Body Cosmos: An Immersive Experience Driven by Real-Time Bio-Data

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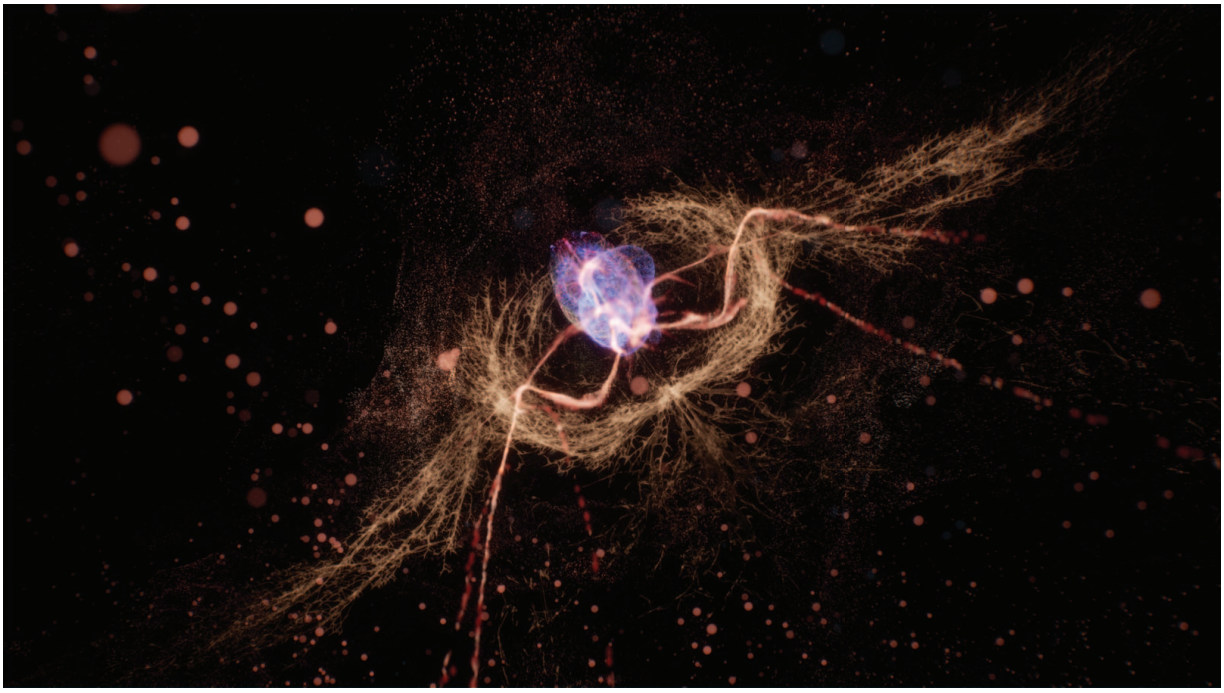

Figure 1: Screenshot of Unreal Engine's real-time demo (© Rungu Lin 2023)

ABSTRACT

This paper presents "Body Cosmos", an artwork that creates a symbiotic relationship between the human body and a simulated cosmic environment through volumetric rendering and particle system. Drawing from DICOM data to simulate the human body and nebulae, we create an interactive and dynamic virtual environment. The real-time bio-data of users, collected via heart rate sensors and EEG devices, is integrated into the visualization, fostering a personal engagement and unity within this 'cosmos.' Body Cosmos provokes curiosity and expands users' imagination, and deepens their understanding of life's macrocosm and microcosm. This exploratory project redefines traditional perceptions of the human body in relation to the universe, creating a unique lens to view selfhood, embodiment, and identity. As we look to the future, the system's evolution will include incorporation of more bio-data sensors, an investigation into its potential psychological and physiological benefits, and the development of social interactive features through multi-user capabilities.

Index Terms: Human-centered computing—Virtual reality; Applied computing—Arts and humanities; Human-centered computing—Visualization; Human-centered computing—Interaction design;

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1 INTRODUCTION

Artists and scientists have been fascinated by the human body and the cosmos for centuries. In this paper, we present "Body Cosmos", an immersive experience that synthesizes cosmic and human body visualizations. The project creates a responsive, interactive environment that metaphorically bridges the macrocosm of the universe and the microcosm of the human body. The project utilizes real-time bio-data, EEG readings and heart rates, to dynamically influence the visual and interactive elements of the experience, thus fostering a sense of unity between the user and the cosmos. This artwork has been selected to participate in Ars Electronica Campus Exhibition in September 2023 (Figure 2).

