Universitat Oberta de Catalunya

artnodes
E-JOURNAL ON ART, SCIENCE AND TECHNOLOGY

https://artnodes.uoc.edu

ARTICLE

NODE «IN THE LIMITS OF WHAT IS POSSIBLE: ART, SCIENCE AND TECHNOLOGY»

DIFFUSION: Emotional Visualization Based on Biofeedback Control by EEG

Feeling, listening, and touching the real things through human brainwave activity

Shuai Xu
Alibaba
Zhe Wang
Central Academy of Fine Arts (Beijing)

Date of submission: April 2021
Accepted in: May 2021
Published in: July 2021

Recommended citation

Xu, Shuai; Wang, Zhe. 2021. « Diffusion: Emotional Visualization Based on Biofeedback Control by EEG (Electroencephalogram). Feeling, listening, and touching the real things through human brainwave activity». In: González Díaz, Paloma; García Méndez, Andrea (coord.) «In the limits of what is possible: art, science and technology». *Artnodes*, no. 28: 1-11. UOC. [Accessed: dd/mm/yy]. http://doi.org/10.7238/a.v0i28.385717

Abstract

Diffusion is an area of research exploring the interactive relationship between human consciousness and computational practice by analyzing human brain data from electroen-cephalogram (EEG)-based brain-computer interfaces and interactive devices that can generate music and synchronized visual images by biofeedback. Although interactive experience is not a new topic in computational art, it has provoked thought due to the significant influence of technology on human ideology, emotions, morality, ethics, etc. Diffusion is the result of attempts to establish a connection between human physiological information and digital technology. As well as

experimental research, it based on the ethical level of artificial intelligence (AI). Diffusion uses music visualization to transform intangible brain activity (thoughts or emotions) into perceivable things (sounds or objects). The research emphasizes human consciousness in AI and points out the blurred boundaries between AI and human creativity. Therefore, the installation evaluates human motivation, which can present as abstract structures—like creativity, emotion, and insight—which enhance the interactive experience of participants and deconstructs the inherent meaning of the material and spiritual, reality and virtual reality or humans and machines. By reviewing and contextualizing EEG and digital music development research, we finally outline a future research area that will involve deep collaboration across interdisciplinary and multiple technologies to realize emotion recognition.

Keywords
EEG, visual stimuli, Max/MSP, physical computing, interactive installation

Difusión: la visualización de las emociones controlada por la bioautorregulación mediante electroencefalograma (EEG)
Sentir, escuchar y tocar lo real a través de la actividad de las ondas cerebrales humanas

Resumen
La difusión es un área de investigación en que se explora la relación interactiva entre la conciencia humana y la práctica informática con conexiones cerebro-ordenador mediante electroencefalogramas (EEG) y con otros dispositivos interactivos que analizan datos del cerebro humano para generar música e imágenes visuales sincronizadas mediante la bioautorregulación. A pesar de que las experiencias interactivas no son nada nuevo en el arte digital, esto nos lleva a la reflexión debido a la influencia de la tecnología en la ideología humana, las emociones, la moralidad, la ética, etc. La difusión es el resultado de los intentos de establecer una conexión entre la información fisiológica humana y la tecnología digital. Aparte de la investigación experimental, se basa en el grado de ética de la inteligencia artificial (IA). La difusión utiliza la visualización musical para transformar la actividad cerebral intangible (pensamientos o emociones) en algo que podamos percibir (sonidos u objetos). Con esta investigación se enfatiza la conciencia humana en la IA y se muestran los límites poco claros entre la IA y la creatividad humana. Así, la instalación evalúa la motivación humana, que puede presentarse como estructuras abstractas –como la creatividad, el sentimiento o la introspección– que mejoran la experiencia interactiva de las personas que participan y deconstruyen el significado inherente de lo material y lo espiritual, de la realidad y la realidad virtual o de los humanos y las máquinas. Al revisar y contextualizar el EEG y la investigación sobre la creación de música digital, esbozamos, por fin, una futura área de investigación que conllevará establecer una estrecha colaboración entre tecnologías distintas e interdisciplinarias para hacer realidad el reconocimiento de emociones.

Palabras clave
EEG, estímulos visuales, Max/MSP, computación física, instalación interactiva

1. Introduction

1.1 Background

From intelligent identification technology to virtual digital platforms and today's 5G network and big data statistics technology, AI has integrated into many aspects of daily life and brought about tremendous changes in human society. AI is a new technological science that studies the use of computers to simulate, extend and expand human thinking, conscious processes, and intelligent behavior. In other words, AI uses computers to simulate the process of human perception (Li, 2020).[1] This is consistent with McLuhan's description of the final phase of the extensions of man: 'The technological simulation of consciousness when the creative process of knowing will be collectively and corporately extended to the whole of human society'

1. Li, Xinkui. "Looking at Artificial Intelligence from McLuhan's 'Extension Theory'." Chinese Academy of Social Sciences: June 8, 2020.

(1964).[2] With the help of science and technology, human beings realize the exploration of simulation and extension themselves. These have shifted from imitating appearances to reading and expressing consciousness, thought, and spirit. AI is like a giant network shrouding this era, while the diverse world becomes more complicated by the collision and blending of multi-dimensional space.

