METAGARDEN SPHERE2
Tanja Vujinovic

A garden “is never a garden of merely private concerns into which one escapes from the real; it is that plot of soil on the earth, within the self, or amid the social collective, where the cultural, ethical, and civic virtues that save reality from its own worst impulses are cultivated. Those virtues are always ours.”

Robert Pogue Harrison

What will our future gardens, the gardens of the third millennium, look like? Will they be made of objects, machines, and living beings that synergistically maintain their flexible systems and communicate with their surroundings?

MetaGarden is an ongoing project that reflects upon a complex relationship of humanity and its technologically fortified environment of nature-culture, and focuses on a particular issue within each installation.

Through MetaGarden Sphere2, I attempt to examine not only what exists within our lives, but also what multiple possibilities and changes might emerge in biopolitical, social, and environmental domains.

Throughout history, the garden as a sheltered environment has been re-emerging as a special location for human contact with nature, recreation, and rethinking of mythologies, social relations, and allegories.

Gardens have never held unitary functions or forms. Filled with idealised flora and fauna or devised as minimalistic environments, gardens would sometimes induce ecstatic feelings or provoke meditative immersions and reflections. The classical Greek Epicurean school promoted understanding of the world through the tending of gardens and, instead of overcoming, it was all about transfiguring nature and self-cultivation. Epicurus viewed gardens as places in which reality could be reconceived and reimagined.

Michel Foucault thought of gardens as the perfect heterotopias – the other places, detached from ordinary life. Within gardens, we immerse ourselves in relationships with living and non-living objects or non-human agents, and seek in them the forms of transitional, comfort objects. Gardens infuse us with molecules and affect our senses, but we also infuse gardens with our states of mind and impose forms onto nature. Gardens echo our lost contact with nature brought forth by the rapid development of industry and technology. They are associated with regeneration of human beings, our reconnection with nature, and the notion of care and cultivation of both ourselves and our nature-culture environments.

Since the very beginnings of civilisation on Earth, humans have turned to plants for food, shelter, and medication. Recreation in nature has always been advised in the
form of walks\(^1\), meditation, observation of plants, breathing of the healing air in the woods, and tuning in to the countless signals and chemical communication channels of the surroundings. Gardens might be seen as networks of engineered man-made and natural elements that promote the flow among non-human and human agents.

Jean Luc Nancy’s concept of synaestetic touch that underlines the necessity to pay special attention to senses other than vision, like touching and smelling, might pave the way for cultivating a novel attitude towards nature in the post-digital world.

Gardens might also be microcosms that temporarily separate a person from the rest of the anthropocentric world and enfold one into their special texture. As Michel Foucault would say, “the garden is the smallest parcel of the world and then it is the totality of the world.”\(^2\)

What might our future habitats look like? Are we going to seal ourselves off from the atmosphere due to pollution and live in chambers that look like an Apple parking building or Amazon Spheres? If so, who will be able to afford the type of hi-tech water, air purification, and maintenance of plant growth inside the future farming facilities? Such future chambers may enable us to experience the world of “wilderness” to its fullest in a tamed form, devoid of any danger, disorientation, darkness, and of anything uncontrolled. Aquaponic gardens for industrial production of plants operated entirely by robotic agents offer a glimpse into a potential future scenario.

Utopian ideas have occasionally sprung up of an idyllic garden spreading around the whole Earth, like the one envisioned by futurist Jacques Fresco with his Venus project. We might be very far from such a scenario, but we could at least work towards curbing environmental pollution and providing everybody with access to clean natural environments. A potential way towards the MetaGardens of the future is co-creation with nature and the engineering of upcoming civilisation informed by bionics and biomimicry. Biomimicry, the term coined by Janine Benyus in the 1990s, is the outlook that strives not to extract from nature and domesticate it, but to create solutions learned from the ideas that appear everywhere in the natural world. As Benyus writes, some of the core principles of nature are that it runs on sunlight, uses only the energy it needs, fits form to function, recycles everything, and rewards cooperation. These principles, i.e. functions of nature, should be embedded in the materials of future design – from apparatuses to buildings and infrastructure.

