PERFORMANCE ANIMATION

Special Project on "*Capturing Facial Expressions*"

Guide: Prof. Phani Tetali

Project by

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APPROVAL SHEET

Special Project entitled

Performance Animation

By:

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Guide _____

DECLARATION

I declare that this written submission represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all the principles of academic honesty and Integrity and have not misrepresented or fabricated or falsified any idea/data/fact/ source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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I take this opportunity to thank our guide, Prof. Phani Tetali, for not only providing his valuable guidance, but also for the constant motivation throughout the project.

Jaison

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ABSTRACT

Affordance and low tech savvyness are the reasons why small budget films and independent film makers are not able to access the available high quality motion capture technologies. This project deals with the study of how to make an affordable technology for capturing facial expressions. It started with the study of the different kinds of motion capture, followed by their usage in films and the reasons why they are not affordable.

Different techniques were evaluated based on their ease of use, learnability, affordance and quality of the captured data.
Based on the study, a low cost technique was tested and the process was documented as quick learning tutorial for shortening the learning curve of a user.

The deliverables for this project is a report(Ashwin Vasudevan) and a video scenario(Jaison Jacob).

Note: *The software used is a 30 day trial version of the original software, downloaded from the original website.*

INTRODUCTION

Performance animation, widely known as 'Motion Capture' is way of recording movements or expression of individual people or their interaction with an environment. Its application is in numerous fields, such as medicine, entertainment, military, robotics and so forth.

The use of motion capture for computer character animation is relatively new, having begun in the late 1970's, and only now beginning to become widespread.

Motion capture is the recording of human body movement (or other movement) for immediate or delayed analysis and playback. The information captured can be as general as the simple position of the body in space or as complex as the deformations of the face and muscle masses. Motion capture for computer character animation involves the mapping of human motion onto the motion of a computer character. The mapping can be direct, such as human arm motion controlling a character's arm motion, or indirect, such as human hand and finger patterns controlling a character's skin color or emotional state.

The idea of copying human motion for animated characters is, of course, not new. To get convincing motion for the human characters in Snow White, Disney studios traced animation over film footage of live actors playing out the scenes. This method, called rotoscoping, has been successfully used for human characters ever since. In the late 1970's, when it began to be feasible to animate characters by computer, animators adapted traditional techniques, including rotoscoping. At the New York Institute of Technology Computer Graphics Lab, Rebecca Allen used a half-silvered mirror to superimpose videotapes of real dancers onto the computer screen to pose a computer generated dancer for Twyla Tharp's "The Catherine Wheel." The computer used these poses as keys for generating a smooth animation. Rotoscoping is by no means an automatic process, and the complexity of human motion required for "The Catherine Wheel," necessitated the setting of keys every few frames. As such, rotoscoping can be thought of as a primitive form or precursor to motion capture, where the motion is "captured" painstakingly by hand.

Performance animation is greatly used in animation and filmmaking, as it increases the liveliness of their characters. It is a flexible technique of animation. It is easier for a director to choose from a number of camera angles post the shoot. the present scenario the movements are converted to 3d data, so that it can be directly mapped onto the model.

Some believe that motion capture, rotoscopy, limited animation as such are technical cheats. Which maybe but the fact is that these are method to bring realism to unrealistic world. Just to make people believe it possible. These methods allow the animator to capture very subtle motions, that in real life carries a lot of emotions. This in ways enhances the quality of storytelling.

A BRIEF HISTORY OF PERFORMANCE ANIMATION

How it all started?

In the earlier times, there was a point in space. But nobody could communicate the point to others. it was either this point or that point.
With developments in maths the point could be plotted on paper and communicated to others. the point had a name and also the path of the point could be plotted as well.
then name of the point came to be (x,y,z) and its path F(x,y,z).
but still the path was not realistic enough since there the object rotates in its own path while it moves in its trajectory. This is where the eulers angles yaw, pitch and roll, help in our capabilities of understanding motion.
Together with path F(x,y,z) and euler angles, motion of any point could be tracked efficiently in space.

