SPACESHIFTER

A Virtual Environment with Emotional Intelligence

CHRISTOS GEROTHODOROS[1], ANNA KARAGIANNI[2],
VASILIKI GEROPANTA[3] and PANAGIOTIS PARTHENIOS[4]
[1,2,3,4] Technical University of Crete
[1]cgerothodoros@tuc.gr, 0009-0000-1800-8674
[2] annakaragianni@tuc.gr
[3] vgeropanta@tuc.gr
[4] pparthenios@tuc.gr

Abstract. In the post-SARS-CoV-2 era, technology has played an increasingly important role. Telepresence has risen to prominence, reshaping the way people socialise, work, and inhabit the virtual world. In this, the demand for intelligent virtual environments that adapt to the user has grown.

This article presents "Spaceshifter," a project which aims to address challenge of designing responsive to human emotions digital worlds. The project introduces an interactive application that is displayed via a VR headset and serves as an interface to biometric data obtained via an EEG device. Real-time brainwave signals, captured by the device, adjust virtual spaces based on user's mental states. The result is a dynamic ever-evolving virtual environment that conveys a sense of empathy.

"Spaceshifter" undertook several approaches through its various design phases, to explore different options and parameterizations of the virtual environment. These efforts aimed to adapt the space to the brain's radical shifts, creating a coherent experience for the user. This project aims to bridge the gap between technology and human emotions and shape an evolving landscape of interaction between humans and technology.

Keywords. Adaptive environment, Virtual environment, Biosensor, Human – Computer interaction.

1. Introduction

In our exploration of human augmentation through technology, it becomes clear that navigating the rapidly evolving technological landscape presents a formidable challenge. While technology's influence on our daily lives is undeniable, often it is associated with isolation and lack of connection due to the pronounced gap between the world of computers and the intricacies of human existence. However, this paper argues that this divide can be bridged by creating a common language that fosters mutual understanding and ultimately leads to symbiosis.

As the design is entwined with the constant parameterization of neural data, it is necessary to consider an evolutionary, gradual progression. Time stands not as a mere element but as a pivotal parameter, orchestrating changes akin to a slider rather than a switch. Moreover, filtering out noise from the brainwave signals becomes imperative, ensuring the design's transformation maintains a delicate, gradual change rather than jagged which consequently leads to a coherent user experience.

Furthermore, the project argues that a uniform rate of parameter change results in a linear experience, a space lacking the intricate complexity inherent in the human emotion. To capture this richness, the introduction of diverse parameters and dynamic alterations is essential. These additions appear throughout the experience, crafting an ever-shifting landscape that mirrors the multifaceted nature of the mind.

Embarking on this endeavour demanded extensive experimentation and exploration of diverse ideas and design concepts. This paper unravels the process that led to these insights.

2. Research Project and objectives

The project describes the development of an app that intends to connect user real time brain data with spatial parameters. In a 3D digitally constructed environment, neurodata are real-time extracted and translated into geometry, thus creating a spatial experience and establishing a continuous feedback loop between space and user.

In this topic, the important design challenge was to achieve a seamless and coherent transition of the environment into all these different states. To address the potential problem of chaotic changes we take a minimal design approach to develop a hierarchy between the different spatial elements of the environment on the belief that disconnected spatial elements that are constantly changing on their own would lead to chaos.

But also a hierarchy of the parameters and changes themselves should also be developed. If the changes in the environment take place at the same rate and the parameters are on the same scale it contributes to this chaos.

Besides the mechanics of the environment, the project aims at a simple and abstract visual language in an attempt to depict the mental states in a way that they would be universally understood and every user can reflect and identify with them.

These aforementioned objectives aim to perceive the environment as one single entity and to develop an experience that gradually increases and escalates, similar to user's emotional state. In this way, the environment would seem alive and the user would be more willing to interact with it.

3. The experiment - Methodology

The methodology followed for the project was dual: initially three different geometrical spaces (sphere, plane, ring) were designed in Touchdesigner, creating the basic space for experimentation. Then, the authors used equipment that measures neural activity on themselves on several occasions, to observe their experience inside and create the basis for parametrizing the geometries. This led to the generation of multiple spaces, altering in turn the experience of the user. All these steps are documented below in three distinct phases.

