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Paper

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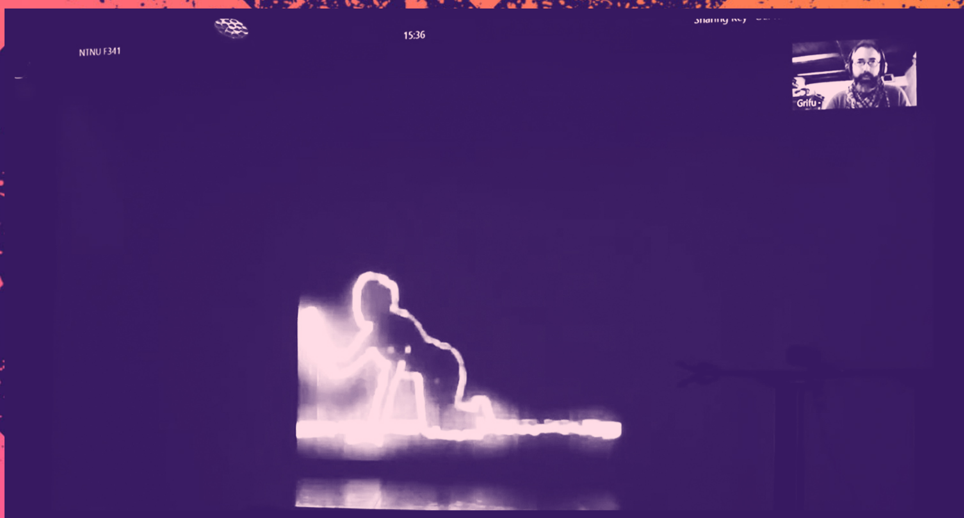

Solitária - Gestural Interface for Puppetry Performance

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Abstract. *Solitária* is a performance that employs puppetry techniques to manipulate digital media. The performance was designed upon the duality between the material and the non material existence, between the physicality and the virtuality. A gestural vocabulary was developed to manipulate both sound and visuals in realtime. We have built an interactive system to support both tangible and intangible manipulation, as well to respond and react to a specific body movement. This work explores puppetry techniques with sound and digital animation, engaging the audience with a dialog between the body language and the digital media. We found that sound and visuals can be manipulated in a similar manner through puppetry methods, as if we pull the strings from the same instrument. This framework was implemented with success responding to the requirements of the performance. *Solitária* was presented at the Festival Internacional de Marionetas do Porto (FIMP19) in October 2019. In this paper we describe the project's concept, the methodology and the outcomes.

Keywords. Digital Puppetry, Performance Animation, Digital manipulation, Digital Performing Arts

Figure 1: *Solitária* is a performance that employs puppetry techniques in the manipulation of digital media.

Introduction

This paper describes a digital framework designed to support a multi-dimensional and multi-modal puppetry performance. This framework was developed to expand the creative possibilities during the design process of a puppetry performance, by supporting and facilitating the interaction design and the integration of digital media. The interaction design was based on tangible and non-tangible manipulation challenging the puppeteer to explore methods with his body to change the media in an expressive manner. The relation between the puppeteer (controller), the media object (puppet) and the audience was a key aspect for the interaction design. In particular, methods to provide a directness feeling to the puppeteer while manipulating a non-physical media object, and to enhance the perception of the audience to this mediative choreography.

Technology and Performing Arts

Performing arts can take advantage of the interactive dimension provided by low-tech technology as a creative resource to augment the performing experience. The most common aspects addressed by performance-based digital interactions is the notion of time and space. There are multiple strategies for designing interactive performances based on body motion, and create digital contents responsive to the performer's behavior. The performer's space-time motion dimension, which refers to features such as gesture speed; gait; body posture; global/local position, provides a rich and expressive resource for manipulating digital contents. Generally, there are two common motion-based techniques employed in interaction design based on the performer's body: 1) motion tracking; 2) motion triggering. The first refers to the capability of tracking the movement of performers in space. The later refers to the digital response of a recognised motion (impulse) in a certain amount of time and space.