1.1 Background and Motivation

The motivation for this project stems from our personal interest in the cosmos and the human body, as well as our curiosity about the potential of virtual reality technology to create immersive and meaningful experiences. We have been fascinated by the cosmos since we were young, but it is too distant and inaccessible for ordinary people. We have also been interested in the human body, but we may not fully understand our own bodies that are closest to us. At the same time, we noticed that the distant nebulae and the microscopic of the

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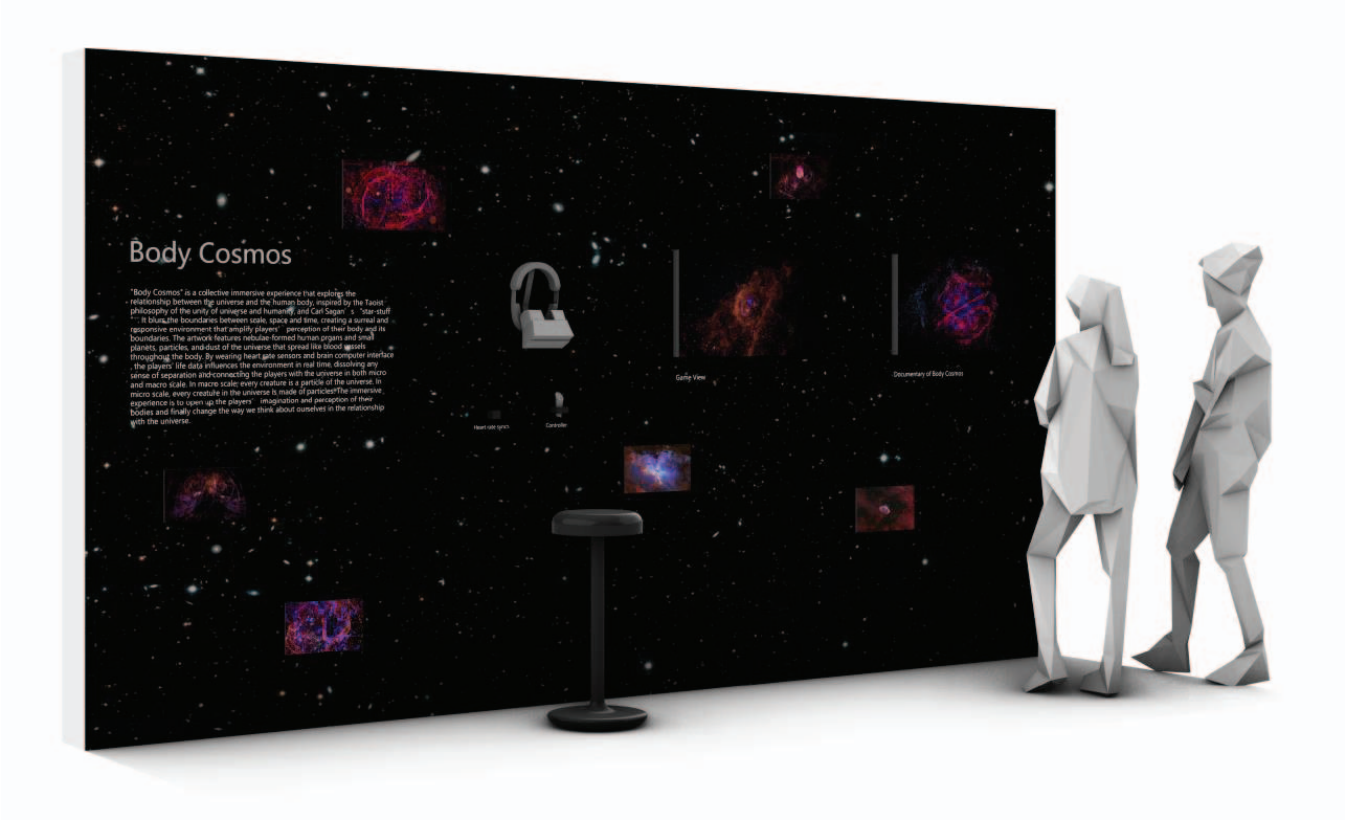

Figure 2: Booth design for Ars Electronica Campus Exhibition 2023(© Rungu Lin 2023).

human body represent the extremes of scale, space, and time. Yet both share remarkable similarities in terms of visual and structural features. We wonder if there was a way to connect these two realms and let users experience the connection between the universe and our bodies in a surreal way.

We embrace virtual reality as our medium and envision a realm of immersive engagement enriched by the integration of real-time bio-data. This bio-data personalizes the experience, creating a symbiotic loop between the user and their surroundings. Our endeavor mirrors the constant flow of data, extending our understanding of the world and our existence within it. Our project transcends immediate presence, reflecting on the intertwined relationships that humans can form with digital data, thus nurturing a perpetual presence within the cosmic expanse.

1.2 Historical Context

The human body and the cosmos have been subjects of fascination for both artists and scientists throughout history. The pursuit of understanding our place within the cosmos and the intricate connections between the macrocosm and the microcosm has been a driving force for exploration and innovation since ancient Greek philosophy.Figures such as Anaximander, Plato, and Aristotle theorized the human body as a microcosm, mirroring the macrocosm's order and harmony [2].

