Opinnäytetyö AMK

Kuvataide

2022

Alexandra Trufanova

DIGITAL SYNESTHESIA

– Between 0 and 1

TURKU AMK
TURKU UNIVERSITY OF
APPLIED SCIENCES

Opinnäytetyö AMK | Tiivistelmä

Turun ammattikorkeakoulu

Kuvataide

2022 | 26 sivua

Alexandra Trufanova

Digitaalinen synestesia

- 0:n ja 1:n välissä

Tämä opinnäytetyö tutkii digitaalisten teknologioiden taiteellisia mahdollisuuksia ja niiden soveltamista visuaalisen datan muuntamiseen. Pääpaino on digitaalisen synestesian ilmiössä kaikkien digitaalisten teknologioiden yhtenäisyytenä, joka perustuu binäärikoodiin. Tässä opinnäytetyössä esitetään, kuinka tämä mahdollistaa yhden mediumin muuntamisen toiseksi esimerkkinä digitaalisen kuvan muuntaminen ääneksi.

Asiasanat:

Digitaalinen synestesia, digitaalinen taide, binäärikoodi, valokuva

Bachelor’s Thesis | Abstract

Turku University of Applied Sciences

Fine Arts

2022 | 26 pages

Alexandra Trufanova

Digital Synesthesia

- Between 0 and 1.

This thesis explores the artistic possibilities of digital technologies and their application in the transformation of visual data. The focus is on the phenomenon of *digital synesthesia* as the unity of all digital technologies based on a binary code. This thesis shows how this allows the conversion of one medium into another in the example of converting a digital image to sound.

Keywords:

Digital synesthesia, digital art, binary code, photography

Contents

Images

1 Introduction

Digital technologies have changed our lives. They have influenced many areas, including art. These words are banal and repeated many times differently. But it is hardly possible to exhaust the theme of changes. Artistic research, unlike scientific research, tends to lean more toward human experience. Art fills the gap between ordinary people and science, which has grown and become hundreds of times more complex. We use technology and technological devices everywhere, but how they work remains a mystery to many. Science has become magic. In this work, I will talk about digital synesthesia as one of these magic tricks and show how I use it in my artistic work.

Technology has divided artists into two camps. Some embrace the new tools and possibilities with enthusiasm, discarding old ways. Others cling tightly to the traditional processes, denying the artistic value of digital art. And of course, some prefer to travel freely in between.

So, what happens to the art wedged between these points of view? How does the combination of digital and analog expand the possibilities of their understanding? How can the digital absorb and produce material art at the same time?

The work’s main thesis is that the digital can function as an intermediary between traditional artistic mediums. The binary code allows not only a link of artworks within one analog medium but also to transform them from one medium to another.

2 Origins

2.1 Wondering

I was born in the USSR in an almost analog world. Our family didn't even have a phone. To see friends, one had to go to their home and knock on the door and arrange meetings in advance. Those friends, who had a telephone at home and could call and chat, I considered being privileged. Our dorms had only one telephone, and the children were reluctant to use it. Information flowed from one person to another slowly and naturally, from one voice to another in person. The Information was stored in books, the books in libraries. Any search for information included physical efforts and movements in space.

My mother taught me to read at a very early age. Our little apartment was filled with books. There were books on shelves in several rows, on the mezzanines, in cabinets, and even under the table. Reading became one of the modes of my being, as well as to escape from all my problems. Until the age of nine, I read the entire collection of library books for primary school. Kind librarians sometimes agreed to give me books for "older" children. However, there was no censorship at home, and I read books from the row, whether it was Victor Hugo, Harry Harrison, or romance novels. Was it worth reading all this at such a young age?

Yet I remained a child. My favorite genre was science fiction, my favorite series was Kir Bulychev's books about a girl from the future Alisa Selezneva. The world he described seemed simply incredible. Computers, robots, traveling to other planets, and other achievements of science. For example, there was a videophone that allowed you to communicate at a distance and see the interlocutor. And this seemed like an unattainable fantasy to me.