Among the performing arts, dance is probably the most susceptible in exploring technology as a creative tool. Embracing the fusion between art and technology, motivating the exploration of new grounds, and new artistic processes. Many choreographers have been stimulating the integration between the human performer, and the machine, between the physical, and the virtual space. This integration can be used to extend the body of the performer, as seen in the work of Troika Ranch[1], a company that combines dance, theatre, and digital media (Masura and University of Maryland, College Park. Theatre, 2007). Towards the integration of the body of the actor, and the machine on stage, their work reflects the human condition, and its extension through different media. Many dance projects use motion tracking intensively, to trigger and model the digital media (visual and sound), such as the *NUVE* (2010) produced by João Moura and Né Barros (Moura, 2012); *Seventh Sense* (2011) produced by Anarchy Dance Theatre; *Apparition* (2012) produced by Klaus Obermaier and Ars Electronica Futurelab; *Hakanaï* (2013) produced by Adrien M & Claire B; or *Presence* (2013) by the art collective Universal Everything - Nowness, to name a few.

On the other hand, gestural control of computer music has been a popular research topic, and subject of extensive work. Interactivity has been employed in both music composition, as well as in music performance to control musical interfaces and digital instruments. The close relationship between music, and mathematics was determinant to push the exploration of computational systems, within music composition. On the other hand, the gestural control of musical interfaces, is related to the traditional methods of playing instruments, in a similar manner as the manipulation techniques from puppetry. In this way, we can establish a connection between manipulating a control interface in puppetry, as in music. The notion of gesture-to-sound mapping, can be described as a way to unconstraint the performer's body, through space and time dimensions. The pioneer in exploring non-contact gestures for music production was Lev Termen who developed the Theramin in the 1920's, an electronic music instrument controlled just by gestures. This can be consider the forerunner of the gestural control of digital musical instruments. While Wanderley (Wan, 2001) introduced the term *digital instrument*, to distinguish the gestural interface from the sound generation unit, Chadabe (Chadabe, 2002) introduced the term *Interactive instrument*, to establish the dynamic relation between the performer, and the instrument. Where the interface can be consider the instrument itself, controlled by the performer's body underling the interactivity.

Animation and puppetry are two related areas that received important contributions from the artistic and the scientific communities in the fields of interaction design and live interfaces. Lee Harrison III developed the first motion capture system based on a 'data suit' for animation in the early 1960's. An armature made with Tinker Toys, and potentiometers placed at the actor's joints. A human performer wearing this armature was able to animate a character in real-time (Harison et al., 1992). On the other hand, Jim Henson, the Muppet creator, introduced digital puppetry techniques into the media production framework (Jones, 2013) exploring novel puppetry and animation methods, in particular hand devices such as the Waldo - an embodied custom interface that allowed puppeteers to achieve expressive puppet control remotely. Since then, many devices were developed for live manipulation. A wide range of comercial interfaces are available and can be adapted and employed into sound and animation control. Today, independent artists explore the potential of accessible interfaces for their creations, such as the Microsoft Kinect. This wide offer, challenge the interaction designers to choose the appropriate device. The design space of input devices is based on properties that determine its use and performance. The designer must choose the most natural, efficient and appropriate device to a given task, taking into account what is sensed by the device for an appropriated mapping between the input and the output. Some researchers propose guidelines for choosing the most appropriate device for a specific task (Sturman and Zeltzer, 1993). Other's present interaction models to manipulate digital media

[1] Troika Ranch web site: http://troikaranch.org

in realtime (Leite and Orvalho, 2017). There are approaches that focus on the design space of animation interfaces (Walther-Franks and Malaka, 2014) supporting interoperable multimodal environments (Leite, 2018) (Leite et al., 2018). An interaction approach can provide the appropriate interface design to handle the multitude of media that characterises the performing arts, supporting its expressive manipulation in real-time.