1.2 Research question

The program is named Diffusion, which has inherently meaning about the problems and challenges faced in the AI era. Meanwhile, as an artistic program, Diffusion combines creative forms of new media, which is the most avantgarde and contemporary of art forms (Graham and Cook, 2016).[3] However, the key spirit of art history development is still reflected, especially in its continuation of the humanistic spirit. We are aware that the existence of art always revolves around the 'human,' and its reflection of the current relationship between humans and technology is also a focal point in contemporary art.

As a result, Diffusion adopts the combination of art and science as an entry point. It explores the visualization of brain activity and the interaction of biofeedback (intangible signals) and real-world feedback (tangible signals), including how participants' brain activity can interact with a digital system (Healthline, 2018)[4] and the relationship between embodied cognition and music perception. The purpose is to analyze both sides of the interactions, especially the relationship between human brain activity, biofeedback, and the on-site experience of brain-workers. Therefore, two questions are proposed for a deep consideration and to guide this experiment:

1. How can we create connections to connect brain activity and audio-visual installation during interactive experiences?
2. How does a variation in audio-visual stimulus alter an individual's state of human brain activity? How do they influence each other?

To discuss the issues detailed above, this article will be divided into four parts. First, it explores related theories and practical cases; focuses on the relationship between EEG and artificial; and reveals the inspiration and background behind the creation of Diffusion in terms of conceptual thinking, interactive methodology, and aesthetic presentation. Second, the article discusses Diffusion's generative music system, explaining how the audio component of this interactive device can generate music from the biofeedback generated by EEG. It also shows how this musical system can bring inspiration or change to the understanding of 'artificial.' Finally, it explains the audio-visual installation design of Diffusion. It presents scenarios of human–computer interaction to make a performance assessment of human-made processes, which anticipates reflection in this research and indepth future study.

2. Contextual review

2.1 Inspiration

We will present two inspiring artworks that focus on studying brain activity and its interaction with machine art. The purpose is to show the source of inspiration for Diffusion and discuss how to make creative improvements in terms of concept, technology, and aesthetics.

Brain Factory (2016) (Figure 1), created by Maurice Benayoun and Tobias Klein, is an interactive installation that converts intangible data into tangible objects.[5] Benayoun and Klein tried to examine human motivation through conceptual constructs such as love, freedom, and desire. As a result, real-time biofeedback data from brain activity is used for secondary creations, which could help read and connect emotional responses in binary results. In addition, *Brain Factory* gives shape to these data by creating 3D prints that, alongside abstraction brain activity, become a naturally formed bridge between the tangible and intangible.

Figure 1. *Brain Factory prototype*, 2016

Eunoia II (2014) (Figure 2), created by Lisa Park, is a live performance that uses EEG to engage with the audio-visual project in real-time and then to visualize the artist's consciousness and thoughts.[6] It created a productive relationship between emotional values and sound waves. As indicated in the first research question, we wish to find a way to connect brain activity with an audio-visual installation.

2. McLuhan, Marshall. Understanding Media: The Extensions of Man. New York: McGraw-Hill, 1964.
3. Graham, Beryl., and Cook, Sarah. Rethinking Curating: Art after New Media. Translated by Long, Xingru. Beijing: Tsinghua University Press, 2016:36.
4. Healthline. "EEG (Electroencephalogram): Purpose, Procedure, and Risks." Accessed April 3, 2021. https://www.healthline.com/health/eeg.
5. Benayoun, Maurice. "Brain Factory." Accessed April 3, 2021. https://benayoun.com/moben/2016/03/05/brain-factory/.
6. Park, Lisa. "Eunoia II". Accessed April 3, 2021. https://www.thelisapark.com/work/eunoia.

Figure 2. *Eunoia II,* 2014

Eunoia II inspired us to use EEG data to make instruments or use with music software, connecting to a music system to complete the interactive experience.

2.2 Literature review

In the long history of art, science, technology, and art have intertwined, inspiring and influencing each other. In Ancient Greece, exploring the world's origin through philosophy and science influenced the pursuit of natural aesthetic standards such as the golden ratio in architecture and painting in fine art. The development of science and technology in the 19th century also affected the artistic expression of light and color in Impressionist art. Furthermore, Futurism pursued technological development and increased speed in the mechanical processing of art. This led to new creations incorporating digital interactions, human emotions, and artificial life in contemporary new media art. Together, this revealed the exploration and pursuit of technical and philosophical issues hidden in art history's development. Similarly, the development of AI art embodies the close logical relationship between art, philosophy, and science.

The term 'human-made' can be found in Western epic records and Eastern epic records. 'Human-made,' also known as 'artificial,' is an extension or revision in human nature (McLuhan, 1964).[7] But the development of AI art is first based on materialism (Zhang, 2018).[8] Although the seemingly unmonitored development of AI, in which arithmetic skills beyond the human brain can be seen, the 'human's subjective role has never withdrawn. Benayoun argues that AI is human 'by design' (2017)[9] In this context, artists use media, technology, language, and symbols to transform free imagination into concepts and emotions. These combined realize the humanized expression of technology.

