

Production Friendly Character Skinning

Johannes Saam, Jon Macey*, Jian J Zhang*

National Centre for Computer Animation. Bournemouth University. United Kingdom

Abstract—Muscle-based skinning is well-known for its ability to produce detailed visual quality. Unfortunately, this advantage has not been well realised in the animation industry, because it works against the normal animation production pipeline. In this paper, we present a novel muscle-based technique, which rather than modelling muscles inside-out, will start from an already modelled character. We provide a number of tools for placing and shaping muscles inside the body of the character. By associating the muscles with the bony skeleton and the skin surface, animating the bony skeleton results in the animation of the skin surface. Compared with other muscle-based skinning methods, our method is not only able to produce detailed visual quality, but more importantly place an emphasis on the usability for production by an animator. Our preliminary experiences suggest that our technique is fully compatible with the current production flow and could be easily used in animation production.

Index Terms—Character Animation, Deformation, Muscle Simulation.

I. INTRODUCTION

Skinning animated human or creature characters is arguably one of the most time-consuming tasks for character animation. The film and animation industries require an ever increasing level of visual realism, whilst, trying to reduce the associated labour cost. Although a number of techniques exist there are two prevalent approaches to character skinning. The first and the most commonly used method is known as the smooth skinning, which involves direct deformation of the character's skin surface. The second method is based on the manipulation of the anatomical structures and elements, including the skeleton, muscles and fat, and thus is known as the anatomy-based approach.

The advantage of smooth skinning lies in its intuitiveness. It is comparatively simple to establish and efficient to compute. However, due to the complexity of skin movement and its relationship with other body parts, smooth skinning quickly reaches its practical boundaries. In order to achieve complex and visually pleasing results for characters, other techniques and deformation routines have frequently been explored, often defeating the intuitive nature of smooth skinning. Despite its disadvantages, in practice the smooth skinning approach has been widely accepted by the animation industry. Animators are so used to the work flow that it is unlikely that the industry would adopt a new approach, if it means that a different work pattern is to be enforced.

The anatomy-based approach, because of its ability to reference the knowledge of the character's body structure, can

often lead to more visually pleasing results. Deformation is produced based upon the geometric and physical properties of the anatomical elements, such as muscles, fat and skin, taking the complex mechanisms of the character's body into account. While this can be very tedious to establish, anatomy based models are becoming more appealing in production. What is unfortunate, however, is that with the anatomy based approach the traditional skinning process is effectively reversed so the animator must initially build the bones and muscles over which the skin surface is draped. While the level of realism achieved can be largely improved, as the skin shape is now truly reflecting the underlying muscle structure, this may interfere with the traditional creative process.

In order to take advantage of the muscle-based technology and at the same time overcome the issues caused by the reverse production flow, in our previous work [9], we allowed the work to start from an already modelled character, rather than forcing the animator to build muscles in a bottom up manner. This method extracts muscles by studying the geometry of the skin surface. Since the animator does not need to worry about how the muscles are generated, he/she can concentrate on the artistic aspect of the skin deformation allowing realistic skin animation to be produced with ease. The problem of our previous development, however, is that it can only extract major muscles which show clear influence on the skin. This is because our muscle extraction system does not rely on any prior knowledge of the anatomy. Due to the same reason, we were only able to produce muscles of relatively simple shapes. This weakness has unfortunately limited the realisation of the potentials of our technique.

In order to retain the advantage of our recently developed technique and improve its limitations, in this paper we present a mechanism for skeleto-muscular deformations on human like creatures, which again is geared towards usability. With this new technique, the user will again start from an already modelled character. The difference however, is that we instead allow the user to specify necessary muscles according to their scenario by providing the user with a number of muscle modelling and deformation tools. This way, the animator will always have the maximum amount of control without being exposed to tedious processes. To maintain a suitable working environment, Autodesk's Maya was chosen as a platform for the development for all the tools. Thus the user remains within his/her known processes.

II. RELATED WORK

Mesh deformation is a subject in 3D computer animation that has experienced significant improvements in recent years. The first approaches to skin deformation were achieved with smooth skinning [3]. The skin mesh is treated as an external

*{jmacey,jzhang}@bournemouth.ac.uk <http://ncca.bournemouth.ac.uk/>

shell that moves based on the implicit bones inside the surface. The skin points are moved by a weighted combination of the joint transformations of the characters skeleton [2].