Nowadays I take my smartphone out of my pocket and make a Skype call. Through the smartphone, I have access to a huge database of information. I take a picture, touch the screen, and see the photo on the screen. I put my

phone back in my pocket. And I think: where is this photo now, what is it? Wondering gives the impulse to explore.

For a younger generation (or people of my age living in countries where digital technologies appeared earlier), technology is not perceived as science fiction. For them, technology is simply an integral part of life and the world, it is what has always been and what will be. But I got my first push-button mobile phone at the age of 16, my first computer at 18 years old, and my digital camera at 19. The key issue now is the development of technologies, not their emergence and existence.

The difference between me and the younger generations (Z and Alpha) is that I now live in a fantasy world that seemed impossible to me, and they live in a world where technology is just part of the reality given to them from birth, providing practical tools that do not cause surprise. For them, fantasy is a world without technology.

2.2 Synesthesia as a Neurological Phenomenon

To understand what digital synesthesia is, it is necessary to talk a little about the medical concept of synesthesia.

Humans interact with the external world through the system of sense organs. The brain processes the received signals and turns them into individual subjective experiences. This is our way of structuring the outer world, which certainly has little to do with our inner experience. We see grass as green and the sky as blue, but the color is just a wave that hits the eyes and is interpreted by the brain. Colorblind people, for example, cannot distinguish colors. So does grass have a color, or does it exist solely in our perceptual system?

It is believed that a person has 5 senses: sight, smell, hearing, touch, and taste. However, modern science highlights a much larger number of senses, such as kinesthesia, thermoception, vestibular sense, and so on.[1]

Synesthesia is a psychophysiological phenomenon of the subject's internal subjective perception, in which excitation in one sense organ also gives rise to subjective perception in other sense organs.[2] For example, when sound gives rise to a sense of color or taste. Synesthesia can involve any of the senses, although some variants are more common than others.

This phenomenon is currently explained as follows. Our senses receive information from the outside world (stimuli). In the brain, there are separate areas for processing various sensory stimuli, the so-called auditory, visual, etc. centers of the brain. However, due to the neuroplasticity of the brain, these centers can receive additional functions and learn to process signals from the associated sensory organs. It turns out that the same received signal from a sensory organ is processed simultaneously in different centers of the brain. So, for example, a subject receives a visual stimulus, which is additionally processed in the auditory center, and the person perceives color and sound at the same time, that is, the person hears color. [3]

Synesthesia is an innate feature; it occurs without the participation of a will of a person, and it is impossible to learn. Also, the experience of synesthesia is not a metaphor or a product of conscious activity (memory), but a real internal subjective experience (sense experience). The perception of a single stimulus is interpreted by different centers of the brain at the same time so that this experience cannot be divided. This has been proven experimentally. The brain scans of synesthetes show how they differ when receiving signals. One signal causes activity in two areas of the brain at once, which was not observed in non-synesthetes.[4]

[1] Gsöllpointner 2015, 8
[2] The American Heritage® Medical Dictionary, 2007
[3] Weibel, 2016, 91
[4] Campen, 2007, 4-6, 14-15

3 Code

3.1 What is Code?

The binary code in digital technology is a way of representing data (numbers, words, and others) as a combination of two characters, which can be denoted as 0 and 1.[5] Sometimes one can come across an erroneous opinion that the binary code inside a computer is written in the form of ordinary zeros and ones. This is a consequence of a lack of understanding of the technical side of the issue. There are no zeros and ones familiar to us on a computer. The "characters" of the computer binary code are the presence or absence of a certain feature in the smallest memory element.

For example, a computer's RAM is a microcircuit made up of a million small cells made from microscopic transistors and capacitors. Each such cell can either contain an electric charge or not. Combinations of charged and discharged RAM cells form a binary code in it. In a similar form, information is stored in all other memory chips (flash drives, SSD media, etc.). The computer processor processes the binary code also in the form of electrical impulses.

An interesting thought arises from this: since the symbol 0 corresponds to the situation of registering the absence of a signal, does the digital information consist of half of the void?