Humans expect AI to be endowed with emotional or perceptual human abilities to control, decide, or design. However, they need to maintain a peaceful way of getting along together or put themselves in a dominant position rather than being controlled by AI. However, both on a biological and technological level, particularly in modern times, it is impossible. There is still controversy over whether AI will surpass human intelligence, including the boundaries of intelligence, mind, and synthetic and human intelligence (Zhang, 2018).[10] The boundaries between them are constantly being blurred, and any inner meaning is continuously being deconstructed. Can deep-learning technology read and translate human thoughts? In other words, will the development of AI technology produce consciousness that is independent of human beings? Can AI surpass or replace the human brain? Can AI art replace artists? At present, the answers to these questions are inconclusive. Although the human body and soul are not eternal, AI technology has released the artist's soul condensed behind an artistic work and communicates directly with humans. (Liu, 2017)[11] In this kind of relational aesthetics, art plays an essential role in creating itself. The artist plays the role of facilitator rather than producer, and art is regarded as the information exchanged between the artist and the audience. This is not only an explanation of *Zeitgeist*, as suggested by Taine (2012).[12] It is also a creative expression that integrates the individual experience of the artist and the participants because society plays an indispensable role in the art production process and individual experiences, memories, and emotions.

In such times, new questions in science and technology naturally arise relating to society and the humanities. First, how can we realize the simulation and extension of human consciousness through technology? Second, how do humans deal with the complex relationship between technological choices and moral ethics in the development process? Based on the review of theories and cases, combined with the exploration and thinking of human–computer interaction and aesthetic forms, this project, Diffusion, decided to explore 'human-made' sensations by accessing EEG biodata. The computational methods are used to redefine the biodata in a new format. When ferrofluid and brain waves are used to simulate the movement of brain activity to help participants understand or feel what is artificial (human-made), this main technical highlight is something we would usually ignore. Participants will output perceived things such as sound, visual system, and ferrofluid through brain activity during meditation, recall, thought, or dance. During the interaction, people can explore the relationship between music and the body. However, because human embodied consciousness is very complicated, affected by many factors, we cannot summarize human consciousness in a few

7. McLuhan, Marshall. Understanding Media: The Extensions of Man. New York: McGraw-Hill, 1964.
8. Zhang, Haitao. "A brief history of AI and AI artistic concepts." Accessed May 14, 2021. https://mp.weixin.qq.com/s/3Agr1gB9LUPIMGDtoW5UpA.
9. Benayoun, Maurice. "Artificial Intelligence, All Too Human." Accessed April 3, 2021. https://benayoun.com/moben/2017/08/29/artificial-intelligence-all-too-human/
10. Zhang, Haitao. "A brief history of AI and AI artistic concepts." Accessed May 14, 2021. https://mp.weixin.qq.com/s/3Agr1gB9LUPIMGDtoW5UpA.
11. Liu, Runkun. "Can AI replace artists?" Ethnic Art Studies 30, no.2 (2017): 71-76.
12. Taine, Hippolyte Adolphe. Philosophy of Art, Translated by Fu Lei. Nanjing: Jiangsu Literature and Art Publishing House, 2012.

words. Perhaps only 'intelligence' can recognize the so-called 'artificial.' Figure 3 shows the structure of this project.

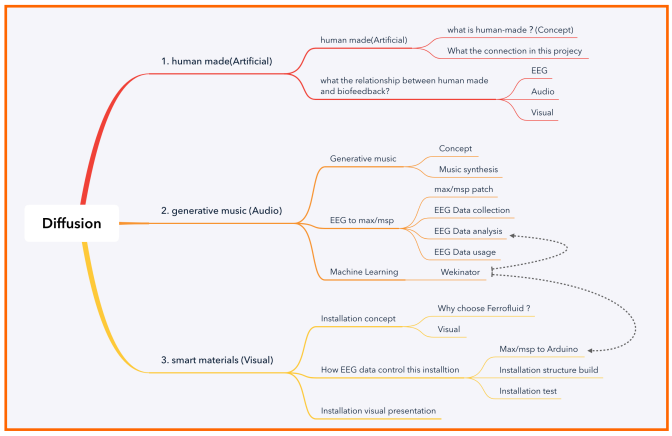

Figure 3. *The structure of this project*

3. Brain activity and Human Computing Interaction (HCI)

3.1 The EEG data

Today, scientists, researchers, artists, and engineers are increasingly operating in Brain-Computer Interfacing (BCI). However, most work is directed toward improving assistive technology to help people with disabilities communicate or use devices such as wheelchairs and prosthetic limbs. The EEG test has become a helpful tool for reading and measuring signals from the brain. An EEG is a test that analyzes the electrical activity in a person's brain. It provides a scientific representation of the electrical impulses that provide for communication between individual brain cells. In science, the EEG can be used to improve potential problems associated with such activity (McLuhan, 1964).[13] Neural activity creates electrical areas that can be tracked and shown by using electrodes attached to the scalp with wires. These plates investigate the electrical impulses in the brain that form the basis of the EEG data. These signals are transferred to computers that record the outcomes. An EEG result is always shown in wave patterns (Figure 4). Consequently, the EEG is an essential tool for engaging with human brain activity. As a result, it links brain activity and computational techniques that can then discover, perceive and understand the notion 'human-made.'

