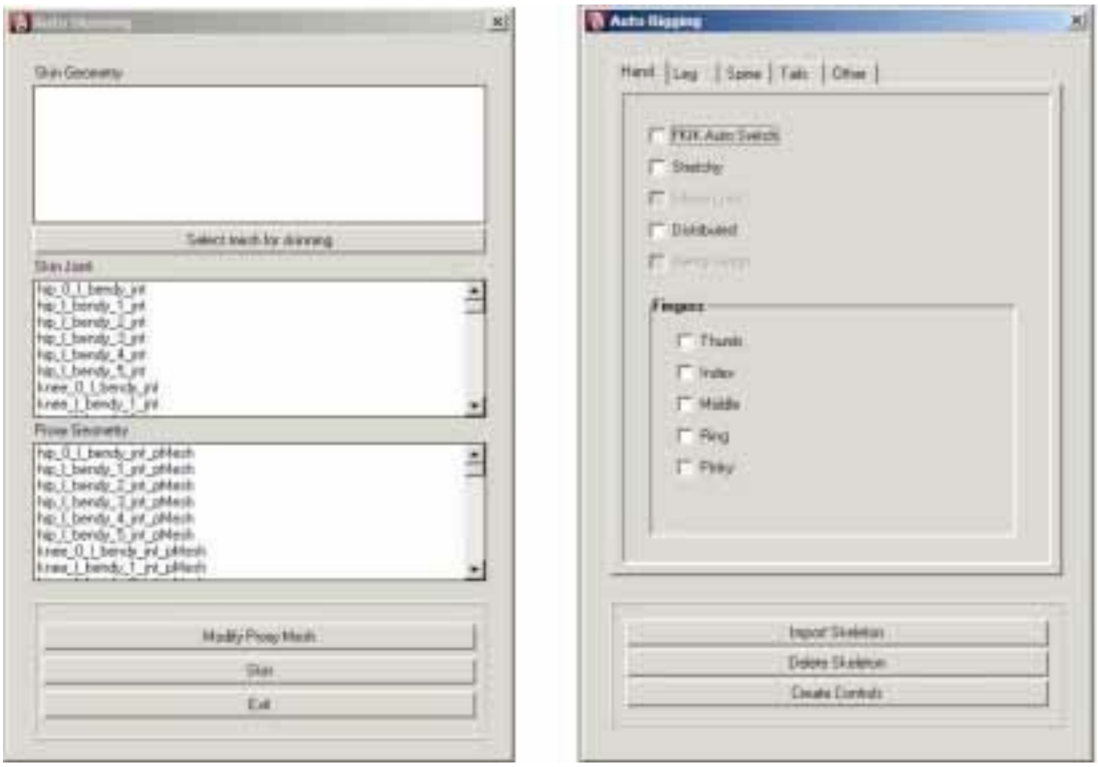

Figure 1. Lakakwar, R, 2009 Graphical User Interfaces generated by his Automatic Rigging/Skinning script.

Figure 2. Example of the issues with Subspace Skeletal Deformation showing loss of volume through bending and rotating joints to extremes.

