Achieving Naturalistic Animation Through Look Development and Performance Capture

Stephan Ehl

Submitted in Partial Fulfillment of the Requirements
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Abstract

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It is becoming common to see movie stars sharing extensive periods of time on the screen with a fully computer generated cast. Motion capture has become popular over the first decade of the 2000s with films such as *The Lords of the Rings*, *King Kong* and *Avatar*. In all of these movies, there were talented animators working on the film. But on top of that, there were actors, not just supplying the voice for a character, but actually performing the roles as well. What the digital character looks like is entirely up the director.

This thesis will explore the work necessary to create a realistic character, from an anatomical approach in relation to the mesh, the texture and the rigging. Additionally, this thesis will explain techniques in digital modeling pipelines which will help to optimize the artist's workflow. When a computer-generated character looks human, but is not well animated, it will tend to appear uncanny, no matter how realistic or attractive it may look. Moreover, in order to communicate certain messages or emotions in an animation properly, facial expression plays an even more crucial role. Details such as the rate and the pattern of eye blinking can make all the difference between creating an automaton and an illusion of realism. Performance capture and, in particular, facial motion capture can be a great tool to overcome the challenge of generating naturalistic motion. Realism is a simulation of the ideal and it is realized by creating key element triggering specific reactions in an audience.

Introduction

It is becoming common to see movie stars sharing extensive periods of time on the screen with a fully computer generated cast. Motion capture has become popular over the first decade of the 2000s with films such as *The Lords of the Rings*, *King Kong* and *Avatar*. In all of these movies, there were talented animators working on the film. But on top of that, there were actors, not just supplying the voice for a character, but actually performing the roles as well. What the digital character looks like is entirely up the director.

This paper will explore the reason behind the use of realism. It will also cover how to address the challenges of using motion capture, especially facial motion capture in order to achieve a believable naturalistic animation. The process can easily become a technical nightmare if the pipeline is not set up properly. The rig has to be tested and ready before the data is use on it because Maya does not allow the referencing of rig if it is used with motion capture. The actor has to be put in a situation similar to those of the animated scene. The result can be uncanny and unattractive but through controlled exaggeration the result of human feature the uncanny valley can be avoided.

Since the thesis leans more towards the technical side of animation, one shot will be created to support my research and demonstrate the point made in my thesis paper. The goal is to create a scenario depicting the daily life of a character in a naturalistic manner. The scene will show an old bar owner at the end of his shift, counting the register, and possibly enjoying a glass of wine before finally lighting a cigarette, and thoughtfully looking at the empty street at night. He is a man who is coming close to the end of his life, and finding a small moment to look back upon the good and the bad.

Observation and Theory

Long before the invention of the movie projector and computer, artists spent considerable effort to create realistic human representation in sculpture and painting to display to the masses religious, mystical, and dignitary figure. In order to approach the use of realism in animation or visual effects we need first to understand why we create realistic piece of art. The use of realism can be separated in three aspects: the symbolism, the idealization and the fantasy; though there is a great deal of overlap between the three, they are used in the representation of abstract ideas by the means of allegory and personification through the human figure.

Symbolism gives a form to abstract concepts. Figure 1 illustrates this idea. It is a representation of the roman Emperor Commodus created during his short reign that lasted from 180 AD to 192 AD. In this bust the lion pelt and the club were added to portray him as the mystical figure of Hercules. Many of us we can identify Hercules in ancient Greek vase painting or sculpting because it wears the skin of the Nemean lion he killed with a club during his first labor.[1] It was an effort justify his reign as a divine right by reinforcing his image as a demi-god and son of Jupiter (chief deity of the Roman state religion).

There is a difference between creating the representation of a mystical and religious figure and one of a dignitary. The work created for the first group was an attempt to give a more human interpretation to the abstraction. On the other end the artistic representation of dignitaries is or was an effort to elevate the image of an individual to the status of a symbol and to transcend the fact of being just human. In a broader terms artist were asked to create idols. An idol can be

[1] Helen Gardner "Gardner's art through the ages : the Western perspective 11th edition" (Boston, Massachusetts: Wadsworth Cengage Learning, 2010) 143-144

described as a representation of an image held in the mind, which receives veneration and admiration but in the absolute it has no concrete substance in itself. The physical representation of such symbols have been a fixation in art and through the different periods of history artists have tried through different technology and a multitude of approaches to embody them.

Figure.1 *Bust of Commodus as Hercules (144 AD)*

Figure.2 *Lysippus, Weary Herakles (320BC)*

Realistic human representation in art lead to the concept of idealization; it created an subconscious shared concern about the aesthetic judgment and anxieties surrounding the human

form. Greek sculpture studied with a mathematical approach the perfect proportion of the human body (the essence of being human). Masters of the renaissance had a perfect knowledge of the human proportion but they came to realize that the sculpture could look heavy and stocky if they were blindly used. The human appearance can be distorted through scale and perspective to convey an ideal of beauty by bringing a more convincing lightness and liveliness to the work. Even since the early days of cinema the actors' image has been manipulated by banks of light and make-up to accentuate the aesthetic of the glamour or heroism.In Rotta delle Sobina (figure2) Giambolagna voluntarily elongated the proportion and used highly stylized poses to accentuate the dynamism and drama to his sculpture.

Figure.3 *Rotta delle Sobina by Giambolagna*

Fantasy is the effort to recreate an inaccessible model because its core concept only exists in the mind and a shared heritage of a particular society. In an attempt to create a representation for value or virtue such as heroism, femininity, beauty, courage, justice, power, evilness, intelligence, self-reliance, etc. the artists invented fantastic images by combining elements that would best represent them[2]. In the absolute justice or courage, for example, neither have substance in themself nor a representation in nature. Through realism the artist created key characteristics to bring to reality or to simulate an abstract human system of value. The simulation of the model became self-perpetuating renewing itself and evolving over time taking on other meaning.

A few common examples are figures that personify the cardinal virtues (prudence, justice, temperance, fortitude, etc.), the theological virtues (faith, hope, and charity), the arts, the church, victory, the seasons of the year, industry, and agriculture. Many mythical beings have an invented image based on the combination and metamorphosis of animal and human form. For instance: Victory takes the form of a winged woman.

[2] *Encyclopædia Britannica Online*, s. v. "sculpture," accessed August 15, 2013, http://0-www.britannica.com.library.scad.edu/EBchecked/topic/530179/sculpture

Figure.4 Winged Victory of Samothrace

The Egyptian sphinx used as a guardian of the entrance to a temple has the face of man to represent his intelligence and the body of lion to embody his strength. Today, fantasy also takes the form of avatars (graphical representation of a personality or idealized the human figure), allowing the player to assume a dissociative identity for the time of a game.

Realism is nothing more than an embellished version of reality; it is representation of idealized concepts and symbols that evolve with different cultures. The idea of realism is a control environment, a chimeric form reality. An illusion is perceived by misinterpretation and distortion of sensory stimulus.

Contemporary Applications

The use of realism in art today is far removed from the heroic day where representations were created for the history of mankind. With the transition to a consumer based society, and the invention of film and television we move toward a celebrity based culture.[3] They, in a way, embody now the ideals of virtue and self-reliance assumed in the past by a set of mythical characters, heroes, military figures etc. Who is to say that the next phase of fame resembles nothing so much as a three dimensional hologram? With technological intentness the stars will not only be available live on stage, on the air or moving across the silver screen but also on demand performing at the wish of customers. With proper AI they could interact and enter in conversation with people, pushing the envelope of realism further. It may sound like science fiction but there are already examples of technological advance pointing toward such future development. Hanson Robotics built an android named Philip K. Dick. Its cognitive A.I. is capable to react and improvise to a conversation. Facial recognition software tracks the face and analyzes read expression and speech recognition software transcribes the words recorded. The answer is created from the data collected by using web browsing and a database built in the program.[4]

In the past decade characters designed for animators in films, as well as in games are continually increasing in reality. During the 2012 Coachella Valley Music and Arts Annual Festival, the audience witnessed the virtual resurrection of Tupac Shakur in a live performance. The image was created on a computer, using physical characteristics and movements captured from

[3] Amy Henderson, Media and the Rise of Celebrity Culture, OAH Magazine of History, Vol. 6, No. 4, Communication in History: The Key toUnderstanding (Spring, 1992), pp. 51

[4] NOVA scienceNOW , what the next big things, http://www.hulu.com/watch/263523

recorded performances.[5] In movies now we see the appearance of rejuvenated iconic actors: the younger version of Jeff Bridges in *Tron Legacy* or the CG cameo of 1984 Arnold Schwarzenegger in *Terminator Salvation*. Sure, the audience could still perceive them as fake because the illusion of realism was broken when the camera moved too close to their face. In those two movies the uncanny valley was used at the advantage of the plot. In *Tron Legacy* (2010) the CG character was used to portray an evil digital doppelganger of one the protagonist. In *Terminator Salvation* (2009) it was a remorseless cyborg killer. In *Superman Returns* (2006), Rhythm and Hues created a speech sequence of Jor-El (Superman biological father) portrayed by Marlon Brando who died a few years prior the movie. To do so the VFX and animation studio team created a footage reference by finding a clip where the eyes and head movement match with the new dialog in the 1978 *Superman: the movie*. Brando's 3D model visage (created from the same reference) was then animated using this reference. The mouth was lip synced to the new dialog (created from bits and piece of audio clip). After some adjustment of the texture the facial animation was believable and looked as if Brando played the part himself from beyond the grave. Uncanny Valley or not, using full CG human character is a glimpse of what CG in cinema, digital media and entertainment could bring.

Computer graphics not only create the illusion of keeping death at bay but can also resurrect the dead. Pretty soon it will be possible for a film director or an entrepreneur to bring deceased actors back on demand for new roles. Starlets will never grow old, legends will never fade, and celebrities will never die. They will be polished and prepared for prosperity; they will look and sound better than ever.

So many efforts are made to give a feeling of humanity to virtual representation to create an illusion of reality. But a CG representation of a popular character has no humanity. When an actor

[5] Ethan Smith, Rapper's de-light: Tupac "Hologram" may go on Tour" The wall street journal, April 16, 2012

plays a role he or she is mostly a celebrity, with their humanity tucked safely away for later. At home, they are someone else, but on stage they fill a role assigned to them by their fans and perhaps by themselves. To answer the need of people's fantasy, only the image of celebrity is required. In the absolute, if Tintin (a purely fictional character), Tupac 'hologram' (the digital representation of decease celebrity) or a character played by Jeff Bridges all conveyed the same level of believability on the screen they would be received the same way by an audience. The difference between a flesh and bone celebrity and computer generated one is leveled. The distinction between fiction and reality has vanished.

