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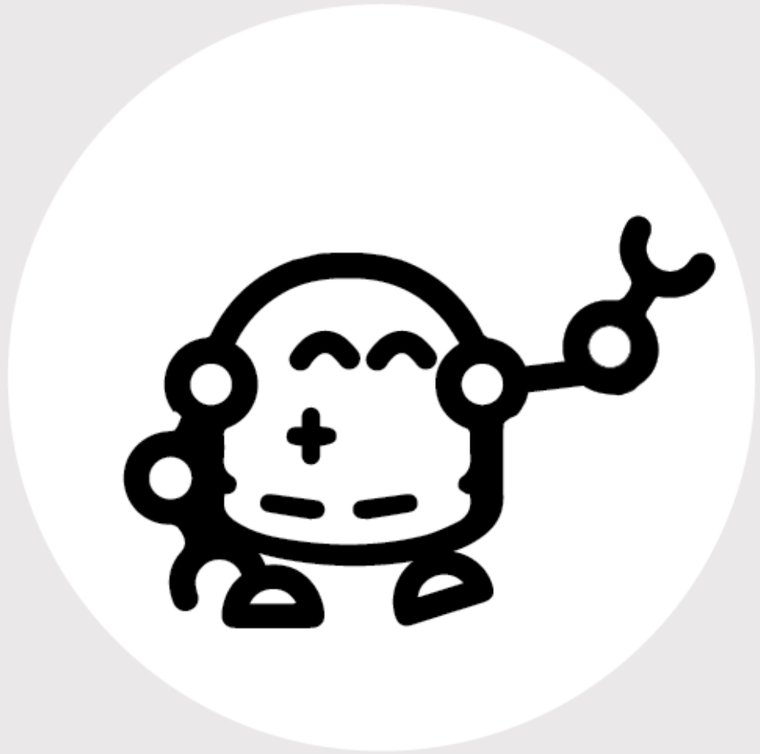


THANK YOU FOR READING!

APPENDIX 1
Voxel 8 troubleshooting

Observation	Problem	Solution
Printhead extrudes plastic but does not perform the print	The printbed is not connected well enough	Wiggle the bed untill connection is made and bed temperature is displayed
The silvertip collides with the printer	The printbed is not connected	Place the printbed back
Unable to jog	Unknown	Reboot
Printer disconnects and stops midprint	Something with IP Address	Connect to different Router
Ticking noise while printing plastic	Partial clog	Clean head and perform Atomic Pull
There is filament but it is not extruded	The filamentroll can be too heavy for the gears	Unroll the filament partially
Printhead smudges the silvertraces while printing	The silver clamp padding is broken	Replace silver clamp
Plastic/silverdetails are not printed	The details are too small for the slicing software	Check the print preview before printing and enlarge details
Trouble lowering and raising silver	Unknown	Remove silver nozzle configuration from its base to examine and place it back
Nozzle is automatically alligned but seems to be too far from the bed	Debris is stuck between the lever and the printbed	Remove printbed and check for debris
Silver align keeps failing	Silver ran out or tip is clogged	Check the status of the silver and replace the tip
Print is canceled but the print continues	Printer wants to finish its command	Use stop motors
Silver trace is broken during printing	Consistency error	Check surface quality and try again
Printhead is so close to the printbed the printbed is knocked off	The silver tip has been dislodged during leveling	Secure the silver tip better and level again

BEST PRACTICE

- “Lowering silver” is the quickest way to lower the bed
- If it has been a few days that the printer is not used perform just a silver align instead of a pressure wipe
- Don’t print silver directly on the bed
- When jogging the Z-axis press UP for the bed to go DOWN

APPENDIX 2
Grasshopperfile PTA

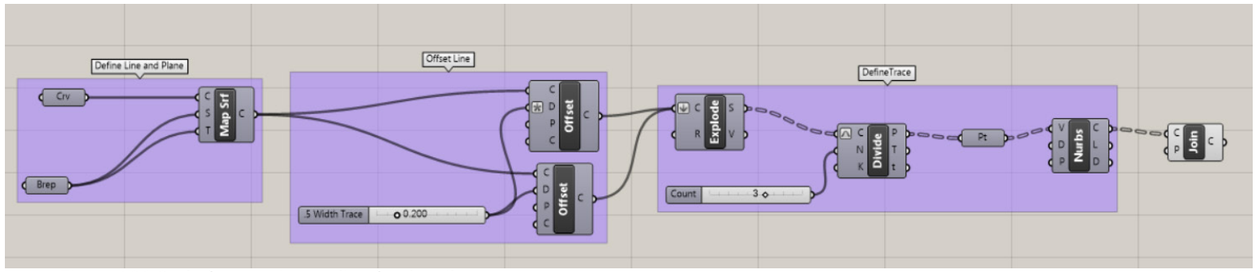


Figure 106 Code for creating outline for the silver trace

Grasshopper is a graphical algorithm editor for Rhinosceros 3D modeling software. To aid in this project a parametric model has been created. This Grasshopperfile can generate a copy of the PTA that is used for observations in June of 2017. It can create a base, rim, connection for power-source and a silver trace.

