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LIVE WIRE
Do-it-yourself – Bioelectronics – Art

Victor Frankenstein is electrified. Just a few moments ago he was barely able to follow the lesson, he was so devastated by the loss of his dog Sparky who had been run over by a car the day before. But now his physics professor demonstrated how you can use electricity to revive a dead frog: the legs of the animal were twitching forcefully, just as if it was about to jump.
Filled with anticipation, Victor hurries home after school. Using an umbrella as a lightning rod, a toaster and all kinds of household appliances, the boy constructs a complex device in the attic. He wants to use it to achieve what his namesake sought in Mary Shelley's novel "Frankenstein," first published in 1818. Following the example of the scientist in the novel, he now digs up his dead dog and patches him up in a makeshift manner before attaching him to the device. And then he anxiously waits for the next thunderstorm. Sure enough his experiment is a success: Lightning strikes, a spark leaps over – and Sparky lives!
Is it simply by coincidence that Tim Burton adapted his charming short film "Frankenweenie" (1984) in 2012 into a full-length 3D-animated movie? Hardly. As is generally known Hollywood's enthusiasm for experiments is limited – especially in the case of complex and therefore expensive productions.[1] The film captures the spirit of the times in several ways. This is probably not only due to its reference to the horror story and its various film adaptations, but also to its motive: Even in the 21st century we are still preoccupied by the question of what holds the world together at its core, what "life" means and how it is created. And whether human beings should use science and technology to venture into this innermost being and intervene with life.

Genetically modified plants and glowing rabbits

Today genetics has moved to the centre of biotechnological developments and with it the ethical debates that accompany this process. Just a few years ago only very few people could imagine becoming personally involved in a specific aspect of this field. For a long time this was due to a lack of the necessary knowledge of the details of the genetic code. This changed not least due to the enhanced performance of our computers: in 1990 the HUMAN GENOME PROJECT was started with the objective of completely sequencing the genome of the human being. In 2000 Craig Venter achieved this with his private company.
From the beginning artists reflected these developments in relevant projects.
In 1993 artist Alexander Popper and biologist Katrin Stockhammer invited visitors of the Ars Electronica Festival for technology, art, and society[2] to a laboratory demonstration, where they offered to manipulate the genetic material of plants brought along by the visitors – and were surprised to see how many people accepted their invitation and were willing to let them perform the experiments.

In 2000 Brazilian artist Eduardo Kac caused a great stir with his GFP-BUNNY ALBA.[3] His idea to introduce into a white rabbit the gene responsible for bioluminescence in certain algae – GFP stands for "green fluorescent protein" – was not realized at the time. As with Popper and Stockhammer, Kac's intention first of all was to motivate people to start thinking about the possibilities of biotechnology.
Today, however, anyone can not only commission a DNA analysis for comparatively little money, but a PCR machine – a device that serves the same purpose – can even be purchased as a DIY kit. PCR stands for "polymerase chain reaction." Through polymerase chain reaction DNA can be multiplied in vitro – an important basis for various microbiological and biotechnological applications, including DNA sequence analysis. In DIY BIO communities this procedure is meanwhile just as commonly practiced as the in vitro isolation of DNA of plants and microbes.

Wired frogs and mimosas

Meanwhile we are still living in the "electrical age" whose beginning Mary Shelley describes in her novel – and neither the relevance nor attraction of electricity and electronics have diminished, even in view of new biotechnologies. Though at best they are based indirectly on the findings of Luigi Galvani and Alessandro Volta, whose experiments at the time of course not only inspired literary phantasies like Shelley's "Frankenstein" but also encouraged scientists to continue research in these fields. For example the German physicist Johann Wilhelm Ritter: In order to prove the existence of certain galvanic phenomena, Ritter not only attached frog legs to live wires. He was convinced that the nervous system could also be electrically stimulated and the impulses communicated. In his laboratory he conducted experiments on his own body and also on living animals and even plants. He chose the mimosa, because at the time – due to its reactivity – it was believed that this plant had muscles and nerves.[4]
Today we would use the term "biofeedback" to describe what Ritter was really looking for – but he never achieved real breakthroughs in this field. His main contribution was rather in fundamentals of electrochemistry, where in the course of developing his own variations of the voltaic pile he discovered the principle of the accumulator.