Furthermore, film makers and entrepreneurs probably would enjoy replacing stuntmen and perhaps temperamental stars with computer generated versions. Film franchises could go as long as a fan base supports them with or without the person incarnating the main character. Is this just the effort of a big studio to cash on their fans, or is there something more? Do they answer our natural need to believe in something beyond the norm of everyday life? Is the audience seeking to feel that such character could be met by accident around the corner or to have a life beyond the average ninety minute of their adventure? Why spend so much time and resources creating shots that could be done by an actual person? The use of realism in modern media answers the same doubt traditional art did in the past. Questioning our uncertainty about physicality, the fear of aging, dying, and the incertitude of the promises on what come next can be a strong motivator. Creating something that one day could not only encapsulate our being but correct all the imperfection of life while, keep one alive long after their physical envelope is gone is very appealing.

Application and Challenges in Animation and Visual Effects

It is becoming increasingly easier and cheaper to generate naturalistic animation and realistic visual content. The technology can be integrated more easily in smaller productions. Most midline personal computers are built with Cpu's, memories, storage capable to support application running Ray-tracing algorithm for photorealistic rendering and to process and to clean motion capture data. It is possible to create basic equipment with consumer-level tools and open source tracking programs. Blender (open source software) added a motion capture toolset to its platform. Simple web cams or devises like the Microsoft Kinect can offer a cheap alternative to capture data. In the case of this project a Hero camera mounted on a helmet was used. The advantage of this type of camera is that it can be controlled with a smart phone or a tablet. Being able to capture every subtlety of an emotion can greatly enhance the quality of the animation of a photorealistic character and trick the audience to believe that they may have a life beyond the realm of a movie construct world. Motion capture will not replace key frame animation but it is making the process faster by laying down action, timing and capturing realistic motion.

Motion capture technology itself is far from new. It was developed in in the 70's for medical and military application. The CGI industry explored the potential of the technology since the 1980's.[6] Often the results obtained for movies in the early years were not as satisfying, often transforming the production into a nightmare, due to the huge amount of computing necessary to enable the use of the data collected and the Ray-tracing render algorithm. Mocap became popular for film makers over the first decade of the 2000's thanks to the computer generated character and the more than believable performance of Gollum in the *Lord of the Rings* trilogy or *King Kong* in the movie of the same name. Software and hardware application developed by companies such as Mova

[6] Midori Kitagawa, Brian Windsor, "Mo Cap For Artist" (Focal Press Burlington, MA,2008) 8-12

allowed the performance of photorealistic virtual characters to become increasingly more believable due to accurate capture of facial expression as well as the kinetic performance of the actor.[7] The technology offers the possibility to convey the illusion of life in the artificial character and big budget features integrated more and more virtual characters to their cast. In 2012 alone, computer generated character and performance capture was used with success in *The Avenger* with the Hulk, the Tharks in *John Carter* or all the cast of *The Adventure of Tintin*. Most of those movies avoid the uncanny valley by creating distortion of humans in bipedal character design and allowing the audience to sympathize with them.

The first entirely performance-captured, photorealistic computer generated feature film based on the principles of live action cinema, *Final Fantasy: the Spirit Within* was a commercial failure.[8] *The Polar Express* and *Beowulf* met the same fate. The main challenge of those types of movies was to preserve the illusion of realism. Part of their dismissal (beyond the story issues) came from the fact that the characters of their films fall in the uncanny valley. The more lifelike in his motion and appearance a digital human is made, the more empathy for it turns to revulsion as the viewer's brain realizes there's something wrong. The characters of those films were so close to real that they ended up looking creepy.

In 1970, Mori Masahiro, a Japanese roboticist, published the *Uncanny Valley in Energy*. The article identified the impression of finding humanlike objects eerie as the 'uncanny valley'. Though he had no hard data, his theory proposed that increasing humanness in a robot was positive only up to a certain point[9]. The 'valley' refers to the dip in a graph of the comfort level of humans as subjects

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[7] http://www.mova.com/ accessed October 25, 2012

[8] Livia Monnet "A-Life and the Uncanny in Final Fantasy: The Spirits Within" Science Fiction Studies , Vol. 31, No. 1 (Mar., 2004), pp. 97-121

[9] Mori, M. (2012). "The uncanny valley (K. F. MacDorman & Norri Kageki, Trans)" *IEEE Robotics and Automation*, 33-35

move toward a healthy, natural human likeness described in a function of a subject's aesthetic acceptability. The sense of creepiness is most likely a part of our instinct for self-preservation and the result of evolution. It is the instinct that kicks in when we perceive that something is off or not looking quite right in another living being. This weird sense of repulsion or eeriness was felt to different degrees after the encounter with an unhealthy person, body deformities, a corpse, the sight of missing limbs, etc. Our instinct informed us of potential risk for our own health.

The ‘uncanny valley’breaks down into two general characteristics: appearance and movement. The erosion of the ‘uncanny valley’may be more heavily related to the movement of a subject rather than its overall visual look. The problem with appearance can be solved by controlled exaggeration of the human form and proper texturing.

But when a computer-generated character looking human or close to it is not animated well, it tends to look uncanny, no matter how realistic and attractive it is. If a hyper stylized character or a less human-looking robot does something that isn't human, we might not even notice it as much. The fact is that we are sensitive to flaws in the behavior of human-looking characters because a person has an intrinsic knowledge of what a living human being should resemble.

Moreover, in order to communicate properly in an animation certain messages or emotion, facial expression plays an even more crucial role. Details such as the rate and the pattern of eyes blinking for instance can make the difference between creating an automaton and the illusion of realism. The range of emotion in a cartoony character can be limited in comparison to a realistic human face. It is possible to easily and clearly recreate the seven universal emotions: disgust, anger, fear, sadness and contempt, by exaggerating them through certain body posture and pushing the facial deformation. However, it is a bit trickier to convey micro expressions with this type of

character because the types of involuntary facial expression are brief and extremely subtle.[10] The reason is that the faces of hyper stylized characters tend to lack some of the features necessary to create micro expressions.

Facial Expression Anatomical Studies

Nonverbal communication and body language also play an important role in order to achieve realism. For instance a smile is in the absolute a dynamic sequence of facial deformations around the corner of mouth, the cheeks and bottom of the eye. Nailing the look is not enough, and the expression's timing has to be right as well. The speed of the deformation is crucial if the animator wants to convey the feeling in a humanlike fashion. If the timing is double, instead of looking happy or showing openness and good faith, the expression turns creepy and mechanical. Before a smile even happens, there will be a series of involuntary facial movements according the emotional state of the character that anticipates the facial expression. The deformation also creates other details such as wrinkles and skin folds. The use of motion capture can help the animator to block and to capture the subtleties of natural human movement using the performance of an actor. But in order to convey the illusion of realism it is important to understand the mechanics of the body and any facial expression, especially if the data capture are going to be used on a more stylized character.

When studying anatomy in relation with facial behavior and emotion from the point of view of an animator, a rigger or a modeler, it is more important to know it from a functional perspective and how muscles function in groups. The complexity is the result of how we use facial muscles. They signal and/or regulate our emotional state. The orbicularis oris (the muscle in the lips) is a complex

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[10] James A Russell and Jose Miguel Fernandez Dols, " The psychology of facial expression ." (New York Cambridge University press, 1997)

muscle composed of four independent quadrants (upper, lower left, right). The full structure of this muscle (the combination of the pars peripheralis and pars marginalis) is absent in non-primate mammals and uniquely developed with speech in humans. Each quadrant works in a pair with a labial tractors and zygomaticus. We use the group muscle forming the mouth to speak, to eat, or as conversation regulator. The facial musculature is fairly unique and makes it one of the most used signal systems available for human communication.

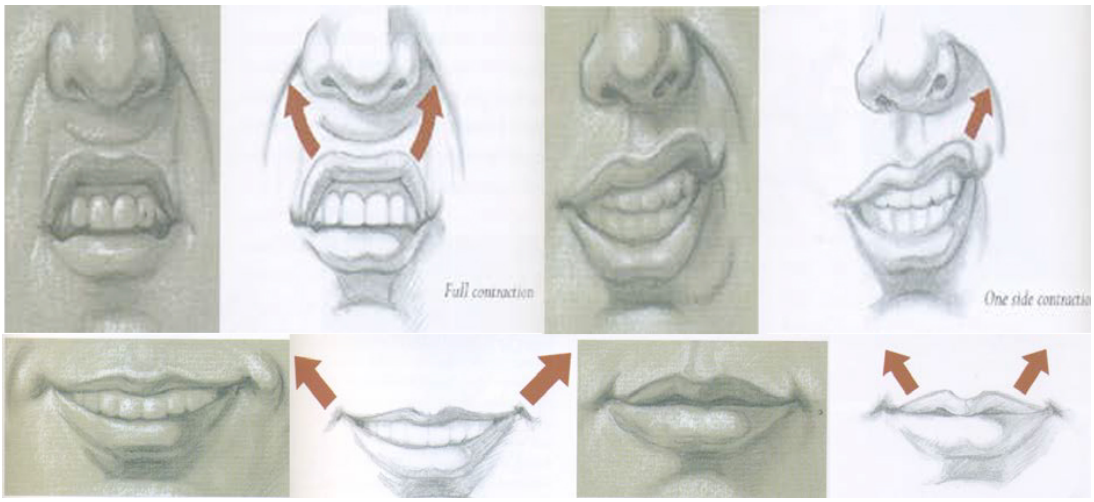

Figure.5 *(Example of Orbicularis Oris muscle working in pair Labial Tractors and Zygomaticus)*

Another good example can be the Frontalis muscle. It is the large flat muscle on the forehead used to move the eyebrow; its inner and outer parts can move independently from each other.

