EXPERIMENTS ON HUMAN-COMPUTER INTERACTION THROUGH ELECTRICAL BODY PART STIMULATION

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Abstract

The goal of this work is to show how a future of a human-machine symbiosis could look like and what questions and answers it might bring along.
Recent advancements in science and technology introduced new ways of thinking about the field of human-computer interaction (HCI) and showed potential to change the way of defining it. In this work, I am trying to anticipate near feature scenarios of HCI by experimenting with today's technology mixed with recent findings and visions about the future.
All of those experiments follow the basic idea of building and analyzing interfaces and objects that create a unique way of interaction. In a human-machine symbiosis the human can control the machine, and on the other hand, the device is capable of controlling actions of the person that is using it. The interaction that is happening between the machine and the human might not seem obvious for an outsider observing it. Whether being it a good looking photograph or a high score in a computer game, the experiments create situations where one can not tell for sure if the machine or the human decided about the output.
In all experiments, a "transcutaneous electrical nerve stimulation" (TENS) device is used to control the human. With its help, one can artificially stimulate desired nerves and contract connected muscles. The resulting movement can be used for many different outputs. The fields of interest in this work range from the basic understanding of what human-computer interaction means, over Cybernetics and future ideas of a fully functioning brain-machine interface to computer games and neural networks. The experiments and the resulting projects create a unique and new form of human-computer interaction and enable not only answering questions about possible futures but also encourage to ask new ones.

Concept

This work shows new ways for a functional human-computer symbiosis which is different from classic back and forth interaction we are familiar with.
With experiments in the field of digital media, media art, interaction design and speculative design three of those new interactions have been created and designed. Each of the projects is based on a different underlying theme while always using the same technology. A human is connected to a TENS unit attached to a computer. The TENS unit is capable of sending electrical impulses back into the human, triggering contractions of nerves and muscles.
When interacting with those devices, not only the person is operating the machine, but also the device is capable of controlling the human whenever needed. It is not clear anymore what the actual interface is in those scenarios. The initial user of the machine can become the interface. One of the major aspects is the moment of not knowing anymore if the machine or the human is responsible for a particular output. A symbiosis is created, where it becomes not clear and even irrelevant to find out who did what. The goal is to show some of many possible futures that can happen.
The work combines thoughts and ideas in a compressed form of devices prototypes and interfaces. They are proof of the underlying concept more than they are commercial products. However, those can originate through talking and interacting with them.

Props and Probes (Motivation)

The motivation behind this work is the question of how the future is going to look like regarding technology. Particularly interesting is the creation of projects in the field of HCI placed between nowadays technology and the science fiction idea of a fully functioning brain-machine interface (BMI).
BMIs have become a benchmark for the ultimate symbiosis of humans and computers. Because they seem so far away in the future one could just imagine how a world with them will look like. The experiments present one possible answer along the way of getting there. They can be considered probes which are sent into the world gathering data almost like actual testing probes. The desired information, in this case, are the stories and visions interaction with them generates.
They are not only probes but also props for narratives and stories that have never been told before. Analyzing those stories might result in an accurate glimpse into the future or be the reason not continuing an individual pathway.
I enjoyed the idea of letting a machine control actions of a human, through the human. What fascinated me about this, is the fact that you are not just giving up control over a device or object but letting the machine unwillingly control you.
As always in speculating about the future, none or all of the presented ideas can become a reality. The experiments should encourage to talk and think about the good and the bad of the given scenarios.

1_Theoretical Part

The Third Paradigm
Of Human-Computer Interaction (HCI)

"Humans interact with computers through a user interface. This includes software, such as what is displayed on the computer monitor, and hardware, such as the mouse, keyboard and other peripheral devices. As a result, the study of HCI focuses on user satisfaction.." [1]

HCI is the is a field of research which focuses on the interfaces humans use to control computers and how both interact with one another. Since 1982 the Association for Computing Machinery is organizing an annual event for HCI. It is called Conference on Human Factors in Computing Systems (CHI) and brings together ideas, definitions, and examples of current HCI. Attendees of those conferences define what the rest of the world understands as current HCI. Because of advancements in technology and other fields, the definition or paradigm of HCI is changing and shifting.
The paper "The three paradigms of HCI" discusses a potential next paradigm shift in HCI.
"*A paradigm shift, then, could be said to occur when a new generative metaphor is driving new choices of what to research and how, and can be identified when problems and issues that used to be marginalized have moved to the center.*" [2]
Paradigms define how we think and act about certain topics with the knowledge given. Especially in science, they are changing every time a discovery happens. Answering long time unanswered questions is not only solving old problems but also enabling to ask questions one could not have imagined before. Examples of scientific paradigm shifts are the acceptance of the continental drift or moving from Newtonian to the relativistic physics. Paradigms should be seen as a new way of thinking about a certain topic, not as the only way. In the end, they even can co-exist and often do so.
Also in HCI paradigms define the understanding of it. Two major intellectual waves formed the field of human-computer interaction. The first was driven by engineering and the goal of optimizing man-machine fit. One example for this is the design of first airplane cockpit interfaces.
The pragmatic desire of error-free flights formed the interaction between the pilot and the complex control system of the plane.

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1 What is Human-Computer Interaction (HCI)? , accessed 28.05.2017, retrieved from https://www.techopedia.com/definition/3639/human-computer-interaction-hci

2 Ibid.

Cognitive science and the new knowledge about how we perceive information initiated the second wave of HCI. The focus of HCI shifted from just interacting with the computer to also examining how interaction also affects cognitive processes.
The goal is not just to transfer the information but do it most efficiently. Hearing a warning is, for example, much more efficient than reading it. As discussed in the paper, a third paradigm is not fully defined yet, even though it probably exists. The paper calls it the "phenomenological matrix" for now.
Disciplines as participatory design, user experience design, embodied interaction, affective computing, ethnomethodology, value-sensitive design or critical design often create an interaction that can not be defined precisely with previous paradigms. As mentioned earlier this could be a sign of a paradigm shift. What most of those disciplines have in common is to treat interaction not only as information processing but as a form of meaning making. That is one of the first approaches of labeling the third paradigm.
The paper makes it clear one has to acknowledge that paradigms can coexist and that there is no need of disapproving the old ones. They should be considered as alternative ways of thinking. It suggests waiting for future works and thoughts to resonate within the reader to form the correct and precise name for it.

	Paradigm 1	Paradigm 2	Paradigm 3
Metaphor of interaction	Interaction as man-machine coupling	Interaction as information communication	Interaction as phenomenologically situated
Central goal for interaction	Optimizing fit between man and machine	Optimizing accuracy and efficiency of information transfer	Support for situated action in the world
Typical questions of interest	How can we fix specific problems that arise in interaction?	▪ What mismatches come up in communication between computers and people? ▪ How can we accurately model what people do? ▪ How can we improve the efficiency of computer use?	▪ What existing situated activities in the world should we support? ▪ How do users appropriate technologies, and how can we support those appropriations? ▪ How can we support interaction without constraining it too strongly by what a computer can do or understand? ▪ What are the politics and values at the site of interaction, and how can we support those in design?

Table 1: Paradigms compared [3]

	Paradigm 1	Paradigm 2	Paradigm 3
Appropriate disciplines for interaction	Engineering, programming, ergonomics	Laboratory and theoretical behavioral science	Ethnography, action research, practice-based research, interaction analysis
Kind of methods strived for	Cool hacks	Verified design and evaluation methods that can be applied regardless of context	A palette of situated design and evaluation strategies
Legitimate kinds of knowledge	Pragmatic, objective details	Objective statements with general applicability	Thick description, stakeholder "care-abouts"
How you know something is true	You tried it out and it worked.	You refute the idea that the difference between experimental conditions is due to chance	You argue about the relationship between your data(s) and what you seek to understand.
Values	▪ reduce errors ▪ ad hoc is OK ▪ cool hacks desired	▪ optimization ▪ generalizability wherever possible ▪ principled evaluation is *a priori* better than ad hoc, since design can be structured to reflect paradigm ▪ structured design better than unstructured ▪ reduction of ambiguity ▪ top-down view of knowledge	▪ Construction of meaning is intrinsic to interaction activity ▪ what goes on around systems is more interesting than what's happening at the interface ▪ "zensign" – what you don't build is as important as what you do build ▪ goal is to grapple with the full complexity around the system

Table 2: Epistemological distinction between the paradigms [4]

3 Ibid.

4 Ibid.

Electric Body Part Stimulation

There are ways to stimulate and activate muscles and nerves artificially. The most popular ones are the TENS and the EMS device.
TENS stands for “transcutaneous electrical nerve stimulation“ and EMS for “electrical muscle stimulation.“ Both are used for slightly different causes. The TENS device is often used for pain relieve by applying electrodes on the right spots to block the pain in the nerves whereas the EMS device has become more prevalent in sports. It can be used as a method to enhance sports exercises by stimulating the right muscles when needed. Placement and wavelengths decide about whether the muscle or the nerve gets stimulated. Even though they behave differently, one can also use a TENS unit to activate muscle contractions. Attaching the electrodes at the right place on the body causes the connected muscles to contract when current is applied.
When using a TENS unit, there need to be at least two electrodes to close an electric circuit. One of them is always the ground and the other one the actual signal. Older TENS units have analog knobs to change the amperage and the frequency by hand. Newer devices have pre-programmed sequences so one can only choose a predefined program. The needed electrodes are often square shaped silicon pads with conductive carbon film inside. There are also variations on those. Conductive silicon straps or just conductive foil can also be found and used for different applications.
TENS devices are primarily used in modern medical context. Rehabilitation patients are treated by applying electrical stimulation to nerves that are not working properly. By stimulating them artificially, the brain can sometimes relearn movement again. Foot drop, for example, is a nerve disease many patients encounter after a stroke. It causes the foot not to move up while walking. There are devices for treatment with a built in TENS unit. Those can be applied to the leg of the patient. When registering that the affected leg is moving, they send electrical impulses into the foot causing it to move up at the right time. TENS units can also be found in not applied approaches to this topic. A company called “Backyard Brains” initiated making neuroscience accessible for everyone. They provide lots of experiments and products around this subject. One can easily reproduce those experiments at home. Some of them also involve a TENS unit. They are a cheap and convenient way to achieve good results in electrical body part stimulation.

