EXAMINING THE USE OF AUGMENTED REALITY AND COMPUTER VISION TECHNOLOGIES IN DIGITAL ARTWORKS, THE CASE OF: "PoNR/ANOMIE"

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Abstract

This paper is an extensive technical and creative review on the interactive, audiovisual art installation "PoNR/Anomie - Point of No Return/Lawlessness" that was presented in Athens Digital Arts Festival in May, 2018. The artwork was submitted after a call for pieces inspired by Singularities. It was based on the concept of Black Holes and was implemented mainly with Augmented Reality techniques, integrated with Computer Vision and extremely focused sound to create a unique experience for each viewer.

To achieve this goal, we had to examine and take into consideration the scientific theory and elements of Black Holes, and then use them to invent a metaphor for the artwork's plot. Inspired by the "Event Horizon" within which both Particles and Energy are inevitably dragged to collapse into an unpredictable Singularity, ignoring any established Physical Law, we created an installation that once the viewer is found within its active area, gets trapped in a personal experience of unremitting consecutive sentimental stages: Attraction and Inability to Escape, Catalysis / Abolishment of Information and Identity, and finally Compression / Annihilation in the Singularity.

Keywords: *Augmented Reality, Computer Vision, Singularity, Black Hole, digital art*

Introduction

This is an extensive technical and creative review on the interactive, audiovisual art installation "PoNR/Anomie - Point of No Return/Lawlessness" which was implemented with Augmented Reality techniques, integrated with Computer Vision. This experiential piece was created to be presented in the 14th Athens Digital Arts Festival (ADAF2018) held in May, 2018 in Athens Concert Hall after an open call on the theme of Singularities. For our project, we chose Black Holes as examples of Space Singularities and attempted to create a metaphor with parallelisms to the theoretical experience of being captured by a Black Hole.

Photo 01. View of the art installation in ADAF2018

In Astronomy, the term "Black Hole" describes a region of spacetime exhibiting such strong gravitational effects that nothing, neither matter, nor energy, can escape once entering inside it. What's more, as the particles and energy are collapsing into a single point of extreme mass in space, their identity as types of matter or photons ceases to exist. The fact that no one actually knows what happens inside a Black Hole, added to the mystery we required for our story. This "Event Horizon" in the center of a Black Hole was the main conceptual idea for the plot of our experiential interactive artwork: Within its limits, both Particles and Energy are inevitably dragged into an unpredictable Singularity, ignoring any established physical law, while capturing and dissolving any form of Information.

Taking the theory into consideration, we recognised the challenge to create an act where the viewer, once attracted by the Event Horizon, gets trapped in a personal experience of the following unremitting, consecutive, sentimental stages: Attraction and Inability to Escape, Catalysis / Abolishment of Information and Identity, and finally Compression / Annihilation in the Singularity.

To build this emotional experience, we had to find a way to recreate a large scale interactive spectacle of a three-dimensional Black Hole and enrich it with characteristics of personalised experience for each viewer. For this reason we selected Augmented Reality as the main carrier of the experience but also because it conveniently added to the allegory of the artwork. An AR enabled portable device acts as a visor for the viewer to see a spectacle that scientists have not actually spotted yet and definitely invisible to the naked eye. Supporting our metaphor, we also had to find a way to "lure" the viewer

to bring himself near the Event Horizon (Point of No Return), into the accretion disk of our virtual Black Hole, and for this purpose we decided to utilise a form of focused sound. Once found there, the unsuspecting viewer is presented with a tablet running our AR application, where he watches a symbolic entity with physical characteristics of himself, captured without knowing, to participate in an already commenced, predefined sequence of allegorical events, where the inevitable end is to collapse inside the Singularity. All this act is taking place in the vicinity of a physical installation, containing the various supporting devices and also acting as a trigger and calibration marker for the AR system.

Methods

The project's implementation is divided into two main seperate sections, the scientific theory inspired plot and related creative tasks, and the systems integration that was required to realise it for the public.