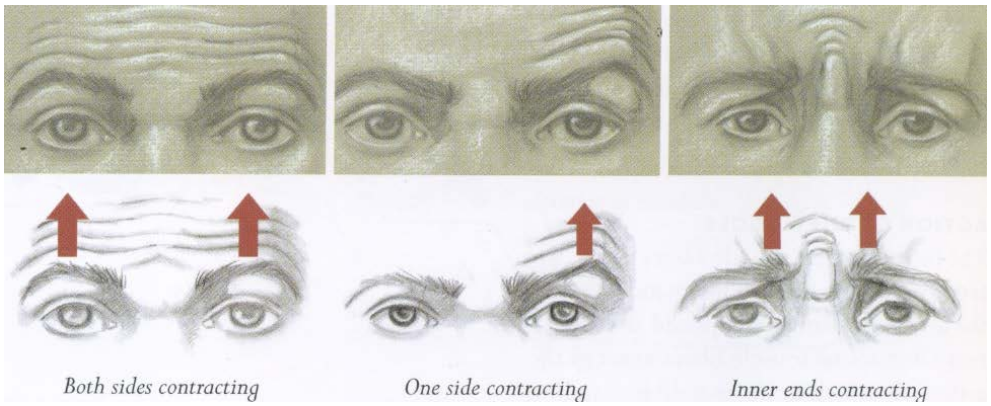

Figure.6 *(Example of Frontalis muscle part contracting independently from each other)*

Each of the functional muscle units of the face can be innervated with different timing and intensity. The facial musculature structure is composed of 43 muscles in the face, most of which are controlled by the seventh cranial nerve (also known as the **facial nerve**). This nerve exits the cerebral cortex and emerges from the skull just in front of the ears. It then splits into five primary branches: temporal, zygomatic, buccal, mandibular and cervical. These branches reach different areas of the face and enervate muscles that allow the face to twist and contort into a variety of expressions.[11] The complexity of animating realistic facial expression is due to the fact that there is not a one to one correspondence between structure and function. Each facial expression requires more than one muscle in order to form and sometimes only part of a specific muscle contracts. For instance, when a person frowns, the action of bringing the brows down and together requires a group of three muscles called corrugators. Some types of muscle are unique to the face; it is the only part of the body where muscle is attached on one side to the bone on the other side to skin. They are the only somatic muscles in the body, and their movements are for specialized facial expression.

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[11] Churchill Livingstone, "Gray's Anantomy 38th edition" (New York: Churchill Livingstone, 1999) 789-800; 1911

Looking at the Facial Action Coding System can greatly help to understand the deformation necessary to recreate accurate facial expression. The system was developed by Professor Paul Ekman and Wallace Friesen in 1978. The system can manually code nearly any anatomically possible facial expression, deconstructing it into the specific Action Units (AU) and their temporal segments that produced the expression. The system appends letters (A to E, A being a trace and E the Extreme) to an Action Unit number to annotate the intensity. Action Units can be defined as a record of possible action group of underlying facial muscles can create they are number to 46. [12] (Refer to table 1 and 2)[13] [14]

[12] P. Ekman and W. Friesen. Facial Action Coding System: A Technique for the Measurement of Facial Movement. Consulting Psychologists Press, Palo Alto, 1978.

[13] Churchill Livingstone, "Gray's Anantomy 38th edition" (New York: Churchill Livingstone, 1999) 789-800;

[14] Hamm, Jihun; Christian G. Kohler; Ruben C. Gur; Ragini Verma). "Automated Facial Action Coding System for dynamic analysis of facial expressions in neuropsychiatric disorders". (Journal of Neuroscience Methods 200, 23 June 2011)): 237-256.

Table 1: *list of facial action recorded by Paul Ekman, it includes the Action Units with its number and the related underlying facial muscle.*

AU#	FACS Name	Muscular Basis
0	Neutral Face	
1	Inner Brow Raiser	*frontalis* (*pars medialis*)
2	Outer Brow Raiser	*frontalis* (*pars lateralis*)
4	Brow Lowerer	*depressor glabellae*, *depressor supercilii*, *corrugator supercilii*
5	Upper Lid Raiser	*levator palpebrae superioris*
6	Cheek Raiser	*orbicularis oculi* (*pars orbitalis*)
7	Lid Tightener	*orbicularis oculi* (*pars palpebralis*)
8	Lips Toward Each Other	*orbicularis oris*
9	Nose Wrinkler	*levator labii superioris alaeque nasi*
10	Upper Lip Raiser	*levator labii superioris*, *caput infraorbitalis*
11	Nasolabial Deepener	*zygomaticus minor*
12	Lip Corner Puller	*zygomaticus major*
13	Sharp Lip Puller	*levator anguli oris* (*also known as caninus*)
14	Dimpler	*buccinator*
15	Lip Corner Depressor	*depressor anguli oris* (*also known as triangularis*)
16	Lower Lip Depressor	*depressor labii inferioris*
17	Chin Raiser	*mentalis*
18	Lip Pucker	*incisivii labii superioris* and *incisivii labii inferioris*
19	Tongue Show	
20	Lip Stretcher	*risorius w/ platysma*
21	Neck Tightener	*platysma*
22	Lip Funneler	*orbicularis oris*
23	Lip Tightener	*orbicularis oris*
24	Lip Pressor	*orbicularis oris*
25	Lips Part	*depressor labii inferioris*, *or relaxation of mentalis or orbicularis oris*
26	Jaw Drop	*masseter*; *relaxed temporalis and internal pterygoid*
27	Mouth Stretch	*pterygoids*, *digastric*
28	Lip Suck	*orbicularis oris*
29	Jaw Thrust	
30	Jaw Sideways	
31	Jaw Clencher	*masseter*
32	[Lip] Bite	
33	[Cheek] Blow	
34	[Cheek] Puff	
35	[Cheek] Suck	
36	[Tongue] Bulge	
37	Lip Wipe	
38	Nostril Dilator	*nasalis (pars alaris)*

Table 2: *Descriptions of Facial Muscles (and Other Nonverbal Behaviors) Involved in the Emotions Darwin Considered Universal and that Research has Shown to be Universally Expressed and Recognized.*

Emotion	Darwin's Description (non-facial elements in parentheses)	FACS AUs Associated with Darwin's Description
Anger	nostrils raised, mouth compressed, furrowed brow, eyes wide open, head erect, (chest expanded, arms rigid by sides, stamp ground, body sways backwards/forwards, tremble)	4, 5, 24, 38
Contempt	lip protrusion, nose wrinkle, partial closure of eyelids, turn away eyes, upper lip raised, (snort, body expiration, expiration)	9, 10, 22, 41, 61 or 62
Disgust	lower lip turned down, upper lip raised, expiration, mouth open, spitting, blowing out protruding lips, clear throat sound, lower lip, tongue protruded	10, 16, 22, 25 or 26
Fear	lips retracted, eye brows raised, (crouch, pale, perspiration, hair stands on end, muscles shiver, yawn, tremble)	1, 2, 5, 20
Happiness	eyes sparkle, skin under eyes wrinkled, mouth drawn back at corners	6, 12
Joy	zygomatic, orbicularis, upper lip raised, nasolabial fold formed (muscle tremble, purposeless movements, laughter, clapping hands, jumping, dancing about, stamping, chuckle/giggle)	6, 7, 12
Sadness	corner mouth depressed, inner corner eyebrows raised (low spirits)	1, 15
Surprise	eyebrows raised, mouth open, eyes open, lips protruded, (expiration, blowing/hissing, open hands high above head, palms toward person with straightened fingers, arms backwards)	1, 2, 5, 25 or 26

Methodology

1. Creating the character

Keeping in mind the anatomical study and how to avoid falling in the ‘uncanny valley’, a few steps were taken in the concept and modeling phase. The body ratio was changed, the head was made slightly larger, and some facial features were exaggerated to accentuate the expression. The goal was to caricature the look of realism while keeping a photorealistic look. To accelerate the process it is easier to create the concept directly in Zbrush. In this part of the pipeline the focus is on shape, silhouette and looks alone. Through the different alteration, the goal was to give to the character natural feel and personality. Nineteenth century editorial caricatures were a good source of inspiration.

The figure below shows some of the early attempts. When the exaggeration went too far the result became alien. Also if the character is too stylized, it falls out of the audience’s familiarity zone. The consequence is that the message or the feeling the piece is supposed to carry cannot be delivered because the meaning is not clear and becomes open to interpretation.

Figure.7 *(Facial study during the early conceptual phase)*

All the modeling applications offer some sort symmetry tool which is very convenient for the artist to block the model; it makes the process faster and saves some problems when it comes to rigging. However, the end result may look somehow artificial and break the illusion of realism. People and animals have asymmetrical faces to a certain degree. Most of the time it is not noticeable; however, if this feature is omitted it is very obvious. If the exaggeration goes too far, the result becomes too abstract and it is not recognized as being a life.

The age and gender of the character also change the way to approach the design. Overtime the skin and tissue become less elastic and allow the soft tissue features of the face to sag due to the pull of gravity. The facial soft tissues also gradually atrophy, resulting in a visual thinning of the

facial soft tissues and making the bone appear more prominent. More elusive detail in the texture can indicate part of the history, the type of temperament and life style of the story of the film.

The concept sculpture at this point of the pipeline stopped at a mid-level detail, enough to see the muscle of the neck, fat folds and, depending on the age of the character: the worry lines, glabellar lines, the nasolabial folds, oral commissure of the perioral region, the (crow feet), the epicanthic folds, the palpebral fissures, the philtrum and the (marionette lines). Those facial features are the result of repeated muscle movement forming different facial expressions. Aging causes those different marks to become gradually more pronounced (see Figure below).