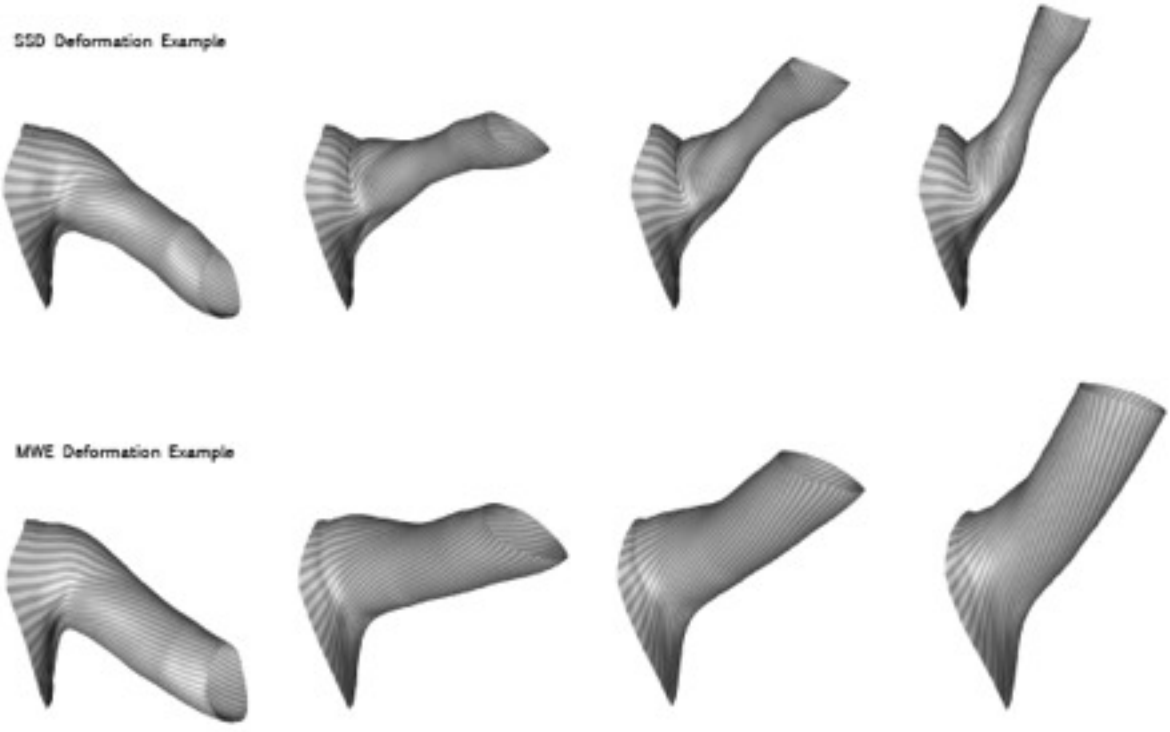

Figure 3. A comparison of Subspace Skeletal Deformation with Multi-Weight Enveloping highlighting the differences in deformation quality. Images taken from Phillips, C, Wang, X C, 200

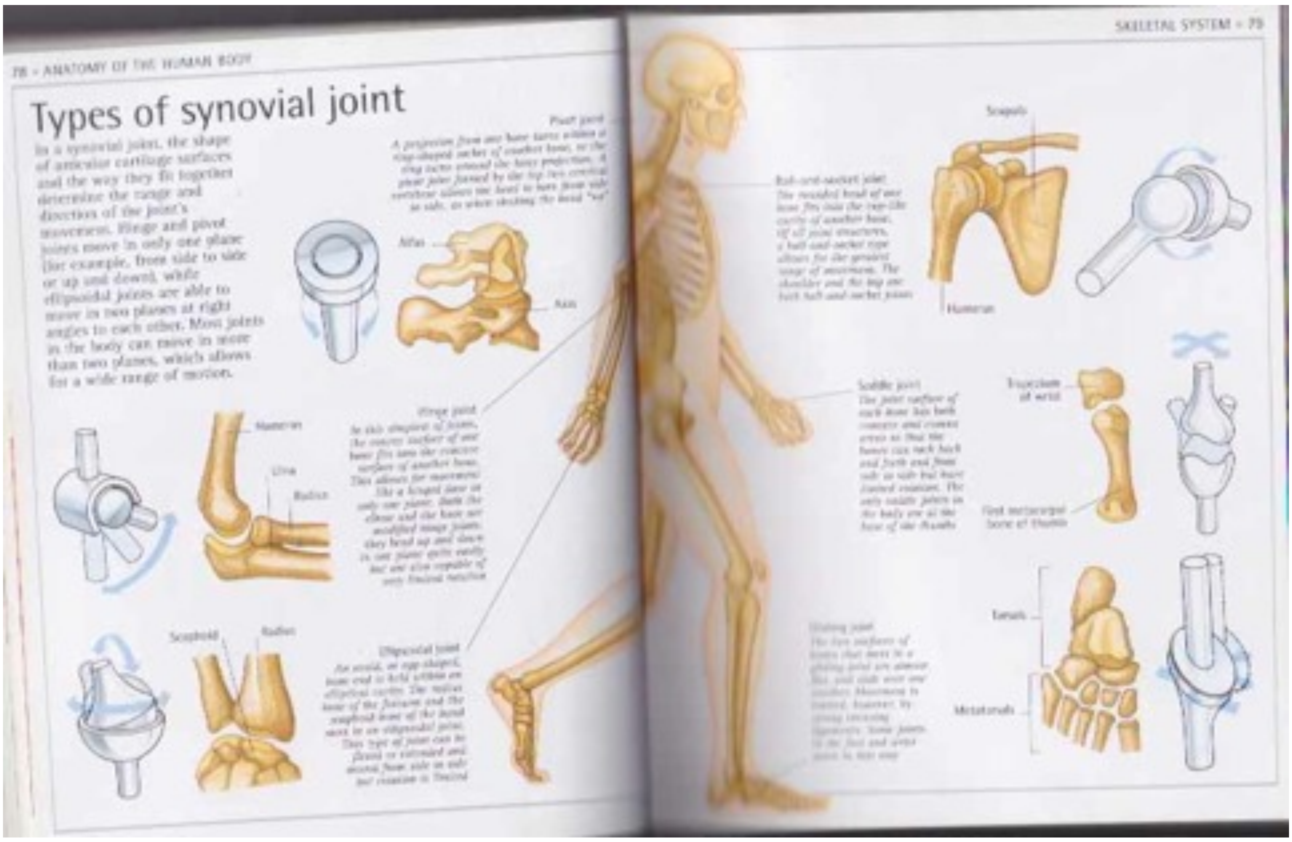

Figure 4. A double page spread taken from Baggaley, A ed, 2000 illustrating the range of joints in the human skeleton.