A photograph is a light that hits a photosensitive material or a digital camera sensor. Photography can only happen if there is a physical outside world and photons piercing through space to leave their mark inside the camera. Thus, the light becomes its hostage. As Niklas Kullström points out, in analog photography all parts of the process that results in an image fixed on paper are determined primarily by chemical reactions.[6]

[5] Reas, 2010, 15
[6] Kullström 2017, 11-15

In analog photography, light hits the film, which reacts to light intensity and creates tonal gradations. If a portion of the film came out black, does that mean there was no light? Photons are, in principle, always present in the surrounding space, so most likely we can say that there was not enough light.

Any digital technology is an electromagnetic phenomenon. The information received from the matrix of a digital camera is stored exclusively in binary form: either there is a signal, or it is not. Thus, a digital photograph is always discrete, divided into “zeros”, “ones”, and pixels.[7]

Figure 1. Detail of “tässä_eddie_pesee_autoa_ja_pikkuinen_nukkuu_huhtikuu71.jpg”, 2022.

[7] Reas, 2010, 33

3.2 Binary Reality

The code is an absolute binary reality. It is rigid and precise and thus uncomfortably, disturbingly inhuman. The natural science that is called mathematics describes the world and its laws. However, it is much more conventional than, for example, physics, because it does not contain experiments using objects from our world. Everything happens only in the plane of numbers and operations on them. This is a man-made system for explaining, calculating, and predicting the phenomena of our world and a practical tool for using the knowledge gained. Not because the world is mathematical, not because it describes everything exactly as it is, but because a tool was needed to give order to the surrounding space and social interactions.

The number 1 does not exist in nature, there is just an object. Here, for example, one sword and one apple. Mathematics says that 1 equal 1, but one sword is not equal to one apple. An apple can be eaten, and a sword can kill. For mathematics, in this case, there is neither the problem of choice (do I want an apple or a sword?), nor the question of value (which is better, an apple or a sword?). It declares absolute and crystal-clear equality. The funny thing is that in this case, this declaration feels completely illogical.

Mathematics simplifies the world and makes it more understandable. But it lies beyond morality and human emotions. It is frightening and not existential, not human, all nature resists it: no two leaves, snowflakes, or fingerprints are exactly alike.

Technophobia has always gone hand in hand with the development of new technologies. People are afraid of many aspects of digital technologies and the consequences of their use. Maybe this inhuman equation frightens them too: for mathematics, and therefore for a machine, one living person is equal to one dead person.

Digital technologies give rise to many questions that require separate research. Nevertheless, for me, the question of how technologies exist is more interesting. And how people managed to create such an unnatural system that could outlive all of humanity.

Let us turn to the ideas of Immanuel Kant and his system of the world. Without going into details, he proclaimed the fundamental impossibility of knowing the existing world of things as it is. Things exist on their own (in “themselves”), in contrast to how they are "for man" in the process of cognition. Due to the limited perceptual capabilities of a person, one cannot go beyond sensory experience. So, for Kant time and space are built into human nature’s ways of structuring our perceptions, and not inalienable properties of being.[8]

From this follows the natural conclusion that man does not discover the laws of nature but prescribes them. Although such a claim ultimately does not stand up to scrutiny, the idea of things-in-themselves correlates in some ways with some advances in science. For example, the fact that sound and color are just the way our brain decodes certain wavelengths.[9] So, what exactly is a red apple, and what does a sword swing sound like? One can understand and describe this phenomenon, make calculations, and so on. But I still see the red apple.

I have always been fascinated by the idea that the world is not the way we see and feel it. This makes me curious. But not only is it curious what the world is but also those planes (levels) that arise between the world and people. For me, mathematics, code, and technology are like those new planes.

I explored this idea in my work “Taso v0,10121815”. I used ten smartphones in a row. Each phone took a real-time picture of the screen of the previous one. The first phone of the row was aimed at the classical vanitas installation. It seems to us that the objects that make up the composition and their properties are reality (is it so?). The first smartphone makes an image (a photograph that did not take place) and thus creates a new plane between the world and us.

