Internship Report Fablab Amsterdam

"Design of a physical computing starters kit for use within a Fablab"

Student: Pepijn Fens (s0080237)

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Coach: Jean-Bernard Martens

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Preface

This report aims to be a research- and internship report in one. With this report I want to present the research I have done during my internship but also explain the vision of the place where I have worked this semester. I have learned many useful things during my internship; for example how to control machines and how to present for groups of people. Not everything that was helpful for me this semester is related to the research that I present in this report, therefore I created an extra chapter in the back which describes some of the extra activities more elaborately. Working on different smaller design projects at the fablab thought me more about designing and working together, than my own research project, which was more aimed at developing a product with the competencies I have. Nevertheless, I have enjoyed every day as an intern for the Fablab in Amsterdam and in the future I will return regularly to work on other projects.

The red colored “Reflection” headings emphasize moments in the design process that made me reflect on what I was doing. Also reflection headings are placed near activities which have had an influence on my vision.

Introduction

The goal of the product is to introduce FabLab visitors to the possibilities of interactive products. Interactive products usually consist of electronics (sensors and actuators). The problem is that designers who want to add interaction to their products do not have the necessary knowledge about electronics to achieve this interaction. They might know what sensor or actuator they want to use, but they cannot achieve this through electronics. Therefore, the goal of the project is to give people without skills in electronics the tools to prototype interactive products.

The product I have designed during my internship at the FabLab in Amsterdam is able to teach people basics of physical computing. With this product, people with no earlier experience can create an interactive prototype easily. The product also functions as a stepping-stone for people who want to dive deeper into programming and physical computing. People visiting a FabLab can use the product, and eventually a global adoption of the product by the FabLab community would be interesting.

From the beginning, I focus on FabLab visitors, because the final product should be available at multiple FabLabs. I will use Arduino (see page 12) as the hardware platform to build the product upon, since it is an easy to use hardware platform, which already has much support from the community.

Design Context

FABLAB

The first definition of a FabLab comes from Neil Gershenfeld, one of the founders of personal fabrication:

> *"A FabLab is a collection of commercially available machines and parts linked by software and processes we developed for making things." (Gershenfeld, 2007)*

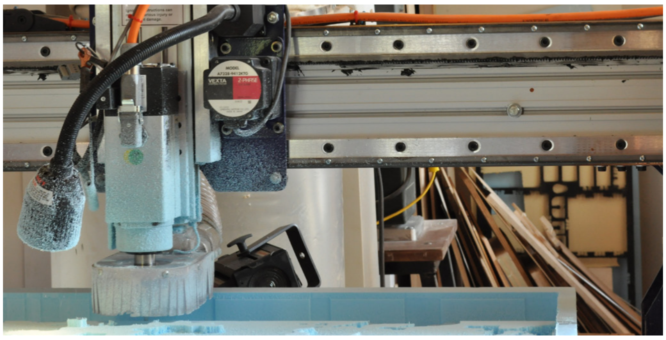
This quite a broad definition; over the years the definition has developed to become more than just a collection of machines, it is a social workplace for makers. The key element of the lab is the collection of machines; without these, there would be no possibility for making. FabLabs around the world have a standardized set of machines in their inventory, to ensure that they can reproduce the shared digital designs from each FabLab on earth. The second key element of the lab is the workplace as a social community; people working on different projects in the same workplace often help each other. This is motivating for both, and helps them to finish the designs they work on. A positive side effect is the possibility of influencing each other, and therefore designing even more. At that point, a community starts to take form, and this is the goal of a Fablab: "Supporting the community of makers".

DISMANTLING A FABLAB

An inventory list of a starting FabLab has to have the following machines:

Laser Cutter

This device (Spirit GE Laser Cutter) is able to cut materials with high precision. Used for thin wood, Perspex, cardboard and different textiles.



CNC Milling Machine

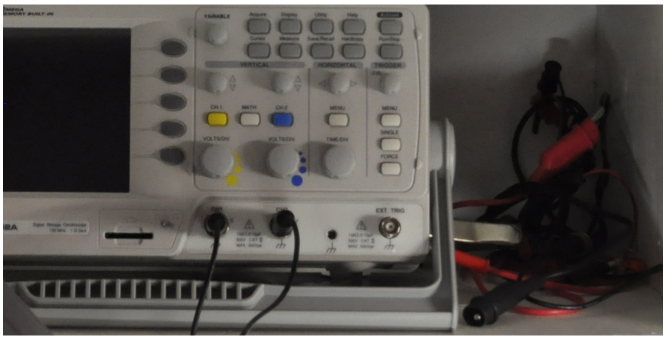
Milling machines are able to mill a 3 dimensional shape from a digital drawing in any material with high precision. Smaller milling machines offer higher precision while bigger machines are able to mill much bigger pieces of material faster. In Amsterdam, we have the Modela for high precision and the Shopbot for large pieces.

Vinyl Cutter

This device can be useful for creating stickers or other graphic material. Custom designed vinyl stickers can enhance a dull design. The vinyl cutter can also cut out flexible circuit boards from copper vinyl.

Automatic Embroidery Machine

Unique in the Fablab in Amsterdam is the Automated Embroidery machine. This machine is able to embroid digital drawings into different kinds of fabric.



Electronics workshop

An electronics workshop gives people access to electronic parts to design their own electronic circuits. These parts can be sensors, actuators, or other parts such as resistors and capacitors. Standard tools such as a soldering iron and power supply are available.

Regular Tools

Next to all the digital fabrication machines, a FabLab

should also have an assortment of regular tools. These tools simplify work when digital fabrication just does not cut it.

Related products

Searching for similar products is a great way to define how the product should look like. All of these products share one or more aspects that I would like to see back in the final product. The main goal of these products is to teach the user how to work with interactive systems.

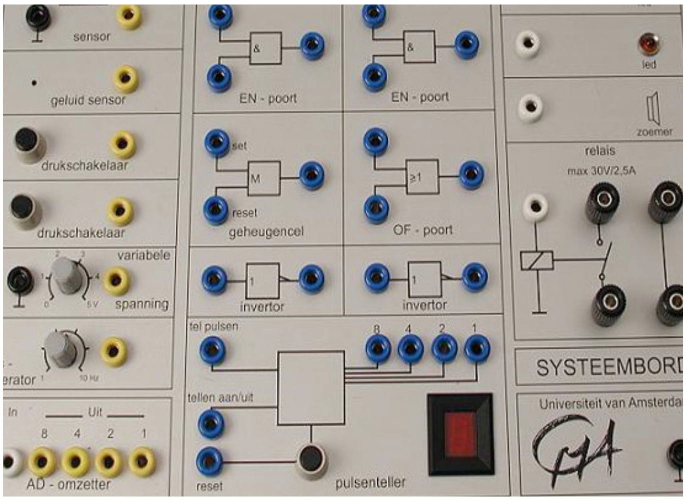
SIMPLE ELECTRONICS BOARD

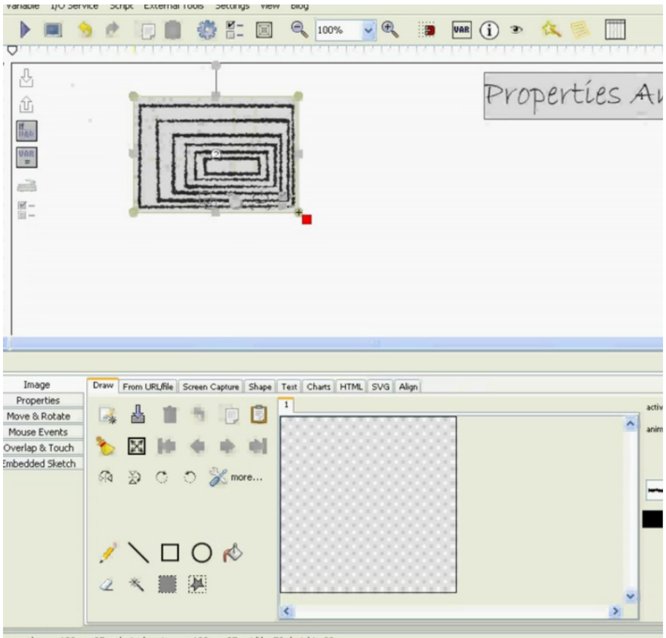
The electronics system board is a widely used tool during the physics course. The board gives high school students practical experience with electronics without hurting themselves, and without having to solder complicated electronics circuits. It is aimed at teaching students the logic behind electronics using sensory input, processing using transistors, and output as an actuator, in the form of light or sound. There is also a software version of the board available, in which the user can draw lines between the different modules, instead of physically connecting them.

SKETCHIFY

Sketchify is software that can help users in creating interaction via sketching boxes and connecting these. The goal is teaching children logic, by replacing programming text with a user interface. Sketchify can also connect to all kinds of external services and sensors to make working a lot easier.

Sketchify has been developed at the ConceptLlab by Obrenovic in collaboration with the faculty of industrial design. (Obrenovic & Martens, 2011)





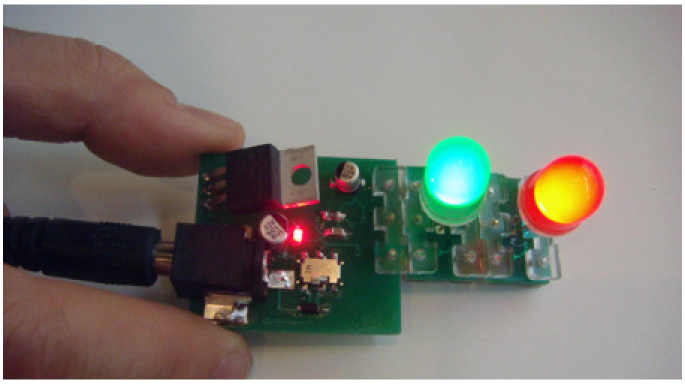
EYEBEAM LITTLE BITS

Eyebeam created a modular toolkit called 'Little Bits'. This kit contained all kinds of modules that designers can connect to each other to form an electronic circuit. This way, they can create an interactive prototype, even in an early stage of the design process. (Eyebeam, z.d.)

"littleBits is an open source library of discrete electronic components pre-assembled in tiny circuit boards. Just as Legos allow you to create complex structures with very little engineering knowledge, littleBits are simple, intuitive, space-sensitive blocks that make prototyping with sophisticated electronics a matter of snapping small magnets together. With a growing number of available modules, littleBits aims to move electronics from late stages of the design process to its earliest ones, and from the hands of experts, to those of artists, makers and designers." (Eyebeam, 2008)

CUBELETS

Another modular toy set is "Cubelets" from the company "Modular Robotics". Cubelets comes in a set of 20 modular blocks, where each block has its own function: sensor, action and operator blocks. Combining these blocks allow users to program with blocks instead of with wires. Downside of these blocks is the price: one set of building blocks costs 300$. (Modular Robotics, z.d.)



PICOCRICKETS

Picocrickets are a set of modular sensors and actuators specifically created for children. Software is included to program using colored drag and drop boxes, and the sensor and actuator modules are compatible with LEGO® to make sure that children can let their own creations come to life with toys they already have. (PICO - playful invenction company, z.d.)

REFLECTION

I notice there are already many starters-kits on the market to learn people with different age (e.g. children) or different background (e.g. designers) the principles of physical computing. I did not expect this amount already. Apparently, there is a market in teaching people the principles of physical computing. This motivates me even more to create my own designs that set itself apart from the examples I already mentioned.

THE NEED FOR ANOTHER TOOL SET

A FabLab gives the user lots of possibilities to let their ideas become reality. So why should I research the possibility for another toolkit?

While most of the devices in a FabLab are aimed at providing the user with physical results (a wooden/plastic/cardboard model), there are no devices that can “create” interaction for the user. This has to do with knowledge; a big part of product interaction is based on micro controllers and other electronics. Working with these has an even higher entry threshold than working with the other machines. The laser cutter and milling machines work with easy to user software, and results can be evaluated immediately. Programming microcontroller requires knowledge of both programming and physics. It is interesting to research this entry threshold and see how I can design a starter’s kit that reduces the entry threshold and can be accessible for people with no previous knowledge of electronics, as well as people that are more experienced.