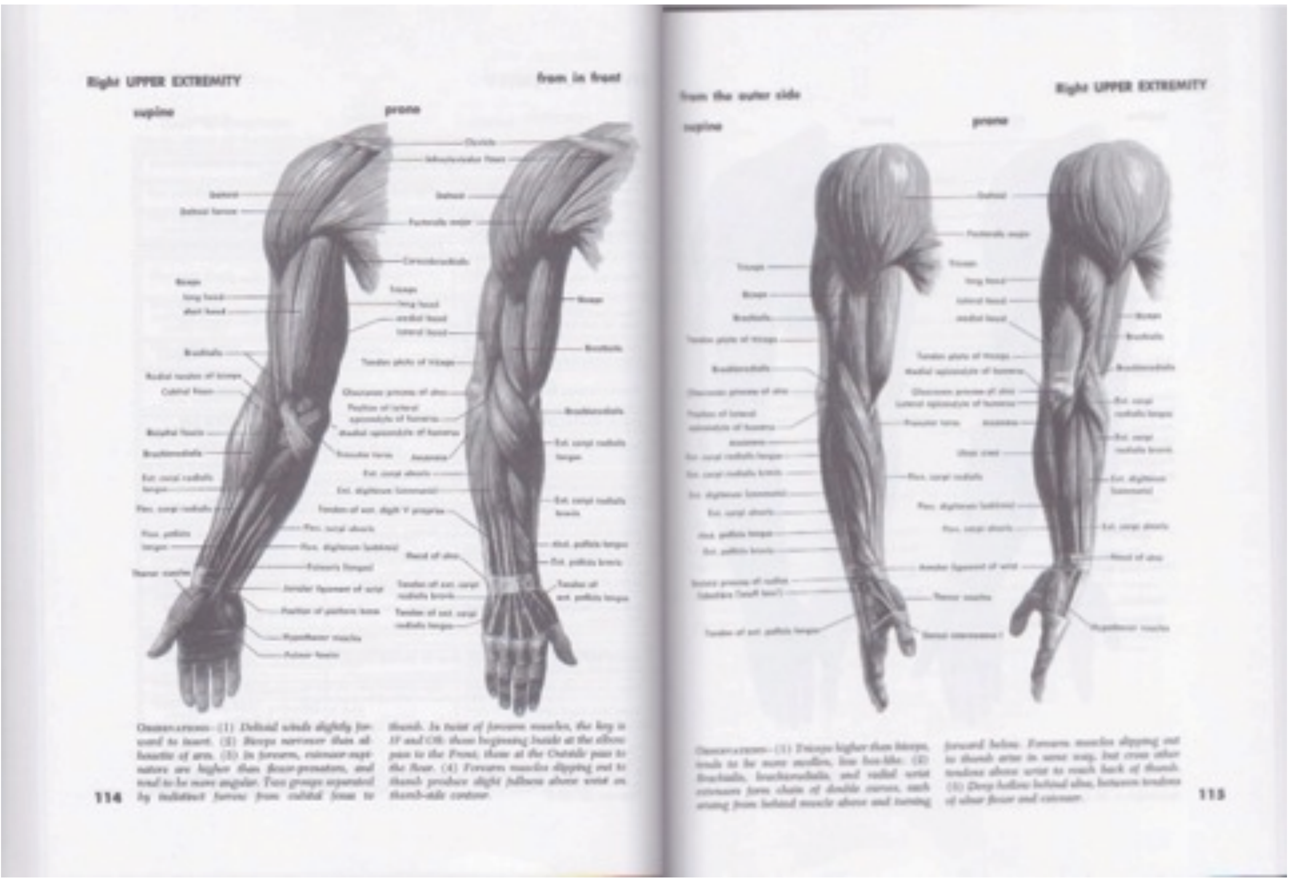

Figure 5. A diagram illustrating the muscle system if the human arm taken from Peck, S R, 1979.

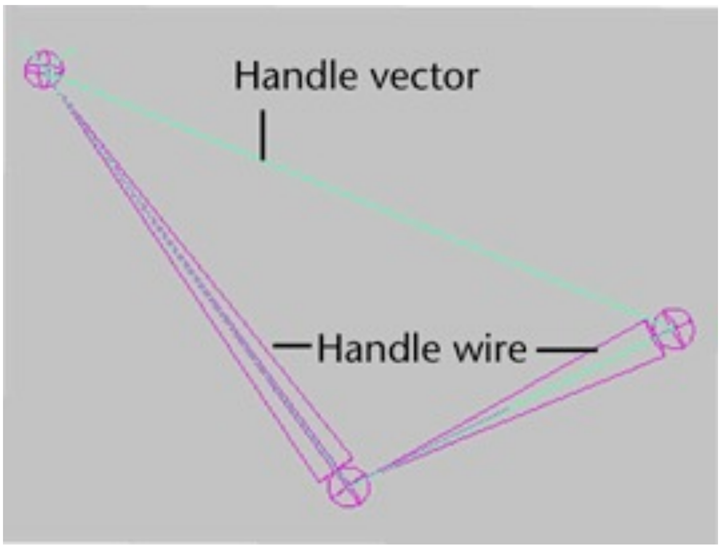

Figure 6. Standard IK Handle components. Image taken from Autodesk 2013 Help Guide (Autodesk, 2013)