Creative tools

In the early conceptualisation phase, it is determinante for the artist to have access to a wide range of interactive media tools that facilitate the experimentation. The creative process should not be blocked or constrained by limitations of the software which prevent the artist to put in practice his ideas and explore his imagination freely. During the creation of *Solitária* we survey tools and frameworks that responded best to our needs. At the end we developed a methodology that combined several pieces together based on interoperability, allowing the tools to communicate and share their properties. We developed an orchestra of digital tools. Instead of wasting our time solving technical issues we had the opportunity to focus mainly on the creative aspects of this production. This digital orchestra was composed by a constellation of applications including: Openframeworks, Pure Data, MaxMSP, eMotion, Kinectar, Ableton, QuartzComposer, Qlab, Osculator and Synapse. Most of these applications became active during a specific moment in the play and handled by a central application - Qlab. This digital "maestro" handles the digital flow through a cue list instructing the system to open and close a specific application. The media and control flow method is based on digital media flows such as MIDI, OSC, Soundflower, and Syphon, which allows the applications to communicate and exchange data. We also explored other applications that were easy to integrate in this ecosystem such as FAAST, Kinect Spaces, or TUIOkinect. In this section the conceptual creation of *Solitária* is described as well as its technical implementation based on each challenge.

Concept

Solitária is a project that explores the human condition (loneliness) in the solitary confinement, envisioning the behavior of a prisoner through his mind and body (Figure 1). How do we move, see, listen and think in a place where there is no light? The absence of light removes any spatial–temporal references and draw us to an unbalanced world. We are trapped in a tiny place where we can barely move. Our body is the only connection to the physical world. However, our sensorial capabilities begin to misbehave and soon we became disorientated. The solitary confinement is commonly described as a prison within the prison. The prisoner is held in a cell of approximately 7 square meters for 23 hours a day with just one hour of exercise in a cage outside the solitary (Broadhead and Kerr, 2002). What are the effects of this isolation on humans? Some reports point that prisoners held in isolation become disoriented and have hallucinations, leading them to despair. Solitary can contribute to make prisoners more dangerous to themselves, engaging in self-mutilation.

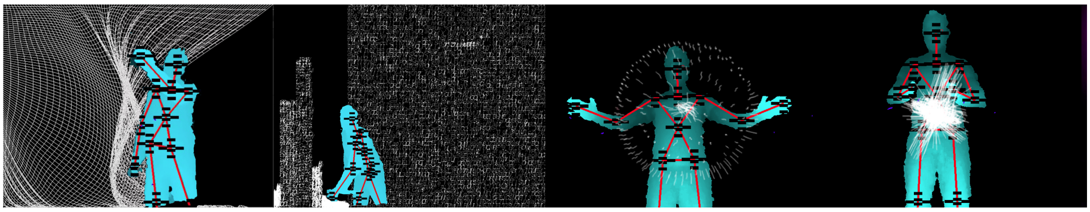

Figure 2: Envision interaction for *Solitária* performance.

This play attempts to recreate the experience of an inmate in isolation in a solitary confinement. Our focus was on the relations between the human gestures and the space that surrounds the prisoner, the progressive behaviour during isolation, from an initial disorientation behaviour to the hallucination phase. Our main reference to represent this experience was the human behaviour - body and mind. We wanted to explore a puppetry approach using the body of the puppeteer as the main controller, manipulating both sound and visuals. These elements are generated in real-time by the performer according to the character's emotions and state of mind. The project was created in two distinct artistic residences at *Convento da Saudade* in Montemor-o-Novo. One, dedicated to the sound manipulation (sound puppetry), and the other, to the image generation (visual puppetry). In both explorations the main focus was the body manipulation of media through a space-time approach, transposing puppetry techniques to a full digital media manipulation. With this approach we wanted to answer to questions such as:

- Can we manipulate sound in a similar way as we operate a puppet?
- Does intangible manipulation provide engagement with objects creating the sense of directness?
- Does the audience understand the body manipulation in a similar way as in puppetry?

This puppetry project depends exclusively on the performer's body, and on the digital media (sound, visuals). This interplay is determinant for the success of the performance (Figure 2).