Figure: Construction of 3D images from photographs using Lambert's Spacial Resection

1774

Space Resection by Johann Heinrich Lambert is one of the earliest works.
It allowed the estimation of the viewers postion by the use of geometric perspective.
In motion capture, know the position of the camera is essential in tracking the motion.
[1]

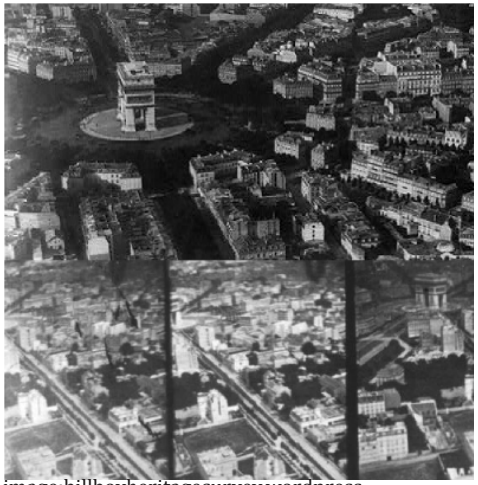


image:billboyheritagesurvey.wordpress.com/2012/03/07/the-aerial-view-how-did-we-get-here/

1849

Aimé Laussedat - First person to make maps using photographs
In 1867 he exhibited the Phototheodolite, where he had used the principles of resection to make a plan of Paris using photographs taken from rooftops. Thus, cartography started to drive development of the mathematics that underlies photogrammetry. [1]

Figure: The first images created to measure movement

1872

Eadweard Muybridge - He was the first person to create motion through photogra phs. Muybridge essentially helped to settle a wager over whether all of the horse's feet left the ground at the same time, during a trot. For this, he photographed the trotting horse, within short intervals. And when he played back the photographs together in series, he could see a horse in motion. This lead to the development of motion pictures and the subsequent video systems that we have now.
[1]

1980-1983

Simon Fraser University — Goniometers
In the early 1980's, Tom Cal vert, a professor of kinesiology and computer science at Simon Fraser University, with the help of potentiometers drove computer animated figures for Clinical assessment of movement abnormalities in human bodies. To track the movement, he strapped a kind of exoskeleton to hands and legs which gave analog output according to the movements and it was converted to a digital form and fed to the computer animation system. [1]

1982-1983

MIT — Graphical Marionette

In the early 1980's, both the MIT Architecture Machine Group and the New York Institute of Technology Computer Graphics Lab conducted an experiment using optical tracking system. This system was based on flashing LEDs or small reflecting dots that were attached to a body and a series of two or more cameras focused on the performance space. They would capture the position of the markers according based on the data from the multiple camera. [1][2]

1988

deGraf/Wahrman — Mike the Talking Head

In 1988, deGraf/Wahrman developed "Mike the Talking Head" to show off the real time capabilities of the 4D machines. The system allowed a single puppeteer to control the character's face, including mouth, eyes, expression, and head position. [1][2]

1988

Pacific Data Images — Waldo C. Graphic
Waldo C. Graphic born. Waldo's strength as a computer generated puppet was that he could be controlled in real-time in concert with real puppets. The controls were based on the feedback received exoskeleton suit made with potentiometers.[1][2]

1991

Videosystem — Mat the Ghost
Mat was a friendly green ghost that interacted with live actors and puppets on a daily childrens' show called Canaille Peluche. Using DataGloves, joysticks, Polhemus trackers, and MIDI drum pedals, puppeteers interactively performed Mat, chroma-keyed with the previously-shot video of the live actors. Since there was no post-rendering, animation sequences were generated in the time it took the performers to achieve a good take. Videosystem, now known as Medialab, has continued to develop the performance system to the point where it is a reliable production tool, having produced several hours of production animation in total, for more than a dozen characters. [1][2]

1993

Acclaim

At SIGGRAPH ‘93 Acclaim mesmerised the crowd with the performance of two animated characters. Acclaim quietly developed a high-performance optical motion tracking system which was able to track up to a 100 points simultaneously in real-time. [1]

The age of computers

Computers influenced all aspects of photogrammetry. Stereo plotting machines began using potentiometers and servos connected to a computer instead of mechanical gears.
Later, photographs were scanned, digitized and analyzed directly in the computer in a process called “Soft image photogrammetry.”
An operator was still needed to identify common features in each of the images. For the process to be further automated, features in the image would need to be automatically identified.

1967

HUMMING BIRD

A ten minute computer animated film by Charles Csuri and James Shaffer was awarded a prize at the 4th International Experimental Film Competition, Brussels, Belgium, 1967. A line drawing of humming bird with the movements of a bird were programmed with the help of 30,000 images having 25 motion sequences. [1][2]

Meanwhile in Human Computer Interaction

Research in Robotics and Machine Vision yielded a means of finding discrete, high contrast markers (like white marker dots) in a digital image and calculating the 2D position of their centers (centroids) with subpixel accuracy

1996

Motion-Analysis
They developed their first “efficient” algorithm. This helped in establishing initial marker data and also helped in re-establishing it if lost from the viewport. [1][2]

After the introduction of this algorithm, the number of efficient systems developed shot up. But along with it the cost of these systems rocketed.

