Escola das Artes da Universidade Católica Portuguesa
Mestrado em Som e Imagem

The Use of Motion Capture in Non-realistic Animation

Computer Animation 2013/2014

João Pedro Tavares Medeiros Paiva

Thesis Advisor: Prof. Dra. Sahra Kunz

September 2014

Acknowledgements

I would like to thank my advisor Sahra Kunz for all the help and dedication throughout this year.

I would like to thank the project mentors Sahra Kunz and Ricardo Megre for their support and incentive in the production of *Napoleon's Unsung Battle*.

I would like to thank my course colleagues for the insightful criticism during this process. I would specially like to thank João Moura for finding time to help me despite working on his project.

Finally I would like to thank my family for the support given throughout my academic journey.

Abstract

The *Use of Motion Capture in Non-realistic Animation* explores the possibility of creating non-realistic animation through the use of motion capture.

In this study we look to the particularities of cartoony/non-realistic animation while trying to ascertain if it is viable to create this type of animation through the process of motion capture.

This dissertation will, firstly, expose the historical, theoretical, technical and artistic context. There will be a brief description of important landmarks and general overview of the history of animation. There will also be an explanation of how animators' will to mimic real life motion, led to the invention of several technologies in order to achieve this goal. Next we will describe the several stages that compose the motion capture process. Lastly there will be a comparison between key-frame animation and motion capture animation techniques and also the analysis of several examples of films where motion capture was used.

Finally there will be a description of the production phases of an animated short film called *Napoleon's Unsung Battle*. In this film the majority of its animated content was obtained through the use of motion capture while aiming for a cartoony/non-realistic style of animation.

There is still margin for improvement on the final results but there is also proof that it is possible to obtain a non-realistic style of animation while using motion capture technology. The questions that remain are: is it time effective and can the process be optimized for this less than common use.

< Key words: Animation, Motion, Motion capture, Non-realistic animation >

Content Index

List of Figures

YUzXzpBgVpM/s1600/sn1.jpg>

Fig. 13 – *Snow White and the Seven Dwarves* (Cottrell, et al., 1938) [26th of January 2014]: <http://www.thatfilmguy.net/wp-content/uploads/2012/04/ snow_white_and_the_seven_dwarfs.jpg>

Fig. 14 – *Snow White and the Seven Dwarves* (Cottrell, et al., 1938) [26th of January 2014]: <http://www.newrepublic.com/sites/default/files/migrated/SnowWhite6.gif>

Fig. 15 – *Gulliver's Travels* (Fleischer D. , 1939) [26th of January 2014]: <http://img560.imageshack.us/img560/2103/gulliver07bluray10reduc.jpg>

Fig. 16 – *Gulliver's Travels* (Fleischer D. , 1939) [26th of January 2014]: <http://img827.imageshack.us/img827/7356/gulliver03bluray3reduce.jpg>

Fig. 17 – *Gulliver's Travels* (Fleischer D. , 1939) [26th of January 2014]: <http://img444.imageshack.us/img444/535/gulliver04bluray4reduce.jpg >

Fig. 18 – Goniometer [21st of January 2014]: <http://www.biometricsltd.com/images/n400le-large.jpg>

Fig. 19 – Motion capture exoskeleton [21st of January 2014]: <http://www.sfu.ca/~mma25/iat445/Mechanical.jpg>

Fig. 20 – *Graphical Marionette,* frames from the video posted on Vimeo [21st of January 2014]: <http://vimeo.com/43287234>

Fig. 21 – *Mike the Talking Head* [22nd of January 2014]: <http://mambo.ucsc.edu/psl/mike.html>

Fig. 22 – *Waldo C. Graphic* [22nd of January 2014]: <http://themuppetmindset.blogspot.pt/2011/04/weekly-muppet-wednesdays-waldo-c.html>

Fig. 23 – *Dozo* [22nd of January 2014]: <http://collgran.files.wordpress.com/2007/10/dozo.jpg?w=468>

Fig. 24 – Dataglove [22nd of January 2014]:

<http://www.yorku.ca/mack/BarfieldF4.gif>

Fig. 25 – Polhemus tracker [22nd of January 2014]:

<http://www.epicos.com/EPCompanyProfileWeb/Content/CYBERMIND/Polhemus%20FASTRAK%C2%AE.jpg >

Fig. 26 – *Face waldo and Mario* [22nd of January 2014]:

<http://themuppetmindset.blogspot.pt/2011/04/weekly-muppet-wednesdays-waldo-c.html>

Fig. 27 - Motion database example (Liverman, 2004)

Fig. 28 – Forty one markers full body configuration example (Liverman, 2004)

Fig. 29 – Motion capture suit example (Andy Serkis, *Gollum, Lord of the Rings Trilogy* (Jackson, 2001-2003)) [27th of January 2014]:

<http://www.gamasutra.com/blogs/MitchellClifford/20131017/202611/Motion_Capture_on_a_Budget__Animating_Satellite_Reign.php?print=1>

Fig. 30 – Facial motion capture example (Bill Nighy, *Davey Jones, Pirates of the Caribbean: Dead Man's Chest* (Verbinsky, 2006)) [27th of January 2014]:

<http://images.usatoday.com/life/_photos/2006/07/17/pirates-topper.jpg>

Fig. 31 – Example of an athletic performer [28th August 2014]: <http://static.guim.co.uk/sys-images/Guardian/Pix/pictures/2010/6/8/1275998611998/Rory-McIlroy-006.jpg>

Fig. 32 – Example of character motion performers [27th August 2014]:
<http://www.mocapclub.com/images/Drake_Mocap_Comp.jpg>

Fig. 33 – Example of stunt motion performers [29th August 2014]:
<http://www.obstructedviews.net/wp-content/uploads/2013/11/Actors-at-The-Imaginarium-011.jpg>

Fig. 34 – Frame from *Ryse: Son of Rome* motion capture session [16th December 2013]:
<http://vimeo.com/81269346>

Fig. 35 – Squash and stretch example (*Black Pete*, Disney) (Johnston & Thomas, 1995, p. 50)

Fig. 36 – Anticipation example (*Marty*, *Madagascar* (Darnell & McGrath, 2005), DreamWorks) [11th August 2014]:

<http://1.bp.blogspot.com/_lbuWqhMHtGc/TSnapwULSII/AAAAAAAAAC4/BWig3AyTsUY/s1600/Anticipation.jpg>

Fig. 37 – Staging example (*Jiminy Cricket*, Disney) [11th August 2014]:

<http://www.87seconds.com/assets/img/Blog/4-Twelve-Principles/03_staging-disney-WardKimball.png>

Fig. 38 – Follow through and overlapping action example [11th August 2014]:

<http://margarettsang.files.wordpress.com/2013/03/principi_animazione_follow_through.jpg>

Fig. 39 – Slow in and out example [10th August 2014]:

<http://mile.mmu.edu.my/orion/luqman/files/2013/04/SLOW-OUT-AND-SLOW-IN.jpg>

Fig. 40 – Arcs example [9th August 2014]:

<http://www.viz.tamu.edu/faculty/parke/ends489f00/section6/lofaCats.jpg>

Fig. 41 – Secondary action example [8th August 2014]:

<http://jordannwharton.files.wordpress.com/2012/09/secondaryaction.jpg>

Fig. 42 – Timing example [10th August 2014]:

<http://www.animatorisland.com/wp-content/uploads/2012/05/charanim_03.png>

Fig. 43 – Exaggeration example (*The Ren & Stimpy Show* (Kricfalusi, 1991), Nickelodeon) [10th August 2014]:

<http://www.smashingmagazine.com/wp-content/uploads/2012/10/a07.33.jpg>

Fig. 44 – Solid drawing example (*Homer Simpson*, *The Simpsons* (Groening, 1989)) [10th August 2014]: <http://mnmtanimation.weebly.com/uploads/9/7/5/3/9753703/5204398.jpg?399>

Fig. 45 – Appeal example (*Wallace and Gromit*, Aardman) [11th August 2014]:

<http://facweb.cs.depaul.edu/sgrais/images/AnimationPrinciples/wg2.jpg>

Fig. 46 – Frame from *The Polar Express* (Zemeckis, 2004) [20th August 2014]: <http://www.slantmagazine.com/assets/film/polarexpress.jpg>

Fig. 47 – Frame from *Final Fantasy: The Spirits Within* (Sakaguchi & Sakakibara, 2001) [20th August 2014]: <http://4.bp.blogspot.com/-WckWWM7pvo8/UN8dmIKcpUI/AAAAAAAAAic/fcWEB49EPE8/s400/fftsw.jpg>

1 Introduction

1.1 About this dissertation

Motion capture is a technique that allows for the capture of a performer's movement through the tracking of specific markers located in the joints and other reference points of the performer's body. This technique is most commonly used to obtain hyper-realistic animation, that is, as close to real life motion as possible. Therefore is not usually used when a less realistic or cartoony style of animation is intended.

We will analyse non-realistic animation and study the particularities of characters' motion in this type of animation. We will then try to ascertain if it is possible to recreate this characteristic motion through use of motion capture technology.

A short film (*Napoleon's Unsung Battle*) was made in parallel with this dissertation, and in this film over ninety per cent of the character's animation was obtained using motion capture while aiming for a cartoony style of animation.

1.2 What are the goals and what questions need answering

Nowadays, with the constant evolution in 3D animation software, animators are being presented with increasingly better tools to develop their art. It is possible to obtain excellent results with key-frame animation and every year we get closer to the fluidity of movement that seemed to be only possible to obtain with traditional 2D animation.

Even with the constant evolution of available tools, animation is still a very time consuming process and most studios have to hire large numbers of animators in order to meet public demand for animation features.

Nowadays motion capture is mostly used when hyper-realistic animation is required, like for instance, CG characters interacting with live action characters, animation in video games and in some cases fully animated feature films.

We believe that the industry has not yet begun to tap into the possibilities of using motion capture technology to produce cartoony styled animation. If it is possible to obtain motion captured hyper-realistic animation using smaller animator teams in less time it may also be possible to do the same for cartoony animation.

Initial motion capture systems weren't very accurate and led to a very time consuming process of cleaning up[1] the obtained data, which caused studios to stay away from it. Nowadays with modern systems it is possible to use the captured data with almost no cleaning up whatsoever. So with this in mind isn't it possible through directing of performance actors to achieve a cartoony styled animation. Some of the motions characteristic of cartoony animation are physically impossible to perform by an actor but we believe this is a limited percentage of the overall animation and this can still be worked upon and added in the post capture phase. Some scripts have been developed so that when they are applied to motion capture data they automatically add stretch and squash to the animation.

1.3 Methodology

In order to write this dissertation a large amount of research was required. The use and study of motion capture for cartoony animation is still somewhat rare nowadays therefore, it is virtually impossible to find information on the subject. Because of this, research was conducted on motion capture in general, in order to understand the particularities of this technology and how to proceed during the process in order to achieve the best results possible.

A generalized research on the subject of animation was made in order to situate the dissertation's theme historically, theoretically, technically and artistically and to understand the aspects that comprise cartoony styled animation.

This research was conducted by consulting several books, scientific papers and specialty websites.

1.4 Description of the dissertation structure

This dissertation is comprised of four chapters.

In the first chapter an introduction is made and the goals and questions raised are presented. There is also an explanation on the methodology used in writing this dissertation and a description of its structure.

In the second chapter a historical, theoretical, technical and artistic context of the subject is presented. There is a brief description of the history of animation followed by a more detailed description of techniques developed by animators in order to obtain animation as close to real life motion as possible. Next we present detailed research on the process of motion capture, its stages

[1] Motion capture systems will sometimes produce motion data with gaps or errors. This situation is addressed by manually replacing bad data or by filling the gaps with the best possible guess.

and how to optimize the results obtained. Next there is some information on the 12 principles of animation and an explanation on how they were adapted to 3D animation and how they can be recreated when using motion capture technology. Lastly there is an analysis of several examples of motion capture animation both common and uncommon in their use or realistic and non-realistic.

In the third chapter we present a production overview of the short film (Napoleon's Unsung Battle) that was produced in parallel with this dissertation. There is also an explanation on how the research made in the second chapter was applied to the making of this short film.

In the fourth and last chapter, we present the conclusions of this dissertation and future prospects.

2 Historical, theoretical, technical and artistic context

In this chapter, as expressed in the title we will try to provide a historical, theoretical, technical and artistic background for this dissertation.

As this dissertation deals with motion capture technology, it seems important to start by introducing why and when animators first felt the need to copy real life motion, and what the first technologies attempted were. Therefore we will start by explaining Max Fleischer's rotoscope and then write about early motion capture technologies passing through to contemporary technologies and future prospects.

Next we will extensively explain the technical aspects of the motion capture process and the several stages of production of this process.

Then we shall discuss the twelve principles of animation and how they can be adapted to 3D and Motion Capture technology.

In the final part of this chapter we will analyse several features with characters animated using the motion capture technology examining both realistic animation and non-realistic animation examples alike.

2.1 Motion capture history

2.1.1 General overview

In the early 1900's animation was comprised of primitive jerky and very mechanical like, animated cartoons. These cartoons were screened before the movies in the theatres, as a novelty or parlour trick. Even in this crude form audiences liked them (Fleischer, 2011, pp. 13,14).

In 1906, with the aid of the American inventor Thomas Edison, James Stuart Blackton, an American newspaper cartoonist, released *Humorous Phases of Funny Faces*, the first animated cartoon to be released on film. In this novelty we could see flickering drawings changing over time, while Blackton himself drew them using chalk on blackboard, giving the illusion of movement and provoking laughter on audiences instantly turning it into a hit (Williams, 2001, p. 15).


Fig. 1 and 2 – Humorous Phases of Funny Faces

Émile Cohl, an early French animator, released *Fantasmagorie* in 1908 in which simple stick figure characters were animated over simple backgrounds. Windsor McCay, an American cartoonist and early animator, released his first animated film in 1911 where one could see his well-known comic strip character, *Little Nemo*, move (Williams, 2001, p. 16).