In the realm of art, one of the earliest representations of the human body's and cosmos' interplay is Leonardo da Vinci's Vitruvian Man (1487). It depicts a man within a circle and a square, symbolizing human body proportions and their relationship to geometry and nature [13]. Similarly, Zodiac men diagrams also illustrate the relationship between the human body and the cosmos. They feature a human figure divided into 12 parts, each connected to a zodiac sign and a month, suggesting an intricate system of influences and correspondences between the human body and the universe [23].

Despite the early modern scientific revolution challenging the divine, living cosmos model in favor of a mathematical, mechanistic one [2], the artistic exploration of human-cosmic unity persevered. Notable examples include Michael Druks's 'Druksland' self-portrait, which maps facial features onto a geographical outline [4], and Grayson Perry's 'Map of Nowhere', which modernizes world maps with contemporary culture and societal aspects [20].

The famed astrophysicist Carl Sagan beautifully encapsulated this connection by saying, "We are star stuff, we are a way for the universe to know itself." [21] 'Body Cosmos' is grounded on these historical perspectives and employs modern technology to express this inherent connection vividly. By integrating artistic visualizations of the cosmos and human body using real-time bio-data, we aim to provide a unique perspective on the cosmos' interconnectedness and our perpetual presence in the universe we inhabit.

1.3 Contributions

This paper offers the following contributions:

- The creation of a immersive experience that blends artistic depictions of the human body and nebulae using real-time bio-data visualization. This technique allows users to gain insights into their physical and psychological states, thereby fostering a profound understanding of their relationship with the cosmos.

- A comprehensive discourse on the project's theoretical and historical context, including exploration of concepts such as cyberbody, virtual body, biobody, embodiment, identity, and virtual reality. This discourse situates within bio-art and VR

art, offering a deeper examination of the potential and challenges involved in crafting immersive experiences that unify the human body with the cosmos.

2 RELATED WORK

Our project, Body Cosmos, intersects three main fields: bio-data art, VR art, and medical data art.

Bio-data art is a burgeoning field that employs biological data, including heart rate and brain activity, to generate artistic expressions. For instance, 'NeuroKnitting Beethoven' utilizes EEG data to weave patterns corresponding to the brain activity of the pianist during a performance [22]. Similarly, 'Beyond Human Perception' enables audiences to compare human and plant responses to the same stimulus - live music [15]. Body Cosmos enhances these techniques by applying real-time bio-data in a VR setting, creating an immerisve connection between user and body cosmos.

In the realm of VR art, immersive and interactive experiences are created to stimulate the user's senses and emotions. Examples include 'EVOLVER' by Nicole Shanahan et al., which employs 4D medical scan data for a VR journey following the flow of oxygen through the breathing body [17], and 'Deep Connection' by Marilène Oliver et al., which uses MRI data for an interactive VR experience [18]. Another notable work is 'My Data Body,' where artist Marilène Oliver's MR-scanned body is juxtaposed with various layers of her digital data, including Facebook, Google, and Mac terminal information, offering a unique, datafied view of the human body [19]. Our work advances the field by presenting a cosmic and human body visualization that dynamically responds to the user's bio-data.

Lastly, medical data art utilizes various techniques to artistically present medical data, such as CT and MRI scans. Notable works in this field, like 'Deep Connection' [18], 'EVOLVER' [17] and 'My Data Body' [19] create immersive experiences via artistic and scientific visualization of medical data. In Body Cosmos, we learn from the techniques of medical data visualizations, driven by real-time bio-data, to provide a novel perspective on the interconnectedness of our bodies and the universe.

3 CONCEPTUAL FRAMEWORK

3.1 Cyberbody, Virtual Body, and Biobody

Our project leans on the notion that the human body is not fixed, but rather a dynamic entity that can be reshaped and extended through technology. As McLuhan famously said, "the medium is the extension of man," emphasizing the profound influence of media on human beings and their environment [16]. Within this context, we explore three manifestations of the human body in relation to technology: the cyberbody, virtual body, and biobody. This motivates us to explore three technological expressions of the human body: the cyberbody, the virtual body, and the bio-body. Each of these representations expands our understanding of embodiment and drives the discourse at the core of our project.

The cyberbody, arising from cyberculture, is a cultural construct born from human and digital technology interaction. It tests the boundaries between self and other, nature and culture, human and machine. This fluid, dynamic entity, susceptible to modification and augmentation through various forms of digital mediation, serves as a site of resistance and subversion [3] [6]. As Haraway's Cyborg Manifesto suggests, the cyberbody represents a form of posthumanism, transcending biological body limitations and investigating new modes of embodiment, identity in digital spaces [7].