TYPES OF PERFORMANCE CAPTURE SYSTEMS

Electromagnetic Mocap

These systems work on the principle of constant origin, which is a small low frequency magnetic generator(transmitter sorce) and this signal is picked up by the sensor placed on the body. The transmitter and the sensor is connected to computer where the movement of sensor is analyzed with respect to the source, which in turn gives the 3D directions data.
Magnetic mocap generally uses 6 - 11 sensors to capture a body's motion. These systems are less expensive but the data is riddeled with disturbances. [3]

Disadvantages

- Sensitivity to metal
- Limited range
- Slippage of markers
- Markers offset from actual joint centers
- Repeated re-calibration
- Low effective sampling rate
- Latency
- Azimuth problems
- Proximity based distortion with multiple actors
- Lower sampling rates due to noise

Electro-mechanical Mocap

Movement is captured through the placement of sensors (or markers) on or near each joint of the body. As each joint moves the positions or angles between the markers are recorded. Software records the, angles, velocities, accelerations and impulses, providing an accurate digital representation of the movement.

These are also known as exo-skeleton mocap, as the sensors are attached to the performer in skeletal like structure. in this system the constant origin is within the suit, so the recorded data will be static, which means there will be no data of displacement of the character in an environment. [3]

Advantages

- Real time capture
- Inexpensive
- No occulsion
- No magnetic or electrical interference
- High portability
- Large capture range

Disadvantages

- No global translation
- Restrictions on the subjects movements
- Breakable
- Fixed configuration of the sensors
- Low sampling rates
- Deformations cannot be captured so no facial expression

Optical marker systems

In these kinds of systems, the actors wear a suit cover with makers. The exact position of the maker is calculated within the image of the camera. Since more than two or more cameras are being used, the position and movement of the data is calculated with help of initial calibration of object with camera. These systems have usually have 2 to 50 cameras. There are systems of 300 cameras, so as to reduce the maker swapping.

One of the main advantages of the system is that it is able to capture the movement at a high frame rate, this make it possible to record very fast movement like that of a martial artist, gymnast or athlete. Also, there is no restriction of movement due to small capture area. The area can be as wide as possible. [3]

Passive Reflective marker

Passive optical system use markers that are coated with a retroreflective material which reflects the incoming light that is projected on them to the cameras lens. These camera's threshold are set to sample only the bright reflective markers. [3]

Advantages

- Infrared, visible or infrared strobes cameras used(resolution-1 to 4 million pixels)
- 120-250 frames/sec (max 2000 frames/sec)
- cannot be used outdoors

Disadvantages

- No glossy or reflective materials
- Tight clothing
- Occlusion of markers by limbs or props

Active marker

These system calculate positions by illuminating one or multiple LED with a software, rather than using reflective markers. Each LED marker can be lit separately in sync with the capture time, which makes it possible to differentiate between each marker. This make it possible to do real time motion tracking to gain immediate feedback. [3]

Advantages

- Real time motion capture to display is possible
- No marker swapping
- Outdoor capture
- 3,600 x 3,600 resolution
- 120 frames/sec (128 markers or four persons)
- 480 frames/sec (32 markers or single person)
- 1/3 the cost of passive systems

CASE STUDIES OF PERFORMANCE CAPTURE IN MOVIES

Avatar

The first thought about this film started in 1995, since there was a lack of technology to execute that, the production was delayed until 2007. The crew came up with a Head rig that can be worn over the actor's head, it tracks life cast of the actor's head and has a laser scan to capture the facial expressions. The camera shoots the facial expression is locked off even if the actor is jumping around or doing anything. The head cap can capture everything from the actor's lips to the eyes.

Technology

Performance Capture – AVATAR's Crowning Glory[4]

Motion capture is only half of the story. Bringing together an enhanced form of the motion capture technology used to create Gollum in the

Lord of the Rings trilogy with James Cameron's virtual camera system allowed the motion of the actors to be instantly recorded, converted into digital information and relayed to the director as an augmented reality on a monitor. With this, Cameron was able to alter angles and look around the whole virtual landscape while in front of him the actors went about their business in front of an array of positioned cameras.

Performance capture, AVATAR's real star, allowed the actors to display emotion and speak, move their heads, blink and so on while apparently looking like a member of the Na'vi but without applying a single drop of makeup.

Director James Cameron pioneered a brand new type of camera specifically designed for this purpose. Worn by the actors like a skull cap, the device is equipped with a small boom that hangs over the forehead and places a camera around 6 inches from the actor's face.

This improved method of capturing facial expressions was then recorded digitally and used later on by animators to deliver the most revolutionary computer generated imagery (CGI) performances seen on film.

