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The Motion Capture Pipeline

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by

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Abstract

Motion Capture is an essential part of a world full of digital effects in movies and games. Understanding the pipelines between software is a crucial component of this research. Methods that create the motion capture structure today are reviewed, and how they are implemented in order to create the movements that we see in modern games and movies.
Keywords: Motion Capture, Mocap, Computer Graphics, 3D, Maya, MotionBuilder.

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1 Introduction

35,000 years ago, drawings of animals were painted on cave walls. On some of them the animals had four pairs of legs to show motion. [1] In 1968, "the flipper book" appeared. [1] Motion drawings were painted on a pad with multiple pages and when someone flipped the pages, the drawings seemed to be moving. My research will be focused on one of the newest areas in the historical timeline of animation, Motion capture.

We have since then developed new methods and techniques to refine the art of animation. Today with the aid of computers, animation has become an interesting new field, which differs somewhat from traditional animation techniques where ink and paper is used.

Although many hours of training are still required in order to create stunning computer animations, the digital method of "painting every frame" shares the same problem as the traditional skills of how to make weight, movement, and timing perform to the satisfaction of the viewer.

This paper will focus on a technique that is used to record live motion events and translating them to mathematical terms. By tracking an object with markers attached on various key points in space and over time, a three-dimensional representation can then be obtained.

Many different techniques of capturing motions exist today. Some systems use a camera that records the key positions of the object in focus and then combines them together digitally. There are also systems that use electromagnetic fields to track the markers on the object, and mechanical systems that for example determine the joint rotations of a human actor.

The aim of this research is to examine the pipeline that exists in different types of motion capture methods. Also, I want to determine how data and information is transferred from a test object with a motion capture rig to the available Autodesk Maya/MotionBuilder software for this project. I am planning on determining the pipeline used in this complicated process.

1.1 Hypothesis

Within the area of motion capture, I plan to conduct my research which will lead to a result that can be used by future students. Regardless of how well the motions are translated from the system to the software, I believe that anyone will be able to tell the difference between the captured data and the original footage due to imperfections that may occur.

1.2 Purpose of the research

Motion capture has become more common and the motion capture systems are now available for individuals. They can now be used with greater ease. The reasons for this research paper are to examine the process of transferring data from one medium to another and to explain the steps that need to be taken in consideration in order to have realistic movement.

1.3 Anticipated problems

The human eye is far superior when it comes to detection of any type of motion and the audience in a movie can in a matter of seconds see if animated humans or animals behave similar to the real world.

Today realism is a major factor and it is to a greater extent harder, almost impossible with the time provided on certain projects to create fully realistic human or animal movements and animations.

The techniques of motion capture rapidly speeds up the process of animating. It is widely used within game companies and in the movies. It saves time and creates the realism that the audience demands.

The pipeline between different software is a crucial part of a project and every component must work flawless in order to maintain professionalism, especially in the motion capture area where there are so many steps in the chain that leads to the end result. To achieve a result with a small margin of error is something that will always be the focus.

1.4 Questions at issue

The motion capture technology is an extensive area, and all data cannot be processed within this research paper. The main focus will be on the elements in the motion capture pipeline that are specially interesting and relevant for my research. The questions that will be focused on are;

- When and why is it better to use motion capture data?
- Why is motion capture used instead of key frame animation?
- How will Maya performed with MotionBuilder?
- Are there any limitations in the motion capture system?

Also in *EA games* “Fifa” series motion capturing was used to capture movements of famous football players, which added realism to the experience while playing the game.

Motion capture needs increased speed of the technology. The cost of the Mocap systems must be lowered so that independent artist and consumers can have more access and experiment with the technology. The more experimentation results in the increased of accuracy in the results.

2 Related work

Computer generated motion is today used in everything from action movies, commercials to games. In the trilogy "Matrix" directed by *Andy Wachowskiand* and *Larry Wachowski*, a large amount of work was created with the actors to capture their actions. [16] The information was then used to create special effects, where impossible moves were made, however they still seemed real and amazing.

2.1 Past research

In the history of animation, reducing the time and money for creating animated images has been a problem for producers.

Working with the pipelines of motion capture is an area where research has been conducted. Companies have wanted to establish better and faster approaches between the systems that capture the movements. Software research has been produced in order to create the systems that we have today. Even attempts to capture fluid based materials like tornados, smoke, flame, etc. from video references with the approach to explore vision based motion capture has been explored. [6]

Mike the talking head, was in 1988 a step towards *animators being able to direct control their character rather the drawing their actions*. Silicon Graphics worked with deGraf-Wahrman Inc in order to create a new type of animation tool that would allow animators to have a better control of their characters. They used different input sources to control the face and scanned in the facial movements used in pronunciation. This resulted in: *Mike mouthing the words as a person speaks into a microphone*. [17]

2.2 Current Research

Since motion capture is a technique that is still evolving, many companies and universities are trying to improve the technology and the performance of Mocap systems, as well as creating better algorithms for the software and better recording systems.

The University of Ohio is doing research on recognizing the difference between male and female walking movements. It can prove helpful in what the University calls "gender recognition tasks." This type of research has been going on for several years but still needs more research conducted. [6]

> *"We present a three-mode expressive-feature model for recognizing gender (female, male) from point-light displays of walking people. Prototype female and male walkers are initially decomposed into a subspace of their three-mode components (posture, time, and gender)."-http://www.journalofvision.org/4/5/2/*

Other research fields are matching motion capture data to music. Games companies and movie productions will be using the Motion Capture technique more in the future. Computer Vision which is discussed later on is also an interesting field where no markers are used in order to generate the Mocap data.

2.3 Methods

Originally, I planned on using the departments new motion capture equipment which they were purchasing. However, the equipment was faulty and the school decided not to purchase the system. Since no equipment except the different software is available at this time, this research project will be mainly a theoretical study in how to transfer motion capture data between different applications.