Electricity generated from fruits and vegetables

While Volta and Ritter built their batteries themselves, we are used to simply buy them in a store. Yet a do-it-yourself construction is ideal to familiarize yourself with the basics of their functioning. And here the use of biological material as well as taking recourse to the bioelectrochemistry of Galvani, Volta, and Ritter may perfectly serve the purpose.
Many of us have learned to build a lemon or potato battery in physics class. You stick a copper and a zinc nail or corresponding metal plates into the fruit or tuber; and for example a small lamp can then be attached with wires.
The fruit acid causes the base metal to emit electrons, which are then bound by the noble metal, thus creating electrical voltage – and currents passing through the electrolyte. This is an extremely simple experimental setting, but art shows that it can be expanded upon: Danish artist Mogens Jacobsen uses a battery of potatoes connected in series to operate entire installations such as POWER OF MEMORY/

POWER OF MIND (2004), which projects into a room an interview with a politician that was downloaded from the Internet and transformed into an audio file.[5] When the potato battery begins to dry up, there are outages in the flow of speech – until this flow eventually runs dry completely together with the battery. Karl Heinz Jeron's project FRESH MUSIC FOR ROTTEN VEGETABLES, which is presented in this book, works in a similar way – only here the electrical currents are directly converted into sound.

Biofeedback maps and flower pictures

Of course the vegetables are not generating these sounds as biofeedback. The sounds are not coming from the plants but rather from an electric circuit that is installed from the outside and is modulated by changes in the biomass, in other words by the degree to which the plant is drying out or decomposing. In the case of biofeedback, however, it is crucial to observe the changes of state variables of biological processes in a living organism. In order to detect these changes, a much finer set of instruments is needed.[6]

Although the idea of a body communicating by means of electricity that fascinated Ritter was taken up time and again, it was not until the 20th century that instruments were developed to measure such impulses. One of the most important milestones was certainly an instrument to measure and record summarized electrical activity of the brain (electroencephalography), presented by Hans Berger in 1924.[7]

Meanwhile, it is much easier to measure the resistance of the skin than the electrical activity of the brain. Based on this principle, the polygraph or lie detector was also developed in the 1920s. It builds upon the assumption that people perspire when they are fibbing and this in turn increases the conductivity of their skin. Depending on the model, the polygraph can be used to measure various different biofeedback data: usually skin conductivity as well as blood pressure and pulse. But using such data to determine whether or not someone is telling the truth remains controversial. Nevertheless, in the United States, the polygraph's country of origin, this instrument is still being used today for crime detection.

It is very easy to build a simple model of such a skin resistance measuring device yourself; every electronics shop offers cheap basic construction kits. And of course this idea can be creatively expanded upon. With his BIO MAPPING TOOL developed in 2004, which combines the data obtained by measuring the skin resistance of somebody's fingers with GPS data, Christian Nold created entire maps he calls EMOTION MAPS.[8] Nora Dibowski's TOUCH PAINTINGS presented in this book do not require an interface. She paints with conductive lacquer and therefore simply by touching the wired painting the electrical circuit is closed and the attached lamps light up.

Smart breeding of plants and fungi

Living organisms can conduct electricity, this means they possess their own electrical resistance and can emit electrical impulses. These characteristics can be used to serve many purposes, especially if data are collected and their changes are included in further experiments. Whereas biofeedback in science and also art is primarily measured in vertebrates and humans, other species like plants could also play a role.

The daily care of useful and ornamental plants offers ample room for experimentation. Light and soil provide the basics for their nourishment and growth – a human being must find a suitable location and ensure a regular water supply. It is easy to collect and record the corresponding data.