The virtual body, resultant from computer modeling, is a technical construct simulating human anatomy and physiology. However, unlike the fluid cyberbody, the virtual body is fixed, stable, measurable, controllable, and optimizable [8]. Reflecting the norms and values of dominant cultures or systems, the virtual body reduces the biological body to a data object, exploring new modes of efficiency, accuracy, and performance in digital environments [8].

Based on the research of the cyberbody and the virtual body, we introduce bio-body, driven by bio-data. The bio-body is a hybrid construct emerging from the integration of bio-data and digital technologies. The bio-body is neither fixed nor fluid but a complex, adaptive entity that can be influenced, modulated, or generated by various forms of digital feedback. It's a site of experimentation and expression, capable of creating or discovering new patterns, trends, or insights hidden within complex datasets.

It is in this context that the 'Body Cosmos' finds its roots, navigating the intricate relationship between the human body and technology. It facilitates an immersive expedition into the realms of selfhood, embodiment, and identity, bridging the gap between the cyberbody, virtual body, and the bio-body. By intertwining these concepts, Body Cosmos constructs a narrative about our perpetual presence, underscoring the profound relation between humans and the universe in a dynamic digital medium.

3.2 Embodiment and Identity

In the context of Body Cosmos, the concepts of embodiment and identity need to be redefined beyond their traditional meanings.

Embodiment is not just the experience of having a body. Virtual reality offers a digitalized embodiment and allows us to experience changing embodiments [9]. In virtual reality, having a virtual body can enhance our emotional responses to virtual stimuli [5]. The Body Cosmos, embodied by bio-data, blurs the boundaries between data and flesh, input and output. This embodiment expands our bodily abilities and sensations in real-time.

Identity is not just an individual's sense of self but as a performance of the individual ego in virtual reality [12]. Body Cosmos dissolves human-centered identity by merging the player and the universe as a whole, as particles in micro and macro scales. Our creation of a bio-nebula visualization technique combines cosmic and human body data in real time, challenging the distinctions between human and nature, microcosm and macrocosm to form a unique, evolving identity.

Lastly, our perception of virtual reality is transformed in the Body Cosmos. The cognitive and cultural factors that traditionally shape our construction of virtual reality [9] are now intertwined with real-time bio-data. This system questions the understanding of life and Alife, creator and creation, providing users with an immersive experience that alters their sense of what is real and unreal in a digitally-enhanced world.

In summary, Body Cosmos not only engages with embodiment, identity, and virtual reality, but also challenges these concepts, providing a experimental experience that bridges the gap between the human body and the digital cosmos.

4 METHODOLOGY

4.1 Synthesizing Nebula and Human Body: A Volumetric Approach

In this section, we describe our method for creating a dynamic and interactive visualization of the human body as a nebula. We first explain the common technique of volumetric rendering and how it applies to both DICOM and nebula data. Then, we present our novel approach that combines a particle system with real-time bio-data input. Finally, we illustrate our method with an example of creating a brain nebula.

4.1.1 Volumetric Rendering of DICOM Data

Volumetric rendering is a technique that visualizes 3-D data by assigning each voxel (a 3-D pixel) a color and an opacity value. This technique is widely used for visualizing DICOM data and nebula data.

DICOM data is derived from medical imaging devices such as CT or MRI scanners, which provide insights into the internal structure of the human body [18]. DICOM data is typically stored as a series

