B3.1 Internship Report

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MultiMaterial 3D printing for Signify

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This is an NDA report, use only for grading purposes

INTERNSHIP REPORT

Summary

This is the report of my internship at Signfiy 3D printing, a company 3D printing luminaires and fixtures for consumer and professional markets. For 17 weeks I was a research and development engineer working on MultiMaterial printing.

This multi material printing research was executed in five iterations, where we first explored and later specialized. We eventually built a completely new MultiMaterial printer capable of printing with two materials.

During this process I've gained a lot of knowledge on 3D printing, more specifically g-code, printer layout, Arduino integration and much more. This experience also gave me a lot of inspiration for my own future and it motivated me to focus my Vision and Identity more towards digital manufacturing.

I've also learned a lot about working in a multinational company and everything that pairs with it. Fun times, such as meeting, brainstorming and building. However, also less fun times, collaborating, debugging and ttempting to innovate. It really showed me how important it is to have both formal and informal relations with colleagues, and how company culture can or cannot have a positive effect on innovation implementation.

In the end I've grown and learned a lot, and I am very excited to start my FBP the next semester!

INTRODUCTION

This internship was initialized with my passion for digital manufacturing and 3D printing. I think that 3D printing and other fully digitalized production techniques are the bottleneck of development of industry 5.0 and the drive to a more sustainable product production future.

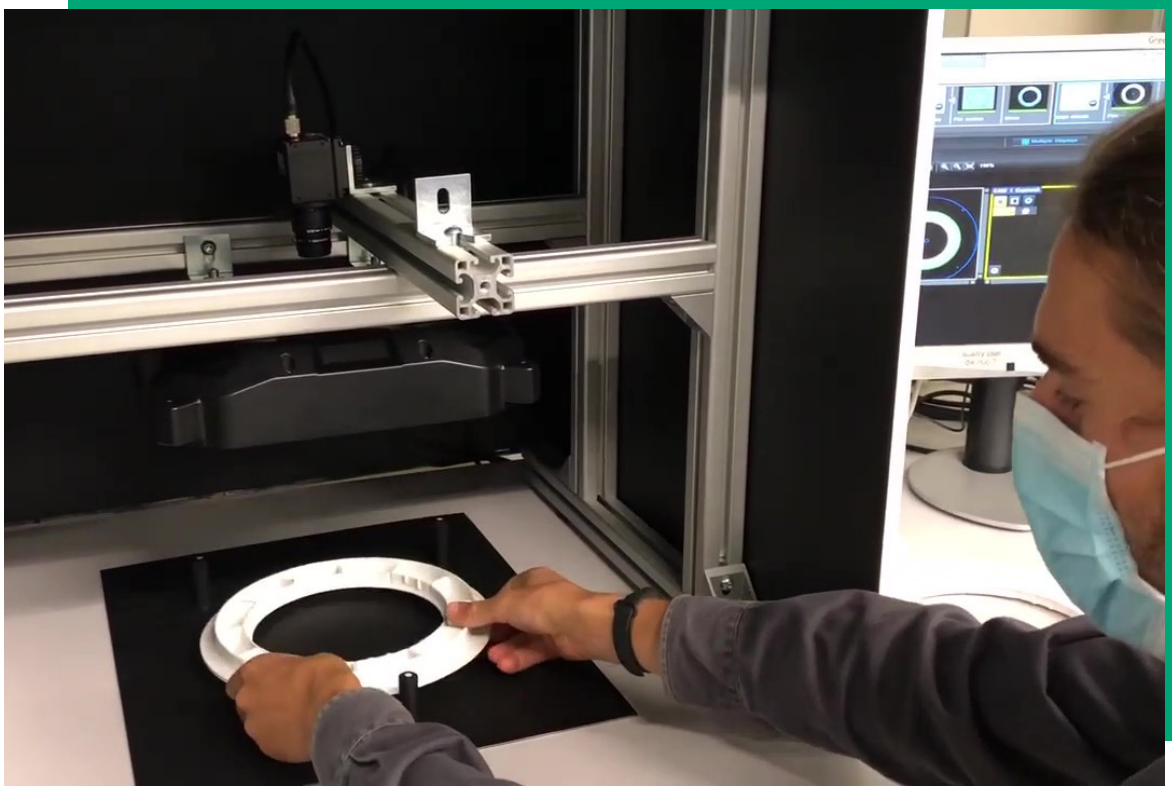
At first, I wanted to experiment with an academic/research career, after my publication I felt very motivated to continue in this area. I had established contact with the Morphing Matters lab in Pittsburgh and got an internship there. This however was before the COVID-19 crisis and because of it I had to cancel the trip to America.

However, at the same time I was also very interested in exploring this research interest of mine within a company. And thus, I wondered how it these two would compare, it seemed logical to then start from the company side. As a very motivated and enthusiastic physical maker/researcher I would like to work in the context of making and experimenting. An R&D department of a larger organization seemed like a proper place to get the means to experiment.

When doing my project at the crafting everyday soft things squad, I met Koen van Os, who was working at Signify 3D printing. We had talked quite a bit about printing, and it sparked my interest for Signify 3D printing. Investigating further I found out that Signify is a company who strives for Environment goals and tries to improve their position through different production, namely 3D printing. This really interested me and motivated me to start this internship.

My internship report will be divided in two main chapters, I will first go into the subject of the internship and corresponding hard skills. And secondly, I will dive more into the experience of working for Signify and what soft skills I've picked up during this period

Note: Because of NDA, I will exclude specific details from this report. I would love to provide specific details in correspondence with my coach Koen van Os.



Company description

In my internship I will work for Signify [7], a large multinational with a total revenue of 6220 million in 2019 [9]. Signify is a large company which is focused on the light industry and one of the key players in this market according to Fortune Business Insights [4]. Originally Phillips Lighting N.V. the company changed its name to Signify in 2018 however continues to use the Philips brand name [8].

Signify is a company with a large focus on sustainability, and moreover increases these effort year by year [9]. It has already achieved the Paris Climate agreements to become 100% carbon neutral in 2020 [3], to me it seems that Signify is really a company who strives to push the renewable agenda through business as I talk about a lot in my Vision. Moreover, their Brighter Lives better world program, focusses on providing light to those who do not have access [9], these efforts signal a company that is interested in not only working for profit but also for the world.

More specifically I will be working at Signify 3D printing, a venture which aims to 3D print tailor made luminaires for professionals and Consumers [7]. I will be working at a smaller scale production and research facility in Maarheeze, Noord Brabant. Where they produce fixtures and shades as visible in the picture below, there they also have a R&D department, where I will work

This venture, Signify 3D printing, is in operation for a couple of years now, and my coach Koen van Os started working from Signify at Signify 3D printing when it was founded. He already worked at Phillips and Signify for quite a while, and besides Maarheeze has also worked at the High-Tech campus. Within Signify 3D printing he does a lot of R&D and design work. He specializes in scoping new techniques and trying them out, as well as scouting other businesses to seek relations and collaborations. He is very used to 3D printing but also very knowledgeable on the challenges that lie within exploiting 3D printing in a business environment.

Company assignment

Before I started my internship together with Koen, we discussed potential internship assignments. We eventually decided because of company and personal interest into researching Multi-Material FDM 3D Printing, Multi-Material will be further referred to MM. This would entail researching/ experiencing MM printing on Signify 3D printing machines. We discussed the initial approach and left the end more open with midterm evaluation to discuss the outcome. This assignment and how I tackled it will be covered later in the report.

I've set preliminary goals at the start of my internship in my PDP, which is added to the appendix. These however had to be altered slightly during the internship to accommodate for the COVID-19 regulations changing and the personal path I've chosen during my internship. These are my revised goals that I approached during the internship. My goals will be split in two main categories, into skills and experiences.

Skills

Internship assignment

In line with my internship assignment I aimed to have a very inclusive internship assignment which would cover three or more expertise areas. In this case with MM printing, it would entail at least;

- Technology and realization, as I research MM printing we will need to modify/build 3D printers in order to access functionality we want/need, this will entail electronics, mechanics and software. In order to achieve this growth, I will do all assembly and designing myself, however always in accordance with Koen.

- Math data and computing will be necessary to process G-code to make the 3D printer read it, as most slicers do not have MM integration this will need to be done by ourselves. Especially this part will be very interesting to me. In my FabriClick publication [4] we did not optimize machine code directly, which necessitated us to use some other tricks. I hope by improving my understanding of 3D printing and G-code to further aid my toolbox in realizing projects. In order to achieve this, I want to generate and program all the code myself, including firmware for printers etc.

- Creativity and aesthetics, in order to communicate results I will need to make example prints, I will aim to make them fit within the Signify 3D printing company profile. In order to achieve this, I will at least communicate multiple MM designs to my colleagues.

I believe this all could be very beneficial for my personal skills profile, as I will aim to learn more about production and digital manufacturing. As mentioned, before I think these new techniques will provide a way towards more sustainable production, and in the future, I hope to be a part of it.

Documentation

My last goal is also still valid since my last project, however now applicable in a professional environment. I want to work more structured, documenting progress and communicating with my colleagues. In order to achieve this, I want to make at least a final presentation and a midterm presentation. Moreover, I want to make a weekly reflection/ progression session, where I will digest my previous progress and make plans for the next week.

Experiences

Future work

My main goal for this internship was experience in the work-field, I would like to know what kind of companies I could work for in the future. And more specifically how these companies operate. As I outlined in my vision, I believe that businesses are the only entities that can directly influence their impact on the planet, by helping others and reducing their footprint. Signify seems like a company that has a large focus on this area it is however really the question how that translates into the day-to-day work.