Spacehifter was developed in the Touchdesigner application. The EEG device that was used is the ‘Mindwave Mobile 2’ made by Neurosky. This device is a low-cost, non-invasive EEG device that provides three dry electrodes that measure neural activity. It is connected by Bluetooth to the computer that is receiving the OSC signal via an open source application, “BrainWaveOsc” found on GitHub and developed by the user “trentbrooks”. Then this OSC signal is sent to Touchdesigner, in real time, and all the device's metrics are available for further use.

The EEG device provides metrics such as Raw Data brain wave frequency and strength percentages of different brain waves (Delta, Theta, low Alpha, high Alpha, low Beta, high Beta, low Gamma, and high Gamma). These different wave frequencies are known to be closely related to the subject's mental state. Additionally, it offers metrics for "Attention" and "Meditation," indirectly related to Alpha and Beta brainwaves. The "Attention" metric gauges user focus, while "Meditation" assesses calmness. High "Meditation" has shown to improve performance in attention tests (Crowley K., et al., 2010). Elevated focus and meditation levels often correspond to increased Gamma activity, associated with mental clarity (Li et.al., 2019). With EEG data in hand, the challenge was parametrization. The key objective was to avoid a linear and one-dimensional progression, as this would oversimplify the portrayal of the user's mental and emotional state. The "MindWave Mobile 2" provides "attention" and "meditation," resulting in a two-dimensional field for parametrization, offering more depth to reflect various mental states.

These metrics, akin to neural activity, change instantaneously. Not accounting for these drastic changes in metrics could result in an experience that is disorienting, as concluded in a similar experiment conducted by Maghool et al. (2020). The environment's continuous change, resembling lifelike essence, necessitates a fluid design approach. The design object's form is not rigid but fluid, acknowledging the importance of the fourth dimension of time.

These metrics, as the neural activity itself, will frequently change instantaneously and can seem chaotic. But the experience needs to be coherent for the user. If not taken into consideration these drastic changes of metrics the result could be disorienting at least, as concluded in a similar experiment conducted by Maghool et al. (2020). This means that the environment has the characteristic of continuous transformation. The movement is constantly in progress and continuous which gives it a lifelike essence. This requires a different approach, as the form of the design object is fluid and not rigid as it usually is. This inherent characteristic needs to be addressed as the designer needs also to take into consideration the importance of the fourth dimension of time.

3.1. DESIGN PHASES OF THE LOOP

3.1.1. Space 1: Metaballs

In an initial phase, the project employed spherical entities called 'metaballs.' Their organic form allowed them to meld when close, giving the project a characteristic of fluidity. Dynamic manipulation of metaballs, guided by noise texture-image data, permitted controlled yet seemingly random movements.

Parameterization linked the user's "meditation" state to colour schemes, and vibrational patterns emitted by spheres mirrored the user's calmness. Drawing inspiration from water behaviour, vibration represented the virtual environment's fluidity. "Attention" influenced sphere behaviour, transitioning from erratic to smooth movements with increasing attention. Beyond this, heightened attention initiated spatial convergence, symbolising focus and concentration.

This interactive phase established a continuous dialogue between user and virtual environment, fostering mutual influence in an exchange of 'input and output.'

