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Make the Smell Dancing – Designing an Experimental Interactive Purifying Device near an Open Fire for Frequent Users in Finnish Lapland

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Abstract

In Finnish Lapland, a "laavu" is a lean-to structure that is used by the Finnish people in the open air to get warmth and rest. It is a cultural heritage that evokes the positive feeling of relaxing in a safe place and enjoying nature with family and friends. Often people who use the laavu do not mind the smell of the smoke even though there are a few airborne pollutants generated by burning logs as the fuel. In my research, I am approaching the dilemma of the cultural and simultaneously pollutant phenomenon of smoke by designing an interactive purifying device using negative ionization technology to cluster the pollutant to the ground for the benefit of the users and the environment. Besides, previous studies show that applying a negative ionizer has a positive effect on depression and stress (see Flory et al., 2010; Jiang et al., 2018; Xiao et al., 2023). The thermoelectric effect is used to power the device as a clean energy source (Mamur & Ahiska, 2014).

The research methods are Design-Based Research, Service Design and the Agile process method, and Art-Based Action Research. The data was collected on the site in the form of a questionnaire and the researcher's observation diary, and from the interviews of people in the University of Lapland. The artistic production as the result of the research project is presented by several interactive prototypes, the structure of which aims to integrate modern technology and interactive art into the traditional experience of using a laavu. The comparison and conflict between the diverse individual feelings towards fire, smoke, and artistic technology applied to nature and the environment is also probed and discussed.

Keywords

laavu, open fire, smell of smoke, negative ionizer, thermoelectric technology, experimental interactive device

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1. INTRODUCTION

This study is carried out as a part of the Sustainable Art and Design master's program from the faculty of Art and Design at the University of Lapland. It belongs to the broader project, the "Laavu - Sheiling" project in collaboration with the Glasgow School of Arts in Scotland. The funder is the Scotland Arctic Collaboration Fund and Finland Institution in the UK. The "Laavu and Savottapiha" project was the sub-project of the broader one where the Laavu cultural heritages were investigated in Finland. The sub-project took place in Savottapiha Meltosjärvi, Ylitornio, which is a less populated village with an estimated 70–80 residents near the border of the Arctic Circle in the Finnish Lapland. The purpose of the broader project is to preserve the Finnish cultural heritage by various means. For example, the conventional ways include recording and filing the visual, verbal, and written information about the village of Meltösjärvi and its forestry history and traditions.

As a team of researchers, we started the project together with the Art Education students who also did their research on the Laavu tradition. We documented the details of the laavu and the Finnish students recorded the verbal stories told by the local villagers. The aim was to build a similar laavu in Scotland as an outcome of the broader "Laavu - Sheiling" project. Under the guidance and help of our supervisor, Elina Härkönen, I worked with my co-researcher, Chia-Chen Chang, who was responsible for designing the elements for "Timber Drifting" traditions related to the whole Savottapiha site. We together utilized the collected information about the site and Chia-Chen illustrated an information board and I made a website to increase the accessibility of the information on the traditions for visitors and passersby.

My research interest started to formulate as I was triggered by the experience of the first visit to the site with the locals in the laavu by the open fire for hours. On the way back, I was a bit annoyed by the fact that the smell of smoke would linger on my clothes for quite a long time. However, if you try to avoid the smoke by sitting far away from the stove, you will not get enough heat from the fire to keep your body warm. I started to wonder what the locals thought of this and how this situation could be improved. In accordance with the aims of the broader project, my research question focuses mainly on using design-based methods to explore the necessity and possibility of designing a functioning prototype of an experimental interactive device in an artistic way to touch the environmental protection issue from a relatively more

technical perspective.

According to Ranta (2018), laavu is defined as log or wooden resting places built along hiking trails, which is the most famous accommodation with an open fire as the heat source among other open dwellings and a vast majority of the laavu structures are starting to function more as sausage roasting huts than for overnight stays over the decades (paras. 1–2). Ranta (2018) comments that the campfire in front of a laavu was made more freely in the past because it was more used for cooking in addition to heating (para. 7) and the fireplaces in front of the laavu are often in the wrong position and have the wrong height for winter accommodation (para. 2), which resonates with my experience of getting the warm from the heat while dodging the smoke.

Lapland is the northernmost and geographically the largest region of Finland, in which the Arctic Circle crosses through. The temperature throughout the year is between about -30℃ to 25℃ depending on the specific place. During the whole year, it is a common situation that more than half of the twelve months embrace snow. As a result, using a laavu to rest while keeping warm is a necessity even on some summer nights. The smell of the smoke from the fire also functioned as a mosquito-repellent in the old times considering that Lapland is famous for its appalling rather aggressive mosquitos.

Finnish Lapland is often considered one of the cleanest areas in air quality compared to the rest of the world, where the air quality can be problematic from time to time as I experienced myself. It alerted and concerned me when there might be harmful particles generated from an open fire, which then arose as a starting point of this study. Previous research shows that "small-scale wood combustion and traffic are the most significant sources of emission in Finland" (Peltola & Sarala, 2014, p. 21). Finnish Lapland has a relatively lower population than the southern parts of Finland, which makes it less polluted from the source of human being activities or industries.

However, apart from pollution from traffic and industry, there is still a relatively smaller amount of pollution generated from burning biofuels in the open air where people leave traces in the form of ashes and particles of the wood burning clustered on the ground and on the surface of the building after they utilize facilities like laavu to grill sausages and boil coffee. Often, the material used for making a fire is dried chopped firewood (such as birch) collected

and stored in the storage nearby. When the wood is burned, there are particles produced alongside the smell of the smoke, among which some particles are harmful to the human body as well as to the environment.

Incomplete combustion by manmade industrial combustion from biofuels during small-scale fireplace burning will produce black carbon (BC) in grassland or in the forest (Ruppel, 2015, p. 10). The initial aim of my research project is to deal with the detrimental particles, to be specific, BC or PM 2.5 (particulate matter 2.5) from different perspectives because from many previous well-established scientific researches and experiments conducted these mini-scale particles are not only harmful to the human body when inhaled, but also influence the soil and the air in the fragile open outdoor environment in the Arctic zone.

I have approached this particle issue by interviewing locals and international students both in Meltojärvi and Rovaniemi where there are strong Laavu traditions. The data from the interviews have guided my design process, in which the double diamond diagram framework from Service Design and the Agile process method is applied as my methodology. The aim is to design an interactive device using negative ionizing technology to purify the smoke-soaked hot air accompanied by burning biofuel in an open fire. With the device, the daily users of the laavu can be protected from the airborne pollutants and the lingering particles on their clothes for further impact and obtain a positive side effect on health thanks to the negative ions generated (Xiao et al., 2023, p. 69833). Besides the influence on humans, a decreased amount of particle pollution captured by the sink also benefits the soil and air in the environment.

The interactive device belongs to the category of interactive installation, which is a form of artistic expression based on installation art, but more interactive (Li, 2020, p. 8). I am curious to see how the application of the not-so-commonly seen modern technology is perceived by different groups of people with various backgrounds. An artistic perspective is added to the device by making it interactive when nearby human activity is detected to discuss the relation and ethics between human engagement and the seemingly passive but ceaselessly changing environment guided by Art-Based Action Research (ABAR).

Jokela & Huhmarniemi (2022) point out that “new genre Arctic art and Arctic education can revitalize ecoculture and northern knowledge” (p. 4). Ecoculture describes the connection between ecology and culture (human-nature relationship). The nature of the Arctic changes

rapidly due to climate change, the greenhouse effect, and the industrial use of resources from nature. These changes can affect the ecoculture and people's living conditions accumulatively (Jokela & Huhmarniemi, 2022, p. 5). Thus, it is of high importance for the research of the sustainability development for the environment to take place in the Arctic area.

Art and design, as a means to raise awareness and provoke thinking and further action, are applied in this project because I, as the designer of this project have limited knowledge of scientific theories and engineering, although I am keen to make more practical products to solve the issues mentioned above completely, have to choose another way by combining design, art with technology to serve the purpose of benefiting the health for human being and the sustainability development of the environment.

The thesis is constructed with the "Literature Review" as the start to give some theoretical information about the background context, followed by "Methods, Data and Analysis, Ethics" explaining the methodologies that guide the research and data analysis in the pre-stage for further decision making in the design process. Then, comes the "Process and Prototypes" chapter elucidating the design process in detail framed by the double diamond diagram from Service Design. In the end, a conclusion and reflection are made to discuss about the achievements, challenges, and potentials of the research project.