Data for location factors such as humidity and temperature are not collected directly from the organisms themselves, but rather the sensors are placed in the ground and in the air. Additional know-how is required for more sophisticated uses of the data. A prominent example is Luke Iseman's project GARDUINO GEEK GARDENING, developed in 2009 for "Make:" magazine, that can be used to control and regulate the water and light supply of plants.[9] Laura Popplow's project MUSHROOM GROW KIT presented in this book works in a similar way – and her construction manual also contains an original design for a fungi greenhouse. Her project FUNGUTOPIA is not only about breeding fungi, but also explores the relationship of humans and fungi from an interdisciplinary perspective and with creative means.

Music with philodendrons and moss

But what if technology actually enabled us to communicate directly with plants and other organisms? Projects like BOTANICALLS or its German variation BOTANIFON – potted plants that send us SMS or Twitter messages when they want to be watered – play with this idea. But here too, the signals are sent by sensors that merely measure the humidity of the soil in the flowerpot.[10]

Stefanie Wuschitz' project MOSSCILLATOR presented in this book seems to come a little closer, because the conductors are attached directly to the moss or the moss cushions. Nonetheless, it would be saying too much that here the moss itself is making music. Moss has a very limited capability to regulate its water needs – the entire surface absorbs water; moss grows irregularly and this helps to store water. That is why moss is well suited as variable resistor. However, only one factor can be measured: the degree of humidity of a specific point in the moss cushion.

It's a different story when Miya Masaoka plays music on stage with a philodendron and synthesizer in her project PIECES FOR PLANTS (2002). Masaoka attaches electrodes directly to the leaves of the plant to obtain feedback on her music performance and to include it in the performance.[11]

Attempts to communicate with other species

You could say that Miya Masaoka also explores the relationship between humans and plants – but she only uses the plants' signals as part of her live composition. Cleve Backster, on the other hand, was convinced that his plants wanted to communicate with him when, in the late 1960s, he connected the dragon trees in his office to a polygraph and registered signals generated by them.[12] Probably his contemporaries were justified in doubting his interpretation of the data. Nevertheless, his experiments inspired countless numbers of electronics hobbyists as well as artists to begin experimenting themselves.[13]

Martin Howse builds on these historic experiments with his INTER-SPECIES COMMUNICATION PLATFORM, a comparatively simple construction described in detail in this book. It inspires further exploration of electric currents that can be measured in fungi and in plants – as already observed by Johann Wilhelm Ritter at the time. Yet the question whether or not these are impulses even though these species do not have a nervous system, must remain open here.

DIY MICROSCOPE and PCR machine

In fact plants and fungi prefer other processes to transport signals and to communicate. Therefore chances are slim that true communication can be established on the basis of the analysis of electrical signals. In order to develop an interface that could be connected to electronic information and communication technologies, we would need to know a great deal more about the respective species. And we would also require a much more complex set of instruments.

American artist Joe Davis takes a step in this direction with his BACTERIAL RADIO (2011). He employs advanced techniques of molecular biology and genetic engineering: only through genetic manipulation and the use of a modified culture medium the E. coli bacteria in his project obtain the ability to function as organic conductors.[14] Yet also with the BACTERIAL RADIO it is not possible to communicate with the bacteria themselves. But it leads directly to the field where relevant research is presently being carried out: bioelectronics. Scientists in this field attempt to directly combine biological and electronic components to create a useful technical application – whereby they work in a micro or nano range. The starting point for this research is the observation that electrical currents generated by electrical impulses or voltages play a role in biological systems as well as in computer technology.

These worlds are open to interested amateurs and committed hobbyists as well, as the growing do-it-yourself community involved in bioscience initiatives shows. It is to the benefit of all involved that here – unlike institutions working in close collaboration with industry – it is not a matter of marketable patents, but rather of knowledge sharing. In this community people work with open source software and hardware; curiosity, creativity, and the desire to experiment are highly valued. A good example of how important these characteristics can be for successful research and development is a prominent project of BIOCURIOUS,[15] a DIY BIO initiative in San Francisco: Anybody can use the OPEN-PCR-KIT[16] of Tito Jankowski and Josh Perfetto to perform a DNA sequence analysis – a process that until recently could only be carried out in high-end laboratories.

