‘イ’(1926) by BioLuminescent Bacteria

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ABSTRACT

"‘イ (I)’(1926) by BioLuminescent Bacteria" is a work created by printing an image on agar media using luminous bacteria as ink through digital silkscreen printing. The printed image is the "イ (I)" first displayed on a television CRT display by Kenjiro Takayanagi in 1926. Unlike conventional printed materials, this image has a temporal development. The luminous image gradually glows, then deteriorates and vanishes as the luminous bacteria undergo growth and die.

CCS CONCEPTS

• **Human-centered computing** → *Displays and imagers.*

KEYWORDS

visual media, bioluminescence, digital silkscreen

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Fig 1: "‘イ (I)’(1926) by BioLuminescent Bacteria"

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1 INTRODUCTION

In recent years, research in the HCI field has often focused on non-human organisms, exploring the concept of more-than-human [5]. For instance, Pataranutaporn et al. proposed Biological HCI, a framework for describing and designing interfaces between biological systems, digital systems, and humans [12]. Kim et al. delved into microorganisms, typically invisible to the naked eye, discussing the necessity for a microbe-specific community within HCI [9]. A parallel trend in the field of art practice, known as “bioart,” involves the utilization of living organisms and molecular biology in the creation of artworks [10]. Even within our interest in visual media, there are several examples, such as a work that employs squid chromatophores as audio visualizers by Yokokawa et al. [17] , and a project by Rotko that creates living images with yeast, aiming to comprehend the relationship with the world, surroundings, and nature [13].

Our work develops such curiosity in organisms other than humans on the edge of scientific research and art practice in HCI by treating bioluminescent microorganisms as visual media. There have been several precedents in the use of microorganisms as visual media. Germ painting by Alexander Fleming in the 1930s is the earliest example of the use of microorganisms for visual expression, in which various pigmented molds and bacteria were used to depict pictures instead of paint [6]. Hofmann created experimental typefaces, “Mould Bold” and “Mould Inside,” using mold. Mold spores grew on alphabet frames placed on a medium, forming the typefaces during the growth process [2]. Nakagaki et al. harnessed the characteristics of true slime molds to visualize the shortest distance in a maze [11]. These practices incorporate not only the color of microorganisms but also the temporal development of phenomena like growth and movement in the creation of visual images. We extend the context of such visual media practices by producing a visual medium with temporal development, differing structurally from contemporary digital displays.

2 LUMINOUS BACTERIA

Luminous bacteria, on which we focused, have the visual characteristics of emitting light. Luminous bacteria, primarily found in marine environments, exhibit bioluminescence when their population reaches a certain density. Although their emitted light is faint, it is visible when in the dark. Historical references to these bacteria date back to Aristotle’s time [8]. During wartime in Japan, they were partially used as an affordable and proliferative low-intensity illumination during the Blackout [7][8]. In the present day, there are studies that attempt to use luminous bacteria for 3D printing, and Thomsen et al. converted luminous bacteria into living ink for 3D printers as a practice to design bioluminescence as a building material and to explore what a living architecture is[15]. Binelli et al.

used luminous bacteria for light-based 3D printing as living materials with complex geometries and programmable functionalities[3]. The luminescence of these bacteria hinges on the availability of nutrients and oxygen. Bioluminescence, in this context, is a form of chemiluminescence initiated by oxidative reactions, with the trigger linked to bacterial density [14]. This luminescence arises from oxidative reactions involving a light-emitting substrate protein transitioning to an excited state. In the case of certain species including fluorescent proteins, the excitation energy transfers to the fluorescent protein, which becomes excited, leading to a reaction akin to phosphorescence [16]. This process mirrors the emission of light by a fluorescent material when subjected to an electron beam from a cathode-ray tube (CRT) display, although the luminescence of luminous bacteria is completed inside the body process. *Photobacterium aquimaris* strain employed in this work contains a blue fluorescent protein [18].