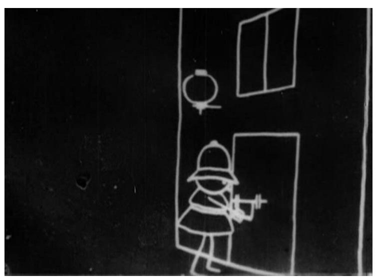


Fig. 3 – E. Cohl's Fantasmagorie

Fig. 4 – W. McCay's Little Nemo

In the early 1910's cartoons in general were poorly animated and constituted of poor gags delivered through the use of dialogue balloons resembling a filmed comic strip. This was due to the fact that most early animators were newspaper cartoonists. In the later part of the decade audiences were growing tired of these cartoons, by this time there is evidence of some animators striving to improve the quality of their animation. Gregory LaCava, a newspaper cartoonist, took charge of William Hearst's cartoon studio and began improving the quality of its animation by increasing the average number of drawings from three to six per second to sixteen per second, and he also strived for smoother movement by creating characters with more curves in their design and avoiding unnatural angular movements. Most of the first animated characters were inherited from popular newspaper comic strips; they were drawn as very rigid vertical forms that tended to stutter when animated. In order to achieve smoother animation both a larger amount of drawings and characters with more curves in their design were required (Barrier, 1999, pp. 18, 19). In nature most living things move in arcs or circular trajectories (Johnston & Thomas, 1995, p. 62), therefore if we have vertical forms the movements will appear rigid and mechanical.

Max Fleischer, one of the most important animators/inventors in animation history, was a big fan of movies himself and especially of these primitive cartoons. Besides being an artist, Max had a sense for machinery as well, so he decided to come up with a way of turning these very crude cartoons into something that was more lifelike and looked better. From this will to improve cartoons, rotoscopy[2] was born (Fleischer, 2011, p. 15).

J. R. Bray, an American animator and founder of Bray productions, which released over five hundred cartoons between 1913 and 1937, had invented a process that allowed for faster production of animated films. It involved the use of clear sheets of celluloid that allowed the artists to draw the moving characters separately from the backgrounds, therefore cutting the necessary number of drawings by half.

In 1916 after signing a contract with J. R. Bray, Max Fleischer used his new invention, the rotoscope, to produce *Ko-Ko the Clown* shorts as a part of J. R. Bray's *Paramount Pictograph* series. (Fleischer, 2011, pp. 25, 26).

Fig. 5 – Model sheet of Ko-Ko the Clown

In 1924 Fleischer studios created the bouncing ball. The bouncing ball consisted of a ball bouncing over the words of the lyrics in a sing-a-long film. The sing-a-long film was not a novelty at the time but the Fleischer's invention turned it into a more interesting experience for the public, who was used to a slide show of still images. Besides the bouncing ball they also animated characters somewhat illustrating the music's lyrics. The bouncing ball gave birth to a long series of very successful cartoons called *Song Car-Tunes*. At this time Dr. Lee DeForest, an American inventor, who had created a new synchronization process, was looking for ways of publicizing his invention and found that the Fleischer's *Song Car-Tunes* was the perfect medium to do so. From this partnership the first synchronized sound cartoon called *My Old Kentucky Home* was born (Maltin, 1987, pp. 91-93).

[2] Rotoscopy – the process of producing animation by tracing live-action footage frame by frame.

In 1928, four years after *My Old Kentucky Home*, Walt Disney released *Steamboat Willie*, wrongfully considered the first synchronized sound cartoon. This release and its subsequent success are also considered to have forced all the major studios to embrace the production of sound cartoons (Maltin, 1987, p. 27).

2.1.2 Rotoscopy

Max Fleischer was so overwhelmed with the movies that he decided to open an outdoor movie theatre with his four brothers and his brother-in-law. This enterprise soon ended in financial disaster but because of it, Max came to be in possession of a hand-cranked projector. He soon began to experiment with his projector with the intention of coming up with a mechanical means of making lifelike cartoons (Fleischer, 2011, pp. 14,15).

He figured that the best way to achieve lifelike animation was to find a way of copying human motion. He realized that if a human in motion was captured on film and then the film was projected one frame at a time and each frame traced with ink on a piece of paper he would have a perfect copy of motion. As simple and logical as this may seem no one had thought about it yet, so he rushed to file a patent application and named his invention the Rotoscope. Now he just had to build his invention and prove it worked. Once again Max recruited the help of his brothers: Joe who was an electrician, Charlie who was a mechanic, Lou who was a musician and Dave who was a film editor. All of them had jobs at the time so they only worked on this project at night in Max Fleischer's living room and using the funds that Max's wife was able to save from her household allowance to buy the parts and materials they needed (Fleischer, 2011, pp. 15-17).

With the help of his brothers he was able to transform the old projector into a frame stop camera and then they went on to develop a wood support that was connected to the camera and to a glass where the film was to be projected frame by frame in order to trace the image with ink onto paper (Fleischer, 2011, pp. 16,17).

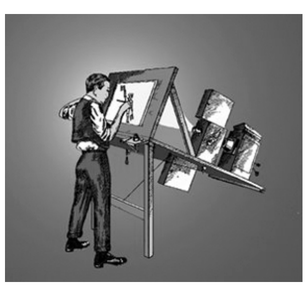
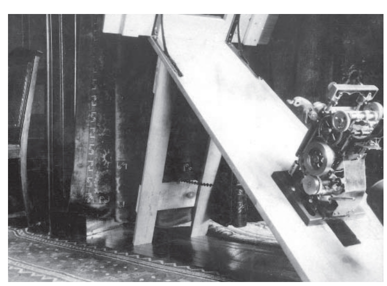



Fig. 6 and 7 – Rotoscope

His brother Dave dressed himself in a clown outfit and performed for the camera. Then they readapted the camera into a frame-by-frame projector and painstakingly traced all the frames projected on the glass with ink onto paper. Next they turned the projector into a frame stop camera once again and photographed all the pieces of paper obtaining the perfect motion of Dave as a clown, this way giving birth to *Ko-Ko the Clown* and rotoscopy in animation (Fleischer, 2011, pp. 18,19).

Armed with his new technology Max Fleischer produced several *Ko-Ko the Clown* shorts. In these there would usually be a mix of animation and live-action with *Ko-Ko* interacting with live-action objects or people (Barrier, 1999, pp. 23, 24).

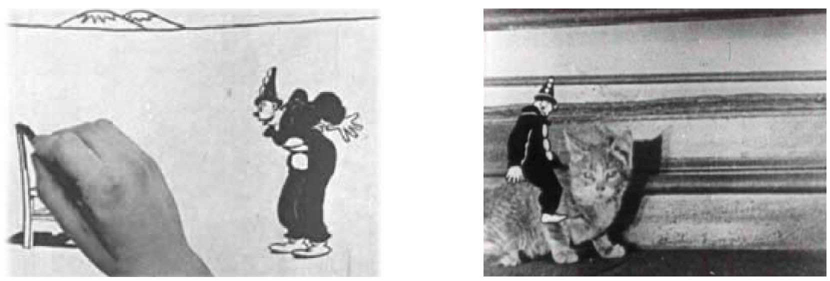


Fig. 8 and 9 – Ko-Ko the Clown

Throughout the years that followed the Fleischer Brothers created several successful cartoons. They continued to explore *Ko-Ko the Clown* until the late 1920's producing some of the best and most popular cartoons of their time.

After a long run of *Ko-Ko the Clown* and *Song Car-Tunes* cartoons Fleischer's studio brought to life new and memorable characters such as *Betty Boop*, introduced for the first time in 1930, and *Popeye the Sailorman*[3] introduced in 1933 (Maltin, 1987, pp. 101, 106).

[3] The Fleischer brothers negotiated the rights to Popeye the Sailor that was a part of the popular comic strip, Thimble Theater created by Elzie Segar.

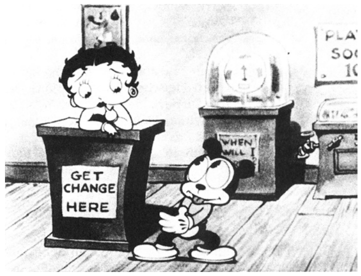


Fig. 10 – Betty Boop and Bingo

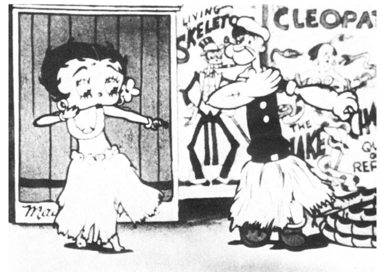


Fig. 11 – Popeye's debut

By then other studios had realized the possibilities of rotoscopy and began to use it.

In 1938 Walt Disney Studios released *Snow White and the Seven Dwarves*, the first animated long feature film. The rotoscope was extensively used to animate several of *Snow White*'s sequences and some of the *Prince*'s as well. A young dancer was hired to perform all of *Snow White*'s actions for the camera, she was dressed in similar clothes to the ones that the character would have in order for the animators to have references for the way the dress would move. There were also props used to simulate tree branches or other objects that the character would interact with. The animators discarded what they did not like or needed from the traced live-action and then altered the proportions and actions. The rotoscope could not substitute a good animator because it did not distinguish the essential from the non-important. The animators had to exaggerate what needed to be exaggerated giving weight and mass to the character. Despite all of the animators' efforts the realistic animation of *Snow White* and the *Prince* still contrasted with the fluidity of the other characters, animated from scratch (Barrier, 1999, pp. 166, 195,196).

Fig. 12, 13 and 14 – Snow White and the Seven Dwarves (1938)

Only a year later Max Fleischer released his own feature film, *Gulliver's Travels*, in which the rotoscope was also extensively used to animate the main character, *Gulliver*. In this film the animators made no effort to conceal the live tracing of the rotoscope making *Gulliver*'s animation ultra-realistic. The animators delivered beautifully animated sequences, but when combined, *Gul-*

liver's character ultra-realistic animation, characters *David* and *Gloria* semi-realistic animation and the more cartoony animation of the rest of the cast do not work (Maltin, 1987, pp. 116-118).



Fig. 15, 16 and 17 – Gulliver's Travels (1939)

2.1.3 Early motion capture systems

Motion capture consists of tracking physical markers attached to the performer's body. These markers keep track of the performance motion over time allowing the creation of a 3D representation of this motion (O'Neill, 2008, pp. 231,232).

In the 1970's, at the New York Institute of Technology Computer Graphics Lab, artist and researcher Rebecca Allen developed a technique in which the captured images of a dancer's motion were projected onto the computer screen allowing her to key pose[4] a computer generated dancer. With this adaptation of the rotoscope she was able to create a fluid human motion in a computer-generated character. This technique required the animator to manually set the key poses every few frames, even if a little easier than traditional rotoscopy it was still a time consuming process (Sturman, 1994, p. 1).

In the early 1980's, at the Simon Fraser University, Tom Calvert, professor of kinesiology and computer science, attached potentiometers[5] (Fig.18) to an exoskeleton[6] (Fig. 19) and used the information retrieved from these sensors to drive computer-animated figures. He applied a potentiometer alongside each knee to the exoskeleton around the legs, and this permitted him to track knee flexion, which was then applied to the digital character (Sturman, 1994, p. 1).

---

[4] Key pose - key poses are the most significant poses in a character's movement, they are usually the extreme poses of said movement.
[5] Potentiometer – an instrument for measuring an electromotive force by balancing it against the potential difference produced by passing a known current through a known variable resistance. – Definition from Oxford Dictionaries [8th of August 2014] <http://www.oxforddictionaries.com/definition/english/potentiometer>
[6] Exoskeleton – in this case it is a structure that supports the attached sensors.

Fig. 18 – Goniometer

Fig. 19 – Motion capture exoskeleton

A few years later, commercial optical tracking systems were being used by MIT and The New York Institute of Technology Computer Graphics Labs to conduct experiments in order to optically track human motion.

Optical tracking consists of the tracking of small markers attached to the body of the performer. Flashing LEDs (Light-emitting Diodes) or small reflecting dots are positioned in order to map the joints of the performer and also the position of the most important points of his/her body. A variable number of cameras records the position of the markers over time, then by comparing their position in the images, of all the different cameras, the software is able to calculate the three dimensional position of every marker over time.

Because of hardware limitations, in the beginning, it was only possible to track a dozen markers. The technology limited the speed at which the markers could be examined therefore, it was not possible to neither capture a large number of markers at the same time nor capture sudden movements very accurately. Nowadays these problems are overcome by the greater processing capacity of computers, which also allows for a larger number of cameras to be used during the capture. The higher number of cameras not only allows for a larger amount of markers but also helps to counter the occlusion of markers by the performer's body. The better resolution capabilities of contemporary cameras contribute to differentiate markers close together, thus allowing for a more accurate capture of the performer's motion.

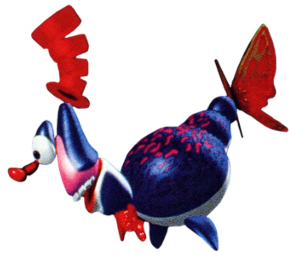
In 1983, at MIT (Massachusetts Institute of Technology), computer scientists Carol Ginsberg and Delle Maxwell presented the Graphical Marionette. In this project, a body suit with LED markers and two cameras with special photo detectors were used. These cameras gave the two-dimensional position of each LED marker in their fields of view. The computer used the position information of the two cameras to obtain three-dimensional coordinates of the markers over time. The system then used that information to move a stick figure with immediate feedback. The data was also stored in order to be used in a more complex digital character. At this time, the very low rate at which the computers were able to render this information and significant financial costs of putting together a motion capture studio, posed the biggest hurdle for the success of this technology (Sturman, 1994, pp. 1,2).

Fig. 20 – Graphical Marionette

In 1988, deGraf/Wahrman, a special effects company, presented Mike the Talking Head (Fig. 21) at SIGGRAPH. This project consisted in a specially built controller that allowed a single puppeteer to control many parameters of the character's face, which included mouth, eyes, expression and head geometry. The Silicon Graphics 4D hardware allowed for real time interpolation of the character's facial expressions over time as controlled by the puppeteer. Even if not directly related to motion capture, this project demonstrated that the technology had reached a level that allowed for the full exploration of motion capture in animation production (Sturman, 1994, p. 2).


Fig. 21 – Mike the Talking Head

Also in 1988, Pacific Data Images, a computer animation production company, created an input device that was able to control the position and mouth movements of a low-resolution character in real-time, this was called *Waldo C. Graphic* (Fig. 22). Later PDI developed a lightweight plastic exoskeleton that was able to track movements of the performer's torso, arms and head. The movements were tracked through the use of potentiometers placed in the exoskeleton. This system proved to be less than perfect, because of the noise[7] in the electronics and the limitation of the performer's movements due to the exoskeleton (Sturman, 1994, p. 2).