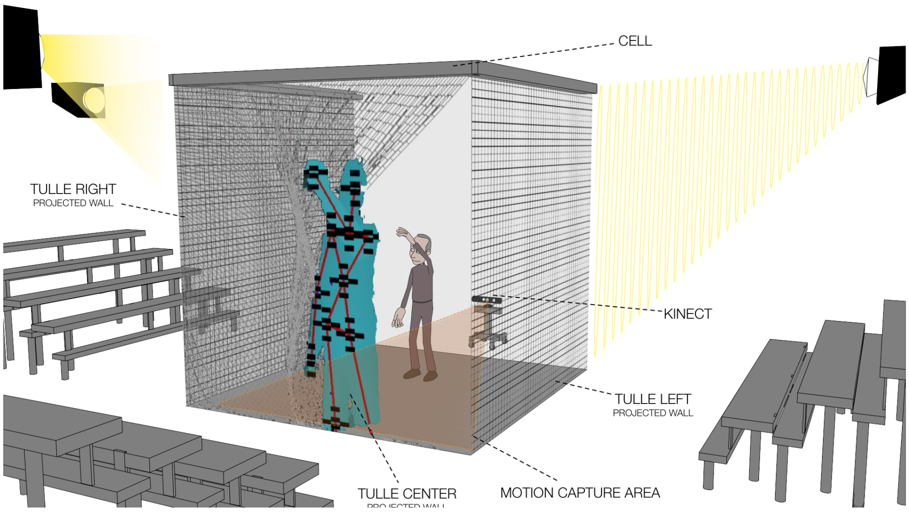

Figure 3: Simulation of the theatrical setup of *Solitária*. 3D character model by Rodri Torres.

Interaction Design

The Scenic Space

The scenic space recreates a cell with 9 square meters. The initial concept the cell was delimited with three translucent walls (Figure 3). These semi-opaque tulles could be used as screens for the visual environment. The audience could see through the tulles and see the actor and the other walls. However, to avoid too much noise and light interference we chose to have just one screen, and the other walls were represented with some tubular lights on the ground. The initial concept was composed by three front projectors, one Kinect, a web camera and several piezoelectric. The stage floor was divided into 9 squares of 1 meter that were used to segment the play (Figure 4 - Left). Each square was mapped to different functions and allowed the performer to trigger specific actions. Dividing the space for segmenting and for triggering actions based on the performer's body location is not new: Oskar Schlemmer also divided the stage (space) with visible coordinates mapping it to the performer's interaction (Masura, 2007).

The Body

We explored multiple dimensions for body interaction using: the body location in the stage; the body's posture; the body's gestures. The system was based on two distinct positioning coordinates (Figure 4 - Right):

- Position related to the camera (world space)
- Position related to the center of mass (body or local space).

The world space allows to manipulate parameters taking as reference the location of the actor in the stage, and it is useful for site-specific actions such as triggering behaviors or making objects to follow the actor. On the other hand, in the local space the position of the body parts depends on the body of the actor itself (pelvis) independently of his location in the stage, and is useful for gesture recognition.

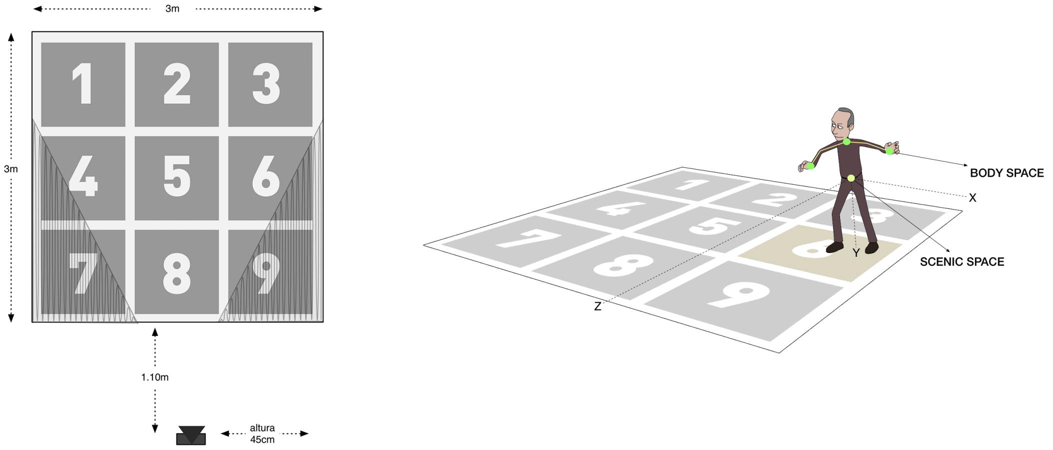

Figure 4: Left: The stage floor was divided into 9 squares for triggering actions; Right: Body space (local coordinates) vs scenic space (world coordinates) in *Solitária* setup