Rise of planet of the apes

Rise of the planet of the apes is the first live action film that has its main character as a full feeling, self-aware animal. The aim was to make real looking apes. The basic use of performance capture in this film is to create apes that are infused with heart and soul of an actor's performance. It wasn't possible without the help of Andy Serkis, the lead actor who played the role of "Caeser", the main character of the film.

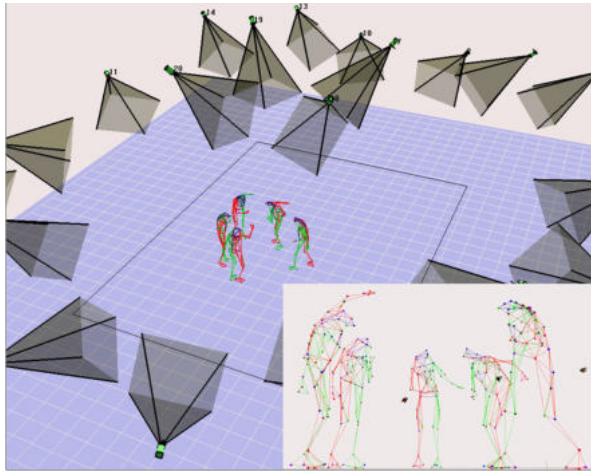
Motion capture[5]

The film crew went to the same people who had prior experience working with avatar and king kong to execute this project. One of the important changes they have done in this film from avatar is that they worked a lot on capturing the fine details of the type of imagery they were getting from the cameras gives more facial information. That subtlety helped them achieving more realistic apes. The VFX for this film was done by WETA VFX. They started with concept art, then studied the muscular system, the skeletal system and the body movements. They also made custom textures with wrinkles for each apes. The modeling department did the grooming

of the fur and after shades. Finally everything was combined together with the actual film in the shots. The performance capture for the first time, was moved into a live action location including the Golden gate bridge set.

Technique used

They used Motion Analysis Raptor system for the motion capture.[5]



Raptor-12

RealTime Digital System[7]

These motion systems were designed alonside with Mtion Analysis. Its unique feature is it allows motion capture both indoor and outdoor eith out any changes in hardware or software.

The Raptor-12 Digital RealTime System consists of Raptor-12 digital cameras and Cortex software, which captures complex motion with extreme accuracy. Real-time capabilities allow users to see capture results at the same instant as the subject is performing a specific task. With Calcium Solver software, users can solve directly to a character skeleton - a feature that is unmatched by any other motion capture company. Real-time previzualization is a reality with the systems (seefigure). Post processing data is clean and minimal, if at all, and Sky Scripting can be used to quickly process results and do batch processing.

Raptor-12 Camera[7]

First of its kind to be specifically designed for motion capture.

Advantages:

- User can see live feed on screen while acting with the actual location
- Sensor size, pixel size, optics, depth of focus, quality of the ring light and other mechanics all contribute to a motion capture camera's effectiveness.
- Cameras are also in focus throughout the entire volume and can equally see markers close and far away
- Accurate in fetching the facial markers

Disadvantages:

- Maker based
- Setting up the hardware and equipment takes time.
- Facial expression capture relies on the accuracy of the facial markers.

TED

In this film Seth MacFarlane played the CG character of TED, he wore aXsens suit to stimulate TED, it was shot livewith the other characters. The off camera was capturing the performance of the other characters and it was done live so that they can capture the spots and embellish. The interactions felt so organic and real, and it's a great tool. Nobody has so far used this technology so far for traditional character comedy. [8]

The main star- TED the bear is an animated character. The character animation was done by two studios- Iloura and Berkeley (Australia) and Trippett Studio (California). However, the film has nothing to do with what the actor has shown in the film promo. [9]

Motion capture of TED

The motion capture was focused from his waist up- because he had a lot of mannerisms with his hands and body. What they also did was keeping a high definition camera on his face. That way they could capture a visual representation of what the actor does with his eyebrows and his eyes. The animators used these videos as a reference to capture the facial expressions and apply manually to the bear