\(^1\) “We should take wandering outdoor walks, so that the mind might be nourished and refreshed by the open air and deep breathing.” Seneca, XVII.

MetaGarden Sphere2 is an ecosystem made of futuristic machines as ur-forms. These objects, synthetic being-devices, are inspired by paleobotany, and technologies of artificial intelligence, plasma physics, and nanostructured materials. Through the virtual world and physical installations, I explore the twists between synthetic and natural. Works connect the past with the future and merge facts and elements from science and history with mythology. As the title suggests, I also draw inspiration from numerous metaphors related to gardens and their elements. Works that make the Sphere2 are Carboflora, Fontana, Arbora, and Genera. Carboflora is an endless virtual simulation, within which virtual flora grows according to measurements of air pollutants. Fontana cleans water with the help of plasma, while little fountain disperses plasma-treated water into the air. Genera cleans the air with the help of nanotubes. Arbora analyses emotional states through voice and generates binaural sound.

References


ARBORA

Objects (3D printing, custom-made electronics, custom-made software, sound)

Installation by Tanja Vujinovic
Programming and custom-made electronics for Arbora object: Dr. Vid Podpečan, Department of Knowledge Technologies, Institute Jozef Stefan
Custom-made electronics for Arbora Protectors objects: Gregor Krpič
3D printing: RogLab
Consulting: Jan Kušej, Tomo Per
English language editing: Derek Snyder
Production: Ultramono and SciArtLab, Department of Knowledge Technologies, Institute Jozef Stefan, 2019

Placed within the MetaGarden Sphere2, Arbora is one of the objects that takes care of our health and the health of our environments.
As a wise, old tree rising from the MetaGarden, Arbora is infused with a neural network that understands and responds to human emotions.
Three protector objects that accompany Arbora and Carboflora’s virtual environment are all inspired by the plants of the Carboniferous era. Outer surfaces of some objects are covered with bark that resembles scales, much like the Lepidodendron tree that existed approximately 300 million years ago. Fossils of this plant sparked the imagination of our ancestors and might even be responsible for the imaginary conception of dragons.

Emerging from the cloud of mythology, three protector objects are synthetic young trees grown in software. They resemble sprouts and like three ancient Greek gods of medicine, Telosphoros, Hygieia and Asclepius, monitor and reflect the overall environment of MetaGarden.

Arbora senses the emotions expressed in the voice. Our voices can give clues about both the physiological and emotional state we are in. A specially developed and trained deep neural network deciphers the emotional components encoded in the captured voice in order to model a soothing binaural sound. By doing so in synergy with its environment, Arbora, together with its helpers, works towards improving our well-being.

Technical description

Arbora is constructed as a three-dimensional object and printed using 3D printing technology, with the addition of a hardware metal stand. Custom-made electronics placed inside the object are Raspberry-Pi, a module with four microphones, and with headphones placed on the stand and connected to the Raspberry-Pi.

Arbora is devised as a sentient device, with all of the references already mentioned in their general description: human interacting with the tree, the ancient Greek gods of medicine, biomimetic forms of plants and futuristic medical devices. Arbora should react to the voices of people in their vicinity who wish to interact with them.

For this purpose, we developed a deep neural network model that analyses sound captured from space. Software is written in Python programming language using several libraries like num.py and others. A neural network is constructed based on the Tensor Flow open code library that enables the development of models for machine learning. Tensor Flow previously trained on the Ravdess database was implemented for this purpose. This database is made of voices of actors pronouncing the same sentences with different emotional input.