Furthermore, the brain is an essential part of the human body. All human activities are implemented via instructions issued by the brain. Additionally, brainwave data are first-hand feedback, providing more direct data about feelings and thoughts than any other data

Figure 4. *An example of EEG brainwave data*

type. The raw EEG data is fascinating but difficult to understand. EEG data have great potential for interaction. Therefore, we wish to engage with these data to help others understand or sense the 'human-made' (artificial), tangible things, and things to which we do not usually pay attention.

3.2 Audio-visual brain activity

To expand this investigation into the 'human-made,' the computational art project itself is necessary to convert the intangible into tangible things. During the initial stage of research on the biosensor, the project will primarily emphasize two main topics: audio and visual. An EEG sensor will be used as the biosensor for this project to intuitively record participants' brainwave data.

First, we intend this project's investigation into the audio component of our study will be mainly about the relationship between EEG and audio. We aim to create an interactive relationship between computational generative music and EEG data that reflects a participant's status in real-time. Next, we will use physical computing, combined with smart material (ferrofluid), to represent the data visually (Figure 5).

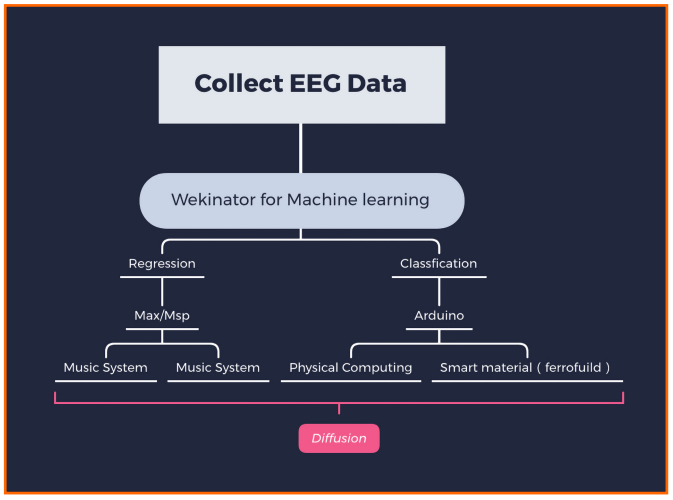

Figure 5. *Workflow*

13. McLuhan, Marshall. Understanding Media: The Extensions of Man. New York: McGraw-Hill, 1964.

4. Generative music and EEG

4.1 Generative music and InterHarmonium

'Generative music' is a term popularized by Brian Eno used to describe music generated by a computer system but driven by creative guidelines. The music's rhythm is always varied (Bainter, 2019).[14] According to the definition of generative music, it shares characteristics with brain activity. Both are unpredictable and varied. Therefore, under these uncertain factors, it is possible to produce exciting results. In this project, the core elements are a set of generative music rules within the music system. This system should look for data in the EEG signal and match the musical feedback with attached productive programming processes. For instance, the system can recognize a series of prominent data in the EEG and then provide an audio feedback associated with the EEG data. As a result, this system can determine the different types of music associated with a participant's mental states at a deeper level.

Brouse (2001)[15] states that the InterHarmonium has been conceived as a network living in the brainwave music performance system. Its primary purpose was to provide geographically divided performers and make musical compositions using their brainwaves simultaneously. In this essay, the InterHarmonium is envisioned as a bridge that connects creative explorations with our central nervous systems. This bridge will become the topographies of computer networks as a metaphor between creative explorations and brain activity. Additionally, the InterHarmonium is considered the most appropriate form to represent an 'auditory display' (Kramer, 1994)[16] because it attempts to present real-time brainwave activity in such a way that makes it intuitive and immediately comprehensible to listeners. In this project, when the EEG sensor receives brain signals, they will be digitized and correctly transferred to a proper format. These signals will then be sent over regular Internet Protocol networks by the InterHarmonium servers. Finally, this signal will take the brainwave sources and generate sound through the music system.

4.2 Technical features

4.2.1 Max/MSP (The music system)

The Muse 2[17] EEG headset (produced by InteraXon) was selected to gain participants' brainwave data. This is a good EEG headset to receive brain waves for primary research. This sensor can accommodate four channels of EEG data, which separately correspond with four parts of the brain (left ear, left forehead, right ear, right forehead). Max/MSP[18] software (maintained by San Francisco-based software company Cycling' 74) was used to build the music system to obtain an artistic music intention. The Max/MSP patch is built upon four main elements: the data input from the EEG sensor, leading music generator, sound effects, and music filters. Max/MSP includes lowpass, bandpass, and highpass filters and a distorted and transformed audio output.

There are three main controls for the core music generator in the Max/MSP patch (Figure 6).