Xsens MVN

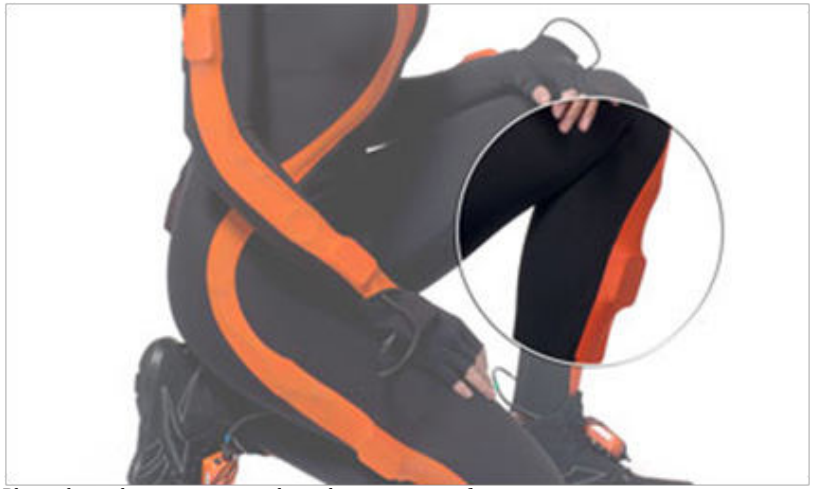
Xsens MVN is a full body, camera less inertial motion capture solution. It is a flexible system that can be used indoors as well as outdoors. It is known for its clean and smooth data.[10]

Highlights:

- Ease of use
- Production ready motion capture
- Robust motion capture system

Overview:

- Intuitive software (MVN Studio)
- Real-time motion capture visualization
- Unlimited capture volume
- Can save up to 80% post-processing time
- Short setup time (10 min.)
- On-set and/or outside motion capture
- Can easily be worn under clothing
- Ready-made pipelines for Autodesk products and Unity
- Network Streamer compatible with UDK and CryEngine



Plastic baseplates in suit to reduce skin motion artifact

Gutters in suit to contain the cables

Advantages

- Setting up time: 10 mins
- It is wireless
- Low budget
- Can be shot live with other charac ters
- Best for capturing body move ments

Disadvantages

- Doesn’t support capturing facial expression:

Facial expressions are captured with traditional methods like capturing high quality video of face and post processing it.
Plastic baseplates in suit to reduce skin motion artifact

HOW PEOPLE MOVE FACIAL MUSCLES TO EXPRESS WIDE RANGE OF EMOTIONS

21 Emotional States [12]

Some scientists, using software's, covered a range of human emotions that humans express on thier faces. The study states that there are 21 emotional states including "Happily disgusted" and "sadly angry", this was a break through since it was more than the known number of facial expressions that are expressed in the same way by everyone.[11]

The future scope of this study is to aid the diagnosis and treatment of conditions like autism and post-traumatic stress disorder.

The new trends in cognitive science is that the researchers are trying to map what governs the emotion in the brain and how this emotions are linked with facial expressions: The only expressions known until now were: happy, sad, fearful, angry, surprised and disgusted.

The researchers basically wanted to find the algorithm that is implemented in human brain that can be used to recognize the emotions in facial expressions.
Around 230 students(100 males/130 females) were photographed while responding to the cues designed to trigger emotions.
The responses were photographed and then

sorted based on the similarities as well as differences, that resulted in the creation of an expression database that is widely used in body language analysis: Facial action coding system. The result was 21 emotions which also had the combinations of the first 6.

This was done by tagging the prominent landmarks of facial muscles such as corners of the mouth or the outer edge of the eyebrows. this helped scientists to match emotions to movement.