This method is simple, easy to compute and therefore very fast. However the animator has to input the weights of every bone by painting weight maps. This initial job can be time consuming and tedious and for certain areas of the body, such as the parts where multiple joints affect one vertex, it requires an experienced animator to optimise settings. While the final result can be visually pleasing it can be extremely difficult and tedious to achieve.

In addition to smooth skinning, other methods of shape interpolation have been documented. Example based skeleton driven deformations [1] and multi-weight enveloping [7] are some of the techniques explored so far. All these methods give the animator a greater amount of control over the resulting shape, but can be very time-consuming and require the storage of large amounts of data. In addition, producing example shapes is a major task and can be unintuitive because effects are additive and may produce unpredictable results.

Thalmann et al presented the first metaball based approach to a physically and anatomically based deformation model [6]. This technique was not very detailed in modelling the muscles. Techniques that allow a higher amount of detail were developed later [5], [4], [8]. Scheepers's paper in particular suggests a very interesting approach where a system is developed that use simple shapes to represent muscles based on the physical attributes. This technique is easy to implement, however the disadvantage to this approach is that the deformation model has to be built from inside out. This is, as discussed earlier, counter-intuitive to the traditional way of setting up characters and so efforts are needed to learning the method.

Because of the inherent disadvantages, the current approaches to muscle dynamic simulation are more of an academic curiosity than anything easy to use for production. Our previous work [9] tried to address this problem. This paper will further the current techniques aiming to ensure the user is at the focus of interest and in the same time maintain maximum visual fidelity.

III. OVERVIEW

The pipeline of the system is developed using Maya, however the approach may be adapted for any animation package as it uses standard API components. In addition this system may also be adapted to run using real-time engines for computer games / V.R. type application.

Given an already modelled character, the internal skeleton of the character is developed and the bones are placed inside the character, this has the advantage that the skeleton can be developed at the same time as the animation rig, allowing an iterative development process of both animation control rig and skeleton. This is exactly the same as the existing process used by the current industry as shown on the left branch of Fig 1. We then allow the animator to model muscles that are connected to the bones according to the anatomical properties of the creature. A number of tools are provided for the user to shape, adjust and fine-tune the muscles and their relationship

with both the bones and the skin. By animating the bones, the muscles are animated/deformed, which in turn deform the skin. To add another layer of visual quality, each muscle is represented by a mass-spring soft body, an existing feature of the Maya system. This proves very effective in achieving realistic dynamic secondary motions during animation. Fig 1 shows the pipeline of our technique with the right branch of the diagram highlighting the muscle setup steps.

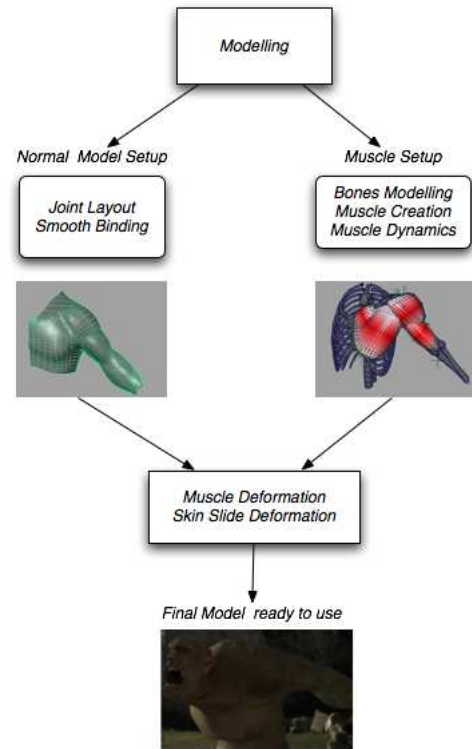


Figure 1. Skinning Pipeline

IV. PRE-REQUIREMENTS

To be able to start the setup procedure a skin surface must be modelled and bones inserted into the character. For best results basic smooth skinning [3] is used, this has the advantage of allowing several nearby joints to have varying influences on the same skin points, and is a standard feature in most animation packages. At this point a decision has to be made on how the underlying skeletal system is to be developed. One advantage to doing this step early is that it can inform the rigging process at the same time. Usually the animators knowledge of anatomy and rigging can make this process simple allowing for quick construction of the skeletal system. Another benefit of this method is that the more time that is available for setup, the better the results can be produced. This is in contrast with our previous work [9] and the user is now able to add flexible muscles at any time, allowing iterative construction of the character

V. MUSCLE SETUP

In this paper only two types of muscles are discussed: *fusiform* and *multi-belly* as described by Scheepers[5]. There

are many more muscle types in the human body, but these two categories can approximate many different forms in a visually pleasing way. The parameters of these muscles control the shape, volume preservation and tension. Simple muscle shapes are linked together to form more complex geometry if needed and therefore are sufficient for the purpose of animation.