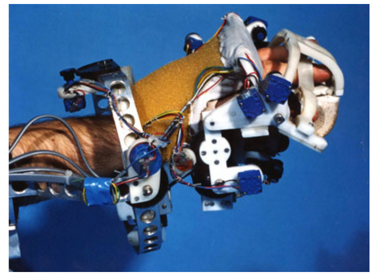


Fig. 22 – Waldo C. Graphic

In 1989, Kleiser-Walczack, a special effects company, produced Dozo (Fig. 23), a computer animation that was made with the use of an optical motion capture technique. To capture the motion they used several cameras and reflective tape placed in the body. The biggest problem with this technique was the difficulty to track the position of the points because the performer's movement occluded them. For Dozo the tracking of these occluded points was obtained through a time consuming post-process (Sturman, 1994, pp. 2,3).

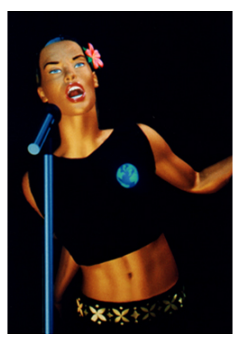


Fig. 23 – Dozo

In 1991, Videosystem, a video and computer graphics producer, created a real-time character animation system that was used to daily produce an animated character called Mat the Ghost. This character was captured in real-time and no post-render was necessary, therefore with this technique it took about a day and a half to produce seven minutes of animation. Several puppeteers animated the character through the use of DataGloves[8] (Fig. 24), joysticks, Polhemus trackers[9]

[7] Noise – in this context it is the unwanted information that harms the quality of the sensors' signal.
[8] Data glove – a glove that works as an input device tracking the movements of the user's fingers and transmitting this information to a computer. More advanced gloves can also track the movements of the wrist and the elbow.

(Fig. 25) and MIDI[10] drum pedals. A puppeteer controlled the movement of the upper body through the use of a suit with Polhemus trackers (Sturman, 1994, p. 3).

Fig. 24 – Dataglove

Fig. 25 – Polhemus tracker

In 1992, SimGraphics developed a facial tracking system called "face waldo" (Fig. 26). This system used mechanical sensors attached to the chin, lips, cheeks and eyebrows and also electromagnetic sensors attached to the helmet that supported all of this. With this system it was now possible for a single actor to control a character's facial expressions in real-time. Using this system an actor performed in real-time in a Nintendo product announcement controlling the Mario character, from the Super Mario Video Game, while responding to the audience's questions and comments (Sturman, 1994, p. 3).

Fig. 26 – Face waldo and Mario

In 1993, Acclaim, an American video games developer, released a two-character animation done entirely with motion capture. They had developed their own proprietary motion capture system. It was an optical motion capture system similar to the one used for the Graphical Marionette, but this one allowed for the tracking of up to one hundred points simultaneously in real-time (Sturman, 1994, p. 4).

---

[9] Polhemus tracker – an electromagnetic motion tracker that is able to measure the motion of the user.
[10] MIDI – short for Musical Instrument Digital Interface.

In the early 1990's several companies (Ascension, Polhemus, Superfluo, amongst others) released commercial motion tracking systems allowing for the development of this field of animation.

2.1.4 Contemporary motion capture systems

Several motion-tracking systems have been developed over the years. The most common in the industry are optical motion capture systems (Liverman, 2004, p. 9).

There are five groups of motion capture systems: Acoustic Motion Capture, Magnetic Motion Capture, Optical Motion Capture, Prosthetic Motion Capture and Digital Armature Devices.

In Acoustic systems the performance actor is equipped with sound emitting transmitters placed at his joints. By measuring the time that sound takes to travel to the receivers it is possible to triangulate the position and movement of the actor over time.

In Magnetic systems the performance actor is equipped with magnetic sensors placed at his joints. The magnetically measured distance between the sensors allows the tracking of the position and movement of the actor over time. (Kitagawa & Windsor, 2008, pp. 10, 11)

In Optical systems the performance actor is equipped with reflective markers placed at his joints. With the two-dimensional coordinates retrieved by several cameras it is possible to triangulate the position of the markers in a three-dimensional space over time. (Kitagawa & Windsor, 2008, pp. 8-10)

In Prosthetic systems an external structure is attached to the performance actor, and there are several sensors that measure the rotation and position of the performer's joints over time.

Digital Armature Devices are very similar to Prosthetic systems. On both cases an external structure equipped with sensors is used. The main difference between the two systems is that with digital armatures the performer will generally pose a position and then key frame[11] it as opposed to real time capture of the movement in prosthetic systems (Liverman, 2004, pp. 8, 9).

Some authors do not differentiate between Prosthetic systems and Digital Armature devices naming both of these Mechanical motion capture systems. (Kitagawa & Windsor, 2008, p. 11)

Apart from acoustic systems, which have almost completely disappeared, all other systems are

[11] Key frame – a frame of an important part of a sequence. In computer animation the animator can pose his characters in these key frames and the computer will automatically calculate the interpolation between them.

still in use today. There are advantages and disadvantages to all of these systems. Prosthetic and digital armatures are either limited to some limbs at a time or in case of full body prosthetic systems the actor is limited by the weight and range of movement of the structure. Magnetic systems require the placing of wires and a transmitter on the actor, this may also limit is performance (Liverman, 2004, p. 9).

Both mechanical motion capture systems are extremely portable in comparison with optical systems and no occlusion occurs during capture. (Kitagawa & Windsor, 2008, p. 12)

In 2006's *Pirates of the Caribbean: Dead Man's Chest* (Verbinsky, 2006), a motion capture system permitted simultaneous characters' performances to be captured on set including facial capture as well. The actors no longer had to go into a studio to recapture the motions, they could now do it live on set with the rest of the cast.[12]

Weta digital[13] and Vicon[14] developed a new system for *Avatar* (Cameron, 2009) that allowed the director to have real time feedback of the CG characters in the CG environment. The director would have a six inch monitor where he could see live feedback of the actors' performances on the CG generated characters and environments and use it to adjust camera angles and focus.

For the first time, advances in motion capture technology allowed for simultaneous capture of several actors' performance in an exterior live set on the film *Rise of the Planet of the Apes* (Wyatt, 2011). Instead of the traditional reflective markers, LED markers were used to help the cameras distinguish them from other reflective surfaces on location.

2.2 Motion capture process

The motion capture process can be divided into three separate stages: the preparation phase, the capture session and the post-capture phase (Liverman, 2004, p. 15).

Nowadays it's cheaper to build a motion capture studio than it used to be, but it is still a significant expense, and most companies prefer to use outside studios for their projects. These studios are highly specialized in processing the captured data and can obtain better results because of that (Liverman, 2004, pp. 27, 28, 32).

[12] [5th of August 2014]: <https://www.yahoo.com/movies/a-brief-history-of-motion-capture-in-the-movies-91372735717.html>
[13] Weta Digital – is a VFX company.
[14] Vicon – is a company that develops and sells motion capture systems.

Whether an outside motion capture studio is hired or not, time constrictions are a constant in animation. In order to get the best possible results in the least amount of time it is very important to plan everything in advance and as thoroughly as possible.

2.2.1 Preparation phase

If done correctly, motion capture allows for eighty per cent of the animation process to be complete even before the animators start to work on a scene, this is important if one considers that the main reason that leads companies to use motion capture in their productions is the time it saves and that fewer animators are required (Liverman, 2004, pp. xiii, 23).

According to information gathered from *The Animator's Motion Capture Guide* (Liverman, 2004) and also the personal experience achieved during the production of a short animation film produced last year, if one does not plan thoroughly before starting a capture session it is very easy to waste time and end up with results very far from perfect. This could happen due to overlooking some of the motions needed or capturing too many takes of one particular motion making it harder for the animator to choose which to use, amongst other reasons.

Last year a short animated film was produced using motion capture as the main animation technique, due to the production team's lack of experience, it was decided that each member would perform all the actions for all the characters and we would later choose the best motions for use in the film. This resulted in an overwhelming amount of motion data from witch to select the animations and because no record was made while the sessions were taking place no one knew which the best takes of each action were.

When planning, one should begin by putting together a motion list[15]. In this list motions are divided into three parts: the beginning position, the action and the end position (Liverman, 2004, p. 43). The three-part breakdown is important because it will later help the animator to seamlessly sequence different motions together.

The next step is to create a motion database[16]. In this database the actions are more extensively described than in the motion list, there is information about the number and name of the performers involved and the number and the nature of the props involved. During the capture session one can use this document to take notes regarding the number of takes for each motion and for indi-

[15] A motion list consists of a list of all the motions that are required to be captured.
[16] The motion database consists of a more complete motion list.

cating the best that will be selected for processing. According to a motion database example in *The Animators Motion Capture Guide* (Liverman, 2004, p. 87) one can also find other information such as: the studio name, the project name, the motion studio name, the shoot date, the name of the motion file, the priority of the motion and the number of frames.

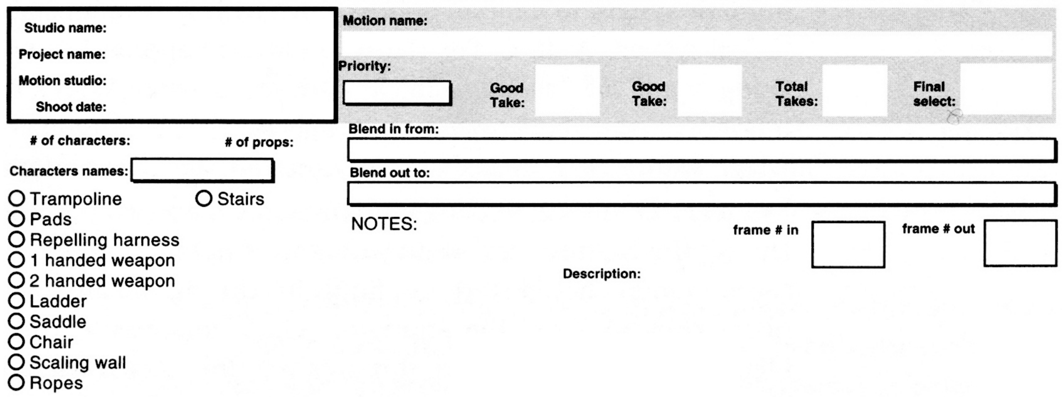


Fig. 27 – Motion database example

The motion list and the motion database are extremely important, the latter is used not only for the capture session but also for the post capture phase helping to keep things organized which in turn can save a lot of work and time in complicated projects with large numbers of motions and therefore files (Liverman, 2004, p. 103).

Another important aspect of the preparation phase is the marker[17] configuration. For the capture of the motion of the body a basic thirty eight to fifty markers configuration is commonly used. The number, the size, and even the way markers are positioned can vary according to the technical specs and the number of the cameras used, to the skeleton[18] of the character and to the type of motion required (Liverman, 2004, pp. 132, 133).

[17] Marker – a retro-reflective sphere or hemisphere which is attached to what is to be captured in order to allow the cameras to track its position.
[18] Skeleton – a hierarchy of joints that are used to control a digital character.

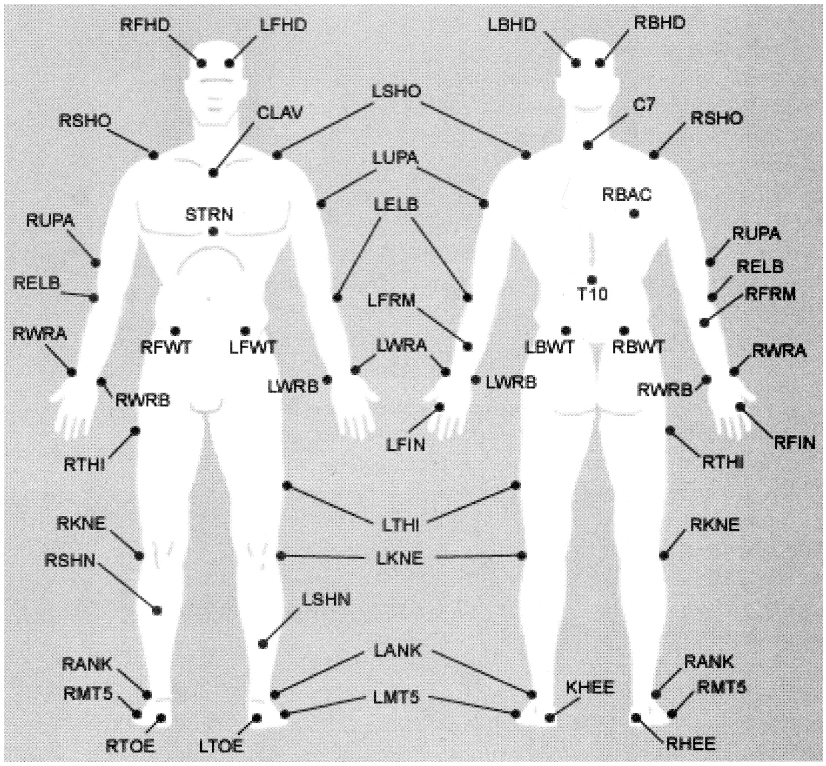


Fig. 28 – Forty one markers full body configuration example

In a common marker configuration one can find the markers positioned to track joint rotation and skeleton position and also three special types of markers with special functions, these are called asymmetrical markers, redundant markers and virtual markers. The asymmetrical markers, as their name indicates, are positioned asymmetrically on the performer’s body in order for the computer to distinguish the left from the right side. Redundant markers are used to counter the effect of marker occlusion by the performer’s body. Virtual markers do not exist physically, they are an equation created by the computer to find the true position of the centre of the joint in order to compensate for the fact that the actual markers are positioned on a suit or on the skin and not in the exact centre of the joint itself (Liverman, 2004, pp. 133,134).

Markers can come in different diameters that can range from three to fifty millimetre spheres. The size of the markers is usually dictated by the resolution of the cameras and by the type of motion required. When hand or facial motion capture is required three or four millimetre markers are usually used. Facial motion capture can require as many as one hundred markers that are positioned directly on the performer’s face using double faced tape or a special glue. For hand motion capture three to four millimetres markers are also used and twenty five is the average number used for each hand. Hand and facial or expression motion capture is usually done separately from the body motion capture but nowadays some studios, like Red Eye Studio for instance, are able to do a full body motion capture using a total of one hundred and thirty three markers (Liverman, 2004, p. 137).

Fig. 29 – Example of a motion capture suit

Fig. 30 – Example of facial motion capture

The next step in the preparation phase is to choose the performers. Depending on the type of motion required one could choose: animal performers, athletic performers, character performers and stunt performers. It is very important to select the best performer possible for the specific motion (Liverman, 2004, p. 174).