Above products are not open for expansion of the input- and output devices. Therefore, the user will hit the wall at some point. At this wall, there are no further possibilities available. An open starters-kit does not have this problem, since users are free to build their own modules,, and therefore expand their possibilities.

Physical Computing

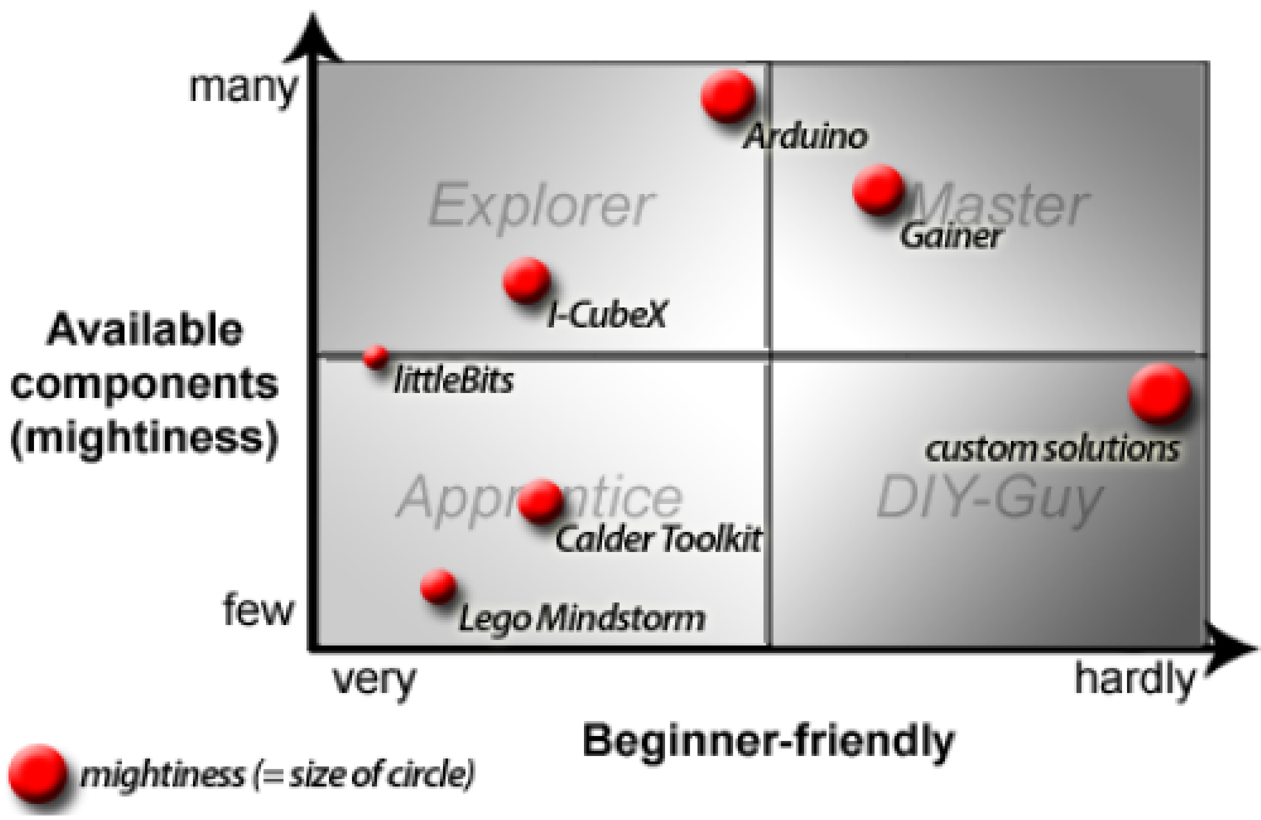
Physical computing is a form of computing, which in this context is related to 'programming a computer system'. Therefore, this term literally means 'Physical Programming', so Programming a computer physically instead of digitally. The complete definition of physical computing is as follows, according to Wikipedia:

> *"Physical (or embedded) computing, in the broadest sense, means building interactive physical systems by the use of software and hardware that can sense and respond to the analog world."*
>
> *(O'Sullivan & Igoe, 2004)*

While computing is often related to technicians and programming experts, physical computing can be a form of computing which does not require technical knowledge. The physical aspect communicates vague programming terms to the users in an understandable way.

With only this basic set of rules and physical 'tems' to play with, and the restrictions each sensor brings with him it is near impossible to create lots of variation with a limited amount of sensor. Therefore, either I can design different output modules, or I can add more complexity to create more possibilities with the same set of sensors I already have. This makes the makes the framework more "mighty" but reduces the beginner-friendliness of the whole (see picture)(Kowalski, 2010)

The starter's kit should also have a position in this matrix. This position is important, because it should not overlap with specifications of one of the otter tool kits. It should be positioned relative to Arduino, which is positioned halfway beginner-friendly and has many available components. The level of available components remains the same and because the product lowers the bar for physical computing, it moves to the left on the "Beginner-friendly" ax. This results in a position in the "Explorer" group.



ARDUINO

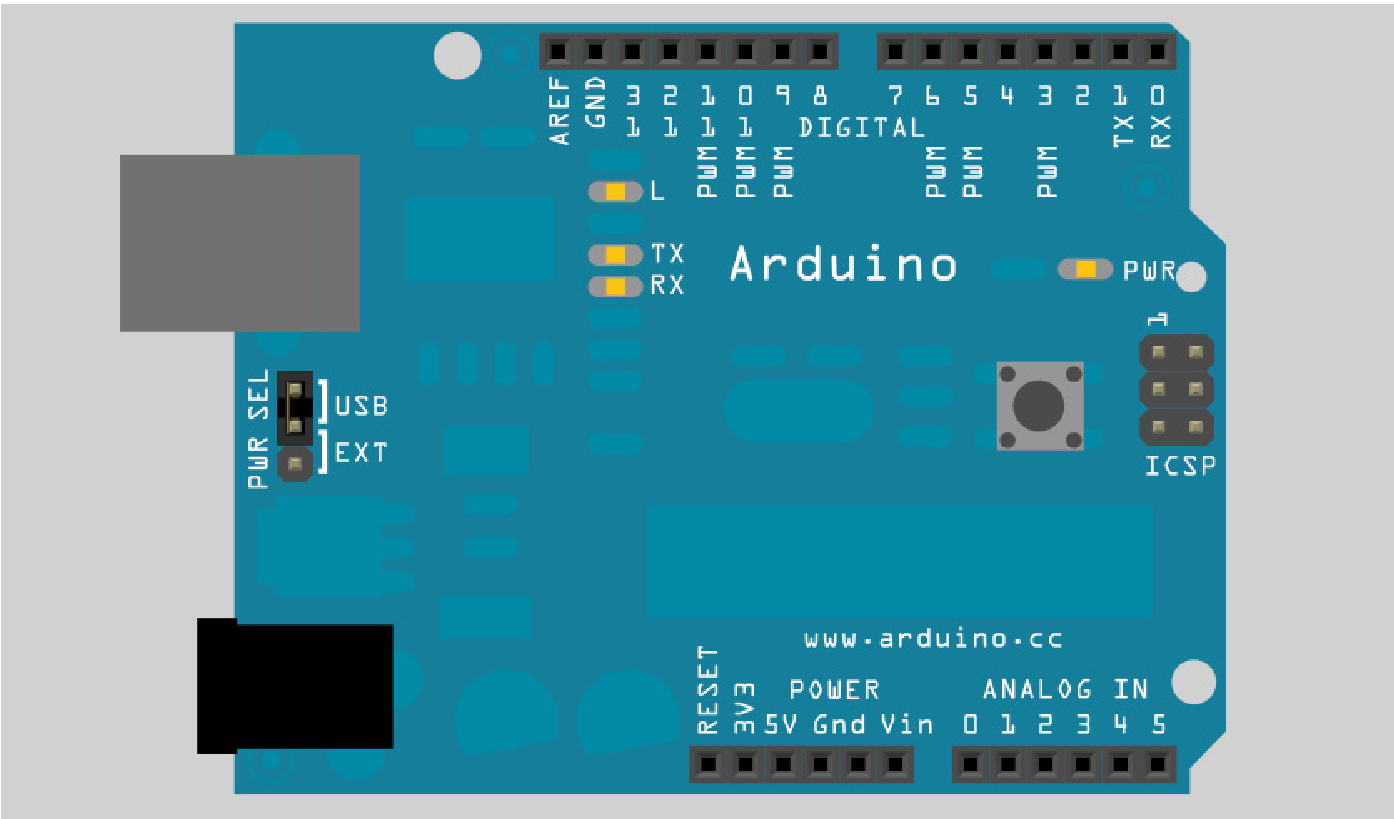
Arduino is an easy to use and open source microcontroller board and programming IDE that aims at people just starting out with programming micro controllers, but still offers all possibilities of a normal microcontroller for advanced users.

> *"Arduino is an open-source electronics prototyping platform based on flexible, easy-to-use hardware and software. It's intended for artists, designers, hobbyists, and anyone interested in creating interactive objects or environments" ("Arduino - HomePage", z.d.)*

While gathering information, I noticed that most physical computing sets are closed, and teach a person to work with particular components instead of teaching a person the basics of programming a microcontroller. Therefore, I want to make a physical computing set that teaches people the basics of physical computing, while also teaching people the basics of working with the Arduino hardware.

Working with arduino has even more advantages; Lots of documentation can be found online, and almost every sensor sold online is compatible with Arduino. In addition, a very active online community can help people out with any problems they are having.

The starters-kit is uses the arduino hardware platform. It is a cheap, open-source, easy to use microcontroller with support from an active community.



User research

How do current FabLab users experience the workplace? Do they feel the need to add electronics to their creations? If so, do they think the learning curve is steep?

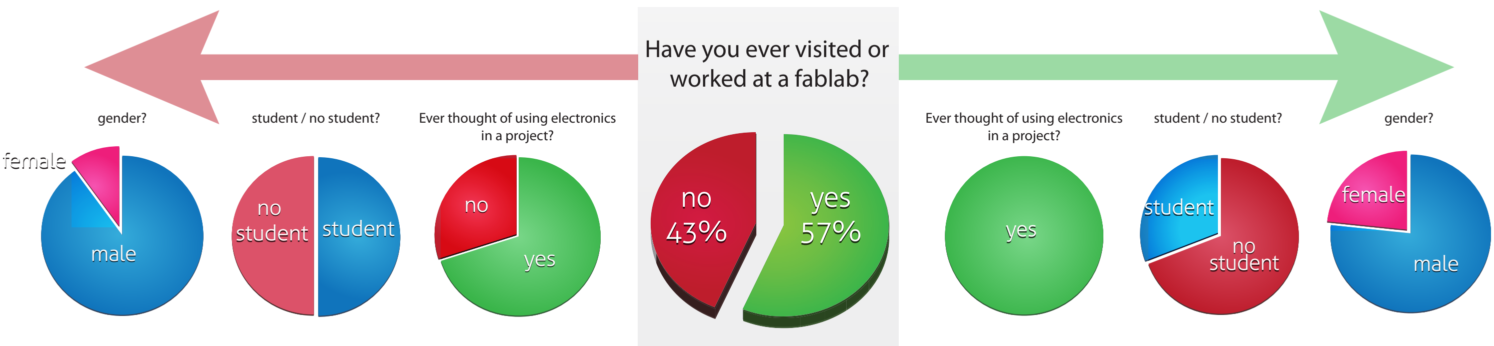
To find out more about the average FabLab visitor I will ask them a set of questions. In these questions, I hope to clarify the motivation of FabLab users and try to measure their experience in electronics, the part I will be focusing on. I base my questionnaire on questions of Universal Theory of Acceptance and Use of Technology as found in Vakatesh et al. (Venkatesh, Morris, Gordon B. Davis, & Davis, 2003). These questions can give a good image of Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions in Relation to the users Characteristics such as Gender, Age, Experience and Voluntariness of Use. Some aspects of this questionnaire are not so relevant in this situation, so I did not incorporate these in the questionnaire.

I have sent the questionnaire to Waag Society employees, TU Eindhoven students and Vrije Universiteit Amsterdam Students who subscribed for a workshop in physical computing.