Variables that can be influenced are:
- Length Base
- Width Base
- Height Base
- Depth Power Connection Base
- Thickness Rim
- Depth Rim
- Width Silver Trace
- Amount of detail in Silver Trace

To use this model the user needs to input a plane and a polyline. These are used to create an outline for the silver trace.

To export a PTA from the Grasshopper to the Rhino software they need to be baked into the correct layers. The plastic and silver can be exported separately and joined where necessary. For the silver trace only the lines are generated. After baking the lines need to be joined and extruded .2 mm.

A PTA does not need to be generated via this grasshopper file or a model created in Rhinosceros. But using a parametric model has advantages

- The model is completely symmetrical
- Iterations can be made in a controlled way
- Iterations can be made quickly
- Different silver traces can be generated with little effort
- Each design can be placed in a new 3d model file

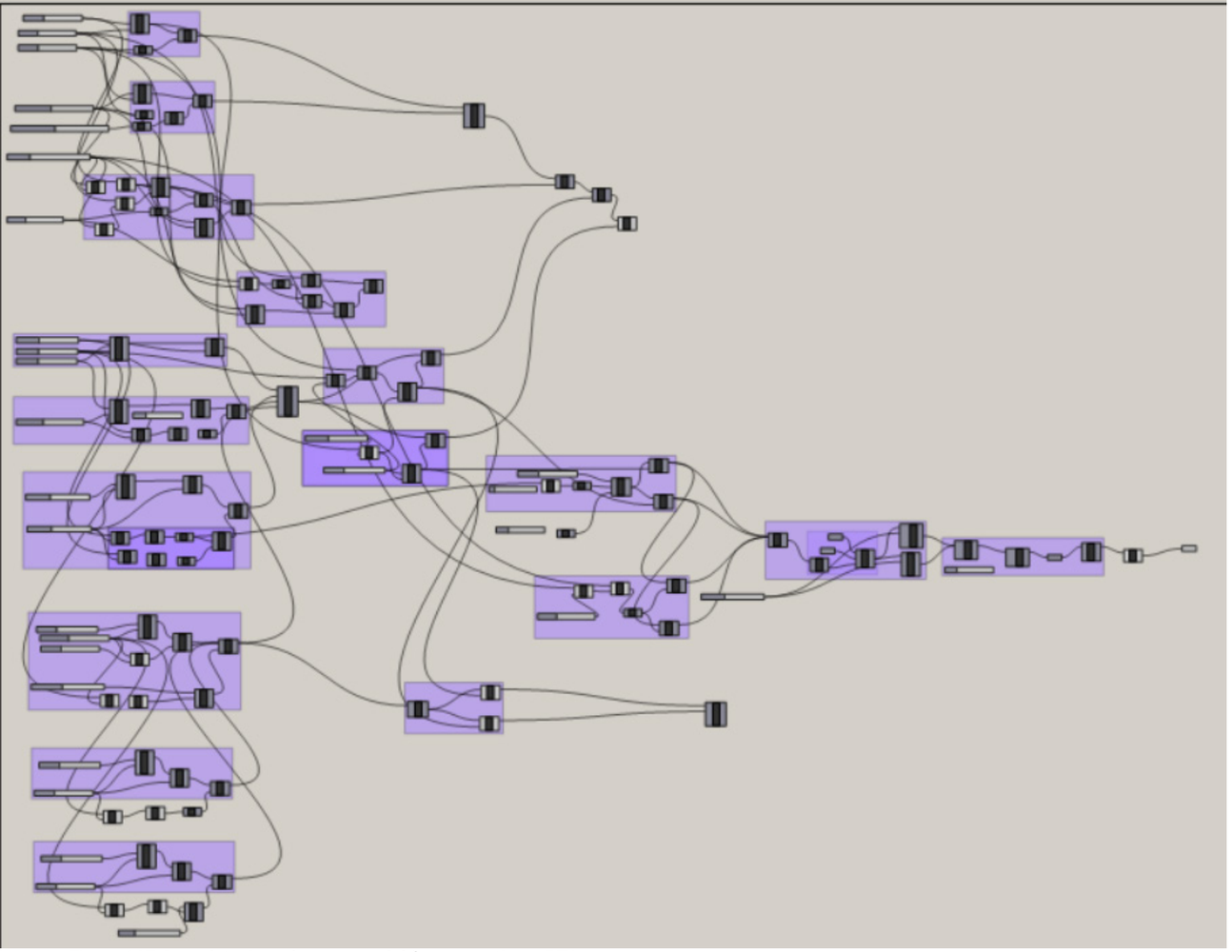


Figure 107 Complete Grasshopper model for generating a PTA

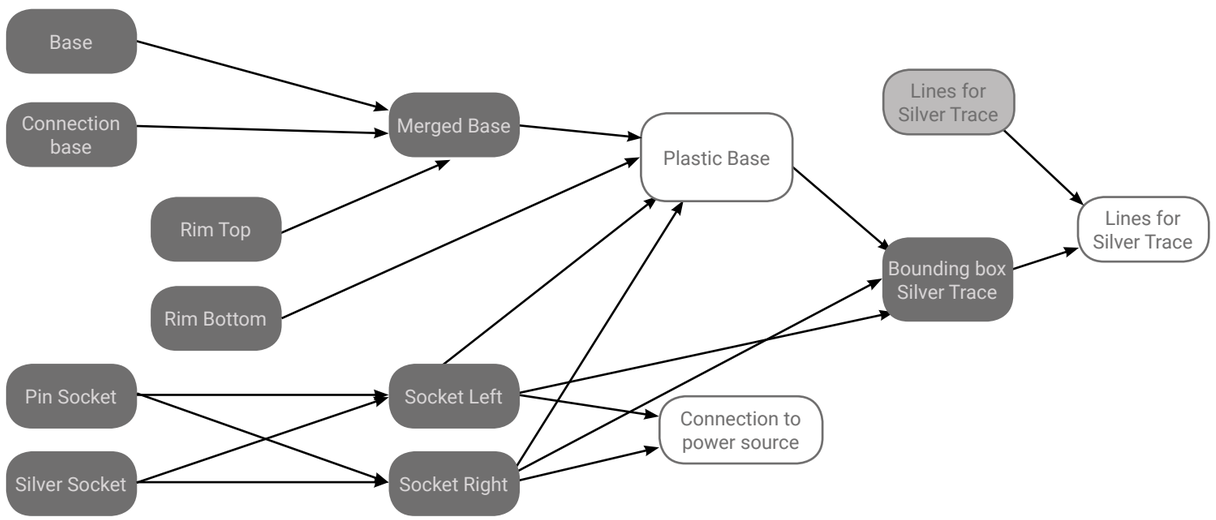


Figure 108 Diagram of Grasshopper model

APPENDIX 3
Results Usertest

HOW WOULD YOU DESCRIBE THIS SAMPLE TO A FRIEND?

Black piece of paper with silver pattern on it, Gray plasticlike rectangle of flexible material with silver drawing, Black plastic with electronics rumming over, Platic sheet with copper circuit, Component of an electrical device, Black rectangle with silver metalic parallel lines with larger dots at both ends, It is black and contains a metal strip, Black strip that probably directs current, Flat rectangle black looks like a battery or memorycard, Flexible, bendable small rectangle with thin lines and 2 squares, Small plastic chip with a metallic printed wire, Small black rectangle, size of an sd card with 2 silver paths at the bottom connected with a pattern of lines, Small black strip with an antenna like sensor, Flexible rectangular chiplike thingy, A long flat piece with silver pattern. A pattern like a battery, A piece of plastic with an electric current drawing on it

WHAT DOES THIS SAMPLE REMIND YOU OF?