TENS unit against foot drop [5]

The "possessed hand" experiment by Backyard Brains [6]

5 Foot Drop System, digital photograph, accessed 28.05.2017
https://images.agoramedia.com/everydayhealth/gcms/Pros-and-Cons-of-Functional-Electrical-Stimulation-for-MS-Related-Foot-Drop-RM-1440x810.jpg

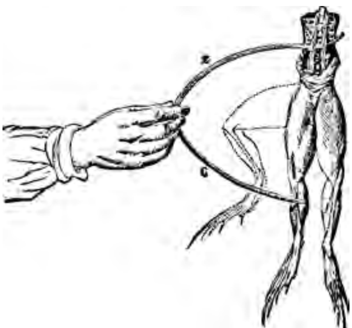
6 Photograph of a TENS unit experiment, digital photograph, accessed 28.05.2017
https://i.ytimg.com/vi/rSQNi5sAwuc/hqdefault.jpg

From Frankenstein To Neuroscience

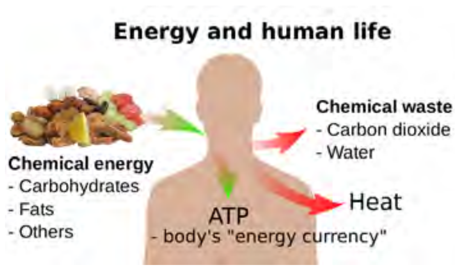
““Galvanism” can be defined as the effect of the application of electric current pulses through body tissues that causes muscle contraction.“ [7]

Today galvanism is called electrophysiology. It is the study of galvanic effects on biological creatures. Luigi Galvani was an Italian scientist living at the end of the 18th century. He discovered that a frog leg twitches when applying connected copper and zinc needles to it. He called it “animal electricity“ and thought he had found the hidden elixir to life. What he has not realized is that he has just created an electric circuit by using a zinc and a copper electrode, having the muscle as a load and the salt water as the electrolyte. Further tests involved his assembly being tested outside during a thunderstorm. Each time lightning appeared the leg started twitching. Even though this was a side project to his research, this was the inspiration for the novel Frankenstein by Mary Shelley.

Galvani’s research was a huge step forward for neuroscience. Unfortunately, the state of knowledge was not far enough yet. Biologically created electricity and action potentials in nerves and muscles do indeed exist. Also, technically thinking they are the elixir of life. Without action potentials and electrical current, we would not be able to live. All our actions, thoughts and even emotions are controlled by an electric current that is produced by ourselves. It took almost 100 extra years after Galvani to realize that biological processes in our bodies create the electric power we need to live.



Galvani’s frog experiment [8]



Energy production in the human body [9]

7 Galvanism and Scientific Discovery, accessed 28.05.2017, retrieved from https://frankensteinproject.wordpress.com/galvanism-and-scientific-discovery/

8 Picture of Galvani’s frog leg experiment, digital photograph, accessed 28.05.2017 https://upload.wikimedia.org/wikipedia/en/3/3c/Galvani’s_legs.gif

9 Illustration of the energy production in the human body, digital illustration, accessed 28.05.2017 https://media.licdn.com/mpr/mpr/AAEAAQAAAAAAAAb_AAAAJDFmMjgyNDM0LTUxNjQtNDg3MC1hNWFkLWQ3NmU5YjNhY2U2Zg.png

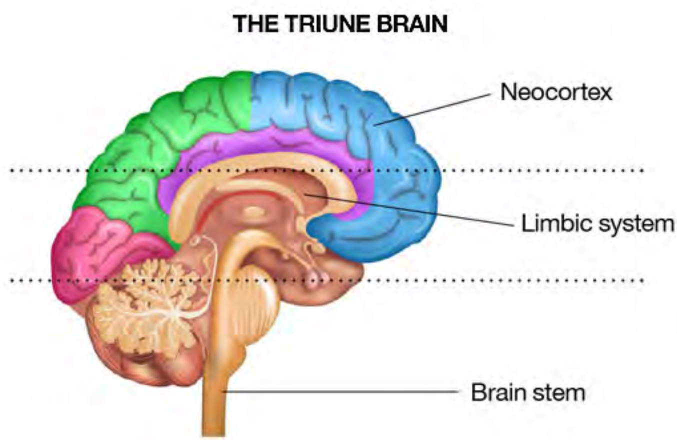
The Human Brain And The BMI

“If the human brain were so simple that we could understand it, we would be so simple that we couldn’t.“ - Emerson M. Pugh [10]

Our brain is probably the most complex object in the universe. It was formed over an extended period of millions of years. Many evolutionary cycles were needed before it became what it is today. It is a collection of uncountable neurons that are arranged in the most space-saving way imaginable. Considering how it looks, one could recognize the different stages of its evolution. It consists of three major parts. Beginning from the inside, the first part is often just called the reptilian brain. The official title is “brain stem.“ It regulates everything humans need for not dying. Processes as the heart rate and the body temperature are unconsciously controlled here.

The second part is the limbic system. It is also responsible for survival but does this on a different level. The emotions and instincts are placed here. Everything also animals can experience is part of the limbic system. It controls survival instincts like hunger, thirst, our sex drive and fear to name but a few.

The third and last layer is called the cortex or neocortex. This part of the brain is responsible for lots of things. All our senses, motor skills, thoughts and even our personality find their place in different parts of it.

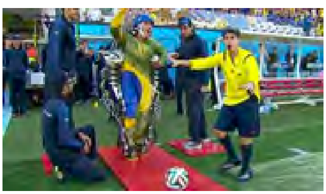


The Triune Brain [11]

10 Emerson M. Pugh quotes, accessed 24.08.2017, retrieved from http://thinkexist.com/quotation/if_the_human_brain_were_so_simple_that_we_could/204428.html

11 The triune brain, digital illustration, accessed 28.05.2017 http://www.vietnow.com/wp-content/uploads/2016/08/thetriunebrain.jpg

Even though neuroscientists know roughly which part of the brain is responsible for what action, the processes happening inside of it are still very complex and hard to understand. Nevertheless, research in this field is advancing. Many scientists believe, fully understanding the human brain is just a matter of time. With technological advancement, the help of neural networks and financial investments into the research, things are looking more promising than ever before.
Imagining movement of body parts in the human mind can trigger measurable activity in the corresponding regions of the brain. Researchers in the field of brain-machine interfaces (BMI) are analyzing those activities. The goal is to someday someday a fully connected interface that can not only read but also trigger the human brain with electrical impulses. BMIs we know today can measure certain brain activities and use them for different applications. One has to differentiate between invasive and non-invasive methods to get those measurements. The fastest and most popular method is using an Electroencephalography (EEG) which is a non-invasive method where electrodes are placed all over the outside of the head. This method is not as precise as those that involve opening the skull.
State of the art was shown at the Soccer World Cup ceremony 2014 in Brazil. A research group around Prof. Miguel Nicolelis from Duke University developed artificial legs, which can be operated by the mind. A paralyzed person who was attached to those legs kicked a football at the opening ceremony by only using his mind. Other promising applications in this field can regain hearing or eyesight in some degree for people who were deaf or blind before.


BMI Worl Cup opening [12]


BMI retina chip [13]

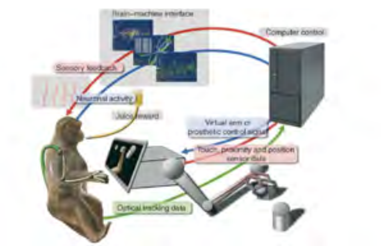
Cochlear hearing implant [14]

12 Photograph of BMI during world cup opening, digital photograph, accessed 28.05.2017 http://4.bp.blogspot.com/-gqRf4dSnLuA/U5r69KcV44I/AAAAAAAAAnMQ/_deAkHMvNBU/s1600/exoesqueleto.jpg

13 Picture of retina implant, digital illustration, accessed 28.05.2017
http://28oa9i1t08037ue3m1l0i861.wpengine.netdna-cdn.com/wp-content/uploads/2018/04/6x6-argus-retinal-implant_2d.jpg

14 Picture of cochlear implant, digital illustration, accessed 28.05.2017
https://www.nidcd.nih.gov/sites/default/files/Documents/health/hearing/images/cochlear-implant-web-pic.jpg

More advanced research is right now happening by experimenting with apes and the first BMIs that are not only reading information but also giving feedback directly back into the brain. First experiments have shown promising results. The apes were able to use an artificial hand to distinguish objects from one another.



BMI with feedback loop [15]

Big companies as Facebook and known persons like Elon Musk invest a lot of time and money into the research of BMIs. Facebook, for example, is trying to build a BMI that can translate thoughts into words. They have successfully made it possible to write eight words per minute by only using the thoughts of a human. The goal is to get faster than the average writing speed. That would be beyond 100 words per minute.
Whereas Elon Musk's recent project is called "Neuralink." It is a vision to build an ultra-high bandwidth brain-machine interface. What this exactly means is not clear yet, but it sounds promising. With the rise of neural networks and a bigger interest in this field, it is hard to tell how fast the technical progress with BMIs is going to be. However, the first steps have been made.

Facebook BMI typing demo [16]

"Neuralink" BMI project by Elon Musk [17]

15 Illustration of BMI with multiple feedback loops, digital illustration, accessed 28.05.2017
https://www.researchgate.net/profile/Mikhail_Lebedev2/publication/6925844/figure/fig2/AS:277846661582850@1443255214429/Figure-2-A-BMI-with-multiple-feedback-loops-being-developed-at-the-Duke-University.png

16 Facebook is building brain-computer interfaces for typing and skin-hearing, digital photograph, accessed 28.05.2017
https://techcrunch.com/2017/04/19/facebook-brain-interface/

17 Picture of Elon Musk, digital photograph, accessed 28.05.2017
https://www.techworm.net/wp-content/uploads/2017/03/ElonMusk-Merge-Brain-Computers-032717-lt.jpg

Memories In The Muscle

A scene from matrix showing the process of implicitly learning how to fly a helicopter. [18]

Memories can manifest in different forms. Not only thoughts but also body movement and skills can be memorized and used when needed.

This behavior is commonly known as muscle memory. The official term is motor learning, and it is a part of the human procedural memory. Motor learning describes that specific motor tasks can be learned through repetition. ”Repetition is the mother of skill“ or “Learning by doing“ are known sayings referring to this topic.

When repeating, for example, a trick in skateboarding for hundreds of times, it becomes more and more effortless to perform it. The neurons in the brain filter out the noise over time and just remember the pure and clean motion. The attention towards the task has to be very high in the beginning. During the process of repetition and learning, one strengthens the needed and weakens the unimportant areas of the brain that are responsible for the desired output. Eventually, such skills and motor movements become part of the procedural memory. It is a type of implicit memory that can be used unconsciously. Mastered skills can be performed almost automatically without the need of using as much thought process as in the learning phase. There have been reports of short term amnesia happening right after such actions. The person is then not even remembering the moment of performing.