The same way a live-action director strives to cast the best actors for each part the same is true with motion capture performers. If we need to capture athletic performances, as for instance, a baseball pitching motion one should hire a performer that is experienced in baseball. When fighting or otherwise more dangerous physical motions are required one should hire a professional stunt performer. If a dramatic character performance is needed one should a performer that has traditional acting training.

The athletic performer is specialized in providing athletic motions such as gymnastics, martial arts or other sports motions. When capturing athletic motions it is important to choose your performer carefully, he needs to have good motor coordination and be able to perform the necessary motions in a small space, most studios prefer using the smallest capture space possible in order to increase the quality of the captured data (Liverman, 2004, pp. 177-179).

The athletic performer is mostly used in situations where accurate sports motions are required like for instance in football, baseball or basketball video games.

Fig. 31 – Example of an athletic performer

In the image above we can see Rory McIlroy, a professional golfer, taking part in a motion capture session for the video game *Tiger Woods PGA Tour 11* released by Electronic Arts in 2010.

When capturing motion that has to imprint a unique personality on a character one should choose a character motion performer. These performers need to have and understanding of movement, timing, and body expression. (Liverman, 2004, p. 179)

Fig. 32 – Example of character motion performers

In the image above we can see the actors, Nolan North and Emily Rose, taking part in a motion capture session for the game *Uncharted* released by Naughty Dog in 2007.

For dangerous stunts one should search for a stunt motion performer, they are specialized in performing dangerous physical stunts. These stunts may involve nasty falls or being thrown in the air by pulleys. It is important to hire someone with experience as a stunt and preferably in motion capture as well, in order to assure one gets convincing motion performance and avoid any accidents or injuries (Liverman, 2004, pp. 180,181).

Fig. 33 – Example of stunt motion performers

In the image above we can see a capture session with stunt actors performing the extremely physical fighting scenes for the video game *Ryse: Son of Rome* released by Crytek in 2014.

The same way stunt actors usually perform dangerous scenes in live-action movies, professional stunt performers should also be employed when capturing dangerous motions is necessary.

The final stages of the preparation phase involve gathering reference material that should be brought to the studio in order to show the performers what the animation director is looking for. This material can be photographs of key poses or reference videos. (Liverman, 2004, pp. 196,197).

Ultimately one should prepare a daily shot list, containing the order and the motions to be captured on a given day. When preparing such a list one should bear in mind the priority of the motion, complexity, time of day, performers involved and performer's fatigue. One should consider the performer's comfort and stamina when preparing the shot list and also their availability as well if several performers need to be captured together (Liverman, 2004, pp. 200, 201).

2.2.2 Capture session phase

In the beginning of every capture session it is necessary to calibrate the capture system, prepare the capture volume and every prop required for the capture session. One should start by capturing simple motions, for instance walk cycles, in order to test if marker configuration and skeleton are working properly. While capturing the motions it is important to create markings of the performer's foot placing when capturing motions that will sequence together, this will save the animators a lot of time while editing (Liverman, 2004, pp. 208-212).

It is customary to have video cameras record the capture session, these videos will serve as reference for the animators when editing the motions. (Kitagawa & Windsor, 2008, pp. 36, 37)

The motion director is responsible for directing the performer during the capture assuring he gets the desired motions and selecting the take that will be processed. It is important to have an assistant director to help communicate with the performer and to guaranty the motion is captured properly. When capturing, and depending on the type of motion, the director and assistant director can divide their tasks by paying attention to different parts of the body for it is impossible for one person to cover every single detail in complex and most of the time fast motions (Liverman, 2004, pp. 214, 215).

Nowadays it is possible to have real-time feedback of the capture, this can be very helpful. By this time one should have a simple mesh[19] of the characters and scenario in order to act as reference for the real-time playback of the motions, it is better if one can use the final mesh but this is usually impossible because the real-time playback requires a limited use of polygons due to the real-time processing required. Using real-time playback can contribute to assure that the character is not going thru solid objects and is performing the motions correctly on the required relative positions it may also help the performer to get into character. With real-time playback the director can view the motion several times and from various different angles allowing the making of a more informed decision when choosing the take that should be processed (Liverman, 2004, pp. 216, 217).

An example of real time feedback on simple meshes can be found on the live footage of a motion capture session of the video game *Ryse: Son of Rome*.[20]

Fig. 34 – Frame from Rise: Son of Rome motion capture session

[19] Mesh – is the geometry of a 3D character or object
[20] [16th of December 2013]: <http://vimeo.com/81269346>

It is important to take notes during the capture session. These notes will later serve for updating the motion database. If working in a project that requires multiple capture sessions, one should evaluate the work done at the end of each day and make any necessary adjustments to the general motion capture schedule. For safety reasons one should have at least two good takes of each motion in order to avoid complications if the capture data is corrupted or unusable by any reason, this is called a safety take. The safety take can add to the performers fatigue and to the overall time the capture session takes but it is an important safety measure especially if there will only be one capture session. When capturing cycle motions, like walks or runs, the performer should start and end the motion outside of the capture space this avoids speed variations during the cycle (Liverman, 2004, pp. 218-220).

2.2.3 Post-capture phase

The first part of the post-capture phase consists cleaning-up the raw data, to do so one needs the remove any spikes[21] in the animation curves, correct bad bone rotation and residual noise in the movement. When processing motion data one could use specific software, such as *Autodesk Motion Builder*, that have filters that when applied solve most of the mentioned problems but, if one is not experienced in this, choosing the correct filters and how to apply them can be very time consuming and one could very easily make the motion data quality worst instead of better. When choosing the frame range it is important to leave some handle frames to make sure that the animators can blend together the different motions, to choose the frame range one could make use of the capture session's recorded video for reference. When working with cycle motions the entire motion should be processed, this will later help the animator to choose the most constant and better-looking part of the motion to be cycled. The frame range selection should be finished as soon as possible because the studio cannot begin the post-processing without it (Liverman, 2004, pp. 224-228).

Before the animators start editing the motion it is important to update the motion database with notes taken during the capture session, these will assist the animators to do their job, specially the one who were not present at the capture session (Liverman, 2004, p. 231)

[21] Spikes – in this context it refers to errors that sometime occur when capturing motions. For example, if a character has is hand next to his hip in one frame the hand appears next to the head and in the next frame appears next to the hip again, this causes for an identifiable spike to show up in an otherwise smooth animation curve.

There are two ways of editing motion data: destructive editing where original key-frame information is deleted and non-destructive editing where the animator works on a different animation layer and blends the original animation with the new one (Liverman, 2004, p. 224).

2.3. Motion Capture vs. Key-frame Animation

"The old knowledge applies to any style or approach to the medium no matter what the advances in technology." (Williams, 2001, p. 20)

Throughout the years, at Walt Disney Studios, animators created a set of rules and principles to help them produce believable lifelike animation. Some of these principles can be applied regardless of the medium therefore, even though they were created with traditional animation in mind, they can still be applied to 3D computer animation (Lasseter, 1987, p. 2).

In motion capture as in all other animation techniques the same set of rules and principles still apply.

2.3.1. The twelve principles of animation

In 1981 Frank Thomas and Ollie Johnston released their book *The Illusion of Life, Disney Animation*. In this book they set some principles that had been put to use throughout the years, by the animators at Disney Studios, with the intention of producing animation that followed the natural laws of physics being realistic enough to produce characters that seemed to have life (Selby, 2013, p. 11).

1. Squash and stretch – as the name indicates refers to the squashing or stretching of the shapes along the animation. This principle is used to create fluidity giving a sense of weight. In real life squash and stretch occurs in flesh or other non-rigid materials. The most common example used to explain this principle is the bouncing ball, when the ball hits the ground it squashes becoming flatter and wider and in the highest position the ball stretches becoming narrower and longer (Johnston & Thomas, 1995, pp. 47-51).

   Besides the sense of weight this principle is used to give a sense of rigidity of an object as well, if after being completely squashed the object rapidly regains its original form it transmits the impression of a very soft material. The most important rule when applying this principle is to maintain the object's volume, if the object is scaled up in the y-axis it needs to be scaled down in the x and z-axis in order to maintain the same volume (Lasseter, 1987, pp. 2, 3).

Fig. 35 – Example of squash and stretch

As we can see in the example above when Disney's *Black Pete*'s belly is fully squashed in the last drawing it expands to the sides in order to maintain its volume. In the middle drawing he immediately regains its original form after having is stomach and chest squashed together, this gives the idea of a very soft material. Even if exaggerated, as it is for comical purposes, it gives an impression of mass and level of rigidity to the animated object.

2. Anticipation – this is the action that comes before the base action, and is used to prepare the audience for the upcoming action and as a comic effect. A good example of this principle is a baseball pitcher winding up before the pitch or a character taking a few steps backward before running forward (Johnston & Thomas, 1995, pp. 51-53).

   Anticipation is what prepares the audience for the action that is about to take place. The amount of anticipation should be inversely proportional to the speed of the action that is to take place. If an action is extremely fast there should be more anticipation in order to guarantee that the audience does not miss the action itself. (Lasseter, 1987, p. 4)

Fig. 36 – Example of anticipation

As we can see in this example[22] from DreamWorks' *Madagascar* (Darnell & McGrath, 2005), *Marty* is drawing his breath as anticipation for the action of blowing out the candle. The backwards movement is highly exaggerated in order to emphasize and prepare for the upcoming action of blowing out the candle.

3. Staging – the pose or action of the character and the overall look of the frame should clearly translate the information to the audience. One should pay attention to the background and the framing as it should all help transmit a clear message to the audience. It could be compared to composition in painting (Johnston & Thomas, 1995, pp. 53-56).

   Everything in the scene: the action, the framing, a personality, among other things should be there to clearly transmit a single idea at a time to the audience. When there is a lot of movement the attention will go to whatever is still or when everything is dark it will go to what is lit therefore, when a scene is properly staged the eye of the audience will be directed to wherever the animator intends it to be. In the early days Disney's animators would animate an action in silhouette because at that time it was all black and white therefore, the characters' arms, legs and body were all the same colour. Nowadays this is still done as an exercise including in 3D if a scene works in silhouette then it was well staged. (Lasseter, 1987, pp. 4, 5)

[22] [11th August 2014]: <http://1.bp.blogspot.com/_lbuWqhMHtGc/TSnapwULSII/AAAAAAAAAC4/BWig3AyTsUY/s1600/Anticipation.jpg>

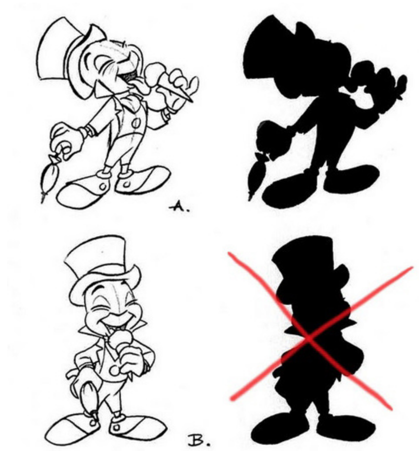


Fig. 37 – Example of staging

As we can see with Disney's *Jiminy Cricket*'s image above[23], proper staging makes for more perceivable action as portrayed in the top part of the image above.

4. Straight-ahead action and pose-to-pose – straight-ahead animation is to animate in sequence as you go, this gives spontaneity to the action but the character as a tendency to change volume and proportions over time. In pose-to-pose animation the animators first set the key poses of the movement and then fill the in-betweens this tends to a more controlled animation and allows for the key animator to do just the key poses and leave the in-betweens to an assistant (Johnston & Thomas, 1995, pp. 56-58).

   In 3D animation the computer automatically interpolates the in-betweens therefore, if one would create a complete pose at a time it would be very difficult to control how the in-betweens came out. The correct approach is to set the various parameters of every key pose one at a time. One should begin by key posing the translation on one axis at a time and only when each of them have the wanted animation one should work down to rotation and scale working hierarchically trough each parameter. Doing so allows for different extremes and in-betweens for each parameter and or axis giving one more control over the spacing of the in-betweens and also over the slow in and out. (Lasseter, 1987, p. 5)

5. Follow through and overlapping action – when a character suddenly stops its limbs, hair, clothing, among others, continue to move following the character line of action with a delay, this is called follow through. Overlapping is when a character is moving in one direc-

[23] [11th August 2014]: <http://www.87seconds.com/assets/img/Blog/4-Twelve-Principles/03_staging-disney-WardKimball.png>

tion but some parts of his body are moving in the opposite direction, for example when a character suddenly changes direction but his head continues to move in the original direction (Johnston & Thomas, 1995, pp. 59-62).

Because objects have different masses they react differently to gravity. Not all parts of a character move at the same speed during an action. A common example is the hair or tail moving slower than the rest of the body. By overlapping actions the animation becomes more fluid when portraying a series of different actions. (Lasseter, 1987, pp. 5, 6)

Fig. 38 – Follow through and overlapping action example

As we can see in the example above[24] the action on the cape finishes long after the one of the character. So we have two overlapping actions the character landing and the cape settling down and they occur in different timings. This helps to show that the body has a different mass than the cape and makes the stopping of the character less abrupt.

6. Slow in and slow out – in the beginning and the end of an action the frames or drawings are closer together. This makes the action slower at the beginning and the end turning it smoother (Johnston & Thomas, 1995, p. 62).

   By applying this principle the animator makes the key-poses more perceptible to the audience causing the character to smoothly change from one key pose to another. In 3D animation software the slow in and out is controlled through the adjustment of the splines[25] of the animation curves. (Lasseter, 1987, pp. 6, 7)

[24] [11th August 2014]: <http://margarettsang.files.wordpress.com/2013/03/principi_animazione_follow_through.jpg>
[25] Spline – in this context it refers to adjusting the slant of the control points (key-frames) in the animation curve.

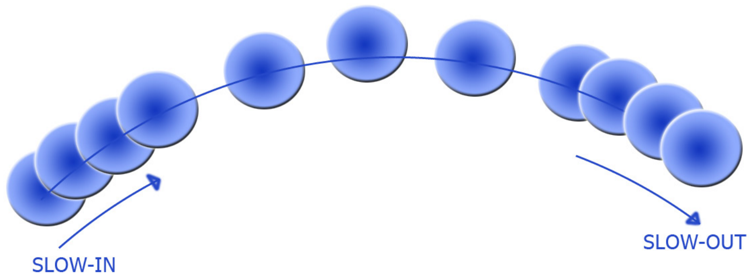


Fig. 39 – Slow in and out example

As we can see in the example above[26] the in-betweens are closer together in the beginning and end of the action. This causes different actions to blend together smoothly and allows for the audience to clearly perceive the key poses.