2.3.1 Choice of method

The main research and method will be to examine the overall pipeline between the motion capture session (where data is recorded), and follow it all the way to the standard applications used today for editing motions. One of which will be Autodesk Maya.

2.3.2 Description of method

Focus will be on the recreation movements recorded by the motion capture data from an external source and implement the data with the software. Less focus will be put on aspects such as rendering and modeling. A human model has been provide by Mikael Johansson, and will be used for parts of this project.

2.4 Expected results

The expected results are to understand the pipeline for a motion capture device. With a pipeline, I plan on listing all the steps from recording the movements physically to the end product that will be a computer generated animation, which uses the motion data from the motion capture system.

Final files either in image or movies will be rendered in order to present my research results.

2.5 Limitations

All the research will be conducted at the University of Gävle and within the schools Creative Computer Graphics department. Therefore software limitations will be what the school has at its disposal. In my case, Autodesk Maya 2008 will be used as the 3d application.

MotionBuilder and any motion capture software will be further studied if possible.

The university does not have any motion capture equipment of their own, therefore previously recorded motion data will be used in order to recreate the movement of the actor on a computer.

2.6 Contribution

The contribution is organized as follows: Background of what animation is, what methods took us to where we are today, background of what is motion capture, and what systems are used for capturing the data. Also, detailed studies will be on the human anatomy and how it compares to the world of animation and 3D. File formats will be discussed and methods that are used in the 3D environment to achieve different goals.

Several terms will be used throughout this research paper. Motion capture will in this thesis be referred to as “Mocap.” Three Dimensional Graphics will be referred to as “3D-Graphics” or “3D.”

3 Theoretical background

Today computers are mostly used to create animations. Different software specializes in methods that help the animator to create movement of animals, humans, fire or anything that needs to be animated. Using computers for animation saves production time and the results are often stunning.

Traditional two dimensional (2D) drawn animation will consists of a series of images that are showed rapidly in a sequence to give an illusion of movement. The animations can be played back in different techniques, as mentioned in the introduction. The “flipbook” is one of them. With the help of a camera, drawings could also be shot one drawing at a time and are played back as an animation. [2]

In this section, background of animation and related areas will be studied, further on motion capture will be in focus.

3.1 Animation

Walt Disney is one of the most well known animators (1901-1966). He became world famous for creating movies such as *Snow White and the Seven Dwarves*, *Mickey Mouse* and *Three Little Pigs* and many other movies. [3]

Disney was raised on a farm in Missouri and started sketching at the age of five and selling drawings at the age of seven. By 1920, he began a career as an advertising cartoonist in Kansas City. In 1923, he left for Hollywood and joined his brother Roy, and they created a small animated feature in their uncle’s garage and shortly after that they had their first production order. [3]

With *William Garity* who was the head of the Disney Camera Department at the time and *Roger Broggie*, Disney invented the *multiple camera*. The multiple camera method created a better perception of distance in a scene then typically animation cells. The traditional cells had created challenges such as lighting, color shifts and shadow effects. [3]

3.1.1 Cel animation

Cel animation uses different layers of transparent cels that are put under the camera, with this type of technique for example the background did not need to be repainted in every frame which saved time.

The Multiple Camera technique that was used by the Walt Disney studios uses glass plates where the art is placed in layers similar to the cel animation but with a various distance between the glass plates. [18]

3.1.2 Computer animations

There are many steps in order to create animations on computers. In the world of 3D-Graphics, areas including *modeling, texturing, rigging, animating, rendering* and post effects have to be counted for in production. I will briefly go through some of these steps to provide an overall picture of the workflow.

3.1.2.1 Modeling

Modeling is a method to represent objects within the 3D-space. The objects can be created with either polygons or NURBS.

A polygon is composed of three basic elements, *vertices*, *edges* and *faces*. The polygons can then connect to each other's vertices or edges and form bigger meshes that in the end would represent an object as in Figure 1. Polygons can be transformed into subdivision surfaces, which indicate that the original surface is divided into more polygons and it creates a smoother surface on the object. [20]

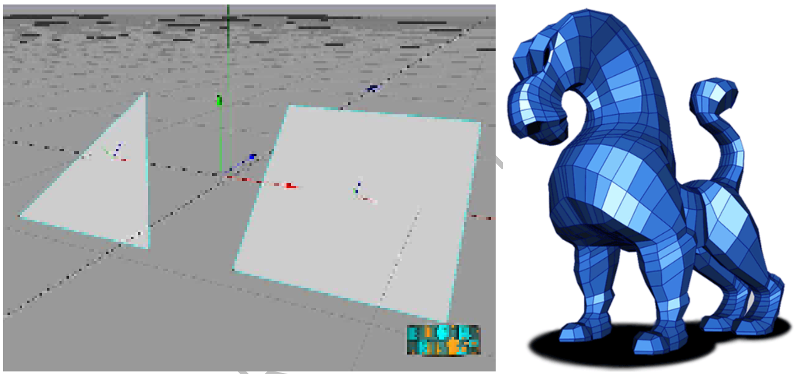

Figure 1: The basic polygon shapes and a mesh built of polygons.

NURBS, short for *Non-Uniform Rational Bezier Splines,* are another method of mathematically describing curves and surfaces. NURBS are characterized by the smooth forms they produce and are often used when modeling organic forms such as human heads. [20]

3.1.2.2 Texturing

Texture mapping is used to provide the impression of detail on an object using an image. For example, a photograph of a brick wall can be used as a texture on a planar surface, which makes it appear similar to a brick wall, without the need of complex modeling. [4] The same method can be used to create skin on a human model or letters on a computer keyboard.

3.1.2.3 Rigging

When objects or models that represent for example humans or animals have to be animated, a procedure called rigging can be implemented. Rigging is the process of creating joints/bones on key positions in the model. For example, the arm bends around the elbow, or any other part that has to be controlled by animators. If it is a model of a human character, it might be useful to study the human anatomy (which will be discussed later), because the 3D human's joint rotation will work in a similar method.

