Matheus Ferraz Petrovich Pereira

Motion Capture as a Method for Animation in Animatronics

Brazil
2017

Matheus Ferraz Petrovich Pereira

Motion Capture as a Method for Animation in Animatronics

Universidade Federal do Rio Grande do Norte - UFRN
Department of Computer and Automations Engineering - DCA

Orientador: Agostinho de Medeiros Brito Júnior

Brazil
2017

Abstract

This report describes the development of a Low-cost motion capture system to assist the process of animatronic characters animation, simplifying the animation process and providing more realism to the final product. The motion capture system is based on image processing from a camera affixed in a capture apparatus which keeps it static in relation to the actor's face. The system can successfully track 13 markers around the mouth and brows, and the user's pupils. The control system is based on a microcontroller and transforms the tracking information into control signals for the animatronic characters' motors. This report will also discuss the process of making an animatronic puppet.

List of Figures

Contents

Chapter 1

Introduction

Seeking to tell bigger and better narratives, the entertainment industry is always transposing its spectators to realities and universes that are far from their daily life. These universes are often inhabited by fictional beings such as talking beasts, mythological creatures, aliens, monsters. Whether in the movies, television, theater or amusement parks, bringing such characters to life convincingly can be a great challenge and require a great deal of time and money. There are two major categories of special effects that allow fictional characters to come to life: visual and practical effects. The visual effects consist of the creation of the character in digital form and its subsequent insertion in the environment using projections (theater and amusement parks) or overlapping of takes (film and tv). But the practical effects rely on the construction of the character so that it is physically present in the environment at the time of the action, be it an actor in a suit, a marionette or even a robotic (animatronic) puppet.

Although the public does not necessarily respond better to Computer Generated Imagery (or CGI), nor are they less expensive than practical effects, many studios now use more digital than practical effects. According to Alec Gillis, owner of StudioADI, a North American special effects company, studios believe CG is a more secure application of resources because it allows aesthetics and performances to be altered in post-production. Gillis claims that as studios make loans to fund their films, paying interest, the film's development timeline has been greatly shortened, to the point where eventually films begin to be filmed without even having the final script. This accelerated rhythm, in addition to shortening the pre-production time (during which the practical effects are planned and developed) opens space for many changes to the story in the unfolding of the shooting. However, modifications in the aesthetics or functionality of the characters and practical effects can not be done easily during production, so the same character would have to be developed again using visual effects. Thus, the studio would have to pay a second time for the creation of the same character, whereas if it had been left to be created only in post-production (where visual effects are developed) changes could be more easily worked on. Still, it is a consensus in the industry that the art of practical effects is far from extinct, not only for its quality and credibility, but also for allowing actors to deliver better performances, having something ”real” to interact in the film set.

Regardless of the technique used, the performance of the characters is fundamental to the spectator's credibility in history. The subtlety of facial expressions represents a significant part of the process of human communication. Seeking an ever-increasing level of realism, the entertainment industry has been using various technologies to make increasingly realistic and credible products, both in the forms and quality of the image, and in animation. In the world of computer graphics realism in animation is usually achieved by using Motion Capture[7].

It is the small details that add realism to the performance of a character and add to the individualism of their behavior. Those can be difficult to create through more traditional methods of such as keyframe, in which every movement is manually inserted by the animator [5] .

The motion capture technique (Mocap) allows for sets of movements, captured from an actor in the real world, to be inserted into the animation of a virtual character. Applying directly the data extracted from the actor to the character, the conscious macro-movements are inserted, as well as the micro-movements associated with the emotion in question. Using this tool, the animator can generate characters with a greater degree of realism and give agility to the process of animation [4].

The method of animation by keyframe can be cumbersome and may require more than one day for an 10 seconds of the animation blocking. The use of motion capture based methods can reduce this time in approximately 7 times. Authors like Shiratori, from Disney Research, reinforce that the agility in the process of blocking animation is essential if the animators are to materialize completely the scene they have in mind. This time economy still allows for animators to explore and experiment with several other possibilities with much less effort, building a base of movements that can be approved by the directors and then refined [9].

There are several techniques for motion capture: sensing based on fiber optics, electromagnetic sensors, potentiometers embedded on special clothing and image processing. The method based on image processing, can be separated into two large classes: with markers and markerless, the first being currently more evident [11]. Methods that do not require the use of markers Tend to have real-time tracing limitations and Margin of error [13].

Good facial movement tracking systems are expensive due to the use of high frame rate cameras, infrared lighting and special lenses. Low cost systems may be interesting for small studios which need to use mocap to animate characters in movies or digital games.

In the practical effects, the animation can happen in real time (direct control or remote control) or through preprogrammed movements. Direct control implies that the animation is performed directly by an actor/puppeteer, whether using a costume or controlling a puppet. The remote control happens in the case of animatronic puppets, while in amusement parks animatronic characters usually perform the same routine in a cyclical way (allowing for a planning and refinement of the movements before the inauguration of the attraction), in the film industry the characters need to be animated in real time, responding to the changes in script and construction of the scene, as well as allowing improvisation and dynamism in the interaction with the other actors. To do so, they are controlled remotely by puppeteers who work together to bring life and movement to the character.