First, we chose to use an EEG data channel, which essentially provided a beat and determined the musical rhythm. The second EEG channel controlled the tempo, which controls the speed of rhythm. The musical element 'scale' was handled by the third EEG channel, which determined the scale degree within the octave, adjusting the high and low pitches in the music. The four EEG channels will form an adjust function for the whole system; it will be another 'scale' that affects the octave. With the Max/MSP patch, users can choose any key, base note, or tonic to generate their music. This is crucial for determining what instrument types make the music.

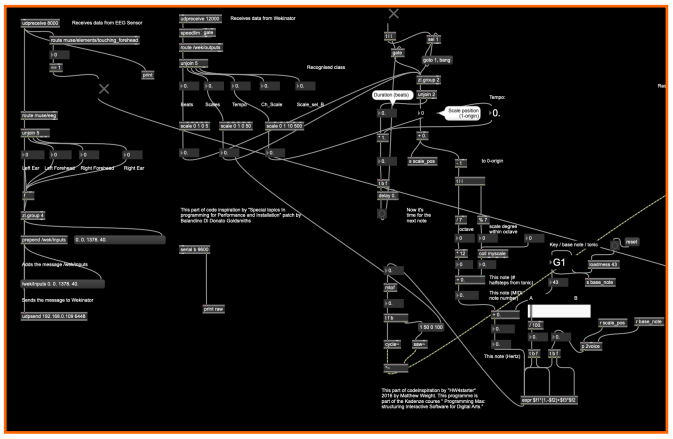

Figure 6. *Main music part in Max/MSP*

Further, the above elements will collectively synthesize a piece of complete music. To build a piece of crisp music, the final sounds will be sent to a sound effects filter (svf), which provides lowpass, highpass, and bandpass filtering concurrently, enabling individual control of different frequencies. In this svf section, the filter achieves a more sympathetic and less tumultuous sound by distorting filtered

14. Bainter, Alex. "Introduction to Generative Music." Accessed May 14, 2021. https://medium.com/@alexbainter/introduction-to-generative-music-91e00e4dba11.
15. McLuhan, Marshall. Understanding Media: The Extensions of Man. New York: McGraw-Hill, 1964.Brouse, Andrew. "The Interharmonium: An Investigation into Networked Musical Applications and Brainwaves." Masters diss., McGill University, 2001.
16. McLuhan, Marshall. Understanding Media: The Extensions of Man. New York: McGraw-Hill, 1964.Kramer, Gregory. "Auditory Display: Sonification, Audification, and Auditory Interfaces." Computer Music Journal 19, no.2 (Summer 1995): 110.
17. Choosemuse. "Muse 2: Brain Sensing Headband - Technology Enhanced Meditation." Accessed May 29, 2021. https://choosemuse.com/muse-2/.
18. "Cycling '74." Accessed May 29, 2021. https://cycling74.com/.

frequencies through a two-function lookup and waveshaper. There is also a button that helps make the wave smoother and a reset button to redraw the wave (Figure 7.)

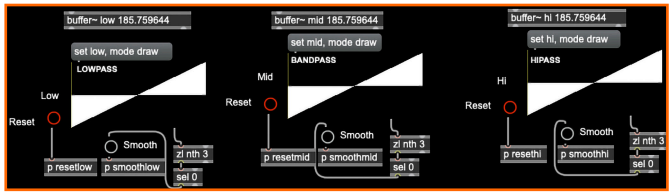

Figure 7. *Waveshaping in Max/MSP*

This is accomplished using waveshaping and lookup tables, which create dynamic changes to the audio signal. By drawing multiple zero-crossing points with a transfer function, additional harmonics are applied to the waveform. This technique is learned by following 'Dynamic Tutorial 3: Distortion' found in Max/MSP refe-rences, and it allows the artwork to achieve distortions on individual frequencies of the svfs. All had low, mid, and high control. Having separate controls also helped control the feedback created within the system. A small amount of the raw slide signal is fed directly to the svf and distorted. Care was required when mixing the tri and raw signals. Too much of the raw signal creates too much feedback (Figure 8).

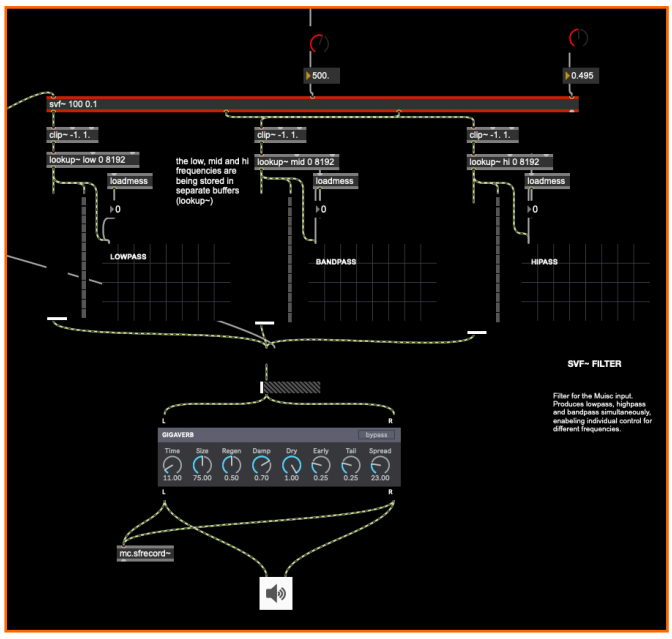

Figure 8. *The svf filter in Max/MSP*

4.2.2 Machine learning

This project uses machine learning as a tool for analyzing EEG data and musical elements. We used Max/MSP as a bridge to receive EEG data, send them to Wekinator[19] (machine learning software by Open Sound Control,) and collect the training data to make the music.