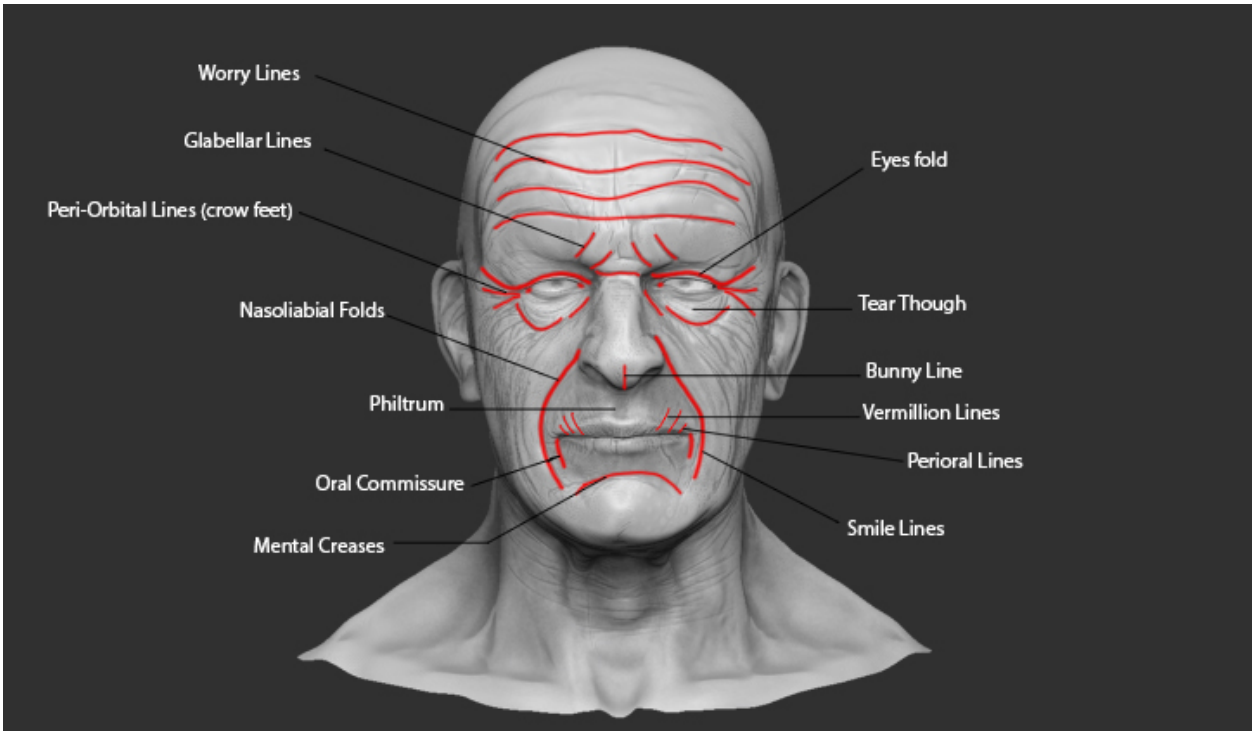


Figure.8 *(Model illustrating the wrinkles caused by facial expression)*

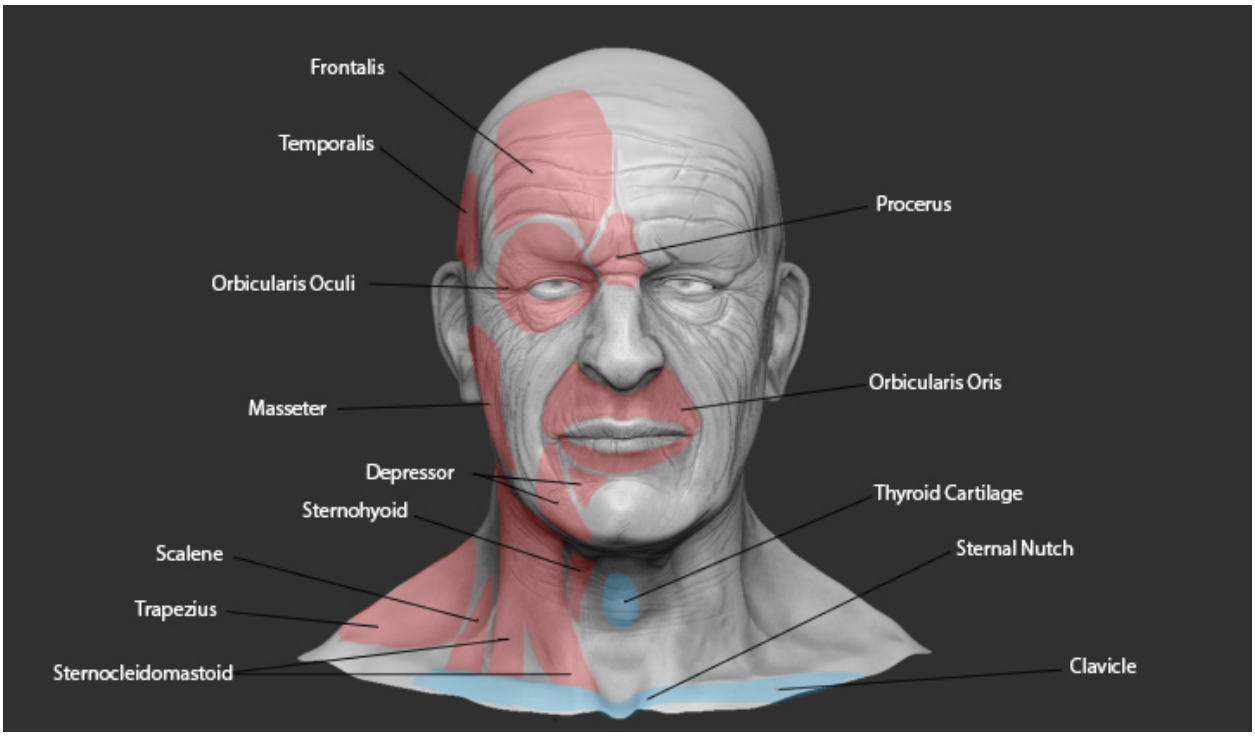


Figure.9 *(Model illustrating major muscle group in red and the cartilage and bone in blue of a bust)*

Once the 3D sketch reaches a satisfying point it can be used as guide for the mesh that will be used for rigging. During the re-topologizing process we have to make sure those facial landmarks are defined by the proper edge loop. Also a minimum of three edges is necessary to create the wrinkles when the mesh deforms (see below, figure 9 and 10 for example). It is crucial to plan where to put the geometry in order to ensure accurate deformation when it will be animated or the motion capture data will be applied to it. Figure 11 illustrates the steps taken in the creation of the final character