In Figure 2, a joint is the building block of skeletons in the 3d software. It is the combination of two or more bones that are attached together, where they can have one or more child joints attached. The bones action is controlled by the joints rotation and movement. [20]

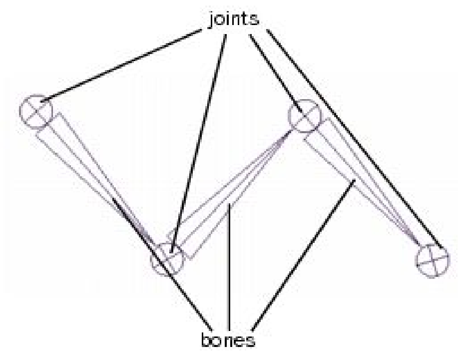

Figure 2: Joints and bones in Autodesk Maya

There are different types of joint behavior, and by adjusting attributes the joints can be restricted so that they only rotate within certain *degrees of freedom* in order to not create movements that are impossible. Three different joints exist, *ball joint, universal joint* and *hinge joint*.

The *ball joint* can rotate around all three of its local axis (XYZ,). An example in anatomy is the human shoulder where this type of joint exists.

The *universal joint* can rotate around two of its local axes and the human wrist is a good example because it has limitations on the extent that it can rotate.

The last joint, the *hinge joint* can only rotate around one of the three axes such as the knee of a human is a hinge joint.

Joints have no shapes and by default they will not be rendered.

When all the joints are placed in the model, there are two methods of posing or animating the skeleton, *forward kinematics* and *inverse kinematics*.

Forward kinematics is also referred to as FK. With FK, each joint needs to be individually rotated until the desired position is reached. If the hand of a character has to be moved, several arm joints must be rotated in order to reach the desired location. With forward kinematics the 3d application interpolates the joint rotations from the root joint, then to the root's child joints and so on all the way down the chain. Forward kinematics is intuitive for more simple motions, but can be tedious when animating complex rigs. [20]

The second method is called *Inverse Kinematics*, and provides the animator an "IK handle" which is an extra control structure. Mostly, Inverse Kinematics is used for certain joint chains such as legs, arms and spine. The IK handle allows the animator to pose the entire joint chain by just moving the single IK handle. This speeds up the process of animating, for example, if a hand is moved to the doorknob, all joints in the chain will be rotate to accommodate the hands new position, and there is no need for manually rotating every joint in the chain of the arm. [20]

3.1.2.4 Skinning

When the skeleton is created, it needs to be bound to the characters surface so that the surface of the character moves with the skeleton during animation. The binding process is also called skinning and the surface of the character after binding is called skin. The skin deforms because the surface's vertices follow the rotations of the joints that is set to control the skin at that area, and is very useful for animating elbows, knees, shoulders and so on. [20]

3.1.2.5 Animation

Separate frames are played back over time and create the illusion of movement, or an animation. Developing actions (poses, timing, and motion) of objects is called animating. Some different animation methods exist in different applications. The most relevant for this research paper is keyframe animation and motion capture animation.

Keyframe animation uses the workflow of keyframes, where basic frames in an animation are created and then the software takes over and creates the points between those keyframes. They are called the inbetweens which indicates that the animator does not need to animate every frame in the animation. Keyframes are used in a variety of software applications, such as 2D animation, video editing, 3D animation and many more. Most things can be animated with this method, which includes lights, colors, smoke and fire. [20]

3.2 Frames per second

A number of frames are needed each second to create the illusion of movement. Each second consists of 25 or 30 frames, depending on where in the world they are supposed to be played. In Europe, Asia, the Middle East, parts of Africa, parts of South America and Australia, a television system called *PAL* is used. PAL has a frequency of 50 fields per second (50 hertz), 25 frames per seconds are therefore compatible with PAL. If an animated film would be played at 24 frames in a country that uses PAL, we would see a black bar rolling up the screen. [2]

America, Canada and Japan are some of the countries that use another system called NTSC. NTSC has an update rate of 60 fields per second (60 hertz) instead of 50 hertz, and therefore the animations should be at a rate of 30 frames per second. [2]

A converter is used to transfer the format between the two systems, so for example a PAL version of a movie can be seen on an NTSC Television. The way this is solved is that 2 frames at a point in the animations are blurred together. [2]

3.3 Human anatomy and 3D

Setting up a system of bones in a human 3D character requires some basic knowledge in human anatomy. A real skeleton has similar overall positions of the bones as a computer generated human would have. Although the real skeleton is far more complex, and the computer models do not need every single bone to animate. Therefore in order to create the necessary movements, the computer model must be rigged correctly, such as the standard joint placement for character setup in Figure 3.

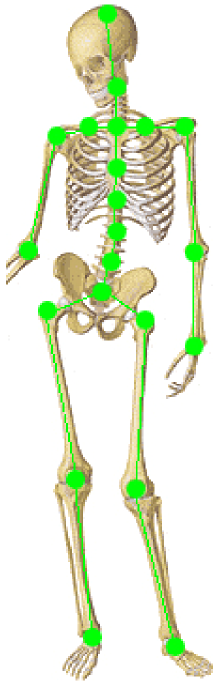

Figure 3: Skeleton with joints

Also, it is important to know how different parts of the body react when they are moved around, such as in a run or walk cycle or how the torso will twist with each step etc.

When rigging a character, the software needs more information about the structure than just joints and bones. They only form the FK technique (Forward Kinematics, discussed earlier) which might not always be suitable for a human character. Some parts of the character will have the FK rig, however in order to create an easier method for the animator IK (Inverse Kinematics) can be implemented.