A. Fusiform Muscles

Fusiform muscles are presented as ellipsoids that stretch from an origin to an insertion point, and have been described by Wilhems et al as the best primitive to represent muscle shapes [8]. In our system to generate a fusiform muscle two Maya locators are placed at appropriated points on the underlying skeleton and a NURBS sphere is created. The sphere is constrained to the locators so that its centre is in the middle of both locators.

To maintain the volume of the muscle, we use the method of isometric muscle contraction [5]. Based on the distance between the two locators (the distance between the origin and the insertion points), the sphere can be rescaled to give the resting pose muscle shape. (Fig 2a). A ratio between the width and height of the muscle is set. Adjustments to this ratio results in a different muscle tension (Fig 3,4). This muscle tension is one of the most important parts in the muscle system as it is used to give the underlying characteristics to the creature being animated, we allow this parameter to be user-controlled - usually, the stronger the creature, the lower the value and the fatter the creature, the higher the value.

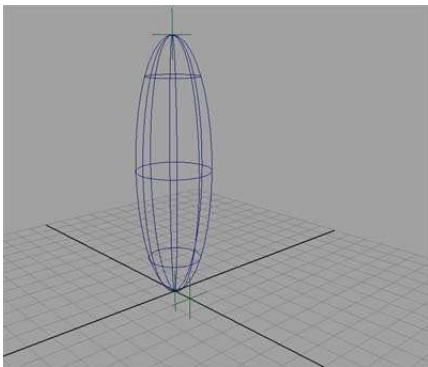


Figure 2. Fusiform at rest

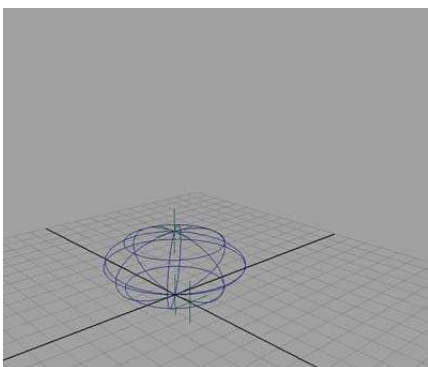


Figure 3. Fusiform contraction

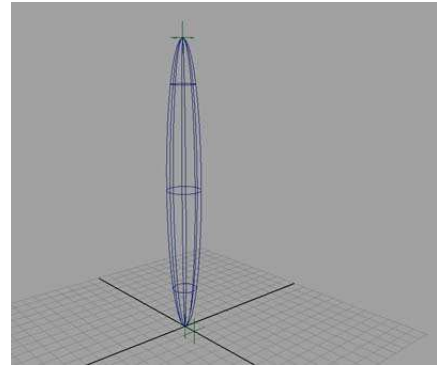


Figure 4. Fusiform stretch

B. Multi-belly muscles

Multi-belly muscles are basically the same as multiple fusiform muscles with the same parameters. However these muscles are controlled by origin and insertion curves (Fig 5) rather than control points. These curves can be linked to bones to make the muscles bend around them. Normal rigging techniques like clustering and wire deformations are used to maximize the realism. These are all internal Maya functions that can be easily setup by the animator as needed.

After the multiple muscles are created, lofting is used to create one resulting muscle shape (a NURBS object) in order to maximize the speed for simulation and deformation. Figures 7,6 show the effect of the muscle deformations.