The questionnaire contains the following description:

> *"A starters-kit that reduces the entry threshold and is accessible for people with no previous knowledge of electronics, as well as people that are more experienced. The starters-kit is based on Arduino hardware, and enables users to create interaction."*

Appendix A contains the full questionnaire.



RESULTS

23 People have filled in the questionnaire; the first set of questions gives a clear image of the average fablab visitor. But the results from the questionnaire are not enough to give a significant answer. It is more a qualitative description of how useful potential users will think the product is. The average scores that came out of the questionnaire are suggest users think the product is interesting. However, quantitative research should be done when people have actually used the product.

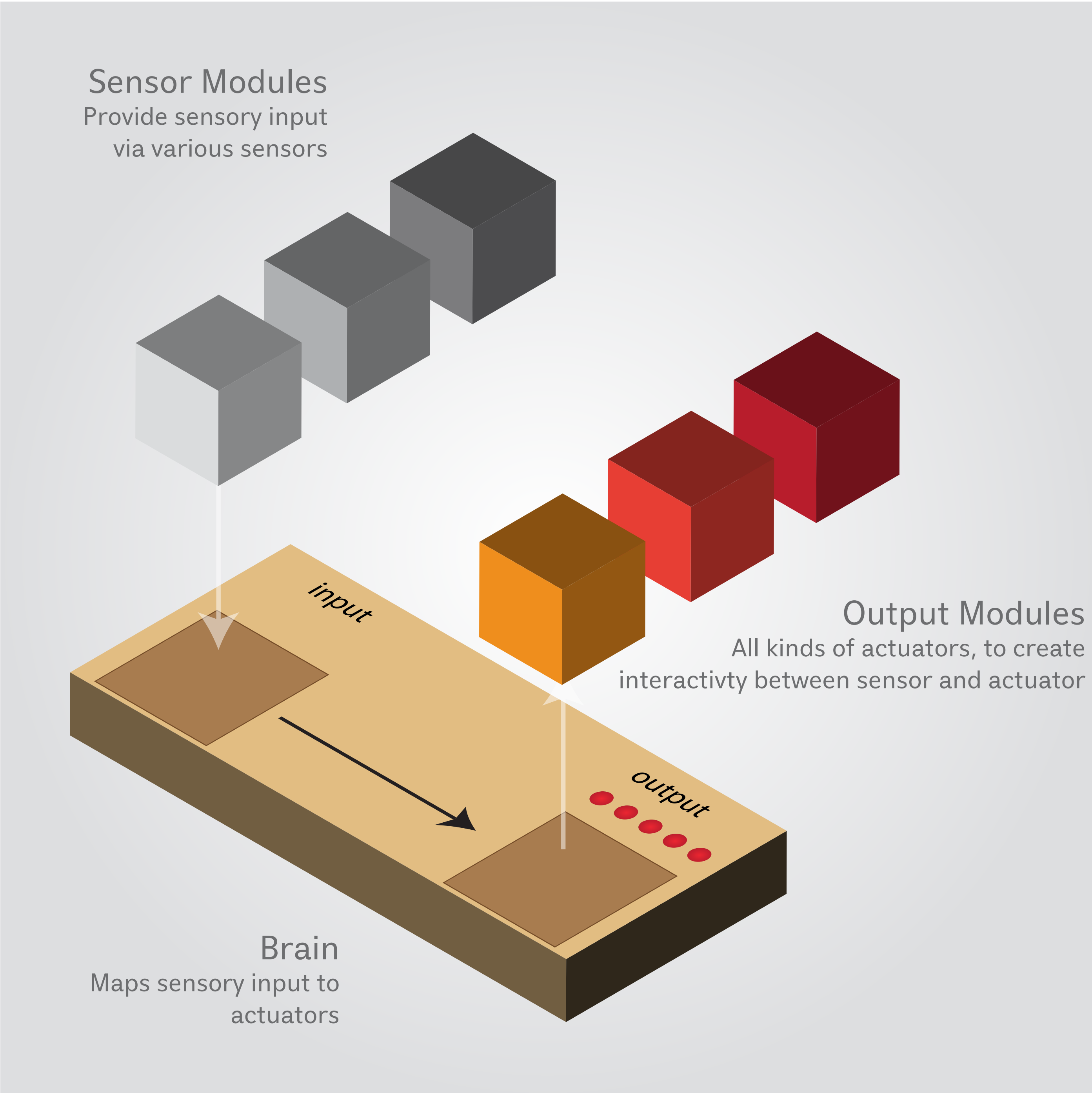
Requirements

Market Analysis shows the current possibilities for modular physical computing, and user research shows that it is likely that people are interested in an Arduino based physical computing kit. A 'requirements and optional features'-table converts these results into design restrictions.

REQUIREMENTS	OPTIONAL FEATURES
The product should be modular	The product as a whole can be used as embedded circuitry in projects rather than a teaching tool
The product needs to be educational	User can create his or her own module via a templating system.
The product should not involve common electronic tasks such as soldering creating copper paths and math's.	The product can be used across multiple target groups
Target group must know how to handle the product within 15 minutes	Compatibility with other micro controllers
Product should be based on the Arduino platform	Product should also involve processing modules such as filters
Product should involve sensors and actuators (I/O)	
Product should be documented according to FabLab standards	
The product should be made using devices from the FabLab	

Modular programming kit for Arduino

The most common task arduino is used for is converting sensory data into a corresponding output. This process usually takes a lot of time due to the assembly of electronic circuitry and programming the arduino. Redesigning the sensors in sensor modules and the outputs in output modules would enhance the flexibility of prototyping with arduino while retaining the accuracy of the sensors to provide accurate sensory data. Each sensor can be combined with any output to create simple working prototypes. This will let the user understand the possibilities of the Arduino platform without having to learn how to program first.



Arduino Starters-kit

The Arduino starters-kit is a modular starters-kit, for people without basic knowledge of electronics. The starters-kit enables these people to quickly prototype interactions, and eventually learn The Arduino software.

MODULES

Modules form the heart of the starters-kit, from which the user can design different interactions, combining input and output modules.

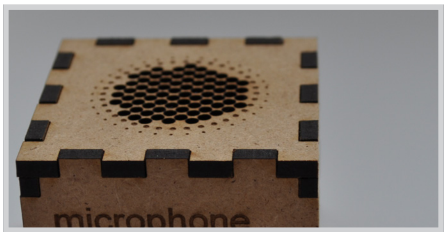
INPUT

Button, press to generate a high

output signal

Knob, turn to vary the output signal

Microphone, converts sound to output



Distance sensor, converts distance into an output signal

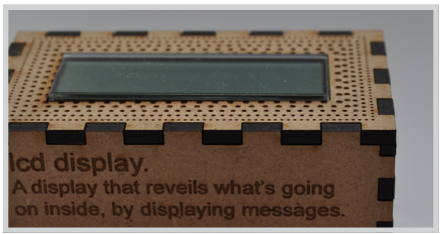
PROCESSING

Arduino Microcontroller, the brains

to which each module has to be attached to work.

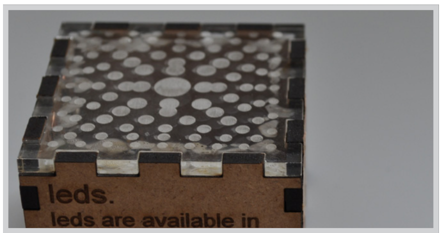
OUTPUT

LCD Display, Can display the input



value on an LCD screen.

LEDs, will vary in brightness



according to the input signal.

Speaker, produces square wave tones with varying frequency, according to the input signal.

PROTOTYPING INTERACTION WITH THE STARTERS-KIT

Designers are able to quickly prototype interaction using the starters-kit, because these modules, upon connection, instantly work together. This enables the designer to iterate between multiple possibilities of interaction quickly, and make well-informed design decisions.

Here are some sample scenarios in which the starters-kit would offer a solution to a designer.

Problem: Design a product that alerts blind people when they come close to a wall

Solution: Using the Starters-kit, a designer can easily test this interaction by connection a distance sensor module to the desired output module. In this case, the designer is creating a product for blind people, so naturally the correct output module will be the speaker module, or the “vibration” module.

Problem: Design a lamp that corresponds with the ambience in the room

Lamps are popular products to design; so many different forms made out of different materials already exist on the market. With this starters-kit, it would be relatively easy to add an extra dimension to a lamp, by implementing a sensor that corresponds with the lighting of the lamp. This way it would be easy to create a sound sensitive lamp, simply by using the microphone module in combination with the led module.

Design

Iterations in form factor, connection method, and technical functionality have come together in the design of the Arduino starters-kit. Tools and principles that make up the design are as follows:

BOX

Box design is created using Magic Box software with a press fit box template to create boxes with specific dimensions. Next, I used vector software to create specific designs and descriptions for each box. The digital file containing the design is send to the laser cutter, which then exactly reproduces the digital design from MDF wood.

CONNECTION

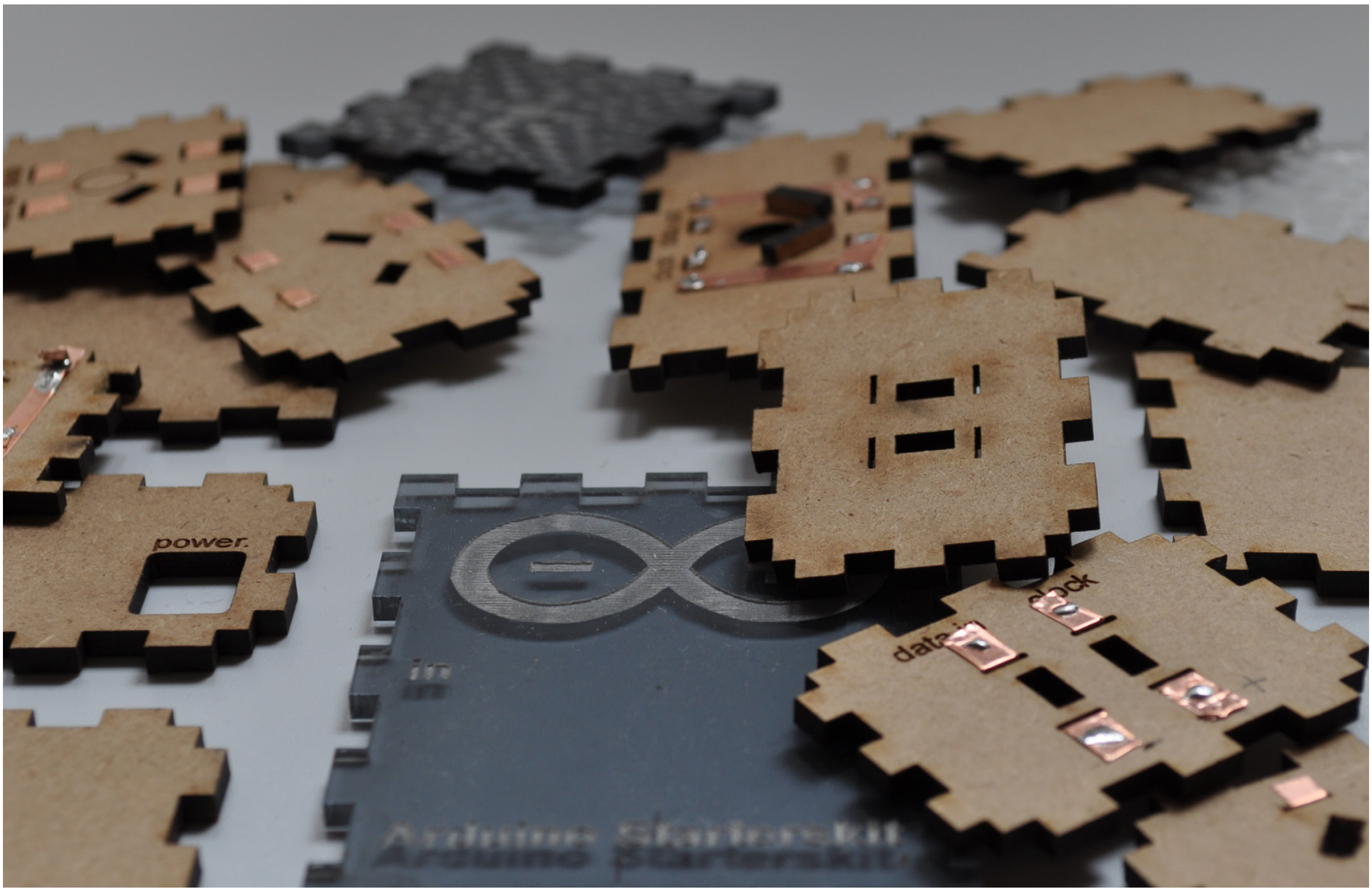
The connection between the boxes consists of pieces of conductive copper foil, which press against each other upon connection. Magnets in both boxes ensure the connection and provide the connection with a 'snappy' feel.