Many researchers think that learning can be separated into implicit and explicit learning. Those definitions describe whether the individual is aware of the process of learning or not. By this definition the first language, for example, is learned implicitly whereas the skill of mixing cards is learned explicitly.

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18 Picture from the movie Matrix, digital photograph, accessed 25.08.2017
http://www.eightyeightdecembers.com/wp-content/uploads/2014/04/trinity.png

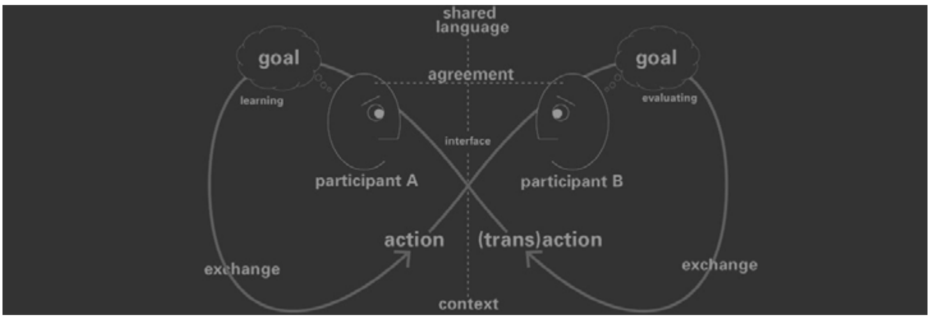
Whatever method is used, the skill can become part of the procedural memory mentioned earlier.
Most experiments show that implicit learning takes longer and is not as efficient as explicit learning. However, in theory, it is possible to apply knowledge and skill artificially. Maybe even by repeatedly stimulating certain muscles for a designated amount of time. Thinking this further it means one could save certain information encoded as muscle-contractions on a human body.

Cybernetics In A Man Machine Symbiosis

"Cybernetics is, at its core, a science of purpose. It enables the formal modeling of human goals in complex situations, including conversations, decision making, and computer-mediated collaboration." [19]

Each system in the sense of Cybernetics has a purpose and a goal. On its way there it has to run through feedback cycles that show if the system is closer or further away from it. All this happens through back and forth communication between different systems and even within the system itself.

Part of modern cybernetics is to look at how humans interact with computers. HCI and Cybernetics are deeply connected. HCI is just one of many fields of Cybernetic thinking. The conversation between the human and the machine should be seen under similar aspects as a conversation between humans.



Conversation loop between humans [20]

"*When I give an order to a machine, the situation is not essentially different from that which arises when I give an order to a person. In other words, as far as my consciousness goes I am aware of the order that has gone out and of the signal of compliance that has come back. To me personally, the fact that the signal in its intermediate stages has gone through a machine rather than through a person is irrelevant and does not in any case greatly change my relation to the signal.*" [21]

19 User Experience and Software Design, accessed 25.08.2017, retrieved from http://pangaro.com/ux-software-design.html

20 Conversation Loop, digital photograph, accessed 25.08.2017, retrieved from http://www.pangaro.com/assets/img/heroes/conversation-loop.jpg

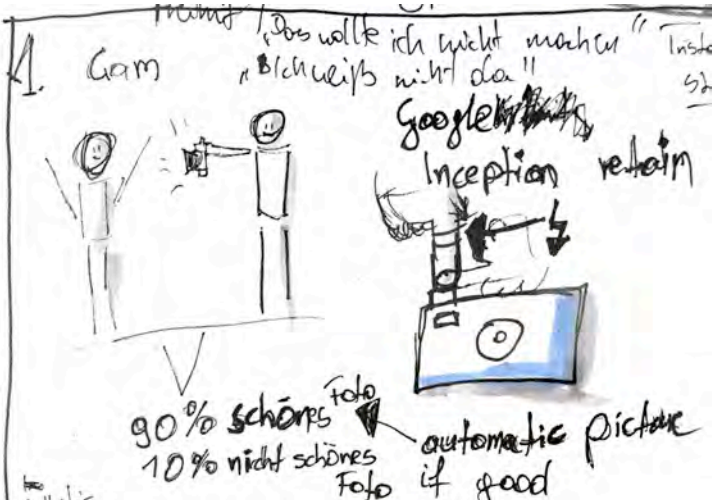
21 How cybernetics connects computing, counterculture, and design, accessed 25.08.2017, retrieved from http://www.dubberly.com/articles/cybernetics-and-counterculture.html

The experiments in this work are about a symbiosis between humans and machines. They extend human capabilities in different ways. Many people fear future man machine symbiosis imagining machines taking over human decisions through brain machine interfaces or similar technology.
One has to acknowledge that we have lived through man machine symbiosis for many years now. A watch, for example, is a machinery extension of human capabilities. A conversation between the human and this watch fulfills the human goal of knowing what time it is. Combining it with the capabilities of modern mobile phones and the experiments from this work, such machines are just making the field of available information bigger. As Paul Panaro mentions in an interview about the future of Cybernetics [22], he believes that in any case, the decisions that seem to be made by the machine are all human driven because humans have built the systems.
Even the decisions that appear to be decided by the machine are just the result of back and forth conversation between the machine and the human driven by human needs. The totality of all available information is responsible for the decision not the machine on its own.

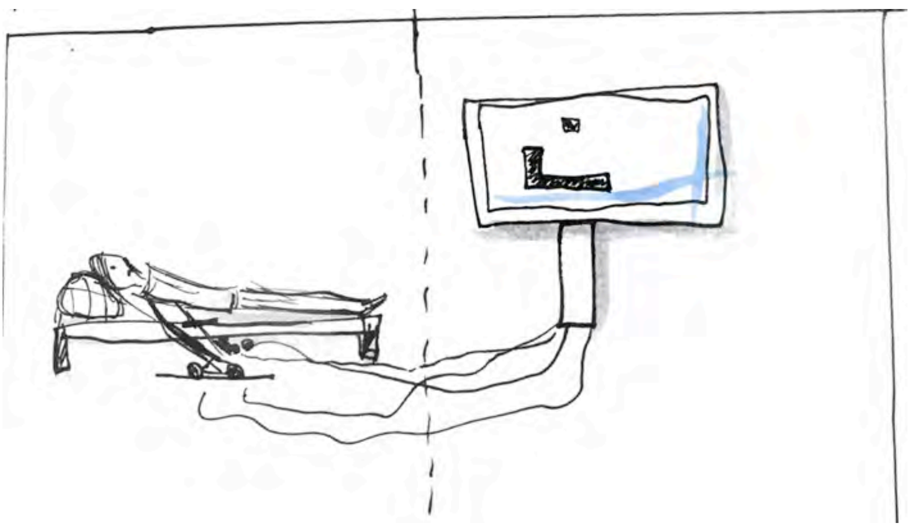
22 The Future Of Cybernetics, video, accessed 26.08.2017, https://vimeo.com/41782296

The Experiments

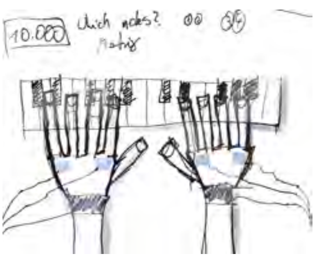
The goal of this work is to build new ways of human-computer interaction. It is accomplished through three different practical experiments. Each of them combines the given hardware and technology of a TENS unit with various theoretical aspects. Digital Media and various design practices are used to eventually manifest in three working prototypes to proof the underlying concept. Arguably those experiments are an addition to the pool of the new HCI and part of the paradigm shift mentioned in the beginning. The TENS unit adds a looping interaction between the human and the computer through the human itself.
Using electrical charge to control human behavior is inspired by the brain and how it controls the body. Calculations within the brain result in parts of the body to act accordingly to the brains goals. Having those goals defined by a computer code and executed by a TENS unit on a body arguably means, being connected to such construction is like having a second brain. How good this "brain" performs, depends then on the code. Each of the experiments is about one main topic chosen from a personal preference mixed with the intention of variation. They are primarily built for conversation. Because they are placed in such a wide range, more people are potentially affected to understand and communicate the concept.

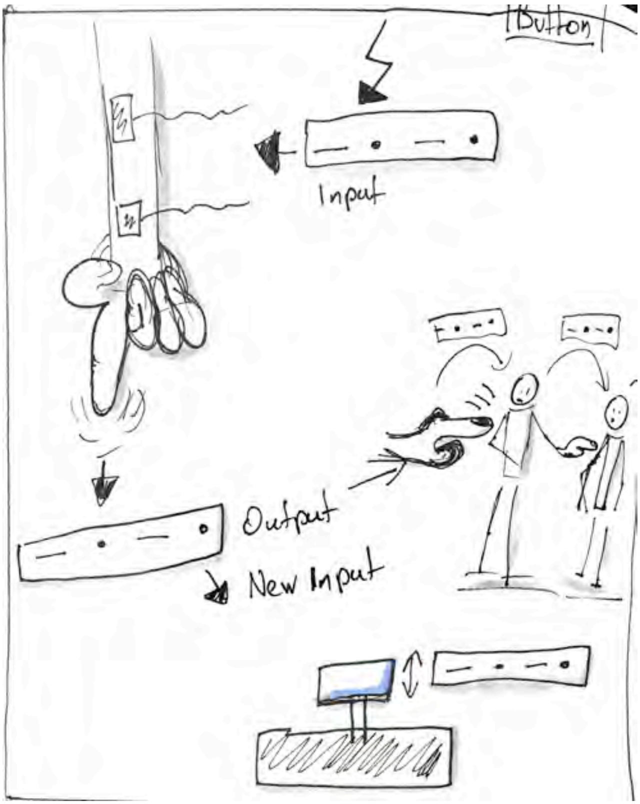


Initial sketch of experiment 1



Initial sketch of experiment 2





Initial sketch of experiment 3

Experiment 1 / AI Photo Assistant

The first experiment deals with the topic of creativity and how AI could change the way we understand it. It is a photo camera that makes beautiful pictures by unwillingly moving the finger of the person holding it. The finger then activates the trigger and makes the photo.
The camera is running an image classifier that is trained on good looking and bad looking pictures. When holding the camera, the classifier is constantly rating the value of the picture that is in front of the lens. Every time the image has a higher score than a predefined threshold of 95% (high-quality), the camera sends an electrical impulse through the human that is holding it. This impulse unwillingly triggers the finger of the person to take a picture. In this setup, it is still possible for the human that is holding the camera to shoot pictures actively. The camera and the photographer are in communication with each other deciding about the best picture.
The idea behind this project is inspired by an advice new photographers often get. They get told that the key of getting better is going outside and taking pictures of anything that gets in front of the lens.
What if the photographer gets back with only beautiful pictures?
In addition to having a working prototype of the camera, the actual pictures taken by the man machine symbiosis should also get exhibited.