Like a circuit, Piece of fabric that is coated, PCB, Flexible PCB rubber protective dud, Some kind of anti shoplifting label, Chip, PCB, Tensile bar, A kind of computerchip, Battery memorycard, A computerchip, A computer chip or a sensor, Computer chip, Tensile bar, Microchip, A battery of a dynamo, something with electricity

WHAT OTHER WORDS WOULD YOU USE TO DESCRIBE THE LOOK AND FEEL OF THE SAMPLE?

Metallic, Paddles, Modern, Sharp, Industrial, Modern, Rough, Flexible, Fabriclike, It looks more flexible than it is, Simple, Striped, Fabriclike, 3D printed black flexible, Plastic, shiny woven, Flat rectangular black, Textile like structure, Camouflagable, Weird, Contrasting colors, flat light textured, Sturdy, Basic

WHY IS THIS EXAMPLE YOUR FAVORITE?

Looks most realistic, Speaks most for itself, Looks Natural, interesting because electronics, I want it to jump, It's like a robot, Because it looks most effortless, Looks nice, It moves multiple ways and looks like an critter, It's just cool, It is pretty, Looks natural, Because it gives the best 3D feel (insead of 2d), Seems the most complex and looks nice, Easy and attractive way to show the principle, Looks like a finished product, Looks like a butterfly that can fly away, It looks like a creature

WHAT DOES THE BEHAVIOR OF A 3D PRINTED THERMAL ACTUATOR REMIND YOU OF?

SeeSaw, Muscle, Spring, Party blower, Flowers opening and closing during the day, Memory shape materials, A paper that curls up when it burns, How flowers or animals move, Flower, animal, Snap bracelets, Relais Phase changing materials, Bimetal Thermometer, Plants, Reflexes Growing plants, surgery arms evolutionair algorithm simulations, a butterfly or insect, Mechanical actuator

WHAT OTHER WORDS WOULD YOU USE TO DESCRIBE WHAT YOU THINK ABOUT 3D PRINTED THERMAL ACTUATORS?

Innovative, new technology, Future, Less industrial than I thought, Fragile, Low cost, easy, It looks versatile, Cumbersome, Sensitive, Cool, It can have a broad application, Innovative with a lot of potential, Gadget, Innovative, Customizable, Movement Strandbeesten, Automatic efficient

WHAT KIND OF APPLICATIONS DO YOU THINK 3D PRINTED THERMAL ACTUATORS WILL HAVE?