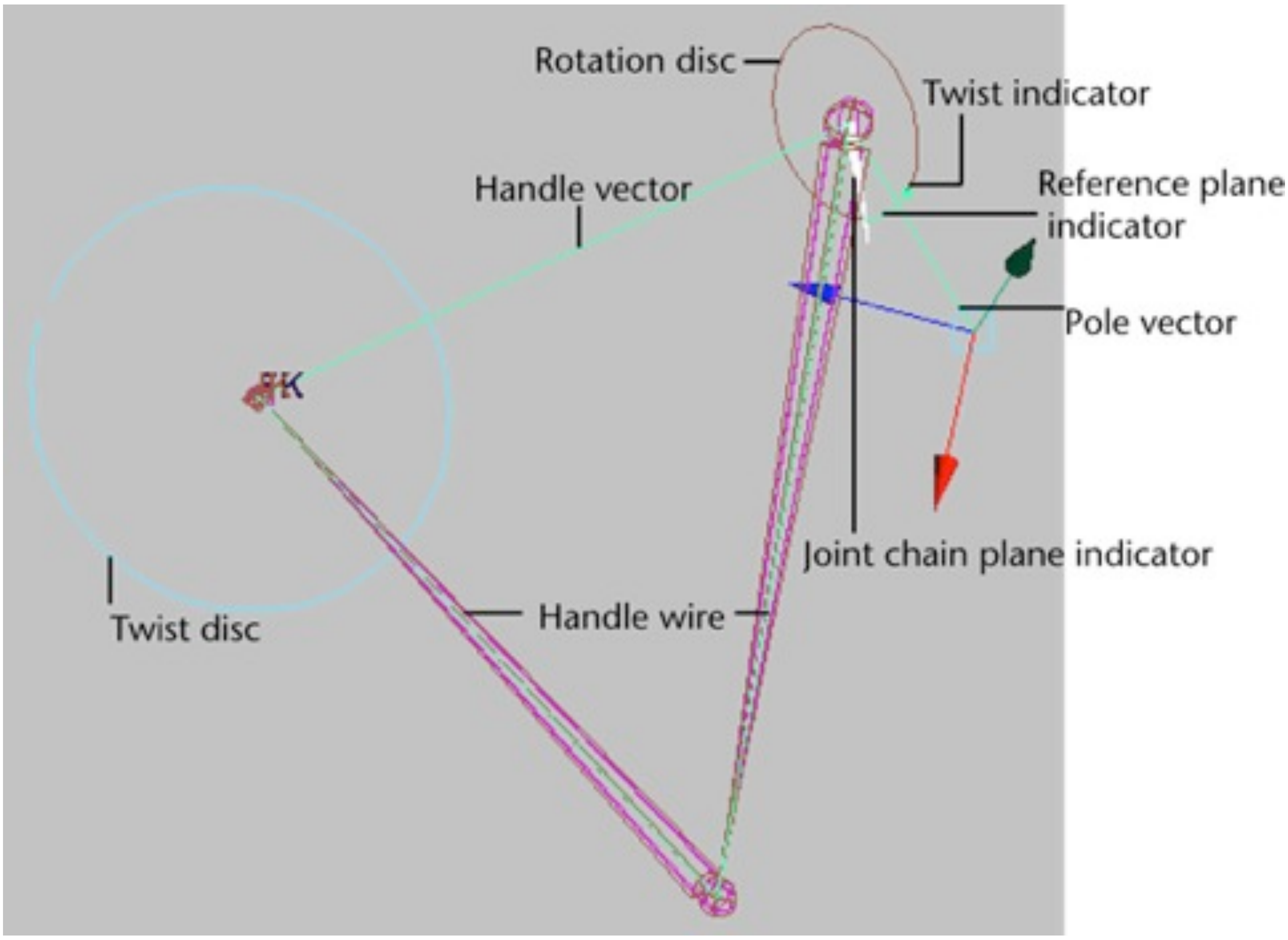

Figure 7. Rotate Plane Solver Componets. Image taken from Autodesk 2013 Help Guide (Autodesk, 2013)