Experiment 2 / Computer Games

The second experiment is inspired by computer games. Especially by new approaches towards this topic. Nowadays games are experienced in more ways than just playing them from start to finish. Millions of people experience them online by watching others play in so called ”Let’s Plays“ or by, for example, training one particular level for a long time to find the perfect path. Later is known as a speedrun.
This second experiment tries to create a new way of experiencing computer games. It is located between the current approaches while at the same time creating something completely different.
A given game is shown on a screen and played by itself either with a hard coded algorithm or with a neural network behind it. The game knows the exact path and the needed inputs to finish itself. Inputs as moving up or down are not executed internally. Instead, they have to run through a human first. A TENS unit is connected to those calculations. While attached to the device, the human receives electrical signals each time an action shall happen. Those signals contract a finger which then eventually presses one of the connected buttons. Each button is assigned to one of the moves the game needs to be played. If, for example, the game has calculated that it wants to move upwards it sends a signal to the finger that is connected to the ”Up“ button. The contraction of this finger only then executes the initially desired input within the game.
The human in this scenario is not doing anything but experiencing the perfectly timed inputs of a self-playing game. One can also just close their eyes and lean back while ”playing“ this system. Additionally, the player can willingly press the buttons between the impulses and intervene into the game. The game then reacts to those disturbances and rearranges itself through the human again. One could even speculate that it is possible to learn to play a given game implicitly this way.
The project is a mixture of ”Let’s Play,“ cheating and speed running but at the same time neither of those.

Experiment 3 / Data On The Body

The third experiment deals with the topic of decoded information of any kind in the form of body part movement. It is inspired by the moment of entering a pin number. Most people can not remember the exact digits after having used the same pin for a certain time. Motor memory is used instead.

This experiment is a device that enables information of any kind to be decoded into muscle contractions. While connected to it, the device is repeatedly contracting the appropriate muscle in an endless loop. As mentioned in the paragraph about memory, enough time and repetition can create procedural memories implicitly. Skills or what ever the learned information is can afterward be accessed without being connected to the device anymore.

The information can be anything. A seemingly uncoordinated twitching finger could be a song when placed on a piano or the right pin number when placed over an input panel of a cash dispenser. Until then even the carrier is clueless about its meaning. Not having access to an appropriate decoding device makes the human just a medium and a messenger between other systems.

The moment of not knowing the learned information is an important aspect of this work. The skill, the password or whatever the information might be, never needs to enter the conscious mind. The knowledge itself is prosthetic. When coming back to the pin number as an example, it is not necessary anymore for banks to send out a four digit number and risk the loss or theft of such valuable information. It would be enough to invite each customer once and record the pin onto their body. Whenever they need to pay, they just have to place their hand onto the appropriate device and fire up the implicitly learned motor memory. The number of possible applications is endless.

2_Practical Part

Prosthetic Photographer


SONY
E 3.5-5.6/PZ 16-50 OSS

setup

The ”Prosthetic Photographer” is a modular system that can be attached to any mirrorless or DSLR camera. It consists of an enclosure and a handle. The enclosure contains a TENS unit and a computer. It can be attached to the so called hot shoe on top of the camera. A small camera module in the front of this enclosure points in the same direction as the lens of the big camera underneath. The handle needs to be attached to the 1/4 inch tripod thread underneath the camera. It holds the power supply and also serves as the handle for the whole system. There are two electrodes integrated into it which can transfer an electrical impulse into the hand of the user.

When in use, the computer within the enclosure continuously analyses the picture seen by the camera module. When it decides, that the motive is worth taking, it sends an electrical impulse into the handle. The user has no choice but to press the button at the front of the handle to eventually take a picture with the digital camera. The interface in the back of the enclosure serves to regulate the strength of the electrical impulse. One can adjust it to the point that is not hurting but still contracting the index finger enough to press the button.

technology

The computer within the enclosure is a Raspberry Pi connected to a camera module. It is continuously running an image classifier script that is analyzing the currently seen picture. Due to computational power, it can classify one picture every 4 seconds. When the classifier gets results of over 95% for a high-quality image, it sends out a signal to the connected TENS unit.

A neural network had to be trained on a database consisting of images labeled as high- or low quality. Transfer learning was used as a method. It means a given and an already trained neural network is used, and just the last layer of it is re-trained with one’s desired data set. Google’s Inception Model, which is a neural network specialized on image classification was used. Inception was previously trained on ImageNet, a collection of millions of semantically labeled images. The power and knowledge of this network can be used for different applications without having a powerful computer at disposal.

Google's Neural Network Inception [23]

The dataset used for this particular application is called CUHKPQ[24] and consists of 17,613 images. They were obtained from a variety of online communities and are divided into seven semantic categories. They were also labeled in categories of high- and low-quality pictures. A photographic community has done this by hand.
During the training process, which was done for 4000 iterations, 80% of the dataset was used to train the network to be able to classify between the given two categories. The result was tested against the unknown remaining 20% of the dataset and achieved a training accuracy of over 90%. It means that new and never seen data can be categorized at such high precision.
First tests were made on random images.

First tests

23 Google Inception, digital photograph, accessed 30.09.2017, https://indico.io/blog/wp-content/uploads/2016/02/inception_cleaned.png

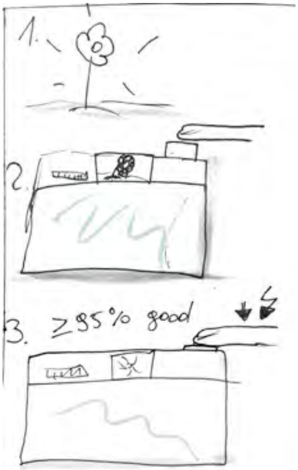
24 CUHKPQ, website, accessed 28.08.2017, http://mmlab.ie.cuhk.edu.hk/archive/CUHKPQ/Dataset.htm

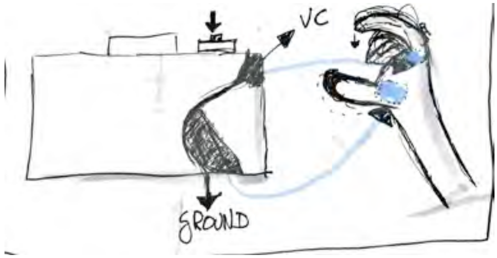
The code was then transferred to a Raspberry Pi. The software library used in this particular project is ”TensorFlow.“ It is an open-source library for machine learning and artificial intelligence. The programming language is Python(3).
A TENS unit within the enclosure is responsible for the electrical current sent to the user. It is connected to the handle and to the Raspberry Pi through a MOSFET circuit to one of its GPIO pins. Every time the classifier is satisfied, it sends a signal to this GPIO Pin and opens the gate within the MOSFET. The electrical current then flows between the electrodes on the handle and eventually through the user's hand causing the index finger to twitch.
There also is a button built into the handle. It sits right underneath the index finger. If it gets pressed the digital camera takes a picture of the current scene. The button also works if the user decides to press it willingly.
To make the system mobile, it needs to be powered by batteries. The TENS unit gets powered by a 9V battery while the Raspberry has to be connected to a power bank that is placed underneath the handle. The power bank also serves as a pedestal for the whole system.
Aluminum tape extends the electrodes on the handle. It runs around the back of it to cover a larger area ensuring enough current to run through the user.
There is no need to attach anything to the user. Everybody is automatically connected to the two electrodes by just holding the handle.

```python
import time
from picamera import PiCamera
from picamera.array import PiRGBArray
import tensorflow as tf

def get_labels():

    with open('../inception/retrained_labels.txt', 'r') as fin:
        labels = [line.rstrip('\n') for line in fin]
    return labels

def run_classification(labels):

    camera = PiCamera()
    camera.resolution = (320, 240)
    camera.framerate = 2
    raw_capture = PiRGBArray(camera, size=(320, 240))

    time.sleep(2)

    with tf.gfile.FastGFile("../inception/retrained_graph.pb", 'rb') as fin:
        graph_def = tf.GraphDef()
        graph_def.ParseFromString(fin.read())
        _ = tf.import_graph_def(graph_def, name='')

    with tf.Session() as sess:
        softmax_tensor = sess.graph.get_tensor_by_name('final_result:0')
        for _, image in enumerate(
                camera.capture_continuous(
                    raw_capture, format='bgr', use_video_port=True
                )
        ):
            decoded_image = image.array
            predictions = sess.run(softmax_tensor, {'DecodeJpeg:0': decoded_image})
            prediction = predictions[0]
            prediction = prediction.tolist()
            max_value = max(prediction)
            max_index = prediction.index(max_value)
            predicted_label = labels[max_index]
            print("%s (%.2f%%)" % (predicted_label, max_value * 100))
            raw_capture.truncate(0)
if __name__ == '__main__':
    run_classification(get_labels())
```