Easier assembly, less fragile, Artificial musle like applications, Toys Robot, Feedback loop, Toys?, Automatic processes, Small monster, Opening and closing circuits that need to react to temperature, Childrens toys, household appliances, “Design for everyone” , Touch sensor placement, Micro nano engineering, small flying creatures that can spy like a drone, Applications where a transient motion is required

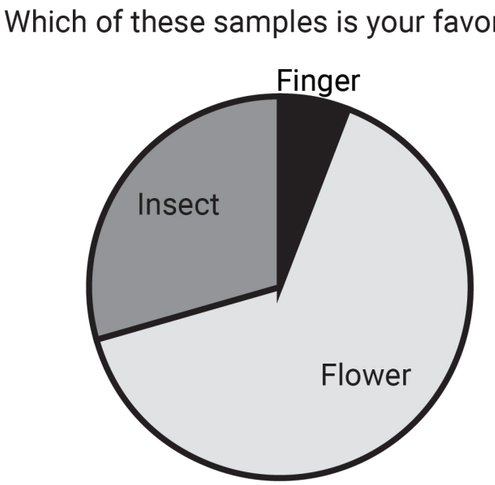


Figure 109 The favorite example of the participants

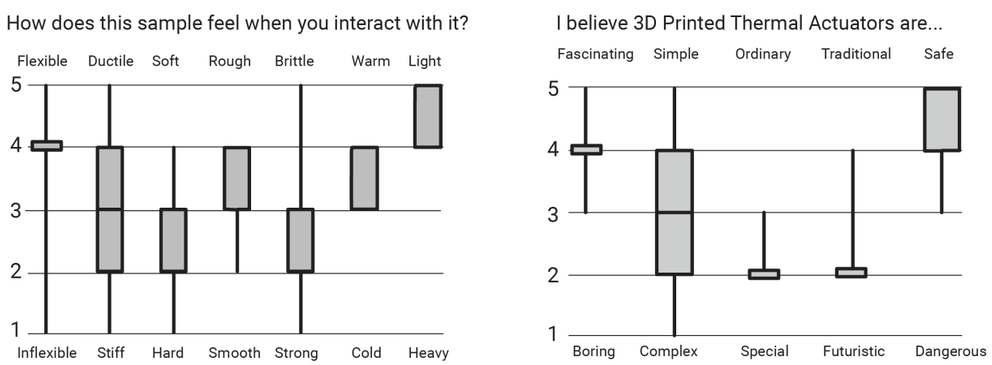


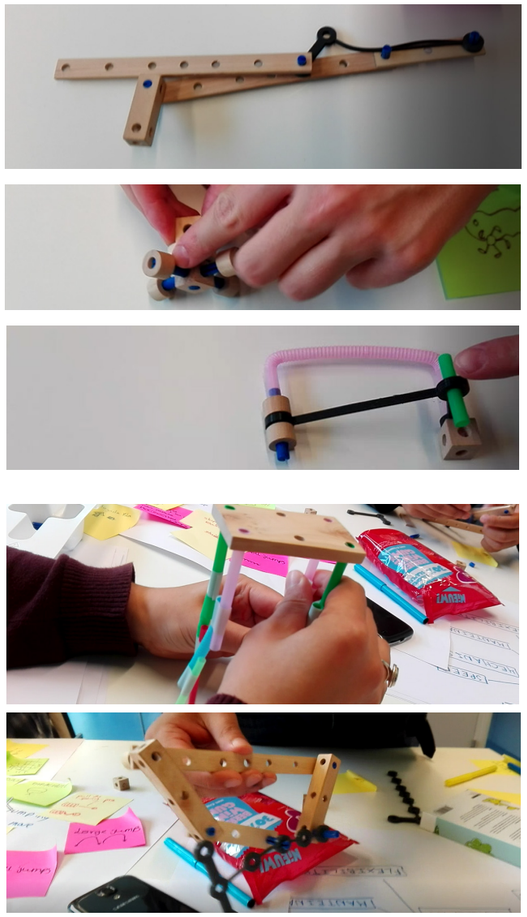
Figure 110 The results of the likert scale used in the questionnaire

APPENDIX 4
Results Creative session

Figure 111 An impression of the creative session

On August 17th a creative session was held. The participants were Gerbera Vledder, Doenja Maris, Laetitia van Wijnen and Guillermo Marquez. The session started with a warming up to get the creative juices flowing. Then the participants received an introduction to the goal of the session. The goal was “Define ways to translate the motion of a PTA into locomotion”. With Guided Fantasy different ways of locomotion for robots were defined. Based on the different animal kingdoms defined in the scope, more ways of locomotion were defined. These different ways of locomotion were clustered in different categories: Screws, Moving the center of gravity, Walking legs, Propulsion, Grabbing, Rolling, Jumping, Floating, Sticking to surface, Heat, Sensing, Muscles, Crawling legs, and Joints.