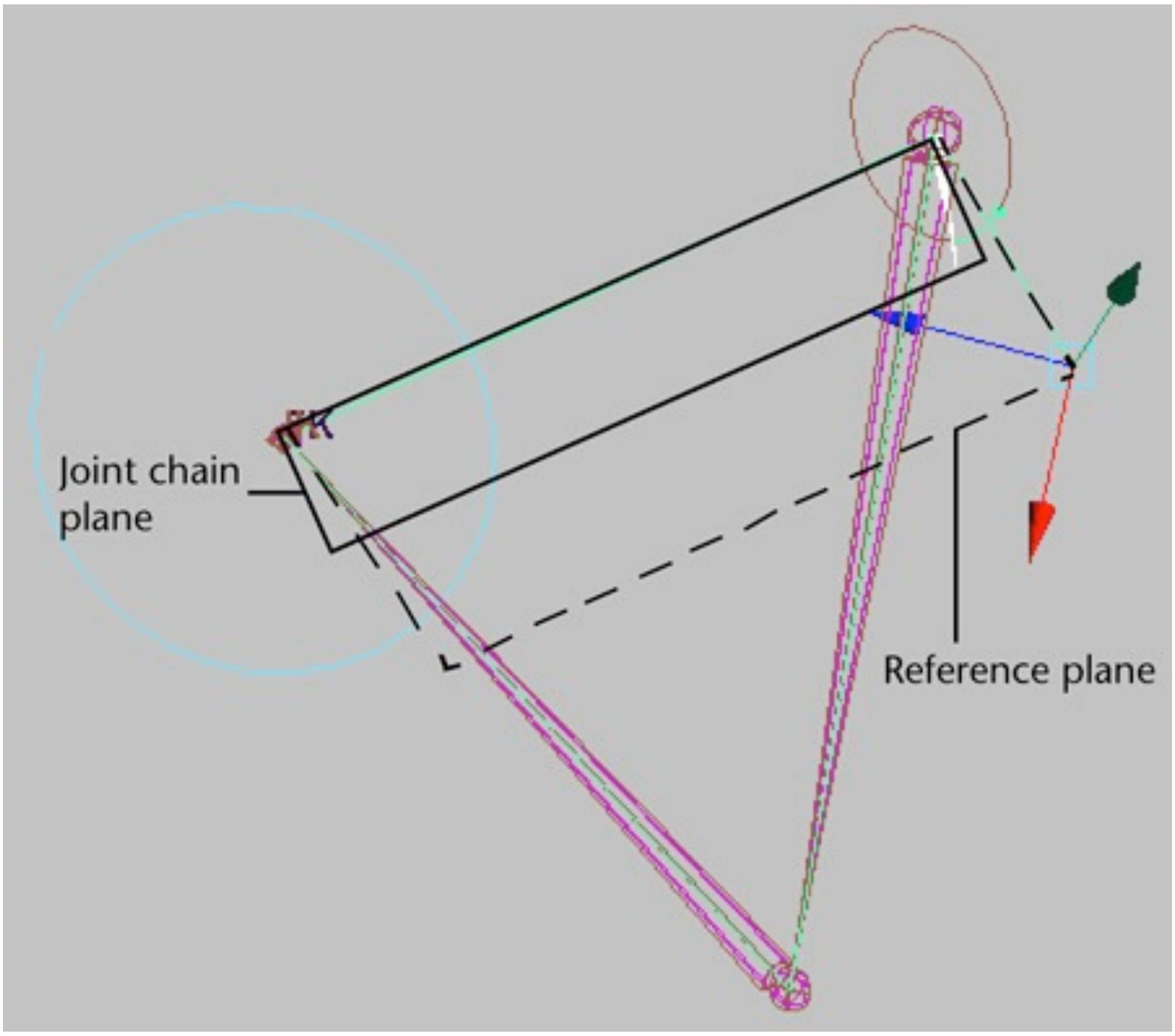

Figure 8. Rotate Plane Solver Componets. Image taken from Autodesk 2013 Help Guide (Autodesk, 2013)