I also wanted to visit smaller companies that work together with Signify 3D printing. In my PDP my goal was to visit 3 companies/entities that collaborate with Signify 3D printing.

Collaboration

As outlined in my professional identity I believe that in this high-tech production environment effective collaboration is essential to innovate. Especially in a practically "new" environment such as production 3D printing where design is influenced directly by the production process, and where very quick iterations can be made.

In order to gain experience in a professional setting my goal was to collaborate/interact with at least 4 different departments during my internship, namely: production, design, software and sales.

In this chapter I will explain what I've achieved and learned from this internship, I will try to give ample examples, but I will not go into details to keep this report concise. I would be happy to answer specific questions during my oral exam. Just as the goals section this will be divided in skills and experiences.

Skills

As mentioned before, the internship assignment chosen was MM printing. The challenge started out experimenting with MM printing, which ended up in developing a MM printer. Throughout this process I went through five iterative cycles, every time reflecting on the previous results, and outlining further needed control or specifications. For us it was important to work fast and efficient, optimizing for the most amount of learning for the least amount of investment time and costs, I will try to outline how we aimed to achieve this in all iterations.

MultiMaterial 3D printing

Iteration 1

Content

The first iteration started with manually changing the material, this meant hand feeding the material in and out of the printer. The printer would at a certain layer height, pause the print. Then I would pull out one material and insert the other, after which the printer continued. In this iteration I also started with writing a post-processing program for G-code, for this iteration the program inserted a pause the print every 5 layers into the G-code. This was made using python.

Reasoning and results

This first iteration was necessary to understand the build of the Signify specific 3D printers, and the nozzle behavior they express.

First, the prints are made with a very large nozzle. This poses ample problems when attempting to switch material through the same nozzle. Because it is so big it also always drips plastic when hot. Secondly, because the melt chamber is so big there is always a lot of melted plastic which tends to mix with the new plastic you insert. These two themes will remain the main challenge throughout the iterations.

Conclusion

This first iteration was finished very quickly, and in a few days, I was able to work with the new printers. Assessing key problems and opportunities and figure out the next step in the MM progress.

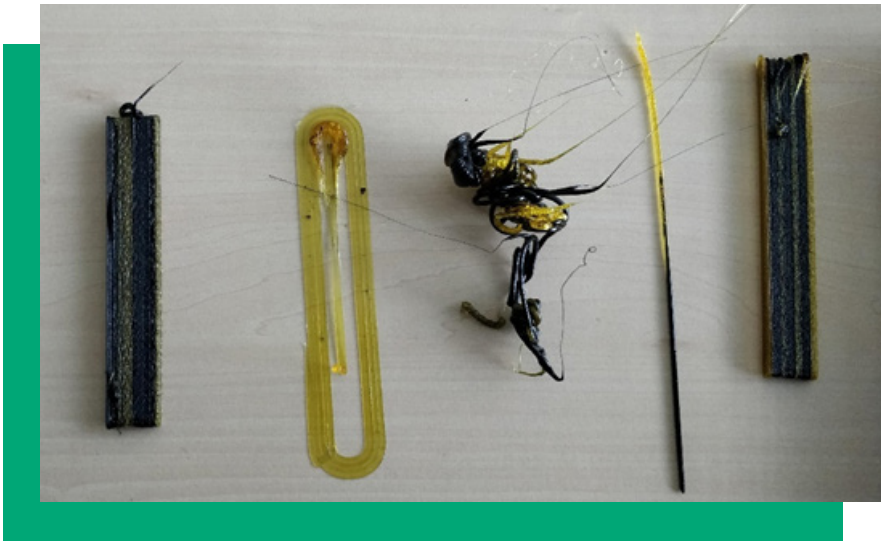


Fig 1; In the picture a few samples are presented, from left to right; The first sample, paused manually on the machine, Extrusion problems with the first layer on my processed g-code, purge material, a clear purge line printed form yellow to black, final example color changing every 5 layers.

Iteration 2

Content

The second iteration was focused on automating the process in iteration 1, this was done by integrating a Y-intersection for the Bowden tubes right above the hotend (fig 2). It allows two extruder assemblies with Bowden tubes to feed into one nozzle, this allows the printer to automatically retract and insert one of two materials into the printer.

In order to print with this printer, I made a g-code post-processing code, where I was able to at certain height intervals change the extruder. This code also allowed for custom G-code to be inserted when this extruder change happens. This G-code consisted of a few main principles that make the material change possible:

--> Printing G-code, an extruder change is registered.

-G1 E-250 *// G1, is a printing Move, E-250mm means retract 250 mm on the extruder.*

-M400 *// Wait for all previous commands to finish before reading further.*

-T1 *// Change the active extruder to T1.*

-G1 E250 *// Extrude 250mm of material, inserting it into the nozzle.*

-G1 X10 Y10 *// Move to coordinate X10 Y10.*

-G1 X100 E50 *// Extrude 50 while moving to X100, thus printing a line.*

--> Rest of G-code continues.

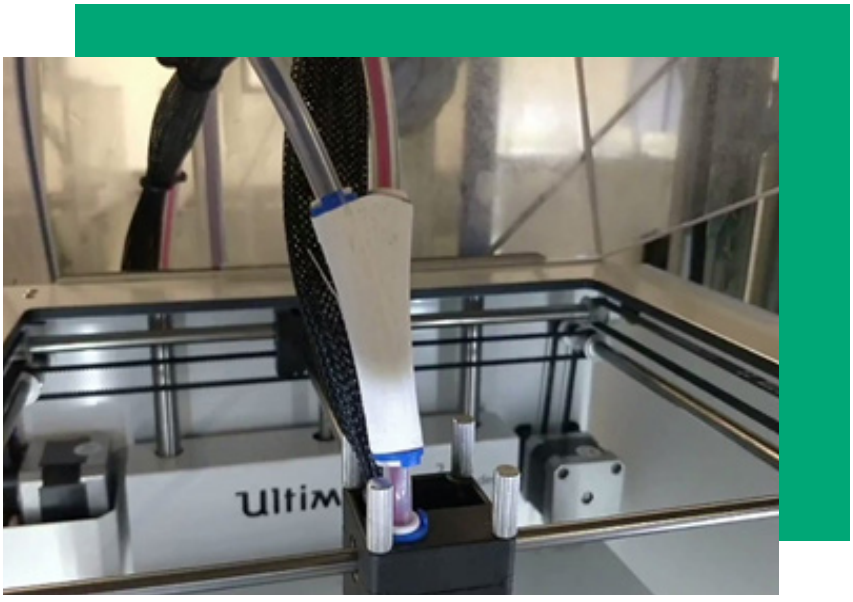


Fig 2; The Y-piece attached to the Bowden feeding into the hotend.

Command like these are necessary to make the printer switch the material, during this iteration a lot of time was spent experimenting with this sequence, for instance other print sequences could be inserted as well, purge towers and more.

We did some experiments into the behavior of the purge amount, comparing different colors temperatures and speed. These were tested on a flat line print, and one of the most noticeable variables was material color.

Reasoning and results

This approach was chosen to quickly learn the inherent flaws of automation. And, the flaws of a one nozzle MM printer. One of the main issues is the time and material involved in changing color. When changing color every layer of the print, more than 75% of the total material used was for purging the nozzle (fig 3). The purge tower for both colors was just massive. Off course optimization was possible but for every layer color changes this was not possible.

We however also found that when not purging the color transition could give a very interesting effect, however very material dependent. From transparent to black the change was immediate, however black to white it really took a few layers to get a clean white. This could give some very interesting effects.

Conclusion

This iteration was highly successful, in two weeks of work we found the issues that related to this one nozzle MM printer, however we also found potential application areas. It also taught me how I could work with G-code to move the machine in certain ways and automatically change materials for the first time!

Fig 3; The final example print, left and right are the purge towers.