Typically for animatronics in the movie industry the control is given through radio-controls used in model cars and planes due to its practicality and adatability, reducing the development time of the project. However, some companies develop their own control systems for certain characters or complex movements to reduce the amount of control devices needed and the amount of puppeteers involved. The first step in this direction was given in 1980 by Jim Henson's Creature Shop, which developed the Henson Performance Control System (HPCS) to be used to control the characters in his new series **Fraggle Rock**. HPCS allowed realistic expressions to be created and sets of movements such as the character's characteristic winks and smiles to be stored in the controls, simplifying the animation [10, 2]

This report aims to contribute to the integration of tools typically applied to improve the process of animation in the visual effects to the practical effects realm, presenting a proposal of a low-cost facial motion capture system as a tool to animate animatronic characters. The system consists of a head gear onto which the camera is attached, and an image processing software

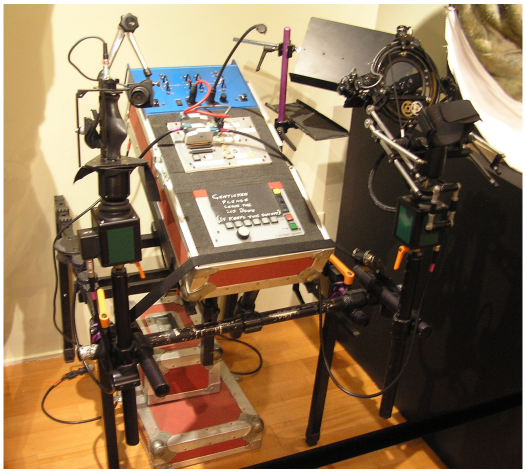

Figure 1.1: HPCS Seen on Display *It's Alive!* [12]

to process the video stream and transforms the tracking information into control signals for the animatronic character animation.

This report is organized in 5 other chapters. Chapter **??** describes the system developed, like the tracking processes for the eyebrows, mouth and eyes regions. Chapter **??** describes the interaction between the mocap system and the mechanical structure of the character. Chapter **??** explores the process of building and finishing the animatronic character. Chapter **??** discusses the results found. And finally, chapter **??** concludes the paper, presenting perspectives of improvement and expansion of the usefulness of the tool.

Chapter 2

Motion Capture System

2.1 Motion Capture Model

The head gear is composed of a polyester resin helmet reinforced with fiberglass and a camera attached to an aluminum arm. The helmet is made from a model of the user's head, obtained in a molding process with plaster bandages. Molding is necessary for the helmet to stay firmly on the user's head, minimizing camera movements in relation to the face.

Over the head model were laminated layers of pigmented polyester resin reinforced with fiberglass. Opennings were made on the back of the helmet to allow for flexibility and a strip Velcro was attached for adjustment, so that the helmet stay tight on the user's head. Inside the helmet were glued pieces of felt to improve comfort and help maintain the helmet stable, so that the camera was always static in relation to the user's face. The helmet structure is shown in Figure 2.1.

Two screws were used to affix an aluminum arm to the helmet on the end of which there is a USB camera that will capture the video stream of the user's face. The aluminum bar needs to be measured and molded to allow the camera to have a complete view of the user's face.

The capture software allows several parameters to be configured in order to adapt the system to lighting conditions and face position. Images are captured in the resolution of 480 horizontal points by 640 vertical points. In this resolution, the system can capture and process images with speed around 20 frames per second from the USB camera.

Figure 2.1: Complete Head Gear

2.2 Marker Tracking

The markers used in this work were made from Styrofoam pellets painted with yellow paint and glued to the user's face using Pros-Aid ® adhesive. This adhesive is produced by ADM Tronics ® and used widely in the entertainment industry in makeup and special effects[1]. An example of the markers glued on the user's face is seen in the Figure 2.2.

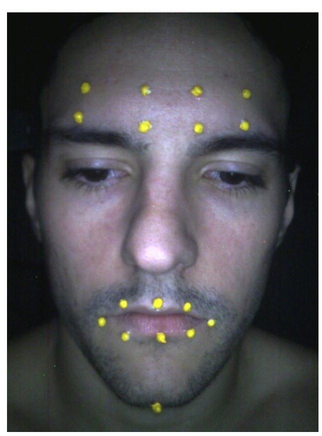

Figure 2.2: Passive Markers Glued onto Performer's Face

Tests were carried out with styrofoam pellets in white natural color and painted with blue, red and green PVA paints. However, the yellow color was the one to produce better separation conditions from the rest of the image elements.