[8] Kant, 1890
[9] Karin de Boer, 2014

Cameras are designed in such a way that they show the world as we see it. Therefore, the image on the screen of the first smartphone is not a reflection of reality, but a reflection of our idea of it. Data from a photosensitive matrix is processed using algorithms created by developers. Does this mean that we see the reflection of their idea of reality?

The second smartphone was aimed at the screen of the first, which was aimed at the composition that we perceived through our senses, but we do not know what it is. The third smartphone was aimed at the screen of the second and so on. The image on the tenth screen is significantly different from the original. It resembles the original rather than depicts it. Between them are ten planes created by technology, which we can contemplate at the same time in real-time. A visitor to the exhibition stood between the installation and the first smartphone, waving a hand. Her friend was laughing at the distorted version of her on the screen plane of the tenth smartphone.

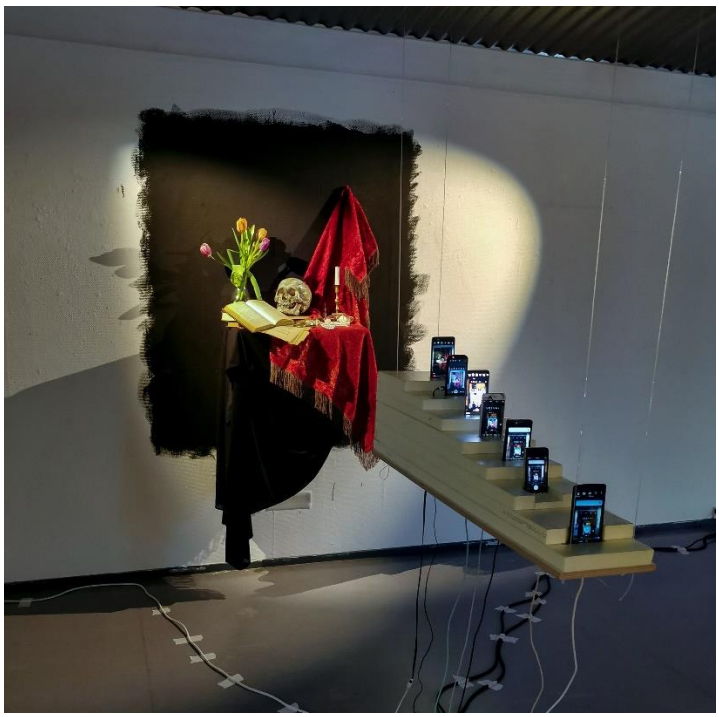

Figure 2. Taso v0,10121815, 2021

4 Digital Synesthesia

4.1 Definition

Now we come to the term digital synesthesia. The term itself is quite new and was introduced within a framework of the arts-based research project Digital Synesthesia, which states the theoretical background of the term, research questions, and assumptions. This research project was held at the Department of Digital Art at the University of Applied Arts Vienna from 2013 to 2016.[10]

When defining the complex phenomenon of digital synesthesia, it is important to highlight two aspects. Firstly, digital synesthesia is the unity of digital technologies based on a binary code and has nothing to do with psychological subjective experience. This is a mathematical and technical operation and objective phenomenon. It happens in the physical world according to the laws of nature.[11] Synesthesia in this case indicates that the same digital information (chain of code) can be read (decoded) in different ways, just as one sensory signal is processed in several parts of the brain at once.

Secondly, digital technologies process data so quickly that the call-response operation occurs almost simultaneously.[12] This makes it possible to simulate the synesthetic experience, including through interactivity. Of course, interactivity is also inherent in analog technologies, but digital synesthesia expands the concept of interactivity and its types through high-speed processing and transmission of large amounts of data. A simple example is video communication. Analog technologies made it possible to transfer information from a video camera to a TV screen located on the other side of the planet. However, wave signals take time to travel long distances. Having asked a question to the interlocutor, it was necessary to wait for an answer for up to several minutes. Such pauses break the experience of communication and

[10] Gsoellpointner, 2015, 2
[11] Weibel, 2016, 91-92
[12] Gsöllpointner, 2016, 12

make it unnatural. Skype and Zoom solve this problem: the speed of the digital signal is many times higher than the speed of the analog one. A delay of a fraction of a millisecond does not affect the pace of the conversation. So digital synesthesia mimics the experience of direct multisensory communication (we see and hear the interlocutor). Incoming visual and audio information is converted into binary code, sent over optical wires, and decoded at the other end back into audio and visual.