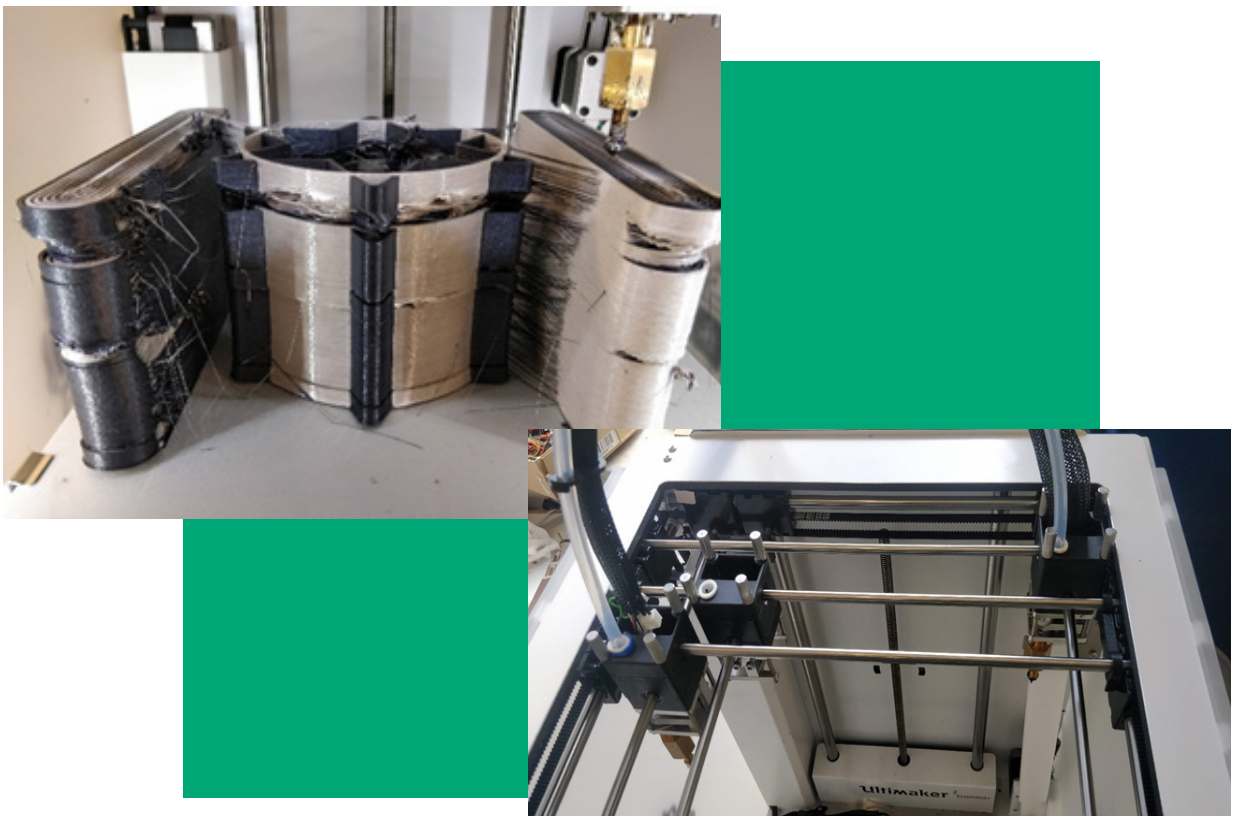


Fig 4; he 3D printer with 3 carriages, on the right below the second head you can see the clip connecting the two rods.

Iteration 3

Content

In this iteration the goal was to explore multi nozzle MM printers, logically multiple nozzles mitigate the purging issue of the singular nozzle setup. For this setup every material has a separate nozzle, it however ensues to highlight the issue found in iteration 1, a nozzle not in use drips. That is why we didn't choose for conventional dual nozzle printers. But we chose to explore a setup where both nozzles can be moved separately from each other.

For the first prototype we made use of an Ultimaker, we inserted two additional hotend carriages into the printer. The system would work through the center driving carriage this did not have a hotend attached. This center carriage then would be connected to either carriage with plastic clips (fig 4). The connected nozzle was changed manually in this iteration.

Again, a separate post-processing code was made in Python to account for different offsets per hotend. It also accounted for pauses in the printing. This manual process was a lot of work, just as the first iteration.

To make the 3D printer to work, the Ultimaker firmware had to be changed as well, with some help from software colleagues we were able to set this up.

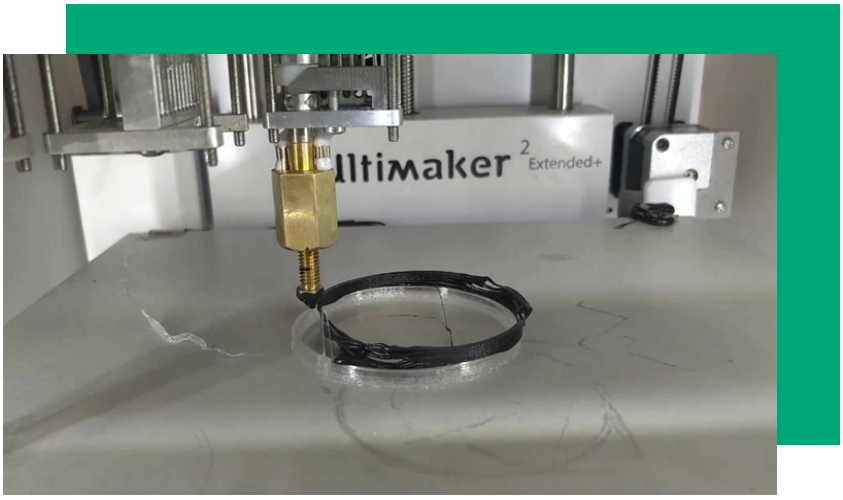


Fig 5; A not very well calibrated print.

Reasoning and results

This iteration was initiated to very quickly learn how to work with multinozzle setups. The issues found in iteration one were extremely valid for this technique namely the dripping of the nozzle. It became evident that for multinozzle setups this would become the main challenge.

Also, calibration was key, as you are working with multiple nozzles it is suddenly not the case that one nozzle lines up with the other (Fig 5). This calibration was very peculiar work and required some calibration prints to be made.

We found that the area taken up by the additional printer carriages was a lot, from the 220*220mm build volume only around 80*80mm was left. Also, the 8 different connection points (4 per hotend) were quite a lot to further automate.

Conclusion

This iteration quickly gave us leeway to work with the multinozzle setup, in under a week we were printing and experimenting with this technique. The quick process and starting with printing realty helped understand the limited build area and what needed to be improved in the next iteration.

It also proved promising as the concept did work quite quickly to print actual MM prints (fig 6). The next step would be to automate such a design.

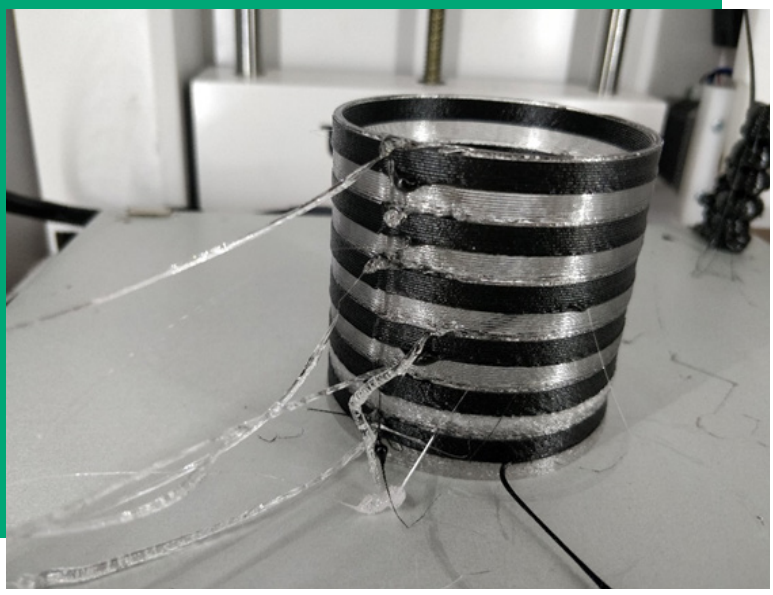


Fig 6; One of the first calibrated prints. It is however evident that drooping needs a remedy.

Iteration 4

Content

From iteration 3 we made our new design; this was based on two moving gantries instead of three. This made the whole system a lot more compact and allowed the connection points to be reduced from eight to only two.

We used two nozzles with different heights to the built plate, one carriage was connected to the X and Y stepper motor directly and thus called the driving carriage. Attached to this carriage was a hotend with a shorter nozzle of +/- 10 MM (fig 8).

The other carriage was attached to the same X-movement rod and to a separate Y-movement rod, it thus was not directly connected to the Y-stepper motor, thus called the following carriage. This carriage could be connected to the first carriage with two servos mounted on either side (fig 7). The following carriage unlike the driving carriage has a longer nozzle of approximately 18MM. This difference in height allows for the MM printing.

When printing with the driving carriage the following carriage is disconnected and floated on the back of the printer. Leaving it completely out of the way of the part. When switching however, the print plate moves down 8MM, the following carriage is attached to the driving carriage with two hooks connected to two servos. And then it continues printing with the longer nozzle.

Flow control of the shorter nozzle was very important as this would float above the print while printing with the longer nozzle. We opted for physically blocking the nozzle, this was achieved by attaching an iron bar to the following carriage which would when attached, slide under the short nozzle and block it physically (fig 8). For the longer nozzle we attached an iron bar on the backside of the printer, where it would move over.

The plastic connectors between the stepper and driving rods were redesigned to accommodate for the servo's and connectors, more than three different designs were made and tested (fig 7).

Fig 7; Iteration one of the servo-controlled connectors.