ELECTRONICS

Electronic circuitry inside the various modules is both handcrafted and created using digital fabrication techniques. Small circuit boards in the output modules are milled out of copper boards; the rest is soldered.

The different modules communicate through a Two-Wire interface, an interface comparable to a USB plug.

More about the manufacturing process can be found in Appendix B



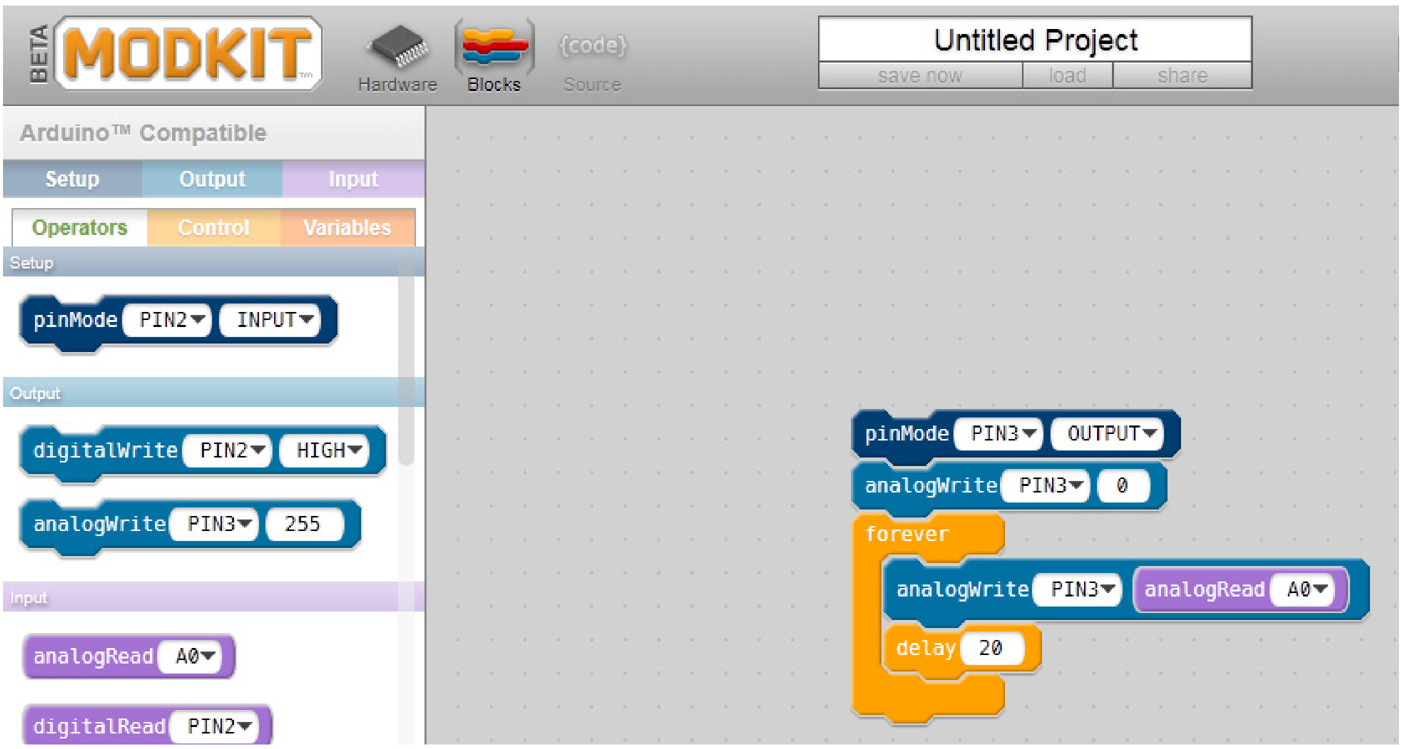
Discussion

The arduino starters-kit lowers the threshold for designers and other creative visitors of the FabLab to use physical computing. Lowering the threshold of a technology has its positive and negative effects. On one hand, stimulating people to work with new technology through a starters-kit works as a revelation. People can make products that are more complex without losing themselves in the details of electronics. On the other hand, these pre-assembled starter kits have a limited amount of modules, and designers will not be able to prototype all possible interactions with a standardized starters-kit. This limits a designer in his possibilities, and might have a negative influence on a final design.

Recommendations

Programming is an essential part of creating interaction, so learning users how to program would greatly improve the possibilities of a starters kit like this. In the end, the starters-kit will be more flexible, and the possibilities with a limited amount of modules will increase. The user can still switch between modules for testing out different interactions, but can also add new intelligence through code.

Simple programming solutions for Arduino already exist. One of these solutions is Modkit (Modkit LLC, n.d.), a web-based microcontroller programming tool. With this application, the user is able to program a microcontroller trough dragging and dropping different code blocks on top of each other. The current version (0.1) is still extremely limited, but the idea of programming by stacking blocks of code is clear. Using an application such as Modkit in combination with the starters-kit would greatly improve the possibilities for the user.



Conclusions

User research shows that some fablab visitors might be interested in designing interaction using a starters kit with pre-assembled modules. Research after related products shows that there is not one single open hardware initiative specialized in teaching people physical computing. The Arduino Starters kit presented in this report is able to ease the process of designing interactions without requiring knowledge about electronics or programming. Furthermore, it is based on the “Arduino” open hardware standard, which allows users to customize and expand the starters kit themselves. Future plans for such an open standard include expanding the amount of modules available, and introducing people to (simple) programming language.

Other Internship Activities

FABFOOS

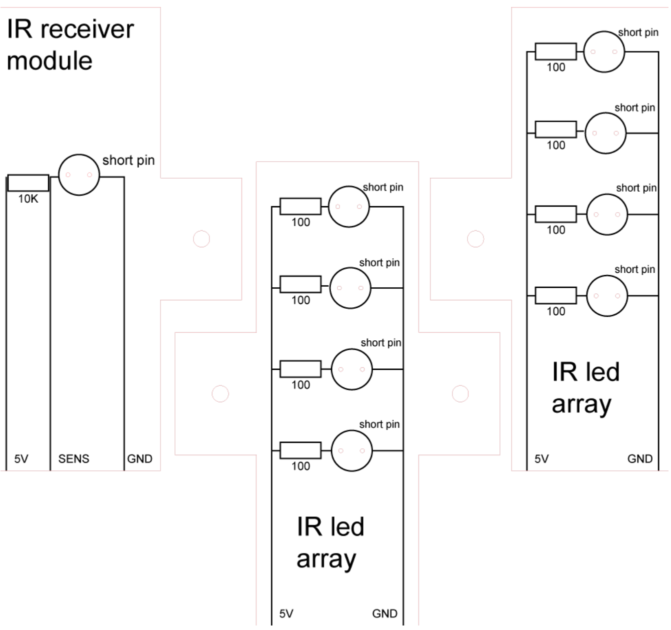
The first weeks of the internships were used to finish another project, namely the design and fabrication of an open source soccer table, the FabFoos. For this project, I designed sensor modules that can detect whether a goal has been made. These modules use Infrared LEDs to detect if the ball is passing through a beam of IR light, and Arduino is used to process this information and keep up te score for both players.

MODULES

One sensor consists of a receiver and a send module. The send module consists of an array of IR led's and the receiver module works with a IR sensitive photo resistor. When attached to a microcontroller such as Arduino, the values of the photo resistor can show if an object is passing trough or not.

REFLECTION

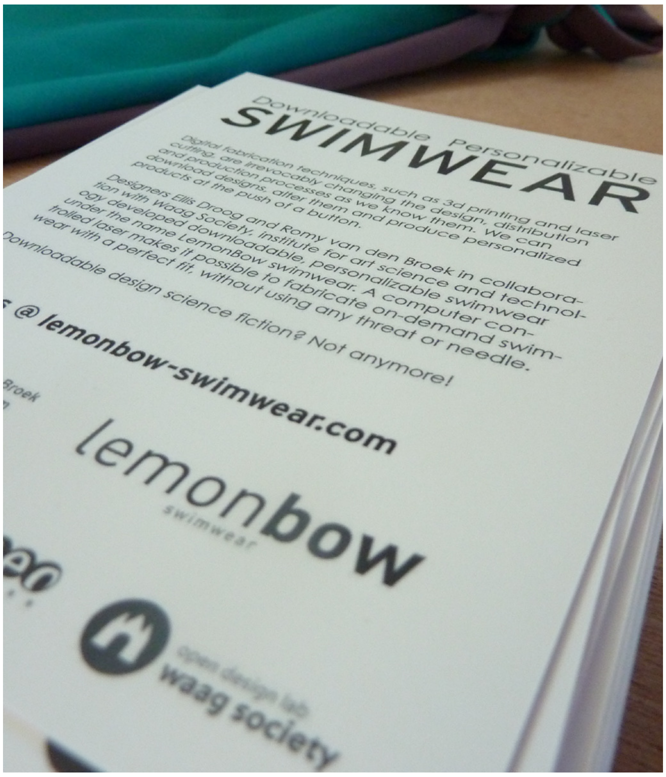
I totally did not see this project coming when starting with my internship, but I immediately noticed I fitted at this internship when doing this project; I felt like I had the right knowledge for the situation. This project set the mood for the rest of the semester; occasionally I had to work on other projects than my own, but I see this as a good thing, because it helped me develop different skills and learn about other possibilities of digital fabrication that I otherwise would not know about.



EXHIBITING AT DMY BERLIN

At the end of my internship period I got the offer to go to a design conference in Berlin called the DMY. At the exhibition, two designers who called themselves 'Lemonbow' needed technical support for the laser cutter that they would be using during the exhibition time.

Lemonbow Swimwear is about producing personalized swimwear with digital fabrication techniques. People can generate their own personal swimwear by measuring their bodies, and then a laser cutter is able to make a complete bikini out of two pieces of textile in just a few minutes! Lemonbow demonstrates how downloadable personal design should be.



REFLECTION

Because my interest in both open design and digital fabrication have been sparked during the internship, I have decided to join them at the exhibition. It was a learning opportunity for me to be present at a big international exhibition, and also a good opportunity to meet new people. The exhibition in Berlin fell together with the "Open Design Now!" book launch, that has been written by a group of people to promote openness in the design industry. Being at an exhibition has made an impact on my vision of the design industry. Looking at what other studios were doing in design, it seemed to me that Lemonbow was one of the most radical concepts that has been presented at this exhibition. I would also like to present a product of myself on an international scale one day.

DIGITAL FABRICATION AND DESIGN

The internship at the FabLab introduced me to the concept of digital fabrication, using dedicated machinery to fabricate products from digital drawings. Before this internship, the only way for me to fabricate a prototype is by using the standard machines from the woodshop, and patience.

Digital fabrication opened up a new world of possibilities. For example, I was able to cut extremely detailed wooden pieces, with precise engagements using the laser cutter and I was able to cut thick pieces of wood into shapes a normal saw would not bend in, using the CNC milling machine. Looking back at earlier projects and thinking how this could be achieved using these machines I got to know here, I figured I wasted quite some time in creating prototypes by hand. This is exactly where the strength of digital fabrication lies; using digital fabrication to create prototypes saves time in the design process to actually reflect on the result, and improve the design.

While I am amazed by what digital fabrication machines have to offer, I also could not help but notice negative points that come with these machines. It has to do with prototyping when it is not just an activity to reach a 'goal', but the activity itself is actually a way of exploring the possibilities.