After defining the most relevant clusters the designers discovered different ways to move based on the clusters: Joints/Muscles, Sticking, Legs, and Jumping. After the different ideas were shared each of the designers picked a method to recreate using Meccano with custom bending pieces to simulate a PTA and straws.



APPENDIX 5
MDDM Cards

When working with the Material Driven Design Method different qualities of the new material are collected. These qualities have been captured in a set of cards. These cards can be moved around and patterns can be discovered. Three categories of cards have been made. Experiential Qualities have been collected with a user test. Technical qualities have been collected with tinkering. Finally, a set of cards have been made based on a benchmark. This last set ended up not being very useful since the shape morphing materials that have been compared were not relevant enough to the goal.

Experiential Qualities

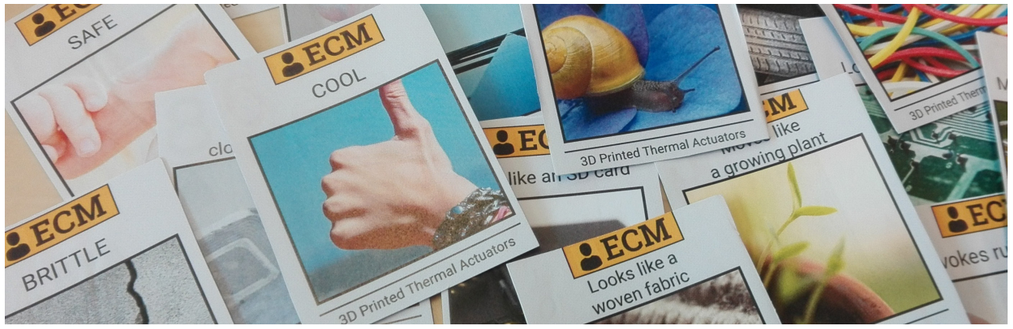


Figure 112 Cards for Experiential Qualities

- LIGHT
- FASCINATING
- SAFE
- COOL
- FLEXIBLE
- MODERN
- BRITTLE
- SIMPLE
- THIN

- Looks like a PCB
- Looks like a woven fabric
- Looks like rubber
- Looks like an SD card
- Looks like a clothing RFID tag

- Moves like a spring
- Moves like a growing plant
- Moves like a party blower
- Moves like burning paper
- Moves like a muscle
- Moves slow

- Evokes bending
- Evokes holding
- Evokes rubbing

Technical Qualities

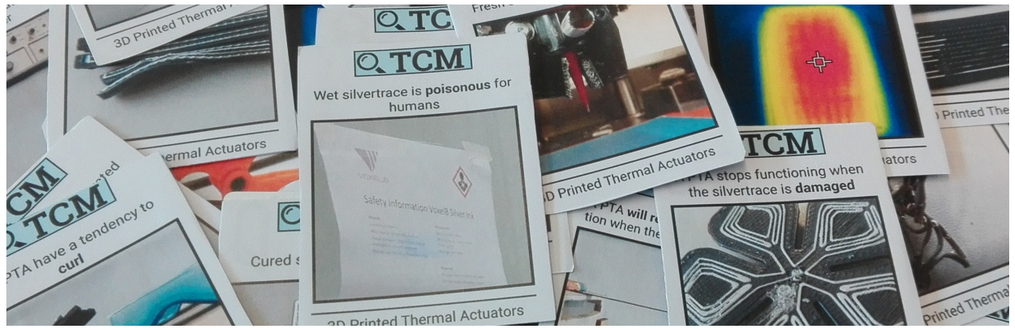


Figure 113 Cards for Technical Qualities

- A PTA needs about **1 Watt** of power
- A PTA gets **hot** when activated
- A PTA needs to be **tethered** to a power supply
- A PTA needs to be 3D printed with a **Voxel 8 FDM** printer
- A PTA consists out of **PLA and a silvertrace**
- A **thin** silver trace get's hotter than a thick silver trace
- An increase in **density** of traces will increase the temperature
- Thin PTA have a tendency to **curl**
- A PTA is **pliable** at 50 degrees Celsius
- A PTA **melts** at 200 degrees Celsius
- Silver traces **erode** when touched often or without care
- A PTA will not function when in **wet conditions**
- The silver trace is the only part of the PTA that is **conductive**
- A PTA is **not sensitive to magnetic** fields
- Fresh silver trace is like a **liquid**
- Cured silver trace is **brittle**
- A PTA stops functioning when the silver trace is **damaged**
- The position of the **brim** will determine the way the PTA will bend
- If the PTA has more PLA it takes **more time and energy** to bend
- Wet silvertrace is **poisonous** for humans
- PLA is made out of plantlike materials
- A PTA will **bent** when activated
- A PTA **will return** to a similar position when the stimulus is removed
- A PTA loses its internal stress after **three days**
- Creating a PTA in bend position is harder than in **flat position**
- A broad PTA has a tendency to **arch** which limits bending
- By manipulating the silver trace behavior can be **programmed over a time**
- **A PTA can be created in a large range of different sizes**
- A PTA can **repeat** it's motion
- A PTA can be produced in **under 30 minutes**
- A PTA is **not sensitive to human errors** during production
- A **cool environment** has positive effects on the lifespan of the PTA