The EEG sensor, Muse2, provided four EEG data channels; the original signal concerns brain activity; the experimental proof that the original signals are not rules, which only shows electrodes' feedback on the performer's head. As a result, we sent all the raw data to Wekinator for preprocessing to gain more easily controlled data. In Wekinator, the four channels of data were processed separately by linear regression (Figure 9).

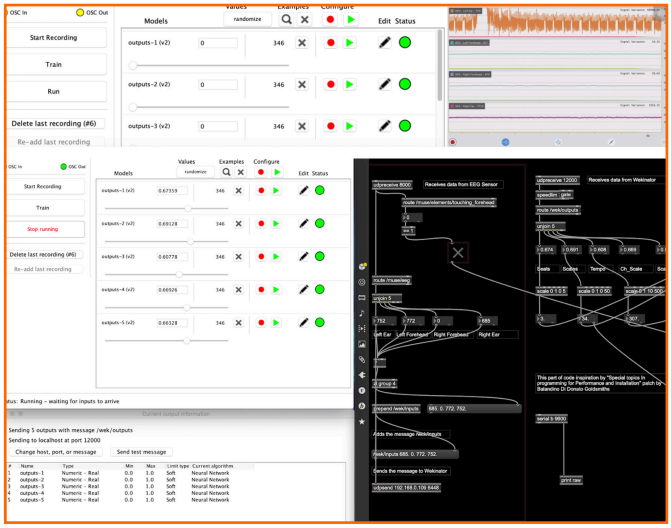

Figure 9. *Brain data and Wekinator*

5. Project showcase

5.1 The performance of *Human-Made*

We have utilized human creativity and emotion design within an interactive system throughout this project, including sound, visuals, and sculpture. Our team achieved this by using EEG sensors to track each performer's brain activity to interact with sound, visuals, and ferrofluid sculpting. The performance had three performers, each with different types of behavior and bodily movements. The results provided excellent responses to the two research questions. Each performer served as a satisfactory bridge while connected to the audio-visual installation. For example, when a performer was calm or meditated, the installation provided an interactive experience; and the sound, visuals, and ferrofluid maintained a soft result. Conversely, when the performer did strenuous exercise or thought about various

19. Wekinator. "Software for Real-Time, Interactive Machine Learning." Accessed May 29, 2021. http://www.wekinator.org/.

Figure 10(a). *A performance by Yuhao Yin*

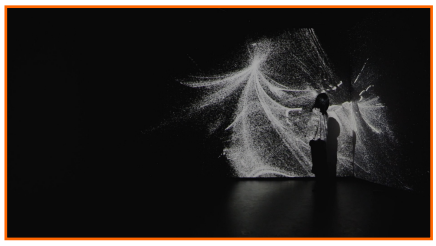

Figure 10(b). *A performance by Dahong Wang*

Figure 10(c). *A performance by Meijun Xu*

things, the brainwaves fluctuated sharply, and the sounds, visual system, and fer-rofluid also changed drastically.

This project was affected by human brain activity. However, during the performance, the performers are also affected by their environment, and the sounds and visual system. These factors potentially influenced the performer to relax, become tense, fill them with thoughts, anger, and reflection. This means that the performer becomes a part of creating the performance's meaning. The performer builds a relationship between the audio-visual and human brain activity. They are not autonomous; they supplement each other (Figures 10(a)–10(c)).

5.2 Discussion

Nowadays, 'New media are not just emergent; more importantly, they are everywhere.' (Galloway and Thacker, 2007).[20] At least the artifacts are part of its result and create a new relationship in the everydayness of the digital (e-mail, phones and the Internet). Bourriaud (2002) regards relational aesthetics as the human relationship and their social background as the point of departure from theory and practice into artistic practices, rather than an independent and private space. [21] Digital art, including digital music, is relevant with such a proposition of space, which means that traditional physical and social spaces tend to break. The concept of 'relation' provides a good support for understanding Diffusion as an AI art, as it focuses on process, participation and interaction. In other words, it is concerned with how the system becomes both the space and the material of the artwork. (Graham and Cook, 2016)[22] It is object-based art, or art that is based on interactions between people (including material and immaterial forms), so it attaches great importance to the participation or reaction of the audience. As for the reflection of relational aesthetics in AI art, two conditions must be met in terms of spatial relations, namely, physical interactions and casual encounters (Bourriaud, 2002).[23] The body's intervention highlights the dilemma encountered by the disembodied cognition when dealing with the environmental interaction issues involved in information processing. The study of motor coordination and the brain confirms that the brain and the body participate in cognitive activities simultaneously (Ding and Chen, 2009).[24]