2. LITERATURE REVIEW

2.1 Research Context

2.1.1 A “laavu” with a campfire in nature

A “laavu” is a semi-open wooden free-standing lean-to structure that is usually used as shelter by hikers and backpackers in nature, where there is a vast open space near a lakeshore or on a flat in the forest with all the natural landscape and plants growing around. Ranta (2018) points out that although laavu made of wood or log is well known by hikers nowadays, there are also laavus made of fabric, which is not an exclusive invention by the Finns historically. There are various customs and details for different kinds of laavu in different regions from different cultures. A laavu often comes with a live fire (a campfire) as the heat source (Ranta, 2018, paras. 1–4).

Fig 1. The front and back view of the laavu in Savottapiha, Meltosjärvi, Lapland, Finland. Photo taken on Oct 8, 2022, when the researchers and the supervisors visited the place for the first time. Credit: Fangchen Dai, 2022.

The definition of “Nature” on a popular level, according to Lippard (1997), “has been diminished to mean everything outside the city, including farmland and countryside”, or “is used to connote wilderness, which in Europe once meant the lair of wild animals” (p. 11). A laavu is an artificial shelter constructed by human beings with a sloping roof and open walls intended for temporary accommodation (Ranta, 2018, para. 4). However, its semi-openness feature makes it cross the boundary between Nature and a manmade place, providing a kind of

semi-protection from the uncertainty and the threat of the “complexity” and “unpredictable change” (Lippard, 1997, p. 12) of nature.

The word “environment” is used to replace and demythologize a large part of what used to be considered “Mother Nature”, although human beings are still the center “surrendered by everything else” (Lippard, 1997, p. 12). In this statement, the nature (or to be generalized further, the otherness) is placed on the subordinate place that is to be explored, dominated, and utilized.

Nevertheless, in the case of a laavu, somehow, I feel that it does not have a strong repressing effect from humans against nature, partly due to the fact that it is not sealed as a traditional building, such as a residential house. It seems to welcome equal communication in a less intense way based on mutual trust. Unlike other tightly secured houses where keys are needed to enter, a laavu can be easily accessed by wild animals living in the same area. Other than this, it is only occasionally occupied by humans, which makes it somehow qualified to be considered as a resemblance to a natural setting (for example, a thick tree with a hollow dug by humans in the trunk) in the wild.

2.1.2 The village and community of Meltosjärvi

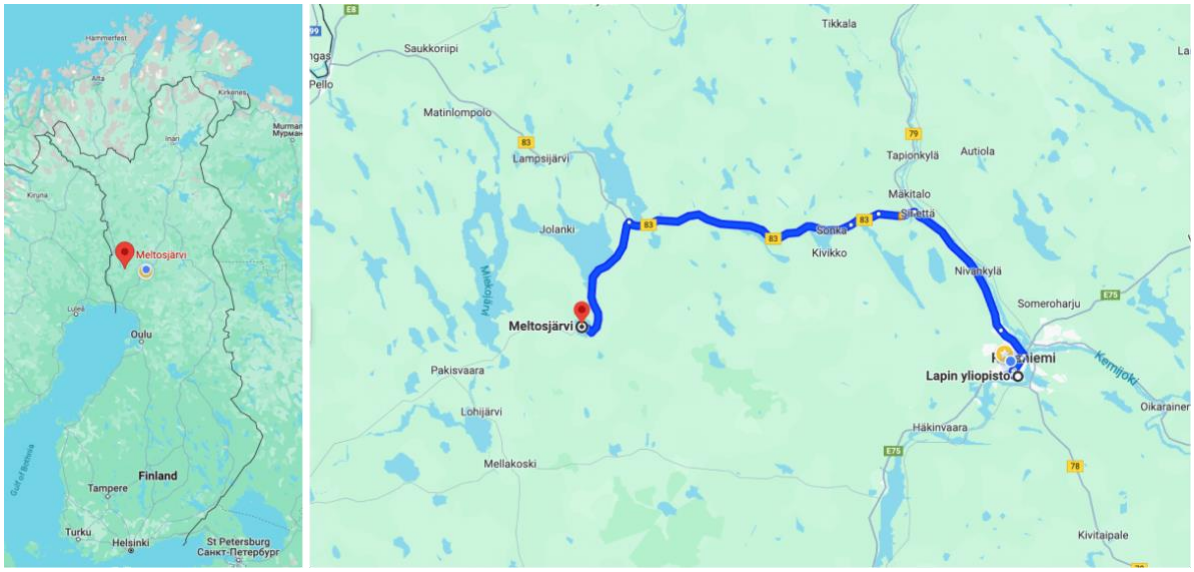


Fig 2. The location of the village Meltosjärvi and its distance from the University of Lapland. Credit: pictures are screenshots from Google Maps, 2024.

The small village of Meltosjärvi, where the project takes place does not even have a Wikipedia page, although there is a Wiki page of the lake “Iso Meltosjärvi”. It tells exactly something about this 458 hectares area that the importance of the lakes in Meltosjärvi as a nature reserve, which according also to the official village website https://meltosharju.wordpress.com, is an important part of the bird protection program in Lapland.

Among other reasons, as the forestry industry gradually withdrew during the past decades, the population declined over time as a result. However, the history of log-cutting has left its trace in several preserved constructions in Savottapiha, which is considered an exhibition space for visitors to get a glimpse of the glorious old times.

Fig 3. The photos taken in the open space of Savottapiha, the information board, the main building, the laavu, and the stove with food and drink. Credit: Fangchen Dai, 2022.

The main building “Savottarakennus” is located near the main road of this village, accompanied by other smaller houses functioning as a sauna, a semi-open garage, and a small bio toilet separately located on the way from the road to the lakeshore. This main building is

moved from its previous location to the current site here piece by piece demolished and put together with numbers marked on the construction logs of the wall (which you can still see today in the place, or on the new website that we designed) in the traditional way that was commonly used in the past when there is the need to relocate the building because of the feature of the forestry industry that after the work is done in one area, all the faculty including the "immovable property" need to move to the next spot of work. More details and the pictures taken of the place can be seen on the information website: https://savottarakennus.webflow.io.

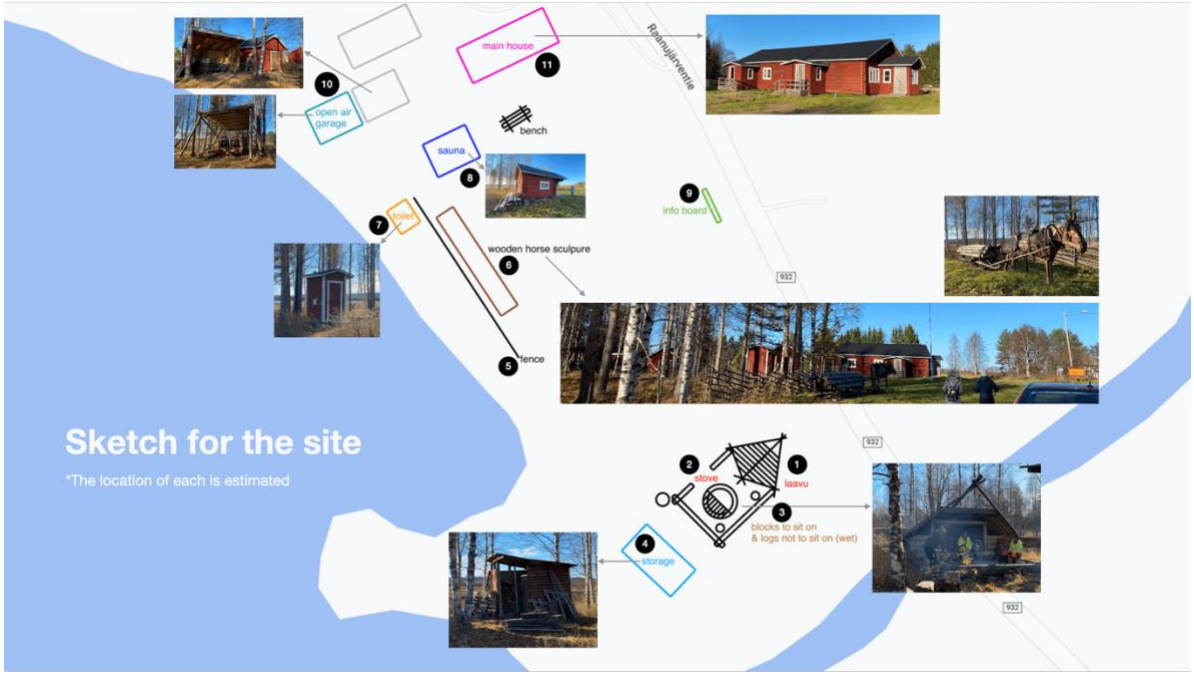


Fig 4. The illustration of the site with the estimated location of each construction. Credit: the background of the map is a screenshot from Google Maps, 2022; the photos are taken and the illustrations are made by Fangchen Dai, 2022.