The mechanism of this action is that the sound is captured and stored temporarily in the sound buffer. Another part of this custom-made software filters the sound and eliminates everything that it does not detect as human speech. One-second-long pieces of sound are analysed, and the average value of determined emotion is extracted. After this, the sound properties pre-assigned to each detected emotion are generated and played through the headphones. Since we wanted to create the situation within which the object would subtly react to a human voice, binaural beats were chosen as one possible type of sound interaction.
The brain is a central powerhouse of the human body, and it is no wonder that the studying of it is of pivotal importance. Brain waves are studied in a variety of academic disciplines, like neurology and its subfield epileptology, within psychology, psychoacoustics, and cognitive neuroscience, among many other fields. While we know that different brain waves are associated with diverse states of mind, for example, delta waves are associated with deep sleep, beta with an alert mind, and alpha waves with a mind that is relaxed, there are numerous research attempts that tend to dive deeper into the fine differences among such waves and associated stimulations that might impact brain functions. Such studies are conducted on both humans and animals. One such potential technique is the implementation of binaural beat (BB) stimulation.

Binaural beats (defined as dual broadcasting of two sinusoids with a small difference in frequency) were implemented for the development of the second part of the software for the Arbora object. Since it is necessary for this particular type of binaural sound to be experienced as two sound streams simultaneously played into both ears, we needed to employ headphones.

Sound is continuously captured by the device. When the visitor speaks near the object, the voice is processed. If there is no new speech detected within the captured sound, the software emits the average pre-determined frequency. Binaural beat, usually consisting of two sinusoidal sounds that differ in frequency might, for example, emit 95 HZ to one ear and 105 Hz to another, and the final setup would provide the following constants: carrier 50, difference 2, and duration 30. Each predefined emotion (neutral, calm, happy, sad, angry, fearful, disgust, surprise) is coupled with the beat that could restore the emotional state back to calm.

The Arbora software is based on state-of-the-art deep neural networks. It is implemented as a real time audio capture, analysis and synthesis loop which continuously records and analyzes live audio data, classifies the extracted speech using a deep convolutional neural network and generates high quality binaural sound waves designed to stimulate electrical brain activity to thus amplify, soften or transform the detected prevailing emotion. This is possible because of the brain phenomenon known as the frequency following response, which reflects the activity of brainstem neurons and is characterized by a waveform that follows the auditory stimulus wave, which is in our case generated by the Arbora software as a precisely designed binaural beat. The parameters used for generating the binaural beat are chosen according to the currently available knowledge about brain waves and their relation to mood and emotions. In addition, a small amount of randomness employed during the selection of the carrier and beat frequency of binaural sounds from the allowed ranges ensures both non-repeatability and continuity.

Arbora protectors are devised as objects that subtly monitor the environment and echo the changes within it through the sound they generate. The custom-made device where all processing happens consists of several connected modules with
analog circuits. Input signals come from three sensors that monitor light and temperature within the space. These signals are being routed into a voltage controlled oscillator (VCO), followed by the voltage controlled filter (VCF). One part of the signal travels directly into the mixer, and one pipeline goes into a delay/echo module. There is also a low frequency oscillator (LFO) that joins the others within the sound composition. Signals can be changed from sinusoidal, triangular or square within the VCO and LFO modules. Output sound is subtle, presenting an organic texture that occasionally changes, and, although minimal, it never feels repetitive.

References

CARBOFLORA
Installation (generative digital environment)

Installation by Tanja Vujinovic
3D objects, generative modelling: Tanja Vujinović
Unity3D programming: Tanja Vujinovic, Gaja Boc, Sara Bertoncelj Čadež
3D objects of carboniferous plants: Dariusz Andrulonis for edukator.pl
Consulting: Dr. Vid Podpečan, Department of Knowledge Technologies, Institute Jozef Stefan; Jan Kuše
English language editing: Derek Snyder
Production: Ultramono and SciArtLab, Department of Knowledge Technologies, Institute Jozef Stefan, 2019