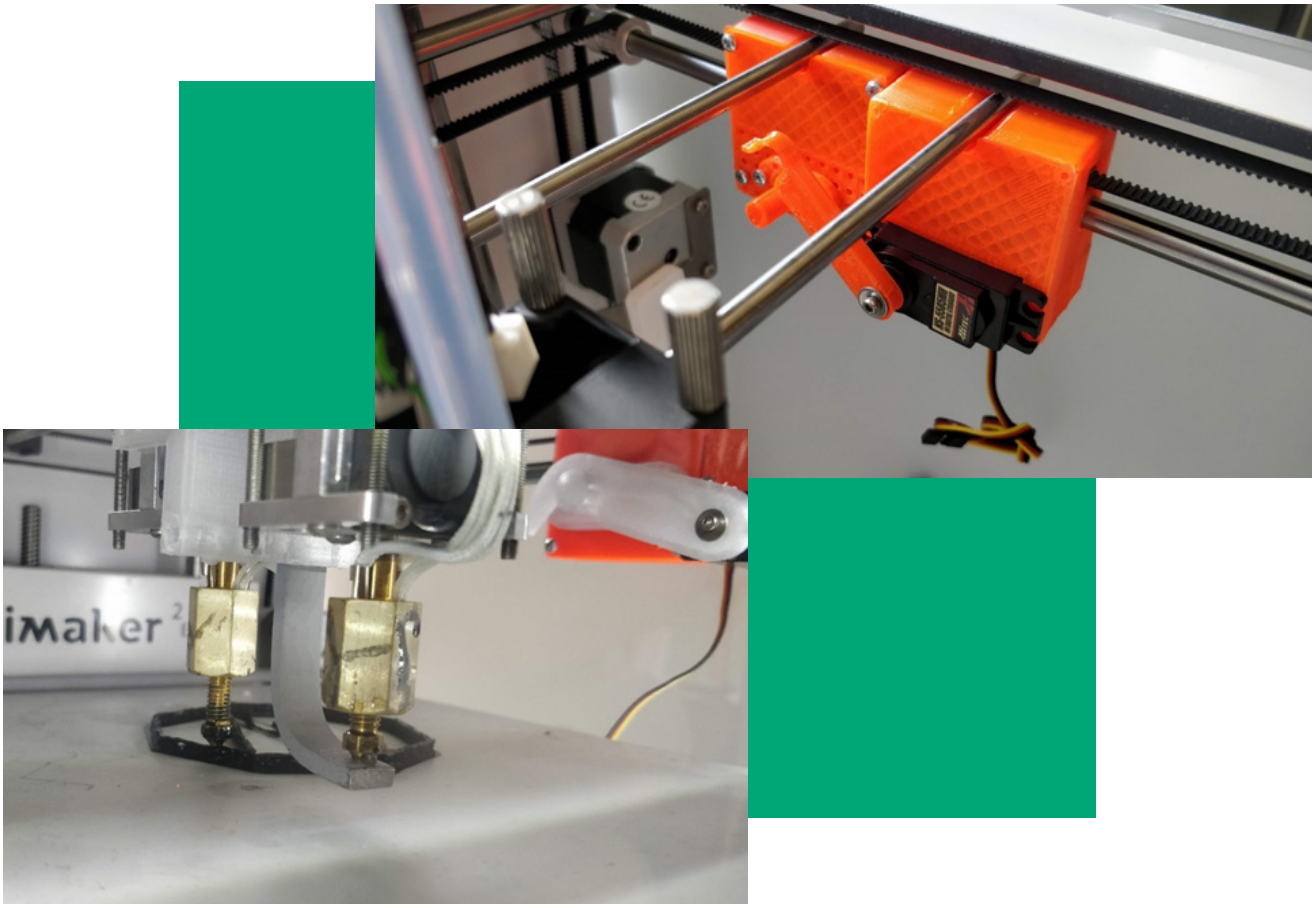


Fig 8; The nozzle setup, two different height nozzles are used, with iron blocker over the shorter driving nozzle.

In order to make the full print work again a post processing script had to be made, however in this case it had to be able to merge two different STL drawings. As we wanted to be able to print more complex multicolor parts, we adopted a method where we would input two g-codes into the final processing code. We first drew both surfaces in SolidWorks, we then saved and processed them in Cura as separate prints. In the end merging the two again with our python script. The python script also accounted just like previous for different offsets but also for the nozzle change routine.

The system also had to work together with a separate Arduino nano for the servo controls, this was possibly one of the harder implementations, as the Ultimaker is only able to process G-code. Luckily there is an implementation where in the G-code you can set certain pins to HIGH or LOW, these were then connected to the Arduino, which reacted with servo motion accordingly.

We also experimented with different nozzle sizes, we however did not have the proper length for a 0.8 nozzle, I thus designed a new nozzle to fit on the printer. This was produced in the workshop. It was a nice exercise to make a real work drawing of the part in SolidWorks (fig 9).

Reasoning/ results

This iteration was done mostly to check the viability of a multinozzle system for MM printing, like the previous Y-piece integration. The use of an Ultimaker and Arduino platform allowed us to very quickly built this machine and test out different material changing routines.

The result of this iteration was very promising, in the end when limiting the amount of layer changes, we did get some nice prints. However, the constant motion of the hotends gave limited options to what we could do when the hotend was parked. We also noted that speed when changing material was of very high importance, as you purge the nozzle you want to be on the part your printing as soon as possible. Otherwise the material has time to droop uncontrollably. This material did not deposit on the print directly as we blocked it with the Iron bars. It did however over multiple layer changes collect on the bar, after which the nozzle deposited this larger chunk of plastic on the print. Sometimes even restricting further printing because of the obstruction.

Again, material flow and calibration were the most important things, and the design of the hook mechanism was very important. But more so reliability over longer prints was very important.

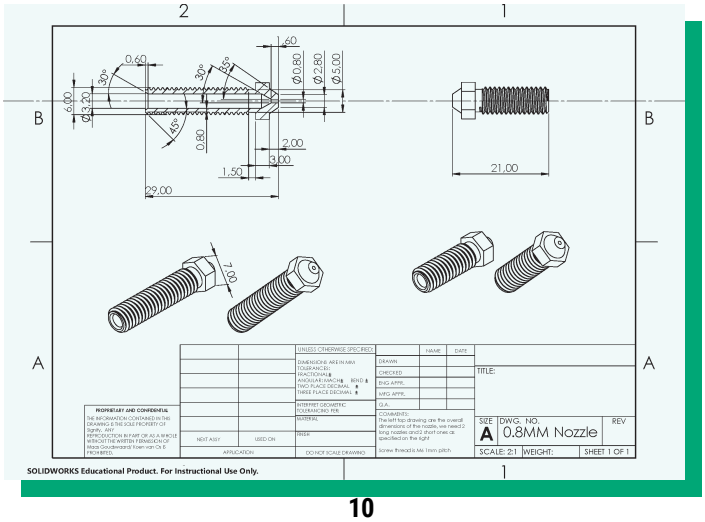
Conclusion

The multi nozzle MM printing approach was promising however the constant motion of the printheads restricts control. This is also the reason that we believe that true separate control of hotends is eventually better, as you can park it somewhere, and have full control of the uncontrollable material depositions.

For me this was also a very challenging and fun prototype, as it involved designing of parts, programming and printing. This combination of all these factors made it really rewarding as we slowly got better prints over time. It also really was in line with my goals I set at the start of the semester.

After this iteration I made a midterm video presentation where I introduced my colleagues to my progress so far and asked for feedback. This will be further described later.

Fig 9; Work drawing of the nozzle designs.



Iteration 5

Content

For the final iteration we believed that we needed to go to complete nozzle control, this meant that we were not able to fit it within an Ultimaker frame anymore. This was mostly because of the movement system that the Ultimaker uses. We saw an opportunity for Prusa design [6] printers like the Ender 3 by Creality [2]. The hot bed Y movement allows for conveyer belt print setups, where you can move the bed horizontally instead of vertically as the Ultimaker. This setup allows for a lot more space for open exploration but also expandability.

In order to quickly build up such a system we decided to buy two Ender 3's [2], to combine them into one printer. This would allow us to use both hotends separate from each other. Giving full control of nozzle flow.

The complete machine was an Ender-Ultimaker Hybrid, we used most mechanical parts from the ender, such as the frames carriage, steppers, endstops etc. However, to account for the nozzle size used within Signify 3D printing, we attached to the ender carriages Ultimaker nozzle assemblies, and Ultimaker extruder assemblies. The whole system was powered by an Ultimaker board (fig 10).

There were a few main parts that needed to be addressed:

- Connecting mechanical parts
- Connecting all electronics to Ultimaker board
- Attach hotend and extruder
- Switch the stepper motors

- Connecting mechanical parts; In order to connect the two frames together we needed to make one long Y-beam as well as connecting the other supporting parts of the frames. This was relatively simple as we ordered I connecters that just enabled us to connect the two frames together (fig 11). Also, longer Y-belts were necessary.

- Connecting all electronics to Ultimaker board; In order for us to use two separate nozzles with separate temperature sensors we were not able to use the Ender PCB. We opted for the Ultimaker board as I already had a lot of experience with this and it was very quick and cheap to get our hands on. The Ultimaker however uses different temperature sensors than the Ender components had so that all had to be switched out (fig 14).

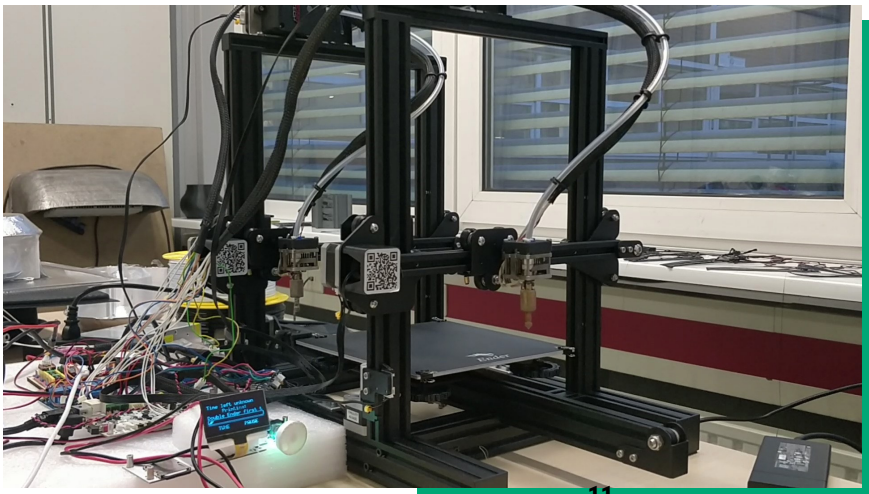


Fig 10; The two gantries mounted on one frame.