Gestural Vocabulary

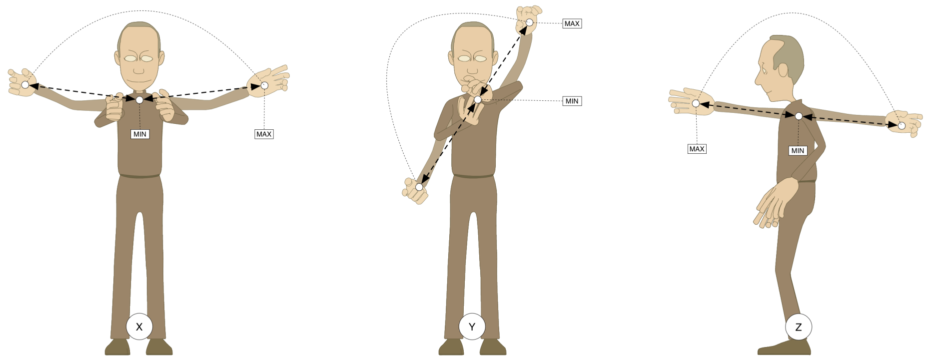

Figure 5: Hand gestures: motion ranges from different axis. 3D character model by Rodri Torres.

The body space coordinates are calculated from the center of mass (COM) of the body and are useful to retrieve the body's posture independently from its position in the set (Figure 5). In this project we use the center of hands (COH) as reference, which is based on the COM with an offset in the Y axis, aligned with the shoulder. The body's interaction is based on the position of both hands to the COH. The XYZ coordinates for each hand are mapped to a motion range between the values of -1 and 1, which represent the extremes (arms full stretched away from the center of the body). Thus, if both hands have a value of 1 in the X axis, it means that they are wide open in the horizontal plane. This is true even if the actor moves in the scenic space because the hands are calculated based on the body itself, not in the location of the body on the set. With this coordinate system and motion range, it is easy to map gestures to one or multi dimensional parameters. For instance, we can increase the volume of the sound, which is a unidimensional parameter, by raising the left arm. In situations where there were multiple unidimensional parameters, we mapped different axes, such as swiping the arm to the sides would change the panning of the sound while raising, and lowering the arm would change its volume. This flexible mapping scheme was employed in the control of sound and visual parameters, providing a great level of control. The puppeteer manipulates the digital media with his hands as if operating a marionette.

We created a vocabulary based on the body posture and gestures corresponding to certain actions or emotions such as:

- **Pain** = compressed gesture: moving the hands to the center (COH).

- **Strength** = expanded gesture: moving the hands away from each other in the X or Y axis.
- **Fear**: raising both hands in front of the face.
- **Disorientation**: sliding the arms forward and backwards.
- **Craziness**: circular gestures with the hands.

Sound-Puppetry

In *Solitária* sound is understood as an object, as a puppet that can be manipulated by the puppeteer. It was our intention from the beginning to explore sound manipulation with puppetry techniques, which we call the *sound-puppetry*. Sound is driven by the body position in space, or the movement of the body limbs. This technique can generate sounds, or drive the sound properties, such as pitch. One of the most important aspects in sound-puppetry is the mapping between the body and the sound property. We developed 4 categories for mapping sound properties to the body:

- Body instrument;
- Sound spatialisation;
- Sound triggering;
- Waveform navigation.

The sound-puppetry methodology is based on 3 steps : 1) To explore the different dimensions with the body we used the Microsoft Kinect for tracking the motion of the body with the OpenNI framework; 2) Osceleton (or Synapse) software was then employed to route the performer's skeleton coordinates, through Open Sound Control (OSC), to Kinectar. This application, used for musical performance, provides techniques for mapping the hands position to multiple actions that are sent through MIDI protocol; 3) Finally, these MIDI messages are mapped in Ableton to multiple functionalities including selection, triggering, navigation or even to play musical notes.