This virtual environment is populated by plants that echo the Earth’s flora from hundreds of millions of years ago, specifically, the plants of the Carboniferous period that now constitute coal fields.
As is widely recognised, our age, aptly named “capitaloscene” by Donna Haraway, is detrimental to the environment and health of all living organisms.
Use of fossil fuels has been repeatedly proven detrimental to the Earth as a whole, yet hope persists that if we completely end our use of fossil fuels, we might reverse some of the effects of global warming and try to restore some of the damage we created over the last two centuries of industrial progress.
Forests of the Carboniferous age consisted of many relatives of contemporary plants – conifers, horsetail, and ferns. Some of the plants, like the early relatives of ferns, could grow to forty meters high. Lepidodendron trees had bark that
resembles scales. Fossils of this plant sparked the imagination of our ancestors and might even be responsible for the imaginary construction of dragons. Although declining, coal is still widely used in industry, not only for direct energy production but also for numerous industrial applications and derivatives; it remains a significant source of carbon dioxide emissions in the atmosphere.

Carboflora environment is connected to tracking the quantities of harmful particles in the atmosphere. Its levels are reflected in the way plants inhabit the virtual system. Properties of virtual plants are connected to a database that tracks air quality in almost real time. More than 10,000 stations throughout the world constantly send data about various pollutants like PM2.5, PM10 (small and big particulate matter), O₃ (Ozone), NO₂ (Nitrogen dioxide), SO₂ (Sulphur dioxide) and CO (Carbon monoxide), as well as the AQI (air quality index). Upon opening, the application chooses the closest physical location and maintains the various properties of plants according to the numbers being sent from the database. Plants as a sort of timeless ur-forms echo the past and possible future within which we might curb our polluting emissions.

Technical description

Carboflora was developed in the Unity 3D game engine using the free version of the software over a period of five months. Research was followed by modifications of digital objects, construction of the virtual space, programming, testing, and debugging. Some of the objects being used in the virtual world were developed using a variety of other commercial and open source software applications dedicated to modelling, generation, and manipulation of 3D computer graphics. A few of these also included the possibility of developing custom patches for generative development of particular forms, of which some became physical objects through the technique of 3D printing. One class of virtual plants consists of the reconstruction of Carboniferous plants made by scientific illustrator Dariusz Andrulonis which he generously donated to the Carboflora project. Dariusz's plants are used in Carboflora without the complex original materials he made: because of the high polygon count, they had to be optimised and simplified in order to be placed in the game engine. All objects within Carboflora were homogenised through using the same uniform white material, just as are the physical objects within other installations of Sphere2, in order to bring forth several conceptual elements that constitute the platform “past-future tense of futurism” and “technological optimism” with references to ancient Greek gods of medicine, medical equipment, and biomimetic patterns of natural plants.

There are five scripts for five separate categories of air pollutants. These scripts were assigned to separate three-dimensional objects. At the initial testing phase, five objects were set to react to incoming data, with the possibility of expanding the number of objects that react to data for larger sets of virtual plants.

In addition to the main script that connects to the World Air Quality Index database and separate scripts for each pollutant, a system of tagging is also used. Tagging of
particular objects enabled the general script to find and control the properties of trees-objects that should reflect the air quality.

Five virtual trees are growing, depending on the values within each category of particles measured at a particular physical location. When the application is opened, the IP address should choose the nearest physical location provided by the World Air Quality Index database.

Each object-tree has an attached script that controls the size of the tree as well as a tag that enables the main script to find it.

Trees assigned to track data are programmed to change their size every 0.5 seconds. Their size is also recalculated in relation to the average daily amount of particular pollutant. This script is invoked every hour. If there are more particles than average, the trees remain lower, and if there are fewer particles than average, the trees grow larger.

The terrain of Carboflora containing all objects is covered with the Navigation Mesh. A first person controller (FPC) with attached camera is devised as an instance of a simple artificial intelligence agent, so it can move through the terrain, avoid particular objects, and enable the generation of sound textures in real time. The script attached to this navigation agent is optimised, so it can find the best appropriate path for moving among the objects and reaching a particular target.