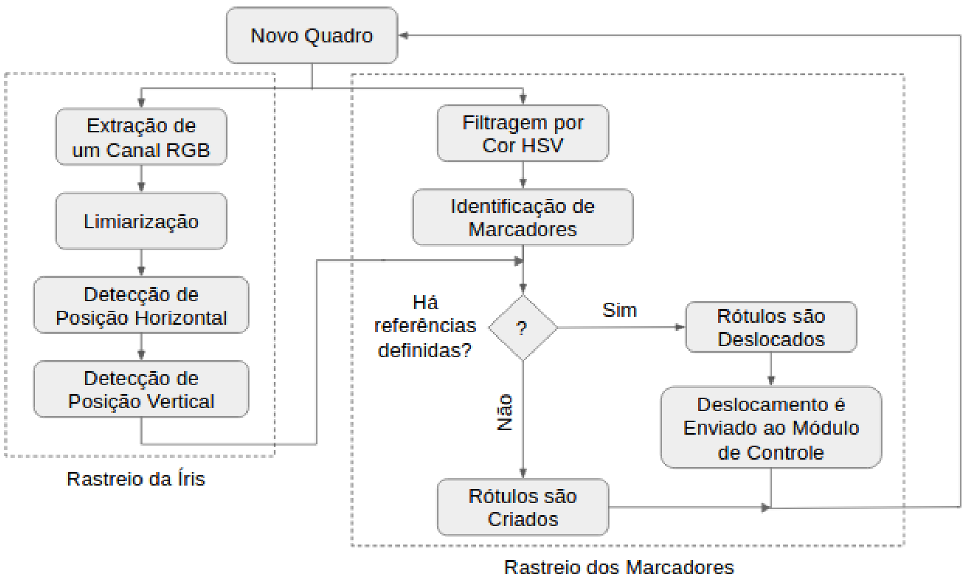

Figure 2.3: Tracking Algorithm Flowchart

Figure 2.3 shows the flowchart of the tracking algorithm described below. The segmentation of images for the extraction of markers is done in the HSV color space using the Hue component. The software allows the user to choose the lower and upper thresholds that limit the region of color shades accepted as the markers. The use of the HSV model is important to unlink the the lighting conditions of the scene. For various tests performed in environments with varying conditions, the $H_0 \in [90, 110]$ range, considering a full range of $H \in [0, 180]$, showed the best results to separate the markers from the rest of the scene. Figure 2.4 shows an example of a binary segmented image with the isolated markers.

The markers are fixed at strategic points with areas of greater movement and expressiveness and greater relevance for the perception of emotions like the mouth and eyebrows [8]. To allow for the points to be tracked, during the capture, each marker receives a label. The number and position of markers

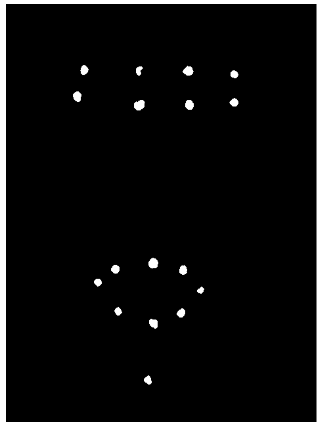

Figure 2.4: Example of Binary Segmented Image

should follow the distribution seen in Figure 2.2.

The segmented binary image seen in Figure 2.4 is then swept, searching for the white regions. When a region is found, it is assumed that it is a circle and its diameter is measured. To avoid the influence of noise naturally occuring during segmentation of the scene, a region will only be accepted as a marker if it has a diameter greater than 7 Pixels (value experimentally established). If the region is accepted, its center of mass coordinates will be labeled and saved for posterior processing. The white region is then removed so it will not be read multiple times.

The identification of the points and their association with the labels is made considering both its position in the image and its position in relation to the other points in the image. To facilitate this identification, points of the mouth region and those of the eyebrow are processed in different data sets, so that they are compared only with the points in their own region. Once the sweep is finished, the points are sorted according to the increasing order of their horizontal coordinates. If it is the first scan of the image, the reference points need to be created, otherwise they will will be moved and receive the displacement information. In both cases, the identification of the labels is done using this same algorithm.

2.2.1 Tracking Eyebrows

The distribution of markers in the eyebrow region should always be as seen in Figure 2.5. The markers are arranged in four columns with two markers each. In this way there will be 4 pairs of points, where each pair has close values in its horizontal coordinates. Thus, by ordering the points in an increasing order of their horizontal coordinates, the pairs of points of each column will always be subsequent in that ordered set.

Each pair of points will then be compared as to their vertical coordinates. The point closest to the top of the image will be labeled as the top point and the one closest to the footer shall be classified as lower point. The figure 2.5 illustrates the marking performed by separating the upper points $s1s$, $s2s$, $s3s$ and $S4s$ from the lower points $s1i$, $s2i$, $s3i$ and $s4i$.