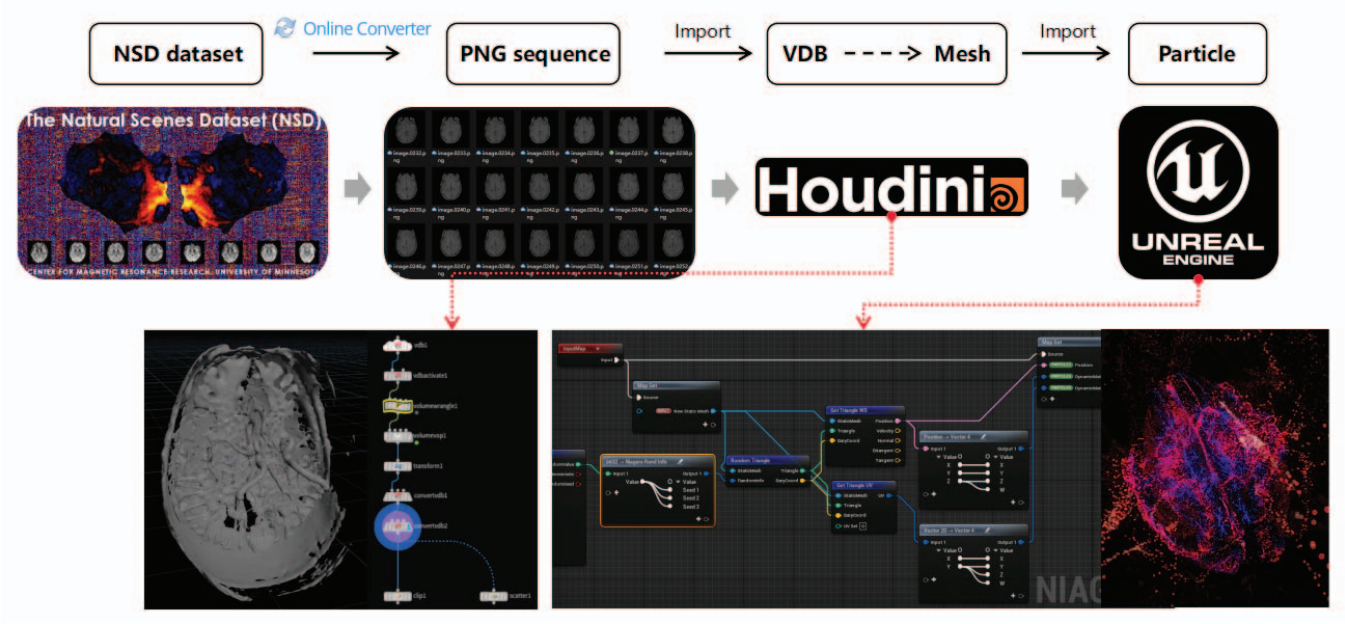

Figure 3: The process of creating a brain nebula (© Rungu Lin 2023).

of 2-D slice images [18], which can be stacked together to form a 3-D volume. By applying volumetric rendering to the DICOM data, we can create realistic and detailed representations of human organs.

Nebula data is sourced from astronomical observations like telescopes or satellites, which depict interstellar gas and dust clouds [14]. Nebula data is usually stored as a singular 2-D projection image [14], which can be converted into a 3-D volume by using a depth map or a noise function. By applying volumetric rendering to the nebula data, we can create artistic and abstract representations of cosmic phenomena.

4.1.2 Particle System with Bio-Data Input

While we draw inspiration from the volumetric rendering technique for DICOM data, we also recognize its inherent limitation: the resulting visualization is non-interactive, depending solely on the input image sequences. To overcome this limitation, we devise a novel approach that intertwines a particle system with the user's real-time bio-data. A particle system is a technique that simulates natural phenomena by using a large number of small sprites or polygons called particles.

We select particles as the foundational visual element for our visualization because they reflect the duality of existence: on a macro scale, every lifeform is a particle in the universe; whereas on a micro scale, every lifeform in the universe comprises particles. By using particles, we can create a dynamic and interactive visualization that responds to the user's bio-data input, such as heart rate or brain waves (Figure 4).

To implement our approach, we use two software tools: Houdini and Unreal Engine 5. Houdini is a 3-D animation software that allows us to create and manipulate volumetric data. Unreal Engine 5 is a game engine that allows us to create and render particle systems in real time. We use Houdini to convert the DICOM and nebula data into meshes, which are then imported into Unreal Engine 5 as particle emitters. We also develop custom shaders in Unreal Engine 5 that control the mesh vertices' parameters based on the bio-data input. These shaders have data interfaces that can receive bio-data input from external devices or applications.

4.1.3 Example: Brain Nebula

To illustrate our method, we present an example of creating a brain nebula using our approach. The brain nebula is a visualization of the human brain as a cosmic cloud that changes its color, movement, and brightness according to the user's brain waves.

The steps for creating the brain nebula are as follows (Figure 4):

- We obtain DICOM data of the human brain from NSD(the he Natural Scenes Dataset) dataset [1] and convert it into image(.png format) sequences using a free online converter.
- We import the image sequences into Houdini, a 3D animation software, and create a VDB(Voxel Data Block) with a "density" property. The voxel size is adjusted and the VDB is centered at (0,0,0).
- A "Volume Wrangle" node is used to write VEX(a high-performance expression language used in Houdini) code that remaps the image sequence length to the Z-axis resolution of the VDB. "Colormap" function is applied to sample the color data from the image sequences and transform it into density values for the VDB.
- We also use a "Volume VOP"(operation runs CVEX over a set of volume primitives) node to apply a ramp that enhances the contrast of the density data set.
- The VDB is then converted into a mesh and exported to Unreal Engine 5.
- In Unreal Engine 5, we use its Niagara system(particle system) to generate particles on the mesh in real time.
- We develop custom shaders with color partitioning that control the mesh vertices' parameters based on the bio-data input. These shaders have data interfaces that can receive bio-data input from an EEG device or application (Figure 5).
- The world positions and UV of the mesh triangles are obtained from Houdini and output as dynamic parameters for the custom shaders.