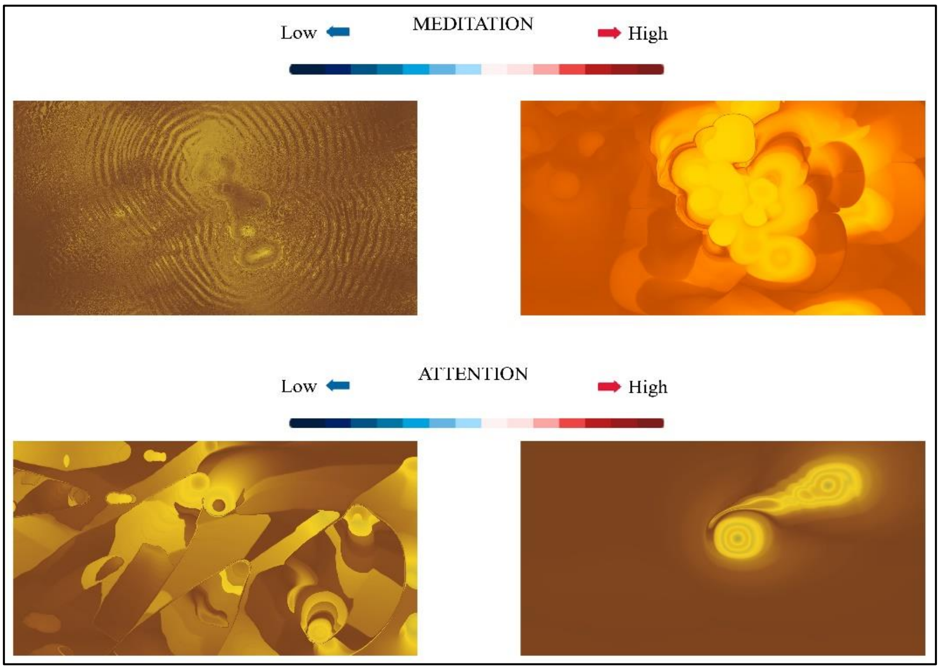

Figure 1. Metaballs reacting to user's different metrics

3.1.2. Space 2: ISO surface

In this phase, focus shifted to enhancing the three-dimensional user experience, aiming to create a 'digital landscape' challenging traditional interpretations that mimic physical environments. A single grid plane symbolised the ground, emphasising the inherent emptiness of virtual realm without user interaction. User metrics dynamically generated height maps, modulating material and grid structure. 'Attention' influenced peak and valley proportions, while 'meditation' smoothed terrain.

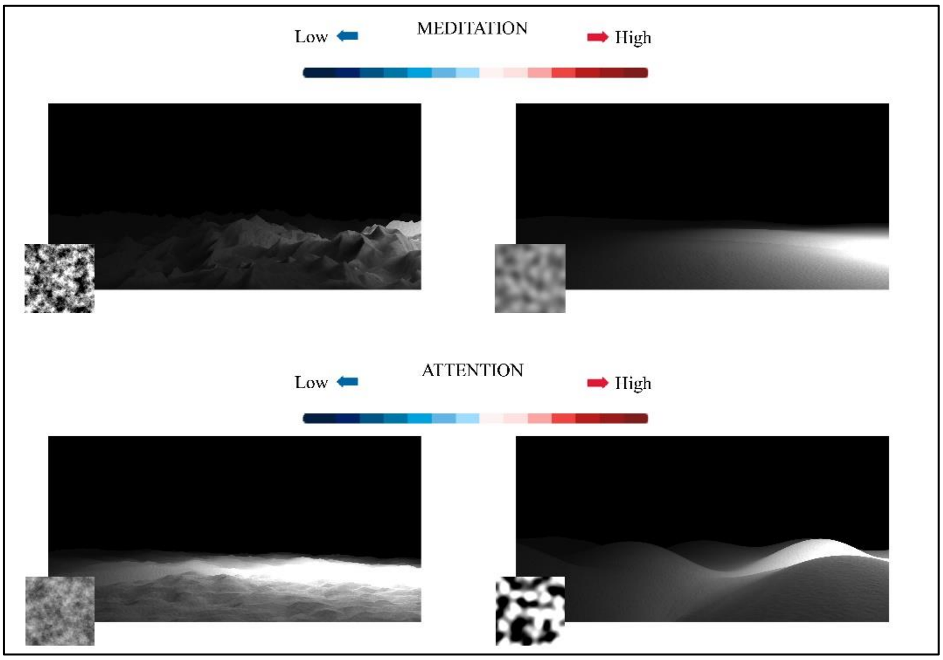

Figure 2. ISO surface reacting to user's different metrics

The height map, applied to the grid around the user, allowed a responsive environment shaped by user's mental state. To address drastic, overwhelming changes, a gradual transformation was introduced. A vertical frame traversed the plane, incrementally rendering a three-dimensional space, portraying the user's mental state progression. This cyclic process continued indefinitely, creating a rhythmic dialogue between human and machine, highlighting the circle of interactivity.