Patterns

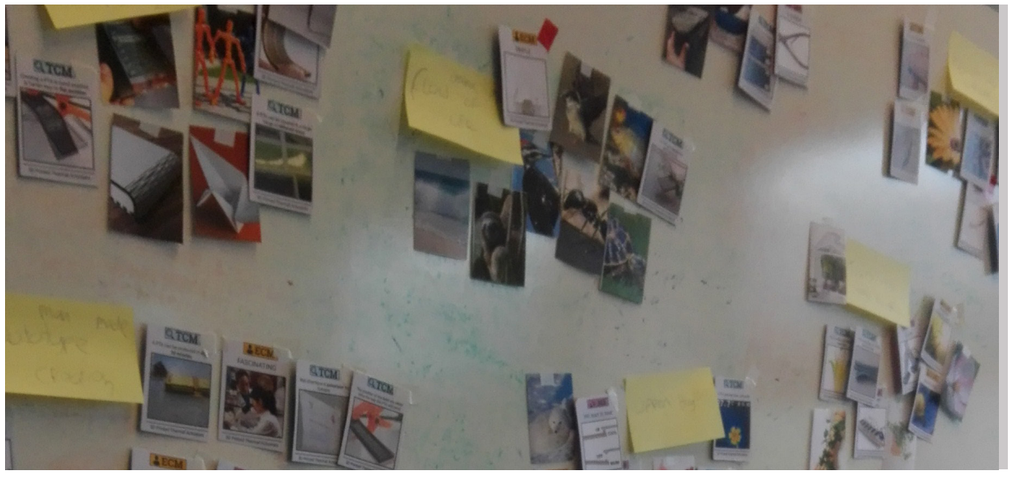


Figure 114 Finding patterns with the MDDM cards

With the cards, different patterns were discovered. That will be explained here.

FOLDING AND MOLDING

In this category, different expressions of bending/folding were explored. Permanent folding can be used to mold different art projects like animations or origami. When PTAs have a sharper bend/fold they would be of use here.

PROTOTYPE CREATION

This category mainly contained the benchmark cards bus emphasized that PTAs are designed by man but created by machine.

TRANSFORMS ENERGY

Seeing a PTA transform is considered to be cool and compared to a number of other things like party blowers and burning paper. The fact that a PTA translates energy into heat, and heat into movement is what makes it special.

WARM HUG

In nature, a warm body temperature is needed to survive. Mammals use coats and birds use feathers to stay warm. Parents can hug their offspring to keep them warm. Humans use hot water bottles to keep themselves hot in the winter. PTAs can also serve as a heat source. But they might need an isolating layer since they might become too hot.

SOFT TISSUE

The behavior a PTA performs once it gets hot makes it seem like it is flexible and even soft. The association with rubber and fabric emphasizes this. A logical step would be to use PTA in the field of soft robotics.

SLOW NATURE

Slow movements are not very common in machines but more common in nature. Plants and flowers move and grow at a very slow pace. Animals like snails and sloths also move slow.

FUNCTIONAL ELECTRONIC PART

In this category, very practical cards could be found. A PTA remains a part of a larger goal and cannot serve a good use on its own.

DELICATE LIKE A FLOWER

A PTA is fragile and brittle. Especially when it is handled often and when it is activated. A PTA should be handled with care. In nature there are also elements are damaged easily and are handled with care by humans, like flowers.

APPENDIX 6
Characteristics

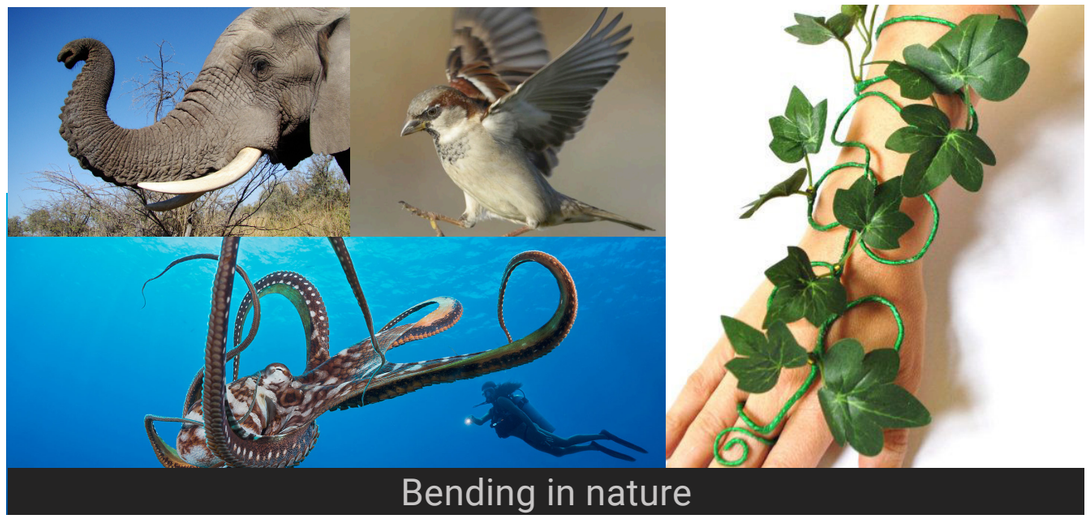
On “Qualities of PTA” on page 45 the most significant qualities of a PTA are defined. Some of these characteristics can also be found in nature and can serve as inspiration for creating concepts for the demonstrator.