These targets are pre-assigned, so the agent needs approximately one hour to move through all currently assigned spots while creating the sound composition in real time. The radius of sounds spreading from objects is predefined and differs in each case. The movement around Carboflora’s terrain is also limited with implementation of contact colliders.

References:
Website World Air Quality Index, https://waqi.info/bs/
Inside gardens and parks, fountains are usually placed as central features due to their symbolism, echoing the historical and cosmological role of water as a substance crucial to life on Earth.

How will we overcome the far-reaching consequences of growing environmental pollution? What novel ways can we invent to clean or recycle water already used in the industrial production of goods?

Sometimes referred to as the fourth state of matter, plasma is an ionized gas almost acting as a tiny lightning bolt. In scientific research, plasma is used for various purposes. Among promising features is its ability to destroy harmful microbes in different environments including water. UV radiation, charged particles, and reactive oxygen and/or nitrogen species are plasma’s constituents that have great antimicrobial properties – these reactive species are believed to be the most important in terms of microbe destruction. Plasma might also be the future technology for cleansing the leftover traces of manmade chemical contaminants in water, from toxic dyes to drugs. Research has also indicated that crops or seeds treated with plasma-treated water are more resistant to diseases and can germinate faster, thus producing a higher yield crop. This type of water management might be a potential future technology that will reduce the use of unnecessary chemicals in water cleansing, not only for industrial and agricultural use but also for safe human consumption.

As a potential technology that might be widely used, the treatment of water with plasma is implemented in the installation – plasma-treated water is both the actual agent of change and the symbol of growth and purity.

The Little Fountain (Fontana) is a custom made device that uses ultrasonic piezo technology. The ceramic disk transforms electric energy into vibration. The sound produced by this transducer is beyond the hearing range of humans. Submerged in water, it vibrates, and by doing so it deforms the structure of the water and
disperses it into the air as approximately one-micron-sized droplets. These droplets form the fog which hangs throughout the space.

References:

**Genera**

Installation (3D printing, custom-made electronics, hardware)

Installation by Tanja Vujinovic
Hardware device development: Dr. Luka Suhadolnik, Department for Nanostructured Materials, Jožef Stefan Institute
Additional hardware: Roman Bevc
3D printing: Stephan Doepner, C2

Advisors:
Prof. Dr. Saša Novak, Department for Nanostructured Materials, Jožef Stefan Institute
Electron Microscopy analysis: Maja Koblar, Center for Electron Microscopy and Microanalysis (CEMM), Jožef Stefan Institute
Additional consulting: Jan Kušej, Lenart Krajnc
English language editing: Derek Snyder
Production: Ultramono, 2019

Placed within the MetaGarden Sphere2, Genera is one of the objects that takes care of our health and the health of our environments. Genera is a model futuristic device for the purification of indoor air. Its shape comprises generic branches converging into a trunk-base, and the air passing through them is drawn through an air purification device located at the base of the object. The air purification device uses photocatalytic technology, which represents a potential system for removal of pollutants from indoor air. Improved air quality would improve quality of life, as the average individual spends most of her life in
confined spaces. The photocatalytic air purification device uses the principles of photocatalytic degradation of organic compounds, bacteria, and other potentially harmful substances. Contaminants are decomposed on the surface of titania nanotubes (the active photocatalyst is activated by UVA light illumination), which are grown directly on titanium substrate using an electrochemical method. Photocatalytic oxidation can play a crucial role in indoor air treatment, as it represents an efficient and cost-effective green technology. In future MetaGardens we could have such branch-shaped devices that maintain safe levels of pathogens in the air.

References
Pichat, P. A brief survey of the practicality of using photocatalysis to purify the ambient air (indoors or outdoors) or air effluents. Applied Catalysis B: Environmental 2019, 245, 770-776.