The community in which we do our research is quite a cozy close-knit one, in which everyone knows each other. Lippard (1997) discusses the impression that people might have when mentioning the concept of "community" that it is "often used as a euphemism for poor neighborhoods and small towns" and is assumed wrongly to be a bunch of people huddling together who could only depend on each other yet "get along more or less fine" but not meant for those too broken or too marginal groups (p. 23). I feel that in Finland, no one truly detaches themselves from the collective although they seem to be always a little bit "further away" from each other with a spacious social space when interacting (and when not). The high welfare societal structure tries to engage everyone so that no one is abandoned on a basic level. In this

sense, the concept of community is applied well in Finland, albeit the scale of a certain community may vary in different settings.

2.1.3 Attitudes toward the smell of the smoke

Lippard (1997) defines that “place is viewed from inside”, but “landscape is everything you see when you go outside” and it can only be viewed “from outside” (p. 8). Through the activity of seeing, people imagine their relationship to nature (Lippard, 1997, p. 8). In other words, what one does in the place matters.

For many Finns, the thinking of a laavu is always accompanied by a constant scent of smoke from the memory of years of burning logs as biofuels in a stove placed just opposite the sitting space in the laavu. They are always evoked with a relaxing feeling of enjoying nature safely and protected, which is not so common for people who do not have the experience of using a laavu at a higher frequency. Even the smoke from the fire, which is fairly considered an indicator of a health threat to the human respiratory system does not affect the positive feelings of many Finnish, at least this is a conclusion I got from analyzing the answers to the questionnaire of the locals.

Lippard (1997) points out that “space defines landscape, where space combined with memory defines place” (p. 9). This statement confirms the positive feeling the Finns have towards the laavu even with the not-so-positive scent of smoke. A conclusion can be drawn that many Finns like the smell of smoke.

Although it is interesting also to compare, as a researcher with an Asian cultural background, that in my culture it is not always so safe to embrace nature like in Finland due to the potential danger in the wild with all kinds of lethal threats from flora and fauna, and possibly from human beings as well. Besides, the smell of smoke always reminds me of the incense burning in the temples, where a large amount of smoke is produced with the religious rituals and ceremonies going on all the time around by a constant stream of people coming and going. All of these are not so nature-oriented, thus not relaxing in the way the Finns do. However, the incense burning ceremony could also lead to a peaceful mindset in the end, although via different means.

2.1.4 Sustainability and cultural heritage

Huhmarniemi & Jokela (2020) point out that when talking about sustainability in the Arctic, the context is often natural resources both ecologically and economically, and arts and culture are used as a means to enhance sustainability (p. 1). They describe an interesting phenomenon through the concept of "Arcticfication" that is used to explain an imagination marginalizing the Arctic historically as a void, snowy, and depopulated zone even though the Arctic is in fact a region with very diverse and rich cultures on the contrary. It is intended as a branding strategy of touristic operation for the sake of adding attractiveness by granting the mystery, magical, and spectacular atmosphere of this place. The authors criticize that the Arctic countries have a very limited and narrow way of dealing with culture, specifically that "when culture is addressed in the strategy texts, it is most often done in the specific context of the region's indigenous peoples". As a result, the non-indigenous residents are ignored even though they are the majority in this area (Huhmarniemi & Jokela, 2020, pp. 1, 5–6). In order to clarify the misunderstandings related to the concept of culture in the Arctic, projects with the aim of protecting the cultural heritage are necessary. In my research and the broader project, different means of action are taken for the purpose of cultural sustainability in the Arctic.

Smith (2006) argues that all heritage is intangible and develops themes of intangible, identity, memory and remembering, performance, place, and dissonance to explore the aspects of the use of the heritage as well as to deprivilege and denaturalize the tangible and self-evident form such as sites and objects. It is the daily cultural processes and activities that make the heritage valuable and meaningful (Smith, 2006, p. 3). Extended from this thinking, the frequent usage of laavu can be considered as a way to protect the cultural heritage by combining personal feeling and experience with the tangible physical place.

Regarding taking action in the northern environment, Härkönen (2021) concludes that the core principles of cultural sustainability are "locality, grassroots agency, cultural diversity, cultural heritages, art as activity, eco-cultural civilization, cultural vitality and awareness" (p. 40). Locality emphasizes that people interact with places tangibly and intangibly. Grassroots agency means that a bottom-to-top decision-making approach with stakeholders should be adopted. For cultural heritage, static protection is not the best way, but rather an actively changing daily way is the solution. In the principle of art as activity, artistic activities shape the way we think and act in life and it contributes to the well-being of society and the overall sustainability. Art,

especially contemporary art, participatory and dialogic as it is, produces knowledge and helps generate thoughts. Eco-cultural civilization emphasizes the importance of culture in obtaining sustainability. As for awareness, who has an equal position with eco-cultural civilization, accelerates changes in sustainability and is viewed as the result of the other principles (Härkönen, 2021, p. 40–44).

I will discuss more the principle of cultural diversity, for which an important thing to ponder is "how change can take place without damaging the cultural continuity to cultural identities" (Härkönen, 2021, p. 43) and some ongoing changes are associated with fear. Especially when it concerns working with nature because Europeans "fear nature and hold her captive 'in awe'" (Lippard, 1997, p. 13). As a result, from what I have observed myself, people here deal with nature in a carefully considerate way. When it comes to the selective process of preservation, it should be considered from cultural and economic perspectives, the form should be balanced between being traditional and being modern, and the future generations should also be taken into consideration (Härkönen, 2021, p. 43).

This assertion of cultural diversity reminds me that when I first brought up the relatively newer means of artistic engagement with technology, most interviewees (Finnish people and international students) were very reluctant to accept the new changes that I wish to exert to the traditional setting with a withholding and negative attitude, even when the idea is far from being executed and there is a rather long period to improve it. I guess it is human nature to have a hard feeling towards any changes to protect their familiar and cherished things from being challenged by an outsider with a different face and cultural background.

When I look back at this cognitive gap, I agree with Lippard (1997) who explains that it is because people coming from different places carry the impact of the place, which inevitably affects our work, no matter whether we like it or not (p. 36). All these contribute to the multicenteredness as a global trend in the ninetieth, but I do not know if this is still the trend in this post-pandemic decade. Another reason I can think of is the difference between the mind of a developed country and a developing country. For an already developed and relatively wealthy place, there is not much space for people living there to make changes or improvements anymore, which is the opposite in a place that still has a lot of development on the way. As a result, people from these two types of places have different attitudes towards the things they see at first sight inevitably.

2.2 Integrating Technology in Art and Design in the Arctic

2.2.1 Pollutant particles in an open fire

According to Ruppel (2015), incomplete combustion will produce black carbon (BC) in grassland in nature or open fire in the forest. BC can also be formed by manmade industrial combustion from biofuels and fossil fuels in diesel or petroleum engines, or "during small-scale fireplace burning" (p. 10). Ruppel (2015) concludes that BC is highly absorptive of solar radiation, stable at high temperatures, and insoluble in water. Besides, BC is often co-emitted with other chemicals such as "sulphate, organic carbon, trace metals and dust" (p. 10). The burning of wood in a laavu is incomplete combustion, which will produce BC in the process. Simoneit (2002) points out that although the types of tree species may vary, all of them consist of "various forms of lignins, celluloses and fillers" (p. 131). The higher the moisture of wood is, the less efficient the combustion is, which often occurs in "campfires and wildfires" (Simoneit, 2002, p. 132). In the case of burning wood material in a laavu, it can be deduced that the incomplete combustion of different kinds of wood produces a considerable amount of black carbon in total.

Black carbon is a threat to the global environment, according to Ruppel (2015), who also points out that currently few BC emissions are produced in the Arctic zone and most of them are transported from a long distance outside the Arctic area. Due to the fragility of the Arctic environment, the air in this area is extremely sensitive to pollution. Although, the research on BC as a "climate-warming agent" is still "a relatively new area of climate research" (Ruppel, 2015, p. 12). Thus, it is important to control the spilling of air pollutants from any possible sources even though the amount is comparably small.

BC has an impact on soil. Semple et al. (2013) argue that BC has been "demonstrated to have a strong sorptive affinity for compounds of environmental concerns" by experiments. Although the understanding of how BC will impact the soil is limited, there is hope to find potential use of BC as a method to reduce "the bioaccessibility of contaminants within soils and sediments" (Semple, 2013, pp. 813–814). It is refreshing to find out that BC can benefit if utilized properly. Treatments of the captive BC on the collector can be designed accordingly.

Human beings also suffer from inhaling black carbon particles. Grahame et al. (2014) indicate that BC and other co-emitted particles are related to “all-cause, cardiovascular, and lung cancer mortality, and perhaps with adverse birth outcomes and central nervous system effects”. These findings are recent as the large-scale monitoring of BC is also recent (Grahame et al., 2014, p. 620).