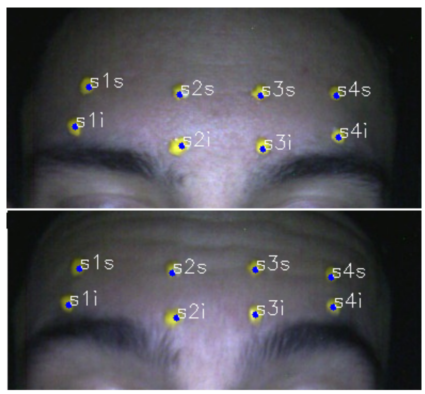

Figure 2.5: Tracking Eyebrow Markers

2.2.2 Tracking Lips

Despite the absence of uniformity seen in the eyebrow region, the mouth markers are similarly identified. The left most point is labelled **corner 1**. The next two points will be compared using their vertical position. The one situated closest to the top of the image will be the top point. The closest to base of the image will be the lower. Then, the next 3 points will be compared, the lowest will be the point of the chin, the highest will be the upper lip and the other point will be the lower lip. The next two are compared similarly to the first pair. The last point will always be the **corner 2**.

Figure 2.6 illustrates the markup process of the mouth points in two different shapes.

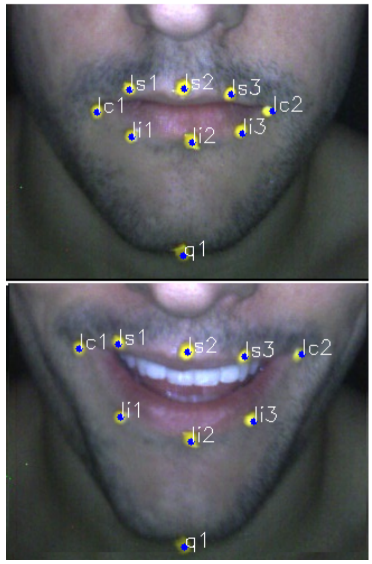

Figure 2.6: Tracking Lip Markers

2.3 Tracking Eyes

The user's eye tracking is semi-assisted. Requires minimal intervention, only to create an initial marking on the eye overall area in the interactive system. Once the eye region is defined, rectangles will appear on the eyes indicating the region processed screening, as seen in Figure 2.7. Since the head gear holds the camera static to the user's face, the position of the eye regions need not be corrected during the capture.

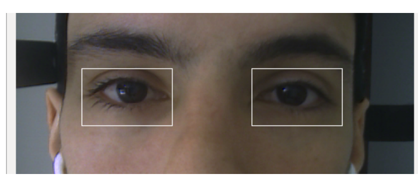

Figure 2.7: Eye Tracking Regions

The tracking takes place in two phases: first the horizontal position of the pupil is found, and then the vertical position. Each eye is isolated in a new image of 60 vertical pixels per 110 horizontal pixels. Grayscale images are obtained from the isolation of one of the color channels of the original

RGB image. Then the images are thresholded, assuming pixels will be Zero (black) if it is less than or equal to the established threshold, and 255 (white) if it is greater than that threshold. The appropriate threshold is set capture software and may be adjusted according to the scene lighting conditions. The thresholded image can be seen in Figure 2.8

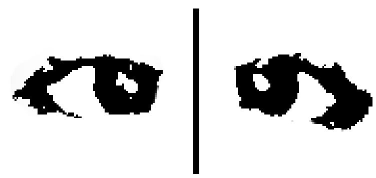

Figure 2.8: Segmented Eye Tracking Regions

The dark regions of the eyelashes cause the appearance of noises in the lateral part of the face. To avoid unnecessary processing of this noise, it was decided to carry out the search in the image from the center of the face towards the sides, in a column first search.

The columns are scanned looking for the first continuous vertical sequence of five black pixels. when this event occurs, the contour pupil was found. To determine the horizontal coordinate of the center of the iris, an offset of 10 pixels is added towards the side of the face.

To determine the vertical coordinate of the center, the horizontal center column is scanned from the bottom edge of the window towards the top. The contour position is reached when a consecutive set of 5 black pixels is found. The first pixel determines the contour. A 10 pixels offset is added towards the top edge of the image and that point will be the vertical of the center of the iris.

The decision to scan from bottom to top in the search of the vertical center, is to avoid the unwanted processing of eyelashes noises from segmenting.

The five pixel count was enough to eliminate noise from the segmentation stage and find the iris successfully. Since the iris diameter is constant, a offset of 10 pixels was sufficient to determine the coordinates of the centers. These parameters can be easily adjusted for alternative image resolutions. The result of the tracking can be seen in Figure 2.9.

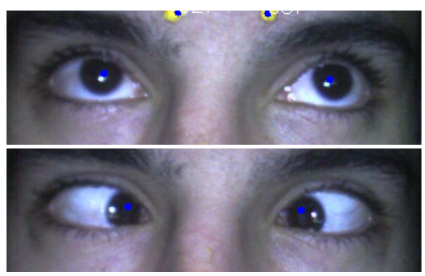

Figure 2.9: Eye Tracking

Chapter 3

Animatronic Puppet

3.1 Construction Process

The term Animatronic was created by the Walt Disney Enterprise department of Imagineering. WDE was company in charge of the creation of Disney's parks and attractions. Always ahead of his time, Walt Disney founded the Imagineering department uniting imagination, creativity and engineering to bring together art and science, using technology to make dreams come true, creating new technologies wherever it was lacking. One such new technology was the Audio Animatronics, robotic structures created with the purpose of bringing to the three dimensional world animated characters from Disney animation studios, mimicking their movements and replicating their appearance. The term Audio Animatronic derives from the expression Electronically Animated by Sound, since originally these robots were controlled using audio tones on magnetic tapes to drive the electromechanical actuators [14].