Artwork Scenario / Interaction Plot

The first step of interaction, was to attract the random viewer into the vicinity of the artwork. To achieve this, we used a special sound device that produced an extremely narrow beam of sound, in front of the installation. This unusual sound form was enough to stun and catch their attention, and also attract the viewers towards the installation, imperceptibly forcing them to approach while staying within the sound beam, and thus following a straight path in front of the artwork.

As they approach staying on a defined path, a computer vision device frames the viewers' face and when the video sampling feed matches the required quality threshold, the device captures a picture of it, crops it and saves it on a local image server.

At this point, the viewer has already approached to a close vicinity of the installation, where he is presented with a tablet computer acting as our Augmented Reality visor, and is guided to aim it towards the installation. Through the visor, the viewer now sees a sizeable three dimensional representation of a Black Hole and also discovers that he is already standing within its rotating, warping accretion disk (approx. 5m wide) while its center, i.e. the "Event Horizon", is placed at the spot of the physical installation.

As soon as the viewer realizes that the Point of No Return is already crossed, while watching the spectacle through the visor he sees a symbolic human face mask to bypass him from the side with a trajectory towards the center of the Black Hole. The mask momentarily turns towards the viewer, who can now see his actual face, captured without his knowledge, moments before, mapped onto it.

The mask with the face of the viewer shatters, and gets drawn within the Black Hole vortex following an accelerating spiral path. As the pieces approach rotating the Event Horizon, they shrink until reaching particle size, radiate a momentary glow, and then disappear into the Singularity. This ends the experiential sequence of the artwork with the viewer being exposed to the following sentimental stages: Attraction and Inability to Escape, Catalysis / Abolishment of Information and Identity, and finally Compression / Annihilation in the Singularity.

Graphics

The piece required for the following real-time 3D Graphics assets creation: The Black Hole. This 3D model though not particularly difficult to create, posed a couple of challenges in design. Firstly, the initial research for its form revealed a series of form concepts proposed over the time, since this space spectacle has only a theoretical representation and no human eye has ever actually seen it. The evolving mathematics and physics models have come up with variating shape forms, with the newest being perhaps more accurate, though not perfectly aligned with the established public perception of its shape, created over the years mainly through art, movies etc. or the earlier scientific representations.

Taking this into consideration, and since it was primarily an art project trying to create emotional states, we decided to partially ignore the latest scientifically proposed shapes and adopt a more familiar, though updated design, in order to cause the least confusion to the audience.

Another creative issue with a technical aspect was related to the use of animated textures for the rotating/warping disk around the Event Horizon. This issue emerged as the Augmented Reality system was being developed for a portable device. Both the graphics engines used to develop 3D environments for portable applications and the hardware of these devices (GPU, storage) set very strict limitations to the use of traditional animated textures. To overcome this without sacrificing any quality or visual features in our design, we utilised a technique where instead of animated textures (footage), keyframed, loop-animated UV coordinates are applied (keyframes). This 2D coordinate animation and the use of seamless textures for the accretion disk combined with texture layering, produced the rotation/swirl (spiral warp) effect as required and also without any quality loss due to compression or resolution degradation. This texture property was experimentally integrated in the latest version of the Unity Game Engine that we used and although not without issues, allowed us to achieve the required effect and also remove a GPU/Storage overhead for the portable device by a rate of 1:240, for a 10 second texture animation loop at 24 frames per second calculated by the following formula:

$$\text{rate} = (\text{move texture fps} * \text{movie texture duration})^{-1}$$

The Fracturing Mask.