Diffusion uses brainwave sensing technology to realize the visualization and artisticization of brain and body activities in a specific scene. This is an exciting and self-exploring process. It reveals the humanization of technology and provides a humanistic reflection of AI art and the revolution of science and technology in relational aesthetics. But, for now, it seems confined to the 'present' of visual art, and we cannot ignore complex factors that affect its accuracy. The experience and memory are the results of the accumulation of evolution in long-term natural and social environments. It is their integration with the body, which is the foundation and dependence of embodied cognition. Therefore, embodied cognition is an organic unity of mind, body, and environment. Neither mind nor emotions are calculable or replicable in nature (Li, 2008).[25] This is the exploratory stage currently being experienced by EEG and AI art.

Although physical and static art believe that virtual reality may cause new media art to fall into disembodiment, the new media art field holds the opposite view. They believe they have never been separated from reality. Even in virtual reality, the embodied can be realized (Hayles, 1991).[26] Things in today's interactive world are neither complete reverie nor reality; and dynamic, but not life or death. Practice in a virtual context may happen but is not entirely accurate (Morse, 1998). [27] As Bosma

20. Galloway, R, Alexander., and Thacker, Eugene. The Exploit: A Theory of Networks. Minneapolis: University of Minnesota. Press, 2007:36.
21. Bourriaud, Nicolas. Relational Aesthetics. Dijon: Les presses du réel, 2002. http://artsites.ucsc.edu/sdaniel/230/Relational%20Aesthetics_entire.pdf.
22. Graham, Beryl., and Cook, Sarah. Rethinking Curating: Art after New Media. Translated by Long, Xingru. Beijing: Tsinghua. University Press, 2016:78.
23. Bourriaud, Nicolas. Relational Aesthetics. Dijon: Les presses du réel, 2002. http://artsites.ucsc.edu/sdaniel/230/Relational%20Aesthetics_entire.pdf.
24. Ding, Jun., and Chen, Wei. (2009). "At the Root of Embodied Cognition: from Mirror Neuron to Embodied Simulation Theory.". Journal of Central China Normal University (Humanities and Social Sciences) 48, no.1 (July 2009): 132-136.
25. Li, Qiwei. "Cognitive Revolution and Second-Generation Cognitive Science." Acta Psychologica Sinica 40, no.12 (2008): 1306-1327.
26. Hayles, N, Katherine. How We Became Posthuman: Virtual Bodies in Cybernetics. Literature, and Informatics. Chicago: The University of Chicago Press, 1999.
27. Morse, Margaret. Virtualities: Television, Media art, and Cyberculture, Bloomington: IU Press, 1998:185.

states, 'It is neither highly materialized nor purely immaterial.' (2006 : 24–39) [28] When our body appears on site, it carries embodied history and creativity, but the boundaries between human creativity and machine intelligence seem to be blurred in this interaction. And this is what our cultural and living environment is changing through the tendency of complementarity of materialization and dematerialization, which is also the inner meaning that Diffusion is trying to reveal.

6. Conclusion

This project used an interactive installation to explore the process 'human-made' and convert intangible brain activity into tangible things. Digital technology, such as EEG apparatus, Max/MSP, machine learning, physical computing, and other computational technology, was used to achieve this. Through this project, we have attempted to understand 'human-made,' including the relationship between virtual reality and reality and between humans and machines.

In summary, this interactive installation and performance attempted to transform intangible things, such as thinking and feeling, into tangible entities, such as sounds, objects, and sculptures. During the process, we found that human emotions and thoughts can be presented in an artistic and individualized way through the interaction of audio-visual devices, which allows us to see the existence of human consciousness in our artistic appreciation, so that it can also aid the participant in understanding or feeling what 'human-made' is. It also refers to real things and their relationship with things we pay no attention to—the things we do not notice.

We plan to engage with 'human-made' in future endeavors. We will keep researching EEG sensors and using other EEG headsets, such as NeuroSky[29] and Open BCI[30]. Meanwhile, our EEG dataset will be expanded. We plan to collect brainwave data that reflect different ages and races, which will make the brain feedback more accurate. Once we have achieved this, we will enter the next stage and combine a virtual reality headset with an EEG sensor. This should create a storytelling game with these technologies. In this way, we expect to give participants a more free and active interactive immersion environment, which will enable them to obtain a more realistic and attractive experience. At the same time, it will help further research on the subject 'human-made' and bring us a diversified and inclusive understanding of the concept of 'human-made.'

Notes

"Max is software for experimentation and invention, " *Cycling 74*, accessed May 14, 2021, https://cycling74.com/.

"Dynamic Tutorial 3: Distortion," *Cycling 74*, accessed May 14, 2021, https://docs.cycling74.com/max7/tutorials/09_dynamicschapter03.

"Low viscosity magnetic fluid obtained by the colloidal suspension of magnetic particles," Patent, Google, accessed May 14, 2021, https://patents.google.com/patent/US3215572A/en.