7. Arcs – most organic and natural movements follow arcs or circles. If the animation follows these arcs turns out smoother and more lifelike. If we analyse arm or leg movements it is easy see that they move in arcs as a pendulum (Johnston & Thomas, 1995, pp. 62, 63).

   When observing nature it becomes apparent that arcs are the most effortless and economic routes for objects to move from one place to another. This principle is applied in animation in order to make it feel organic and smooth. (Lasseter, 1987, p. 7)

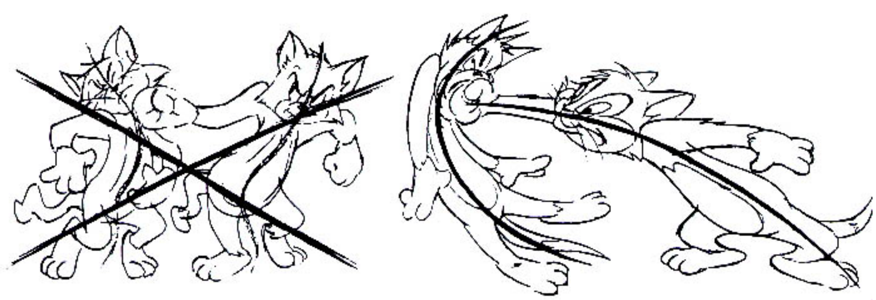


Fig. 40 – Arcs example

As we can see in the example above[27] the action feels more lifelike and organic in the right side where the character's line of action follows an arc.

[26] [10th August 2014]: <http://mile.mmu.edu.my/orion/luqman/files/2013/04/SLOW-OUT-AND-SLOW-IN.jpg>
[27] [9th August 2014]: <http://www.viz.tamu.edu/faculty/parke/ends489f00/section6/lofaCats.jpg>

8. Secondary action – this type of action complements the main action helping to translate the character's personality and feelings. For example, when a character has tripped and shakes his head while getting up (Johnston & Thomas, 1995, pp. 63, 64).

   The secondary action is a consequence of other action, it is there to emphasize the primary one, if it somehow overshadows the primary one or makes the scene confusing it means this principle was not well applied. (Lasseter, 1987, p. 8)

Fig. 41 – Secondary action example

   In the example shown above[28] the chopping of the lemon is a secondary and independent action to emphasize the fact that the character is angry, in spite of saying she is not angry.

9. Timing – the number of drawings or frames in each action determine the time it takes to play out. The variance of timing helps to tell the story and keep the audience interested. With more drawings or frames the action will seem smoother and slower, while less drawings or frames turn the action faster. When well used timing helps set the mood for the story and to give different personalities to the characters (Johnston & Thomas, 1995, pp. 64, 65).

   The timing is the speed at which an action takes place. Depending on how the speed of the action varies over time it is possible to portray the weight of an animated object. If the movement begins slowly and takes a long time to stop at the end it shows we are dealing with a heavy object. The speed at which a character move and the way this speed varies over time can be used to portray the state of mind or personality of such character. If the

[28] [8th August 2014]: <http://jordannwharton.files.wordpress.com/2012/09/secondaryaction.jpg>

character moves fast it can mean it is feeling anxious or excited in the other hand if it moves slow it can mean it is feeling sad. (Lasseter, 1987, pp. 3,4)

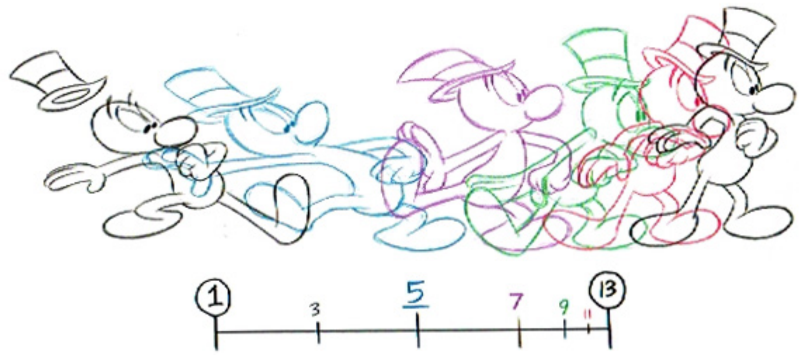


Fig. 42 – Timing example

As we can see in the example above[29], timing not only refers to the time an action takes to play but also to the way the speed of said action varies over time.

10. Exaggeration – it is to exaggerate reality, which could mean to caricaturize a facial expression or exaggerate an action. For example when a character is surprised and his eyes pop out of their sockets (Johnston & Thomas, 1995, pp. 65, 66).

 When applying the exaggeration principle the animator must be careful not to over do it. Exaggeration should be there to emphasize an idea without overshadowing the idea itself. (Lasseter, 1987, pp. 7,8)

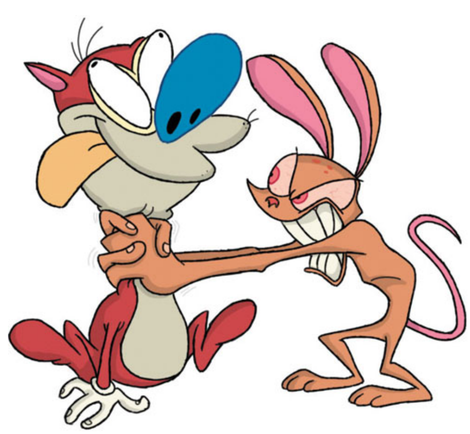


Fig. 43 – Exaggeration example

[29] [10th August 2014]: <http://www.animatorisland.com/wp-content/uploads/2012/05/charanim_03.png>

In Nickelodeon's *The Ren & Stimpy Show's* (Kricfalusi, 1991) image above[30] we can see that the proportions of *Ren*'s hands are off, they are too big in comparison with the rest of the arms and *Stimpy*'s eyes and nose are sticking out of his face. All of the above is there to emphasize the fact that a very irritated *Ren* is strangling *Stimpy*.

11. Solid drawing – the animators base their drawings on real life, volume, shape and light and then adapt this information to the animated world giving the illusion of three-dimensional character. (Johnston & Thomas, 1995, pp. 66-68)

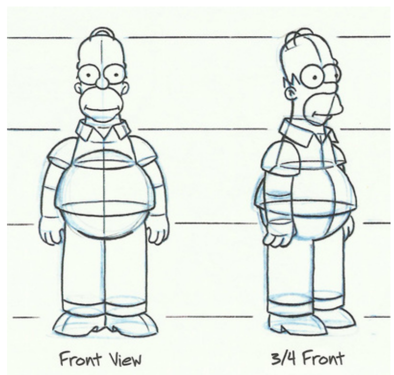


Fig. 44 – Solid drawing example

As we can see in the example above[31] by drawing *The Simpsons* (Groening, 1989) *Homer Simpson* in an angle gives it the illusion of volume. In 2D animation the character has to constantly be redrawn in every frame while maintaining the illusion of volume.

Seeing as in 3D animation characters are modelled in a three-dimensional space this principle does not directly apply to it. The aspects of solid drawing like volume and shape should be observed in the modelling and rigging stage of the character's creation. When one starts animating the character is already modelled and rigged, therefore this principle does not really apply to 3D animation itself as it did in 2D animation.

It is also possible to accentuate the 3D aspect of an object by better choosing camera angles, by manipulating the light or even the camera focal lens.

[30] [10th August 2014]: <http://www.smashingmagazine.com/wp-content/uploads/2012/10/a07.33.jpg>
[31] [10th August 2014]: <http://mnmtanimation.weebly.com/uploads/9/7/5/3/9753703/5204398.jpg?399>

12. Appeal – a good character must have appeal independently if it is a good or bad, beautiful or ugly character they all must be appealing. This is achieved through an easy to read design that transmits personality. (Johnston & Thomas, 1995, pp. 68, 69)

    Appeal does not mean that a character has to be pretty. It means the character should have a simple and easy to read design but at the same time it should have charisma in order to make the audience interested. (Lasseter, 1987, p. 8)

Fig. 45 – Appeal example

As we can see in Aardman's *Wallace and Gromit*'s image above[32] the characters' design is simple which makes them easy to read.

2.3.2. The twelve principles of animation applied to motion capture

In Disney studios' early days, animators where studying the best approach to animation, trying to make their characters come alive. Actors, comedians and sometimes animators themselves would portray a series of actions and expressions in front of a camera to help capture the personality of a character. The films created would be printed frame-by-frame and thoroughly studied, they called these printed frames photostats. By analysing these photostats animators realized that their theories concerning the animation principles like squash and stretch, follow through and overlapping action, timing, exaggeration actually occurred in real life action. They began to realize small aspects of movement that occurred to fast to be detected by the human eye. (Johnston & Thomas, 1995, p. 321)

[32] [11th August 2014]: <http://facweb.cs.depaul.edu/sgrais/images/AnimationPrinciples/wg2.jpg>

A performer who has suffered an injury may, for example favour a leg while walking, this may be so subtle that the human eye won't be able to see it but the motion capture system will definitely capture it. (Liverman, 2004, p. 183)

The more advanced motion capture systems of today are able to capture the subtleties of human movement. Therefore, depending on how the performance is directed, it is possible to obtain motions that comply with most of the twelve principles of animation right from the start. The actor can perform the actions with principles like timing, anticipation, staging, follow trough and overlapping action, slow in and out, arcs, exaggeration and secondary action in mind. It may seem too much to keep in mind while acting, but it is possible to do so if one breaks the actions into small segments and if the animation director closely directs the actor while paying attention to his movement.

The twelve principles of animation were explained in the previous chapter therefore, there is no need to further develop the subject here. When dealing with motion capture the animation director is the animator and the performance artist is the character. Instead of using the 3D software to animate the CG character he has to direct the actor in order to achieve the desired animation.

While making use of the real-time feedback it is possible to try to make sure that the motion is translating to the CG character as intended.

When working with motion capture the system does not capture the natural squash and stretch that occurs on the performer's body, this information has to be added later on in the post capture phase. This can be done manually, by key-framing the scale of the character's body parts, although it can become a very time consuming process in complex actions, and can also be done automatically through the application of filters.

There have been several attempts in finding an automated solution for editing motion-captured data in a way that the final animation obeys the principles of animation. One of these attempts was *The Cartoon Animation Filter* (Agrawala, Cohen, Drucker, & Wang, 2006). In this paper the authors present a filter that when applied to the motion data adds anticipation, follow-through and squash and stretch. When it comes to squash and stretch this filter only analyses the vertical motion of the root node therefore, it is only applied to the vertical scale of the whole figure. The authors of this paper admit that the filtered animation's final results do not match the ones that can be obtained in an experienced professional animator's key-framed animation.

When dealing with staging one can direct the performer in order to make the actions as clear as possible as to convey the desired emotion. When staging a performance an animation director usually has to be sure of the camera angle before hand. This may not be the case when using motion capture. There is no need to choose a specific camera angle for one can apply the motion data to a 3D character independently of its relative position on set or the position of the camera. That being said it is still important that the director knows what camera angle he wants before the capture in order to save the animators the trouble of repositioning the characters in the motion editing phase.

When dealing with motion capture the motion is captured frame by frame so the actor has some freedom to perform the action in a "straight ahead manner" but it is also possible, if the actions are broken into short actions, for the director to ask the actor to perform some specific key poses.

It is possible through the use of props to capture the movement of clothing items like for instance capes or even appendages like tails although with most of these props they can sometimes occlude the body's markers therefore hurting the quality of the motion data from the body. Therefore, it is best to add non-body follow through and overlapping action in the post capture phase.

The same way solid drawing doesn't directly apply to 3D animation it is the same case when talking about motion capture animation. The aspects of this principle are addressed in the modelling and rigging phases before the capture's start.

As it was stated in the sub-chapter before this one appeal has more to do with character design than with its animation therefore, it doesn't make much sense to talk about it here. It is still possible to make a character more appealing through the way it performs its actions, they should be clear and easy to read by the audience. Therefore, the animation director should have this principle in mind when directing the performer.

2.3.3. Typical uses of motion capture

Animators at Disney Studios found that whenever they recreated the action to close to the original photostats or copied it the results came out eerie and strange. They realized they had to adapt the movement to the proportions and shapes of their cartoon characters in order to make it work. Furthermore, it became apparent that it was not necessary to incorporate every aspect of the live action movement into the cartoon character. The animators could and should choose what to show the audience using the actions or the parts of the actions that emphasized the point they wanted to make in each scene. (Johnston & Thomas, 1995, p. 323)

The same way Disney's animators battled with eeriness and strangeness in their animation while using rotoscopy today's animators are battling with the same effects in motion captured animation.

Throughout the years, Robert Zemeckis, an American movie director, directed a number of animated movies, which were entirely performance captured like for instance, *The Polar Express* (Zemeckis, 2004), *Beowulf* (Zemeckis, 2007), *A Christmas Carol* (Zemeckis, 2009), among others. The reviews of these three movies shared a common aspect, all of them stated characters looked fake, eerie and strange.

If we look at Disney's animators' experience with the rotoscope it is easy to establish a parallel with what is happening with motion-captured animation nowadays. The real live-action movements do not translate well into the cartoon or even into the more realistic characters. On the other hand it seems to work very well with less human-like characters in photo-realistic environments like with the aliens from *Avatar* (Cameron, 2009), *Gollum* from the *Lord of the Rings* trilogy (Jackson, The Lord of The Rings Trilogy, 2001-2003), *Kong* from *King Kong* (Jackson, 2005) and *Caesar* and the rest of the apes from *Rise of the Planet of the Apes* (Wyatt, 2011).

In 1970, Masahiro Mori, a Japanese roboticist, published an article where he expressed the theory of "The Uncanny Valley". Even though this theory was developed with robotics in mind it also applies to the world of CG animation. As exemplified in the graph below[33] the emotion response, or familiarity, of the audience is worst in a specific interval between the realism of a stuffed animal and that of a living person. The audience reacts worse to a realistic character that is not quite real than to a very stylized character with some humanoid aspects. This is why the characters in films such as *Final Fantasy* (Sakaguchi & Sakakibara, 2001) and *The Polar Express* (Zemeckis, 2004) are described as lifeless or creepy.