These projects also provided a breeding ground for the DIY MICROSCOPE by Marc Dusseiller and his team at HACKTERIA which is also presented in this book. It enables an ideal access to the "world in miniature" – the world you need to familiarize yourself with if you want to venture into further experiments in such fields as bioelectronics or synthetic biology.

In this sense all projects presented in this book can provide an individual access. You can also carry out such experiments by yourself – but it is more fun to perform these together with others and to jointly develop them further. It is no coincidence that many DIY BIO communities are interdisciplinary: where people with a different scope of knowledge, various interests and abilities come together the space opens up for creative ideas, for artistic experiments – as well as for discussions on science and to what end it is pursued. The decisive point is not really whether or not the DIY principle encourages biopunks and biohackers to exceed limits. Rather it is crucial to join forces, work together, and to share.

1 In 1984 the short film led to a break between the Disney Company and Burton due to the high production costs, plus the film was considered as "not being family-friendly."
2 In 1993 the Ars Electronica Festival was already entirely devoted to this topic. The motto was: "The Eighth Day of Creation – Genetic Art, Artificial Life." A detailed documentation is provided in the festival catalogue (eds. Karl Gerbel and Peter Weibel, Vienna: PVS-Verleger 1993) as well as in the online archive: www.aec.at/festival/en/archiv/ (30.12.2012).
3 Cf. http://ekac.org (30.12.2012).
4 Cf. Klaus Richter: Das Leben des Physikers Johann Wilhelm Ritter. Ein Schicksal in der Zeit der Romantik. Weimar: Böhlau 2003, and Johann Wilhelm Ritter: Entdeckungen zur Elektrochemie, Bioelektrochemie und Photochemie. Eds. Hermann Berg and Klaus Richter. Thun / Frankfurt am Main: Harri Deutsch 1997.
5 Circuit diagrams and further works: www.mogensjacobsen.dk (30.12.2012).
6 More on the subject of biofeedback from the Deutsche Gesellschaft für Biofeedback: www.dgbfb.de; a collection of artistic projects with biofeedback can be found at Hans Diebner: http://diebner.de/htmldocs/biofeedback.html (30.12.2012).
7 About the scientific and cultural history of encephalography cf. Cornelius Borck: Hirnströme. Eine Kulturgeschichte der Elektroenzephalographie. Göttingen: Wallstein 2005.
8 About the project cf. http://biomapping.net and Christian Nold's website: www.christiannold.com (30.12.2012).
9 Luke Iseman: The Garduino Garden Controller. In: Make: 18 (2009); online: http://cm.cdn.fm/fakeup/dow-make/cmweb/entry_assets/MAKE18_Garduino_brnd.pdf (30.12.2012).
10 Cf. www.botanicalls.com and http://bausteln.de/anleitungen/botanifon (30.12.2012).
11 Miya Masaoka's website: www.miyamasaoka.com (30.12.2012).
12 Peter Tompkins and Christopher Bird: The Secret Life of Plants. A Fascinating Account of the Physical, Emotional, and Spiritual Relations Between Plants and Man. New York: Harper & Row 1973. [German: Das geheime Leben der Pflanzen. Pflanzen als Lebewesen mit Charakter und Seele und ihre Reaktionen in den physischen und emotionalen Beziehungen zum Menschen. Frankfurt am Main: Fischer 1977.]
13 Decisive impulses were given by Tompkins and Bird's book as well as by the film by the same name made in 1979. The exhibition project PSYCHOBOTANY assembled historic and contemporary art projects in Los Angeles in 2007: www.psychobotany.com (30.12.2012).
14 Joe Davis received an award for BACTERIAL RADIO at the Ars Electronica 2012: http://prix2012.aec.at/prixwinner/7023/; about his projects: www.viewingspace.com/genetics_culture/pages_genetics_culture/gc_w03/davis_joe.htm (30.12.2012).
15 Cf. http://biocurious.org (30.12.2012).
16 Cf. http://openpcr.org (30.12.2012).

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