3.3.1 Legs and feet

The legs can definitely benefit having an IK rig, since it creates a more natural approach of animating them. With FK the animator would have to rotate each joint in order to create the movements shown in Figure 4.1. It is a tedious work and can easily be resolved with IK. With an IK setup, the animator will have a control object that he or she can move around, and the whole leg will move with it as shown in Figure 4.2. [13]

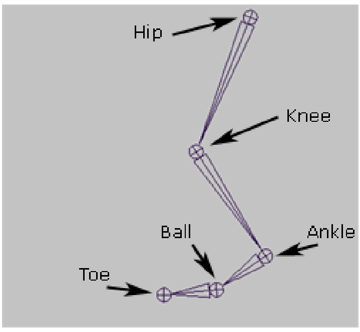

Figure 4.1: Joint names. (Only FK)

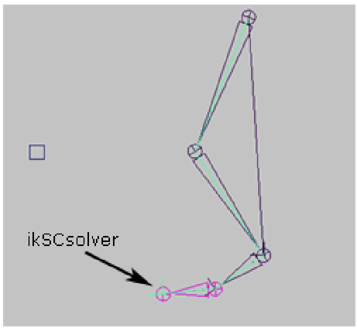

Figure 4.2: Leg with IK

A method to keep the foot locked to the ground is called the *reversed foot lock* which is shown in Figure 5. It is an external set of bones that drives the foot of the character. The name reversed foot lock comes from its reversed construction, backwards from the heel and up the foot to the ankle. [13]

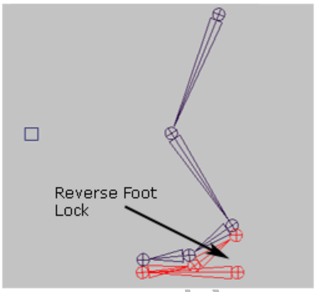

Figure 5: The reversed foot look, highlighted in red.

3.3.2 The arms and hands

The arms setup moves in a similar method as the leg, with an IK constraint from the shoulder joint to the wrist, depending on what type of rig that is being constructed. This creates a technique for the animator to move and rotate the whole arm from a control object instead of rotating every joint by itself.

Creating the bones in the hand is somewhat more complicated than the arm and leg, many bones in a fairly small space. Also, advanced controls have to be built in to make it easier for the animator.

The hand rig performs in a similar manner, but often without any IK. Instead a method called *Set Driven Keys* is used. Set Driven Keys is a method that allows the animator to create objects that reacts with another object automatically. This is a great system to create the controls for the bones that build the fingers in a hand. In the end, the animator will have a slider for each finger he wants to control, or even sliders for different hand poses, such as a control for making the character close his hand to a fist, or just point with the index finger. [20]

3.3.3 The spine

The spine is sometimes used with only FK, depending on what is planned for the character. Although, the spine definitely benefits having an IK chain, for it makes it easier to control. The different control objects can be built in to make it easier for the animator.

In MotionBuilder, which is discussed later, these processes of creating IK rigs are automated.

4 What is Motion Capture

Motion Capture (also referred to as Mocap) is a technique that measures an objects position in physical space, with the intension to copy the objects motion to the computer. The Mocap software records the positions, velocities, angles and accelerations. With that information, it can provide an accurate digital representation of the motion. The information recorded (animation data) is then mapped on computer models. Objects that can make use of the recorded animation data are models of human and non-human bodies.

Facial animations, robots and animals are other objects where the motion capture technique is implemented to create a higher level of realism. This is very useful in bigger game productions where a large set of human characters need to be animated or in movies where humanoid 3D-models will be used. An example is Andy Serkis dressed in a motion capture suit, the actor who created the movements of Gollum in the Lord of the Rings, who is dressed in a motion capture suite shown in Figures 6.1 and 6.2. [5]

Figure 6.1: Andy Serkis *Figure 6.2: A render of Gollum*

4.1 Optical systems

There are several different methods that are used for capturing the movements of actors. One commonly used is Optical Systems that utilizes the data that is captured by cameras and triangulates the objects position in 3D space. The cameras track predetermined points (markers) on the actor's body parts. The markers can be either passive (reflective) or active (light emitting). [15]

4.1.1 Passive (Optical)

Use markers that have been coated with a retro reflective material and reflect back light to the cameras. The cameras use infrared (IR) LED's mounted around the camera lens, they also have an IR pass filter over the lens. Adjustment of the camera's threshold makes it possible to filter out fabric and skin, and only the bright reflective markers will be sampled. [7] [15]

4.1.2 Active (Optical)

Instead of reflecting light back to camera's that is generated by external sources, the active markers are powers by themselves to emit infrared light. With active markers, distances can be greater during capture. [7] [15]

4.1.3 Marker less (Optical)

There are methods for tracking objects without the help of markers. The system is optical and uses multiple cameras. The actor does not need to wear any equipment. This system is called Computer Vision and has the ability to obtain information from images.

The system analyzes the images obtained from video sequences, or for example views from multiple cameras, and uses advanced mathematical algorithms. These algorithms then segment the images and works in a process where the information can be extracted.

Medical Computer vision is a field that can benefit from this technique. The doctors can detect tumors or changes in the body by extracting information from images. It can measure dimensions of organs and blood flow etc. [9]

4.2 Non-optical systems

Different types of methods that do not use the cameras are Non-optical systems which are also very common. The most used of the non-optical methods are *inertial systems*, *mechanical motion*, and *magnetic motion capture*.

4.2.1 Magnetic motion capture

With magnetic motion capture, sensors are placed on the body and measure the low-frequency magnetic fields generated by a transmitter source. An advantage with magnetic system is that it does not suffer from objects standing in the way of a camera. The limitations of this system are that it is directly related to the physical characteristics of a magnetic field. The magnetic fields decrease in power as the distance from the transmitter source increases. [7] [15]

4.2.2 Mechanical motion

An actor/performer attaches a skeletal-like rig to their body and when they move the mechanical parts of the rig also moves. The angle measuring devices then provides angle data of the joint/joints that move. The data is then applied in to algorithms which are used to determine body posture. Problem that occurs with this kind of method is that the soft tissue of the body allows the position of the links in the rig to change relative to the body. [7]

4.3 Facial motion capture and animation

The expressions of a human face are very hard to copy in animation and it is a time consuming and a tedious task. Animators must sculpt each and every facial expression by hand. It also has to be repeated on each and every face that is going to be used in a production.