[33] [20th of August]: <http://www.nature.com/srep/2012/121115/srep00864/images/srep00864-f1.jpg>

Fig. 46 and 47 – Frames from The Polar Express and Final Fantasy: The Spirits Within

The characters' design and animation aim for realism but don't quite achieve it. As humans we are accustomed to the subtleties of the human face and its expressions therefore, we end up unconsciously concentrating in these little details that are off in these CG characters, such as the lack of skin translucency and the stillness of the eyes. (O'Neill, 2008, pp. 10, 11)

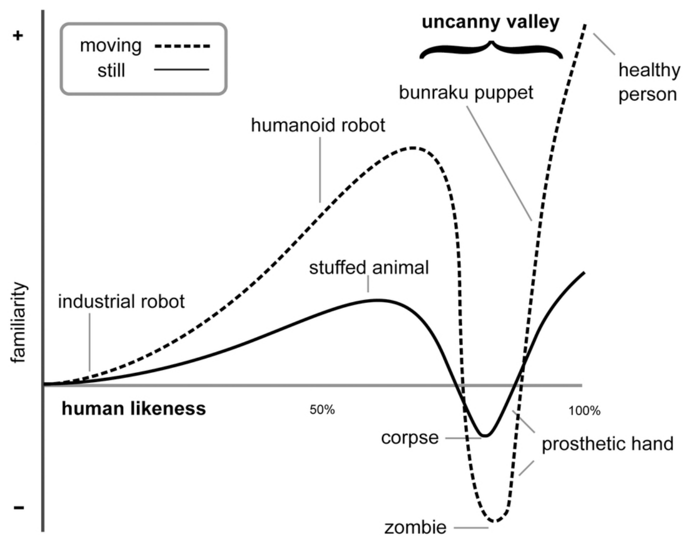


Fig. 48 – Uncanny valley graph

The first successful performance captured CG character in a live action film was *Gollum* in *The Lord of the Rings Trilogy* (Jackson, 2001-2003). *Gollum* is a CG photo-realistic animated character that interacts with a live action cast in these films.

At the time this movie was produced technology did not allow for the capture of facial, hands and feet performance neither for on set capture. The scenes would firstly be shot on set with all the live action actors and Andy Serkis[34] in a white jumpsuit, this allowed for interaction between all

[34] Andy Serkis – Actor who played *Gollum* in *The Lord of the Rings trilogy* (Jackson, 2001-2003).

the actors involved in the scene to take place. In a next phase Andy Serkis would go alone into a motion capture studio and perform the same scene by himself and finally, VFX artists would digitally replace Andy Serkis by Gollum in the filmed footage.[35]

This seems a little restrictive performance wise, the actor has to perform alone in a sterile studio while trying to match a performance that was shot sometimes over a year before.

Facial expressions, hands and feet animation were later key-framed in by a team of animators who were also responsible for refining the performance when the director demanded it. According to Randall Cook, Animation supervisor in the three *Lord of the Rings* (Jackson, 2001-2003) films, as motion capture technology evolved during production less and less refining was necessary even though facial, hand and feet animation was still fully key-framed by the animation team[36].

All things considered the result was a memorable character with brilliant performances that was able to stand out in a film filled with great performances by great actors.

The Adventures of Tintin (Spielberg, 2011) was one of the latest examples in fully motion-captured animation to be released.

In this film there is a different approach to character design when compared to the more realistic approach in *The Polar Express* (Zemeckis, 2004). In *Tintin* (Spielberg, 2011) the artists strive to capture the cartoony aspects of Hergé's[37] original creations. The characters exhibit features like prolonged noses and sausage fingers in extension to the proportions of facial features being somewhat stylized as well. This aspect is most evident in Thomson and Thompson's features. They both have very small eyes that are positioned a little too close to each other.

---

[35] This information was obtained from an article by Gregory Singer in Animation World Network. [25th August 2014]: <http://www.awn.com/animationworld/two-towers-face-face-gollum>

[36] This information was obtained from an article in Cartoon Brew written by Amid Amidi. [25th August 2014]: <http://www.cartoonbrew.com/motion-capture/lord-of-the-rings-animation-supervisor-randall-william-cook-speaks-out-on-andy-serkis-99439.html>

[37] Hergé – Pen name for Belgian cartoonist Georges Prosper Remi, original creator of *The Adventures of Tintin* comic book series.

Fig. 49, 50 and 51 – Captain Haddock, Thomson and Thompson, Silk

According to James Beard[38], animation supervisor in *The Adventures of Tintin* (Spielberg, 2011), Weta[39] used the same motion capture system that was developed for *Avatar* (Cameron, 2009). The actors would perform together using motion capture suits and head rigs were used to capture facial motion.

Fig. 52 – Actors Jamie Bell and Andy Serkis

This system allowed for the capture of motion data from the actor's face, body, eyes and thumb, index and pinkie fingers. A team of animators would use this data and adapt the performances of the actors to the cartoony characters. James Beard also says there was an effort to remain true to the actors' performances while adapting them to the characters which didn't look like the actors

[38] This information was obtained from an article by Barbara Robertson in Volume 34 Issue 9 of Computer Graphics World. [27th August]: <http://www.cgw.com/Publications/CGW/2011/Volume-34-Issue-9-Dec-Jan-2012-/Animation-Evolution.aspx >

[39] Weta – VFX company located in New Zealand which credits include: *The Lord of the Rings trilogy* (Jackson, 2001-2003), *King Kong* (Jackson, 2005), *Avatar* (Cameron, 2009), among others.

and also while taking Steven Spielberg's direction slightly adjusting performances creating an animated film in the process.

The more stylized character designs allied with better and more accurate motion capture systems contributed for this film's box office success and for a significant advancement in motion capture animation. According to one *The Adventures of Tintin*'s review,[40] motion capture animation has evolved to a point where although it still isn't perfect it no longer disrupts the overall viewing experience.

2.3.4. Atypical uses of motion capture

Traditionally motion capture technology has been used throughout the years as a means of producing hyper-realistic styled animation with various applications. Along with the technology's evolution more unorthodox applications of it appeared as well.

Turning to the Masters: Motion Capturing Cartoons (Bregler, Chuang, Deshpande, & Loeb, 2002) presents a method of tracking the motion of traditionally animated cartoons and retarget it into 3D models. The user will draw a contour of selected key shapes in the source material's digitized video and *Cartoon capture* will automatically create motion curve data for the entire sequence using this information. To retarget the motion data the user most manually match the selected key poses in the target model, this will allow *Cartoon capture* to match and retarget the animation in the remaining frames automatically.

Nowadays large public motion data bases exist and it is possible to purchase a wide variety of motion captured animations for personal or commercial use. With this method the authors suggest it would be possible to create a motion data base using traditionally drawn animation which would allow for fast creation of high quality animations with little effort. *Cartoon capture* would also allow for professional animators to easily retarget hand drawn pencil tests to their target characters. According to the authors the final animations maintain the style of the original animation and are expressive and compelling.

In *The Cartoon Animation Filter* (Agrawala, Cohen, Drucker, & Wang, 2006) the authors present a filter that when applied to the motion data adds anticipation, follow-through and squash and stretch to the animation. This tool is very simple to apply, the user only has to specify the overall

---

[40] Review written for the Cartoon Brew website by Amid Amidi. [22nd August 2014]: <http://www.cartoonbrew.com/feature-film/tintin-ushers-in-a-new-era-of-photoreal-cartoons-54672.html>

strength of the filter and all the other parameters are calculated automatically. When it comes to squash and stretch this filter only analyses the vertical motion of the root node therefore, it is only applied to the vertical scale of the whole figure. The advantage of this process is that it allows for very fast results making it passible of using in previsualizations or real-time animation.

The authors conclude that the filtered animation still isn't at the same level as one key-frame animated by a professional animator.

Martin L'Heureux, an Animation director for Crytek Germany, helped to develop a tool that when applied to the motion captured data would automatically create a more cartoony styled animation. This tool automatically creates an overlap in the upper body motion data curve simulating squash and stretch. Martin was able to create a cartoony animation of big foot dancing applying this tool to motion captured data and according to him sixty per cent of said animation was automatically obtained with the tool while the remaining forty per cent was key-framed.[41]

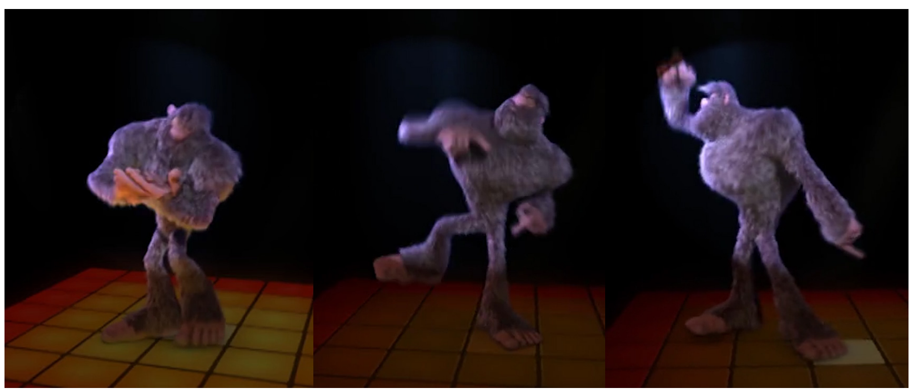


Fig. 53 – Frames from Martin L'Heureux's showreel

Animating Non-Humanoid Characters with Human Motion Data (Ariki, Hodgins, & Yamane, 2010) explores the use of human motion captured animation in non-humanoid characters. The authors present a method of successfully animating a lamp, a penguin and a squirrel using a human actor's captured performance.

The process of obtaining non-humanoid animation begins with capturing a human actor performing in the style of the target character. Later the user will choose key poses from the captured motion and manually recreate them in the non-humanoid character through the use of 3D animation software. Using the matching key poses of the motion data and the non-humanoid character a sta-

[41] A transcript of an e-mail exchange with Martin L'Heureux is annexed to this dissertation.

tistical map is automatically created. Finally the whole sequence is translated to the non-humanoid character through the automatic mapping of every frame using the statistical map.

Fig. 54 – Non-humanoid characters animated using human motion captured data

There are still a few limitations in this system. The mapping accuracy significantly decreases depending on the key poses matched by the user in the initial step, this can require some time consuming adjusting of the selected key poses. The system does not take in account character geometry which can sometimes lead to collisions in the body during animation. And lastly it isn't possible to animate limbs non-existent in the human body as for instance the squirrel's tail.

According to the authors this method significantly reduces the production time necessary to create non-humanoid animation in comparison with traditional key-frame animation.

Even with its limitations this method shows that it is possible to use human motion captured data to animate various anthropomorphic characters. It seems safe to assume that if it is possible to match human movement with animals and inanimate objects' proportions it may also be possible to match it with cartoony characters' proportions and shapes as well.

Despite the fact that some limitations exist in the described processes a tendency to break away from traditional realistic motion captured animation and find new uses for this constantly evolving technology is evident. Animators and scientists continue to strive for faster and more accurate ways of giving "life" to animated characters.

3 Project Napoleon's Unsung Battle

3.1. Production overview

In the initial phase of this project a concept for the story had to be found. The story that was ultimately developed was the third of a list of possible ideas. Both of the first two stories were developed to some extent until found unworthy for production, which in term lead to a significant delay in this initial stage.

After the approval of the concept for the story a script was written which was followed by creation of a storyboard and an animatic. As soon as the concept was approved, the gathering of various references began. This included animation and motion references, costumes and architectural references among other things.

At the same time of the storyboard and animatic's production, work began on character design. After the approval of the character's model sheet the development of its 3D model began. The most significant objects of the set were also modelled in this stage.

On completion of the character's model, rigging began. For this project an original rig was created. The overly technical nature of this task allied with some inexperience in rigging led to significant delays in production schedule.

Next texturing for the character and set began. After basic textures were create began the development of the layout. At this stage the storyboard and animatic were still being revised.

In the blocking phase the character was posed in the more important key pose in order to test the rig and to create a 3D version of the animatic.

In the February the first animation tests began. A capture session took place in which simple walk cycles were captured in order to test the rig and motion retargeting to the model.

After the successful tests, the animation stage began. Two capture sessions were enough to capture the entirety of motions required for this project. Later on a shorter capture session took place to refine small aspects of a few motions.

At the same time of the animation stage there were still adjustments being made to several aspects such as story, camera angles, texturing among other things. The overwhelming amount of tasks to perform at this stage led to less time being spent on editing and refining the animation. At the same time as all of the above tasks were being performed the lighting stage began.

During production, pre-visualization renders for the entire film were required by the project mentors on several occasions. Even though this was extremely important in order to spot overall flaws in the project it required a lot of time to be spent on this task, time which wasn't accounted for while projecting the production schedule.

Even though this project was completed and presented in time for the deadline, several delays during production led to a significant drop in the amount of time dedicated to editing and refining captured animation, which in term led to an overall quality of the resulting animation below what was expected.

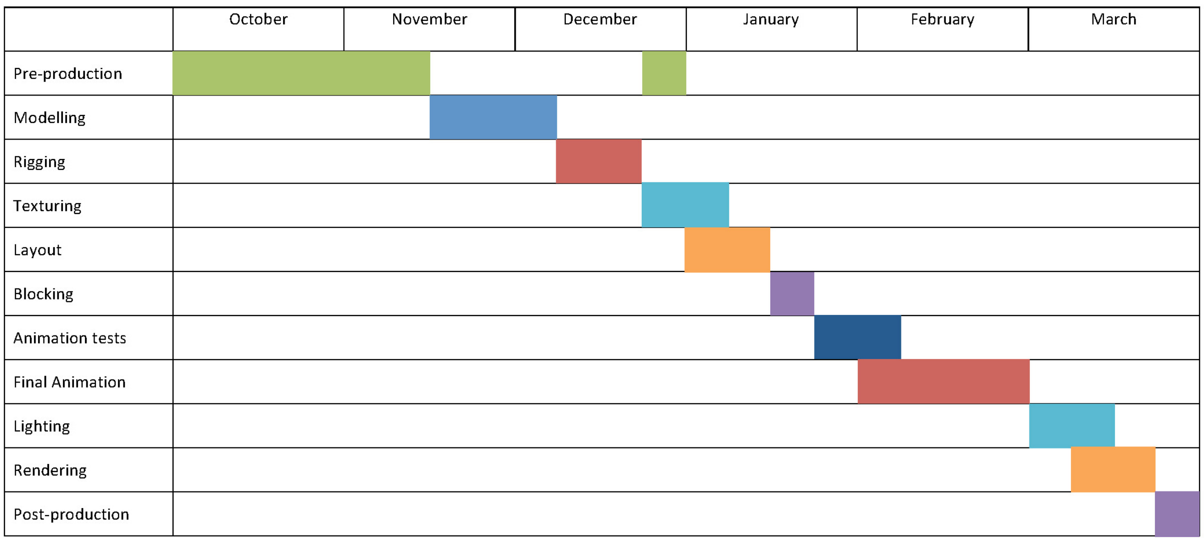


Fig. 55 – Napoleon's Unsung Battle production schedule established in October 2013

3.1.1. Pre-production

To come up with an interesting concept for a story was an extremely challenging task. The limited amount of production time and number of people involved in this project dictated it had to be a very sort film, ideally with no more than three minutes of duration. It is a complicated task to tell a compelling story in a short amount of time especially for the inexperienced storywriter. With the first two failed attempts the story found a way of growing out of its boundaries despite the efforts to keep it simple. Finally a decision was made to tell a story about a historic and recognizable character making for an easier introduction to the public and allowing for more time to be spent on the telling of the story itself

Seeing as there is no dialogue in this film the task of writing an initial script was straightforward and fast. Efforts were made to make a thorough written description of the action taking place in the story. The script was continuously revised right until the final stages of production due to small adjustments to the story that were deemed necessary.