Fig 11; The connected frames.

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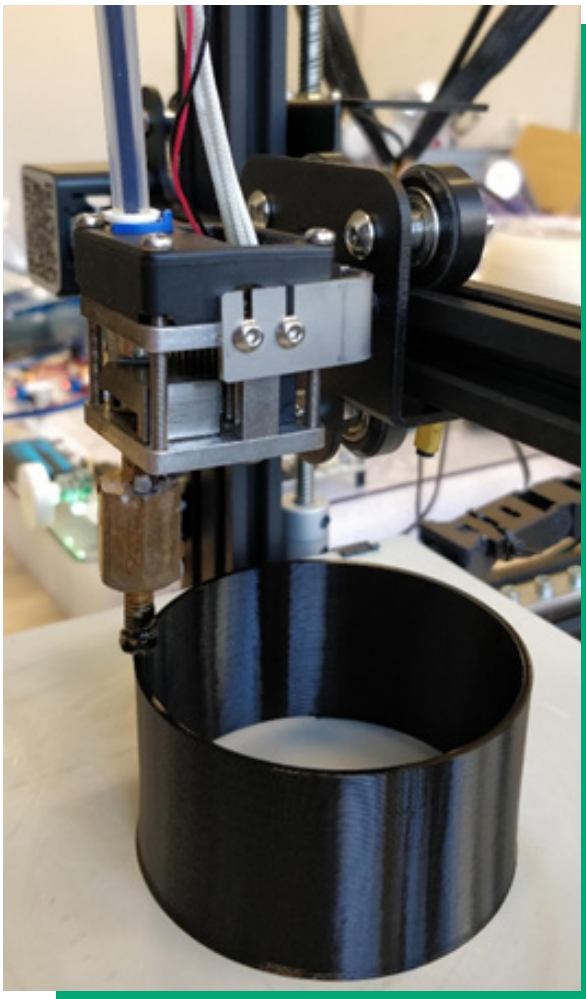
Fig 12; One of the two nozzle assemblies, with custom made bracket.



- Attaching hotend and extruder to Ender carriage; In order to print with 2.8mm material, and also PC we needed the Ultimaker hotends, in order to mount these assemblies to the Ender carriage I designed an adapter bracket for sheet metal production which was a rather simple but new exercise. Also, for the extruder assemblies' new brackets had to be designed and fabricated (fig 12).

- Switch the stepper motor driven by the Ultimaker board; The stepper control was achieved with the use of relays, the Ultimaker board only has 4 stepper motor drivers. An X, Y, Z and E, as well as limited endstops only one X, Y and Z. All the while we needed to drive two X, Z and E stepper motors, and two X and Z endstops. Per stepper two different relays were used. The schematic is visible below (fig 13).

The relays were separately controlled by an Arduino, this was done because the Ultimaker did not provide a stable enough signal to drive the relay boards. Similar communication as in the fourth iteration was used to talk from the Ultimaker board to the Arduino.

This whole system was however a bit of a challenge, we aimed to switch the Z-stepper from either driven by the board to enabled (so it would hold position). This however did not work and ended up with me debugging over a week to find out that it was a certain coil blowback from the stepper motors. To mitigate this, we homed the X and Z every time we switched the nozzle.

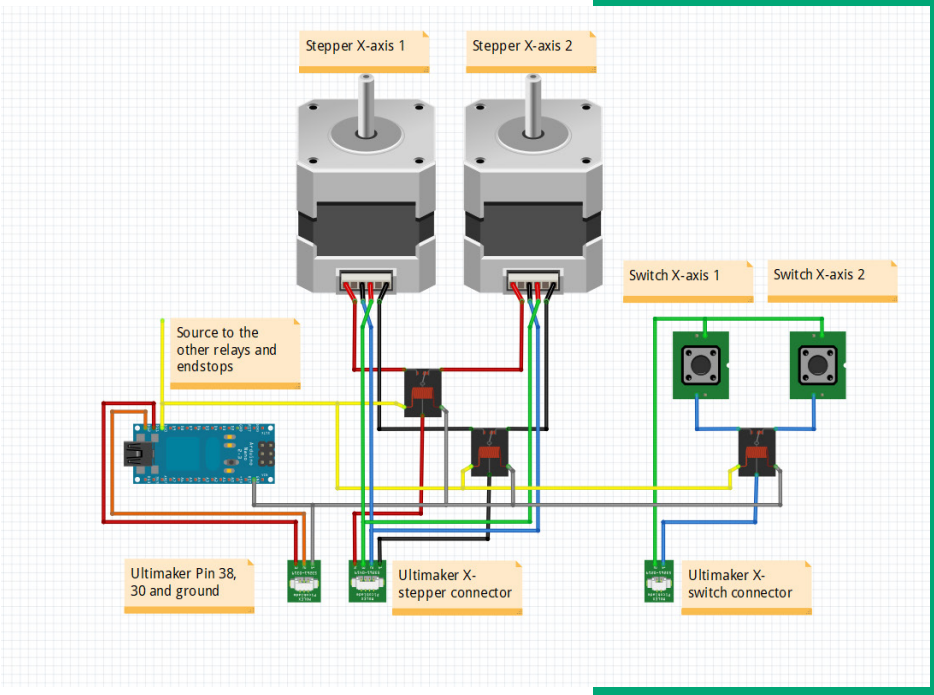


Fig 13; Layout of the stepper switching mechanics.

Reasoning and results

This iteration was the final design delivered to Signify 3D printing and thus also the result of my internship. It was a big challenge and took the most amount of time. I do however think that it was a very nice end results to the research.

When printing this machine is very controllable and reliable. Because there are no separate moving parts as in iteration 4. All the motion is controlled directly by the steppers. We however do only get to control one nozzle at a time.

Conclusion

The result of our exploration was a machine which is very capable of printing with two materials (fig 15). It does however have quite a manual to print with reliably and requires quite some tuning before it prints correctly.

We however do believe that such a concept with the moving Y-carriage could pose an interesting position in the 3D printer market. As it allows for a lot of experimentation with more than just 3D printing. By for instance mounting more gantries on one Y-movement, for instance part placement, visual inspection or screwing. Which all feeds into the concept of product printing instead of part printing.

This iteration really excited me and inspired me for the future. Concepts like this can create opportunities for production that are not on the market yet. And I think they could also really improve manufacturing. It can be done locally and without human costs being a factor, it is also possible to use recycled materials and when done locally this is easier to arrange. And as I describe in my identity and vision these are really the areas where I would like to improve manufacturing.

Fig 14; The electronics mounted on an acrylic plate.

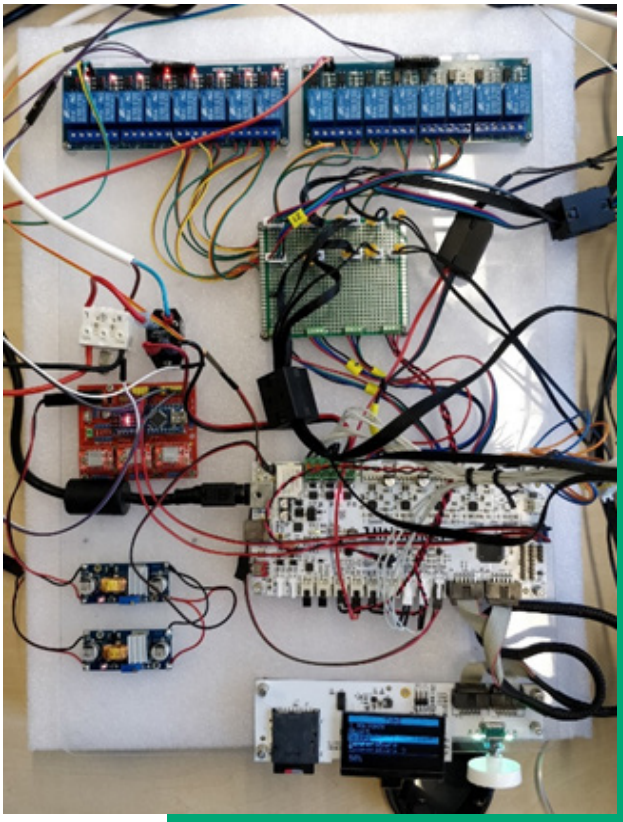


Fig 15; One of the example shades made for the final presentation.

Keyence assignment

Besides the MultiMaterial assignment, we set out from the beginning I also got the chance to work on a second project. This was personally a very good way to switch up the work, and to collaborate with different people.

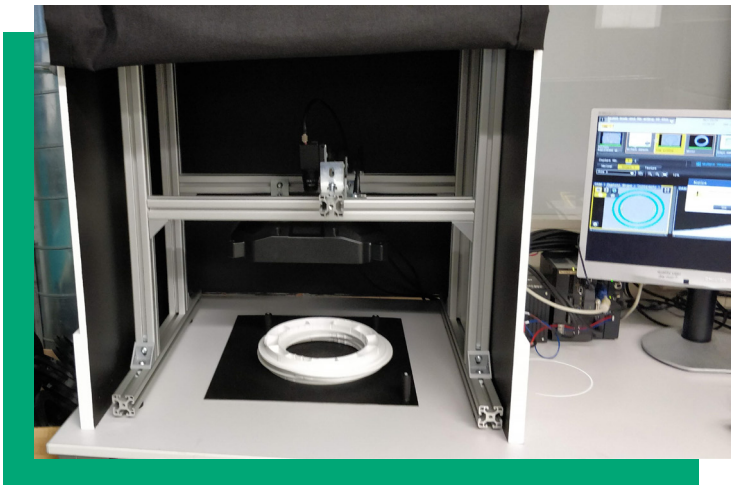
The assignment was based on inspection of 3D printed parts. This now happens by manual inspection, mostly because there wasn't a system yet implemented to clean and scan them. And as the rollout of printing facilities is underway this manual inspection is not possible. We first tested and then bought a Keyence visual inspection system (fig 16), and I programmed the whole system. I worked together with R&D and Operations to try to bring it into Signify 3D printing.