Figure 9. An example of Maya’s Classic Linear Smooth Bind

Figure 10. An example of Maya's Dual-Quaternion Smooth Bind

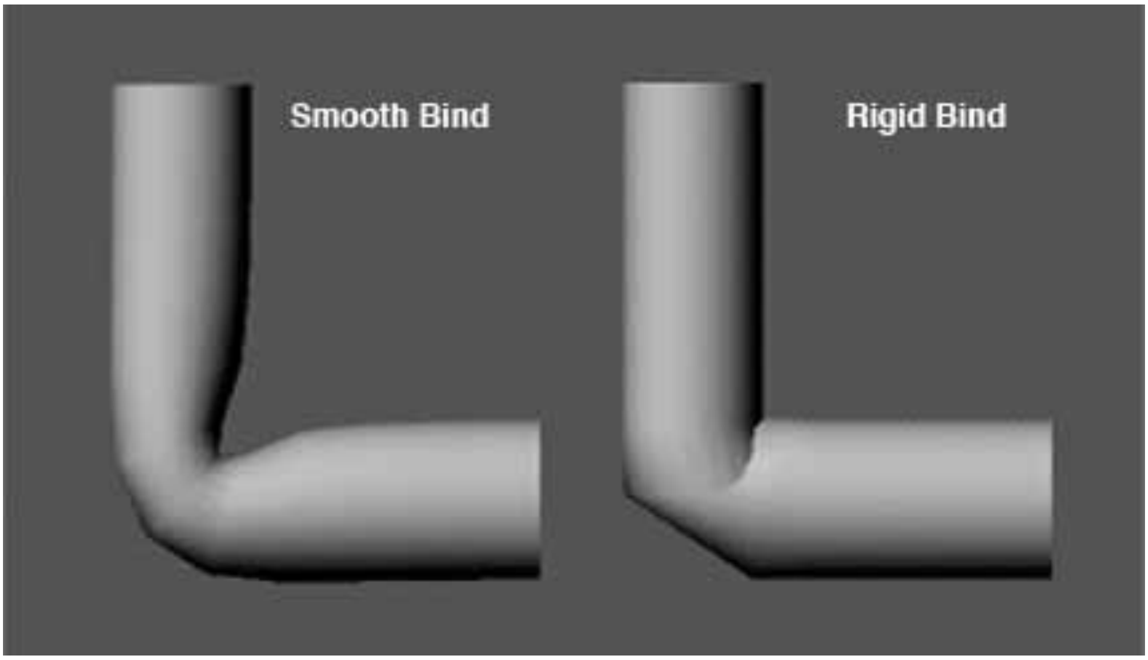

Figure 11. A comparison between Maya's Classic Linear Smooth Bind and Rigid Bind

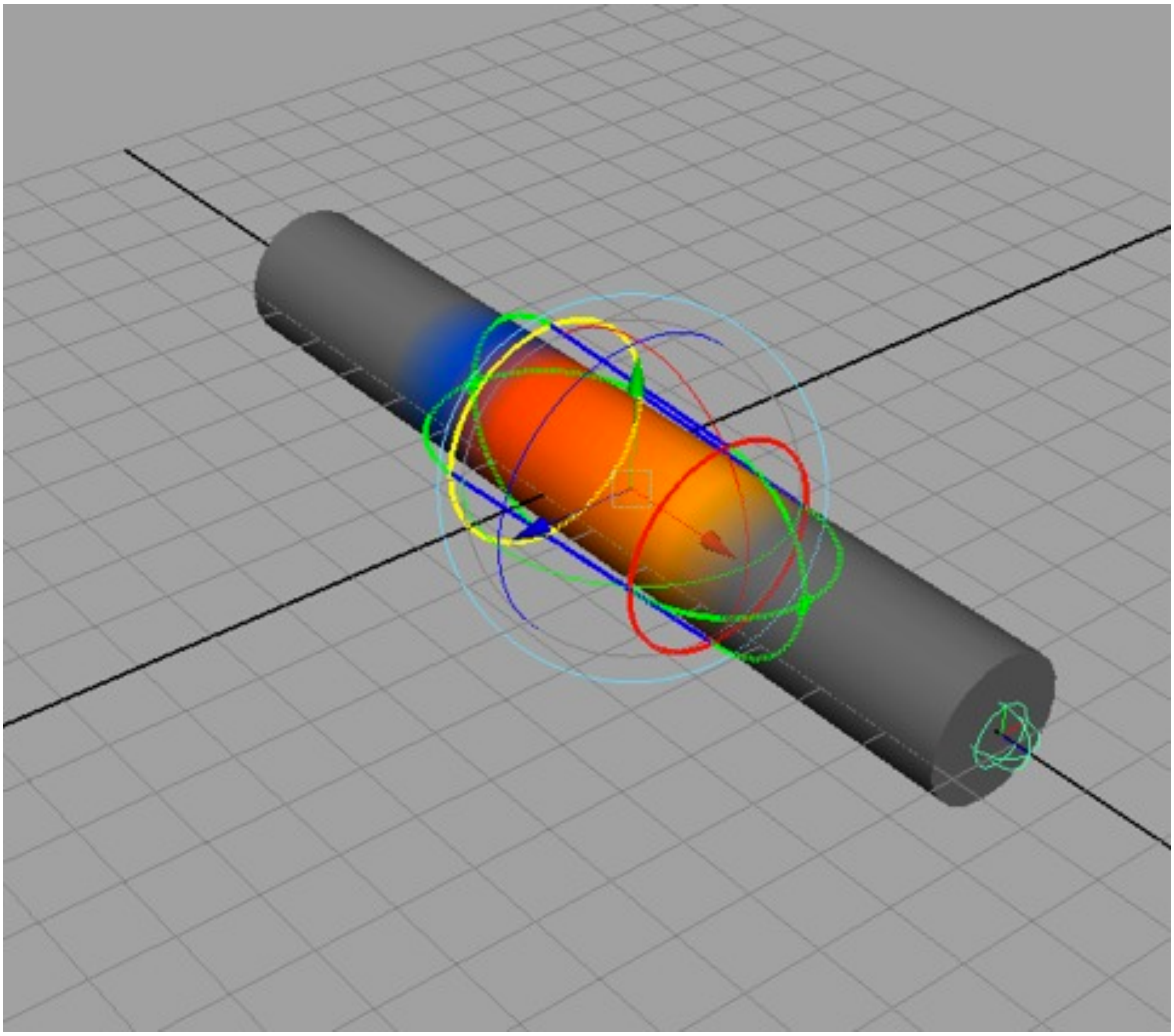

Figure 12. Interactive Capsules used during the Interactive Bind Method in Maya.