Binary code, a computer language, combines all kinds of digital files and programs. Photography, video, sound - for a machine there is no difference between them, these are just chains of code that can be processed using different algorithms and programs, depending on their format. Having received a set of code (digital image), the computer interprets it and displays this image on the screen. We see colored pixels in a certain way - a visual representation of the binary code. But this is, in fact, an intangible object: half impulse, half void, and visuality is just a consequence of the interpretation of the code. From this follows the fact, which strikes my imagination, that the same set of code can be interpreted in different ways, not only as an image but also as text, sound, video, etc.

So, each digital file has a format - this is information about the file, according to which the system understands what kind it is and in which program to open it. The file extension is used to designate it. These are several letters and numbers that are placed immediately after the name and separated by a dot. For example, the .jpg file extension indicates that it is an image, while .mp3 is an audio file. The program determines the binary code decoding algorithm.

Computers make it possible to control and synchronize various types of media through transcoding. Transcoding is the conversion of a file from one encoding method (i.e., file format) to another.[13] Due to digital synesthesia, it is possible to "order" a computer to decode a string of code using an algorithm not originally designed to decode this file format. So, a .jpg file can be decoded using the

[13] Reas, 2010, 79

algorithm for .mp3 audio files. Essentially any file can be decoded (opened) like any other. This is the essence of digital synesthesia.

The possibilities for transforming digital information are almost limitless. A musician and visual artist Ryoji Ikeda explores the relationship between sound and image in the context of digital technologies. He uses transformation algorithms to create audiovisual installations.[14] In a project “test pattern” (2008) Ikeda converts any information into barcode patterns and binary patterns of 0s and 1s using the digital system he created.

Peter Weibel is a post-conceptual artist and one of the central figures of European media art. His work has had a great influence on the development of digital and computer art. For example, in his interactive audio installation “Data Music” (2016), he explores the possibilities of transforming real-time video through participant-produced sounds.[15]

4.2 Artwork in Digital Age

The classical classification of the arts singles out spatial and temporal art, which draws a very clear dividing line between them. This differentiation can be called objective since it is based on the characteristics of the physical world. In this sense, the focus is on the work itself, and not on the viewer and their perception. A work of visual art usually occupies some physical space. It is a physical object that exists on its own. The thing is the same as a table, only having a different function. (Virtual reality breaks this picture). It is understood that the viewer perceives it at the same time, one might say as a stream of waves that determine the perception of texture and color, coupled with a three-dimensional perception. [16]

[14] Ikeda, 2008
[15] Weibel, 2016, 158-162
[16] Bloom, 2019

Temporal art is a complex phenomenon. For example, Levinson highlights fourteen conditions of temporal art.[17] However, temporality is not a subject of my research. Therefore, for this work the following definition is sufficient: temporal art involves or concerns time in some way. For example, the installation “Ice Watch” by Olafur Eliasson and Minik Rosing consists of big melting ice blocks. Thus, the installation exists until all the ice blocks are melted. After that, it is impossible to perceive the artwork with our senses (as it is supposed to be perceived). This work can be repeated, but it will be a different ice and a different period. The same can be said about a theatre play. If one misses the opening night, it is missed as the direct sensory experience of this opening night.

Digital technologies bring a new dimension to the field of temporary art. The play can be recorded on video and uploaded to YouTube, where it will be available to everyone at any time. Each video has its internet address, the path to the code chain stored on the server or computer. The code takes up some space on the hard drive. In this form, it is very similar to spatial art. Although in the digital world the term spatial art also loses its meaning as a physical object. A digital image (or digital photography of the physical work) is just an immaterial chain of code.