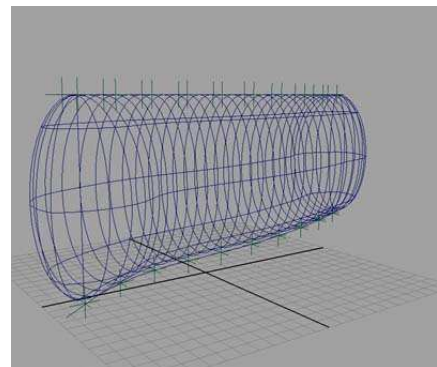


Figure 5. Multi-belly rest pose

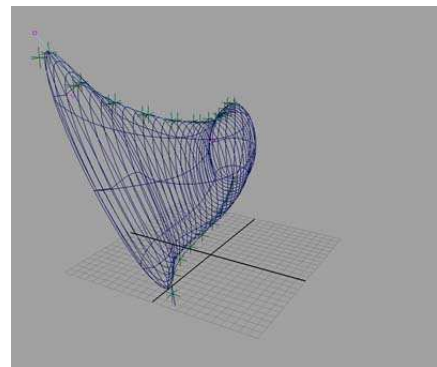


Figure 6. Multi-belly contraction

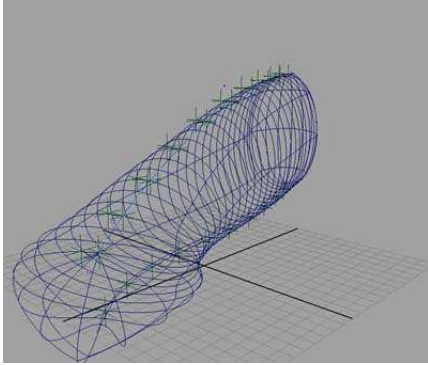


Figure 7. Multi-belly stretch

C. Muscle deformations

The basic muscle deformation follows the method prescribed by Scheepers [5]. Given the user defined parameter t_u being the muscle tension, d being half the distance from the muscle at rest and the current muscle position and v being the pre-calculated muscle volume.

For each point on the muscle surface we calculate the following based on the rest muscle Width and Height W_r and H_r respectively.

$$r = \frac{W_r}{H_r}$$

$$t_f = - \left(\frac{t_u}{2} \right)$$

$$t = r(1 - t_f + (2.56t_f))$$

$$H_d = \sqrt{\frac{3v}{(4\pi d)t}}$$

$$W_d = H_d t$$

To give us the new muscle Width and Height W_d and H_d respectively. The constant 2.56 is derived directly from Scheepers paper however changing this value can lead to interesting results. Initial investigation has revealed reducing this value gives reduced muscle volume and can simulate fat.

VI. SKIN DEFORMATIONS

The skin deformation is the product of two basic deformation models. The first deformer transfers the shape information of the deformed muscles to the skin, this is based on traditional weight maps. The second deformer connects the bones to the skin and is used to deform the skin directly where the bones touch, this shows the sliding effect of the bones underneath the skin.

A. Muscle Deformer

The main muscle deformer is a two stage process, the first stage is a pre-computation stage to store the muscle point data allowing for quicker deformation. For each point on the skin surface (Fig 8) We first find the current point of interest P_s and find the closest point on the Muscle surface P_m from where the Vector \mathbf{B} is formed and the distance d calculated.

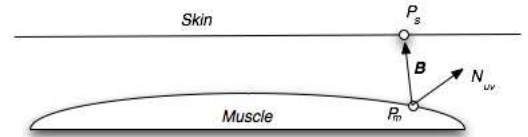


Figure 8. Deformation process

During this stage the undeformed muscle surface normal at the uv co-ordinate (\mathbf{N}_{uv}) is stored along with the uv co-ordinate pair. Finally the vector \mathbf{B} is normalised.

The second stage of the deformation is the interactive stage, every time the muscle is updated the following calculations are made :-

First we get the point on the muscle surface P_m and the normal \mathbf{N}_{uv} . Next the current muscle surface normal \mathbf{N}_d is calculated. The deformation direction vector \mathbf{D} is calculated by forming a quaternion Q from \mathbf{N}_{uv} and \mathbf{N}_d which is the rotation of the vector \mathbf{N}_{uv} into the vector \mathbf{N}_d about their mutually perpendicular axis. Finally the deformation direction $\mathbf{D} = \mathbf{B}Q$ is calculated

To deform the surface we calculate the new deformation vector \mathbf{D}_n as

$$\mathbf{D}_n = P_m + \mathbf{D}d(1 - s) + \mathbf{D}$$

where s is the user defined muscle shrink factor.