The construction of an animatronic is a join of artistic and technological processes. Initially, drawings and character models are made. From the concept, a life-size sculpture of the external aspect of the character is made. For this report a chimpanzee character was chosen. The plastiline clay sculpture is shown in Figure 3.1.

The sculpture is then molded into a multi-layered process. Initially a layer of silicone rubber is brushed over the sculpture, it is given the name of Beauty Coat, its purpose is to register the finer details of the surface. When this layer is close to full cure, it is time to apply a second reinforcement

Figure 3.1: Plastiline Sculpture

Figure 3.2: Ears Sculpted Separately

layer, this time the Aerosil thickener is added to the silicone, to prevent it from being too runny, increasing the thickness of the mold quickly. Because silicone is flexible and captures details but does not hold shape well when it is not so thick, a plaster jacket (or matrix) is created to give it structural integrity. The matrix was cast in two halves to allow access to the inside of the mold and was be reinforced with hemp fibers to increase its strength. The ears were sculpted and molded separately. When the plaster dries, the mold is then opened and the clay removed from the silicone, leaving a negative version of what has been sculpted.

3.1.1 Skin

Inside the mold is placed a layer of clay, representing the space that at one point will be occupied by the rubber skin. Over the clay is laminated polyester resin reinforced with fiver glass. This layer of resin will become the skeleton of the animatronic called the underskull. The mold is then opened, the underskull is removed and cleaned. The clay is removed from the mold and it should also be cleaned. The underskull will then be replicated, one copy will be mechanized, others will be used to make the teeth, the skin,

Figure 3.3: Half Mold in Silicon with Plaster Mother Mold

and support the skin during subsequent painting and finishing processes. The mold should be prepared so that the skin material does not stick to the silicone, first a layer of soapy water was placed, which creates a film protecting the silicone, and then a layer of petroleum jelly. The mold is then closed with the underskull inside, and the skin material is injected into the void formerly occupied by the clay. For this report the skin was made using pigmented platinum cured silicone rubber. When the silicone cures completely, the mold should be opened, the skin removed, cleaned, trimmed, any bubbles or imperfections reappeared, painted and finished with hair if necessary.

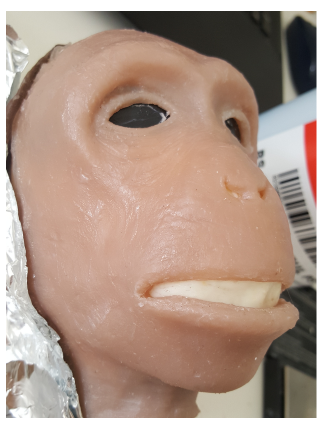

Figure 3.4: Silicon Skin Out of the Mold

The skin was then painted with oil-based, acrylic paints and silicone caulking for durability. The ears were made with silicone caulking pigmented with acrylic paints, and painted with oil paints, when dried they were glued onto the skin using more silicone caulking.

Figure 3.5: Painted Skin with Ears Attached

3.1.2 Teeth

The process of making the teeth begins with an articulated underskull, the upper and lower teeth will be sculpted on it simultaneously. The articulation is important to prevent the teeth from colliding in the opening and closing of the mouth of the final animatronic, so it is essential that the joint pivots at the same point as the final mechanism. After finishing the sculptures, the teeth will be molded using silicone rubber, from this mold the final acrylic resin versions will be made.

The teeth are made in two stages, initially the mold is filled with self-curing acrylic resin of tooth color. When cured and removed from the mold, the entire denture will have a tooth color, the gum part must be cut so that only the teeth remain. The teeth will then be put back into the mold, which will now be filled with gum colored self-cured acrylic resin. When the two steps are completed, the denture should be cleaned and finalized. Using diluted acrylic paints, details like tartar and darkening gum regions to give depth are added.

Figure 3.6: Teeth Being Sculpted on Articulated Underskull

Figure 3.7: Teeth Cast Before and After Final Painting

3.1.3 Eyes

The eyes were made with a process somewhat similar to the teeth, using two polyester resins, one black pigmented cap for the base, and one transparent representing the cornea. The base was sculpted in clay as a semi-sphere trunk, in the flat part of the trunk a small hole was made to represent the pupil, this sculpture was then molded in silicone and replicated in black pigmented polyester resin. On the flat part, around the pupil was painted the iris using acrylic paints. The base and the pupil can be seen in the figure 3.8.

A second mold was made, also in silicone, extending the trunk to a complete half-sphere. The painted iris bases were then placed inside the second

Figure 3.8: Eye Base Before and After Iris Being Painted

mold filled with clear, crystal polyester resin to create the depth sensation and eye lens structure.