These digital fabrication machines quickly and easily give you an exact physical copy of your digital design, but leave no room for some explorative design. All the editing and designing takes place behind the computer, and when you think you made the right blueprint, the only thing you can do is press the button and hope it "comes out right". This completely rules out the physical aspect of prototyping, where a designer can take a piece of foam, cut and sand a bit, pick it up, look at it from some angles, and repeat the process, until I nice shape appears.

I have already decided "how not to fall in this design pitfall" I described above. When still in the exploring phase, I should not even think of using digital fabrication. It ruins my creativity by creating such exact circles and rectangles, that it leaves no room for me to interpret it in a different way. When done with exploring I can start converting my foam models and sketches to digital drawings. Once I have gone digital, I can easily create many variations off my design, and pick the best one to continue with.

DESIGN SKILLS WITHIN A COMPANY

Another thought that shaped my vision during my internship is about design skills within a company. At the FabLab I have made big improvements to my skill set; I have learned how to integrate digital fabrication machines, such as a laser cutter, to the design process. This got me thinking: should I have all of these skills to be a real designer, or can I focus my attention on developing one particular skill? Before this internship, I thought the second option was true, because in the end, companies hire designer with specific skills to come and do that specific job, and do it really well.

After the internship, I notice that companies like the Waag Society have a different way of working. They work with a group of designers on a bunch of projects, but whenever someone want to be responsible for a particular aspect of a project, for example a technical aspect, then he or she can take this responsibility. This way, the group of designers can develop themselves on multiple disciplines, and a designer who has more knowledge about technical aspects can also work on aspects outside of his own specialism. This results in people working at the Waag Society having overlapping knowledge areas. This creates a dialogue between the designers, and eventually results in better design, it also looks more like the situation at our department, whenever people are stuck in something, they can talk to somebody who also has the same knowledge, but looks at it from another point of view.

ELECTRONIC COMMUNICATION TECHNIQUES

This semester I have thrown myself further in electronics, by learning about communication protocols and micro controllers. The principles I have learned can be applied to any product that includes “communicating modules”, which is actually a trending phenomenon these days; especially wireless communication. Since technology is quite a big part of my identity, I am confident I can re-use what I have learned in a future project.

A SENSE OF MATERIAL

Before my internship, I found it difficult to supply personnel at the wood shop in Vertigo with exact dimensions of material I needed. Working with a laser cutter and CNC miller, inescapably put me in touch with lots of different materials; from basic materials such as Perspex and MDF, to special kinds of wood, recycled plastics and textile. Feeling and machining these has given me a sense of material; when I see or feel a material, I can estimate what I can do with it, and how to do this.

I have not worked with all possible materials. For example, we could not work with metal, so I still have no experience in working with metal. Nevertheless, for myself I see this (early) sense of material as an eye-opener: I do not have to make all my prototypes from MDF wood, but I should find the appropriate material for what I want to achieve. At the FabLab, this was quite easy since there was such a large stash of different materials to test. I hope to expand my material knowledge even more back at the TU campus.

INSPIRATION

The more I know, and the more experience I have in designing products, the less I let my design decisions guide by a silly brainstorm. This is a good development, but it also narrows me down to whatever I think is right, from experience; not good for my creativity. The answer to this is inspiration; it encourages trying something new and pushing borders.

I find inspiration in new technologies that remove electronics from being obviously present, such as wireless electricity and wireless communication, between for example large sensor networks. Invisibly implementing electronics in fashion products has sparked my interest during the last semester as well.

Appendix A - Questionnaire Acceptance and Use of an modular micro controller starters kit

While most of the devices in a workplace are aimed at providing the user with physical results (a wooden/plastic/cardboard model), there are no devices that can "create" interaction for the user. This has to do with knowledge; a big part of product interaction is regulated with micro controllers and other electronics. Working with these technologies requires lots of knowledge and therefore has an even higher entry threshold than working with the other machines. It is interesting to research this entry threshold and see how I can design a starter's kit that reduces the entry threshold and can be accessible for people with no previous knowledge of electronics, as well as more experienced people. Therefore I need to research how the user thinks about such a technology, and if they would use such a system. This is where this questionnaire is for. Questions below are based on the Universal Theory of Acceptance and use of Technology, and the technology I want to hear about is **a modular starters kit for micro-controllers, such as Arduino, which makes it easier for people to make create interaction.** *Required

GENERAL INFORMATION

Gender*

Student? *

Have you ever visited or worked at a FabLab? * A FabLab is a workspace that contains four modern prototyping machines. The Fablab has developed into a global network of standardized open hardware setups. People from all over the world are using it to create and develop their own ideas and sollutions.

Have you ever used, or thought of using electronics in a project? * This can have lots of possibilities, think about an interactive lamp, or creating your own speakerset.

PERFORMANCE EXPECTANCY

All questions below will be about "The system". This system, in this questionnaire, means a modular starters kit which would make it easier for people to start working and understand electronics, with the aim to actually create working prototypes in an easy way. Some questions might give the idea that you should have been using this system to answer the questions, but the idea behind this questionnaire is to gauge if people are willing to use such a system, when it would actually be realized.

Each of the statements can be rated 1 (totally not agree) to 5 (totally agree)

I would find the system useful in my job. *

Using the system enables me to accomplish tasks more quickly. *

Using the system increases my productivity. *

EFFORT EXPECTANCY

My interaction with the system would be clear and understandable. *

It would be easy for me to become skilful at using the system. *

I would find the system easy to use. *

Learning to operate the system is easy for me. *

ATTITUDE TOWARD USING TECHNOLOGY

Using the system is a good idea. *

The system makes work more interesting. *

Working with the system is fun. *

I like working with the system. *

SOCIAL INFLUENCE

People who influence my behaviour think that I should use the system. *

People who are important to me think that I should use the system. *

FACILITATING CONDITIONS

I have the resources necessary to use the system.*

I have the knowledge necessary to use the system. *

The system is compatible with other systems I use. *

A specific person (or group) is available for assistance with system difficulties. *

SELF-EFFICACY

I could complete a job or task using the system ...

If there was no one around to teltl me what to do as I go. *

If I could call someone for help if I got stuck. *

If I had a lot of time to complete the job for which the software was provided. *

If I had just the built-in help facility for assistance. *

ANXIETY

I feel apprehensive about using the system. *

I hesitate to use the system for fear of making mistakes I cannot correct. *

The system is somewhat intimidating to me. *

BEHAVIORAL INTENTION TO USE THE SYSTEM

I predict I would use the system in the next ‹n› months. *

Appendix B Product Documentation

Here you find the documentation for using and fabbing your own Arduino Starters-kit. The starters-kit is build out of different modules, fabricated by different machines. You can choose for yourself which modules you make and which you do not make. Each module has its own digital blueprint for the box, and for the inner electronics.

MATERIALS REQUIRED

- Arduino board (UNO or Duemilanove)
- Piece of 3mm MDF
- 3mm perspex (any colour will do, transparent is recommended)
- 8mm magnets
- Copper foil
- Copper boards with following electrical components
    - Resistors: 10K, 49, 10 (1206 SMD)
    - 6Pin Headers
    - Attiny (43U, 44A,45)
    - 10K pot meters
    - Other components depend on which output modules you want to fabricate; think about buttons, SHARP distance sensors, LDRs, LCD display

TOOLS REQUIRED

- Spirit GE Laser Cutter
- Roland Modela (1/100 and 1/32 end mill)
- FabISP or other programmer
- Soldering Iron
- Knife
- Tweezers

SOFTWARE REQUIRED

- Adobe Illustrator (http://www.adobe.com/illustrator/)
- Avrdude (http://download.savannah.gnu.org/releases/avrdude/)
- Neil Gehrsenfeld's Cad.py (http://sourceforge.net/projects/cadpy/)
- Optional: EAGLE (http://www.cadsoft.de/download.htm)
- Optional: AVR Studio (http://www.atmel.com/microsite/avr_studio_5/)

STEPS

The Spirit GE laser cutter cuts out and engraves the physical modules from the digital blueprints.

The Roland Modela is used to mill out PCB boards for the internal electronics. These have to be soldered and programmed in order to work.

Finally yet importantly, you should attach the magnets to the right box pieces, and attach copper foil to the right pieces.

Et voila! You have your own Arduino starters-kit!

Next chapters will go in depth for each step required to fabricate the arduino starters-kit,

Laser cutting

For cutting out the outsides of all the modules, we will use a laser cutter. All the blueprints of the available boxes are included in one file and it looks a bit like this:

The different modules are divided over different art boards, so a person can choose which module to send to the laser cutter.

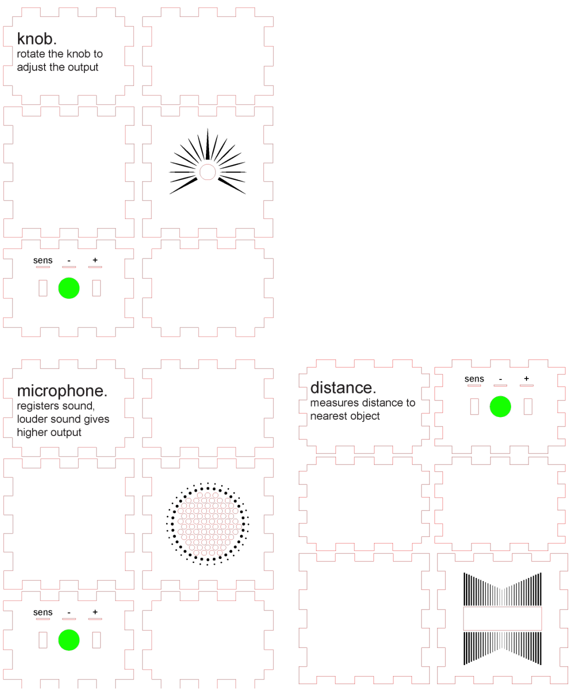
Cutting parameters

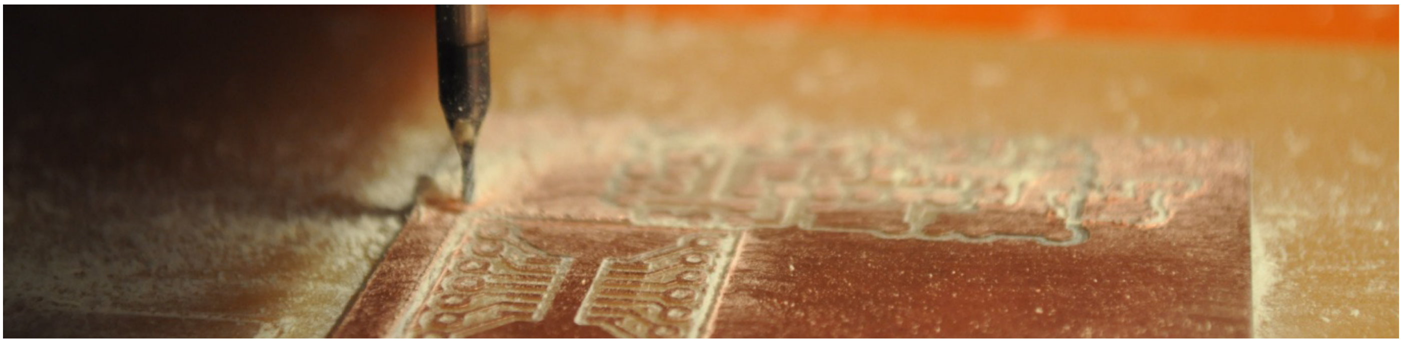
In the blueprints, the following three colors are used:

- **Red** – cutting lines, cuts trough 3mm MDF with Speed: 1.3 and Power: 100
- **Black** - engravings, used for the decoration and information on the boxes. Working settings are Speed:50 and Power 70
- **Green** – Deep engraving, used to engrave pockets in the wood, were the magnets exactly fit in. Speed:10 and Power:90.

If you follow these instructions, you should be able to reproduce the boxes from the illustrator file.