The characteristics light weight, low energy, repeated actions, and 3d printed quickly are not really found in nature and are left out of this analysis.

Slow movement in nature

Animals that carry protection or are on top of the food-chain can afford to move slowly. Turtles and tortoises can hide in the shell if there is a threat. Snails also have a shell in which they can hide.

Sloths do not have any enemies so they can move slowly and eat all day. Flowers move slowly to catch the most sunbeams which helps them to grow and attract pollinating insects.



Bending in nature

In contrary to mechanical machines bending limbs are very common in nature. These bending motions are usually created by combining different muscles as seen in trunks of elephants or tentacles of octopuses. Birds have limbs that repeat a bending motion to create enough propulsion to fly. Flowers bend their petals when they bloom and plants, especially vines, use their winding branches to climb up and receive as much sunlight as possible.

Heat generation in nature

Mammals need to have a specific body temperature to survive. A lot of mammals living in cold conditions have a thick coat to protect themselves from the cold climate. Macaques search for hot springs to stay warm with little effort. Birds that lay eggs use their feathers and body warmth to hatch their offspring and protect them from influences from outside. Volcanic eruptions are natural phenomena that produce a lot of heat. This heat is more destructive than the heat that animals exert.

Delicateness in nature

Delicate- and frailness is relative to the organisms it entails and the organism that exerts handles it. Baby animals are usually considered delicate since they need to grow and develop the proper protection against the weather and predators. Animals have an instinct to protect baby animals, this instinct is triggered by looks that are considered cute. A lot of plants can only protect themselves against forces of nature but not against any other force which can make them delicate. A dandelion whoever makes use of its frailness and uses it to spread its seeds on little parachutes.

APPENDIX 7
Arduino circuit and code

```
/*
  This code is adapted from the example code Blink
  http://www.arduino.cc/en/Tutorial/Blink
*/

// initialize pin 3 as the relay pin
const int Relay =  3;

// the setup function runs once when you press reset or power the board
void setup() {
// initialize relay pin as an output pin
  pinMode(Relay, OUTPUT);
}

// the loop function runs over and over again forever
void loop() {
  digitalWrite(Relay, HIGH);   // turn the relay off
  delay(60000);                // wait for a minute
  digitalWrite(Relay, LOW);    // turn the relay on by making the voltage LOW
  delay(60000);                // wait for a minute
}
```