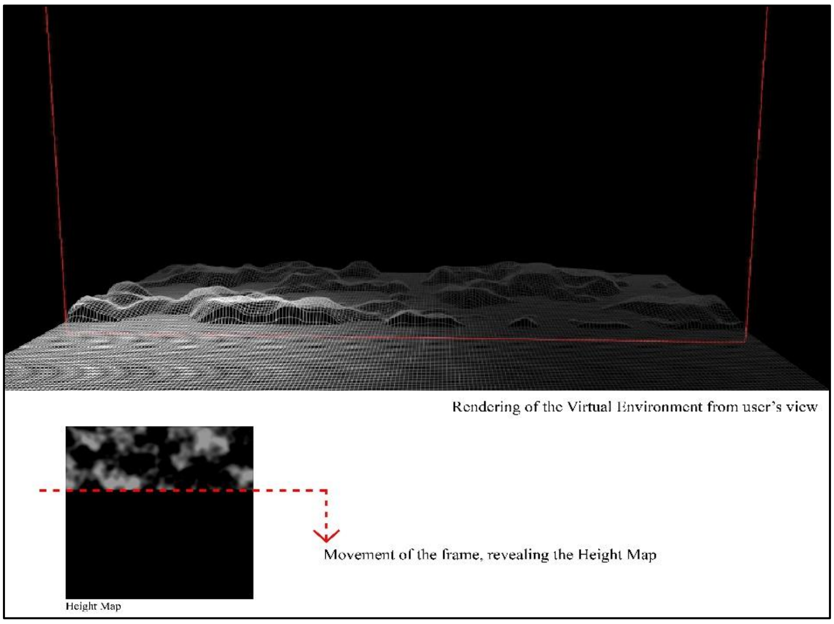

Figure 3. Rendering of the virtual landscape

3.1.3. Space 3: Wave

This phase introduced a shift to a more organic and dynamic interaction model, aiming for a vivid real-time experience with clearer user influence on their environment. The user, positioned at the centre, emitted waves shaping the surrounding grid with ripples that faded gradually, reflecting the user's changing mental state. This design retained the concept of gradual change but introduced real-time responsiveness, allowing immediate impact observation.

Parameterization in this phase was akin to the previous iteration. Wave height responded to user "attention," while smoothness and noise of waves were tied to their "meditation" level. A feedback loop heightened wave intensity in lower "meditation" states, creating a 'storm' effect. Lastly a second grid above mirrored the lower grid, representing waves with precise circles. The colour and size of these circles visually conveyed user mental states, emphasising the gap in how machines and humans interpret data