2.2.2 Negative ions to purify the air and benefit human health

In researching the collection and utilization of BC, I was inspired by one previous study on smog prevention for air pollution in the open air, the Smog Free Tower project conducted by Studio Roosegaarde from the Netherlands. They designed a tower to collect the airborne pollutant particles on a collector plate to compress them later to make a ring. This team is good at using technology as innovation to improve the daily lives of people in urban areas. In their case, the technology of positive ionization is used to purify the air (Studio Roosegaarde, n.d., paras. 1–3, 7, 12).

However, my research context is different from theirs in that the pollution source in an open fire is denser and more concentrated instead of the air pollution in the wide air with much lower density. Later, my focus turns to a direction not so deeply scientific and technical as theirs as well.

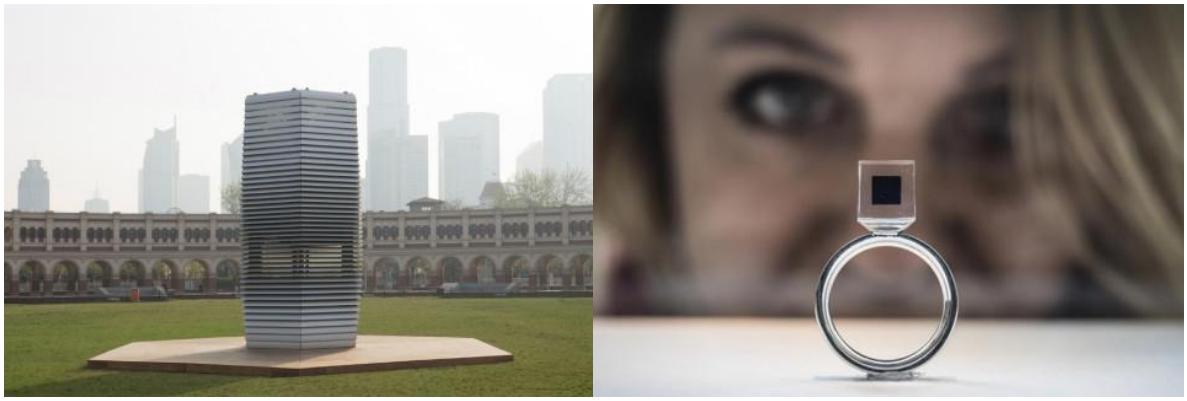


Fig 5. The Smog Free Tower project by Studio Roosegaarde and the ring made of composed particles collected. Credit: the photos are from the website of Studio Roosegaarde: https://www.studioroosegaarde.net/project/smog-free-tower, 2024.

In my case, the function of purifying the airborne pollutant particles from the fire is realized by a negative ion generator because I am not able to make a positive ion generator myself, but a readymade negative ionizer is easy to purchase online. Negative air ions (NAIs) can reduce the concentration of airborne particles, especially PM2.5 and PM10 (Jiang et al., 2021, p. 574–586). NAIs have been widely used for air cleaning (Jiang et al., 2018, p. 1).

A trial conducted for the treatment of Seasonal Affective Disorder (SAD) by Flory et al. (2010) shows that a high concentration of NAIs exposure helps reduce the severity of depression, psychological stress, and anxiety level to improve the well-being of people (pp. 7–14). According to Xiao et al. (2023), negative ions may benefit human health by changing amino acid metabolism by increasing anti-inflammation and reducing antioxidation. Besides, exposure to NAIs can promote energy production, affect the expression of c-fos (to increase neuronal activity), and regulate 5-HT levels (to reduce depressive symptoms) (Xiao et al., 2023, p. 69824).

Jiang et al. (2018) indicate that NAIs have multiple health benefits not only for humans and animals but also for plants by killing some of the microorganisms to promote plant development. Some results might be overestimated and need further verification but there is no data showing the harmful effects on humans and animals (Jiang et al., 2018, p. 12).

2.2.3 Experimental interactive device as an artistic expression

Apart from the selection of the purifying technology, compared to designing a high tower in an open space in an urban area, a smaller-scale interactive device is more suitable for my research topic due to the limitation of resources and setting. Li (2020) defines installation art as an artistic process site-specifically, in which artists directly utilize daily objects physically or culturally to form a new artistic expression to convey “rich spiritual and cultural connotations of certain individuals for groups” and it has a feature of “post-modernism” and is known as “ready-made art” (p. 8).

According to Li (2020), interactive installation is a form of artistic expression based on installation art, but with a more interactive experience added to it and the audience becomes a part of the work when they are invited to participate in it. Typically, an interactive installation

has three parts: input, processing, and output. The input signal can be obtained by sensors of different kinds: infrared sensor, touch sensor, thermal sensor, motion sensor, depth sensor, pulse sensor, and so on. For the processing, processors can be used, such as Arduino using openFrameworks (C++) and Processing (Li, 2020, pp. 8–15).

According to Li (2020), there are two categories of interactive installation: immersive installation and experimental interactive installation. The former integrates people into the environment with large-scale settings which often fulfills the space, while the latter focuses on technological exploration with normally small-scale devices for the audience to interact with (Li, 2020, p. 24). The immersive experience needs a spacious space to install the necessary equipment and arrange the layout, which is out of my capability, but an experimental interactive device can be small and still illustrate the idea well as a prototype. So, I decided to use the form of experimental interactive installation as my artistic production for the thesis project.

However, an interactive project does not always have to be digital. Li (2020) points out that sometimes simple mechanical operations can be used as the framework of the artwork, and for the output, multi-sensory (visual, auditory, and olfactory) experiences (pp. 13–15, 17).

Fig 6. The Triumph Pavilion – Five Line Projects. Credit: photos taken from the book Interactive Installation Art & Design: Art Experience Driven by Technology (Li, 2020, p. 17).

I was triggered by the project “Triumph Pavilion - Five Line Projects, London UK, 2016”, an immersive interactive installation project without any digital design. The installation alters the view of the world of the audience by inviting them to interact with it (Li, 2020, p. 29). It is a self-supporting structure based on the theme of “Energy” and conveys the idea that “a single

action in the community" can trigger and support the belief that "people, regardless of race, gender, beliefs, or identity are the most prominent force", and that "the individual is the single component necessary to trigger a grander action" (Li, 2020, pp. 132–137). The intention of my artistic production shares similarities with it: to provoke thinking on the relationship between human activity and the sustainability of the Arctic, between applying technology and originalism in the protection of cultural heritage in the context of the Arctic, and between a tourist's point of view and that of a local's.

2.2.4 Clean energy by thermoelectric technology from the fire

Also, art and design need to take the matters of sustainability into consideration. In terms of sustainability, the possibility of using new energy as an alternative to generate electricity is always attractive because of its eco-friendliness. Thermoelectric (TE) technology is eco-friendly for that it has no greenhouse gas emissions with the advantage of being silent and durable, whereas the shortcoming is that the conversion efficiency is less than 10% when used commercially (Mamur & Ahiska, 2014, p. 128).

TE technology is a type of low-grade thermal energy for sustainable energy production (Zhang, 2023, p. 1). Ji et al. (2024) point out that compared to the more well-known high-temperature heat sources that have been used as the primary method in energy generation plants and industrial processes, an increased interest in utilizing low-grade thermal energy has been seen in recent years (p. 1).

Thermal power is a method of generating electricity that converts heat energy generated by fuel combustion into electrical energy (Mamur & Ahiska, 2014, p. 128). In the process of thermal power generation, low-grade thermal energy is typically produced as a by-product or waste in industry or daily activities (Ji et al., 2024, p.1). Nevertheless, low-grade thermal energy has been overlooked in energy utilization during the past decades (see European Commission CORDIS, 2024; Ji et al., 2024; Zhang et al., 2023).

In my own experience of using a battery, although it is handy and portable, there will be problems with utilizing the full capacity, recycling, and reusing. In the sensitive Arctic region, using alternative energy or renewable energy to replace fossil fuels, such as sunlight, wind,

surface water, and tides is considered much more environmentally friendly.

The electricity is generated in the TE technology from the temperature difference between the two sides of a thermoelectric generator (TEG) (Mamur & Ahiska, 2014, p. 128) or other thermoelectric modules. In an open fire setting (a campfire as the heat source in a laavu), a difference in the temperature is guaranteed constantly, which naturally provides the condition for generating electricity from thermal power.