On completion of the initial script a storyboard was drawn. This was an extremely complicated task due to poor drafting skills and difficulties felt in visualizing and translating the story in 2D form. Reference videos were filmed at this time but proved unhelpful in terms of storyboarding. The storyboard results lacked in detail and therefore, failed to fulfil their task. Most of the camera angles had to be revised later on in production with help of 3D software and initial basic models of character and set.

Seeing as the animatic is intrinsically related to the storyboard its quality suffered because of that. Efforts were made to find the right timing for each of the key frames depicted in the storyboard. The poor quality of the storyboard made the understanding of timing for the animatic complicated therefore, the timings had to be revised later on using 3D software and early models of character and set.

Thanks to the particular style of animation for this project being chosen at a very early stage in production, the gathering of video references began early as well. Several examples of cartoony animation were viewed and analysed with special attention dedicated to the Warner Brothers series of cartoon shorts *Looney Tunes*[42] and the Hanna-Barbera series of cartoon shorts *Tom and Jerry*[43].

Due to the story's strong comical aspect and lack of dialogue some examples of early silent comic cinema were viewed and analysed as well, such as Laurel and Hardy[44] and Buster Keaton[45] films.

A video of a portrayal of this project's story was filmed in order to serve as a study and reference for the upcoming tasks.

A great number of photographical references were gathered as well. An extensive search for records of costumes and architecture of XVIII century France was conducted. This research proved

[42] Looney Tunes – Series of cartoon animated shorts produced by Warner Brothers and directed by some of the greatest cartoon directors in animation history, like for instance: Tex Avery, Friz Freleng, Ub Iwerks and Chuck Jones. Several of these shorts were nominated and or won Academy Oscar Awards.

[43] Tom and Jerry – Series of cartoon animated shorts produced by Hanna-Barbera and directed by Gene Deitch, Chuck Jones among others. This series won seven Academy Awards for Animated Short Film.

[44] Laurel and Hardy – comedy double act that starred in a number of physical comedy films in the early American silent cinema era.

[45] Buster Keaton – American actor and filmmaker known for his physical comedy films in the early American silent cinema era.

invaluable for the modelling and texturing of the character's clothes and of the set. Several of Napoleon's painted portraits were also analysed in order to observe and try to incorporate some of the real historical character's physical traits into the animated one.

The character design was one of the most well accomplished tasks in this production. Using the references gathered several iterations of a cartoony *Napoleon* were rendered until the final design was found. The resulting character had a simple design that transmitted personality and a funny look to it.

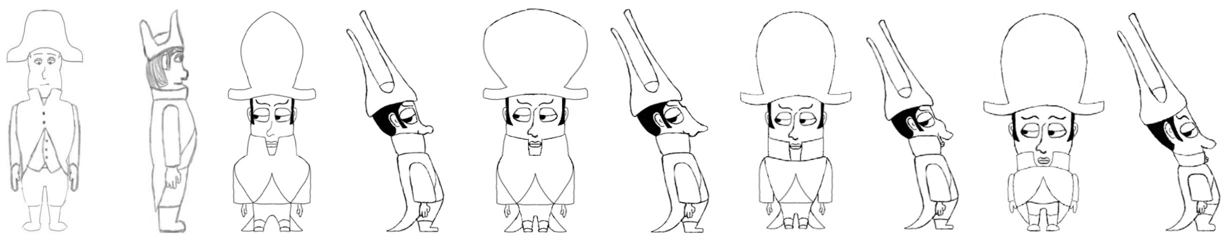


Fig. 56 – Some iterations of Napoleon's design

There were several delays in the initial stages of pre-production. The poor results of the story-board and animatic led to reviewing and alteration of several aspects of the film in more advanced stages of production. This in term, led to more delays which ultimately hindered the final quality of this project.

3.1.2. Production

The modelling stage was completed without any setbacks. Special attention was put into the topology and geometry of the character. Proper topology guaranteed the character deformed as intended. Geometry was kept to a minimum in order to assure that the final model was kept light for rendering purposes and to allow for real-time feedback in the capture session phase.

A lot time was spent on the rigging and skinning of the character. A custom rig was created following the rigging tutorial by Digital Tutors called *Cartoon Character Rigging in Maya*. In this phase special attention was put into guaranteeing the orientation of the character's joints matched the one of the joints in the skeleton from the motion capture software. This step ensured that the motion data could be properly retargeted to the character later on.

This tutorial proposed a method of rig construction that made the arms, legs and torso of the character automatically scale up or down according to the relative position of the controls. For instance, if the distance from the wrist joint to the shoulder joint increased in comparison to its standard the character's arm with stretch and when the opposite occurred the arm would squash. The tails in the back of *Napoleon's* coat were rigged as well, for this *Maya's* hair system was used. The hair system allowed for the coat to be animated automatically by *Maya's* dynamics system. The mass and rigidity parameters needed some testing and adjusting but his method, proposed in *The Skinned Character Rig: Skinning and Deformations with Carlo Sansonetti* by Gnomon Workshop, allowed for some control in animating the rig on top of the dynamics generated animation. For the skinning part of this project the same tutorial by Gnomon Workshop was followed. This tutorial proposed the use of a plug-in in which the user could manually adjust how the character's geometry would deform in extreme poses. This proved invaluable in guaranteeing that the character's several layers of clothing interacted and deformed properly.

Fig. 57 – Frame from Napoleon's Unsung Battle

Due to the cartoony style of the animation textures were kept simple. Efforts were made in order to duplicate the flat and colourful look of the cartoon classics. The creation of normal maps was used to simulate details in the character's clothing instead of building them into the geometry. The textures were extensively revised in the lighting stage especially, in the reflectiveness and specularity aspects.

Fig. 58 – Frame from "Napoleon's Unsung Battle"

In the layout stage, the character was positioned on set for each scene in order for the camera angles to be chosen. Due to problems experienced in the storyboard production most of the work that should have been completed then was done in the layout stage. Instead of just matching the camera angles to the ones in the storyboard a lot of reviewing and testing had to be done.

In the blocking stage the character was posed for the most important key-frames of the story. Some of these frames were later used as visual reference for the motion capture stage. Using pre-visualization renders from the key-poses several versions of animatics were made in order to project the timings for the animation.

In order to test the integrity of the character's rig and also the retargeting of motion data an early motion capture session was scheduled. In this first session only simple walk cycles were captured. The motion data was then retargeted to the character and the rig proved efficient. Despite the significant difference in the character's proportions in comparison with the ones from the performer the motion data translated well retaining its original motion and expressivity when retargeted. Only *Autodesk Maya's* retargeting function was used in the entirety of this project.

After the successful animation tests were concluded two capture sessions took place. In the first session most of the necessary motions were successfully captured. In the second session it was necessary two capture some new motions due to revisions in the story. Some of the motions of the first session were recaptured in an effort to get better performances and correct minor mistakes.

When the motion data was available the first step was to select the motions and the frame interval to use. After the choice was made the animation was retargeted to the character and it was positioned in the correct place in the set. The motion data came out almost perfect from the motion capture software therefore, only a small amount of clean-up was necessary. Next the props were added and their animation was key-framed. Animating of the props consisted mostly in constraining them to parts of the character's body, using the existent animation to drive the prop's movement. Some adjustments had to be made to the character's animation in order to guarantee there were no collisions between the props and other objects in the set. At this stage finger and facial animation was key-framed in.

The next step should have been the improvement of the animation performance by further editing it, due to the lack of time this was not possible.

An effort was made in order to keep the lighting scheme simple in order to accelerate the rendering process and also to achieve the flat look intended for this project. Seeing as the entirety of the story takes place in the same location the same lighting scheme was used for the whole film.

In the rendering stage a choice was made to render several different layers in order to allow more control in the compositing stage. In total there were six render layers in each scene: diffuse, indirect lighting, specularity, motion blur, camera depth and ambient occlusion. Due to the several rendering tests performed throughout this production this task was performed without any problems.

The production stage was hindered by delays in pre-production. Most of the necessary tasks were performed faster than originally planned in an effort to catch up to schedule. Even though some interesting results were achieved this project would have benefited if more time was put into lighting and texturing and most importantly into animation editing.

3.1.3. Post-production

In the compositing stage all the rendered layers were put together to form the final look of this film. Due to different light sources being rendered in separate layers it was still possible to do some fine adjustments to the lighting in this late stage. Due to difference in camera angles and positioning in the set relative to the light sources, colour varied a lot from scene to scene. Therefore an effort was made in order to normalize the colour range for the entire film.

Using the information from the rendered depth maps it was possible to change and even animate the camera's focal plane.

In a final stage small portions of a few frames had to be roto-painted in order to disguise minor mistakes, like for instance, the eye traversing the eyelid among other such occurrences. Minor this like

Seeing as post-production was the last phase there was not much time available. A lot was learned on compositing and to some extent this benefited the final look of the film. If more time was available it would have been beneficial to render and composite a reflection pass and to further test colour correction possibilities.

3.2. Motion capture

3.2.1. Preparation phase

The first step in was putting together a motion list. A lot of thought was put into writing this list. Actions were broken into simple to perform and direct motions when possible. Daily motion lists were put together before each capture session. The simpler motions where put first on the list in order to allow for the performer to warm up and get accustomed to the suit and character.

After the motion list was written visual references were gathered. These visual references either showed specific emotions or movements intended to explain what was wanted for each motion.

Due to the simplicity of this project it was easy to build and maintain updated a motion database. There was only one character, one performer and no props were captured. The motion database included exhaustive descriptions of each motion and notes taken during the capture sessions containing information on each take.

The marker configuration chosen was the *Vicon Blade*[46] fifty one markers default configuration.

When choosing the performer some thoughts were taken into consideration. For this type of cartoony animation it was important that the performer had a deep understanding of animation and of motion capture. The chosen performer is a computer animation student that has had experience both in performing for motion capture and editing motion capture data which made him the best possible choice for this task.

This task was effectively completed. In some cases a little more effort could have been put into gathering better visual references and when possible poses of the actual character could have worked better as reference.

[46] Motion capture software used on this project

3.2.2. Capture session phase

In the beginning of each capture session great attention was put in calibrating the cameras and skeleton and also in checking the marker placement on the performer's suit.

For the first capture session only a few simple walk cycles were captured. These were intended to test how the motion would retarget to the character.

After retargeting was tested the second session was scheduled. In the beginning of the second session the motions to be captured were discussed with the performer and visual references were shown. A significant part of the motion data used in this project was captured on this day. Initially the simpler walk cycles were captured in order to allow the performer to warm up and get into character.

In the third and final session some new motions were captured due to revising in the story. To make use of studio time and performer availability some of the already captured motions were recaptured in an attempt to attain better results.

During the second and third capture session detailed notes on each take were written in order to facilitate the choosing of the takes to use and edit in a posterior phase.

The capture sessions were filmed and the videos were used as reference in the retargeting and animation editing phases.

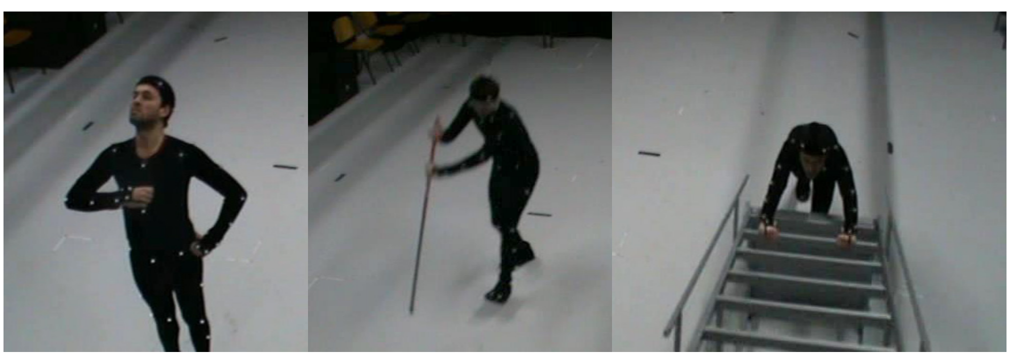


Fig. 59 – Motion capture session

Technical difficulties were experienced in the live feed-back function due to external plug-ins that were used in the construction of the character's rig therefore, it was not used. The props that were used to help the actor perform the motions were not captured at that time.

The capture phase was very successful, good performances where obtained and good quality data as well. The fact that live feedback did not work out properly was a setback. If it had been used the motions could have been captured with the character in its relative place on the virtual set which would have saved time in the animation editing phase. The same applies to the capture of the props.

3.2.3. Post-capture phase

The first step in this phase is to export and organize all of the motion data files into the production folders. The specificities of this projecting made the organizing of the motion data files extremely simple. There was only one character and only one person handling all the files therefore, it was easy to maintain everything organized and simple.

The next step is to analyse and clean up the motion data if necessary. In this project almost no clean-up was necessary for the selected takes. This was probably due to the attention put on the calibration of cameras and skeleton. The fact that there was only one performer being captured at a time and that the motion capture volume was small may have also contributed for clean motion data.

There was an effort to maintain things organized during production and the motion database was updated regularly with the notes from each capture session.

Due to the way this film was cut and also the way the motions were captured no blending of different motions was necessary. For one of the scenes it was necessary to cycle a running motion. It took some time and experimenting to find the right portion of the motion so it would cycle properly.