For the embedment of the symbolic entity of the viewer within the act of the artwork we came up with the idea of the fracturing mask. This asset was quite straightforward to create, having to take into consideration the fact that the model should have the minimum of characteristics in order to be able to represent both sexes, after being mapped with an adequate texture. After modeling, a facial canvas/guide was created based on the 3d mesh in order to have the properties of the required texture that the computer vision system should produce and serve later as images of faces for texturing. The 3d mesh object was fractured with one of Blender3D modeling tools (based on Voronoi tessellation). These fragments were animated with physics onto a rough colliding path on the Black Hole model. The physics animation was then plotted

into keyframes animation, reusable and also capable of importing into Unity Game Engine

Sound

This project had two separate and quite different sound requirements. The first sound source was integrated into the physical installation of the artwork, while the second sound was emitted by the application running on the tablet.

Installation Sound.

As described, the sound emitted from the installation serves mainly as a means of attraction for the viewer towards the installation itself. For this reason a special type of speaker, called Parametric Speaker, was integrated into the installation. This device, instead of using a traditional diaphragm moved by a voice coil to produce sound audible waves, uses an array of modulated ultrasonic transducers that can make air molecules compress and decompress, in a manner that audible soundwaves are produced. These speakers produce very clear, long travelling, low attenuation sounds on a very narrow beam and without the requirement for high volumes. We used a ready commercial product for our needs, SoundLazer SL-01. The sound content playing was an "endless" mix of abstract procedurally generated synthesizer tunes, just intriguing enough to catch the viewer's attention and initiate our interaction plot.

Application Sound.

For the application the sound had a very different purpose. This sound was audible through the tablet speakers, and existed to provide a soundscape for the interaction experience. Since the viewer's position was available thanks to the Augmented Reality engine's camera solving, this sound had spatial properties, in relation to its virtual source, the center of the Singularity. The sound itself was a looping sample of two Black Holes Colliding captured as Gravitational waves and converted to sound waves.

Systems Integration

High Level overview

From a technical perspective, the piece consists of a mobile application and a single-board computer exchanging information over the same network. An infrared camera module assisted by an external infrared lamp provide the required video input while a parametric speaker connected to a portable MP3 player are responsible for the focused sound.

The raw image input from the camera is constantly processed from a script running on the single-board computer and when a face is detected, if certain requirements are met, a properly edited image is stored on the file system. A second script is responsible for serving over the local network the most recent image found. The mobile application receives that image and when the viewer's distance to the AR marker exceeds a predefined threshold, the animation sequence is triggered.

All the components are housed in a custom construction made of oriented strand board (OSB) which also acts as the mounting base installation for the AR marker and - figuratively - the location of the Black Hole. In the following sections we will describe in more detail the different components and the design of the whole system.

Single-board Computer

The computer we use is a Raspberry Pi 3 Model B+ running its official operating system, Raspbian 9 (also known as "Stretch"). For storage, we use a 32GB SD card and the connection to the router is done using the onboard LAN controller. Video input is retrieved with the help of an 8 Megapixel infrared camera, the "NoIR Camera Board v2", connected on the board's dedicated serial interface (CSI-2).

Since the main role of the Raspberry Pi is to process the camera's raw feed in real-time, we decided to use the popular OpenCV library which offers most of the desired functionality. OpenCV supports Linux and has a Python interface, making it possible to run on a Raspberry Pi. Installing OpenCV was a relatively lengthy process mostly because of the need to compile it from the source. We followed the detailed build instructions which produced the appropriate environment for using the OpenCV library in a Python script. In addition to that, we used the picamera interface since it gives easy access to many of the camera's features.

The Computer Vision script

The goal of the script is to detect faces in the camera feed, crop and straighten the acquired image and store it in the SD card. The output image should have a predefined size and the eyes should be at specific points, so that the texture mapping will properly work. Firstly, we setup the camera's video resolution, ISO sensitivity and aperture value using the relevant commands of the picamera interface. We also convert the raw input to grayscale since it helps later on with the face detection and apply a blur threshold so that the output image meets our desired quality criteria. By using OpenCV's Haar Feature-based Cascade Classifiers, we retrieve a rectangle containing a detected face. Within this rectangle we apply another Cascade Classifier used for eye detection, returning the coordinates of 2 points, one for each detected eye. Using these coordinates, we can apply a rotation matrix to the image in order to transform it to the required dimensions. After that, we dump the in-memory rectangle to a file and store it to a predefined folder of the SD card.