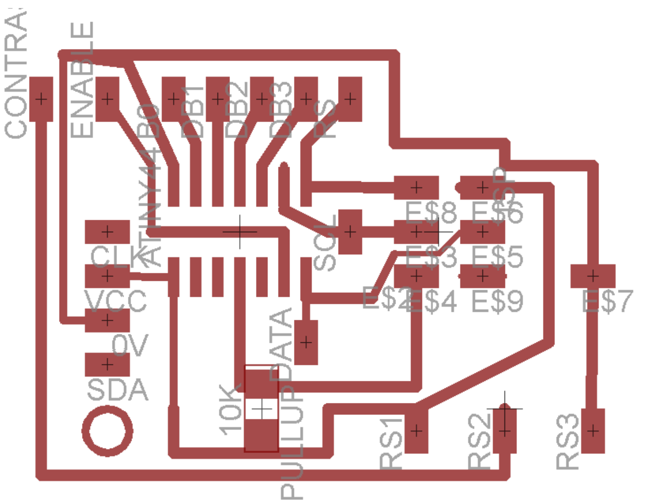
Input Boxes





PCB Milling

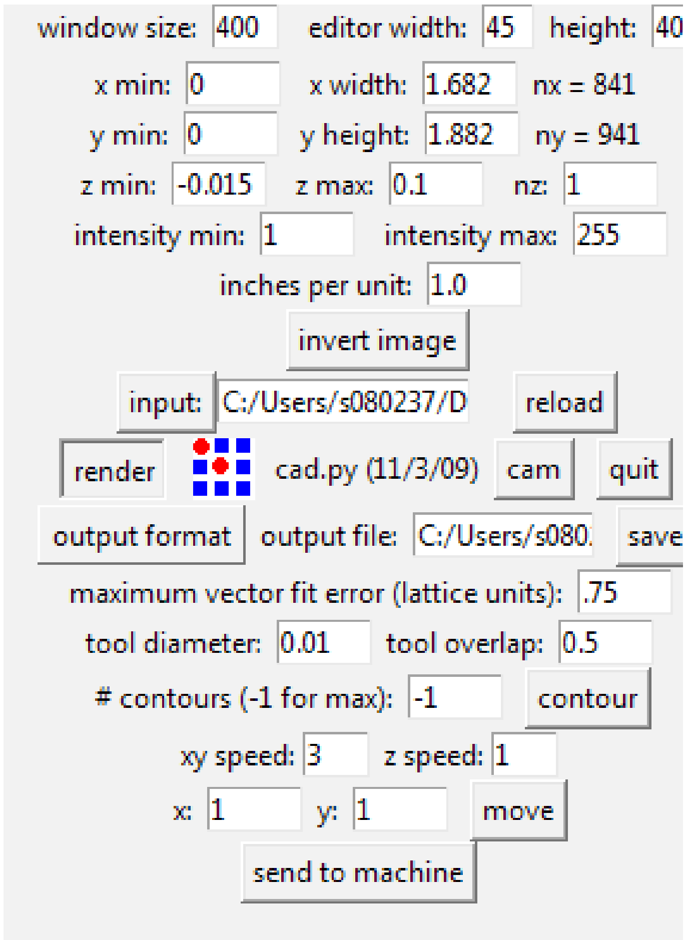
Cutting out the PCB boards requires running the cad.py software from Neil Gehrsenfeld. It is written to convert images into paths that the milling machine can follow. An image of a circuit board looks like the image, on the left. Converted into black and white so that cad.py can calculate the paths, it looks like the image on the right.



Black and white image files can be loaded into the cad.py software. I have included the correct image files to mill out the modules. Inside the software, the following parameters (all in inches!) are important:

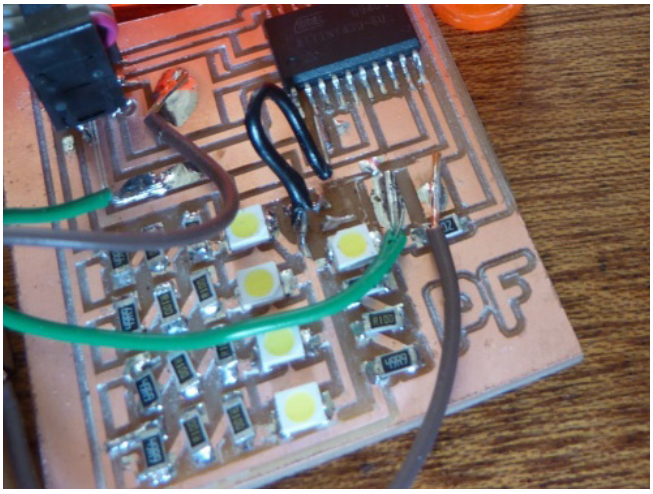
- Xmin and Ymin, the starting coordinates
- Zmin and Zmax, the maximum depth the mill will go , and the height the mill will raise when floating over your work piece. I used Zmin: -0.015 and Zmax: 0.1
- Output format -› Modela
- Tool diameter: 0.01 for 1/100 mill, 0.0156 for 1/64, and 0.0312 for 1/32 mill
- Contours, the amount of contours the software will create, the more contours, the longer it takes. 3 contours is enough.
- X Y and Zspeed. Xand Yspeed can be 3, Zspeed should be lower (1 or so).
- Final step, is zeroing the machine, by putting the drill **just touching the material**, this decides the zero point. Then press **Send to machine,** and it will start milling!

To cut out the PCB board, repeat the procedure, but use the image file only showing the contour of the board, and preferably use a 1/32 drill. XY and Zspeed should be 0.5 when cutting.



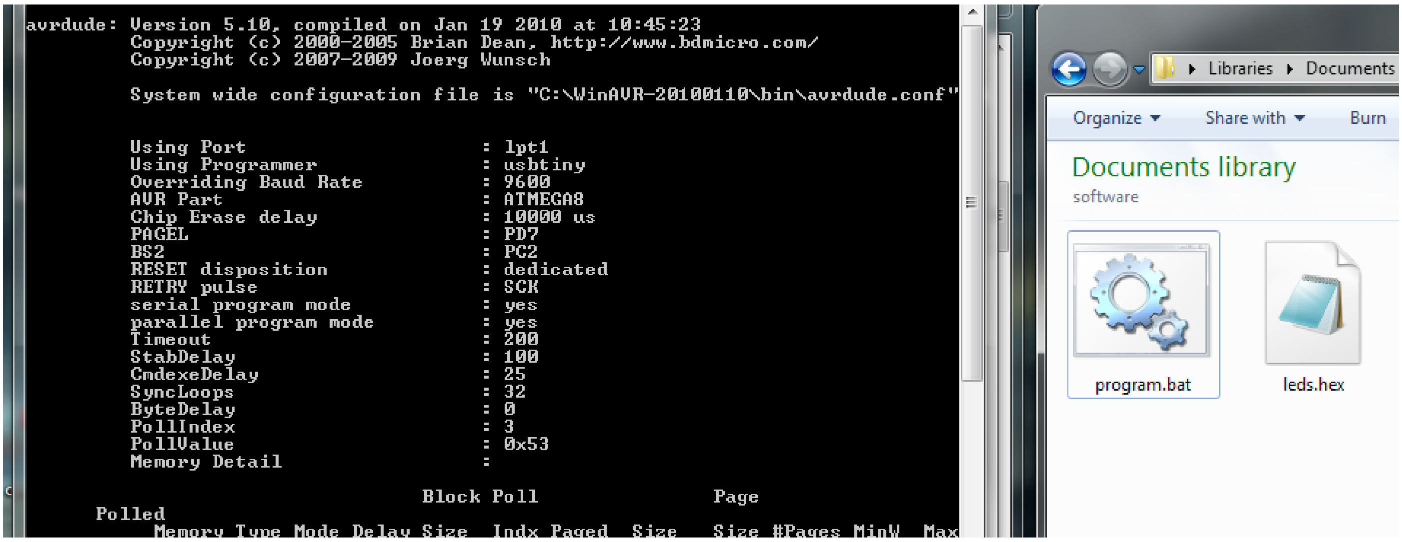
Soldering

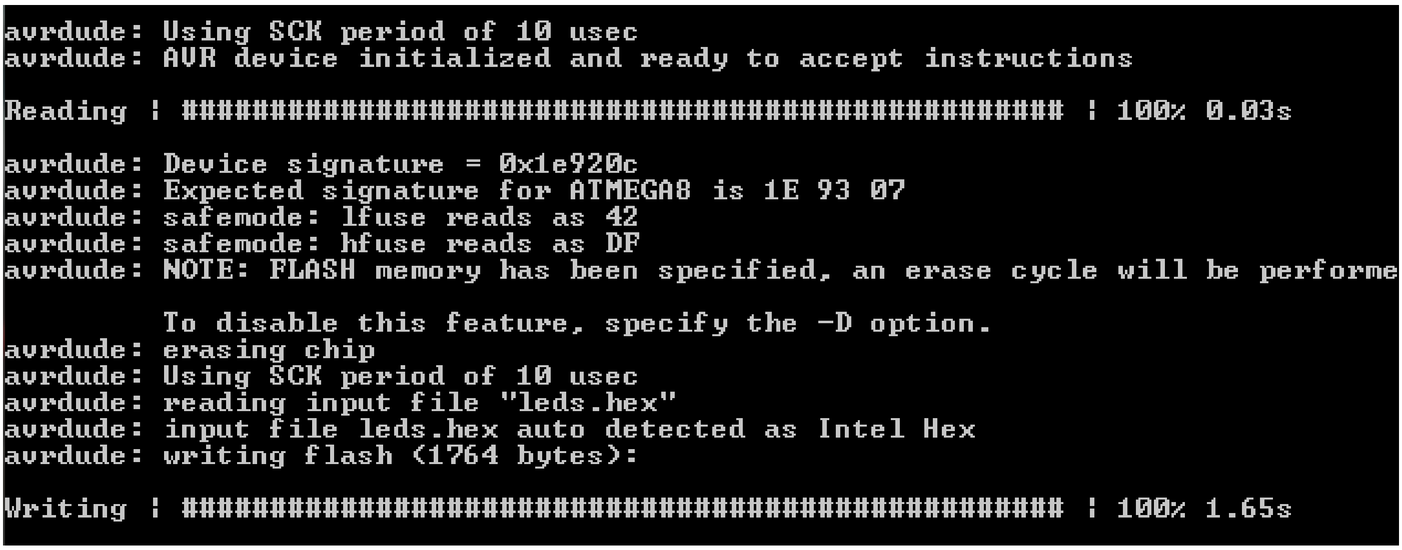
To clear out how to solder each part, image files of the circuit with naming are located inside the .zip file. This will help you solder the parts in the right way. If you solder the parts right, you will have a working circuit board!



Programming

Next step is programming the output module. The right code for the module can be uploaded directly by running the .bat files in the corresponding directories. You have to make sure you have avrdude installed when you run the .bat files and that you have an ISP connected to your computer. The .bat files only work with the FabISP.





Assembly

Putting together the wooden casings and circuit boards requires some manual work. The wooden pieces that connect to each other, need to have extra copper foil and magnets added in the right spaces.

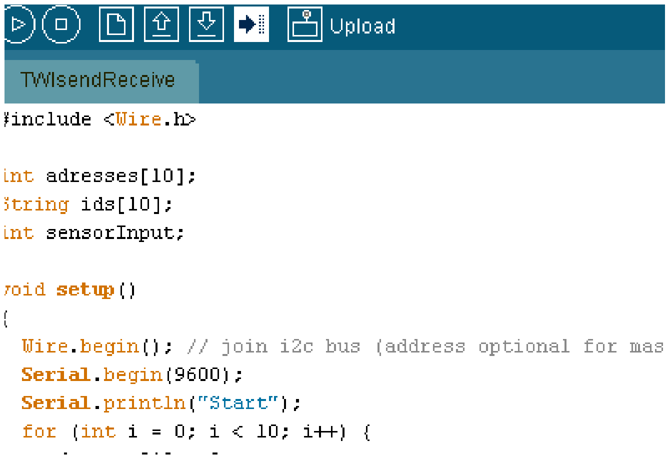
If connected the right way, the assembled boxes fit exactly and the connectors pass the necessary signals to communicate to each other.