Animating the facial expressions that have been sculpted can be created with the blend shape method (shape interpolation), where the animators have control over every facial expression. However, it is also time consuming because the face has to be reanimated in every new dialog. An example where blend shapes were used was in the famous Lord of the Rings, where the character Gollum's face was animated with this method. Gollum had a large number of blend shapes that the animators could then use when animating the facial expressions of the character. [19]

Figure 7: Serkis with markers

The method of capturing facial motions is the same as the body capturing techniques. A set of micro markers are placed on key position on the actors face as in Figure 7, and then cameras (if it is an optical system) can capture the information. The active marker method can also be used. [7] Although, it is more challenging with facial motion capture due to the problems of tracking much smaller movements such as eyes and lips.

4.4 Animation and Motion Capture

When an animator obtains a fully rigged 3D model on his desk, such as a basic human character, and his task is to animate that human model as realistic as possible, he faces some problems. The human eye has an expert ability to see movements and informs instantly if something does not move realistically.

To recreate the motions in a natural appearance, knowledge of the human anatomy is often useful as we spoke of earlier, because different movements can affect parts in the body that the animator is not aware of, such as rotation of the hip, and how it will affect the spine, and shoulders. Motion capture captures these "secondary motions" which causes animations to appear more realistic.

Physical forces that influence the animation can be difficult to animate manually. A body that falls to the ground is affected by many things that are hard to copy by hand. Often, it can be recognized that there is something wrong with the animation, however it is hard to point out exactly which part of the body the problem exists.

The motion capture technique speeds up the process and realism but it is also important to know the limitations while working with Mocap.

4.5 Advantages and disadvantages

There are many aspects where Mocap is the better method to implement in order to create realistic animations, but the techniques also occurs with some disadvantages. What advantages has motion capture compared to traditional computer animations and what advantages does Mocap have compared to live footage, as well as what disadvantages exists? [15]

Advantages

- A single actor can play many different roles within a single film production.
- It saves time and creates more natural movements than manual animation.
- The director can choose between many camera angels in a scene, angles that are difficult to film with real cameras.
- Real time results can be obtained.
- It saves enormously on cost.

Disadvantages

- Different and specific kinds of hardware and software are needed.
- It is too expensive for small productions.
- Capturing movements of four-legged creatures can be difficult.
- Problems can occur, which are time consuming with the transfer of data.

5 Compatible Software

There is a vast variation of 3D applications to choose from at the current time and many of them can manage motion capture data. As mentioned earlier in the introduction, Autodesk Maya 2008 will be used for this research paper. Some of the most common animation software are listed below; [11]

- Autodesk Maya 2008 (3D modeling and animation), one of the more advanced 3D packages.
- MotionBuilder by Autodesk is highly advanced applications that can handle motion captured data and then export it to different types of 3D-packages.
- Autodesk 3D Studio Max (3D modeling and animation), works in the same manner as Maya.
- Softimage XSI (3D modeling and animation)

5.1 Motion capture file formats

The motion capture data comes in several formats. It may include Information about the coordinates in space of the markers, or information about the joint orientations which is later applied to a model. The formats can be divided in *Translational* and *Rotational*.

Translational data is the optical markers described within three *degrees of freedom*, 3DOF (x, y, z - position).

The *Rotational* data is the markers converted to skeleton - joints and bone segments, described within six *degrees of freedom,* 6DOF. (x, y, z - position and x, y, z - rotation) [11]

5.2 Different formats

5.2.1 The Biovision (.BVA) format

A .BVA file format is directly supported by most of the 3D animation packages. For each bone in the skeleton (Biovision calls them Segments), there are nine channels that can be used for animation. Translation, rotation and scale values are represented for each bone and for every frame. Each bone is described in its actual position (translation, rotation and scale value) where there is no hierarchy definition. This can lead to problems however it is easy to use. [11]

5.2.2 The Biovision (.BVH) format

Biovision Hierarchal data or .BHV is an extension of the older .BVA format. .BVH differs from .BVA in several key areas, and the most significant is that the .BHV holds information of the skeleton and the hierarchy in the same file. [11]

MotionBuilder supports the Biovision .BVH format and there is plug-ins for Maya which makes it also possible to import the format. [11]

5.2.3 The C3D format

The C3D format was developed 1987 in an attempt to create a format that should be used as the standard by people who developed the motion capture technology. Also, the C3D file format was needed by the Biomechanics industry to collect and store data during experiments since the studios and laboratories used different file formats. C3D stores the 3D coordinates and numeric data in a single file. [11] [8]

5.2.4 Motion analysis (.TRC, .HTR)

.TRC and .HTR is developed by Motion Analysis, they offer plug-ins to many of the advanced 3D applications, (Maya, 3D Studio Max and MotionBuilder by Autodesk, Softimage XSI is in development – *www.motionanalysis.com*). [11]

The TRC files hold translational data and the HTR files holds the rotational data generated by Motion Analysis own software. The HTR files also holds information about the skeletons hierarchy and data for each bone and scale. [11]

EVaRT is Motion Analysis own software for motion capture.

5.2.5 Film box, FBX

A format developed by Autodesk (former Alias and before that Kaydara) is the FBX format, short for filmbox. It performs as a platform between different software. The FBX format can hold information about joints, textures etc.

The FBX format can also be used with Quicktime, which makes is possible to view motion files on any system. It is a great feature for people who is involved in a project and need to see animation files, but do not have the special software. For example directors on a movie set. [11] [14]

6 Motion Capture Pipeline

The process of capturing data from an actor for example, requires different steps in order to create realistic motion of the actor on the computer. MotionBuilder and Maya exist within the final steps of the chain. The overall pipeline from planning and preparation of the character would include modeling (textures), skinning and defining the skeleton structure (rigging).

When the preparations are completed, the character will have to be exported to MotionBuilder where it will obtain the information that was recorded under a Mocap session.