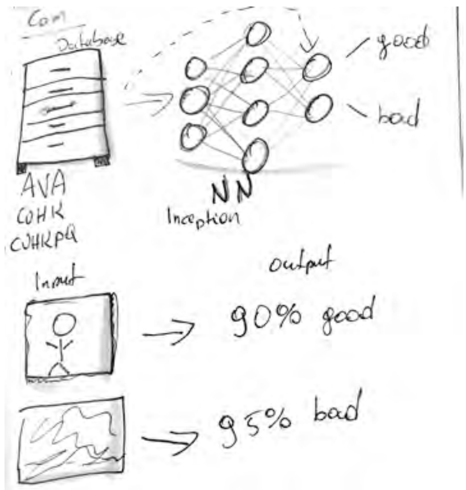
Python code for the image classifier

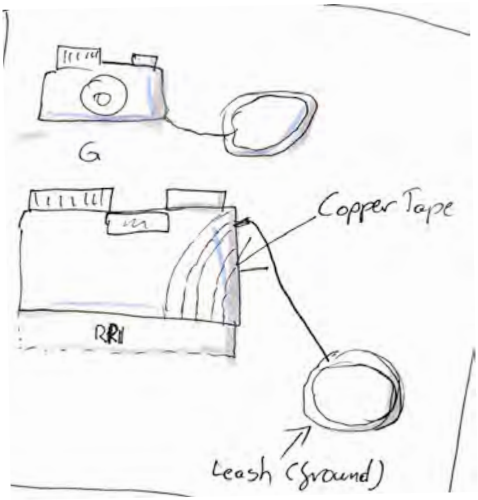
sketches

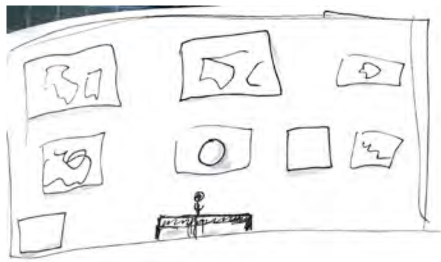

1.
2.
3. ≥ 95% good

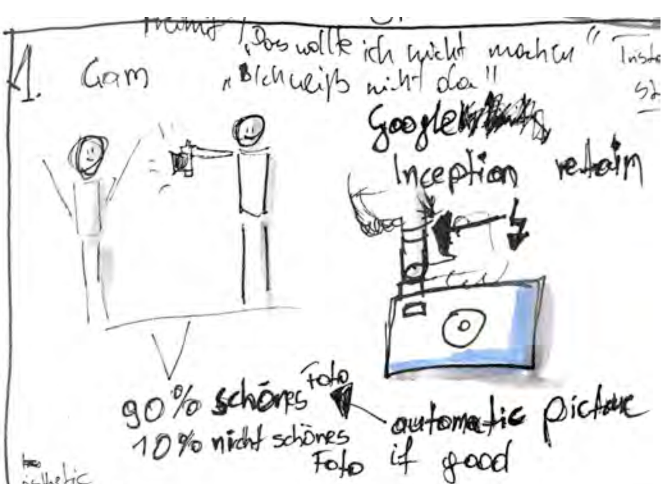

VC
GROUND


VC
ground

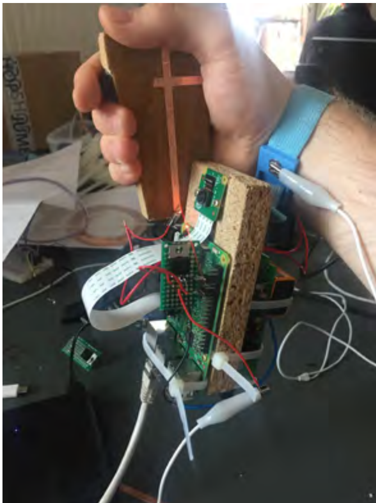

Database
good
bad
AVA
CUHK
CUHKPQ
NN
Inception
Input
output
90% good
95% bad

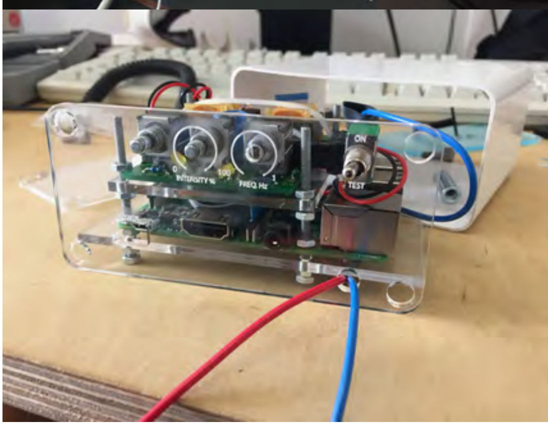

G
Copper Tape
Leash (Ground)

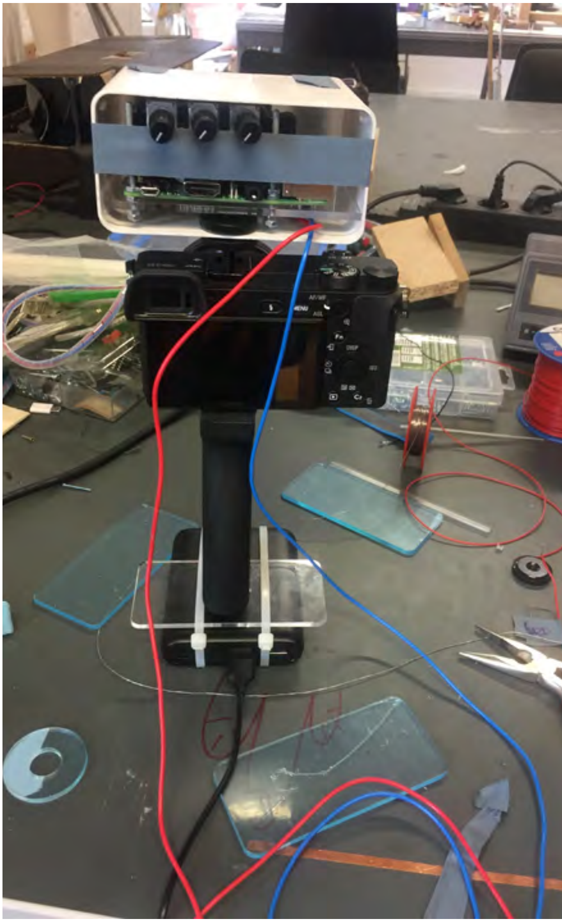



1. Cam
„Das wollte ich nicht machen"
„Ich weiß nicht da"
Inception retrain
90% schönes Foto
10% nicht schönes Foto
automatic picture if good

process





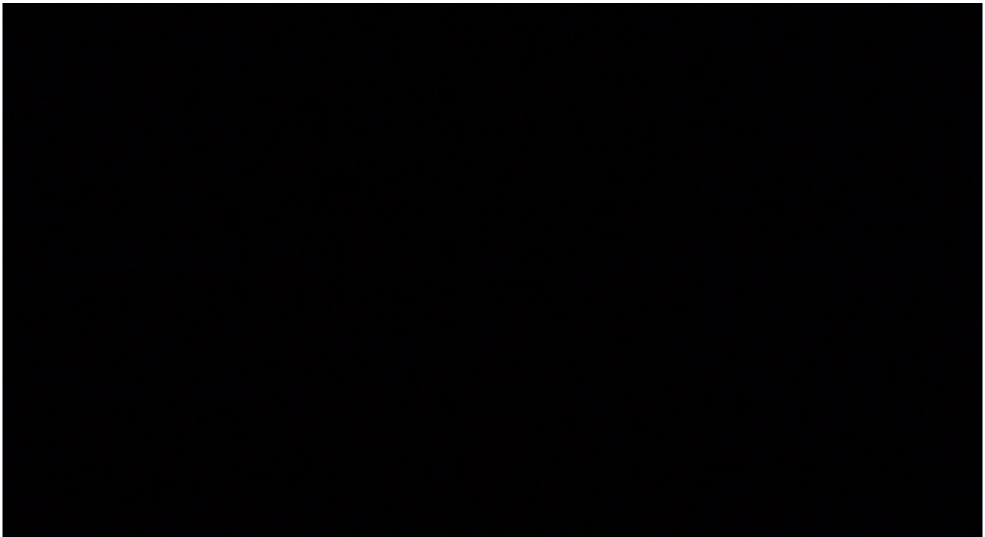


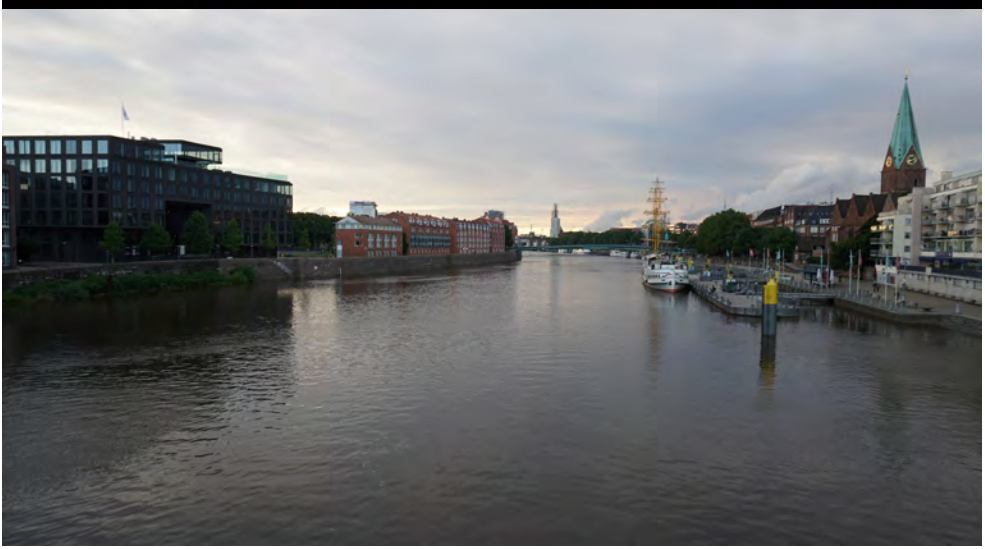
prototype


100
FREQ. Hz
POWER

results


05






HANS WARNER
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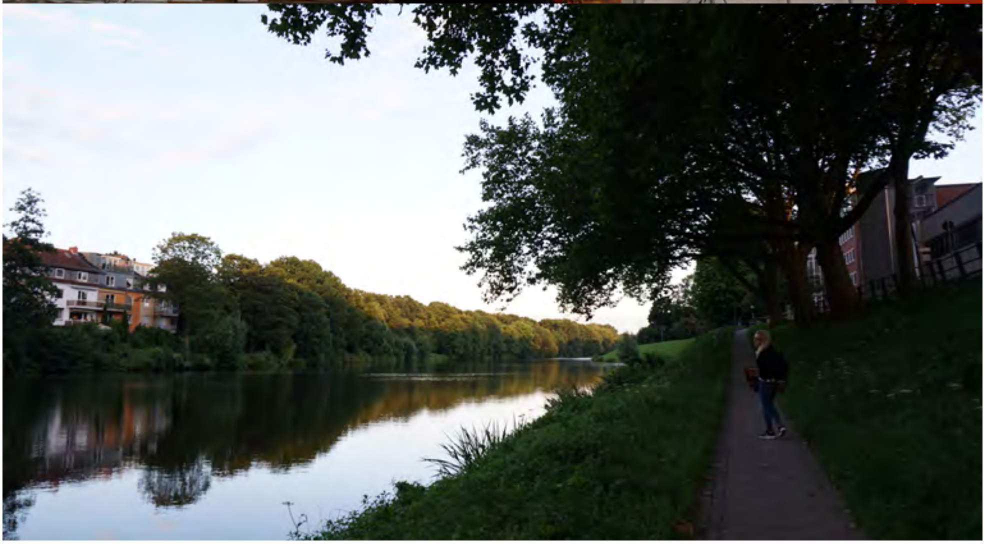


conclusion

With new advancements in Machine Learning and especially with neural networks it became possible to let computers learn about the information they can decide on more precisely than humans ever could.