In my artwork “The Sound of Photograph” I transformed photograph to sound. So spatial art became temporal. As a result, the classical classification of the arts, in principle rigid in my opinion, in the digital age turns into a ghost. Everything is a code. Created by people and placed above people.

“Code is law.”[18]

[17] Levinson, 1991
[18] Lessig, 1999, 1

In the theory of art, there is also a classification according to the types of medium. In a simplified version, a medium is a material from which a work is created or its creation technique. So painting, photography, and music are different mediums. With the advent of digital technology, many have continued to adhere to this system. Music made with a computer remains music, and digital photography remains photography. There was a lot of discussion about the characteristics of digital and analog techniques and their differences but for the most part, these remained within the same medium.

For many ordinary users and recipients of art, the transition from analog to digital has remained almost imperceptible. It has more influence on practical and pragmatic levels. Digital technology has made it easier for ordinary users to use practical tools.

Digital photo and digital cameras, and, as the crown of all, a smartphone that combines multiple functions and tools. One device takes photos and videos, knows everything through Google, and can become a tool for many other operations by applications. They range from serious 3D scanners and photoshop to simple mirrors and rulers. For example, I have an app that measures light and exposure and an app to combat procrastination while writing this theses work.

I think digital is the new medium. Without division into types like photography, music, and drawing. What difference does it make if they are all just a chain of code interpreted by different programs and algorithms by the file type?

In the case of photography, I agree with Kullstrom's point that the search for common elements between digital and analog photography leads to a certain dead end or witches' circle, where the art of digital photography simply repeats the same patterns that existed in the analog world.[19] But the digital, like a new medium, needs to be separated from the old traditions for further development

[19] Kullström, 2017, 26

and find its means and tools of expression. Digital photography is a new medium, not a new form of an old medium.

4.3 Laboratory

Digital medium differs from traditional ones in that it is intangible and invisible to others. The main part of the work takes place inside the computer: the artist uses various ready-made algorithms and programs that require specialized knowledge. At the same time, such tools are understandable mainly for a limited circle of professionals. In addition, a viewer sees only the result. It is clear to the audience that the artist used a computer, but what exactly did he do on the computer? For most individuals, a computer code and its manipulation remain a mystery.[20] The digital medium is a fusion of art and science. Ann-Sophie Lehmann suggests using the term laboratory in this case instead of the traditional artist's studio or atelier.[21] It is impossible to touch digital tools like artists' brushes and paints. And the artist's studio itself fits on a hard drive and a computer screen.

Therefore, I invite you to my laboratory.

It is characteristic of my artistic process that my work begins with a concept that arises in my mind. It is a consequence of the combination of many elements, largely occurring subconsciously (intuitively?) as I see it. Ideas are collected from various sources: books, news, exhibitions, conversations, and, in principle, from any information I received from the outside world. Then the magic happens: the information is connected into one knot and in my mind, as they say, a light bulb lights up. And only after that I can unravel this knot and understand what it consists of.

[20] Hayles, 2010, 23-24
[21] Lehmann, 2009, 35-36

My work is based on digital synesthesia and digital immaterial medium. However, it was important for me to tie my work to the material world. This is an attempt to compare the physical world of analog and digital.

The idea that popped into my head was to take a photograph, turn it into sound, and record it on vinyl. I knew it was possible, but I had no idea how to do it. And I dived into the digital world to explore and learn new things.

Figure 3. The Sound of Photography, 2022.

The incarnation of “The Sound of Photograph” began with analog photographs from the 70s. These are family photos taken on a summer day while the children were playing, the nostalgic depiction of someone's family life. I scanned those pictures, i.e., digitized them.

I then used a special transcoding algorithm to transform the digital image file into a digital audio file. The meaning of the algorithm is that each pixel of the image is assigned a certain sound value. As a result, the algorithm sequentially scans the pixels and presents them in the form of the same sound sequence. This resulting digital audio file was recorded on a vinyl record, i.e., transcoded back to the analog form (LP record). This is how the conversion process is

closed: I go from the analog image to the analog sound through digital processes. Matter becomes immaterial, and then the material is born from the immaterial. It's fantastic!