Figure 3.9: Finalized Eyes

3.1.4 Mecanization

The process of mechanization begins with the planning of the movements that are expected of the character. For purposes of proof of concept, in this work the focus will be on articulation and control of mouth opening and closing. The eyes could also be mechanized to point at different positions and blink, however this effort would raise the cost of manufacturing the puppets and it is not necessary. Using the underskull as a base, the mechanisms are then designed to move the skin giving the illusion of bones and muscles of the character. A point of rotation was chosen for the mandible. Then the mandible was separated from the rest of the head. The correct position of the teeth relative to the mouth on the skin was measured and then one part representing the jaw was cut off from the rest of the underskull (which was split in two to allow access to the motors that will remain therein, the halves being secured by screws to the Center plate), removing enough material so that the teeth could be attached (Figure **??**).

A central plate made of plywood secures and stabilizes the servo motors. Two rods have been added horizontally to provide stability and prevent the plate from shifting inside the underskull. The central plate is also attached to the underskull using 4 screws, two in the front half and two in the back half that can be removed to access the internal mechanisms.

The articulation has one degree of freedom in rotation, it was made of wood in two halves plus a pin that interconnects them. Each articulation was affixed to the interior of the underskull using bicomponent epoxy glue. During the fastening process it is essential that the articulations on both sides have their axes of rotation aligned to allow for a smooth opening and closing of the mouth, avoiding unnecessary overloading in the motor. Initially a wooden linkage was used coupling the motor to the mandible, but it was observed that the rigidity of the wood was interfering in the movement, so it was replaced by a metallic coupling, as can be seen in Figure 3.10.

Figure 3.10: Mouth Mechanism with metallic coupling

A wooden stand (Figure 3.12) was built to hold the character's head allowing the mouth to open freely. The head was affixed to the stand by means of its central plate, leaving free space for both the movement of the jaw and the attachment of the back of the underskull.

Figure 3.11: Mechanized Mandible with Teeth Attached

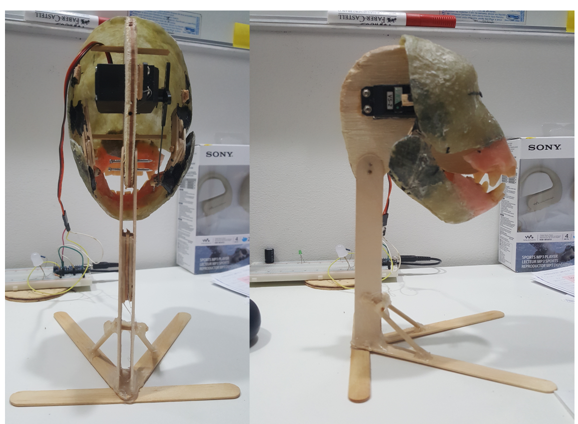

Figure 3.12: Wooden Base

Chapter 4

Control System

The capture system presented here can be used to animate both digital and practical characters. To transfer the movements from the user's face to the character's face, the system has a control module that communicates serially with an embedded system based on the Atmel ATMEGA 328 microcontroller. As the software reads the displacement of the points of interest and turns it into a value from 0 to 255 that is sent via the RS-232 protocol. The hardware receives this value and turns it into a control signal for the servo motor.[6]

4.1 Hardware

The microcontroller sets up an 8-bit asynchronous UART communication protocol to receive data from the software control module. The communication takes place through a USB port and the conversion to serial is done on the hardware. PWM (Pulse Width Modulation) signals are generated from the internal counters of the microcontroller. They are two 8-bit and one 16-bit counters, each counter being able to generate up to two independent PWMs, allowing the control of up to 6 independent motors [3].

Servo motors are DC motors internally controlled by a PID controller, where the desired position is defined by the input PWM signal, and the feedback is given by an internal potentiometer. The servos used have a 180 degree range of motion, and their position is determined by the time the PWM is at a true logical level. The PWM is a square wave (having only two values, zero or one) where the information is stored in the wave width, if the signal is in a millisecond or less, the servo will be in the 0 degree position. If it stays in one for 2 milliseconds or more, the servo will be in the 180 degree position. The interval between the maximum and minimum is divided linearly.

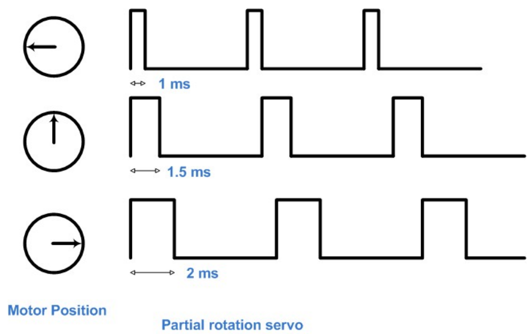

Figure 4.1: Servo-Motor Position and Control Signal

The hardware then waits to receive the message from the control module. For each motor two bytes are sent, the first identifies the motor to which the information is pertinent, the second indicates the value that will be passed to the PMW. As long as there are bytes available for reading on the communication channel, the hardware will read them and change the value of the control signals.