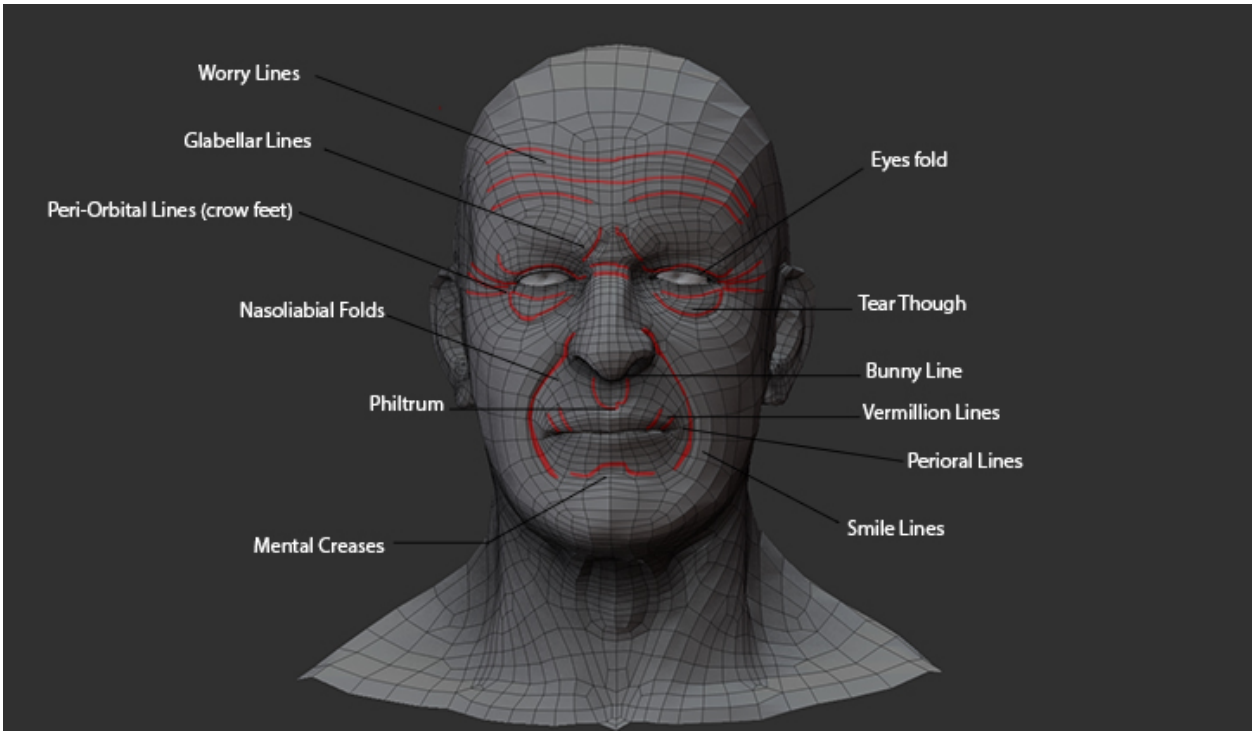


Figure.10 *(Edge flow in relation with expressive wrinkles)*

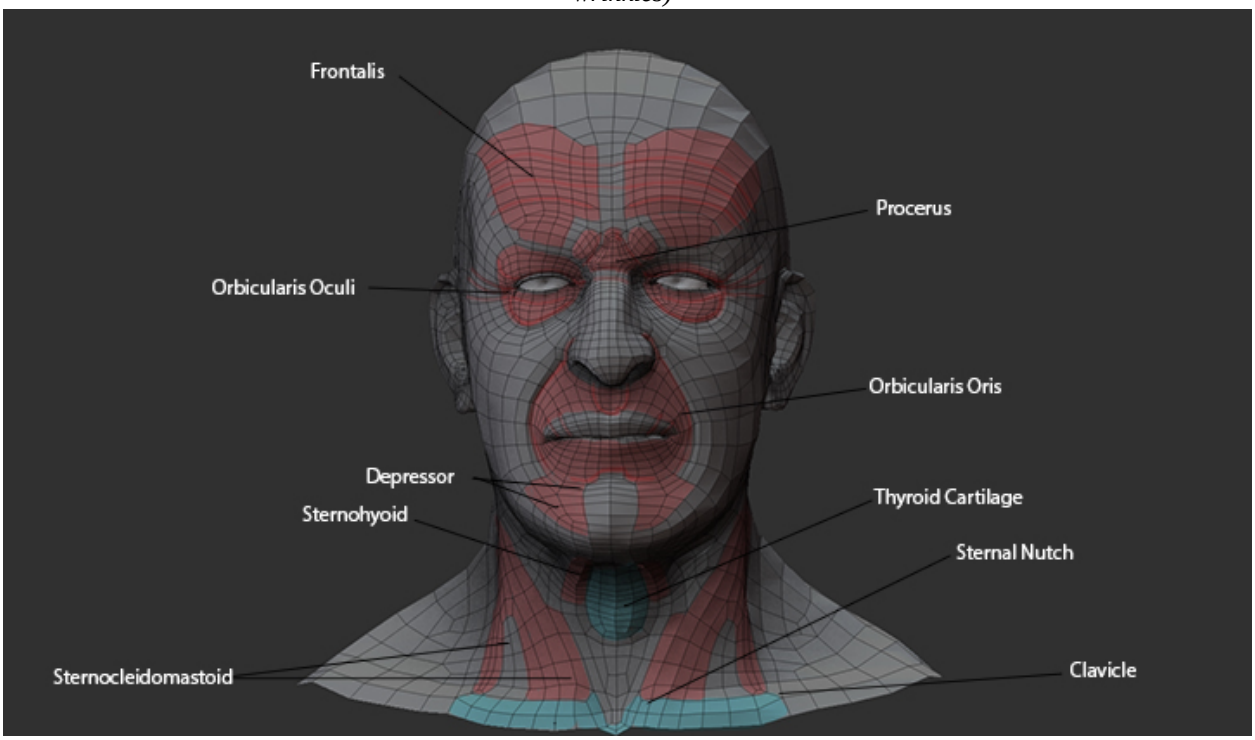


Figure.11 *(Edge flow in relation with muscle groups)*

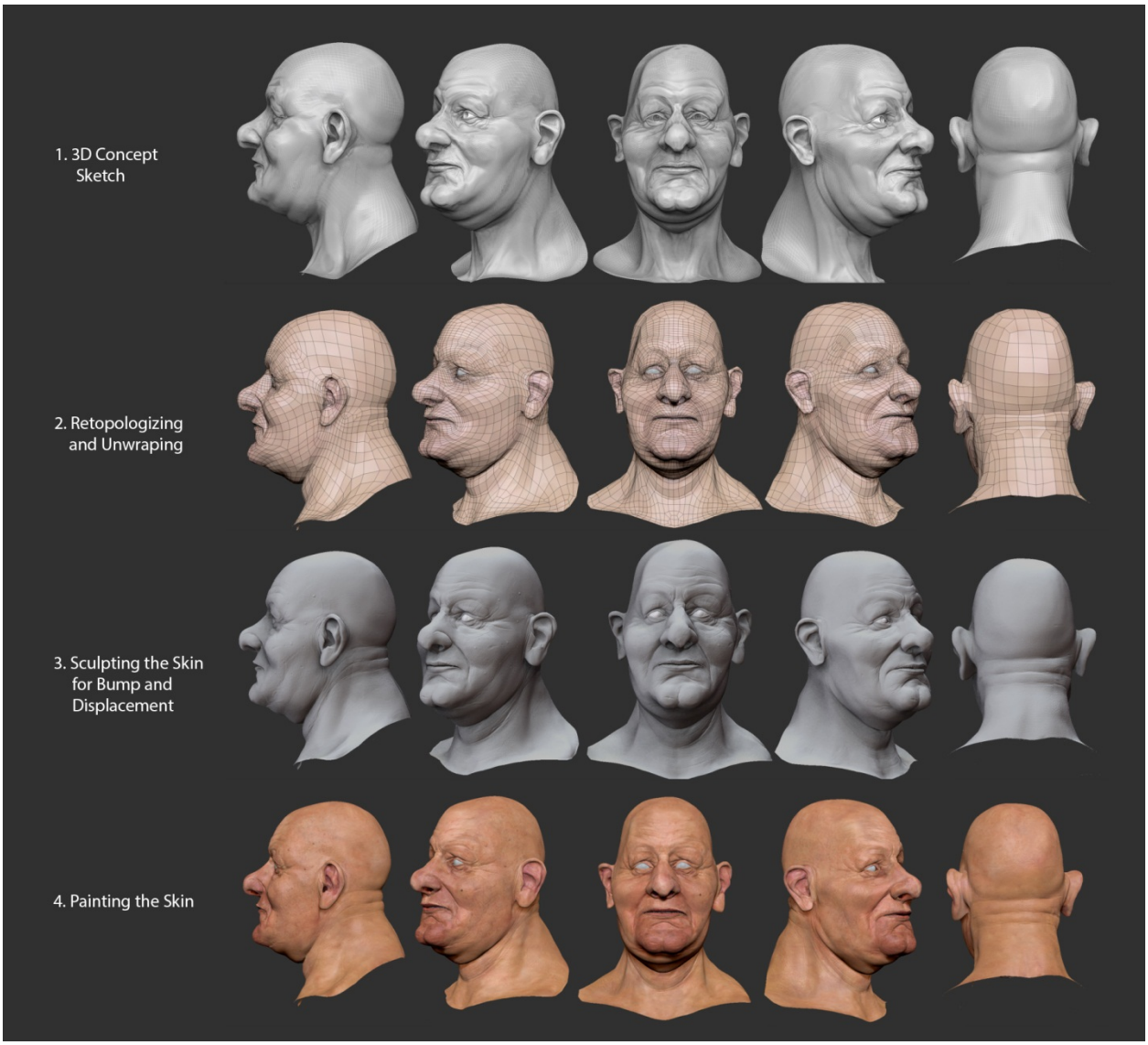


Figure.12 *(Steps showing the construction of the final character bust creation)*

As mentioned earlier, the quality of the motion makes the difference between a realistic character and an automaton. Besides creating an appropriate pipeline (Figure.#), there were three challenges with the use of full body motion capture. The first was to figure out how to create a facial rig and to create a gooey interface allowing us to retarget any capture data. Our approach required building an accurate facial rig using blend shapes. It was also necessary to find the right

balance between automatic deformations to speed up the retargeting process; for instance, every time the jaw opens the cheeks caves in, the skin over the temple stretch and the numbers of control give the animator enough freedom to tweak an expression. The rigging method was to give a set of meaningful expressions based on the Descriptions of Facial Muscles table and the Facial Action Coding System which defined the different shape a mouth opening or an eye closing can take. The facial rig was then attached to Human IK auto-rig. In order to be able to export the rig from Maya to Motion Builder the following naming convention has to be used for the rig.

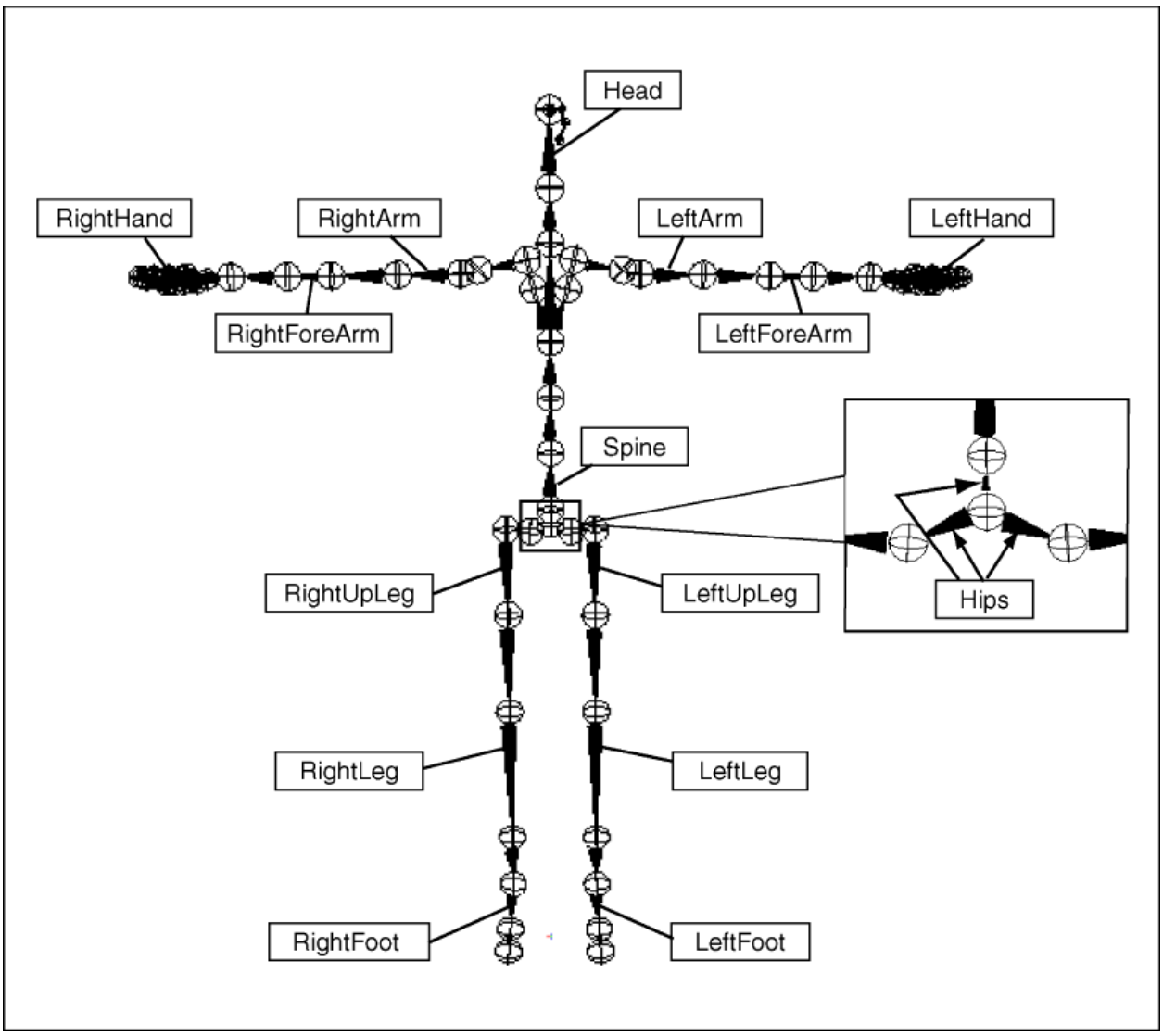


Figure.13 *Motion builder naming convention*

The second challenge came from the fact that we used two separated systems to record the facial acting and the rest of the performance. Vicon Blade was used to record and retarget the body while Faceware was used for the face. The rig also has to be tested and ready before the data are use on it because Maya does not allowed the referencing of rig if it is used with motion capture. It took some adjustment to make sure that the different data matched each other.