This machine works with a camera and a light, the part can be placed under the camera and then a picture is taken with light from a few directions. Then this image is processed in dedicated software, where certain tools "search" for certain manufacturing errors. This all is then led back to an assessment of the part.

It was a very interesting process, as the programming of the device was quite fun an intuitive. Moreover, it also allowed me to really collaborate with some new people who had a direct benefit from this device, contrary to my MM research. We had some brainstorm sessions on how this could be implemented, and I was the "expert", which was a very nice experience.

One of the major learning points while working with this device was the challenge of implementing new (innovative) products/techniques into an already working operation. The employees all have their own agenda to upkeep and their own deadlines to meet. Extra hours to learn or work with new equipment costs time and thus is not always as welcome as you would think. When we were done setting up the device, we had some meetings on how to bring this further, however it there is still no concrete plan on how to implement this in production.

Fig 16; The keyence visual inspection system with custom frame by me.



Documentation and communication

Besides my regular work on the MM printing and the Keyence machine, in total I have made 3 presentations. One Keyence presentation, and more importantly two 10-minute video presentations on my MM research. It was nice to be able to make these presentations as it was one of my goals to be able to reproduce my knowledge more. In the end I think I got a lot more comfortable editing videos which was been quite a hurdle in the past.

The videos will remain internal at Signify but upon request I would love to show them.

Together with Koen van Os I had daily conversations about the project and progress, this was really pleasant for me. From the midterm meeting we also had a weekly meeting together with Coen Liedenbaum who is an R&D manager. It was informative and pleasant to involve someone else in this process. I took these meetings as my weekly reflection moment; however, I did not reflect on them on paper which I aimed to do. I found that I reflect quite a lot, however it is still not intrinsic for me to write it out.

Experiences

Following I will explain more my experience in executing this internship assignment, together with my experiences as working in such a company. I will try to reflect where I would like to go in the future and whether my Identity and Vision are altered because of this internship.

Future work

First, I think it was very interesting to see the application of 3D printing in a business environment. As you'd expect there are much different demands for consumer goods compared to prototypes 3D printers are mostly used for. The printers used at Signify 3D printing were very specialized for 1 certain type of product and that was interesting to experience. Learning limitations of these printers really opened my mind about what printing could do in a consumer market, and how limited it feels now, at least for FDM 3D printers.

I've found that workflow and automation also really tie into the whole process, production isn't quite as straightforward as with 3D printing for prototyping. This process is extremely hard, because of the necessary repeatability. Also, the level of quality expected was quite high and rather hard to achieve with these FDM printers. I found it really interesting to think and brainstorm together with Koen about these inherent issues such as slicing, quality control, code generation etc. It is also the role of the R&D employee to think about these processes together with for instance a new machine.

As stated in my vision I believe it of utmost importance to tackle the making industry as it is a very large emitter. I believe that digital, tailored, local, circular manufacturing can play a large part in this. With printing potentially playing a large role. This makes me very motivated to work in this area and a company like Signify is really motivated to make a change. I think it could be very interesting and motivating to work in such a company who is able to make a significant impact and set a good example for other companies.

Not future work?

However, I've also experienced that there are some other factors that are more important to my own wellbeing. For one I believe that company culture is very important to employees' happiness and wellbeing. A very good example where I experienced that this was important was with the Keyence machine. As R&D we are constantly looking to improve products or process. This is how we came upon visual inspection, now all printed parts are manually inspected however this is a major bottleneck when scaling up production. Thus, as explained before I set the machine up, however even after a few meetings other colleagues didn't start investing time into the equipment. After conversing with Koen about these kinds of issues he also stated that he expected this, and that it was often the case. Which is a shame, and I can imagine very frustrating as R&D designer.

And it also highlights quite well the theory I've learned in my Entrepreneurship courses for my USE learning line. It was highlighted how company culture really is very important to push innovation. At Signify I think one of the main issues was that here there is no real common goal. All the different departments had their own agenda to uphold, and there was little split effort in these instances. This simply led to projects being either R&D or only operations, and this just didn't help in implementing new helpful tools for operations from R&D.

This culture also further translated throughout R&D, In my experience there was little common push for new different Ideas. This was all a really interesting learning experience for me, and really made clear to me what I would want in a company, which is a good communal effort to push the limits of a company. Fighting as a team to be the best in the sector I think really drives innovation. And splits effort between all different departments, you are the same company in the end!

External visits

One of my hopes was to be next to working at a larger company, to be able to see some smaller companies. However, because of the corona crisis we were not able to go to as much other companies as I hoped to do.

We did however go on a small trip to the High-tech campus where Koen showed me a lot of his previous work areas. This was very nice as it was a lot more of an inspiring workplace then Maarheeze. He also acknowledged that area and atmosphere really changes the complete work experience!

We also went to Concr3de [1] in Rotterdam, which was also very nice, it was cool to see how such a big company can seek to engage with a very small company. And it was also very cool to feel like we were the guys to "catch" for Concr3de as a startup. This startup was very interesting and pushing implementation of "new" techniques, to improve manufacturing/ research.

Collaboration

Collaboration during my project was quite hard, as my researhc was somewhat on the background for other employees within our department. It seemed that everybody was very busy on their own different tasks and thus there was little time for either conversation or interest in my objective. I also believe that I could've been a bit more pro-active in this regard, personally it felt very hard to penetrate through existing relationships between colleagues and it also felt as I was not doing something too interesting/ worth explaining. There also weren't any social activities organized with all the colleagues so there was little to break the ice properly. It was all very formal, and I regret that. This was also potentially heavily influenced by the COVID-19 crisis.

I did however have almost daily meetings with Koen, off course because he was my coach but also because we worked in the same office. And I think that was of very high value throughout my internship. I really appreciate the time he took for me, to talk about his past work experience, his present at signify, and the time he put in talking about my MM challenge. As mentioned, before we also had a weekly meeting together with Coen Liedenbaum which was helpful.

Working with other colleagues/departments was as I said before very formal. During the process we aimed to involve other colleagues, showing the printer, the prints and so on. However, because I was working on the subject MM printing, which has such little direct overlap with other departments there wasn't too much enthusiasm. Most probably just saw the amount of work it would take to make the product sellable. Designers just saw the issues with proper material flow, operators saw the amount of strings left on the print and so on. This difference in view and goal is off course inescapable, it is however up to the R&D employee to communicate the results in a way others can understand. This phenomenon I've also experienced with my FabriClick project, there instead of seeing the potential we got mostly comments on the actual application we chose, while we presented it as a technique. This again was a learning point for me, and in the final presentation I've made sure to mostly show well finished examples that really communicate the potential of the technique.

This internship has inspired me in multiple ways, as also described in my reflection. After my internship I was very motivated to revise my PDP and to incorporate changes I've talked about with Koen, and have experienced myself. Most notible is the focus on manufacturing, and I've also thought about the possibility of providing tools for others for isntance. Possibly becoming more of an educator in a sense.

Vision

Whether we all like it or not, the world is changing. The way we, as a society and as individuals, cope with this change is our challenge. CO2 emissions are rising and government restrictions are failing. Global problems require global solutions but a governing function on that scale is still unimaginable.

It thus falls upon us as individuals and communities to make better for the future and improve the way that we interact with the world. This starts by mindset; we should all aim to contribute by choosing sustainably. And I think that designers can make a real significant impact by not only on an individual level hange, but they can exert force by designing and configuring towards more sustainable products and processes, allowing others to choose sustainably as well.

This choice can only be provided by business and industry. The global rise of wealth is paired with bad practice, but it doesn't have to be this way. Through business tremendous achievements have been made, the time is now to go through the second iteration. Companies can funnel efforts in gaining on climate change instead of slowing. I think that In our world capital is the only accelerator faster than the environment.

Designers have an important position in our consumer market, which they can leverage within their current companies to give consumers the choice. The designers are the mediators between technology and product, process and production and thus they bear the responsibility to the outcomes of their designs especially on a global scale.

Professional Identity

Driving innovation through business can start with the beginning, production. Especially our global production industry is extremely damaging to the planet. For example: designing a part, to then make a mold, mold it 1.000.000 times, then store it, sell 500.000 and discard/store the other half. These practices make no sense in our current age of digitalization.

I think local, on demand, digital manufacturing is the key to more sustainable production practices. And I see it is my responsibility to spread my knowledge and expertise in exploring and exploiting these practices. This goal can only be met with expertise in the industry, contacts and most of all collaboration. I hope to be able to provide multiple companies with tools or knowledge that they can appropriate to improve their impact from the bottom up. This can be done both through academics and business.

Collaboration is of utmost importance to be able to bring change, and I would love to work with a team who is driven by contributing to this global cause. On an individual level but also on a professional level.

My goal is to grow towards a designer who is an expert in digital manufacturing and who can investigate potential new applications of these new production techniques in different context. By working for multiple stakeholders providing either tools, or knowledge I believe my impact can be most widespread.