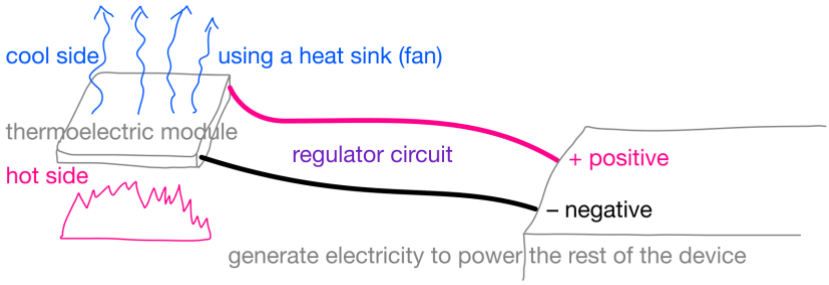


Fig 7. The illustration of my plan to use the thermoelectric effect to generate electricity to power the rest of the device. Credit: Fangchen Dai, 2024.

Since this study is not a strictly scientific one, I will not go too much further into the physical theories but understand and utilize them to realize the function of the design of my product as much as I can. My initial idealistic idea of applying TE technology in my project is to power an Arduino processor using the electricity generated from the temperature difference gathered by an open fire using thermoelectric components. At the time of writing this thesis (2024 spring), as my research suggested, research like this has not been done by anyone yet, which makes it innovative in the cross-discipline area of art, design, and technology. I conducted a series of tests to verify the idea but in the end, I had to settle on powering only a small fan instead of an Arduino processor due to the low efficiency of TE in converting energy.

The thermoelectric effect is indeed not the most effective way to generate electricity and it can be replaced by many other more efficient ways as an alternative, such as solar power and wind power or just a set of traditional steady lithium batteries. The specialty of applying the thermoelectric effect in this study is that it is in an open fire setting in the Arctic, which renders other renewable clean energy like solar power or wind power impossible. The long period of polar night makes using solar power impossible for almost half of the year.

Compared to the extreme coldness in the temperature, the wind here is in a non-proportionally slight amount, which makes utilizing wind power not feasible. Observed from several tests I have conducted using a 9V battery outdoors in the winter, the performance of batteries is also affected due to the low temperature. All these facts make thermoelectricity a relatively better option. What matters most is to explore the possibility of utilizing clean energy in the fragile Arctic nature.

3. METHODS, DATA AND ANALYSIS, ETHICS

3.1 Methodologies

The framework of the theoretical background of my study is formed by Design-Based Research (DBR) as the general and science-and-technology-related research guidance, Service Design (SD) and the Agile process method in the design process of the device, and the Art-Based Action Research (ABAR) for the more implicit, subtle and subjective art-related parts.

3.1.1 Design-Based Research

Scott et al. (2020) conclude that "Design-based research is a methodology approach that aligns with research methods from the field of engineering or applied physics, where products are designed for specific purposes" (p. 19). Before the circle starts, the researcher needs to identify a specific problem that needs to be addressed first. After this, comes the cyclic process of DBR.

Phase 1. DESIGN: design a possible solution for the problem suggested by existing theories and previous research. Phase 2. TEST: test the tools in real-world scenarios. Phase 3. EVALUATE: evaluate whether the result is effective in achieving the goal by the evidence and improve the tools gradually. Phase 4. REFLECT: reflect on the outcomes to see which part is successful, revise those that are considered as not helpful, and point out how the theory used in the experiment is informed by the research. Then the next cycle starts. Although these four steps are listed separately, there is often overlap of the phases in conducting the research, for example, testing and evaluating can happen simultaneously (Scott et al., 2020, p. 19).

According to Scott et al. (2020), the DBR method is different from a traditional scientific experimental approach in its approach to experimentation from four main perspectives (p. 19).

First, the role of participants is different. In traditional experimental research, the decisions are made only by the researcher, and the instructors are the only facilitators. While in the DBR approach, both the researcher and the instructor are responsible for all the decision-making in the whole process. When the research question is self-reflective on how the researcher/instructor can make improvements, it connects more with action research (Scott et

al., 2020, p. 19). This suits my research well because I aim at self-reflective improvement of the design for a specific issue as a researcher.

Second, in experimental research, researchers make a hypothesis to see how a specific intervention affects the result and often there is a control group with all other variables remaining unchanged. However, in design-based research, a hypothesis is conceptualized as a design solution with iterative refinements progressively. Third, in experimental research, the interventions cannot be modified during the whole period, while for design-based research, they can be flexibly adjusted when they are installed in place. Fourth, the conclusion that can be made in experimental research is limited under certain conditions with claiming something meaningful happened, but design-based research has the potential to discover and understand the mechanism of how or why it happened (Scott et al., 2020, p. 19).

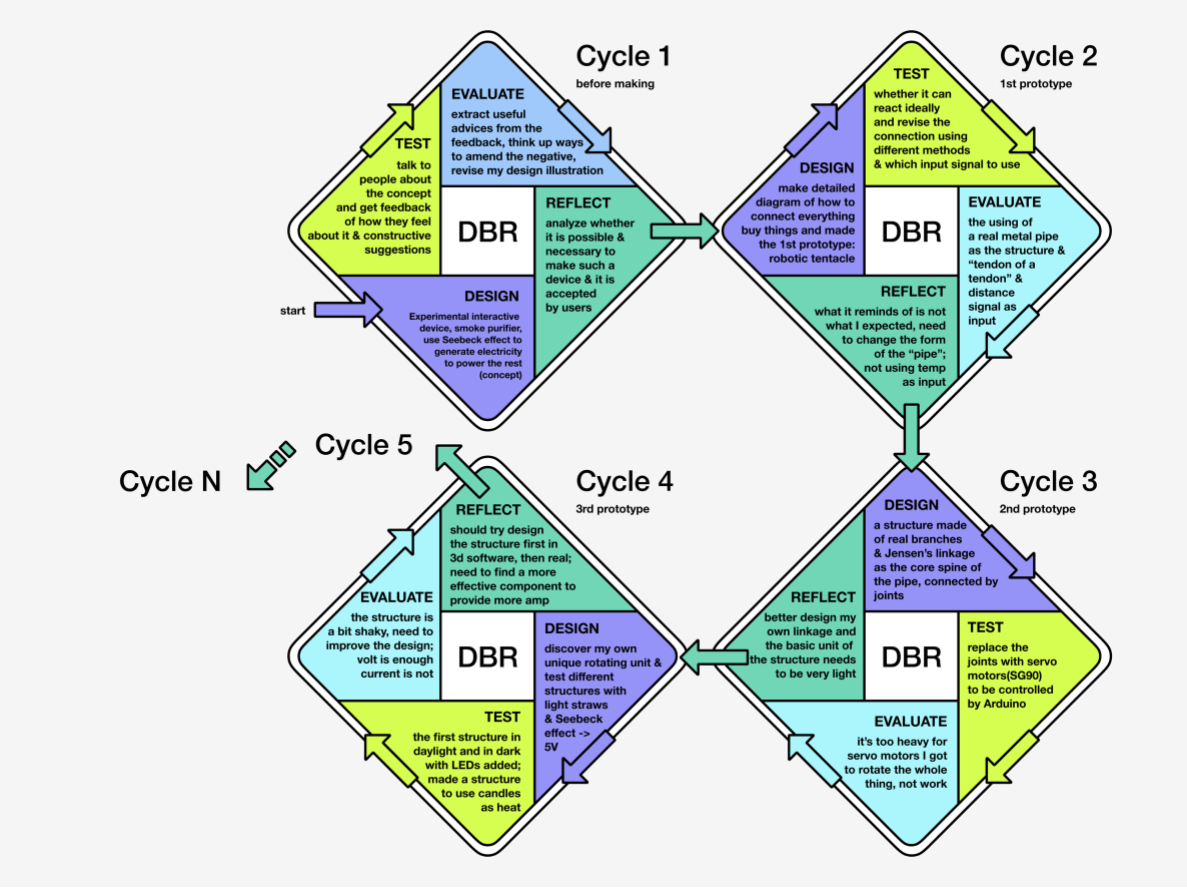


Fig 8. Illustration of applying the DBR method in my research. Credit: Fangchen Dai, 2024.

Although the DBR method is more commonly seen in scientific studies, it is also suitable and instructive in my research project because in designing an innovative product for the benefit of

the environment and human beings, it is inevitable to involve certain scientific knowledge such as physical principles, electrical and engineering knowledge, and coding programs to control the interactive device.

Besides, the actual application of the different stages of my research fits well into the DBR diagram. In my adapted diagram, there are more research cycles than two. The division is by the iteration of the version of the prototype. In one word, design-based research is a general guide walking me through iterative phases in my design process by defining the different phases scientifically and points out what to do next clearly. However, this research method does not go very deep into the details of each phase. This is why I apply the next theory as the guidance of a more detailed working process.

3.1.2 Service Design and the Agile process method

In the book *An Introduction to Service Design: Designing the Invisible*, Penin (2018) explains that services are of very different kinds. Typical services are seen in transportation, restaurants, banks, phone and internet services, entertainment, healthcare, and school systems, in which some are vital infrastructure such as water, plumbing services, gas, and electricity (p. 17). Digital services are also key services, such as social media, communication and data sharing platforms, and "services to facilitate exchanges" (Penin, 2018, p. 17). Aware of it or not, our daily life heavily depends on services.