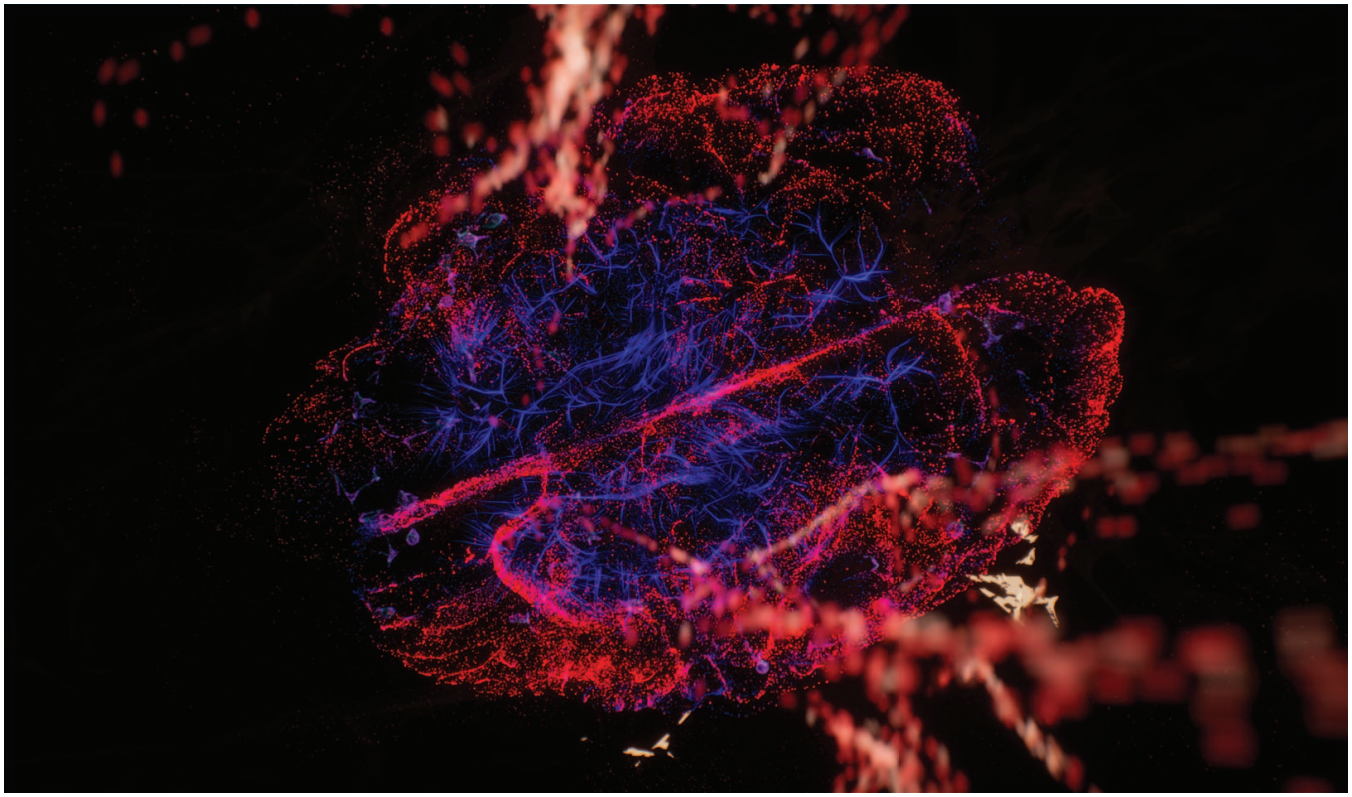

Figure 4: Screenshot of Unreal Engine's real-time demo (© Rungu Lin 2023).

- We use the bio-data input to dynamically influence the color, movement, and luminosity of the particles.

The result is a brain nebula that reflects the user's cognitive state in an immersive and engaging way.

4.2 Synthesizing Bio-responsive Nebulae

Equipped with heart rate sensors and brain-computer interfaces (BCIs), players can manipulate the surrounding environment in real time with their bio-data, thereby cultivating a sense of oneness with the cosmos. We have collaborated with Flowtime [10], a pioneering company in EEG device manufacturing and development of an Emotion Cloud and user-friendly SDK [11].

We use Python and Flowtime's SDK to develop software that operates on a local server. This software is designed to receive the raw data from the EEG device in real time via Bluetooth and subsequently upload this raw data to Flowtime's Emotion Cloud. This cloud platform processes the raw data to calculate specific indicators such as attention, relaxation, and pressure, then transmits the value of these indicators back to the local server in real time, delivering data sets every 0.6 seconds. Our software receives these indicator values, converts the data into OSC format, and transmits them to the Unreal Engine using the UDP protocol (Figure 6).

This bio-responsive immersive environment adjusts various parameters—such as frequency, velocity, brightness, movement, and color—of the particles based on the players' real-time bio-data input.