Body Instrument

We were able to assign the position of the hands to specific notes of an instrument through Kinectar. In this way, the actor was able to play piano with mid-air gestures. It is also possible to play a specific chord when the hand reach a certain position or even to control arpeggios. Each hand can be mapped to a different setup or action using any axes. We have explored these features searching for a correlation between puppet manipulation and music performance.

Sound Spatialisation

The space inside the cell is constrained to a few meters taking the prisoner to walk in circles. To emphasise this circular motion we mapped the center of mass (COM) of the puppeteer to the sound panoramic parameter. The sound follows the motion of the puppeteer in the X and Z axes, generating a sense of spatialisation. In certain parts we played with the sound panoramic to simulate movement while the actor stayed still. In these cases the panoramic is mapped to the right hand position X and Z, while the left hand takes control of the volume or the modulation of the sound.

Sound Triggering

Each square in the scenic space was mapped to a set of sounds associated with an action or emotion, and the actor was free to choose which sound to play according to his location. A hand gesture is required to trigger the sound, these gestures are defined accordingly to each square in the physical space. The body gestures were designed to represent specific actions. For instance, to recreate a basketball sequence with dribble actions followed by a shooting, we define in Kinectar the following mapping: the sound of a dribble will be played every time the right hand reaches the knee (-0.5 to -1) in the Y axis with a specific velocity; the shoot sound is played when the actor's right hand raises above the head (0.5 to 1) with a certain velocity. The velocity is important to avoid unintended triggers and to simulate the natural gesture. Many gestures can be mapped following this model, combining different axes such as knocking on a door, punching the face, or opening a window. With this flexible mapping the actor can improvise on stage triggering different sounds on each location.

Waveform Navigation

We introduced a waveform navigation technique based on the X axis movement, which allows the actor to use his left hand for navigating in the waveform and his right hand for defining the play range (Figure 6). To play the range, the actor needs to make a beat gesture with his hand in the Y axis by lowering the right hand quickly. In this way, the actor can trigger the sound after the range selection avoiding unintended sounds.

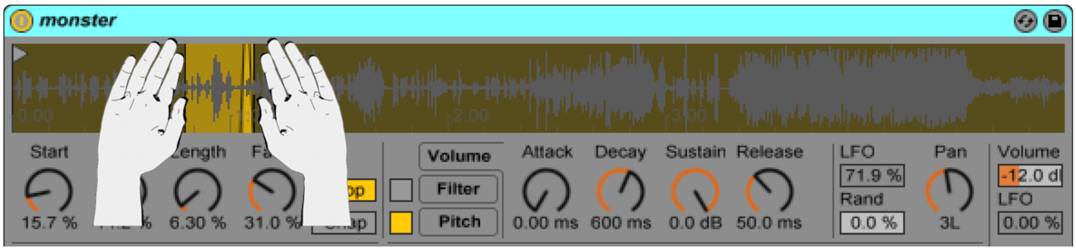

Figure 6: Sound manipulation: left hand marks the beginning of the play range and the right the determinate the end point. This range is updated in real-time.

The actor is able to jump from distinct words on the waveform deconstructing the text creating new sentences. He can also reduce the range constantly until reaching a sine wave allowing the sound to be modulated. After triggering the sound, the actor can move his left hand in the Y and Z axes to modulate the sound.

Narrative

The play was divided into 6 main moments that characterise the evolution stages of the prisoner: 1) Disorientation; 2) Hallucinations; 3) Self-control; 4) Illusion; 5) Memory; 6) The end. Each moment presents a specific interaction design which is described in this section as well as the narrative contextualisation.

Figure 7: The evolutionary stages in the cell from the play: 1) Disorientation; 2) Hallucinations; 3) Craziness.