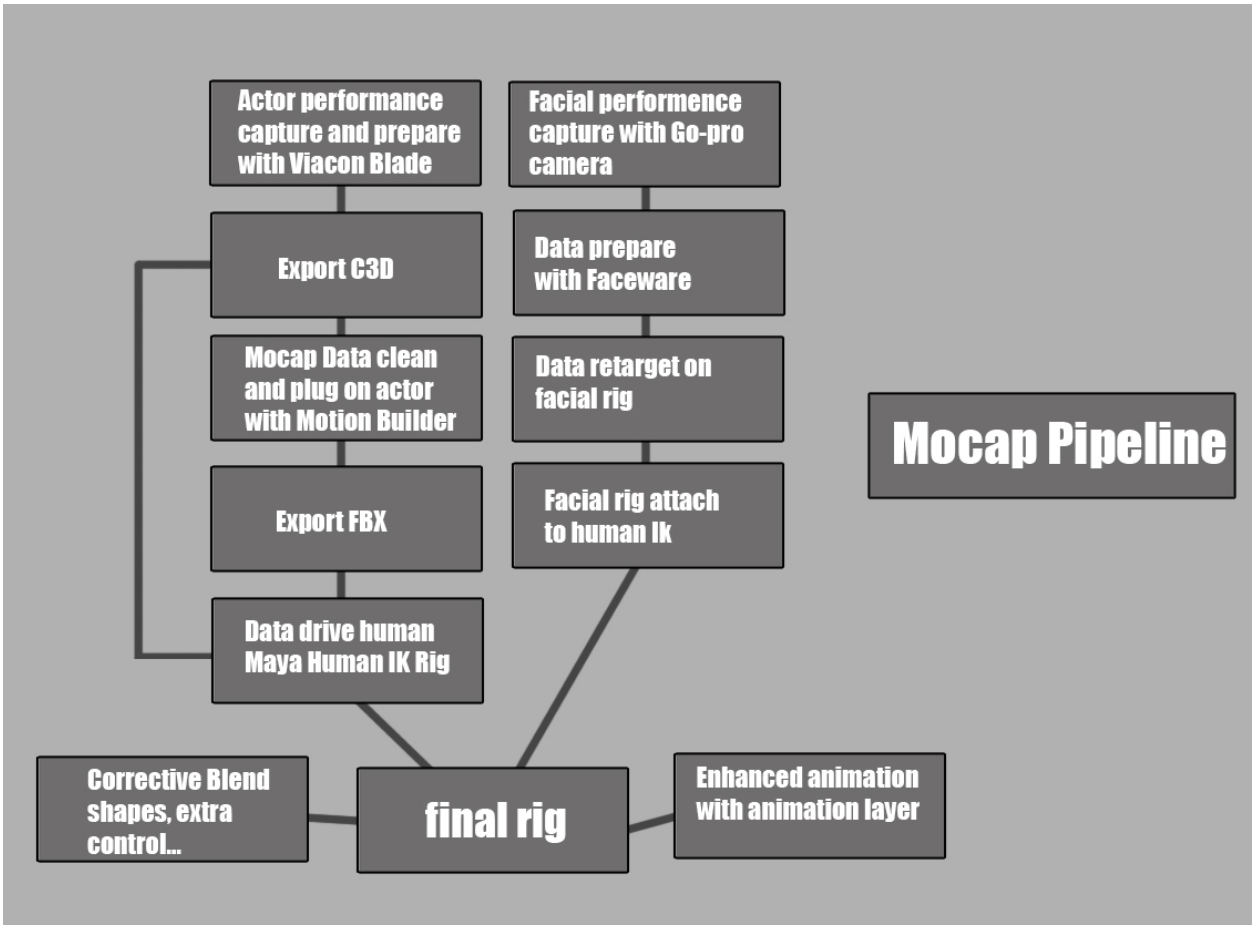


Table.3 *Idea for full body motion capture pipeline.*

Lastly we came to realize that the believability of the CG character was only as good as the performance of the actor. It was important to stage and recreate the conditions appropriate to the scene. Motion capture was only limited to the confined empty spaces of the cameras and the

director's imagination. The few first attempts were rather catastrophic. We were lacking suitable props. Some were just too large, covering so much of the face that it resulted in a huge gap in our recorded data.

The actors also had to be careful to not obstruct his or her face during the performance, to look at the camera pointing at them few inches from their faces and to keep in mind what the digital character he or she portrayed looked like. Even if the software used to record the actor's performance did not require markers, we realized after few attempt that by placing dots contrasting with the skin using make up in specific points it greatly accelerated the data cleaning and the end result quality. The figure below shows the marker placement we used to record our performance.

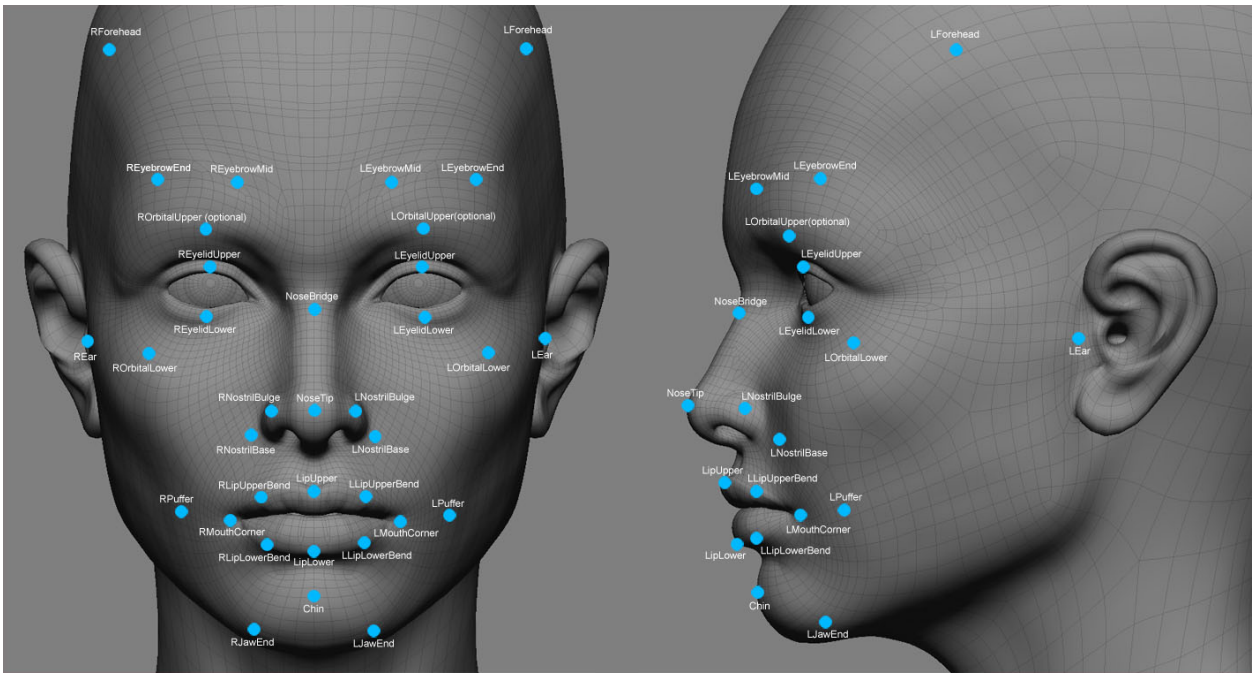


Figure.14 *Motion Capture Marker Placement for Softimage FaceRobot*

2. Texturing

The quality of an animated or lives action film relies on many factor beside the story itself, it includes characters, texture and lighting. When achieving an acceptably realistic character and environment, texturing play an important role by enhancing the visual richness and construct high quality scenery. Texture and lighting have an impact on the mood during the construction of a narrative, if these elements are implemented poorly; cinematography fails in its objective to illustrate drama.

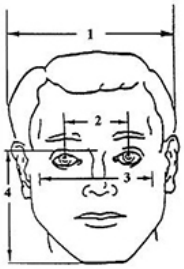
The rendering tool used by computer graphic artists where created to mimic mathematically reality, therefore it is important to understand the proprieties of surface by studying why it looks that way and how light react to it. To illustrates this concept this chapter will focus on the creation of the skin shader use for the face because the same approach can be used with other material and object.

A. Setting up The Scene

Before starting building the skin material for the character, few steps have to be taken in consideration. The first one is to setup the unit of the scene to centimeter, resize the grid and scale the model to a 1:1 ratio. This means that the character will be life size, it makes easier to set up the different input number of the material by basing those number in reality. For instance the average male human head is 15.2 cm (6 in) from ear to ear and 20 cm (7.9 in) from the glabella to the back of the head. The refraction index of the human eye is roughly 1.40. Having some knowledge about the structure of the 3 layers of skin is very useful when it comes the time to paint them- the epidermis, dermis, and subcutaneous tissue and there thickness. The epidermis on the eye eyelids is 0.05mm… Information about human anatomy can easily be found online or in books such as Gray's anatomy. Any anatomical numbers are a good starting point to create any sort of realistic materials.[15]

[15] English: Static adult human physical characteristics of the adult head, from pages 72-75 of Poston, Alan. (April 2000) Department of Defense Human Factors Engineering Technical Advisory Group (DOD HFE TAG). Human Engineering Design Data Digest. Accessed January 24, 2013

Table.4 *Example of useful documentation for realistic modeling, this shows the average statistic of the human head.*



1 **Head breadth.** The maximum breadth of the head, usually above and behind the ears.

Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	13.9	14.3	15.2	16.11	6.5
	(in)	(5.1)	(5.6)	(6.0)	(6.3)	(6.5)
B Women	cm	13.3	13.7	14.4	15.3	15.7
	(in)	(5.2)	(5.4)	(5.7)	(6.0)	(6.1)

2 **Interpupillary breadth.** The distance between the centers of the pupils of the eyes (the eyes are looking straight ahead).

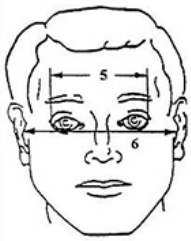
Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	5.7	5.9	6.5	7.1	7.4
	(in)	(2.2)	(2.3)	(2.7)	(2.8)	(2.9)
B Women	cm	5.5	5.7	6.0	6.9	7.0
	(in)	(2.8)	(2.2)	(2.4)	(2.7)	(2.8)

3 **Face breadth (bizygomatic).** The breadth of the face, measured across the most lateral projections of the cheek bones (zygomatic arches).

Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	12.8	13.2	14.0	15.0	15.4
	(in)	(5.0)	(5.2)	(5.5)	(5.9)	(6.1)
B Women	cm	12.1	12.3	12.8	14.0	15.4
	(in)	(4.8)	(4.8)	(5.1)	(5.5)	(5.7)

4 **Face length (menton-sellion).** The vertical distance from the tip of the chin (menton) to the deepest point of the nasal root depression between the eyes (sellion).

Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	10.8	11.2	12.2	13.3	13.7
	(in)	(4.3)	(4.4)	(4.8)	(5.2)	(5.4)
B Women	cm	10.1	10.4	11.3	12.4	12.9
	(in)	(3.4)	(4.1)	(4.5)	(4.9)	(5.1)

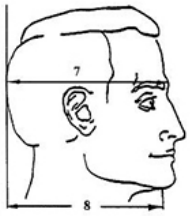


5 **Biocular breadth.** The distance from the outer corners of the eyes (right and left ectocanthi).

Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	11.0	11.3	12.2	13.1	13.6
	(in)	(4.3)	(4.5)	(4.8)	(5.2)	(5.4)
B Women	cm	10.8	11.1	11.6	12.9	13.3
	(in)	(4.3)	(4.4)	(4.3)	(5.1)	(5.3)

6 **Bitragion breadth.** The breadth of the head from the right tragion to the left. (Tragion is the cartilaginous notch at the front of the ear).

Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	13.1	13.5	14.5	15.5	15.9
	(in)	(5.2)	(5.3)	(5.7)	(6.1)	(6.3)
B Women	cm	12.5	12.8	13.3	14.3	15.0
	(in)	(4.3)	(5.4)	(5.4)	(5.7)	(5.9)

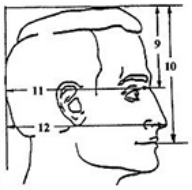


7 **Glabella to back of head.** The horizontal distance from the most anterior point of the forehead between the brow-ridges (glabella) to the back of the head, measured with a headboard.

Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	18.3	18.8	20.0	21.1	21.7
	(in)	(7.2)	(7.4)	(7.9)	(8.3)	(8.5)
B Women	cm	17.5	18.0	19.1	20.2	20.7
	(in)	(6.9)	(7.1)	(7.5)	(8.0)	(8.1)

8 **Menton to back of head.** The horizontal distance from the tip of the chin (menton) to the back of the head, measured with a headboard.

Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	15.7	16.5	18.2	20.0	20.7
	(in)	(6.2)	(6.5)	(7.2)	(7.9)	(8.2)
B Women	cm	15.2	15.8	17.3	18.9	19.6
	(in)	(6.0)	(6.2)	(6.8)	(7.4)	(7.7)



9 **Sellion to top of head.** The vertical distance from the nasal root depression between the eyes (sellion), to the level of the top of the head, measured with a headboard.

Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	9.7	10.1	11.2	12.4	12.9
	(in)	(3.8)	(4.0)	(4.4)	(4.9)	(5.1)
B Women	cm	9.0	9.5	10.5	11.7	12.2
	(in)	(3.5)	(9.5)	(4.1)	(4.6)	(4.8)

10 **Stomion to top of head.** The vertical distance from the midpoint of the lips (stomion) to the level of the top of the head, measured with a headboard.

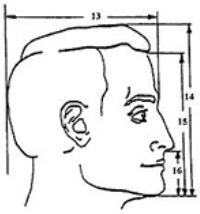
Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	16.9	17.4	18.6	19.9	20.6
	(in)	(6.7)	(6.6)	(7.3)	(7.8)	(8.1)
B Women	cm	15.7	16.3	17.5	18.8	19.4
	(in)	(6.1)	(6.4)	(6.9)	(7.4)	(7.6)

11 **Sellion to back of head.** The horizontal distance from the nasal root depression between the eyes (sellion), to the back of the head, measured with a headboard.

Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	18.0	18.5	19.7	20.9	21.4
	(in)	(7.1)	(7.3)	(7.8)	(8.2)	(8.4)
B Women	cm	17.4	17.8	18.9	20.0	20.5
	(in)	(6.6)	(7.1)	(7.4)	(7.9)	(8.4)

12 **Pronasale to back of head.** The horizontal distance from the tip of the nose (pronasale) to the back of the head, measured with a headboard.

Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	20.0	20.5	22.0	23.2	23.9
	(in)	(7.9)	(8.1)	(8.7)	(9.1)	(9.4)
B Women	cm	19.2	19.7	21.0	22.2	22.8
	(in)	(7.6)	(7.8)	(8.3)	(8.7)	(9.0)



13 **Head length.** The maximum length of the head; measured from the most anterior point of the forehead between the brow-ridges (glabella) to the back of the head (occiput).

Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	18.0	18.5	19.7	20.9	21.3
	(in)	(7.1)	(7.3)	(7.8)	(8.2)	(8.4)
B Women	cm	17.2	17.6	18.7	19.8	20.2
	(in)	(6.8)	(7.0)	(7.4)	(7.8)	(8.0)

14 **Menton to top of head.** The vertical distance from the tip of the chin (menton) to the level of the top of the head, measured with a headboard.

Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	21.2	21.8	23.2	24.7	25.5
	(in)	(8.4)	(8.6)	(8.6)	(9.1)	(9.4)
B Women	cm	19.8	20.4	21.8	23.2	23.8
	(in)	(7.8)	(8.3)	(8.6)	(9.1)	(9.4)

15 **Menton-crinion length.** The vertical distance from the bottom of the chin (menton) to the midpoint of the hairline (crinion).

Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	16.6	17.4	19.1	20.9	21.6
	(in)	(6.5)	(6.9)	(7.5)	(8.2)	(8.5)
B Women	cm	15.5	16.1	17.7	19.2	19.9
	(in)	(6.1)	(6.3)	(7.0)	(7.6)	(7.8)

16 **Menton-subnasale length.** The distance from the bottom of the chin (menton) to the base of the nasal septum (subnasale).

Sample		Percentiles 1st	5th	50th	95th	99th
A Men	cm	6.1	6.5	7.3	8.3	8.7
	(in)	(2.4)	(2.7	(2.9)	(3.3)	(3.3)
B Women	cm	5.7	6.0	6.5	7.8	8.3
	(in)	(2.2)	(2.4)	(2.7)	(3.1)	(3.8)

The second step is to set up a linear flow in Maya and mental ray for rendering and texturing. On Windows computers, the sRGB standard for the web is used so that to the viewer, the monitor will appear to have a gamma of2.2. The monitor applies a small gamma correction of about 1.1 so that the images will appear brighter. The result of this is that linear images appear washed out and it becomes difficult to see the important details. To address this problem, the image needs to be corrected so that the linear data which makes up an image can be displayed on a device that is being used to visualize non-linear data. This is done using gamma. Gamma values on the display device vary depending on the manufacturer; however, the most common gamma value for computer display is gamma 2.2, also known as sRGB. A gamma correction curve is applied to have image color display correctly on the screen (the gamma correction for sRGB devices is 1/2.2 =0.4545).

Since the monitors will more than likely display colors in sRGB space and any color textures used will also be displayed in sRGB space, the problem can be easily fixed by changing a few settings when working on Maya by using a linear workflow with mental Ray.

The last step is to set up the scene with lights. The model can look perfect, with great textures and shaders, but without proper lighting it will be uninteresting and flat. Quick result can be obtained by using a HDRI-image based lighting and final gathering. Two additional lights are used to create a realm light and stronger contrast between highlight and shadow, making the face features pop up.

B. Painting the Texture Map and Creating the Skin Material

It might come as a bit of a shock, but skin is not peachy pink (if you are Caucasian); it's actually a kind of greenish grey color. The pink coloration comes from its translucent quality and the light scattering in the blood under the skin. This is why people "turn green" when they are seasick. The blood has drained from their face, revealing the true color of the skin. The skin color variation is the result pigments present in the living part of the skin. There are two different types of melanin that contribute to the spectrum of human skin colors. Pheomelanin is yellow-red, and is the type of skin pigment seen in Northern Peoples. Cumelanin is brown-black and is the type of skin pigment seen in African people. All other skin colors are based on various levels of these two pigments. Northern people and North American aboriginal people have no genes for the production of cumelanin. Their skin color is derived solely from the reddish type of pheomelanin and its relative density in the skin. Asian people have very little cumelanin, and their skin color is determined by the yellowish type of pheomelanin. African and Middle Eastern people are colored predominantly by cumelanin, and so on. With this in mind it becomes easier choose how to paint the different maps required to create the skin material.

To accelerate the texturing process the map are created using photo manipulation, basic digital painting techniques and sculpting on a high density mesh. The process is very intuitive and convenient for handmade painting or projecting photographs giving the ability to paint directly on the model. The first step was the sculpting of the thin wrinkles, skin pores, and other details creating the illusion of skin, it also helps to create the displacement, bump, and cavity

map used in Maya later on. That map helps to generate the variation of high light and shadow, giving the texture its skin quality.

Starting the texturing process by working on the detailing allowed more flexibility with the painting phase of the skin and it covered some of the imperfections. To accelerate the coloring process photographs were used as reference, switching from Zbrush to Photoshop to fix area that are hard to reach. The photography created the base for the texture maps to reproduce the appearance of blemishes like birthmarks, freckles, pimples, and the pattern of pores, all of which add variety to intensify the skin's uniqueness. Another detail that was taken into consideration was how the color changes on each specific areas of the face. Thick, dense callosity parts of the skin are more yellow and thinner parts more reddish. Arteries and veins appear bluish, and bones underneath the narrowed skin seem whitish. Furthermore, exertion raises the blood circulation, changing the color of the skin partially into more red areas. The texture map paint in Zbrush serves as a base for the different map necessary to create the SSS fast skin material for Mental Ray.

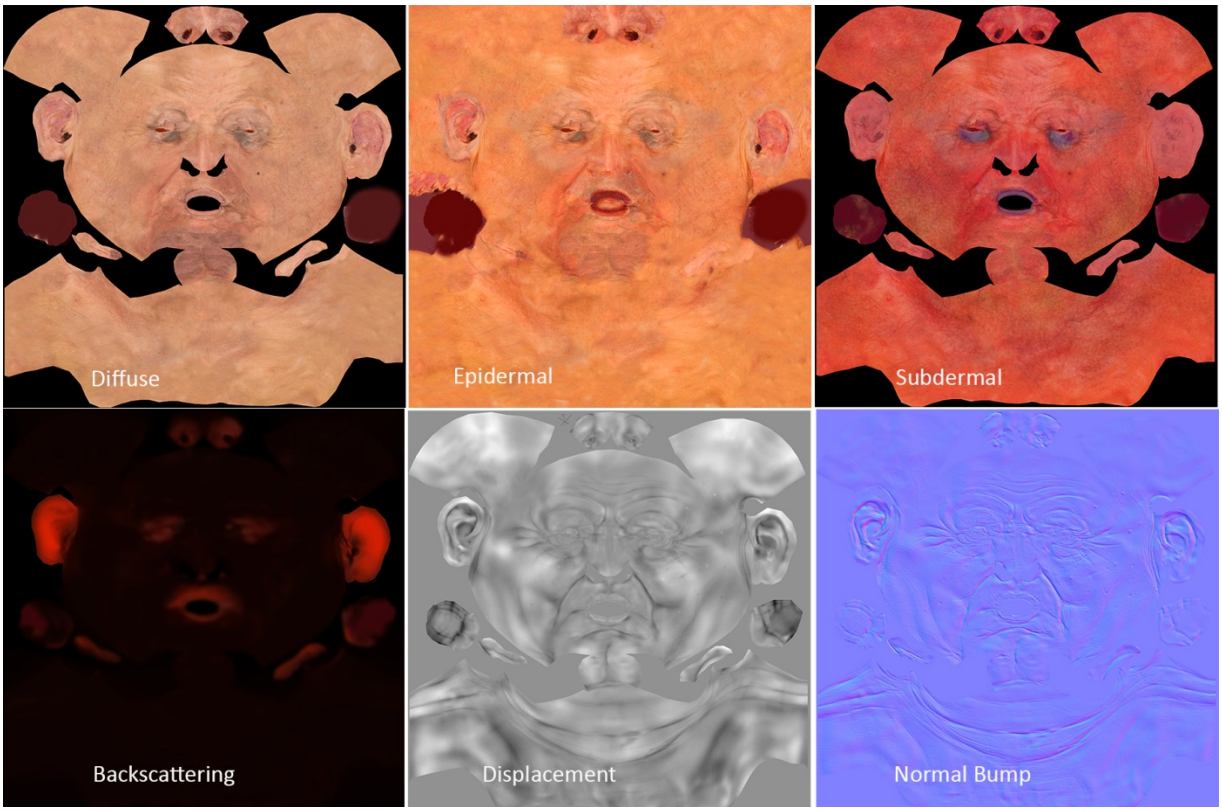


Figure.15 (Painted for Subsurface-Scattering shaders)