Figure 115 The code that is used to control the arduino and relay

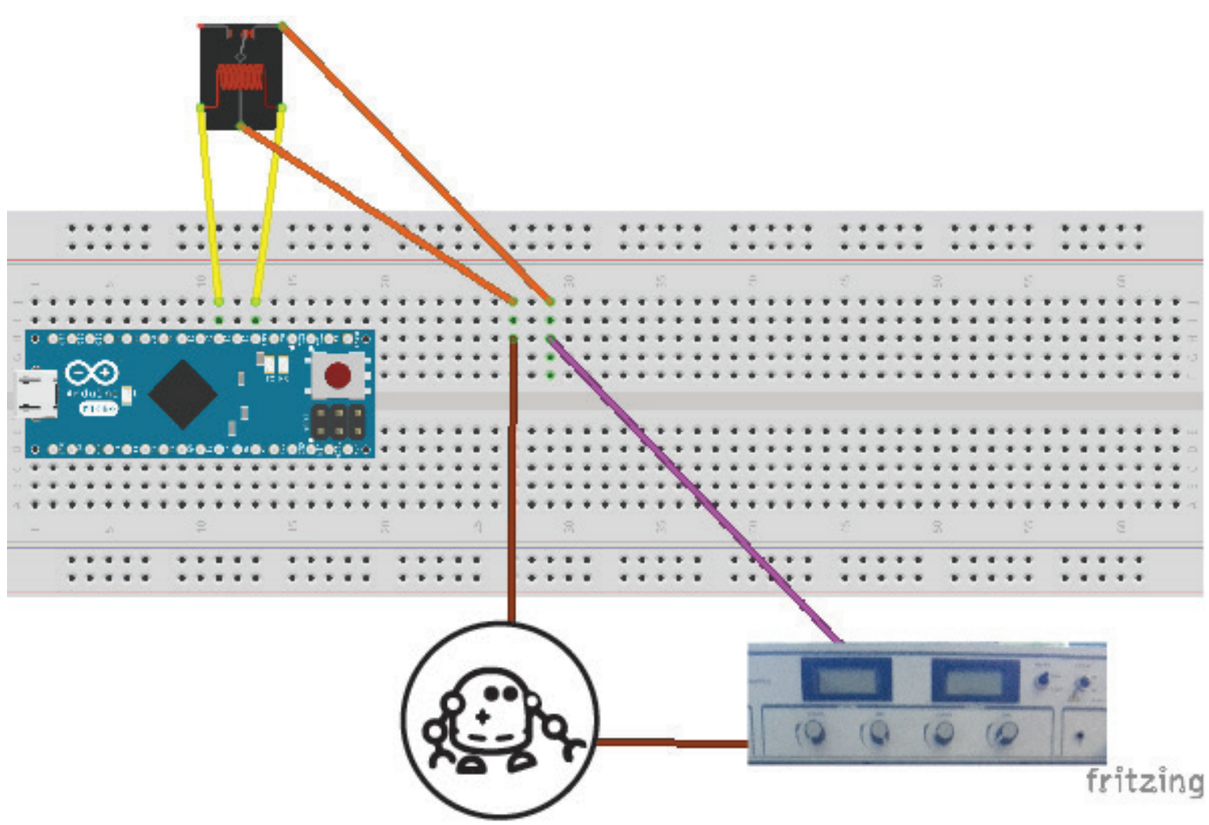


Figure 116 The set-up that is currently used to control the PTAs

APPENDIX 8
Results of Aesthetics Survey

The survey only consisted out of two questions; Which of the turtle shells do you find most fascinating and how exciting do you find the previously mentioned designs.

The survey has been distributed to master students at the faculty of Industrial Design Engineering. The survey completed by 26 participants

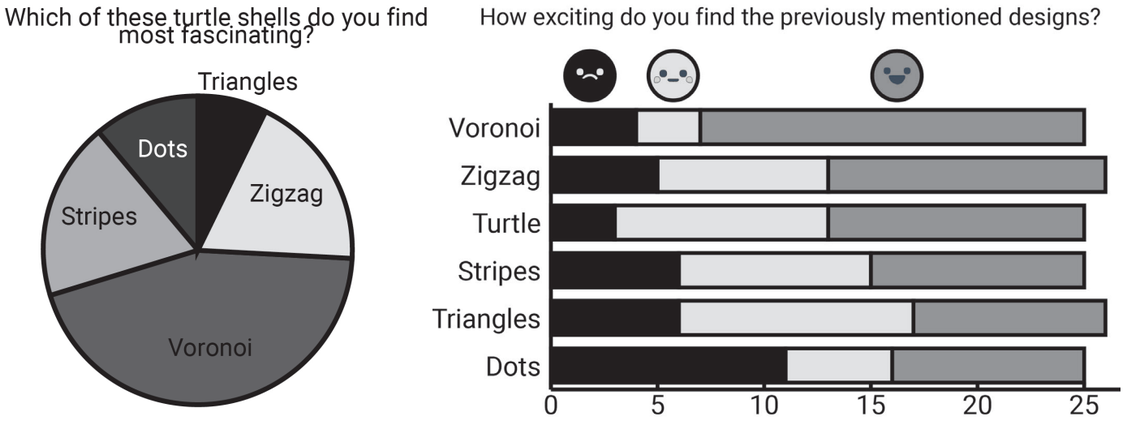


Figure 117 Results of the short aesthetic survey

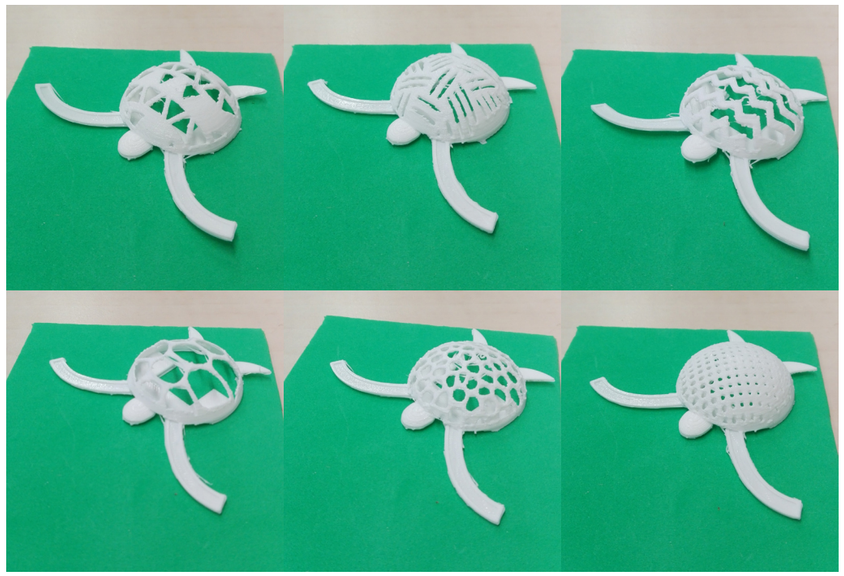


Figure 118 Images used for the survey

APPENDIX 9
Final Design

Turtle Demonstrator
Created by Mariska Maas in 2017

Units in mm