We devise the following interactive rules to merge the Body Cosmos visualization with the real-time bio-data (Figure 7):

- The heart rate sensor collects real-time data that modulates the frequency of the heart nebula and the velocity of the vessel nebula. As heart rate escalates, both the frequency and velocity correspondingly increase.
- EEG attention data influences the luminosity of the brain and nerve nebulae. Higher attention values result in augmented brightness.
- EEG relaxation data affects the noise frequency of the brain and vessel nebulae. Greater relaxation values induce a reduction in noise frequency.
- EEG pressure data impacts the color of the brain and vessel nebulae. The color spectrum transitions from blue to red as pressure values escalate.

4.3 An Immersive Experience of Self-Discovery

We design two distinct modes for players to engage with: the Roller Coaster Mode and the Free Explore Mode.

- In Roller Coaster Mode, we construct a designated path for exploration. The player's avatar is represented by a transparent sphere, bound to this set trajectory, with the head-mounted display acting as a child object of the sphere. This mode simulates a roller coaster experience as the player embarks on a slow, guided tour through the Body Cosmos. While the motion path remains fixed, players can freely turn their heads and bodies to observe different perspectives, engaging with the experience in the order we establish.
- In Free Explore Mode, we offer players the opportunity for unguided exploration of the Body Cosmos. The navigation relies on the cooperation between the player's gaze direction through the head-mounted display and the joystick on their right-hand controller. When the joystick is pushed forward, the player moves in the direction their gaze is focused. Conversely, when the joystick is pulled back, the player moves in the

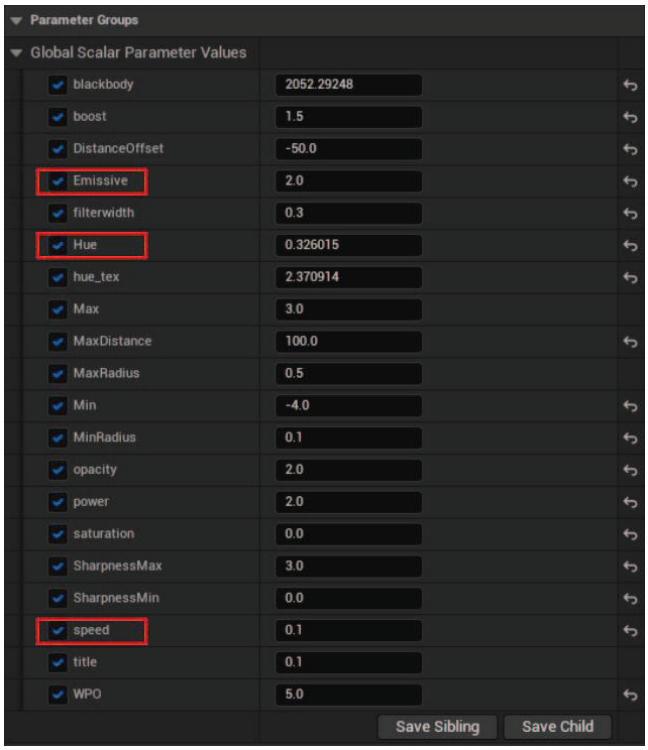

Figure 5: Data interfaces of the shader that can receive bio-data input (© Rungu Lin 2023).

opposite direction, adding a layer of immersion and autonomy to their exploration.

Each mode complements the other, creating a comprehensive, multifaceted interaction within the Body Cosmos, encouraging players to navigate the dynamic interplay between guided learning and personal discovery.

5 CONCLUSION AND FUTURE WORK

In conclusion, our project, Body Cosmos, pioneer a novel approach to visualize the interconnectedness of the human body and cosmic nebulae. Utilizing volumetric rendering techniques, we creatively merge DICOM data and nebulae imagery to create an immersive, dynamic, and interactive environment for users. This integration of real-time bio-data elevat the level of personal engagement, offering users a unique sense of unity within the cosmos.

As an artistic endeavor, Body Cosmos seeks to ignite curiosity, broaden users' imaginations, and foster a deeper understanding of life's macrocosm and nanoscape. Our aspiration is to reshape how individuals perceive their perpetual presence in relation to the expansive universe.

In terms of future work, several opportunities can be explored to expand and improve the "Body Cosmos" experience:

- Incorporating more bio-data sensors, such as galvanic skin response or respiration rate, could provide a richer and more diverse range of input variables for the interactive visualization.
- Further research could investigate the potential psychological and physiological benefits of the "Body Cosmos" experience, as well as its effectiveness as a mindfulness and relaxation tool.
- The integration of multi-user capabilities could facilitate social interactions and shared experiences within the "Body Cosmos" environment, fostering a sense of collective understanding and unity.