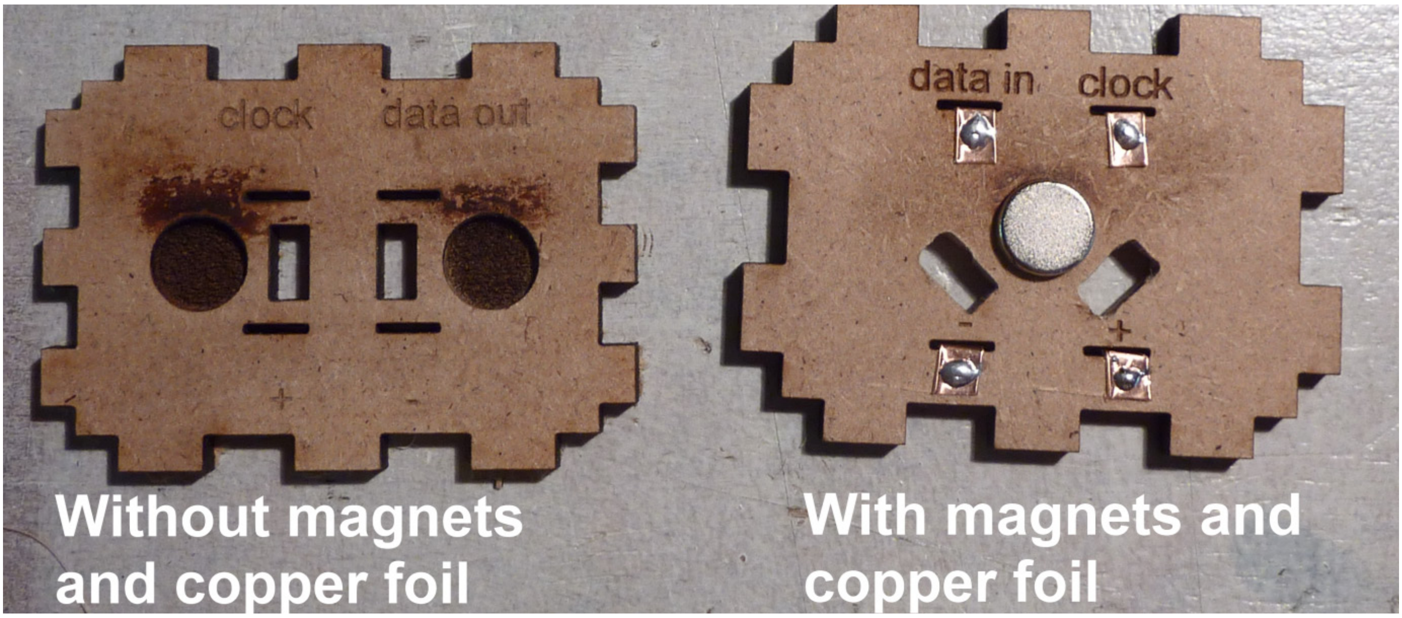
Arduino

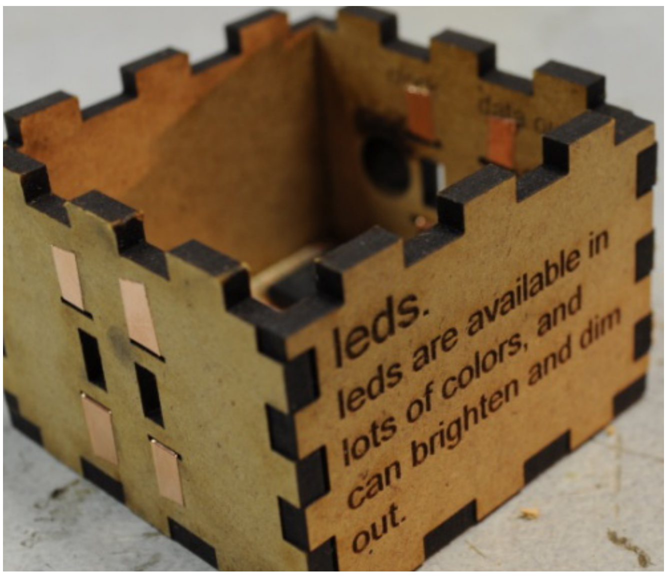
To make sure Arduino is able to communicate with your modules, you need to upload the arduino software (software/ Arduino code) to the board. You need the Arduino IDE for this (http://www.arduino.cc).

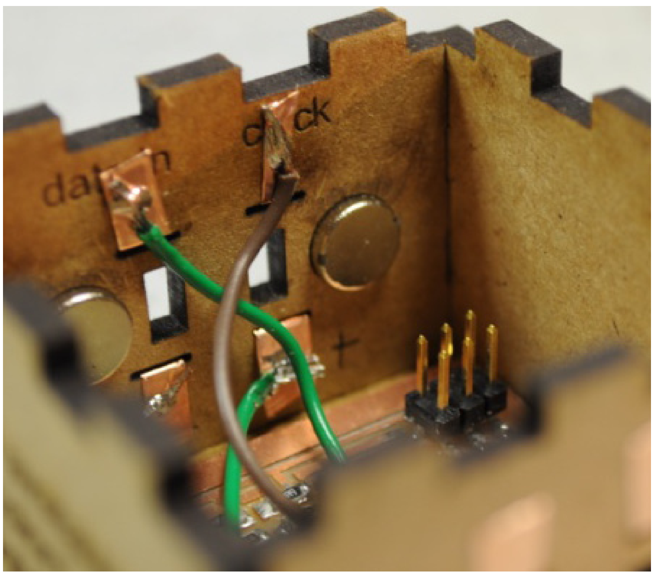
When installed, you have to open the .pde file in the 'Arduino code' folder, and press 'upload'.

Next step is uploading the software and assembling the box for the Arduino microcontroller. After doing this, the microcontroller should automatically work with the modules.







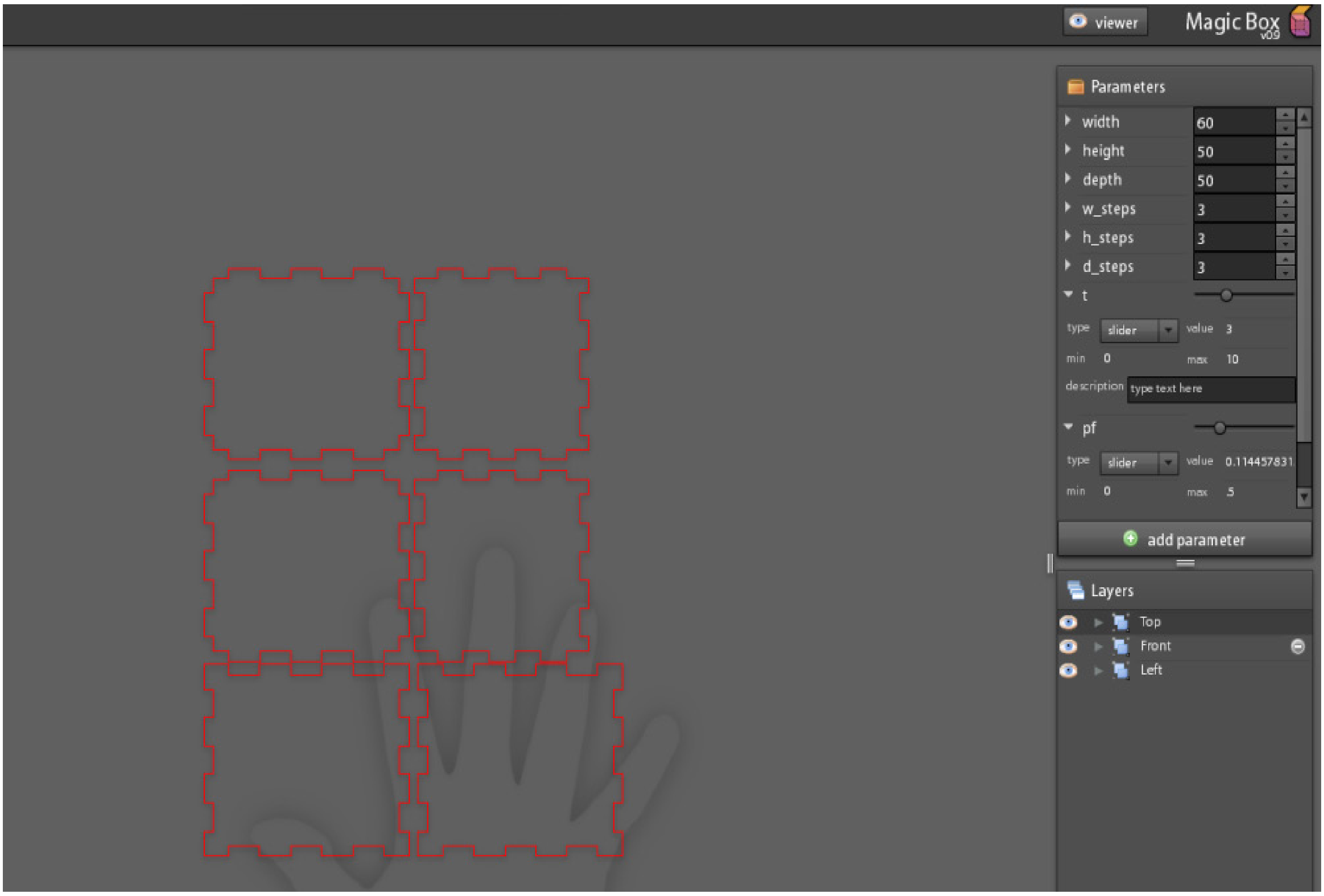


NEXT STEP

Design your own modules! Use the template dimensions from the illustrator file (arduinobox.ai) to design the boxes, and you can add any sensor that has a 0-5V output range to the system.

Output modules are a bit more difficult, but using the provided code files (usitwislave.h), you do not have to worry about the communication. Programming and circuit design experience is required to make your own output modules!

It is also possible to design your own output modules using Studio Ludens' Magic-Box software. Magic-Box is a web-based parametric design software. A template for this application allows you to put in the dimensions of a box you would like to have, and the software will generate a press fit box with these dimensions! This is useful if you want to make an output or input module that has different dimensions than the one supplied in the .ai file.



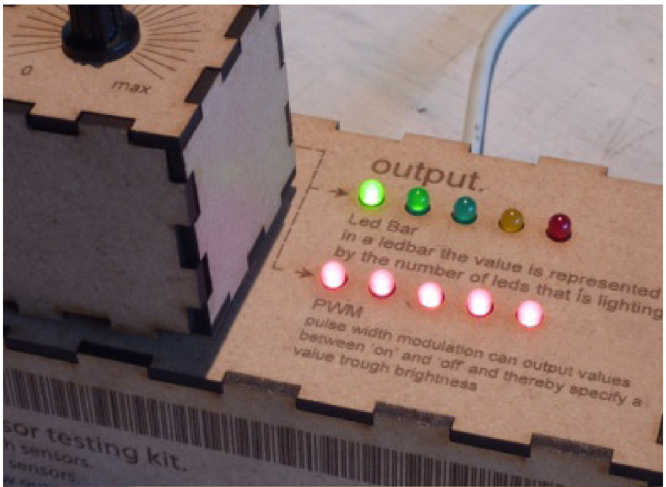
Appendix C – Process

RAPID PROTOTYPE

Because of the rich prototyping facilities offered by the FabLab I was able to quickly make a prototype one of my ideas. This prototype demonstrates the idea about modular sensors and one output box.

With rapid prototyping, I can quickly create high quality prototypes. With these prototypes, I can easily perform user evaluation and design a new product based on the results with this one. I decided to design a module and a processing board that could be part of the modular programming kit for arduino.

I designed the modules in press-fit boxes using Magic-Box software (Studio Ludens, 2011) to ensure easy customization and assembly of the module. Next, I designed the processing unit, which displays the value of the input in both a LED bar and in PWM.

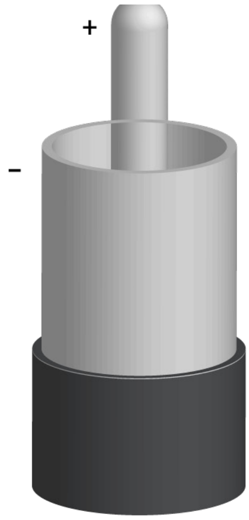


CONCLUSIONS

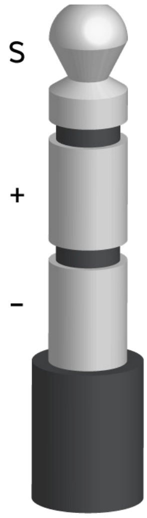
The idea of having modular sensors that can be read by a central sensor box is simple and it provides useful feedback for designers wanting to quickly test multiple sensors. However, some adjustments to the current prototype should make it more usable.