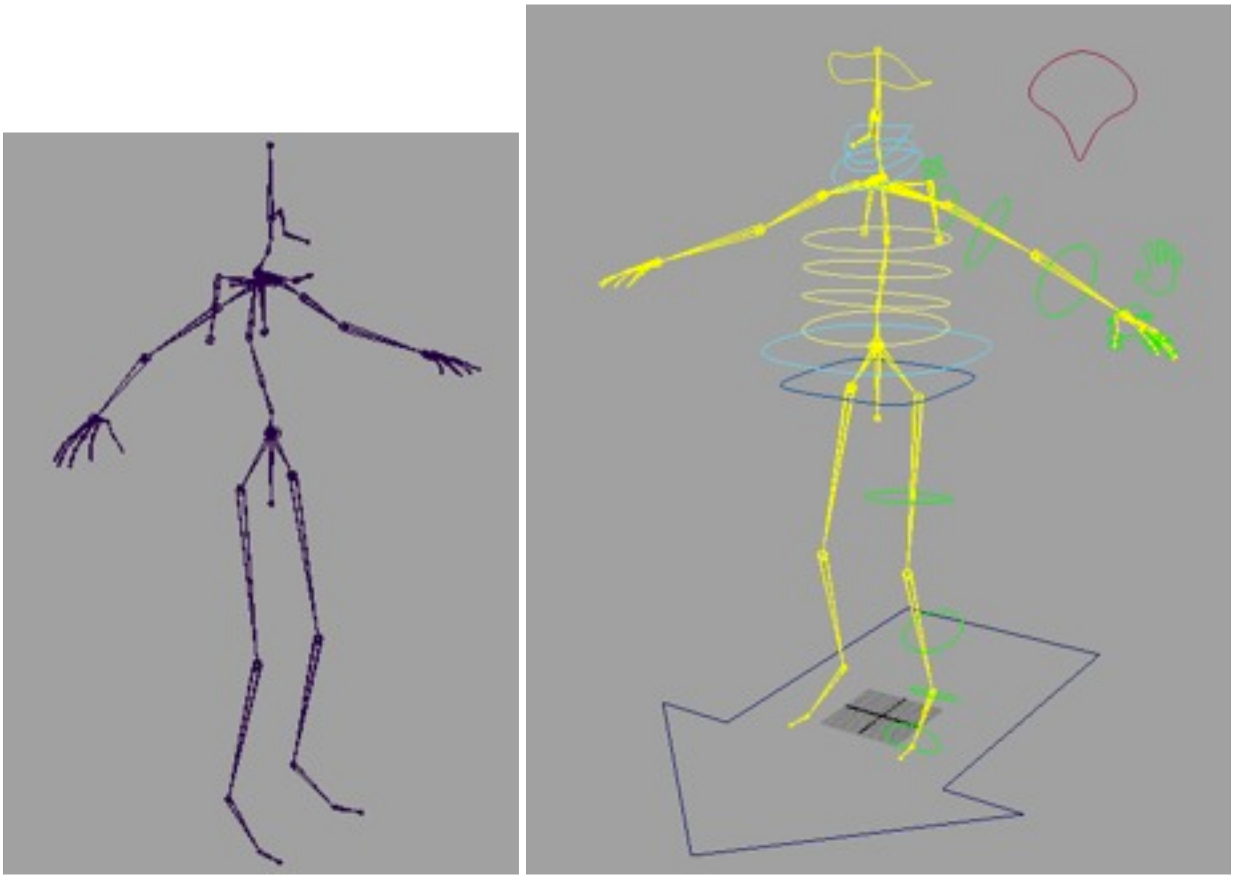

Figure 13. Skeleton created for a realistic human biped character.

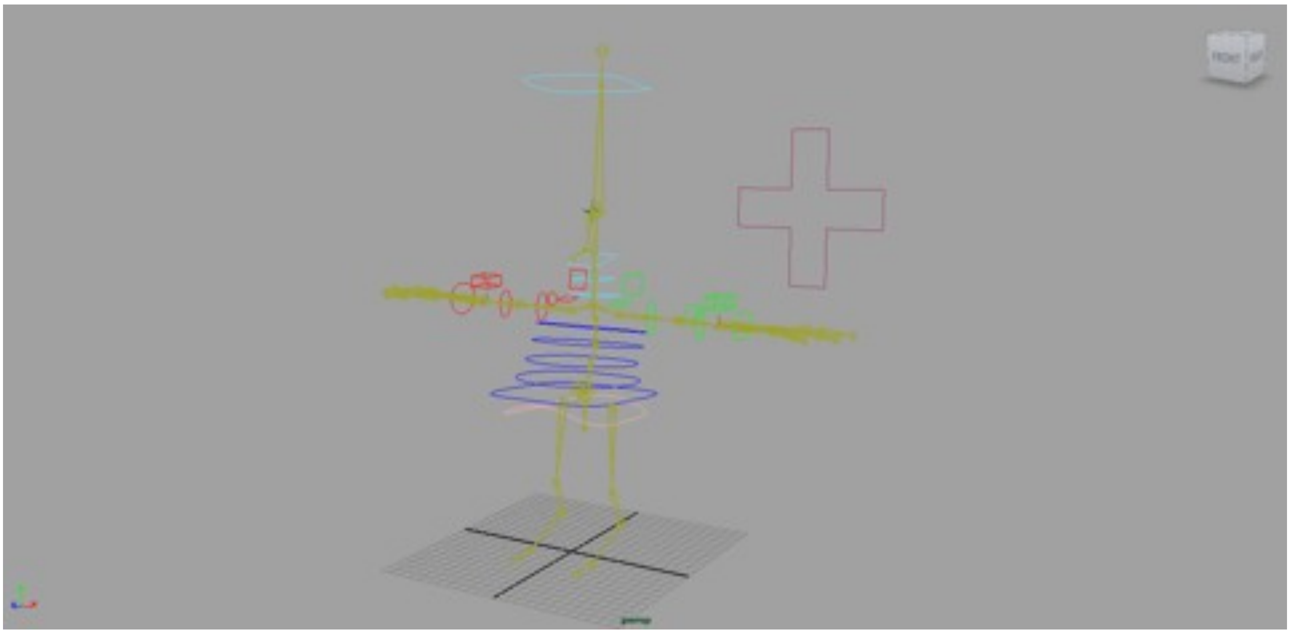

Figure 14. Skeleton created for a cartoon stylised character.