One of the goals of this work was to find out, how this behaves on a subject like art and aesthetics. They are usually experienced on a subjective level. Everybody thinks differently about it. Still, there is art that can delights a huge mass of people at the same time. It is then generally considered as good and beautiful. If it is possible to create such piece of art, there probably is an explainable system behind it that follows mathematical rules. Maybe humans are just not capable of describing and seeing the underlying system but computers are. If it is possible to calculate beauty, one could also reproduce it. True beauty then no longer lies in the eyes of the beholder but within an algorithm on a computer.

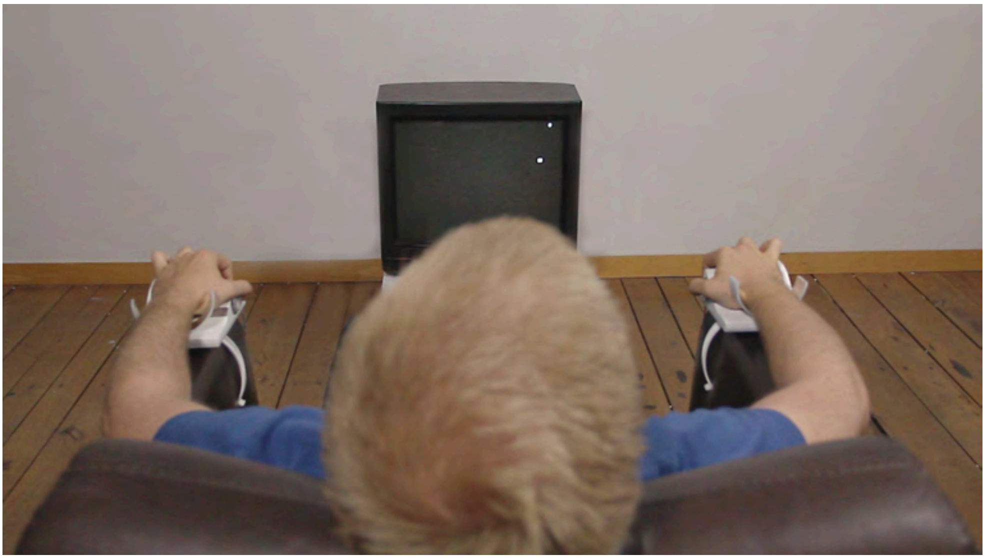
Photography is an excellent art form to test this assumption. There are many data sets available containing huge amounts of pictures that were categorized by their aesthetic quality by humans. Having this information on hand, it is possible to train a neural network on this data. The result makes the computer capable of analyzing and creating art. A skill humans had claimed for themselves before.

The results show that the ”Prosthetic Photographer“ is most of the time capable of creating output that more or less can be considered of higher quality than just randomly pressing the trigger. Some results may look untypical and different though. Images we would not consider of high quality but the algorithm for some reason does. The particular algorithm in this project has a unique understanding of aesthetic. It likes the color blue, for instance, more than other colors and is also more likely to trigger the finger when pointed at stacked objects. Those are just two obvious observations after using the camera for several hours. One gets a sense for what the camera wants to see. More than once assumptions about a motive made by the user were proven true by the camera. The assumptions were getting better over time.

There are many factors to what the particular algorithm classifies as good. The dataset, the neural network that was used and also the learning time are all part of the result. Changing one of those parts can create different aesthetics. In the future, we may see them coexist and act as artists. Some people might enjoy the aesthetics of algorithm X whereas others prefer the beauty of algorithm Y. Machines could act under a pseudonym and people would not even notice. Or artists could just use certain algorithms as assistants for their art. Similar to today's photo filters on mobile devices.

In my opinion, this system is part of a new aesthetic, based on computer-generated decisions that was taught by human skill. Talking about this project and using it is the main aspect of this work and will create many more potential use cases and scenarios. The future will show it if those scenarios have potential to become reality.

Twitch



setup

“Twitch“ consists of a computer running a video game and two controllers that are necessary to operate it. The computer plays a particular version of the game ”Snake“ automatically where an algorithm calculates if the snake has to move up, down, left or right next. The computer itself can not move the snake. It can just send signals to electrodes on the controllers. Each controller can receive two different signals.

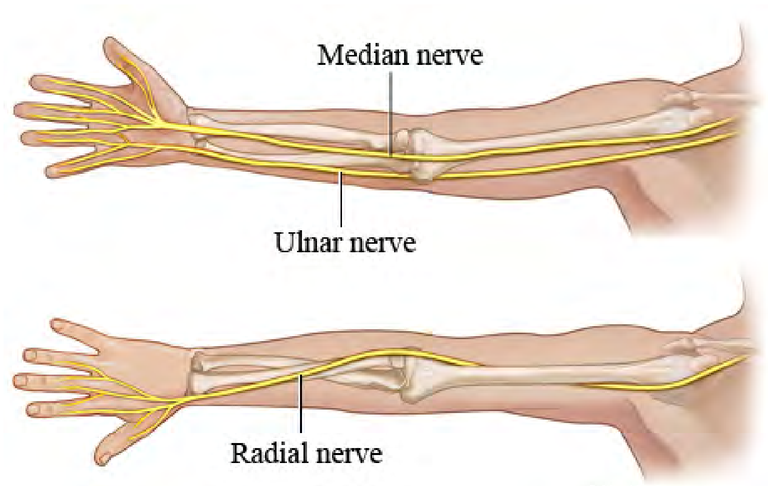
Every received signal lets a different finger twitch and unwillingly press one of four possible buttons. Pressing them moves the snake within the game into the right direction and starts the next calculation loop. The human has not to do anything actively. The game plays itself by activating the right buttons at the right time. However, without a human, the system would not work.

technology

The game itself is a rewritten Python example of a self-playing snake game. This particular example uses a Breadth-first search (BFS) algorithm. It calculates the shortest path towards the goal. Instead of just changing the direction internally, the signal is sent out instead. Through a serial communication with an Arduino, it is possible to activate one of four connected relays. Those relays act as a connection point between signals from a TENS unit and the electrodes on the controllers. Screws are used as electrodes. An aluminum tape around them serves as an extender for the area touching the skin. Buttons on the controller are placed beneath the thumb and the little finger.

Whenever the algorithm calculates a wished input, the corresponding relay is opened, and the electrical signal is sent to the hand causing one of four fingers to twitch. The pressed button sends then a signal back to the Arduino which tells the game over the same serial port in which direction the snake has to move. The position of the electrodes on the controller is crucial for the functionality of the whole system. One electrode always needs to be connected to the wrist while the other two have to be in contact with two different parts of the hand.

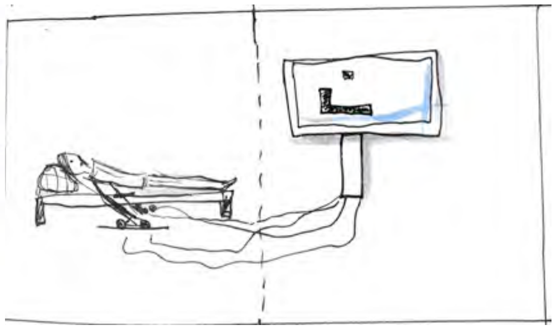
Nerves in the human palm form two bigger clusters. Each triggers when stimulated a different movement of the hand. This way one can at least move the thumb and the little finger by stimulating the appropriate cluster.

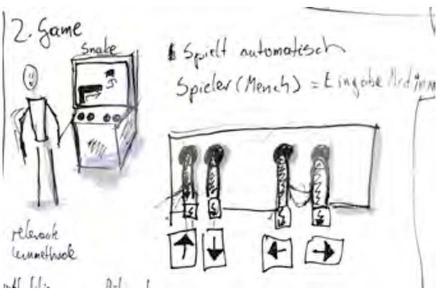


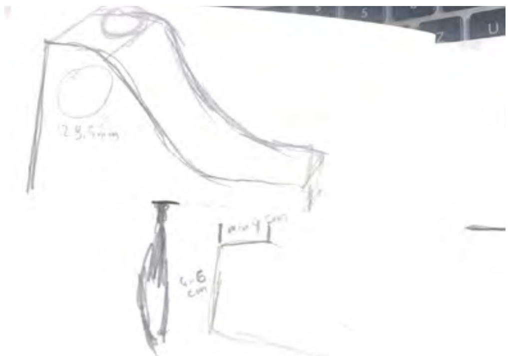
Nerves that run through the human arm and hand [25]

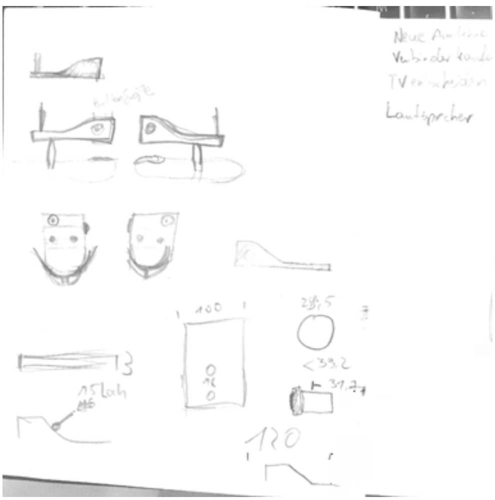
25 Nerves in the human hand, digital photograph, accessed 28.08.2017, retrieved from http://img.webmd.com/dtmcms/live/webmd/consumer_assets/site_images/media/medical/hw/h9991449_001.jpg