ACKNOWLEDGEMENTS

I would first like to thank my coach; Koen van Os, for the time he was able to spend with me. It was great to really talk a lot about my assignment, but also about work and the future of the industry. I think Koen has been a great mentor to me during this time, and I hope to see him some more in the Crafting Everyday Soft Things squad.

I would also specifically like to thank Coen Liedenbaum for taking the time to meet with us over 10 times, it was great to see your projects as well and to have your opinion on our MultiMaterial research.

Furthermore, I would like to thank Lars Waumans, for arranging my internship within Signify and allowing for me to come!

Then lastly, I would like to thank all the other colleagues that assisted me during my project and colleagues that have provided me with feedback!

I would also like to thank Pierre Levy for taking the time to visit us at Signify 3D printing in Maarheeze at the beginning of year, as well as the other digital meeting! These were both helpful in my development and pushed me to think about my future!

REFERENCES

[1] concr3de. (n.d.). CONCR3DE - Stone 3D printing for construction, design & research. Retrieved 2 January 2021, from https://concr3de.com/

[2] Creality3D. (n.d.). Ender 3 3D Printer. Retrieved 29 December 2020, from https://www.creality3dofficial.com/collections/ender-series/products/official-creality-ender-3-3d-printer

[3] Derler, Z. & Signify. (2020, November 3). Carbon neutrality: The new normal for Signify. Retrieved 28 December 2020, from https://www.climatechangenews.com/2020/09/18/carbon-neutrality-new-normal-signify/

[4] Fortune Business Insights. (2020, October). Lighting Market Size, Share & Trends | Industry Report [2020-2027]. Retrieved 28 December 2020, from https://www.fortunebusinessinsights.com/industry-reports/lighting-market-101542

[5] Goudswaard, M., Abraham, A., Goveia da Rocha, B., Andersen, K., & Liang, R.-H. (2020). FabriClick. Proceedings of the 2020 ACM Designing Interactive Systems Conference, 379–393. https://doi.org/10.1145/3357236.3395569

[6] Prusa3D. (n.d.). Original Prusa i3 MK3S+ - Prusa Research. Retrieved 29 December 2020, from https://shop.prusa3d.com/en/51-original-prusa-i3-mk3s

[7] Signify. (n.d.-a). 3D printing by Signify. Retrieved 28 December 2020, from https://www.signify.com/global/innovation/3d-printing

[8] Signify. (2018, May 16). Philips Lighting is now Signify | Signify Company Website. Retrieved 28 December 2020, from https://www.signify.com/global/our-company/news/press-releases/2018/20180516-philips-lighting-is-now-signify

[9] Signify. (2019, December). Signify Annual Report 2019. Signify N.V. Retrieved from https://www.signify.com/static/2019/signify-annual-report-2019.pdf

B3.1 Internship Reflection

Maas Goudswaard

MultiMaterial 3D printing for Signify

Company coach:

Koen van Os

Teacher coach:

Pierre Levy

When preparing for my internship I had an academic internship in mind at the Morphing Matters lab in Pittsburg. However, in retrospect I am not unhappy that it was cancelled due to COVID-19. I've really picked up a lot from the business side which I wouldn't have been able to do in Amerika. I think this internship has been very productive and it is great to see that it was a very good learning experience on both the content as well as the context.

The content was great because It really fortified my heading for me. I think it is more and more evident that I am not only competent in working with digitally driven machines, but I can also find ways to reinterpret these "new" areas, as I've done this semester and did in FabriClick. The internship subject matter has allowed me to achieve my goals in TE, MDC and BE and gave me a lot more tools on how to continue working in digitalized manufacturing.

The context was also very insightful. Working at signify really gave me insight on where I would like to go. In positive ways and negative ways, for one such a large company does have a lot of freedom, at least where we were working. It allowed us to buy and research what we liked. It however is also limiting, because there are so many people involved changes happen very slowly. A companies appearance does not have to match up with the actual work on the floor. This all boils down to the importance of culture, how the company acts from within. And the internship gave handles one what is most important to me.

A big learning point for me was collaboration, at first I was a bit reluctant with contacting my colleagues. I wasn't sure how they would act or react, or what was normal within the company. It didn't feel very open for me to join. This meant that relations with colleagues remained mostly formal during the whole internship which frustrated me, however instead of attempting to solve the issue I pulled back.

This rohibited me from learning the most I could've, for one I would've worked a it faster if I really collaborated more with colleagues, or I could've made a larger impact if others were more involved with the research. Most importantly I didn't learn as much from other colleagues such as designers as I was hoping to. I do believe however that when I am joining in a new environment that I will tackle this differently. By taking more initiative in this area. I did in the end collaborate with a lot of colleagues; >5 but not as much as I wanted. Meaning that my goal was not specified wel enough.

As mentioned this internship has really motivated me to continue researching digital manufacturing, however I am not sure yet whether I want to tackle this challenge from a business approach or an academic approach. In my experience, through business implementation is more direct, however through academics it is more widespread. I plan on investigating the academic side more in my Final Bachelor Project.

FORMAL APPROVAL
INTERNSHIP

Date: 18/5/2020

Student Maas Goudswaard
Teacher coach Pierre Lévy
Period activity ☒ September - December ☐ February - June

Personal Development Plan for formal approval	Does the choice of the learning activity align with the Professional Identity and Vision development of the student and are his/her choices well-argued?	Yes [Additional feedback]
	Does the learning activity contribute to the development of the student?	Yes [Additional feedback]
	Does the chosen learning activity contribute to a balanced development in the Bachelor program of Industrial Design?	Yes [Additional feedback]
	Are the goals well formulated?	Yes [Additional feedback]
	Complete the aspects only for the chosen learning activity:	
Internship (worth 25 ECTS) (requisites: 100 ECTS + P1, P2, P3)	Does the company profile align with the requirements for internships? • *Doing an internship at one-man businesses is not allowed; unless the company owner is currently teaching at the Department of Industrial Design, Eindhoven University of Technology.* • *The company must support development in several expertise areas.*	Yes [Additional feedback]
	Does the company coach align with the guidelines for internships? *The company coach must hold a MSc. degree in (Industrial) Design or has at least 10 years of professional experience as a designer.*	Yes [Additional feedback]
	Can the student work on a clearly framed design project or tasks?	Yes Design and implementation of a multi-material printer.
	Personal Development Goals (minimum 1 - to include on Assessment form as well)*: **Discuss goals and positive and negative points in the coach meeting to guide how the student can develop expertise areas that might not be covered within the internship. The same goals will be included in the assessment form at the end of the internship.*	• Technology and realization; Design of a 3D printer system. • Creativity and aesthetics; The implementation of multi-material in luminaire context. How can multi-material manipulate light. • Math data and computing; The code generation for the multi-material printer. • Business and entrepreneurship; Working in the R&D department of a large company. Talking to different departments (design, software, machine's) about the implementation of multi-material. • [Learning goal] • [Learning goal]
Exchange (worth 25 ECTS) (requisites: 90 ECTS when the student leaves on exchange)	Name Exchange University and Department	[Name exchange university and department option 1] [Name exchange university and department option 2] [Name exchange university and department option 3] [Name exchange university and department option 4]
Minor (worth 25 ECTS) (requisites: 100 ECTS + EC approval for free minor)	Minor at Department of Industrial Design at University of Twente; or at the Department Industrial Design Engineering at Delft University of Technology. (No other departments at these Universities or other Universities in the Netherlands are allowed without permission of the Examination Committee.)	[Name University and Department where Minor is done] [Elective], [Elective], [Elective], [Elective], [Elective]
	Minor at a University elsewhere in the Netherlands	[Name University and Department where Minor is done] [Elective], [Elective], [Elective], [Elective], [Elective]
Electives (worth 25 ECTS)	What are the chosen electives? *In case a student chooses to do more than 15 ECTS worth of electives outside of the Department of Industrial Design, the student needs, next to the formal approval of the coach, to file a request to the Examination Committee.*	[Elective], [Elective], [Elective], [Elective], [Elective], [Generations before 2015-2016 choose 6 electives, later generations choose 5 electives]
Approval	The personal development plan and chosen learning activity are approved by the coach**: ***Provided the request is granted/supported by the Examination Committee.*	Yes [When the answer above is no, please explain why]

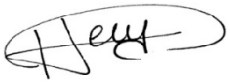
Please note:

More information:
This form needs to be completed and signed by the teacher coach. In case of an internship as activity, the student has to add their personal development plan plus this form signed by the teacher coach to the appendix of their internship report. In case of an exchange, the student needs to deliver (a copy of) this form to the International Office at the Department of ID.

TU/e Technische Universiteit Eindhoven University of Technology

- For exchange and activities that take places abroad it is strongly advised to consult the exchange coordinator for arranging insurance and to explore scholarship opportunities. Please be aware that exchange students need to be nominated by the exchange coordinator.
- For an internships it is strongly advised to contact Annaluisa Franco (Internship Coordinator) for arranging your internship details.
- For all B3.1 options: In total students are allowed to choose a maximum of 45 ECTS of courses outside the Industrial Design Department next to the Industrial Design major. When they would like to choose more than 15 ECTS of electives outside the Industrial Design department, they have to motivate their choices and get approval of the Examination Committee (next to the formal approval of the coach per this formal approval form).