"Software for real-time, interactive machine learning," *Wekinator*, accessed May 14, 2021, http://www.wekinator.org/.

References

Bainter, Alex. "Introduction to Generative Music." Accessed May 14, 2021. https://medium.com/@alexbainter/introduction-to-generative-music-91e00e4dba11

Benayoun, Maurice. "Artificial Intelligence, All Too Human." Accessed April 3, 2021. https://benayoun.com/moben/2017/08/29/artificial-intelligence-all-too-human/

Benayoun, Maurice. "Brain Factory." Accessed April 3, 2021. https://benayoun.com/moben/2016/03/05/brain-factory/

Bourriaud, Nicolas. *Relational Aesthetics.* Dijon: Les presses du réel, 2002. http://artsites.ucsc.edu/sdaniel/230/Relational%20Aesthetics_entire.pdf.

Bosma, Josephine. "Meet the Active Audience," In *Network Art: Practices and Positions*, edited by Corby Tom, 24-39. London: Routledge, 2006.

Brouse, Andrew. "The Interharmonium: An Investigation into Networked Musical Applications and Brainwaves." Masters diss., McGill University, 2001.

Ding, Jun. and Chen, Wei. (2009). "At the Root of Embodied Cognition: from Mirror Neuron to Embodied Simulation Theory." *Journal of Central China Normal University* (Humanities and Social Sciences) 48, no.1 (July 2009): 132-136.

Galloway, R, Alexander., and Thacker, Eugene. *The Exploit: A Theory of Networks.* Minneapolis: University of Minnesota Press, 2007.

Graham, Beryl., and Cook, Sarah. Rethinking Curating: Art after New Media. Translated by Long, Xingru. Beijing: Tsinghua University Press, 2016.

Hayles, N, Katherine. *How We Became Posthuman: Virtual Bodies in Cybernetics. Literature, and Informatics*. Chicago: The University of Chicago Press, 1999.

28. Bosma, Josephine. "Meet the Active Audience," In Network Art: Practices and Positions, edited by Corby Tom, 24-39. London: Routledge, 2006:24-39.
29. Neurosky. "EEG - ECG - Biosensors." Accessed May 29, 2021. http://neurosky.com/.
30. OpenBCI. "Open Source Biosensing Tools (EEG, EMG, EKG, and More)." Accessed May 29, 2021. https://openbci.com/.

Healthline. "EEG (Electroencephalogram): Purpose, Procedure, and Risks." Accessed April 3, 2021. https://www.healthline.com/health/eeg.

Kramer, Gregory. "Auditory Display: Sonification, Audification, and Auditory Interfaces." *Computer Music Journal* 19, no.2 (Summer 1995): 110.

Li, Qiwei. "Cognitive Revolution and Second-Generation Cognitive Science." *Acta Psychologica Sinica* 40, no.12 (2008): 1306-1327.

Li, Xinkui. "Looking at Artificial Intelligence from McLuhan's 'Extension Theory'." Chinese Academy of Social Sciences: June 8, 2020.

Liu, Runkun. "Can AI replace artists?" *Ethnic Art Studies* 30, no.2 (2017): 71-76.

McLuhan, Marshall. *Understanding Media: The Extensions of Man.* New York: McGraw-Hill, 1964.

Morse, Margaret. *Virtualities: Television, Media art, and Cyberculture,* Bloomington: IU Press,1998.

Park, Lisa. "Eunoia II". Accessed April 3, 2021. https://www.thelisa-park.com/work/eunoia.

Taine, Hippolyte Adolphe. *Philosophy of Art,* Translated by Fu Lei. Nanjing: Jiangsu Literature and Art Publishing House, 2012.

Zhang, Haitao. "A brief history of AI and AI artistic concepts." Accessed May 14, 2021. https://mp.weixin.qq.com/s/3Agr1gB9LUPIMGDtoW5UpA.

Project documentation

Full Video: https://youtu.be/t31GOojyXgM
Video Trailer: https://youtu.be/wEwM5AXlxx0

CV

Shuai Xu
Alibaba
xushuai2018@foxmail.com

A creative coder and a new media artist currently based on Hangzhou (China) & London (UK). Now Shuai Xu works at Alibaba as a UX designer, mainly focussing on Computational design, WebGL, and interactive installation etc. Since 2017 Shuai Xu works with computation as a medium and language to investigate the collisions between computational arts, science, and new media technology. As well as he tries working with emerging technologies that bridged the communication between traditional narrative language and computational language, focuses on this interaction relationship between immersive environment and intelligent digital system. Website: shuaimxu.com

Zhe Wang
Central Academy of Fine Arts (Beijing)
lokatwz@yeah.net

Zhe Wang is currently engaged in art management research in Beijing (China). She got her BA in Central Academy of Fine Arts (Beijing) of Art History, then completed her studies with an MA in Arts Administration and Cultural Policy at Goldsmiths University of London. Since doing graduation project in 2019, Zhe began to focus on museum management and the narrative design of exhibitions. Starting from the aspects of curating, visual communication, digital integration and innovation of exhibitions, she studies the application of new media and technologies in narrative design, interaction and communication.