sketches



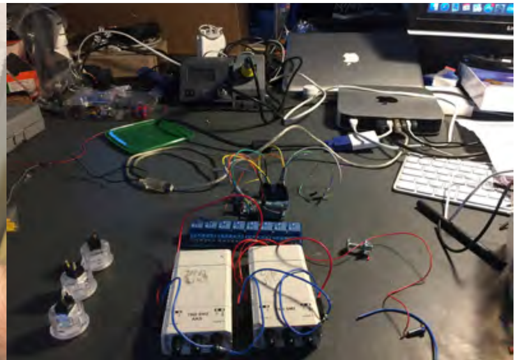


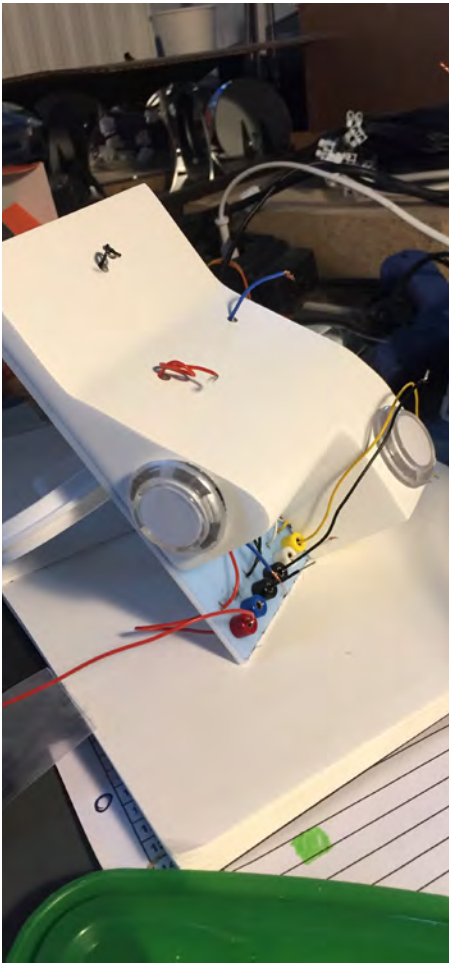
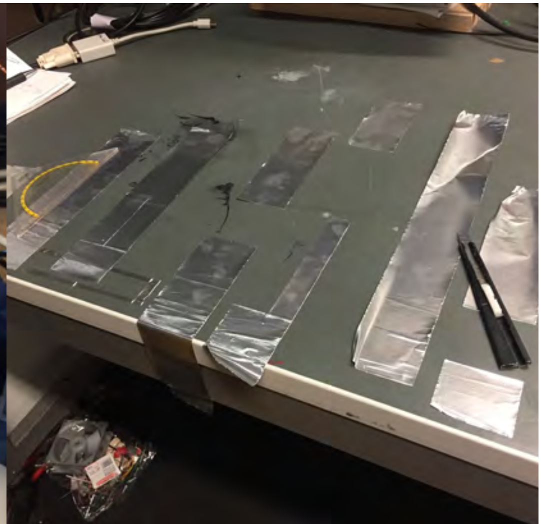
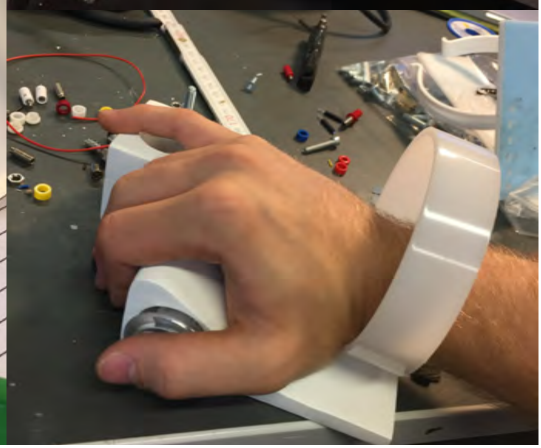



Lautsprecher
100
120

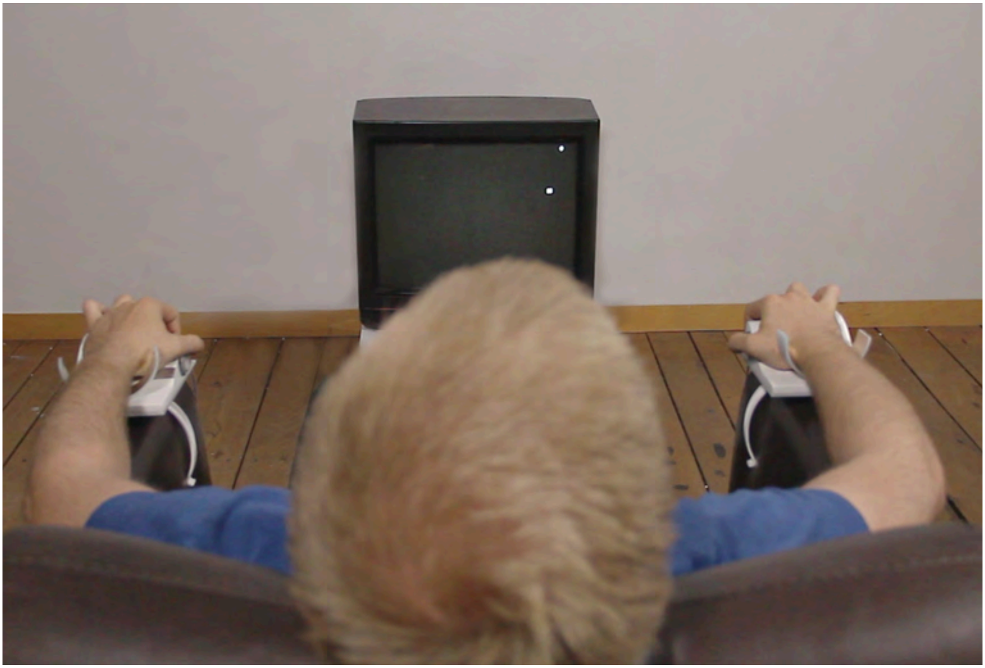

R

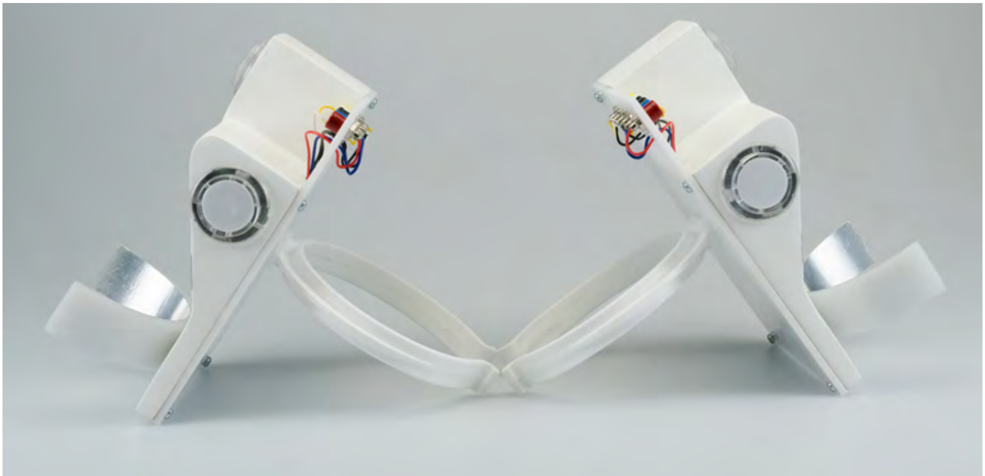
process

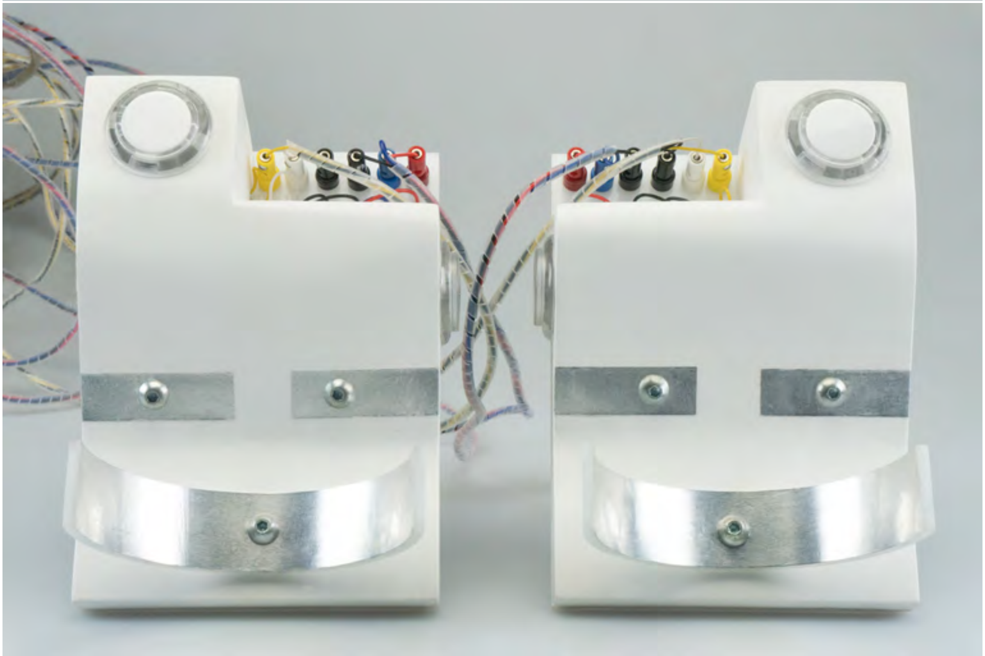


prototype







conclusion

Computer games are generally speaking about having fun. Different from a classic HCI approach there is no real problem one wants to solve as efficiently as possible. Even though it is part of it, it is not easy to categorize computer games with the classic definition of HCI.

There are different approaches toward this. One of them is seeing a game as a task. Finishing it and reaching the end credits is the equivalent of landing a plane or making calculations on a computer. But not all games are designed this way. Computer games nowadays are also used for art where they rather transport a message then being goal oriented. The rise of so-called "Lets Plays" created a whole new industry over the last few years. It has shown that some people enjoy it to experience a game by just watching someone else playing it. So what is the point of computer games then? Is it just the experience?

Evidently, this experience can be transported in different ways. Nintendo, for example, added features for a guided control into some of their latest games. Difficult passages should not frustrate the player anymore, and the game helps to advance. Some people might call this cheating. Real cheating has been present for a long time in other games. Cheaters have a bad reputation. Some games like, for example, "Counter-Strike" have to deal with many of them. Even professional players have recently been accused of using cheats and are not allowed to bring their own gear into tournaments anymore.

Even though the frustration is comprehensible, I still enjoy the idea of a human-computer symbiosis of this nature. It is a fascinating combination of the complex calculations of the cheat and the relatively dull action of the human. Players who are not using cheats are obviously frustrated by performing worse than the cheaters. However, what would happen, if cheating becomes a gameplay element? Would it still be cheating if everybody cheats?