Penin (2018) points out that the core of services is interactions and the basis of service is human actions and relationships. However, service interaction can be unpredictable with no guarantees of what will happen for sure since the uncertainty and unpredictability are rooted in the temporal relationships of human-centric entities over time. Services interact with users via a touchpoint, which not only enables the interaction physically but also is the key to making the service better. Besides touchpoints, there are also other factors to ensure the delivery of positive moments for the service (Penin, 2018, pp. 19–20).

Penin (2018) also points out that the designing for interactions leads to the question of whether interactions can be designed at all. In a more generalized context, designers might only be able to design the conditions for interactions to happen but not the interaction itself. Service

designers may find themselves facing an unassured situation at the beginning of the design process because services are not as tangible as graphics, architects, or industrial products. But to view from another perspective, Service Design could also present the designers with a large scale of possibilities that take them to go beyond a given form or function to a more "intellectual and strategic practice" so that they can "create a deeper social impact" (Penin, 2018, pp. 19–20).

Penin (2018) illustrates the Service Design process with the double diamond diagram, in which two diamond shapes are used to illustrate the different phases in the design process.

In the first diamond, there are two stages: "Discover" and "Define". In the "Discover" stage, designers get to know the problem and delve into people, context, and services. In the "Define" stage, insights in translated and focused design directions and a clear problem space are defined.

The second diamond includes "Develop" and "Deliver". In the stage of "Develop", designers develop possible solutions and generate and test new concepts. Then, in the "Deliver" stage, it is to focus on delivering solutions and specifications for implementation.

Later, a further developed double diamond chart is brought up by Dan Nessler (Penin, 2018, p. 192) to give more details about the activities in different sub-divided stages. It divides one diamond into two with "Diverging" / "Ideation" on the left and "Converging" / "Converging" on the right in different phases (Penin, 2018, pp. 190–192).

I combined the original and revised version of the theoretical charts of the double diamond with my own research data and made one whole diagram of the different phases of my project as shown below. Each stage comes with its own topic and consideration. The back and forth from errors and setbacks are inevitably seen during each iteration, making up the cycles of the design.

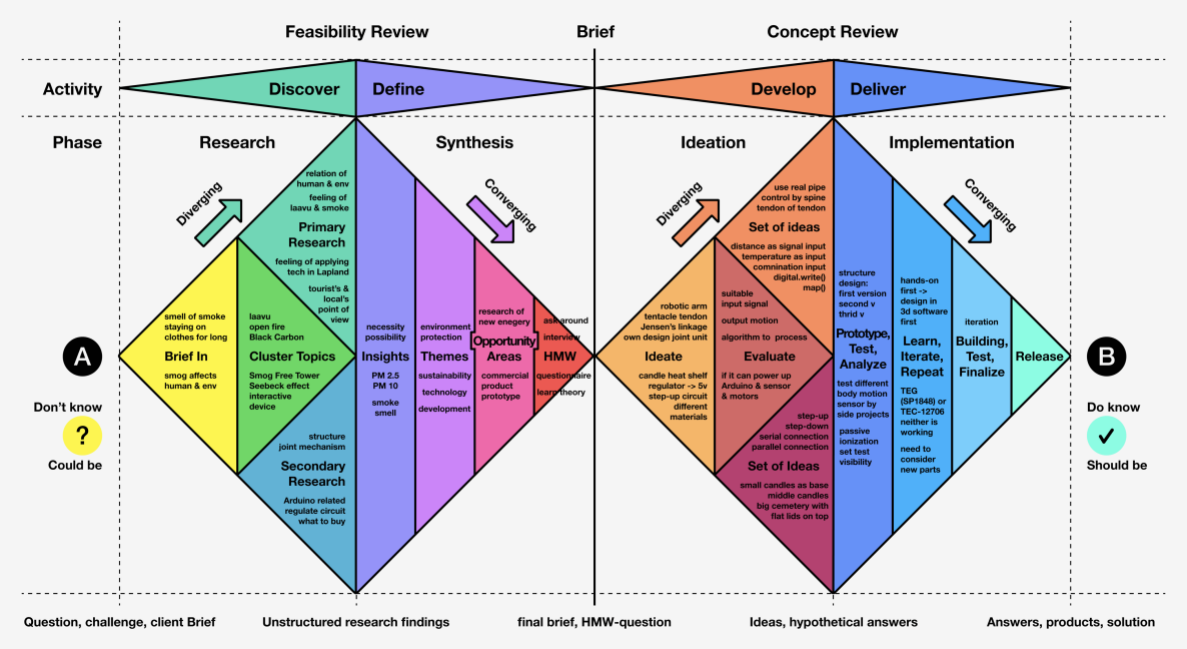


Fig 9. The double diamond diagram applied in the project of my research. The diagrams of the four separated phases with more details will be shown in the later sections. Credit: Fangchen Dai, 2024.

The double diamond method from Service Design guides my study systematically and renders the whole process logically organized, which is why it fits my research well. Compared to the DBR method, the diagram structured by the division of the two diamonds framework guides my designing process in a more detailed and clearer way. The sub-topics in the sub-columns help me decide what actions should be taken in the specific stages. When the previous stage is analyzed, corrected if necessary, and concluded on paper by topics, the next stage is easier to carry out and go in the right direction.

Apart from the double diamond chart, the Agile process takes an important place in my study as well. As a practical application of the methodology, the Agile process is a project management method in UX (user experience) and software development, in which the logic is based on short cycles of development and testing. In the end, a beta version is launched as the final concept. It will then go through adapt and evolve based on the feedback gathered from users (Penin, 2018, p. 192).

Although the prior literature is vague about the definition, Lee & Xia (2010) conclude one common theme of the Agile process is “embracing and responding to change” and the ability

to “efficiently and effectively respond to and incorporate user requirement changes during the project life cycle” (p. 90). In my understanding, one prominent feature of the Agile process is a fast reaction and iteration as the name “Agile” suggests. In practice, it means the developers (in this case, researchers) should put their idea into a workable prototype and get the test result as quickly as possible. If the result is considered positive, the research will continue in this direction and vice versa. If the result of this test is not satisfactory, the development of the product will be turned to another possible theory quickly. The cycles go on until a final version is settled.

In my project process, the Agile process method plays a big part because of my background in the UX/UI design area. Since I have been working as a UI designer for several years, I almost took it as a default to structure the whole process of designing subconsciously, even though this research project does not belong to the software development category. I have tried different means of making the structure of the interactive device from the first version of the prototype to the fourth one. A sad thing but universal truth about designing a perfect product is that it will never be “perfect”, so I need to set a time to call a pause of the iteration and finalize a relatively satisfied one at that moment. The Agile process makes it possible for the iteration cycles to be as many as needed so that the satisfaction of the final version is hopefully higher theoretically. Take my study for example, I managed to iterate the design of the structure four times, during which the final version was comparably better than the first. If the Agile process is not borne in mind, there might not be as many iterations as now. For a starting-from-zero project, the Agile process can help the maker resist the temptation of pursuing perfection of details, which will impede the realization of overall functionality first.

In discussing using theory to guide research, we must always give the context of the project. Given this study is in the art and design area, I always question the role of the seemingly “rigidly defined doctrine” playing on framing a creative process of artwork making, especially for some not-so-rational parts of the process. It is a very subject and sometimes “whimsical” journey of ideation and forming. In fact, I started making the prototypes before I could place them into the charts of either the DBR cycles or the double diamond diagram from SD. In the end, they function more like a generalizing tool after the developing process is done, instead of a guide before everything starts. When you make artwork, it is not so easy to stay logical all the time and follow the rules step by step, and often it goes back and forth not on a rational level but on a freewill mind-flowing level. These “irregular” artistic inquiries could not

perfectly fit into the procedures of the two neat design theories like in a scientific research project. But there is a way to elucidate these parts from an artistic perspective. This is why I integrate the Art-Based Action Research methodology into my research. Although I do have to point out that different people have different understandings of this theory, this is just my own interpretation of it.

3.1.3 Art-Based Action Research

Jokela and Huhmarniemi (2018) indicate that Art-Based Action Research is a qualitative research strategy that guides the process of research in the cycles of action research and uses art as a catalyst for developing work. This often means the empowerment or the better design of the environment. Art can be used for intervention to solve problems and gain new knowledge and understanding. Art can also be the subject of developing the research process or the researcher's tool for data collection and analysis (Jokela & Huhmarniemi, 2018, pp. 10–11).