The method of animation editing chosen was mostly non-destructive editing. In some cases some key-frames were deleted. For most of the editing animation layers were added in order to maintain the original information. Firstly the character was positioned in the correct place in the set for each scene. The next step was to animate the props present in each scene. When these two tasks were completed an attempt of emphasizing the cartoony aspect of animation was made. Initially some key-frames were deleted in places where movement was frantic or unnecessary especially in the arms and hands. After this there was an effort to accentuate some of the key poses. Lastly facial and finger animation was key-framed in.

The first steps of this phase were successfully and rapidly completed. The low amount of files and the small number of people handling them made their organizing easy to achieve and maintain during production. The motion data was almost completely error free therefore, the clean-up stage was simple to complete. Unfortunately there wasn't enough time to properly attend to the animation editing task therefore, only a very shallow first pass was made.

3.3. Motion capture and animation review

All things considered, the intended cartoony styled animation was not successfully achieved in the most part of the film. This was mostly caused by the lack of time spent editing the motion data. Due to several delays in previous stages of this production, when the animation editing began there was not enough time left before the deadline to properly complete this task. Apart from processing the motion data and retargeting it to the character, little else was done animation wise in the post-capture phase. The next step would have been accentuating the most important poses through layered key-frame animation and in the process add squash and stretch as well. This would have made the animation more expressive and appealing.

During the pre-production stage an effort was made to procure a cartoon filter in order to be applied to the motion data. This search was unsuccessful. If it had been otherwise, even with the same time constraints, it would probably have been possible to obtain better results, animation wise.

The motion capture session results were satisfactory. All the initial pre-capture tasks were observed which in term led to successful capture sessions. All added, less than six hours were spent capturing motions. The visual references gathered made it easier for the performer to understand what the motion director intended. The motion list and motion database proved important in keeping things organized during the capture and post-capture phases. The well-organized workflow led to motion data processing and retargeting to be completed fast and efficiently.

This experience proved valuable and a lot was learned in the process of making this film. The importance of the motion list and database was made clear and saved a lot of time and effort during the capture and post-capture phases. The visual references provided important assistance in directing the performer and getting the best possible performances. Through the extensive research that was made for the production of the film of this dissertation a lot was learned on the subject of human motion and animation.

In order to obtain better results in the future more effort and attention has to be put into the preproduction stage and a big part of the production time has to be dedicated to animation editing.

4 Conclusions

Since the birth of animation animators have strived to copy real live motion in order to make their characters feel alive. With the invention of rotoscopy it was possible to accurately copy live motion. Animators soon realized that if they just copied exactly what they saw the animation would look strange. The artists at Disney Studios realized that in order to make the animation more appealing the original live motion had to be adapted. Due to significant differences in body proportions between the live actors and the cartoon characters adjustments had to be made. They could not simply copy every frame of the live motion, they had to choose which ones to use and which to exaggerate or simply overlook and on top of that make the necessary adjustments to make it work in the cartoony character.

Motion capture, which is sometimes referred in the industry as the devil's rotoscope, is merely a different tool to animate and bring life to characters. At this stage animators are still struggling to get the best results out of this powerful technology. If we compare *The Polar Express* (Zemeckis, 2004) to *The Adventures of Tintin* (Spielberg, 2011) it is possible to see it is getting closer and closer to the cartoony full of life style that Disney Studios achieved.

Even with technology constantly evolving the hand of the animator is still essential to imprint the artistry and expression in the animation.

Motion capture allows for shorter production times and smaller production teams which in term leads smaller budgets being required for production.

Weta digital and Vicon's efforts have made the experience of directing an animation movie come closer to the one of directing a live-action one. Steven Spielberg, even though a renowned movie director, had never directed an animation movie until *The Adventures of Tintin* (Spielberg, 2011).

Napoleon's Unsung Battle was produced in a relative short period by a single animator. The organization proposed in the second chapter of this dissertation made for faster and more efficient production of the captured motions. Failure to obtain cartoon filters led an increase in the animation editing. Several delays in this production's early stages made it impossible to dedicate the required time to the editing of the animation damaging its final results.

Important lessons were learned in the various production stages. The final animation lacked expressivity and was not cartoony enough. In spite of the achieved results we believe it was proven that cartoony animation can be obtained in shorter periods of time through the use of motion capture.

Bibliographic references

Agrawala, M; Cohen, M.; Drucker, S.; Wang, J. (2006). *The Cartoon Animation Filter*. ACM, The Association for Computer Machinery, Inc.

Ariki, Y.; Hodgins, J.; Yamane, K. (2010). *Animating Non-Humanoid Characters with Human Motion Data.* Eurographics/ACM SIGGRAPH Symposium on Computer Animation.

Barrier, M. (1999). *Hollywood cartoons: american animation in its golden age*. New York, USA: Oxford University Press.

Beiman, N. (2010). *Animated Performance: Bringing Imaginary Animal, Human and Fantasy Characters to Life.* Lausanne: AVA Book.

Blair, P. (1994). *Cartoon Animation.* California, USA: Walter Foster Publ.

Bredow, R.; Schaub, D.; Engle, R.; Kramer, D.; Hastings, A. (2005) *From Mocap to movie: the making of "The Polar Express"*. USA: ACM SIGGRAPH.

Bregler, C.; Chuang, E.; Deshpande, H.; Loeb, L. (2002). *Turning to the Masters: Motion Capturing Cartoons*. USA: ACM SIGGRAPH.

Fleisher, R. (2011). *Out of the Inkwell: Max Fleisher and the Animation Revolution.* Lexington, USA: University Press of Kentucky.

Furniss, M. (1998) *Art in Motion: Animation Aesthetics.* Sydney, Australia: John Libbey.

Hodgins, J.; Jenkins, O.; Sigal, L.; Vondrak, M. (2012). *Video-based 3D Motion Capture through Biped Control*. USA: SIGGRAPH.

Hooks, E. (2011). *Acting for Animators.* Abingdon, UK: Routledge.

Jones, A.; Ollif, J. (2007). *Thinking Animation Bridging the Gap Between 2D and CG.* USA: Thomson Course Technology PTR.

Kitagawa, M.; Windsor, B. (2008). *MoCap for Artists Workflow and Techniques for Motion Capture*. USA: Focal Press.

Kundert-Gibbs, J. (2009). *Action! Acting Lessons for CG Animators.* Indiana, USA: Wiley.

Lasseter, J. (1987). *Principles of Traditional Animation Applied to 3D Computer Animation.* San Rafael, California, USA: Pixar.

Liverman, M. (2004). *The Animator's Motion Capture Guide: Organizing, Managing, and Editing.* Hingham, Massachusetts, USA: Charles River Media.

Maestri, G. (1996). *Digital Character Animation.* Indianapolis, USA: New Riders.

Maltin, L. (1987). *Of Mice and Magic: A History of American Animated Cartoons.* New York, USA: Plume.

Muybridge, E. (1955). *The Human Figure in Motion.* New York, USA: Dover.

O'Neill, R. (2008). *Digital Character Development: Theory and Practice.* Burlington, Massachusetts, USA: Martin Kaufmann.

Selby, A. (2013). *Animation*. London, UK: Laurence King

Sito, T. (2013). *Moving Innovation: A History of Computer Animation.* Cambridge, USA: MIT.

Sturman, D. (1994). *A Brief History of Motion Capture for Computer Character Animation.* SIGGRAPH.

Thomas, F.; Johnston, O. (1981). *The Illusion of Life: Disney Animation.* New York, USA: Disney.

Webster, C. (2005). *Animation: The Mechanics of Motion.* Oxford, UK: Focal Press.

Webster, C. (2012). *Action Analysis for Animators.* Waltham, Massachusetts, USA: Focal Press.

Wellins, M. (2005). *Storytelling Through Animation.* Hingham, Massachusetts, USA: Charles River Media.

Wells, P. (1998). *Understanding Animation.* London, UK: Routledge.

Whitaker, H.; Hallas, J. (1981). *Timing for Animation.* Oxford, UK: Focal Press.

White, T. (1988). *The Animators Workbook.* New York, USA: Watson-Guptill.

Williams, R. (2001). *The Animator's Survival Kit.* London, UK: Faber and Faber.

Filmography

Blackton, J. (1906). *Humorous Phases of Funny Faces*. Vitagraph Company of America.

Cameron, J. (2009). *Avatar*. Twentieth Century Fox Film Corporation.

Cohl, E. (1908). *Fantasmagorie*. Société des Etablissements L. Gaumont.

Cotrell, W.; et al. (1938). *Snow White and the Seven Dwarves*. Walt Disney Productions.

Darnell, E.; McGrath, T. (2005). *Madagascar*. DreamWorks SKG.

Fleischer, D. (1924). *My Old Kentucky Home*. Out of the Inkwell Films.

Fleischer, D. (1939). *Gulliver's Travels*. Fleischer Studios.

Iwerks, U. (1928). *Steamboat Willie*. Walt Disney Productions.

Jackson, P. (2001). *Lord of the Rings: The Fellowship of the Ring*. New Line Cinema.

Jackson, P. (2002). *Lord of the Rings: The Two Towers*. New Line Cinema.

Jackson, P. (2003). *Lord of the Rings: The Return of the King*. New Line Cinema.

Jackson, P. (2005). *King Kong*. Universal Pictures.

Sakaguchi, H.; Sakakibara, M. (2001). *Final Fantasy: The Spirits Within*. Chris Lee Productions.

Spielberg, S. (2011). *The Adventures of Tintin*. Columbia Pictures.

Verbinsky, G. (2006). *The Pirates of the Caribbean: Dead Man's Chest*. Walt Disney Pictures.

Wyatt, R. (2009). *Rise of the Planet of the Apes*. Twentieth Century Fox Film Corporation.

Zemeckis, R. (2004). *The Polar Express*. Castle Rock Entertainment.

Zemeckis, R. (2007). *Beowulf*. Paramount Pictures.

Zemeckis, R (2009). *A Christmas Carol*. Walt Disney Pictures.

Other references

Sites

A Brief History of Motion-Capture, from Gollum to Caesar [5th of August 2014]: <https://www.yahoo.com/movies/a-brief-history-of-motion-capture-in-the-movies-91372735717.html>

Andy Serkis & the Evolution of Performance Capture Tech – Popular Mechanics. [27th August 2014]: <http://www.popularmechanics.com/technology/digital/visual-effects/andy-serkis-and-the-evolution-of-performance-capture-tech>

Animation Evolution – Computer Graphics World [27th August 2014]: <http://www.cgw.com/Publications/CGW/2011/Volume-34-Issue-9-Dec-Jan-2012-/Animation-Evolution.aspx>

Gollum and Me: My Precious Experience – Animation World Network [25th August 2014]: <http://www.awn.com/vfxworld/gollum-and-me-my-precious-experience>

“Lord of the Rings” Animation Supervisor Randall William Cook Speaks Out On Andy Serkis – Cartoon Brew. [25th August 2014]: <http://www.cartoonbrew.com/motion-capture/lord-of-the-rings-animation-supervisor-randall-william-cook-speaks-out-on-andy-serkis-99439.html>

Martin L’Heureux’s website (Crytek Animation Director) [17th of December 2013]: <http://www.martinlheureux.com/#!copy-of-tv-film/c182q>

Motion-capture Mania – Computer Graphics World [28th August 2014]: <http://www.cgw.com/Publications/CGW/2012/Volume-35-Issue-3-April-May-2012/Motion-Capture-Mania.aspx#articletop>

Raising the Animation Bar with “Tintin” [22nd of August]: <http://www.awn.com/animationworld/raising-animation-bar-tintin>

Spielberg Talks “Tintin” [22nd of August]: <http://www.awn.com/vfxworld/spielberg-talks-tintin>

Talking “Tintin” with Spielberg and Jackson [22nd of August 2014]: <http://www.awn.com/animationworld/talking-tintin-spielberg-and-jackson>

The Two Towers: Face to Face With Gollum – Animation World Network. [25th August 2014]: <http://www.awn.com/animationworld/two-towers-face-face-gollum>

The Man Who Would Be King: Q&A with Peter Jackson – Animation World Network. [25th August]: <http://www.awn.com/vfxworld/man-who-would-be-king-qa-peter-jackson>

"Tintin" Ushers in a New Era of Photoreal Cartoons [22nd of August 2014]: <http://www.cartoonbrew.com/feature-film/tintin-ushers-in-a-new-era-of-photoreal-cartoons-54672.html>

VFX Soup: Tintin VFX Supe Joe Letteri Talks 3D and Mocap [22nd of August 2014]: <http://library.creativecow.net/kaufman_debra/Tintin-Supe-Joe-Letteri_3D-mocap/1>

DVD Tutorials

Digital Tutors (2007). *Cartoon Character Rigging in Maya*. USA: Digital Tutors

Gnomon Workshop (2008). *The Skinned Character Rig: Skinning and Deformations with Carlo Sansonetti*. USA: Gnomon Workshop.

APPENDIX A

A DVD containing the film *Napoleon's Unsung Battle* is attached to this dissertation.

ANNEX A

Mail exchange with Martin L'Heureux:

On Tue, Dec 17, 2013 at 4:29 PM, Martin L'Heureux wrote:

Have a blast!

Martin

On Tue, Dec 17, 2013 at 4:18 PM, João P. Paiva wrote:

Good day,

Yes it helps a lot.
Thank you very much.
Is it ok if I mention the Big Foot animation and try to analyze it on my dissertation?

King regards,

João Paiva

On Tue, Dec 17, 2013 at 10:42 AM, Martin L'Heureux wrote:

You can find a cartoony animation using motion capture on my demo reel.

go to: http://www.martinlheureux.com/#!filmtv-showreel/cee5

look at 00:49. You will see Big foot walk on a dance floor and perform a disco dance move.

I used a cartoony parameter from a tool we created in Canada, Vancouver. The tool would read the body motion capture curve and apply a cartoony feel to the motion. The tool would also create an overlap on the upper body to enhance the squash and stretch illusion. 60% of the animation was done by the tool and the rest was hand keyed.

I hope this helps

Martin L'Heureux

On Tue, Dec 10, 2013 at 10:15 AM, João P. Paiva wrote:

Good day,

I had the pleasure of attending two of your lectures in Trojan Horse Was a Unicorn Festival. In one of those lectures you mentioned that in your studio you used motion capture to produce non-realistic/cartoony animation. This year I am writing my dissertation paper on the use of motion capture in non-realistic/cartoony animation. I would greatly appreciate if you could point me to some examples of cartoony animation produced with the use of motion capture or any other information you might have on the subject.

I am aware that you are a very busy person so I would appreciate any help you can provide.

Thanks in advance.

Kind regards,

João Paiva