Finally the new point on the skin surface is calculated as

$$P_s = w(\mathbf{D} - P_s) + P_s$$

where w is the weight of the muscle at the point

B. Slide Deformer

The slide deformer checks on its deformed cycle with a simple ray-tracing technique. For every vertex of the skin mesh we check for the closest triangle on the bone mesh. An acceleration grid is used to maximise the speed. With the normal and position information of that triangle and a maximum displacement value given by the user the skin mesh is pushed outward. Because such sliding effects occur only at areas where the bony effect is conspicuous, the deformation is always calculated based on the undeformed initial state which makes the bones slide under the skin.

C. System in Action

Fig 9 shows both the muscle setups and the corresponding skin deformations for both fusiform and multi-belly muscles in the initial rest positions. Fig 10 shows the resultant deformation from raising the bones of the arm. Fig 11 shows the effect of raising the shoulder, whilst Fig 12 shows the result of a rotation to the shoulder joint.

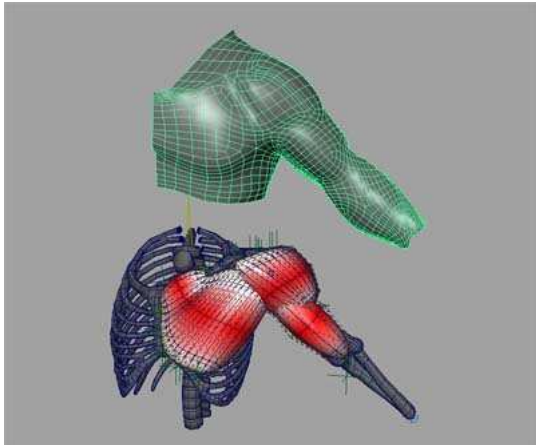


Figure 9. Muscle relaxed

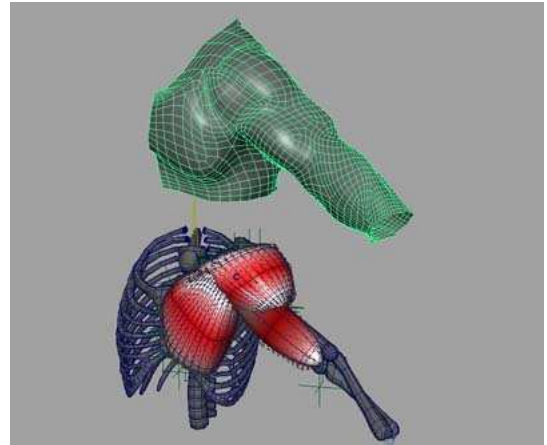


Figure 12. Shoulder front

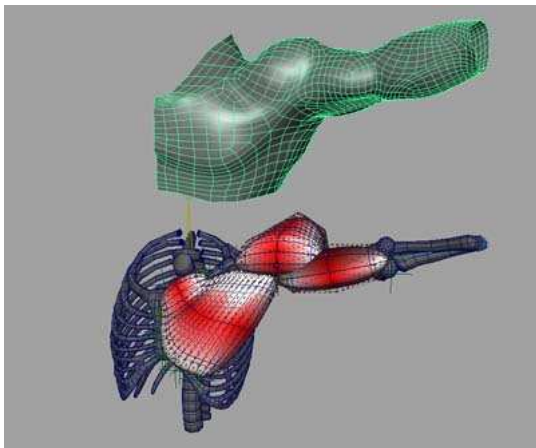


Figure 10. Arm up

VII. DYNAMICS

To add another layer of realism, we can easily perform dynamic simulation of the muscles. Maya's softbodies are used. This technique should be familiar to the animator, as it is a standard animation package function. Particles are attached to every control vertex of the NURBS muscles. Gravity and