Server script

In order to share the image of the detected face over the local network, we use Flask (http://flask.pocoo.org/), a Python server framework. Our script gets the most recent image from the aforementioned predefined folder of the SD card and using Flask's restful API serves the image over the network. A periodic task deletes the folder's contents every 10 minutes leaving just one image, in order to preserve empty space and make sure no personal data is stored apart from the ones needed for the current viewer's experience.

Mobile Application

The mobile application targets the iOS platform and is created in Unity 2018 and Xcode 9. During the Athens Digital Arts Festival it was running on an iPad, however, thanks to Unity's export mechanism, it is possible to work on different devices (e.g. iPhones) and platforms (e.g. Android).

The Augmented Reality functionality of the app was managed by Vuforia Engine, which is integrated in Unity. When pointing the iPad's camera towards the image marker, Vuforia reports its location and the 3d scene can be rendered taking into account the location of this marker in the "real" world. In addition to providing an anchor, Vuforia is also used to calculate the distance between the image marker and the iPad. This distance acts as the threshold to trigger a new animation as the viewer approaches the piece.

When the animation is triggered, Unity makes a request and fetches the latest image from the local server. This image, already transformed in the desired dimensions, is set during runtime as texture to the Fracturing Mask and playback starts. After the animation finishes, all its components are reset to their original state and the application is idle again.

Results

By practically combining all the aforementioned parts, firstly we managed to create a multidisciplinary artwork that integrated some contemporary technologies but also had to fulfill some predefined artistic requirements. This means that while the project was heavily dependent on technology, this should not be so prominent to aesthetically harm the artwork's integrity and immersion characteristics. To actually evaluate positively the technology utilisation, this should result in an almost invisible application, in a state that it "just works" and leaves the viewer unobscured to experience the piece. This was actually achieved for the majority of the viewers.

What's more, the integration of Augmented Reality with Computer Vision, as proposed in a form of toolset in this project, allowed us as artists for a deeper viewer immersion by effectively adding his entity in the artwork and his active participation, leading to a more sentimentally focused interactive experience. Finally this implementation allowed us for accurately creating this experience for the viewer as imagined/designed while keeping the piece open to interpretations and avoiding a strict narration form.

Discussion

The use of Augmented Reality in a digital artwork installation project like the one described can be justified after taking into account several aspects of the project, both technical and also artistic/symbolic. The alternatives considered as means of presenting the spectacle were normal Video projection or Virtual Reality.

Firstly, using an AR system allowed us for producing a large scale virtual scene without serious actual space occupation in an exhibition hall. The projection also supports 3D spatial interaction, in a way that the viewer can watch the action from varying perspectives using the provided mobile device as a virtual periscope, staying

true to the fact that Black Holes are still theoretical phenomenons unseen by the human eye. The portable visor itself as a technological device was completely wireless and was put in a special protective case to blend more into the artwork installation without ruining its atmosphere. AR also presents the

3D scene floating in the actual space of the viewer, producing an interesting visual experience and imitating the actual Black Holes.

In contrast, examining the other options, we believe that video projection immersion capabilities cannot compare with AR, as interaction features are much fewer. On the other hand, VR with its poor portability and complete lack of connection to the physical space, would not be able to fit in our artistic standards set for the piece, forcing it to shape into a completely different and less desired form. Integrating AR with Computer Vision,we also managed to achieve a personalised experience and to amplify the desired emotions for this artwork.

Finally one more important upshot for us, deducted as we worked on the given toolset, is its power as a new form of Storytelling. AR, especially when enhanced with interaction technologies such as Computer Vision as proposed, is very likely to be a new emerging player in the field of content presentation, as it manages to impress the audience, while keeping the interest on the story, be it reality or fiction, in a quite effective way, as we discovered firsthand during the ADAF2018 exhibition.

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