An entirely different approach towards computer games can be found at the scene of speedrunners. They try to find the perfect and optimal way through a given game. Even bugs and unintended ways are exploited.

The subdomain of "tool-assisted speedruns" (TAS) analyses a game frame by frame with a computer so the human can position the character or other gameplay elements accordingly.

With this method, it is possible to create almost the perfect path through a given game. As an addition to that, neural networks also found their way into computer games and probably have the power to even beat tool-assisted speedruns by speed and accuracy. One example for this is “MARI/O“ a neural network with a genetic algorithm behind it that is playing a level of “Super Mario World.“ After countless iterations, the strongest generation of Mario performs perfectly at the given level. This method can also be applied to any other game. All those methods show how different one can approach the same topic. They were the inspiration for this work.
”Twitch“ adds yet another approach to this accumulation. The way it works cannot be described yet. It is a combination of the earlier mentioned methods and it is none of them at the same time. The title is a reference to the website twitch.tv which started the whole ”Lets Play” movement. The success of this website and of the people streaming computer games on it started the discussion about what gaming actually means and if watching a game can be the same experience as playing it.
Using ”Twitch“ really adds a new dimension to the experience of playing a computer game. It is fascinating to experience the perfectly timed moves a computer has calculated physically on the hands. One can even reinforce the experience by not looking at the screen while connected to the game. It becomes irrelevant because the game performs perfectly regardless of whether the user is watching or not. One could even connect a toddler or a really old person to it without changing the quality of the output.
It feels like being controlled but at the same time being in control. Different games can create different experiences. Tetris, for example, could feel very calming whereas games like ”PacMan“ could feel aggressive and frightening. It is not just about playing the game and being played it is also about experiencing the individual characteristics of a game.
Even though computer games are a good way to transport this idea, it is also applicable in many other domains. One example could be the car industry. The future promises autonomous driving for everyone but some people are against it.
They do not like the idea of a machine completely taking control of the vehicle. The sensors in the car would in my scenario not directly steer the vehicle but control the human instead, who then steers it unwillingly.

In my opinion using a human between the calculated output and the input creates a different experience than just letting the computer within its black box control the actions on its own. Even though the result is the same the feeling of being involved changes the whole experience. The human at least has the feeling that he or she could do something even when this never actually needs to happen.
”Twitch“ always needs the human and the machine together, it cannot perform with just one of them. The project is an example of a human-computer symbiosis and there are many more applications that have to be found. Either through usage or through communication of this idea.

Medium Machine

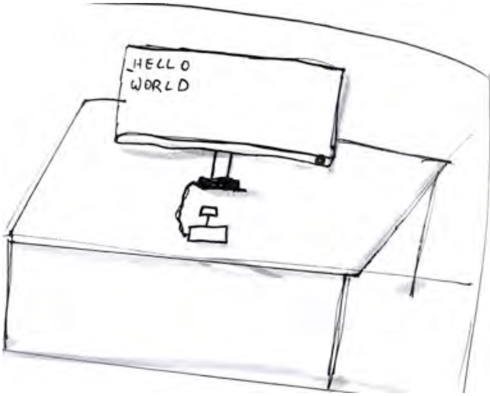
setup

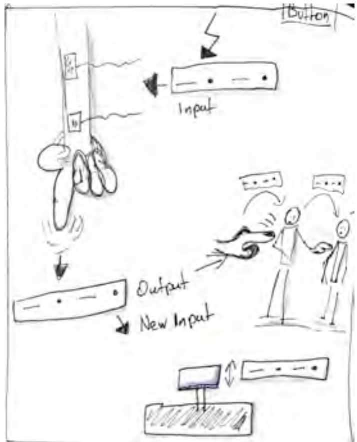
The “Medium Machine“ consists of one encoding and one optional decoding device. The encoding device is a wooden plate with two aluminum rods and a button.
One has to place their arm onto the rods in a way that the index finger is hovering over the button.
Encoded digital data of any kind is sent as electrical impulses into the device. Every signal enables electrical current to flow between the rods and through the user’s arm. It all is happening in a constant loop. The signal lets the index finger twitch and press the button in the rhythm and frequency of the encoded data.
After experiencing the data for a particular time, it eventually wanders into the person’s procedural memory. The user can now replay this information without being connected to the device anymore.
If one wants to understand what the data means, there is a possibility to use an encoding device. It just has a button and is connected to a screen. When using motor memory to press the button the information gets decoded and shown on screen.

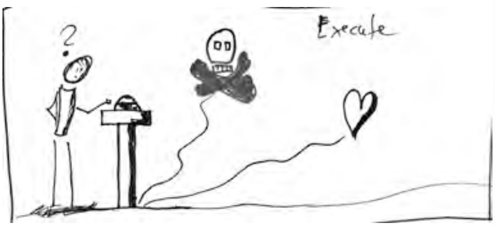
technology

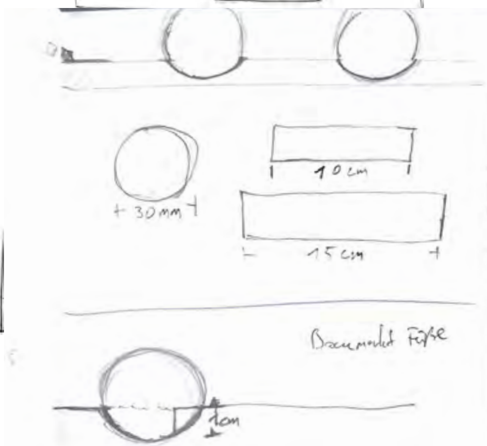
The data in this setup is encoded into morse code with the help of an Arduino. Other encoding methods are also imaginable. The Arduino connects a TENS unit with the aluminum rods through a MOSFET circuit. Each time a signal is sent out by the Arduino, the gate of the MOSFET is opened to allow electrical current to flow from the TENS unit into the rods.
The power circuit that is created in the user’s hand lets the index finger twitch in the exact rhythm of the encoded data. The decoding device is just an optional example of one application for data that was learned in this specific way. It waits for the button being pressed and translates the data back into letters when receiving Morse code.

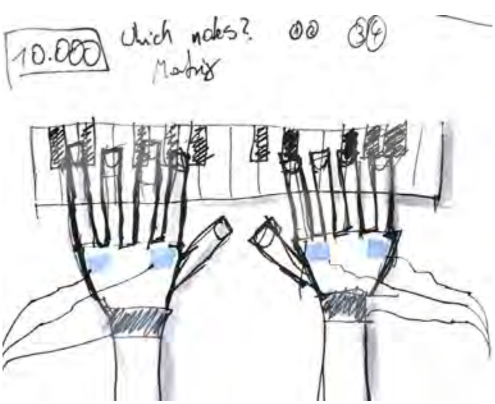
sketches


HELLO
WORLD


Button
Input
Output
New Input

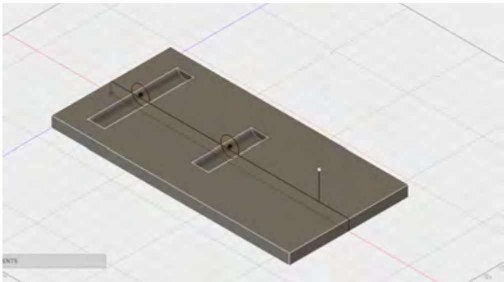

Execute


10 cm
30mm
15 cm
1cm

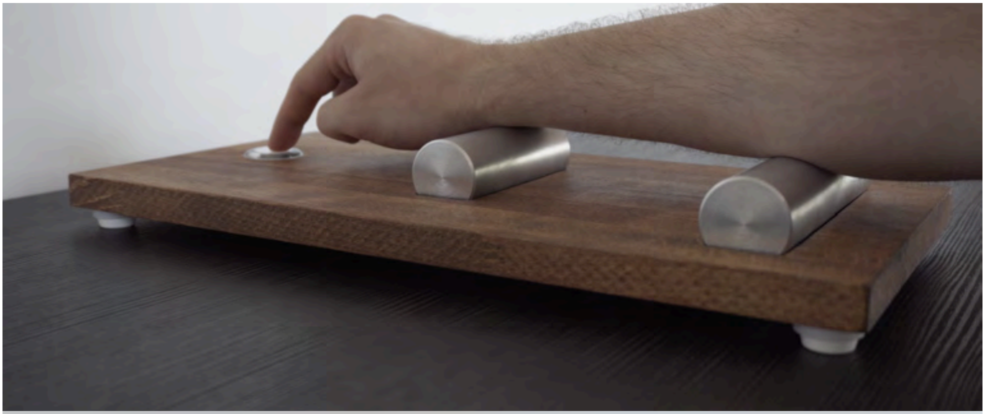

10.000
Which notes?


P1
P2
offline

process



prototype



conclusion

Repetition is the mother of skill. As described before, the skill of learning is a complex process within our brain and our muscles. Some skills as walking or using complex hand motions are just second nature. We are not actively thinking about how we actually perform them. Other skills have to be actively learned first. Nobody just sits on a bike and rides it after the first session. Unknown and new skills have to be experienced and repeated over and over again until the brain and the muscles work in sync. Only then it becomes possible to perform them with less effort.

The ”Medium Machine“ takes advantage of this knowledge and enables to encode information within the unconscious mind by teaching the user a certain movement. Information of any kind can be encoded this way and even repeated when not connected to the device anymore. When connected, the users are just experiencing an undefinable twitching of their hand. They do not know if the information behind it are nuclear weapon codes or just a telephone number. They just act as a medium and transport a given information between interfaces. Those interfaces eventually then decide about the final output.

The idea is inspired by the short story ”Johnny Mnemonic“ by William Gibson, where the main character even had to delete his own memories to save foreign information on his brain to act as a courier for them. Everybody can become a medium with the ”Medium Machine“. It is the basis for future ideas to emerge from. The stored information on its own has no meaning when not interpreted by an appropriate interface. Those interfaces are the actual future this project wants to initiate. The possibilities are endless. Music instruments, vehicle interfaces, passwords, cooking recipes or human to human communication are just some examples that come to mind. Skills and information can just be downloaded and learned by everyone. In the past, people thought differently about the future than it actually turned out to be. Flying cars became electric and autonomous vehicles of today. When talking about brain-machine interfaces, many people seem to have a certain vision of how those interfaces are going to look like. Most of them include devices with a helmet and sensors connected to different regions of the head. Even if this really is how future BMIs will look like, it is still important to think in different directions. Suggestions as the ”Medium Machine“ and its possible applications are also worth to discuss and think about.