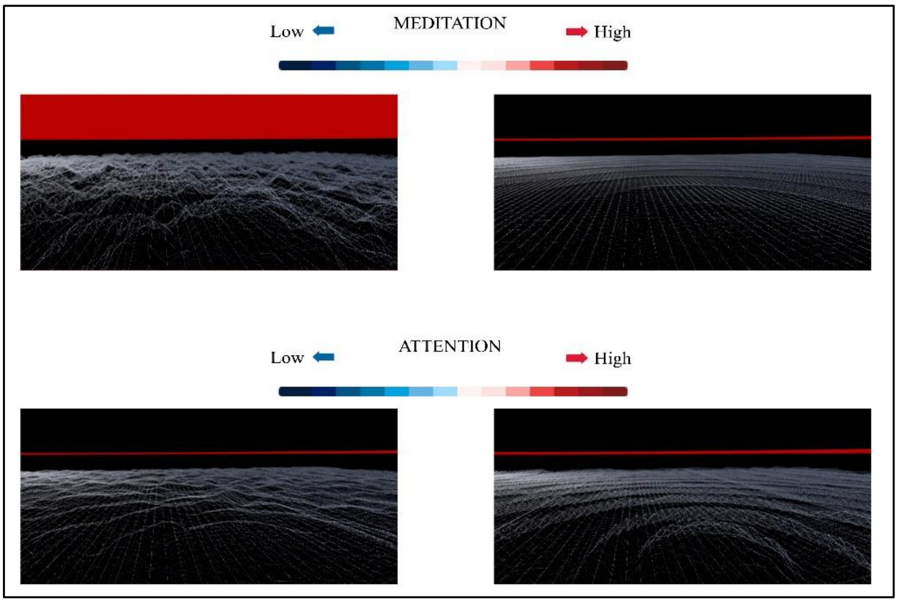

Figure 4. Emitted waves reacting to user's different metrics

3.1.4. Space 4: Infinite Loop

In the final project phase, the goal was to deepen the experience, introducing more parametrization for nuanced shifts in user's state. To visualise intricate connections within user's inner world, the project incorporated three-dimensional movement along a looping path. A circular path was subtly curved by a noise operator, aiming for an organic shape. Rejecting independent user movement was crucial, avoiding gamification elements and maintain the project's conversational focus between user and machine. The user's freedom is centred on the ability to transform space rather than literal movement, offering diverse experiences and consequently rejecting the notion of a predetermined, linear path.

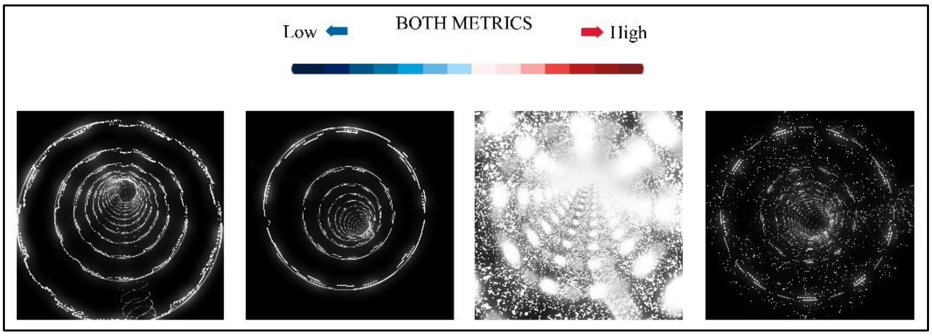

Figure 5. Rings reacting to user's different metrics

User movement was predefined along the looping path, rejecting free movement to maintain focus on the conversation between user and machine. The experience was designed to be nonlinear, allowing participants to perceive different parts of the path uniquely. A two-dimensional plane with an alpha-mapped ring visually represented the path, offering design potential.

Parametrization involved meditation defining noise around the ring, while attention influenced its visual deconstruction. This approach, utilising six parameters for the rings, aimed for dynamic interchangeability, making even subtle changes in user’s mental state visible and enhancing the immersive experience.