Teacher Coach: Pierre Lévy

Signature: 

More information:
This form needs to be completed and signed by the teacher coach. In case of an internship as activity, the student has to add their personal development plan plus this form signed by the teacher coach to the appendix of their internship report. In case of an exchange, the student needs to deliver (a copy of) this form to the International Office at the Department of ID.

TU/e Technische Universiteit Eindhoven University of Technology

Company coach evaluation form

Internship

Student	Maas Goudswaard
Company	Signify
Company coach	Koen van Os
Position	Pre Development 3D printing process
Period	x September 2020 ☐ December 2020
Total weeks	17

Overall Competence of Chosen Design field	**Assignment**	Multicolour 3D printing. Explore the possibilities of printing with two different materials in the Signify 3D printing practice.
	Design and research processes	Intensive discussion with development team Signify and learning by doing. Target is to print every day a new design and adopt machines and designs based on findings.
	Assignment deliverables	Deliver multicolour printed Luminaire designs, a machine set-up and explanation on the process (by means of videos) and discuss it with stakeholders.
Scientific and Professional Skills	**Presenting**	Presenting in Covid time was done twice (midterm and final) by means of a very clear and comprehensive video. The videos were made with high level of quality and are appreciated by many Signify colleagues. The way the broadcast is done is the example of how technology will be disseminated across the company for us. Maas sets the standard! Also, his work on the 'Keyence optical measurement machine (Side activity) was finished with the high level video. ☐ Not applicable / unable to judge
	Reporting	The reporting by means of videos is excellent. Also, the structure and documentation on the machine set-up is done with care and accuracy. Always thought about how others can pick it up. Highly appreciated and excellent. ☐ Not applicable / unable to judge
	Organizing and planning	Always on time. Very accessible to make appointments. Weekly meeting invitations (initiated halfway) made the communication very clear. Even in Covid times it was very easy and joy to work with Maas. The planning is discussed multiple times and the final goal is reached! My experiences with internships is that the final goal is still out of reach at the end of the time. Not this time! It is fully accomplished.
	Reflecting	His critical attitude was okay. Good discussions! If he matures in the organization, he has to develop a way to express his critical opinion to the organization. The main question: Does it make sense to print with 2 colours? is not approached very critical. It is assumed to be the challenge and therefore not discussed. For this traineeship this was okay, but in future you should reflect on the main question even a bit more. ☐ Not applicable / unable to judge
	Cooperating	As mentioned, Maas was flexible, open, inspiring and a very appreciated colleague developed in a few days. He made this impression to many colleagues and is very knowledgeable on the software, hardware, and Keyence system. Het kept this optimistic way of working up to the end of the internship.
Vision and Identity	**Professional identity**	Hands-on experience developed in many directions: design of Luminaires, slicing and printing. Machine building: electronics and programming, Experiences in ordering parts and tools. Making video's! He adopted the

		technology of optical measurement systems (Keyence system) fast and detailed and high quality. His impression is very mature. He spoke the Signify language in the same week he entered the organization. Amazing according to Signify colleagues. He can clearly identify and define critical points in the product/process/technology. His solutions sound as they are based on extensive experience and they are indeed. ☐ Not applicable / unable to judge
	Vision	Maas has the perfect identity to introduce many new technologies in the factory/department. The design challenge is also clear in this area, although maybe not very visible to the design-community outside the organization. This could be a small pitfall: if you work a lot for solutions you cannot dedicate time and effort for example to disrupting iconic designs and new directions. I think he can do this as well, but this will only happen if the time is not fully dedicated to the original assignment. For example, I expect a lot from the idea of combing plants and 3D prints which was once mentioned by Maas. Finally, we did not have time to work on this and I expect many interesting ideas on this topic from Maas in the future. ☐ Not applicable / unable to judge
Contribution and Development	**How do you consider the specific contributions of the student within the internship assignment:**	Internship was certainly above 10% best. It was on time, high outcome, high quality and very pleasant.
	Provide an indication of the development the student has made throughout the internship, independently of the results:	Development: I think Maas took a lot of experience in this job. A lot of experience how a relative old company is moving and how a R&D department is struggling to get things done. A lot of relevant experiences for him. Development on aesthetics and end-user investigations was not part of the subject and did not develop. But it is discussed, and Maas assured this will be part of other projects coming up.
Feedback	I will certainly follow you in the coming years and expect many nice projects. It is very good to focus on different ways how design can contribute to society. And I wish you tons of fun with this!	

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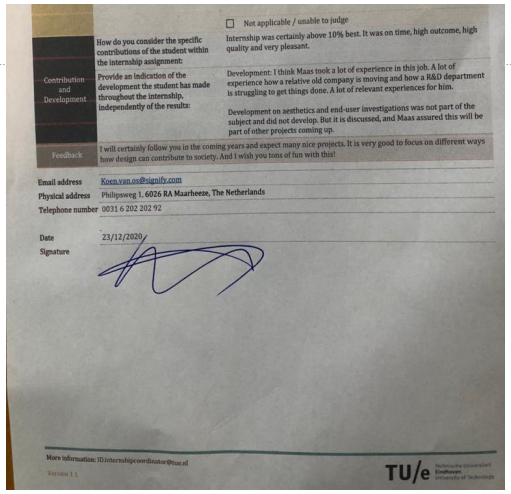
Telephone number	0031 6 202 202 92
Date	23/12/2020
Signature	



Personal Development Plan, before start of internship

Note: This was my PDP made before starting my internship, On purpose I've left my goals a bit more vague to determine in my internship how I can best optimise them for my period. The revised goals are specified at the start of the internship report.

Vision

Whether we all like it or not, the world is changing. The way we as a society and as individuals cope with it is our challenge. CO2 emissions are still not decreasing, throughout the globe nations are failing CO2 accords. These large global problems are impossible to tackle, and without global governing function these wicked problems are hard to tackle.

As the environment will change humans will be displaced, more areas will be inhabitable, and food will run out. Leading to migration and conflict. As a global governing function is unlikely, we as designers and as humans should offer a hand to those in need, I believe that designers can have the opportunity to really make a change.

Tackling these problems starts with responsibility, and companies should feel the responsibility to help others, and to compensate for their influence on the world. Through business tremendous innovation can be accelerated, and real influence can be exited on the world. It is not government who is emitting CO2, it is production, transportation and computing. Businesses should invest and leverage new more friendly alternatives, which might hold a lot of value for consumers as well.

I believe designers are the facilitators in this process, overseeing and contextualizing companies output and constantly pushing to find alternatives. The problem-solving and rapid design processes are excellent for fast changing environments.

Designers are the mediators that translate technology to product and bear the responsibility to push business to make a change.

Identity

Driving innovation through business is what I believe to be most effective in pushing forward. As a designer who is highly technical but also has some knowledge in business, I hope to bring my expertise in an enterprise where profit is not the only denominator.

I highly value sustainable business practices, where I am most interested in production techniques. As most products are still made with conventional practices, I believe that a very large gain can be made there. I am interested in new techniques that will provide not only more value to customer but also shorten supply chains, mitigate overproduction and lower carbon footprint such as 3D printing and embroidery.

As a designer I am a highly skilled problem solver, my explorative physical mindset allows me to experiment fast. This physicalized approach forces to not think but to experience which has brought me a lot of inspiration in the past.

Collaboration is essential for efficient innovation; production is complex and requires a lot of expertise from different fields. We can all learn from each other, and I as a mediator hope to bring together these different perspectives, providing more value for all.

I would love to grow toward a designer who is skilled across the whole production chain and is an expert in finding value in new sustainable practices. Innovating through experiencing, collaborating and creating on the factory floor. I hope to work for a company whose purpose is not solely profit but really making a change and setting an example to other companies.

Goals of this semester

Experiencing

The main goal of my internship is to experience, what it means to work in a company setting. Moreover, in the R&D department of a large company. I would like to experience whether it would be fitting to me as a designer if I would like to work in such a company. Or If I'd rather work somewhere else.

To ensure that I experience both I want to visit at least 3 different companies (startups/ smaller enterprises) that collaborate with Signify, there I hope to see what the differences might mean to a working environment.

Collaborating

I want to learn more about printing, design and machinery. As I've done a lot of prototyping and designing in a "school" environment I am very curious if all my experience applies in a professional environment. Whether I can keep up with the pace and where I need and can grow. I will grow in this by going through a complete design process of a new technique within signify, I'll start with experimenting with MultiMaterial printing (R&D), talk to machine and software developers, Design a prototype (lamp design), talk to sales (How will we sell this), and think about how this could be manufactured in a larger scale. In this process I will seek to collaborate with as much colleagues as possible.

I will have succeeded if I've worked with at least 4 different colleagues on my project, thus somebody from R&D, Software, Design and Marketing.

Creating

My third goal is to learn more about 3D printing and coding, to enable my previous goal to work I need to be able to 3D design the parts and print them. But to make the final machine work I'll also need a lot of coding, for instance in a python notebook. I hope to increase my skill in this department as I believe additive manufacturing, but also working with new machines and digitalization can be a future job of mine.

To enable me to grow in this I will make a daily print, (almost daily) minimal 4 prints a week, where I also write/ manipulate all the code necessary (e.g. post-processing in python and printer firmware in Arduino)

My final goal for this semester is to work more structured, I think that my documentation skills are not on par yet. This concerns me mostly in my ability to write my learnings down to enable others to learn from it as well. I hoped to do part of this last semester however the digital environment allowed this very easy, as well as team members in my project.

I will do this by writing a weekly overview of my learnings and together with pictures reflect on it. This I will do in the morning on every Friday. From now on.