6.1 Vicon

The Vicon8i optical motion capture system is specially designed for animation and can make use of 24 cameras which is similar to the one in Figure 8. The higher number of cameras allows greater volume coverage of the optical markers. Vicon's software also supports work with multiple characters and actors. Adding the iQ2.5 software creates more accuracy and reliability. iQ2.5 will cause the system to always run in real time. [6]

The benefits of realtime consist of;

- Live performances with computer generated characters with live actors.
- The director obtains a greater overview on the performance in a set.
- An actor obtains realtime feedback from their actions.

The Vicon systems have been used in many productions worldwide. For example Polarexpress by Sony Imageworks; [6]

> *"A Vicon motion-capture system was used to amass face and body data from live actors, whose performances were finessed within the digital realm. Tom Hanks took on five roles, including those of the Express Conductor and the Hero Boy, and different mo-cap 'takes' were used to create each character's ideal performance. – www.vicom.com"*

Other productions that Vicon has been involved with are the *Spiderman* movies, *Pirates of the Caribbean*, *Transformers* and game productions such as, *Rainbow Six – Las Vegas*. [6]

Figure 8: Camera from Vicon.

6.2 Pipeline

The motion capture pipeline consists of five steps, *calibration, capture, 3D Position reconstruction, fitting to the skeleton, post processing*. These steps are vital in order to obtain a result that can be used for animation later on in the process. [10]

6.2.1 Calibration

It is crucial to know were each camera is located in the world space coordinates before the markers position in 3D space can be determined in an optical system.

Calibrating the camera is performed by recording a number of images space points whose world space location are know. It can be accomplished by using special calibration equipment such as a *checkboard* or a *calibration frame*. [10]

6.2.2 Capture

As mentioned earlier *optical tracking* devices and *electromagnetic systems* are some of the more common ways to capture movements of an actor.

The optical tracking devices generally use infrared cameras in order to track small reflective spheres that have been placed on an actor. This method allows large areas to be tracked. A problem that can occur is when there more than one actor in the set, and the markers get behind the other actor.

Electromagnetic systems use a centrally located transmitter that emits an electromagnetic field. Receivers that are attached to a body suit make sure that the position and orientation can be tracked relative to the transmitter. This system does not need to worry about objects that can come in the way of another, but the actor has to stay fairly close to the transmitter, approximately 5 feet. [10]

6.2.3 3D Position and Reconstruction

To reconstruct the markers 3D coordinates, the point P has to be seen by at least two cameras. Also, the more orthogonally the two cameras have, the better reconstruction can be made. [10]

6.2.4 Fitting the skeleton

When the motion of the individual markers appears smooth, the next step in the process is to attach the markers to the bone structure. In an utopian approach, each markers position in each frame would be used to position a joint in the skeleton.

Although in practice, the distance from let us say the actor’s hip to the knee joint would change over a period of time. This is not uncommon and can result the foot of the skeleton sliding. It is an effect known as skating. One of the reasons is that the markers are not located on the performers joints, but outside the joint on the surface. A solution to the problem is to place markers on each side of the joint and calculate the midpoint between the markers. This provides a more accurate representation, however more markers need to be tracked. [10]

6.2.5 Post Processing

A number of processes can be made to improve the animation after the motion has been mapped to the 3D model. Motion can be edited by cutting, copying and pasting bits of the motions in the scene. Scaling the size of the actors can be made in order to make it appears as if an adult is dancing with a child. [10]

6.3 Limitations

Inaccuracy of data and the cost are some limitation that comes with the motion capture technology. And that makes it more suitable for larger animation studios. Manufactures can rent time in a motion capture studio, or companies that have bought in motion capture equipment is hired by companies that need to record motion for games or movies etc.

Other problems are that only realistic movements can be captured. For example in the movie *Shrek,* the director wanted a more cartoonish appearance for the characters so motion capture was not used. [10]

6.4 MotionBuilder

MotionBuilder is a software which can function with various types of motions, including keyframed and imported from different sources. It allows the animator to work in real-time and supports all major motion capture formats. Since MotionBuilder is an almost exclusively an animation tool, special effects, high-end rendering, and modeling is not handled by the software. It should be used as a companion to other 3D applications. [12]

6.5 The pipeline between Maya and MotionBuilder

To function smoothly (this applies to all software where rigging is possible such as Maya, 3D Studio Max etc,), the character has to face the positive Z-axis. The character should be rigged with only FK (Forward Kinematics, mentioned before) which is most suitable when using MotionBuilder.

Another important aspect regarding MotionBuilder and how it handles the information that comes from another 3D-package is naming of the joints. In order for MotionBuilder to recognize the joints of the character while applying for example a control rig, they should follow MotionBuilder's standard naming "rules," such as in Figure 9. This is optional; however it makes it easier while importing the character as in Figure 10. [11] And also, templates can be created in the characters own naming schemes.

When exporting from a 3D package, a format called FBX is used, The FBX format will be discussed briefly later.