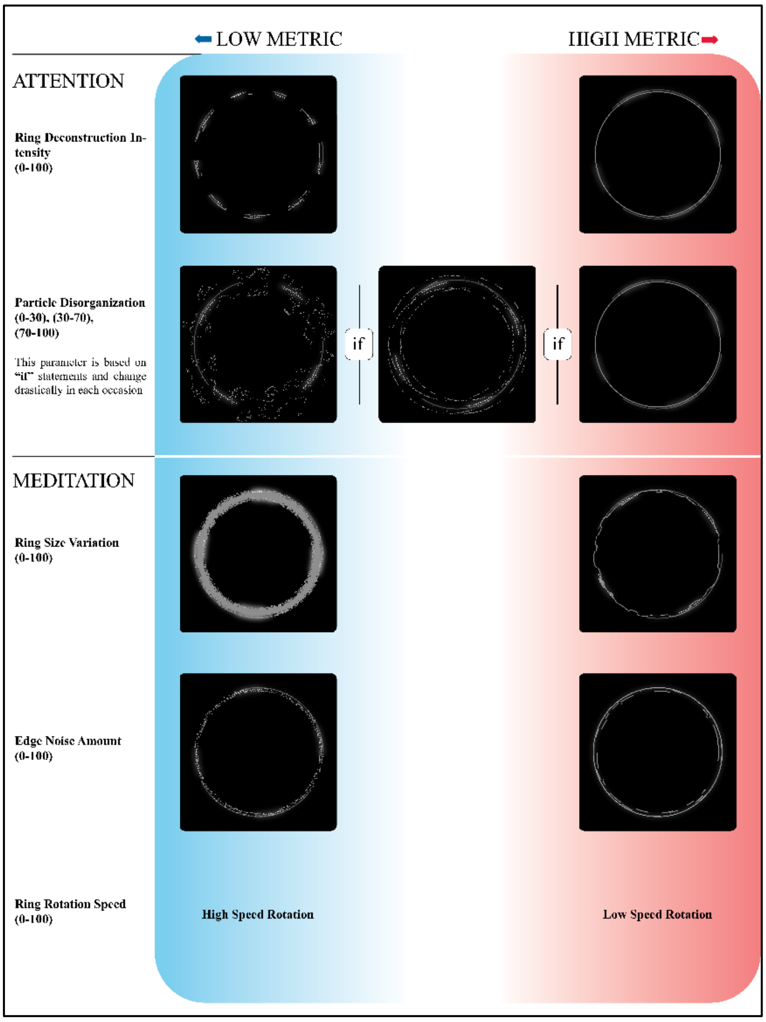

Figure 6. Table of the different ring parameters

3.2. MOMENTS OF EXTREME CHANGES

Those moments occur when both attention and meditation metrics reach extreme values, such as exceeding 90% or falling below 10%. Such extremes signify either clarity of the mind or the opposite, depending on whether the metrics are high or low.

The purpose of “special moments” is that when extreme metrics are simultaneously achieved in both attention and meditation, the entire environment undergoes a radical transformation, while still retaining as core elements of the ring and the user’s movement. Given the rapid pace of metric changes, a minimum display time of five seconds is set for this new visual takes place.

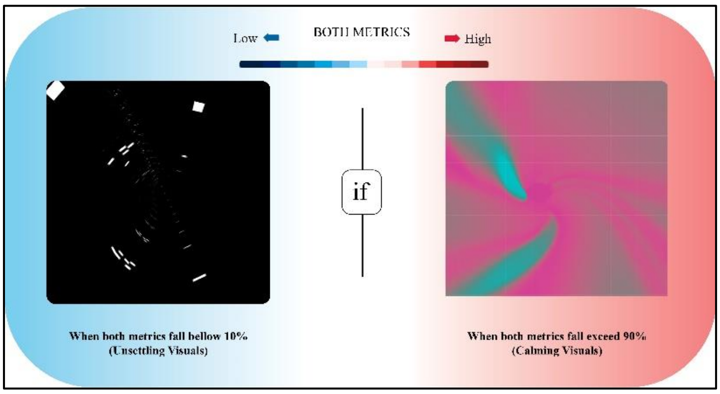

Figure 7. Images of “special moments”

After this period, if participant's mental state alters, the visuals change accordingly; if not, they persist.

These visuals have been designed to reflect the corresponding mental state. For instance, when metrics are high, the visuals are calming and soothing, creating a sense of relaxation. Conversely, when metrics are low, the visuals become unsettling and chaotic. Detailed visual representations of these states can be found in figure7 above.

4. Results and Discussion

This study aimed to bridge the gap between human cognition, emotions, and the computational capabilities of machines in the field of virtual environments. Spaceshifter acts as a testbed to explore the coexistence of humans and machines.

The project was guided by a multidimensional approach, using the metrics "attention" and "meditation" as key parameters for the customization of virtual environment. This dual metric approach enabled the creation of a complex and ever-evolving digital space that mirrors the intricate nuances of user's mental and emotional state.

The main goal was to create an immersive experience that not only responds to user's emotional fluctuations but also engages them in a profound dialogue. Through a hierarchy of spatial elements, a balance between continuous change and coherent interaction is achieved. This design allowed the virtual environment to shift seamlessly through the user's different mental states. This fluid change also gives the environment a lifelike and comprehensible quality

Furthermore, the project emphasised the importance of a simple and generally understandable visual language. In this way, the linguistic and cultural barriers are transcended, enabling users to forge a personal connection with the digital realm.

Beyond the practical implications, Spaceshifter aspired to delve into the broader theme of symbiosis between humans and technology. By reflecting and mirroring user's mental states, the project invited users to partake in a profound self-reflective experience. This empathetic characteristic of the machine paved the way for a deeper mutual understanding, transcending verbal communication.

In conclusion, the Spaceshifter project is showcasing the evolving relationship between humans and machines. It confronts the challenges posed by a world transformed by a pandemic, digital advancement, and the imperative to bridge the chasm between human emotion and computational logic. Spaceshifter is showcasing the transformative potential of design and technology in navigating this new era.

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