3 'I'

The life activity of luminous bacteria was associated with the image of the CRT display, a visual medium that utilized the luminous phenomenon and printed a symbolic character in the history of CRT displays. The character "イ (I)" was the first image displayed on a television CRT display in Japan by Kenjiro Takayanagi. While television research was taking place globally, the Takayanagi experiment employed a Nipkow disk as an image transmitter, and a cathode-ray tube served as an image receiver. The Nipkow disk converted the image into an electrical signal through raster scanning. This electronic signal controlled the electron beam of the cathode-ray tube and received the ever-changing distant image. The electron beam, in turn, excited the phosphor on the surface of the cathode-ray tube, resulting in the emission of light and drawing scanning lines on the screen. Utilizing this mechanism, Takayanagi achieved the first projection of the Japanese character "イ (I)" with a resolution of 40 scanning lines.[4].

4 METHOD

This section describes a method of printing image using luminous bacteria as ink and combining it with digital screen printing. Luminous bacteria were cultivated in 100 mL of Marine Broth 2216 (https://www.sigmaaldrich.com/JP/en/product/sial/76448), a culture medium for marine organisms, for 24 hours at 17°C within an incubator. Subsequently, the bacteria liquid was pasted with 5% gelatin. The support structure was prepared by pouring agar, dissolved in Marine Broth 2216, into a round glass dish previously sterilized under high pressure. To print luminescent bacteria on agar media, we used digital screen printing. Silkscreen printing, a form of stencil printing, involves using a mesh plate with hollowed-out characters and figures to apply ink. It is known for its versatility, as it can be performed on various surfaces such as fabric and metal. This printing method is highly adaptable due to the range of inks available, making it applicable in diverse fields like printed circuits, graphic design, and fashion design[1].

Digital silkscreen making is a computer-controlled automated plate-making method based on binary images. The mesh is pre-filled and then heat-punched in the plate making machine, making it possible to easily produce fine prints such as small letters. To create a binary image of "イ (I)" with 40 scanning lines spaced 1.25 mm apart, Adobe Illustrator, a vector graphics application, was utilized. This image served as the basis for generating a digital screen plate. For the screenmaking process, a digital screen platemaker called Mi screen a4 was employed. The screen plate was then affixed to the agar surface, and the image was printed by applying the bacterial paste with a spatula from the top.

5 TEMPORAL DEVELOPMENT

This work was printed using luminous bacteria and a digital silkscreen. Unlike conventional printed materials, this image has a temporal development. The luminous image gradually glows, then deteriorates and vanishes as the luminous bacteria undergo growth and die. In this section, we show how the life activity of the luminous bacteria produced a temporal development of the image. Immediately after printing, the image was not visible because the bacterial density on the support was insufficient for luminescence. After 12 hours, the bacterial colonies were in the process of expanding and connecting with each other, gradually forming the shape of a screen. After 18 hours, the image printed by the luminous bacteria was luminous clearly(Fig. 2). After 24 hours, the luminous bacteria, initially

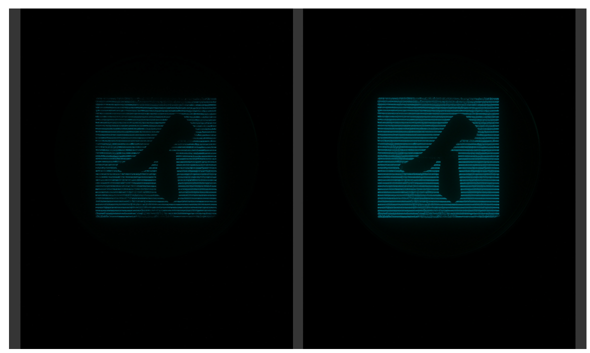

Fig 2: Temporal Development Left: After 12 hours, Right: After 18 hours

creating scanning lines, began to transform into a surface as their growth led to the lines collapsing and connecting both vertically and horizontally. Additionally, there were light particles visible outside the screen, likely originating from individual bacteria that had proliferated. After 48 hours, the light dimmed from the center as the bacteria continued to multiply at the periphery, and contour lines became prominent(Fig. 3).