4.2 Control Module

The control module allows you to configure various aspects of the communication between the capture software and the dedicated control hardware. Initially the user must select a serial port from the automatically detected ports listed by the system as the communication channel to which the hardware is connected. Next, the parameters of the servos to be used must be configured as the label of the marker that serves as reference for its operation and a gain (which can amplify or attenuate the movement of the marker). Maximum and minimum values for the position of the servo can also be configured, since not necessarily the joint that it activates will have the same range of motion as the motor. The configuration can also be mirrored, because depending on how the servo has been embedded in the physical structure, it may be necessary to mirror its motion to correctly replicate the captured motion.

The capture system passes to the control module a data set containing the positions of the markers, their labels, and their displacements relative to the previous position. The control module identifies which servos have been configured to follow which markers and then calculates the value that should be sent to the control hardware. This value is calculated by applying the gain determined by the user, mirroring the measurement if necessary, and then saturating to the maximum and minimum values set for that motor. When a servo's position changes, a message is sent serially to the control module containing a byte that identifies the motor to which the value is relevant, and its new position.

Chapter 5

Results

The system was able to detect the markers and position of the pupils with accuracy most of the time, with some noise in the accompaniment of the markers due to changes in the illumination pattern due to the movement of the markers, which caused variations in its format In the filtered image (figure 2.4), resulting in slight fluctuations in the detection of the center of some markers. As far as pupil screening is concerned, both threshold noise and shadows and blinking result in eventual fluctuations in detection. In Figures 5.1 and 5.2 the functionality of the tracking system can be seen by comparing different facial expressions.

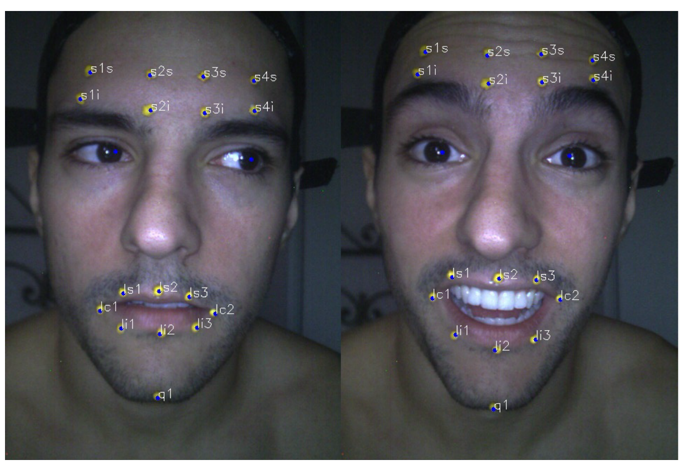

Figure 5.1: Neutral vs Surpresed Expressions

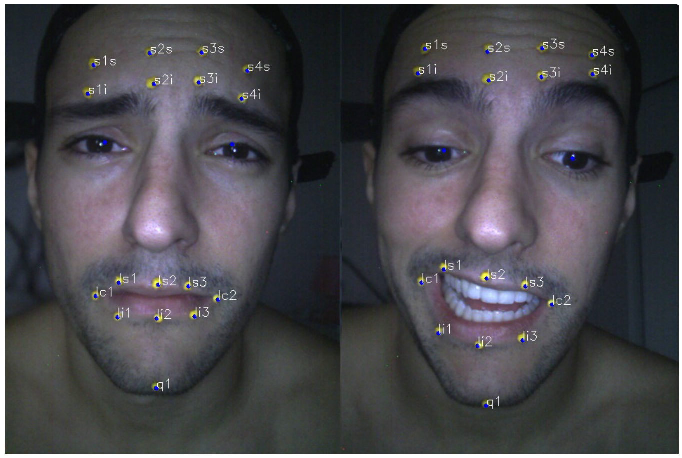

Figure 5.2: Comparing Different Facial Expressions

The animatronic animation focused on the chin marker (**q1**), identifying opening and closing of the user's jaw and transferring the movement attenuatedly to the puppet. The figures 5.3, 5.4 and 5.5 show the capture system controlling the animatronic.