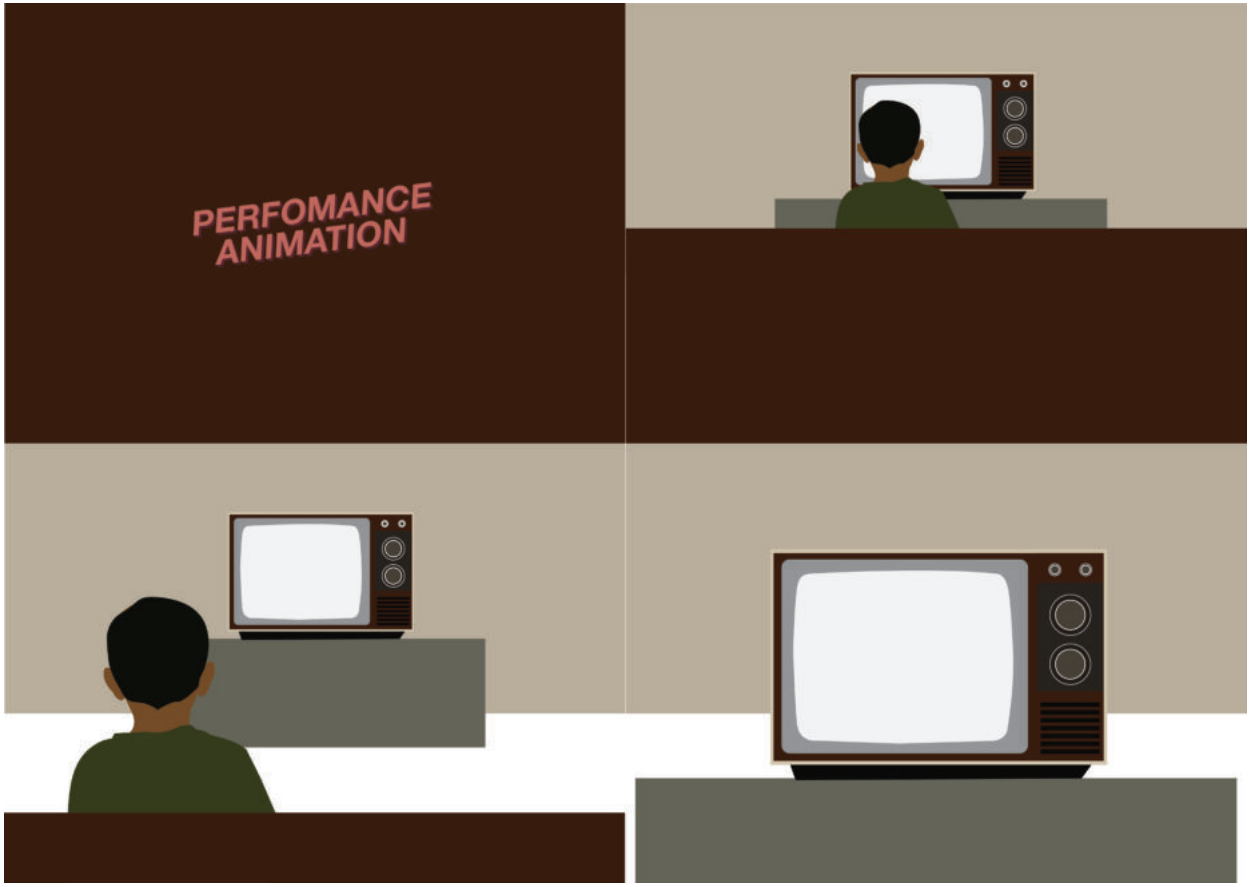
From the studies, it came to the notice that 99% of the participants, draw their cheeks up to smile while happy and 92% of them widened their eyes and opened their mouth when surprised.

Here is the full list of emotional states identified by the scientists from facial expressions: Happy, sad, fearful, angry, surprised, disgusted, happily surprised, happily disgusted, sadly fearful, sadly angry, sadly surprised, sadly disgusted, fearfully angry, fearfully surprised, fearfully disgusted, angrily surprised, angrily disgusted, disgustedly surprised, appalled, hatred, awed.

Conclusion:

If we have a system where a 3D model can be trained in real time with the direct feedback of these 21 facial expressions from the user, we can map the intermediate emotional states by image processing and create custom expressions for the animated 3D puppet.

CONCEPTS



Concept #1

The first concept is to create an animated info graphics on the evolution of the Performance capture. This scenario is designed in such a way that the viewer is taken through the entire history of the evolution of the techniques, each milestones in the evolution of the motion capture technique is carefully designed to help user connect the growth of technology over the years. The info graphic film ends with the state of art techniques used in the Hollywood films like avatar, Planet of the apes etc.

History of

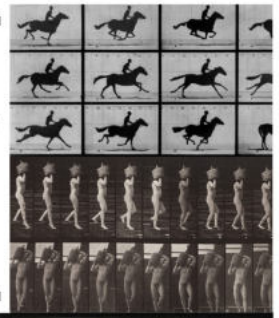
PERFOMANCE ANIMATION

1774 SPACE RESECTION

Johann Heinrich Lambert's Resection allowed estimation of the viewer/position using geometric perspective. Knowing where the viewer is located is critical to measuring where the image features are in 3d

1849 PHOTOGRAPHY FOR MAPS

Aimé Laussedat displayed a plan of Paris made using photographs taken from rooftops. Thus, cartography, started to drive development of the mathematicshed underlie photogrammetry.



1872 MEASURING MOVEMENT

The first images created to measure movement were taken by Eadweard Muybridge. This lead to the development of motion pictures and (eventually) video systems during the 20th century.

1967 COMPUTER ANIMATION

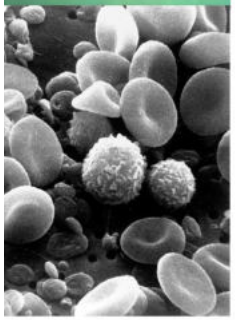
A ten minute computer animated film by Charles Csuri and James Shaffer. The subject was a line drawing of a hummingbird for which a sequence of movements appropriate to the bird were programmed.