6 DISCUSSION

This work is a reproduction of Takayanagi's イ (I)' with luminous bacteria and digital silkscreen printing. From the perspective of non-humans organism in HCI, we would like to redefine luminous bacteria as design elements in visual media. The comparison between the CRT display and luminous bacteria suggested similarities and differences in self-illuminating picture elements and their temporal development. The execution of this artwork was achieved through digital silkscreen printing. This distinction is from precedents utilizing microorganisms. Images for digital plate making are generated by vector image editing on computer. The resulting screen-printed

Fig 3: Temporal Development Left: After 24 hours, Right: After 48 hours

image is based on computer control. The screen’s grid structure also implies that spatial information is discretized, resembling pixels. Additionally, *Photobacterium aquimaris* used in this work emits light by resonance transfer of energy from the luminescent protein to the fluorescent protein (BRET). This is analogous to the electron beam in a CRT display that excites the fluorescent material and produces an image of self-luminescence. Similar to the electron beam and fluorescent material in a CRT display, digital slikscreen printing allows the luminous bacteria can be positioned as components of a computer-controlled image that is self-luminous.

The subsequent temporal development, however, is subject to the uncontrollable biological activity of the bacteria. As these bacteria, arranged in a pixel-like grid, proliferate, adjacent clusters connect to create scan lines. The grid structure gradually disintegrates, and the once-distinct lines merge or appear bacteria as points of light in entirely different areas. Ultimately, as individual bacteria multiply around themselves, the overall aggregate becomes less bright at the center while illuminating the newly expanded periphery, i.e. "Edges". Occurring over several days, yields a visual medium that transforms dots become lines and surfaces by the life processes of the bacteria. It is continuous and can be described as a temporal development without a frame rate. In the contemporary digital age, where images are expressed as pixels and frame rates, computer-controlled digital displays can depict various images with temporal development. Beyond the reproduction of images through external means of computers like cameras and scans, computer graphics, real-time generation through programming, and recent advancements in generative AI technology permit internal image generation by computers, which can then be displayed. Nevertheless, these images remain constrained within the structural boundaries defined by digital displays, with space delineated by pixels and time regulated by frame rates.

The contrasting interrelationship between digital silkscreen printing, which positions luminous bacteria as image components, and the uncontrollable activity of luminous bacteria may allow us to develop the structural boundary of visual media in HCI. By using bacteria that have existed long before the advent of display technology, and by grasping their uncontrollable life activities as the temporal development of the visual medium, this work may suggest a way of images that is different from computer-controlled images.

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REFERENCES

[1] San Bernardino, Csusb ScholarWorks, Madelyne Lastimosa, Corita Kent, and Takashi Murakami. 2022. screen printing. In *The Fairchild Books Dictionary of Fashion*, Sandra Keiser and Phyllis G. Tortora (Eds.). Fairchild Books.

[2] S Bilz, M Mischler, and N Thonen. 2004. Mould Inside, Mould Bold. In *Type One*, Robert Klanten (Ed.). Die Gestalten Verlag.

[3] Marco R. Binelli, Anton Kan, Luis E. A. Rozas, Giovanni Pisaturo, Namita Prakash, and André R. Studart. 2022. Complex Living Materials Made by Light-Based Printing of Genetically Programmed Bacteria. *Advanced Materials* 35, 6 (2022), 2207483. https://doi.org/10.1002/adma.202207483

[4] Shizuoka University Television Technical History Editorial Committee. 1987. *History of the Development of Television Technology at Shizuoka University.* Hamamatsu Promotion of Electronic Engineering.