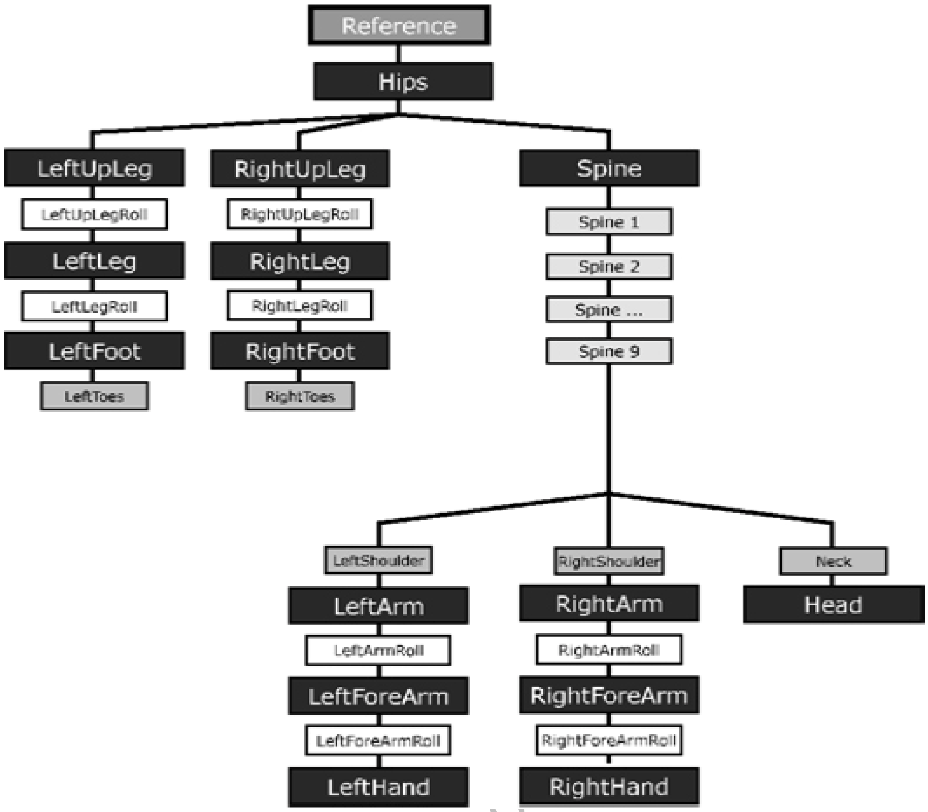

Figure 9: MotionBuilder's standard naming convention.

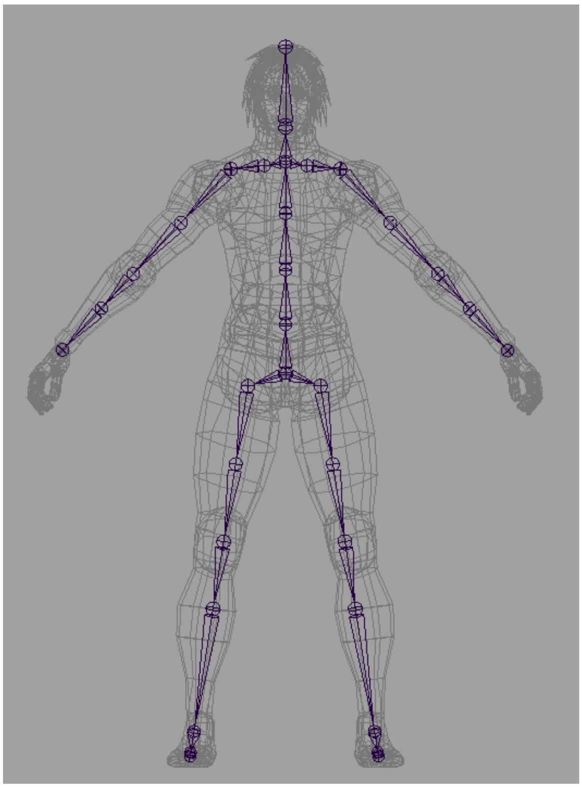

Figure 10: A model rigged in Maya before exported to MotionBuilder, notice the extra joints in legs and arms.

6.6 Setting up the character in MotionBuilder

There are some important aspects to consider after creating the character and the FK-Rig with the proper naming and has been imported into MotionBuilder. MotionBuilder will not recognize the character if the following steps are not conducted, and the rig will not work as it should.

Below will explain how to get a *full body IK* rig on the previous rig with only FK, and how to apply different motions data that already exist within MotionBuilder. [21]

1. Load the model/rig into MotionBuilder after exporting it as the .fbx format see in Figure 11. Before the model and skeleton will be recognized as a character, it has to be *characterized*.

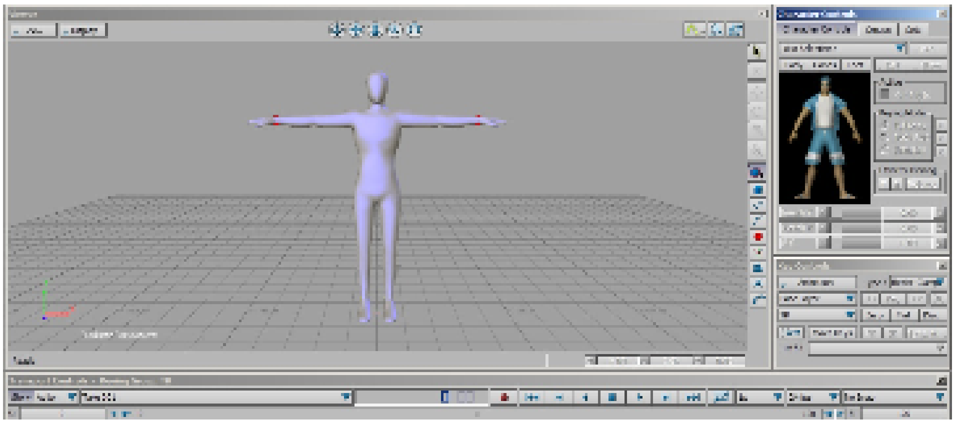

Figure 11: Inside MotionBuilder.

2. Next step is to characterize and add a control rig to the model shown in Figure 12. The animator can decide if the skeleton should be biped or quadruped and if it should be rigged with IK or an FK/IK structure. If all the joints have the correct naming, the model will obtain a full body IK rig. If some joints have the wrong names, the model will not be characterized and it has to be manually corrected in MotionBuilder.