1937 SNOW WHITE & THE PRINCE

Disney Studio used rotoscope technique for the characters of Snow White and the Prince

1915 ROTOSCOPE

The first motion measurement technique directly related to entertainment was Max Fleischer's "rotoscope".



1983 MOTION ANALYSIS

At its founding the company had a 2D tracking technology for living cells seen through a microscope. Their video edge detection technology became the basis for their 3D tracking system in about 1986.

1995 SKELETAL MAPPING

They incrementally built up the technique by deriving rotation from combinations of 3 markers. Eventually their Sagra technique used "virtual markers" offset onto the joints in the performer's body. The virtual markers were calculated as an offset from the actual markers joints in the performer's body.

Concept #2

The second concept is about documenting the entire experiment in which the motion capture was used to capture the facial expressions of the users and to interview professional animators about their view and understanding of motion capture and its applications. demonstrate how the facial expressions can be captured using low cost methods and what difference it can bring to the quality and time consumption for low budget films.

Concept #3

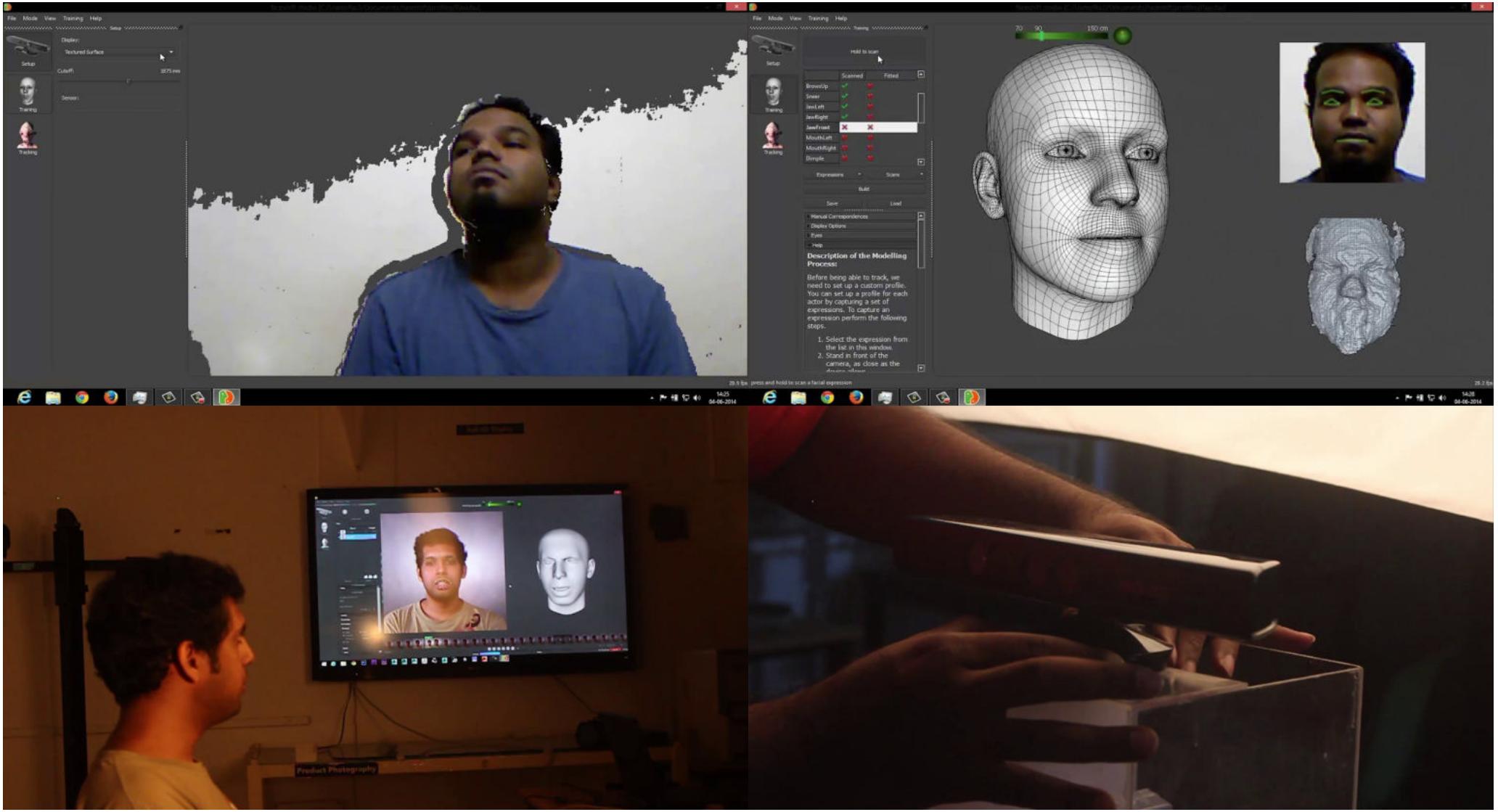
The concept 3 was about merging the most relevant points in the above two concepts; i.e. comparing the state of art techniques and telling the user the difference between the techniques used in Hollywood and Indian films and how this technique can be used in low budget films exposing the difference in quality and the scope for improvement in context of capturing facial expressions of Indian performance arts.