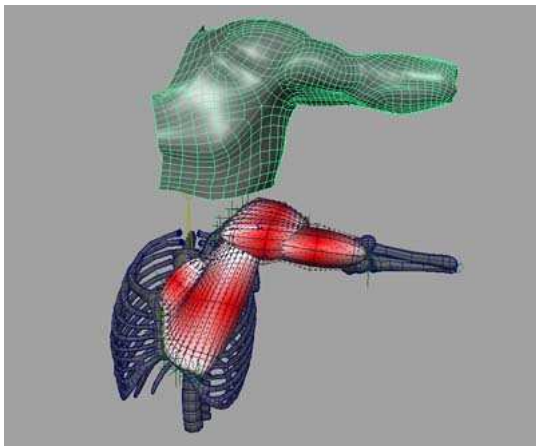


Figure 11. Shoulder up

springs are applied to the particles. Each particle is held together by two sets of springs, one set to its nearest neighbour and the other to the second nearest particle after that. Motion is picked up by the system and distributed by the springs to the nearby neighbours. This is effective to create realistic looking secondary motions because movement results in waves that spread out evenly in the muscle shape. Depending upon the tension of the springs we can simulate stronger or weaker muscles and even fat layers.

VIII. CONCLUSION AND FUTURE WORK

Computer animation research typically solves practical problems which are also of significant intellectual value. Although numerous techniques have been developed in order to improve the quality of animation production, not enough has been done to place the usability at the centre of the technical development. In this paper, we present a novel muscle-based skinning technique, which not only is able to improve the visual quality, but also place the usability high in the priority.

With this technique, the user starts with an already modelled character. Various muscles can be created and then placed inside the body of the character. The user has full freedom in controlling the shape, position and the relationship with the skin surface according to visual needs and artistic purposes. The animation of the muscles leads to the deformation of the skin surface. In addition, we have developed a simple dynamics model which is able to produce effective secondary dynamic visual effects.

In our current version, we have only implemented two basic types of muscle shapes, the fusiform and multi-belly muscles. There are many different types of muscles and the shapes are much more complex. In addition, only a small number of simple muscle deformation functions were formulated. They are effective in modelling the overall skin shape. For better and more detail visual quality, more accurate deformation mechanisms, ideally based on laws of physics, need to be developed. In our future work, we will improve our technique by investigating new and more comprehensive techniques in these two areas.

Other visually pleasing results have been achieved by modifying the 2.56 constant value used in the equations in section

V-C. This value has been exposed to the animator and allows for some interesting results and is worth further investigation. The basic system has been successfully tested in a short animation (Fig 13-20) and the system is being developed into a full plug-in for Maya. Initial feedback from animators is very positive as they can concentrate on character animation and almost leave the system to generate pleasing muscle based secondary animation for them.

ACKNOWLEDGMENT

The authors like to thank James Witworth, Joao Montenegro, Peter Lewis and Malcolm Childs for their help and ideas on the development. The students of the MSc Computer animation course for their testing of the applications. Special thanks goes to Ritchi Moore for the modelling of the Cave Troll and João Montenegro for the rendering.

REFERENCES

- [1] Brett Allen, Brian Curless, and Zoran Popovi. Articulated body deformation from range scan data. In *SIGGRAPH '02: Proceedings of the 29th annual conference on Computer graphics and interactive techniques*, pages 612–619, New York, NY, USA, 2002. ACM Press.
- [2] J. P. Lewis, Matt Corder, and Nickson Fong. Pose space deformation: a unified approach to shape interpolation and skeleton-driven deformation. In *SIGGRAPH '00: Proceedings of the 27th annual conference on Computer graphics and interactive techniques*, pages 165–172, New York, NY, USA, 2000. ACM Press/Addison-Wesley Publishing Co.
- [3] Alex Mohr and Michael Gleicher. Building efficient, accurate character skins from examples. In *SIGGRAPH '03: ACM SIGGRAPH 2003 Papers*, pages 562–568, New York, NY, USA, 2003. ACM Press.
- [4] Luciana Porcher Nedel and Daniel Thalmann. Modeling and deformation of the human body using an anatomically-based approach. In *CA*, pages 34–40, 1998.
- [5] Ferdi Scheepers, Richard E. Parent, Wayne E. Carlson, and Stephen F. May. Anatomy-based modeling of the human musculature. In *SIGGRAPH '97: Proceedings of the 24th annual conference on Computer graphics and interactive techniques*, pages 163–172, New York, NY, USA, 1997. ACM Press/Addison-Wesley Publishing Co.
- [6] Jianhua Shen and Daniel Thalmann. Interactive shape design using metaballs and splines. In *Implicit Surfaces'95*, pages 187–196, Grenoble, France, 1995.
- [7] Xiaohuan Corina Wang and Cary Phillips. Multi-weight enveloping: least-squares approximation techniques for skin animation. In *SCA '02: Proceedings of the 2002 ACM SIGGRAPH/Eurographics symposium on Computer animation*, pages 129–138, New York, NY, USA, 2002. ACM Press.
- [8] Jane Wilhelms and Allen Van Gelder. Anatomically based modeling. *Computer Graphics*, 31(Annual Conference Series):173–180, 1997.
- [9] Xiaosong Yang and Jian J. Zhang. Automatic muscle generation for character skin deformation: Research articles. *Comput. Animat. Virtual Worlds*, 17(3‐4):293–303, 2006.