The backscattering map is the deepest layer of the skin shader. It represents where the skin meets the muscle, fat and bone. It adds a quality to the skin that is subtle but missed when absent. The colors of the layer are not part of the skin but actually the color of what lies beneath the skin. The map itself does not need to overly detailed, major veins, and some muscle detail can be paint on it. It is also a good way to control the translucence of the body depending on its thickness. The color applied in this layer is the most apparent when direct light is shining from the side of the character opposite to the rendering camera. For the ears some small capillaries can be painted on the map, creating an extra level of realism when a light hits the back of the head.

The subdermal layer is the layer where scar tissue, capillaries, and veins are found. If a character has a tattoo, some of the ink color should be visible in this layer. If a character has

some kind bruises the hematoma will also be paint in this layer. Adding cold colors such as blue and purple in some areas in this layer of the material helps to create an overall natural look to the skin.

The epidermal layer is where moles, freckles, pores, embedded hairs, and stubble and in the case of an older person some capillaries can be found. For better results in the final render, the colors in this map have to be particularly saturated. A much lighter and less saturated version of this map can be used in the diffuse channel of the subsurface-scattering shader.

The last step in order to create a realistic looking skin is to control is shin and shin. Sheen is the property of skin that causes it to reflect more diffuse light at glancing angles. This effect is the result of small hairs and dead skin cells that protrude from the skin's surface that catch and diffuse the light. This is the same effect we get with peach fuzz, or velvet. Specularity is simply a reflection of bright light sources in the scene. On skin, this is caused by oils and sweat on the surface. By adjusting the amount of specularity, and its hardness, we can make skin look dry, moist, oily, or wet. Also it is important to keep in mind that light bounce is stronger on bony surface than fleshy because the does not scatter the same way.

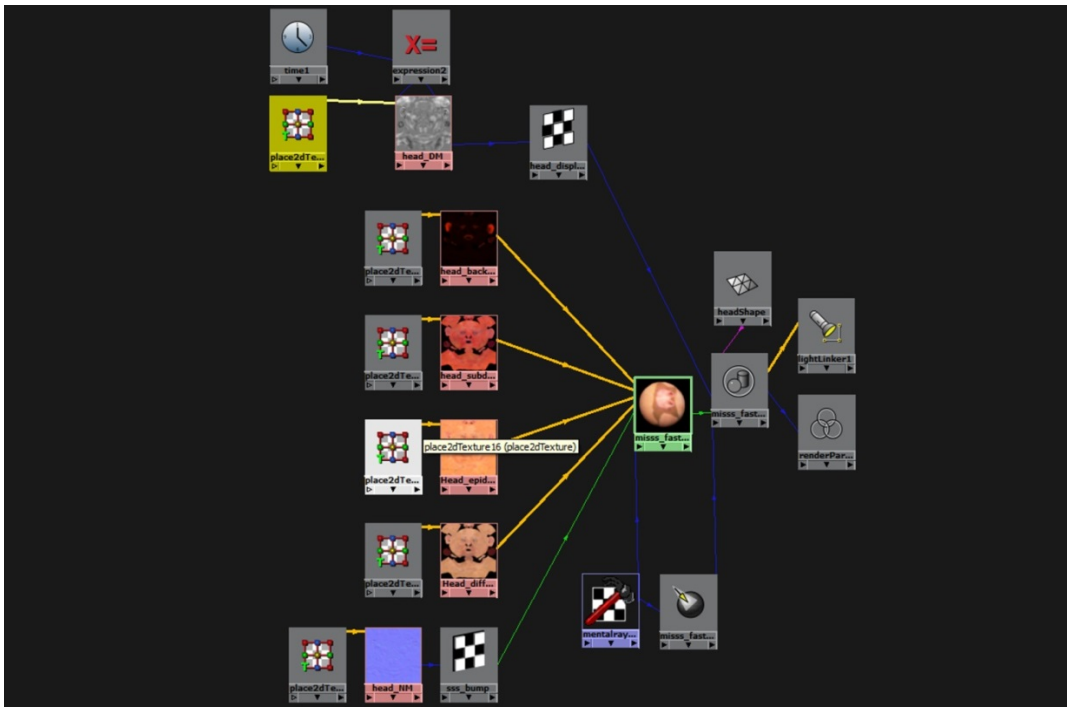


Figure.16 *(Subsurface-Scattering shaders network)*

Figure.17 *(Render Preview)*

Figure.18* (*Final piece)

Conclusion

The filmmakers have continued to use prosthetic and suits, because they were the only means through which actors could portray character of the humanoid kind. But Characters can only be so tall, and can move only according to the performer's physiology and the restriction of the suit and latex prosthesis. No matter how artfully designed and applied, prosthetics can only increase the mass on an actor's face which can limit the range of look that can be achieved. It is possible to make a nose bigger but they are no way without a chirurgic procedure to make a nose smaller. And this is without taking in the hours of makeup necessary to prepare the actor every day slow down production. Some option have been available but stop motion animation, full-scale puppets, animatronics, and later, computer generated animation were all fine for realizing

robots, monsters, dinosaur or aliens with a limited range of emotion. Creating a character of some complexity, with spirit, heart and soul still required a real person to play it.

It is only since motion capture becomes a viable option than emotionally complex computer generated character started to flourish and multiply on screen, but it does not without its flaws. The quality of the final product highly depends on the hardware, the look of the character, the quality of the rig and the performance of the actor. With my personal experience in this project reshooting had to be done because either the data were full of error causing uncontrollable movement or the acting was just bad. The touch of a good animator is still necessary in order to make the animation seemed naturalistic and believable. In fact, without it the result is often “floaty” and can seem so realistic that it comes across as unnerving. Believability is the key to making motion capture successful. What made Gollum and the Na'vi believable is that the directors had chosen to use half motion capture and the rest animation. With the continued improvement of motion capture, and the growing use in both games and films, there is no doubt that motion capture will evolve and flourish in the coming years.

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Terminator Salvation Dir. McG Perfs Christian Bale, Sam Worthington, Moon Bloodgood 21 May 2009. DVD

Superman Return Dir. Bryan Singer Perfs Brandon Routh, Kate Bosworth, Kevin Spacey 28 June 2006. DVD

APPENDIX

Hardware and Software Assessment Documentation and online tutorial

Blender Motion capture Addon -tutorial 1:basic Retargeting
https://vimeo.com/28005237

Blender Motion capture Addon –tutorial2: Location Retargeting
https://vimeo.com/28005319

Blender Motion capture Addon –tutorial3: NLA System and Manual Tweaking
https://vimeo.com/28005365

Blender Motion capture Addon –tutorial5: Retarget Switching and Stitching
https://vimeo.com/28005417

Blender Motion capture Addon –tutorial6: Path Editing
https://vimeo.com/28005421

Blender Motion capture Addon –tutorial7: Baking and Finishing up
https://vimeo.com/28005425

Blender Motion capture Addon –tutorial: advance retargeting
https://vimeo.com/28004438

Face Robot Workflow - Part 1: Getting Set Up for Face Robot
https://www.youtube.com/watch?v=qk53i5weYQI
Face Robot Workflow - Part 2: Creating the Facial Control Rig
https://www.youtube.com/watch?v=qy1lGVOfujs

Face Robot Workflow - Part 3: Tuning the Mouth and Lips
https://www.youtube.com/watch?v=cfMa2Y91G7k

Face Robot Workflow - Part 4: Envelope Weights, Deform Regions, and Wrinkle Map
https://www.youtube.com/watch?v=_o3q5nx_i_4

http://www.mocapclub.com/Pages/SoftMobuPipe01.htm

Face Robot Workflow - Part 5: Tuning the Jaw and Eyelids and Sculpting
https://www.youtube.com/watch?v=yxCW7hKUPqI

Face Robot Workflow - Part 6: Lip Sync Animation
https://www.youtube.com/watch?v=4Zugp9W620s

Face Robot Workflow - Part 7: Working with Mocap Files
https://www.youtube.com/watch?v=323-zmTJcV0

Face Robot Workflow - Part 8: Animating the Eyes
https://www.youtube.com/watch?v=w9Gf63bHAZA

!!Need tutorial about back the animation created in Softimage into F curves to be able to exported it.

Faceware Analyzer and Retargeter (free plugin application for Autodesk Maya, 3DS Max, Motionbuilder, and Softimage combines the video performance of an actor and the artistic hand of an animator to set keyframes on your facial rig.
http://www.facewaretech.com/

Markerless, video-based facial motion capture.
http://www.motekentertainment.com/index.php?option=com_content&task=view&id=17&Itemid=67

Maya, Animating textures on your rig
https://vimeo.com/38122472

Maya/Rigging: Using "Animated" Bump and Normal Maps

https://vimeo.com/38137743

Maya Basic nCloth Tutorial by Stuart Christensen
http://www.youtube.com/watch?v=N8UWFDb7tfk

Softimage documentation about Face Robot
http://softimage.wiki.softimage.com/xsidocs/face_cover.htm

Softimage – Motion Builder Pipeline Tutorial