Leavy (2009) points out that art-based research can be political and collaborative by evoking changes and aims to increase compassion (p. 31). Jokela & Huhmarniemi (2018) agree that Leavy's definition also fits art-based action research, only that the latter can be stronger socially and politically regarding environmental issues. But still, it is in the branch of qualitative research direction. ABAR is case-specific and developmental which follows the traditions of action research that is formed as part of qualitative research. Traditionally, the research methods are based on verbal or written language. In contrast, the art-based method uses art as the method so that the stakeholders and members of the community can be included to gain tacit knowledge and experiences (Jokela & Huhmarniemi, 2018, pp. 9–10).

Art-Based Action Research has the nature of a cyclical process. Thus, the design of the research process is divided into several cycles. Artist-researcher should be prepared for this detour of possibly repetitive collection of data and revising of the process. Jokela & Huhmarniemi (2018) described the Art-Based Action Research cycles into a graph: Reflect, Investigate, Make action/artworks, and Observe. In the first step of reflection, the researcher starts with planning and setting the goals, and evaluates data with the organization, focus group, or users; in the next investigation step, the researcher plans, designs, and organizes; then, they take into action or do the artwork; during the whole process, the researcher observes and documents to collect

data for further analyzation. And when one cycle finishes, a new one is about to set on again (Jokela & Huhmarniemi, 2018, p. 15).

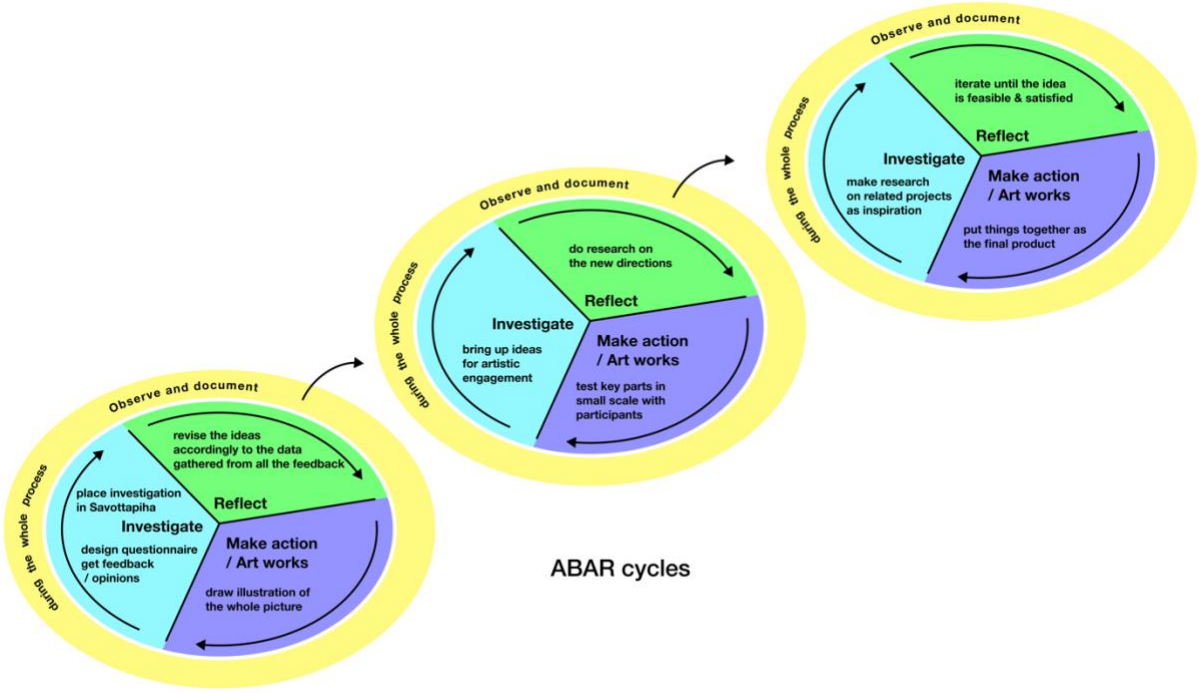


Fig 10. The ABAR cycles applied in my research. Credit: Fangchen Dai, 2024.

As shown in the figure above, I adapted the ABAR methodology specifically for my research based on my own understanding. I put "Observe and document" on the outer layer of the whole circle, in which there are three parts (Investigate, Reflect, and Make action / Artworks) without assigning one as a specific starting step. However what actually happened is that at the beginning after a short introduction in the classroom about the broader project, the researcher team went to the site to make the place investigation as the first step in this research. This is why I put the "Investigation" on the left side as an initiation. Nevertheless, the steps are repeated not in chronological order. For example, although the revising of the ideation is put in the "Reflect" section after the "Investigation", the revision is not done only once and it needs the data interviewed and collected from the previous feedback session in the previous part. Thus, the division is not rigid. Back and forth happens during the whole process, as it is pointed out by Jokela & Huhmarniemi (2018).

Art-Based Action Research answers the challenges of villages and social problems nearby. Jokela et al. (2015) state these challenges include population aging, the isolation of young people, and the underdeveloped creative-industry and cultural services (Jokela et al., 2015, p.

436). Jokela & Huhmarniemi (2018) elucidate that working methods are applied to projects of regional development and well-being work. The projects are place-based and community-based, as well as small and medium companies in the area, where researchers worked with members of the community as a team.

Jokela et al. (2015) explain why Art-Based Action Research is applied to the northern environment with a rapidly changing situation. It is because the northern cultures and identities have formed a close relationship with the environment. Environmental Art and winter art as the main working methods have been proven successful (Jokela et al., 2015, pp. 436–437). Jokela et al. (2015) mention that action research can be divided into two categories, practical action research and participatory action research. Here in Lapland, art educators emphasize the interaction between art and the environment. Thus, a methodology of practical, socially engaging, and community-based is seen as the solution, which can lead to the production of contemporary art of various forms of visual art. This method has been "applied in the art students' theses" (Jokela et al., 2015, p. 441). Action research is the method of this methodology with art being the method of action.

Viewing from this perspective, there is no doubt that my study fits well into ABAR by intending to explore the relationship between human activities and environmental issues via experimental interactive means, although I do not take any traditional arts, such as stationary installation or sculpture as the form. What I am trying to do in this context involves more edgy contemporary measures in a cross-discipline way. But it should not be considered as a wrongdoing after all. In my opinion, creation or creative methods come from exerting new measures from an angle that has not been seen before. I do hope to open a new perspective for the following researchers in the future by doing so.

Art-Based Action Research has a primary feature that stakeholders and community members should participate in the research and development process (Jokela & Huhmarniemi, 2018, p. 10). The participatory feature is reflected in my research in two parts: first, in the ideation and design revision process, several data collection sessions are conducted with different groups of people or individuals, such as with the local people through written questionnaires, verbal feedback gathered with a group of students and the teacher from non-art-related fields, international students, Finnish students, and teachers, professional digital designers, to name a few. Second, when the stable version of the experimental interactive device is finalized, a small

group of people with different backgrounds are invited to interact with it and feedback is gathered.

Many projects that use the ABAR method emphasize including stakeholders in the whole process. However, in my case, at some specific stages of the designing process (such as the circuit connection and choosing which components to use), participants are not necessarily needed. These decisions have to be made solo by the designer (myself). What could make a difference by having more participants is in the stages related to subjective feelings and opinions (the data gathering stage before the actual designing of the details of the device) and the interactive experiences with the product (the testing session after the final version is stabilized). The participatory feature in my research is demonstrated more in a Service Design way.

3.2 Data Collection and Qualitative Analysis

The data collection of this research started on the first visit to the project site in 2022. In the pre-stage investigation, visual information was collected by taking photos of all the potentially useful details at the site, and a researcher's diary was kept in written form as the subjective observation for the ideation of intervention.

After an initial idea was formed, I started to talk to people and ask about their opinions and got feedback from them in interviews and written questionnaires. To reduce the impact of language issues in intercultural research (Trulsson & Burnard, 2016, p. 3), two forms of feedback collection were used. The choice of whether to use a verbal or written way to communicate largely depended on whether the interviewees could speak English. For those who could speak English, I was able to get more information more flexibly. Questionnaires were used with the residents in the village. This feedback collection period is mainly from January to June in the year 2023.

In analyzing the data, qualitative research methods are applied. According to Hsieh & Shannon (2005), three distinct methods are identified to use in analyzing qualitative content: conventional content analysis, directed content analysis, and summative content analysis. Hsieh & Shannon (2005) also point out that among other numerous research approaches,

qualitative content analysis "is used to analyze text data". In their article, they define qualitative content analysis as "a research method for subjective interpretation of the content of text data through the systematic classification process of coding and identifying themes or patterns" (Hsieh & Shannon, 2005, p. 1278).