[5] Aykut Coskun, Nazli Cila, Iohanna Nicenboim, Christopher Frauenberger, Ron Wakkary, Marc Hassenzahl, Clara Mancini, Elisa Giaccardi, and Laura Forlano. 2022. More-than-Human Concepts, Methodologies, and Practices in HCI. In *Extended Abstracts of the 2022 CHI Conference on Human Factors in Computing Systems (CHI EA ’22).* Association for Computing Machinery, Article 150, 5 pages. https://doi.org/10.1145/3491101.3516503

[6] Allexsander Fleming. 1936. The Growth of Microorganisms on Paper. In *Sign of Life.* Massachusetts Institute of Technology, 345–346.

[7] Yata Haneda. 1981. Preservation and utilization of luminous bacteria as a light source. *Science Report of the Yokosuka City Museum* 407, 28 (1981), 79–83.

[8] E. Newton Harvey. 1952. *Bioluminescence.* Academic Press.

[9] Raphael Kim, Pat Pataranutaporn, Jack Forman, Seung Ah Lee, Ingmar H. Riedel-Kruse, Mirela Alistar, Eldy S. Lazaro Vasquez, Katia Vega, Roland van Dierendonck, Gilad Gome, Oren Zuckerman, Angela Vujic, David S. Kong, Pattie Maes, Hiroshi Ishii, Misha Sra, and Stefan Poslad. 2021. Microbe-HCI: Introduction and Directions for Growth. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems (CHI EA ’21).* Association for Computing Machinery, Article 155, 4 pages. https://doi.org/10.1145/3411763.3450408

[10] William Myers. 2015. *Bio Art: Altered Realities* (hardcover ed.). Thames and Hudson.

[11] Toshiyuki Nakagaki, Hiroyasu Yamada, and Ágota Tóth. 2000. Maze-solving by an amoeboid organism. *Nature* 407, 6803 (Sept. 2000), 470–470. https://doi.org/10.1038/35035159

[12] Pat Pataranutaporn, Todd Ingalls, and Ed Finn. 2018. Biological HCI: Towards Integrative Interfaces Between People, Computer, and Biological Materials. In *Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI EA ’18).* Association for Computing Machinery, 1–6. https://doi.org/10.1145/3170427.3188662

[13] Johanna Rotko. 2023. Johanna Rotko //// Portfolio. http://johannarotko.com/. (Accessed on 11/29/2023).

[14] Osamu Shimomura. 2012. *Bioluminescence: Chemical principles and methods (revised edition).* World Scientific Publishing.

[15] Mette Ramsgaard Thomsen, Martin Tamke, Aurelie Mosse, Jakob Sieder-Semlitsch, Hanae Bradshaw, Emil Fabritius Buchwald, and Maria Mosshammer. 2021. *Imprimer La Lumiere – 3D Printing Bioluminescence for Architectural Materiality.* Springer Singapore, 305–315. https://doi.org/10.1007/978-981-16-5983-6_28

[16] Yao Xu, David W. Piston, and Carl Hirschie Johnson. 1999. A bioluminescence resonance energy transfer (BRET) system: Application to interacting circadian clock proteins. *Proceedings of the National Academy of Sciences* 96, 1 (1999), 151–156. https://doi.org/10.1073/pnas.96.1.151 arXiv:https://www.pnas.org/doi/pdf/10.1073/pnas.96.1.151

[17] Juppo Yokokawa, Nobuhiro Masuda, and Kazuhiro Jo. 2022. Chromatophony: A Potential Application of Living Images in the Pixel Era. *Leonardo* 55, 3 (05 2022), 252–257. https://doi.org/10.1162/leon_a_02107

[18] Susumu Yoshizawa, Minoru Wada, Kumiko Kita-Tsukamoto, Akira Yokota, and Kazuhiro Kogure. 2009. Photobacterium aquimaris sp. nov., a luminous marine bacterium isolated from seawater. *International Journal of Systematic and Evolutionary Microbiology* 59, 6 (2009), 1438–1442. https://doi.org/10.1099/ijs.0.004309-0