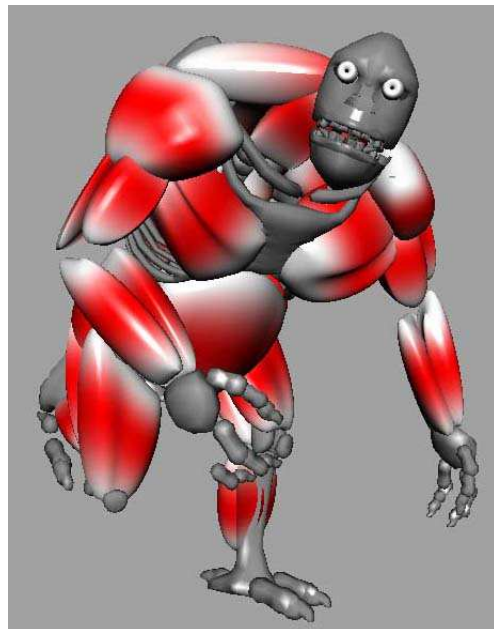


Figure 13. Muscled Cave Troll Character Pose 1

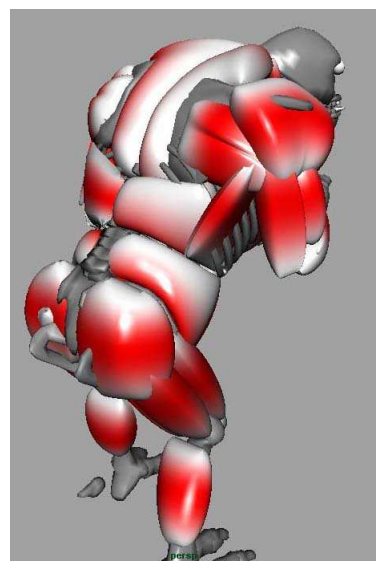


Figure 14. Muscled Cave Troll Character Back

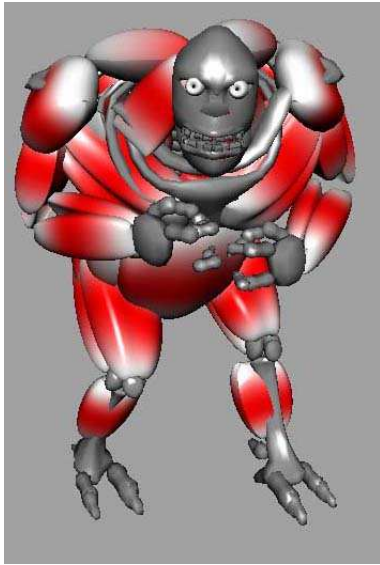


Figure 15. Muscled Cave Troll Character Pose 3



Figure 18. Final shot

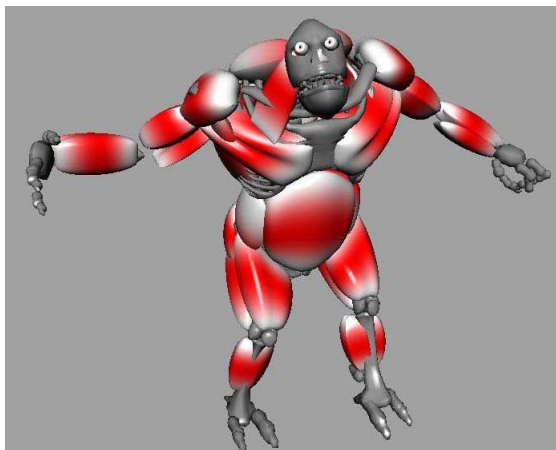


Figure 16. Muscled Cave Troll Character front



Figure 19. Final shot



Figure 17. Final shot



Figure 20. Final shot