- Improve the quality of the connection between sensor and sensor box. The connectors used are providing a very noisy signal, and thus, they are not reliable.
- The sensor box and sensor cube are quite big. This can be much smaller and more portable, so you can actually take it with you, as with "real" tools.
- Current prototype has limited functionality; it can only display sensory input in the form of a LEDbar and pulse width modulation. Richter output functionality would be vibration, sound and "movement". Eventually I would also like to make modular output functionality.
- It lacks educational features. This prototype is a proof of concept, and lacks the educational part; actually teach people how to work with arduino. Working with the starters kit should familiarize the user with the technical terms and educate them about the way arduino works in general.

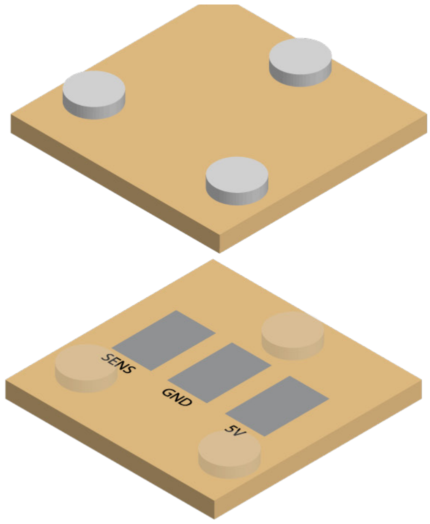
The points above each are goals for the next iteration.



Tulip Plug



Stereo Plug



Magnetic connection

EXPLORING CONNECTIVITY

Connectors

Connecting the different modules is an essential part of the concept, because this “handeling” is responsible for the actual ‘programming’ of the modules. Therefore the modules must have connectors which are easy to connect to each other and sturdy enough to be plugged and unplugged multiple times.

5mm three-phase jack

A three-phase jack plug is a jack plug that is able to communicate three phases (in my situation these are the required 5V, Ground and Sensory data) all trough the same connector. This makes the three-phase jack an excellent connector for connecting a sensor.

Evaluation of the connector

Because of its small size, the connection of the sensor to the central box was weak. This resulted in noisy signals and in some situations in short-circuiting the connection. This is the main disadvantage of having three phases on the same pin; it allows for short-circuiting and both the 5V and ground signal disturb the sensory signal.

Tulip ‘audio’ plugs

Tulip audio plugs provide a sturdier and more powerful connection between the two than the previous three-phase connector does. The tulip plugs are therefore better suitable for our application.

Evaluation of the connector

This connector is often used in audio, which means it is a sturdy connector with a big connecting surface to provide maximal signal transmission. Sadly, it has only room for two phases per plug, so therefore I need to use two of these plugs for the connection.

Magnetic connecting surfaces

Enhancing the stability of a particular connector trough magnetism is a feature we see more and more these days. For example, Apple’s MacBook laptops (DiFonzo, J. C., 2008) use magnetically enhanced power connectors to reduce the damage caused by tripping over the wire and to provide an easy “snapping” mechanism for the user. Because of the benefit of “magnetically enhanced connectors” I will attempt to design my own variant and implement it in my sensor boxes.

Evaluation of the connector

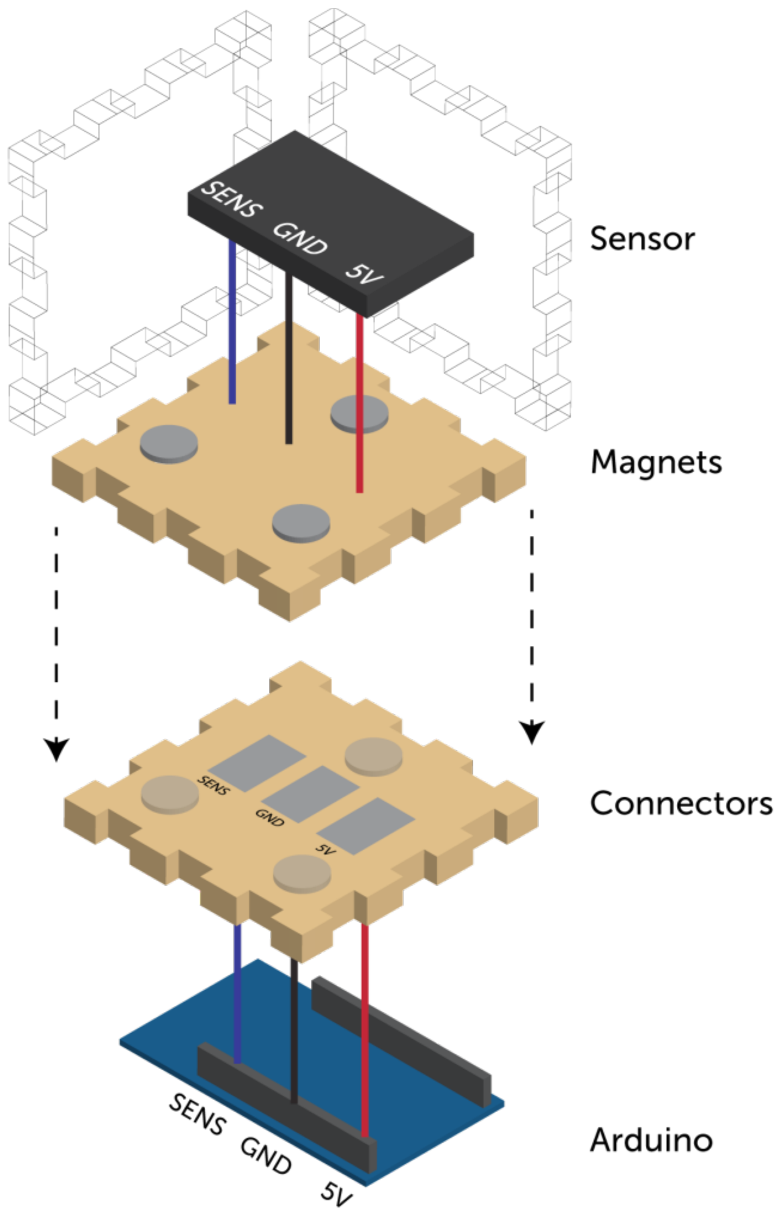
The magnets ensure that the user will connect the boxes in the right way, and because of the way they will be integrated in the sensor box, it leaves no vulnerable connectors.

Conclusion

While at first, the three-phase jack plug seemed most suitable, I noticed that this plug was too small and fragile to provide a sturdy noise free connection between two big objects (sensor boxes).

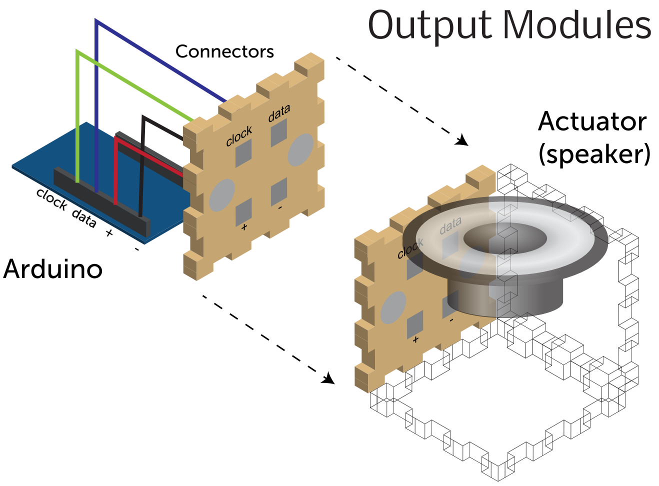
The bigger and studier Tulip audio plugs however, where too big and sturdy to let the user regularly switch between the modules. Disconnecting these plugs costs quite some effort and after a while will damage the sensor boxes.

Finally, the magnets offered a fitting solution. Using multiple magnets created a stable connection between three pieces of copper-foil that form the connectors for the three signals.



Output connectivity

Designing the right connections for output boxes needs some extra research, because each actuator has its own interface, such as Pulse Width Modulation, I2C or Serial interface. The best solution would be a connector that is able to send information for all these protocols. Another possible solution is putting a small chip in each output box, which can receive data from arduino, and translate it to the right output for each output box. This way a digital signal will be translated in all possible outputs.



Two Wire Interface

Making two micro controllers communicate is the easiest by making a two-wire interface (TWI) between the two. This interface can easily send and receive messages between devices, and can be connected to devices that are also connected in the same bus (!)

Prototype

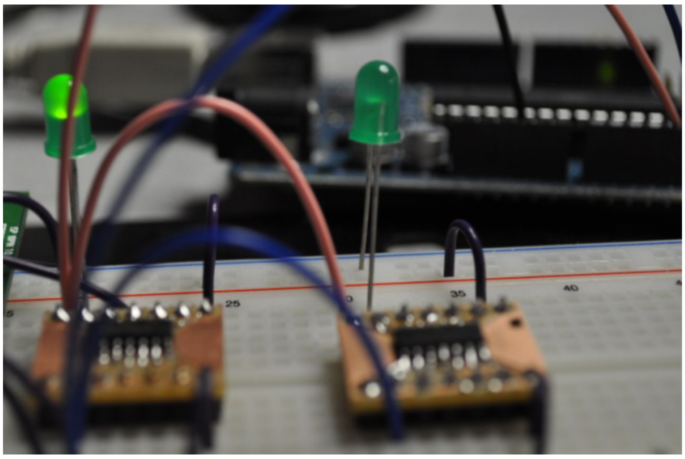
To find out if the TWI interface is suitable for an Arduino starters kit is important for the rest of the design process. People need to be able to realize their ideas faster with arduino, but should also be able to implement new stuff into the starters-kit. Creating a working TWI setup is the way used to find out how to it works.

The test setup was as follows: Arduino has been wired trough Analog pins 4 and 5, to the SDA and SCL pins of the Attiny44. Next, Arduino sends multiple random signals, that can also be values of sensor modules, via the interface towards to the Attiny, and Attiny turns these digital signals into a PWM signal.

Attiny ‹-› Arduino

To research connection possibilities, I have had a meeting with an microcontroller expert. The expert on micro controllers, Nathan, introduced me to Attiny, a smaller AVR microcontroller. With this microcontroller, it would be possible to create a connection (like USB) to Arduino, called Two-Wire Interface (TWI). The Two-Wire Interface works, as the name suggests, with only two data wires. Adding the power and ground wire, the total connection points will be four. With these four connections, it would be able to stack multiple modules together, and make them all work, using the same four wires for all of the modules.

Above solution exactly fits the requirements. The users should be able to experience the sensor module with different outputs at the same time, and in any order they like. The user then experiences programming in a physical and unobstructed way.



EXPLORING FORM FACTOR

While the actual electronics can fit in even the smallest boxes, the dimensions of the sensor modules are an important aspect of the perceived usefulness for the user. A small box will look more complicated than a slightly bigger one, but make it too big and it will actually influence the usability of the whole system. A medium sized box also has some room left for some instructional text and illustration, which makes a sensor module not alone an electronic module, but also a physical reference for more experienced users.

Sensor boxes

Sensor boxes have the form of a flat cube. The width and depth are both 50mm, but the height is 30mm. This way it is clear for the user what side is the top and what is the bottom. Top and bottom are also the most important sides of the module, because they contain the sensor and connectors. The sides (50*30mm each) of the box can be used to engrave instructions on specific for this sensor. For example, Distance sensor: higher output means the sensed object is closer.

Output boxes

Output boxes should look similar to sensor boxes, but there should also be clear differences. It should be clear to the user that these boxes should not be connected in the same way as sensor boxes. It should also be possible to connect multiple output boxes to one sensor, to compare different ways of communicating a sensor value on the fly. For example, a USB connector uses only 4 pins to transfer lots of data in the same time. For the concept, it needs to be possible to connect multiple output boxes at the same time, so I need a similar interface.

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