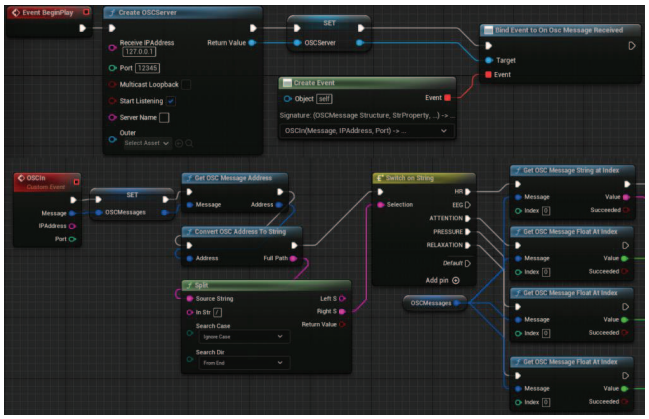

Figure 6: Receive and process OSC data through UDP protocol in Unreal Engine(© Rungu Lin 2023).

Sensor	Indicator	Bio-Nebula	Parameter	Relationship
Heart rate sensor (Integrated in EEG Headbrand)	HR	Heart nebula Vessel nebula	Frequency Velocity	HR(low) HR(high)
EEG Headbrand	Attention	Brain nebula Nerve nebula	Emissive intensity	AT(low) AT(high)
	Relaxation	Brain nebula Vessel nebula	Noise frequency	RE(low) RE(high)
	Presasure	Brain nebula Vessel nebula	Scale color	PR(low) PR(high)

Figure 7: Interactive rules to merge the Body Cosmos visualization with the real-time bio-data(© Rungu Lin 2023).

We are confident that Body Cosmos will continue to evolve and grow. We anticipate that these future advancements will extend the impact and reach of Body Cosmos, further bridging the gap between human beings and the digital cosmos.

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REFERENCES

[1] E. J. Allen, G. St-Yves, Y. Wu, J. L. Breedlove, J. S. Prince, L. T. Dowdle, M. Nau, B. Caron, F. Pestilli, I. Charest, et al. A massive 7t fmri dataset to bridge cognitive neuroscience and artificial intelligence. *Nature neuroscience*, 25(1):116–126, 2022.
[2] R. Allers. Microcosmus: From anaximandros to paracelsus. *Traditio*, pages 319–407, 1944.
[3] D. Bell. *Cyberculture Theorists: Manuel Castells and Donna Haraway*. Routledge, 2006.
[4] M. Druks. Druksland, 1975.
[5] D. Gall, D. Roth, J.-P. Stauffert, J. Zarges, and M. E. Latoschik. Embodiment in virtual reality intensifies emotional responses to virtual stimuli. *Frontiers in Psychology*, 12:674179, 2021.
[6] M. B. Hansen. *Bodies in code: Interfaces with digital media*. Routledge, 2012.
[7] D. J. Haraway. A cyborg manifesto: Science, technology, and socialist-feminism in the late twentieth century. In *Posthumanism*, pages 69–84. Springer, 2000.
[8] N. K. Hayles. How we became posthuman: Virtual bodies in cybernetics, literature, and informatics, 2000.

[9] K. Hillis. *Digital sensations: Space, identity, and embodiment in virtual reality*, volume 1. U of Minnesota Press, 1999.
[10] F. Inc. Flowtime headband, 2023.
[11] F. Inc. Flowtime sdk, 2023.
[12] A. Lasko-Harvill. Identity and mask in virtual reality. *Discourse*, 14(2):222–234, 1992.
[13] T. Lester. *Da Vinci's ghost: Genius, obsession, and how Leonardo created the world in his own image*. Simon and Schuster, 2012.
[14] M. A. Magnor, K. Hildebrand, A. Lintu, and A. J. Hanson. Reflection nebula visualization. In *VIS 05. IEEE Visualization, 2005.*, pages 255–262. IEEE, 2005.
[15] A. V. Maria Castellanos. Beyond human perception, 2022.
[16] M. McLuhan. *Understanding media: The extensions of man*. MIT press, 1994.
[17] T. M. A. C. M. J. Nicole Shanahan, Edward R. Pressman Sam Pressman. Evolver, 2022.
[18] M. Oliver, G. J. Joynes, K. Punithakumar, and P. Seres. Deep connection: Making virtual reality artworks with medical scan data. In *2021 IEEE VIS Arts Program (VISAP)*, pages 37–44. IEEE, 2021.
[19] M. Oliver, S. Smallwood, S. Moore, and J. R. Carpenter. My data body. In *ACM SIGGRAPH 2022 Art Gallery*, SIGGRAPH '22, New York, NY, USA, 2022. Association for Computing Machinery.
[20] G. Perry. Map of nowhere, 1960.
[21] C. Sagan. Cosmos random house. *NY/Carl Sagan Productions Inc*, 1980.
[22] M. C. S. Varvara Guljajeva. Neuroknitting beethoven, 2022.
[23] S. Witherden. Balancing form, function, and aesthetic: A study of ruling patterns for zodiac men in astro-medical manuscripts of late medieval england. *Journal of the Early Book Society for the Study of Manuscripts and Printing History*, 20:79–339, 2017.