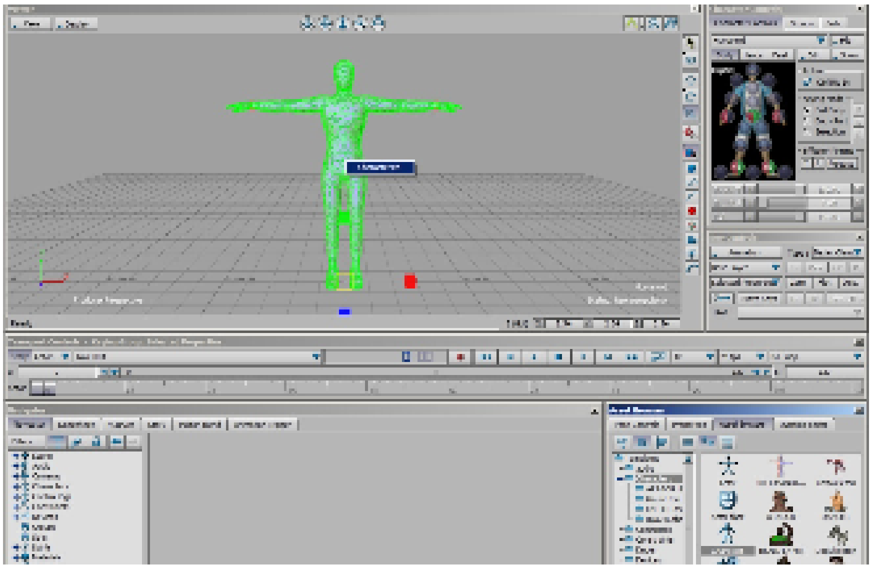

Figure 12: The character is about to be characterized.

The character is now ready for animation. Either it can be animated the regular method by keyframing the movements, or if motion capture data is available from Mocap sessions, it can be used to drive the character's motions. MotionBuilder also support layers, which means that adjustments to the character can be made without interfering with the original animation or Mocap data.

6.7 Exporting back to the 3D application

When the animator is satisfied with the movements of the character, he or she must export it back into the 3D software where the character will later be implemented into the environment etc. Exporting the animation back to the 3D application is a fairly simple task.

In MotionBuilder, the animation can be *plotted*, which means that the skeleton obtains keyframes that represents the motion in MotionBuilder. When performing this, the control rig stops to be active and only the FK skeleton exist, with the new animation applied to it.

Inside the 3D application (Maya, 3D Studio Max etc), the character can be imported to the scene then textures, lightning, and rendering can be used. Depending on the complexity of the characters mesh, the real-time simulation will be lost. [21]

7 Discussion

Since this research paper was written without help of any motion capture equipment, except for Autodesk Maya and MotionBuilder, data about the systems had to been gathered from others research. This resulted in a more of a composite of different areas that have been theoretically studied.

7.1 Research

Research that has been practically conducted except for information gathering is the pipeline between a 3D package and MotionBuilder. This process requires different steps in order to work properly and is very vital in the industries where motion capture is used.

Many different formats can be used as discussed above, for this paper the .FBX format was used while transferring data between Autodesk Maya and MotionBuilder, since the .FBX format are very well integrated in both software. All though a plug-in has to be downloaded from *www.autodesk.com*, in order to export files from Maya.

7.2 Pro and contra motion capture

Since motion capture is fairly expensive it might not be the best solution for especially private persons or smaller companies. For greater companies motion capture is indispensible, in total motion capture saves so much time and the outcome of the technology creates stunning movements that could not have been created without it in games and movies. Thanks to motion capture game players who can recognize individual skateboarders in a skateboard game due to the stars personal skating styles.

Motion capture requires time setting up, calibrating, and post processing, however as mentioned above for large companies, it is well worth the effort, money, and time compared to keyframing everything.

7.3 What could have been done better

This is hard to say since no actual equipment was tested, but better contact with companies in the motion capture field could have been useful in order to obtain more updated information about different aspects and areas.

When rigging my character in Maya and exporting it to MotionBuilder, problems with what I believe was the joint orientations (shown in Figure 13) which caused the arms to not respond to the template motion capture data in MotionBuilder and distort. The full body IK worked though. Fixing the joint orientations would probably solve some of the problems. Also testing different ways to flip the right arm to the left side might have also helped.

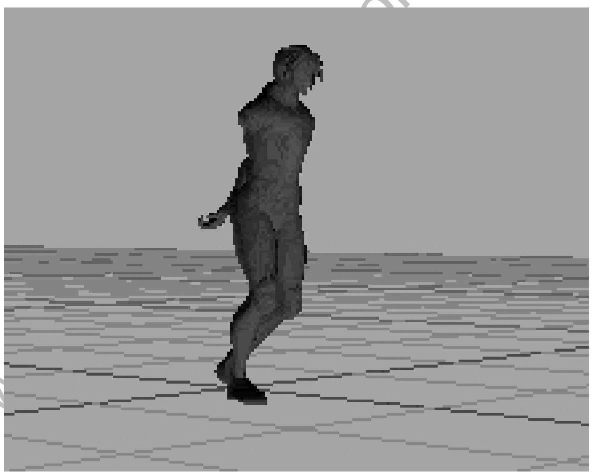

Figure 13: Arm deformations.

8 Conclusion

The purpose of this research was to examine the overall picture of motion capture. I have researched some of the methods and techniques that are used by the industries today. From that I can see, motion capture is a very useful tool in the art of animation and that it will continue to evolve since more and more research is being conducted every day.

Motion capture is used instead of keyframing as discussed before which is a method to obtain a more realistic result, but keyframing is very helpful when adding extra motions to the Mocap data or animating secondary motions that was not recorded.

The process of transferring data between Maya and MotionBuilder was very easy, following the techniques that have been developed. The FBX format proceeded excellent between the two applications.

A very important aspect is that the traditional animation method is the foundation of motion capture. The knowledge from the traditional animation areas is useful for the motion capture techniques for they complement each other, not compete.

The most difficult element in this research paper is trying to summarize this technique without having the proper equipment to review the pipeline that is described. And I think that people can find things in this research that has been further studied in the industries without my knowledge.

Motion capture is only a small part in the chain for creating animated movies and games. Many people are involved in rendering, modeling, and special effects in a project. But it is a fascinating world and I think the entertainment industry will gain much from having it developed more and more but still use and preserve the knowledge of “old school” animation techniques created by Disney and all the others.

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