1 - Disorientation

Narrative: When the door opens to the loneliness of the solitary confinement and the light goes out, the human being becomes a shadow of his existence and becomes disorientated (Figure 7). The character attempts to explore the tiny space that defines the cell by trying to figure out its limits, walking in circles with his hands in the walls. This space is depicted through reverse shadows, shadows in the dark, silhouettes of light that glow with life signals inside our minds in response to the character's behaviour.

Implementation: We developed a silhouette application using Openframeworks using a simple camera to draw the silhouette with glow and trails. When the actor moves he leaves trails that describe the cell space, the trails disappears when the actor stands still.

2 - Hallucinations

Narrative: Reality is portrayed as bright vultures that glow at the heart beat rate. Images from reality are brought into our minds through trails of light as if they were ghosts, fragments of their existence. Extremely deformed images that appear and disappear as hallucinations. They become moving shadows or silhouettes that are not evident.

Implementation: Physical objects and puppets are deformed and manipulated by the actor, who uses a web-camera for capturing fragments of images as signifiers. A patch in Quartz Composer processes the video image captured from the camera, creating a raster image with bright lines and trails of light.

3 - Self-control
Narrative: Our character seeks balance and attempts to control his mind.

Implementation: To materialize this self-control we have adapted the *Chdh Egregore* patch for Pure Data. This audiovisual instrument provides physical modelling algorithms and creates expressive visual effects through particles that are translated into sound. Several parameters were mapped to the actor's body gestures allowing him to control the shape of the particles as well as the sound.

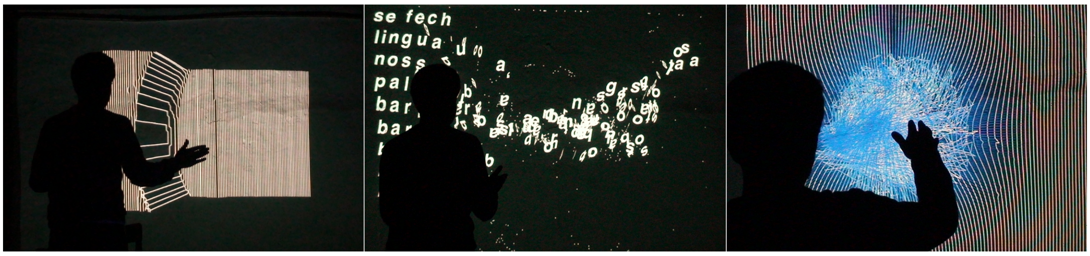

Figure 8: The evolutionary stages in the cell from the play: 4) Illusion; 5) Memories; 6) Despair. Photos by the author.

4 - Illusion
Narrative: Within the illusionary sense of control (Figure 8), our character seeks order and attempts to construct a reality made with geometric elements that are manipulable through his hands, challenging his sanity as well as his dexterity.

Implementation: We used the eMotion application to create patterns using grids made with particles that are manipulable with two touch points that follow the hands positions. These control points have physics-based effectors such as attractors or oscillators, that makes the grid to deform accordingly to the motion of the hands. In this way, the puppeteer can create shapes or interact with the grid. In specific parts, the grid presents physics properties and falls with gravity, simulating a piece of fabric. The puppeteer can manipulate this piece of fabric as a blanket, by pushing or pulling it.

5 - Memories
Narrative: In a journey through memories, the character reorganizes segments of text using his hands. He seeks meaning and attempt to create sentences that remind him of emotions from his memory.

Implementation: In eMotion we animate several pieces of text for different moments. The text made with particles is manipulable in a similar way as the grid. For instance, by attaching an attractor operator to the control points of the hands, the puppeteer is able to grab characters or words and place them in different locations. Another example is the fall operator, that makes the characters fall with gravity when touched by the actor.

6 - The end
Narrative: Memories start to pursue him and the performer tries to runaway until he gives up fighting.

Implementation: We have implemented in eMotion an operator that makes the words on screen to follow the performer. The performer attempts to escape by tricking the words with fast movements. When the words reach the performer, the cell bars start to move, as if the solitary confinement structure becomes alive, transformed into a puppet. Finally, our character becomes a physical puppet and stops moving.