My direct artistic work was that I found a photograph, scanned it, applied an algorithm to obtain an audio file, and ordered the production of vinyl records. The computer was my instrument and laboratory. It turns out that the final work – the vinyl record - is not made by my hands but is the embodiment of my idea.

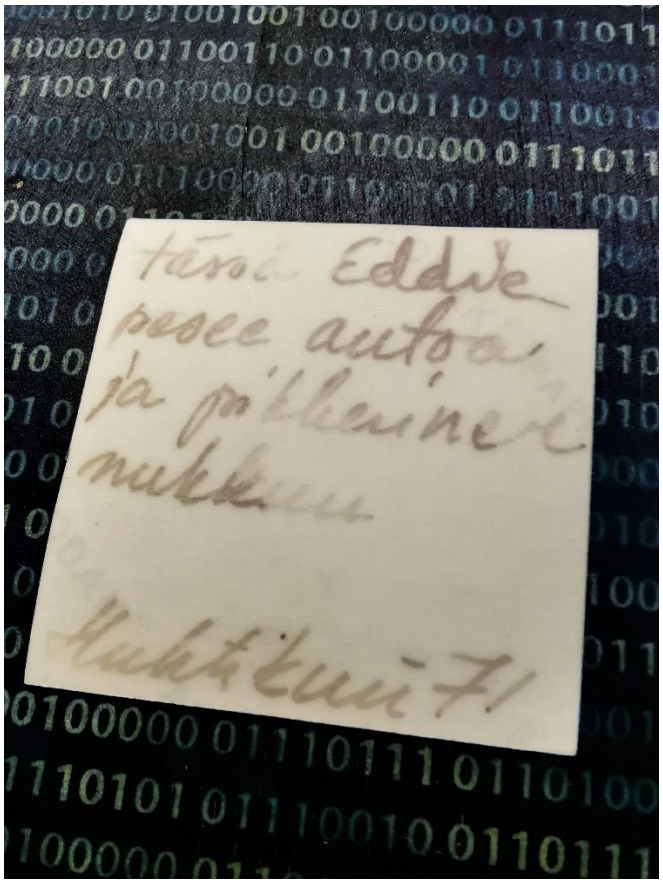

Figure 4. Inscription on found photograph.

In the work “tässä_eddie_pesee_autoa_ja_pikkuinen_nukkuu_huhtikuu71.jpg” I decided to use the traditional art process with the material as well. I took a small analog photograph I found. On the reverse side is the inscription: tässä Eddie pesee autoa ja pikkuinen nukkuu, Huhtikuu 71 (Here is Eddie washing the car

and the little one is sleeping, April 71). I scanned it and transcoded the jpg file into a text file. This file contains the complete binary code of a digital image displayed as a set of zeros and ones. It turned out 570,880 characters. Then I printed all this text on oak boards using cyanotype. Cyanotype is an analogous alternative process to photo printing. It uses iron salts as a light-sensitive material, which is harmless to the environment. For proofing, digital negatives are prepared and printed on transparent film. Sunlight is used as a light source and ordinary water is used for development. It turned out nine boards approximately 50x170 cm printed on both sides. The boards were hung in a circle on a specially-made metal frame.

The work required a lot of time and a lot of physical labor. The computer was used only to obtain the text of the binary code. I used untreated woodcut boards with bark remnants to emphasize their materiality and enhance the contrast between digital and analog.

Figure 5. Installation
“tässä_eddie_pesee_autoa_ja_pikkuinen_nukkuu_huhtikuu71.jpg”, 2022.

Figure 6. Detail of
“tässä_eddie_pesee_autoa_ja_pikkuinen_nukkuu_huhtikuu71.jpg”, 2022.