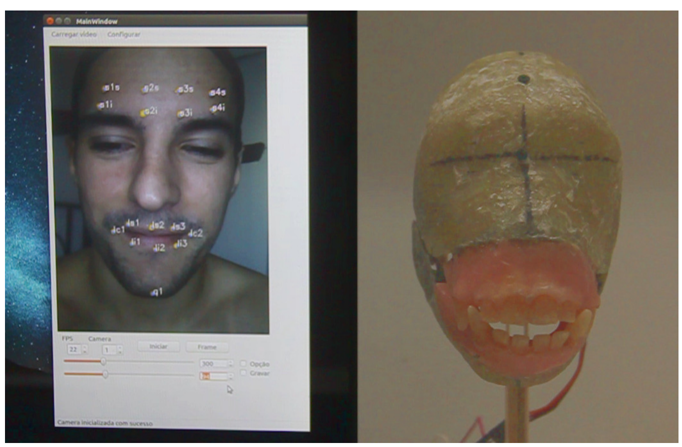

Figure 5.3: Mouth Fully Close

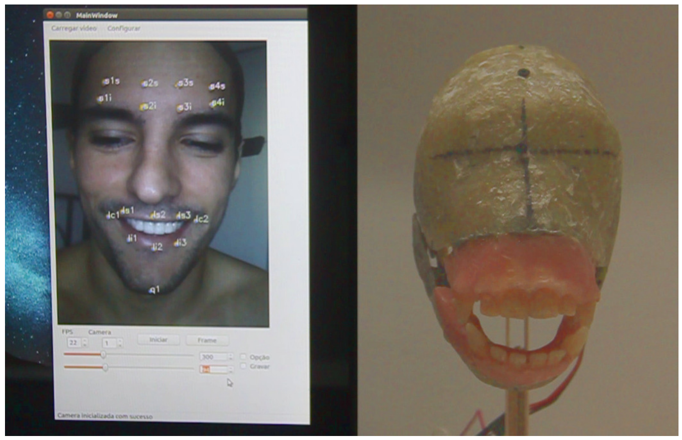

Figure 5.4: Mouth Half Opened

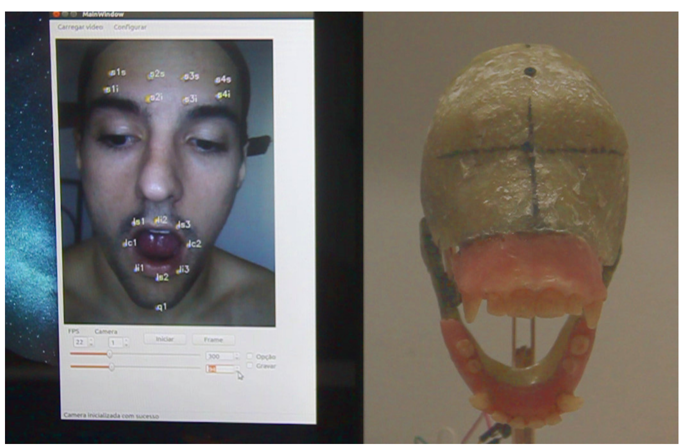

Figure 5.5: Mouth Fully Opened

Chapter 6

Conclusions

Bibliography

[1] ADMTronics, *Pros-aide adhesive*, `http://www.pros-aide.com/original.html`, Accessed: 2016-09-28.

[2] Antonio Camurri and Gualtiero Volpe (eds.), *Gesture-based communication in human-computer interaction, 5th international gesture workshop, GW 2003, genova, italy, april 15-17, 2003, selected revised papers*, Lecture Notes in Computer Science, vol. 2915, Springer, 2004.

[3] Atmel Corporations, *Atmega48pa/88pa/168pa/328p datasheet*, Datasheet, 2009.

[4] Amit H. Bermano et al., *Facial performance enhancement using dynamic shape space analysis*, ACM Transactions On Graphics (2013).

[5] Ugur Gudukbay Fatih Erol, *An interactive facial animation system*, International Conference in Central Europe on Computer Graphics, Visualization and Computer Vision (2007).

[6] Agostinho M. B. Júnior Matheus F. P. Pereira, *Um sistema de captura de movimentos de baixo custo para animação de personagens*, Anais do II Encontro Potiguar de Jogos, Entretenimento e Educação (2016).

[7] Thomas B. Moeslund and Erik Granum, *A Survey of Computer Vision-Based Human Motion Capture*, Computer Vision and Image Understanding **81** (2001), no. 3, 231–268.

[8] Donald Neth and Aleix Martinez, *Emotion perception in emotionless face images suggests a norm-based representation*, Journal of Vision (2009).

[9] Takaaki Shiratori, Moshe Mahler, Warren Trezevant, and Jessica K. Hodgins, *Expressing animated performances through puppeteering*, IEEE 3DUI (2013).

[10] Jim Henson's Creature Shop, *History*, http://creatureshop.com, Accessed: 2016-10-31.

[11] Leonid Sigal and Vladen Koltun, *(marker-based) motion capture*, University Lecture, 2012.

[12] EtPhoto SmugMug, *It's alive! bringing animatronic characters to life on film (está vivo! trazendo personagens animatrônicos à vida em filmes)*, https://etphoto.smugmug.com/Henson/Animatronics-Exhibit/i-ccr36rM, Accessed: 2016-10-31.

[13] Vicon, *What is motion capture*, https://www.vicon.com/what-is-motion-capture, Accessed: 2016-10-15.

[14] Walt Disney World, *The history of disney's audio animatronics*, http://www.magicalkingdoms.com/blog/2008/07/08/the-history-of-disneys-audio-animatronics/, Accessed: 2016-10-29.