Discussion

Technology brought a new paradigm to live performances challenging choreographers to rethink the body boundaries of the performer, and its relationship with the space, influencing the interplay between the performer,

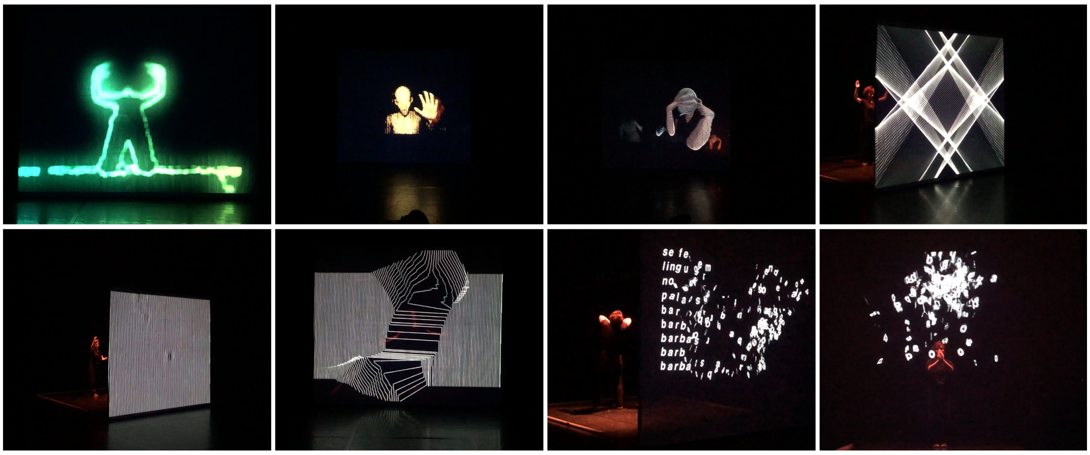

Figure 9: Fragments of the final performance. Pictures from a rehearsal at Teatro Helena Sá e Costa in Porto in October 2019

and the machine. It is important to follow a methodology when designing interactive environments based on the whole body performance (Lympouridis, 2012), and evaluate the need to use a gestural data interchange format (Jensenius, 2008), that can be used to recorded and to share the body interaction. The growing awareness of the structure of digital interfaces, allows the artist to become engaged with this augmented performance. The performance can explore new space-time dimensions through interactivity, such as the interactive performance *Messa di Voce* (2003) created by Golan Levin, and Zachary Lieberman (Levin and Lieberman, 2004). These new digital-assisted performances, should hold the principles intrinsic to the digital media paradigm, including the interactive design; the nonlinear processes; and the real-time signal transformation. The body performance can be choreographed to embrace this technological tools, allowing the body to be extended, changing the way we tell stories, the way we play music, and the way we dance. The production of a digital augmented performance, will incorporate the nonlinear multimedia composition, through interaction design, combining and transposing the body movement of the performer, into digital media processes, such as capturing or editing, augmenting the movement possibilities. This will require new interactive designers, and augmented body choreographers, to be a part of the creative process. Choreographers may choose between events that are previously rehearsed, and unpredicted events that force the performer to react, and improvise, affecting his emotional resonance. The performer becomes the sensorial machine itself.

Conclusion

Solitária challenged the performer to manipulate sound and visuals as a puppeteer (Figure 9), using physical and non-physical objects. We conclude by our experience that when the intangible manipulation presents a direct feedback, the puppeteer becomes engaged presenting a sense of directness. On the other hand, the puppeteer becomes disconnected if the feedback is indirect or subtle, in these cases the performer must focus on the process to be able to achieve expressive manipulation.The manipulation of physical objects and intangible digital media is related and both require dexterity, the great difference rely on the haptic, visual and sound feedback. We had the opportunity to work with a professional puppeteer which recognised that the manipulation experience provided a sense of directness over the digital media, even with the sound manipulation. He used his body as an expressive controller with precise manipulation over the dramatic elements. Apart from facilitating the creative process, this digital interactive framework augmented the tangible manipulation, as well the intangible manipulation of sound and visuals. Above all, this augmented manipulation can be considered the process of transformation, a process of transferring energy from the human agent to the physical/virtual object. It is through this movement that the audience has the perception of a living object.

Acknowledgements

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