5 The Future is Now

Artist Neil Harbisson has been called the world's first cyborg: for more than a decade, he has been living with an antenna implanted in his head that converts light waves into sound. He was born with complete achromatopsia, that is, he does not distinguish any colors. Based on an algorithm created by Adam Montandon, a receptor device “Eyeborg” was created and implanted into Harbisson's skull. Thanks to this, the artist can distinguish 360 hues of color by their musical tones. Digital synesthesia turned him into a synesthete. This technology can be used to help blind people "see" through sound.[22]

Cyborgs, virtual reality, artificial intelligence - digital synesthesia is at the heart of it all. It seems that technology distances us from the real world. But what is the world, and what is reality, if not the totality of our perceptions of it? It seems to me that the convergence of the digital and the material enriches our experience of perceiving reality.

My exploration of data transformation will continue not only as an artistic process but as an experience of living directly in the wonderful world of the future.

[22] Yasenchak, 2013, 1-10

Sources

Bloom, J. 2019: The Spectrum of the Arts: Time and Space in the Human Experience of Art. http://ajourneythroughthearts.com/chapter_9.htm. Referred to 20.11.2022

Campen, V.N., Malina, R.F., Cubitt, S. 2007: The Hidden Sense: Synesthesia in Art and Science. Cambridge: MIT Press

Gsoellpointner, K. 2015: Digital Synesthesia. The Merge of Perceiving and Conceiving. https://www.researchgate.net/publication/272786108_DIGITAL_SYNESTHESIA_The_Merge_of_Perceiving_and_Conceiving. Referred to 13.10.2022

Gsoellpointner, K. 2016: Syn-Aesthetics of Digital Art. In book: Gsöllpointner, K., Schnell, R., Schuler, R. K. (eds.), Digital Synesthesia: A Model for the Aesthetics of Digital Art. De Gruyter, pp. 11-18

Hayles, N. K. 2010: Traumas of Code. In book: Bryant, A., Pollock, G. (eds), Digital and Other Virtualities: Renegotiating the Image. London: Bloomsbury Academic, pp. 23-41

Ikeda, Ryoji 2008: test pattern. https://www.ryojiikeda.com/project/testpattern/. Referred to 25.11.2022

Kant, Immanuel 1890: Critique of Pure Reason. London: George Bell and Sons

Karin de Boer 2014: Kant's Multi-Layered Conception of Things in Themselves, Transcendental Objects, and Monads. In book: Kant-Studien, 105(2). De Gruyter, pp. 221-260

Kullström, Niklas 2017: Digitalization of the Image – A Pixelated Future. Master's Thesis. Aalto University. Department of Media

Lehmann, A. 2009: Invisible Work: The Representation of Artistic Practice in Digital Visual Culture. In book: Bentkowska-Kafel, A., Cashen, T. & Gardiner, H., Digital visual culture: Theory and practice. Bristol, U.K: Intellect, pp. 33-45

Lessig, L. 1999: Code and Other Laws of Cyberspace. New York: Basic Books

Levinson, J. 199: What Is a Temporal Art? In: Midwest Studies in Philosophy, pp. 439-450

Reas, C., McWilliams, C., & Barendse, J. 2010: Form+code in design, art, and architecture. New York: Princeton Architectural Press

The American Heritage® Medical Dictionary, 2007. Referred to 16.08.2022 https://medical-dictionary.thefreedictionary.com/synesthesia

Weibel, P. 2016: Data Music.In book: Gsöllpointner, K., Schnell, R., Schuler, R. K. (eds.), Digital Synesthesia: A Model for the Aesthetics of Digital Art. De Gruyter, pp. 158-162

Weibel, P. 2016: Digital Synesthesia. In book: Gsöllpointner, K., Schnell, R., Schuler, R. K. (eds.), Digital Synesthesia: A Model for the Aesthetics of Digital Art. De Gruyter, pp. 91-98

Yasenchak, D. 2013: Filling the Colorless Void: The Cybernetic Synaesthesia of Neil Harbisson. Referred to 6.6.2022 http://portal.lvc.edu/vhr/2013/articles/yasenchak