FINAL CONCEPT

Concept #3 was finalized as it has the most efficient way to give quick overview of the possibilities of performance animation along with demonstration of facial expression capture using a low cost method.

The method that we used consisted of Microsoft Kinect and Faceshift.[13]

(Refer video in DVD)


Description of the Modelling Process:
Before being able to track, we need to set up a custom profile. You can set up a profile for each actor by capturing a set of expressions. To capture an expression perform the following steps.
1. Select the expression from the list in this window.
2. Stand in front of the camera, as close as the
Product Photography

SCOPE FOR IMPROVEMENT

The Indian text book, *Natyasastra* have defined the facial expressions in context of Indian performance art. There are 8 sentiments or rasas recognized in drama.[14] They are:

1. Erotic (Sringara)
2. Comic (Hasya)
3. Pathetic (Karuna)
4. Furious (Raudra)
5. Heroic (Vira)
6. Terrible (bhayanaka)
7. Odious (bibhatsa)
8. Marvellous (adbhuta)

There are Dominant, the Transitory and Temperamental States:

The dominant States are said to be the following: love, mirth, sorrow, anger, energy, terror, disgust and astonishment.
There are 33 sittranory states and are to be the following: discouragement, weakness, apprehension, envy, intoxication, weariness, indolence, depression, anxiety, distraction, recollection, contentment, shame, inconstancy, joy, agitation, stupor, arrogance, despair, impatience, sleep, epilepsy, dreaming, awakening, indignation, dissimulation, cruelty, assurance, sickness, insanity, death, fright and deliberation. These are defined by their names.

The 8 temperamental States are Paralysis, Perspiration, Change of Voice, Trembling, Change of colour, Weeping and Fainting.[14]

These are not covered in the existing state of art. The user should be able to customize and define the kind of expressions he wants based on his need.

BIBLIOGRAPHY

1. History of motion capture :
https://www.siggraph.org/education/materials/HyperGraph/animation/character_animation/motion_capture/history1.htm

2. Brieft History of motion capture :
http://www.motioncapturesociety.com/resources/industry-history

3. Motion Capture Systems :
http://en.wikipedia.org/wiki/Motion_capture

4. Motion Capture for Avatar :
http://avatarblog.typepad.com/avatar-blog/2010/05/behind-the-scenes-look-at-the-motion-capture-technology-used-in-avatar.html

5. Rise of the Planet of the Apes (2011) HD Weta Featurette Making :
https://www.youtube.com/watch?v=X-M9Pvfq1KhE

6. Dawn of the Planet of the Apes , 20th Century FOX :
https://www.youtube.com/watch?v=3sHM-CRaS3ao

7. Raptor 12 Camera Systems :
http://www.motionanalysis.com/html/animation/raptor12.html

8. TED(2012) Interview with Seth Macfarlane:
http://www.cartoonbrew.com/feature-film/how-seth-macfarlane-created-the-anima- tion-inted-65641.html

9. Making of TED(2012) :
http://www.slashgear.com/ted-mov- ie-hits-the-top-bar-with-visual-effects-supervisor- jenny-fulle-30235396/

10. Xsens Motion Capture Suit :
http://www.xsens.com/products/xsens-mvn/?gclid=COrs2_Ww6LACFeUBQAodOR0pzw

11. Mapping Facical Expressions by Dr Aleix Martinez, Ohio State University :
http://www.theguardian.com/science/2014/mar/31/happily-disgusted-scientists-map-facial-expressions

12. Image Source for 21 Facial expressions :
http://www.telegraph.co.uk/news/picture galleries/howaboutthat/10736128/In-pictures-Scientists-map-21-facial-expressions-and-emotions.html?frame=2868612

13. Faceshift software for capturing facial expressiopns :
http://www.faceshift.com/help/studio/beta/#faceshiftstudiobeta-TrainingExpressions

14. Data of India's cultural History in the Natyasasthra/3. Art/ page no:83