Figure 15. Muscle builder UI

Figure 16. Muscle creator UI.

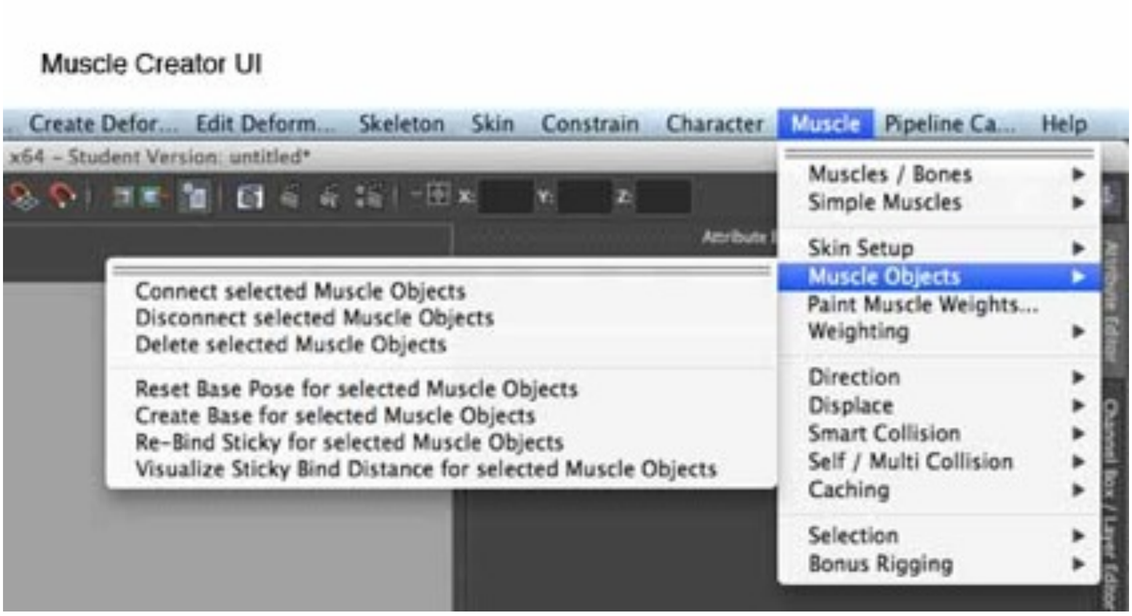

Figure 17. Muscle objects menu

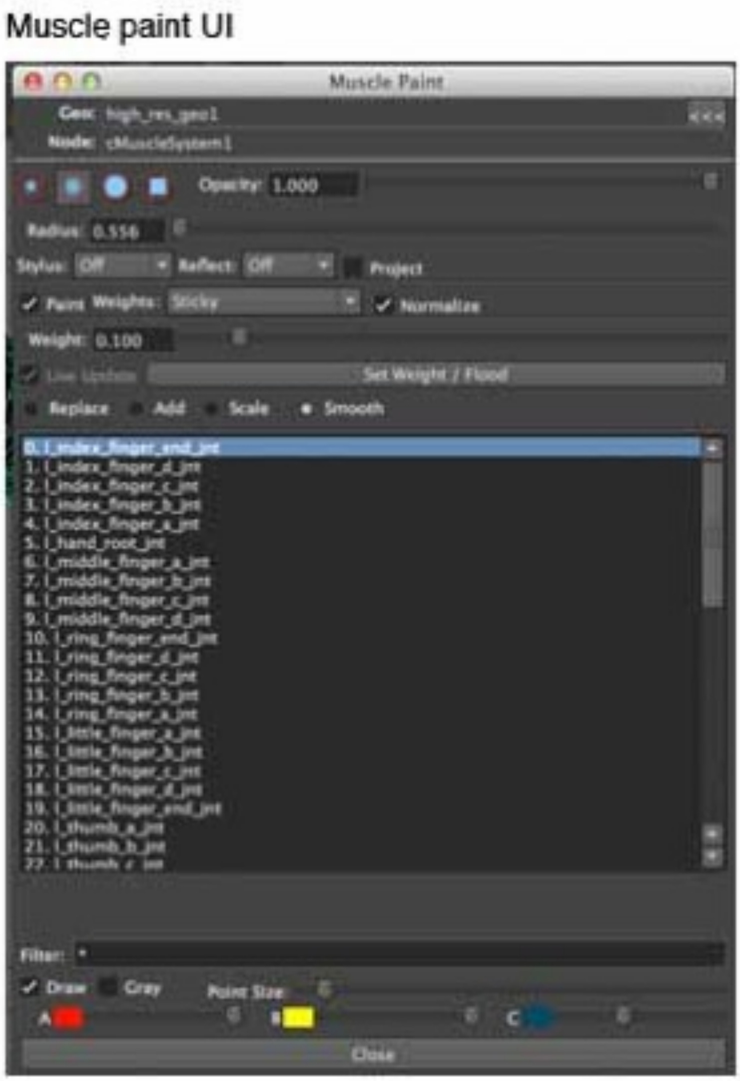

Figure 18. Muscle paint weight tool UI

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