Hsieh & Shannon (2005) make it clear that instead of counting words, qualitative analysis is to understand the deeper meaning of the study by examining the language intensively and making categories of similar content to find exact or speculative meaning underlying. Text data can be verbal, print, or electronic and obtained from narrative responses, open-ended survey questions, interviews, focus groups, observation, or printed media such as articles, books, or manuals (Hsieh & Shannon, 2005, p. 1278).

I use conventional content analysis in analyzing the feedback data from the interviews. According to Hsieh & Shannon (2005), this approach is suitable when existing theories are limited in describing the new study. In this case, categories and names of categories can flow from data during the process of conducting the research. Open questions should be used to avoid confining the analysis. The advantage of the conventional method is "gaining direct information from study participants without imposing preconceived categories or theoretical perspectives" (Hsieh & Shannon, 2005, pp. 1279–1280). Thus, the conventional content analysis fits well in my research as I would not know certain technical terms (which will not be a problem for professionals in the related area as the interviewees) that I need in designing the device.

However, there are also disadvantages to using the conventional method: one of them would be failing to "develop a complete understanding of the context, thus failing to identify key categories" (Hsieh & Shannon, 2005, p. 1280). The problem occurred thereby of "internal validity within a paradigm of reliability and validity" can be solved by "peer debriefing, prolonged engagement, persistent observation, triangulation, negative case analysis, referential adequacy, and member checks" (Hsieh & Shannon, 2005, p. 1280).

When it comes to analyzing the text of the ideation of the device design, directed content analysis seems to be more suitable. Hsieh & Shannon (2005) explain that when further study would benefit previous existing theory, the researcher should use the directed approach which aims at validating or extending the theory from a conceptual perspective. Compared to the

conventional approach, directed content analysis is more structured, in which key concepts are already identified in the beginning (Hsieh & Shannon, 2005, p. 1281).

In my case, I speculate the new finding would possibly lead the design in new directions because I needed to simplify the idea even more. However, the case studies I can find are mostly from the technical area, which is not quite compatible with my context (sustainable art and design in the Arctic). Projects in the Arctic rarely use "heavy technology", by which I mean the relatively "new" or "modern" technology stems from the scientific field. On the contrary, the application of drawing, painting, and sculpture are defined as "traditional arts" in my study. I need to control the technical usage to an acceptable degree, also because it might be too difficult for me to implement. Directed analysis has a shortcoming in that the result could be strongly biased, which could be corrected by using an "audit trail" (Hsieh & Shannon, 2005, p. 1283). I will try to use the audit review and examine the definitions to increase the trustworthiness of my study.

In my study, related previous projects have a clear framework of how to use certain technologies in solving an issue. Thus, by analyzing it, I can pre-define several key concepts that could be useful to my project. In the process, it is sure that new problems will emerge because my topic is not completely identical to the previous studies. Then, these data would need to be decided whether to be categorized as a new code. The results of the directed analysis could be presented more by descriptive reports rather than coded data (Hsieh & Shannon, 2005, p. 1283). New findings could support the prior theory or offer a contradictory view or "might further refine, extend, and enrich the theory" (Hsieh & Shannon, 2005, p. 1283). Saldana (2008) also mentioned that there is no "one specific research genre" (p. 2) to use throughout the whole coding process and liberty needs to be taken when doing the coding.

According to Hsieh & Shannon (2005), usually, there are seven steps of qualitative content analysis: "formulating the research questions to be answered, selecting the sample to be analyzed, defining the categories to be applied, outlining the coding process and the coder training, implementing the coding process, determining trustworthiness, and analyzing the results of the coding process" (p. 1285). I have applied and simplified the steps in my research as follows.

3.2.1 Step 1: The research question to be answered

In the pre-design stage, before going into every detail of those hardcore technological issues to actually make the product, here I wished to explore the feelings of different groups of people (locals and tourists) of the laavu setting in Finland first. I was interested if their attitudes could be affected by the smoke lingering on their clothes and whether they were aware that PM2.5 and PM10 could be generated from an open fire. I wanted to find out whether it affects them when they realize the effect of smoke might have on their health and the environment. Apart from the topic of the relationship between humans and the environment, I also wanted to probe into people's opinions on applying new technology in Lapland. To sum up, I wished to draw a conclusion on whether it is necessary to make such a device and the possibility of realizing it:

Q1. Why or why not a smoke purifying device is necessary for a laavu?
Q2. Is it possible to make such a device technically and how?

3.2.2 Step 2: The material for analyzing

The data of the material are the records of the interviews with different groups of people at the University of Lapland, from international students to Finns in different positions which are later categorized into two groups representing diverse opinions. It is mainly in the written text of ideation of planning and self-reflection, pictures of related concepts and theories, illustrations, diary of the whole process of how the concept design of the device is formed.

The structure of the diary is my own design and planning with illustrations and diagrams being mainly on the top part, while the feedback collected is separated by a horizontal line listing on the bottom side in written words. Nevertheless, this diary is not kept in a strictly grammar-perfect way, but the spoken and informal language remains the way they were generated, which is in accordance with the principle of the Agile process.

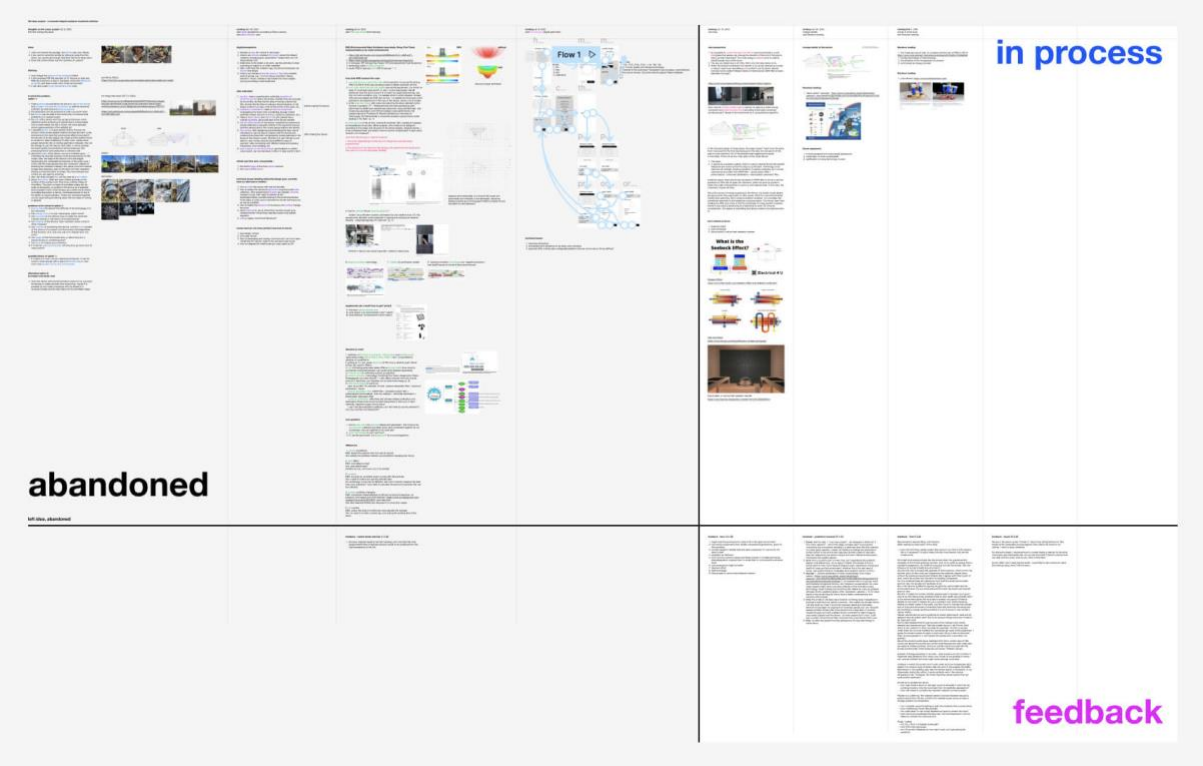


Fig 11. Screenshot of the material to be analyzed in written text and pictures. Credit: Fangchen Dai, 2024.

The left part in the light grey background is abandoned as the idea develops and changes based on and supported by constructive feedback gathered from different interviewees. The design iteration in the process is on the right canvas with the white background color. What is not reflected in the diary of the feedback collecting is that there are two teachers from the University of Lapland, to whom I reached out by email explaining what I was hoping to do and wished to get some suggestions but there were no replies.

3.2.3 Step 3: Coding process in cycles

Saldana (2008) defines coding as "a word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data" (p. 3). Saldana (2008) also points out that coding is a heuristic and exploratory problem-solving technique without rigid procedures to follow which leads to further analysis and interpretation and coding is cyclical. Often only one round of coding is not enough and multiple cycles would be needed. (Saldana, 2008, p. 8)

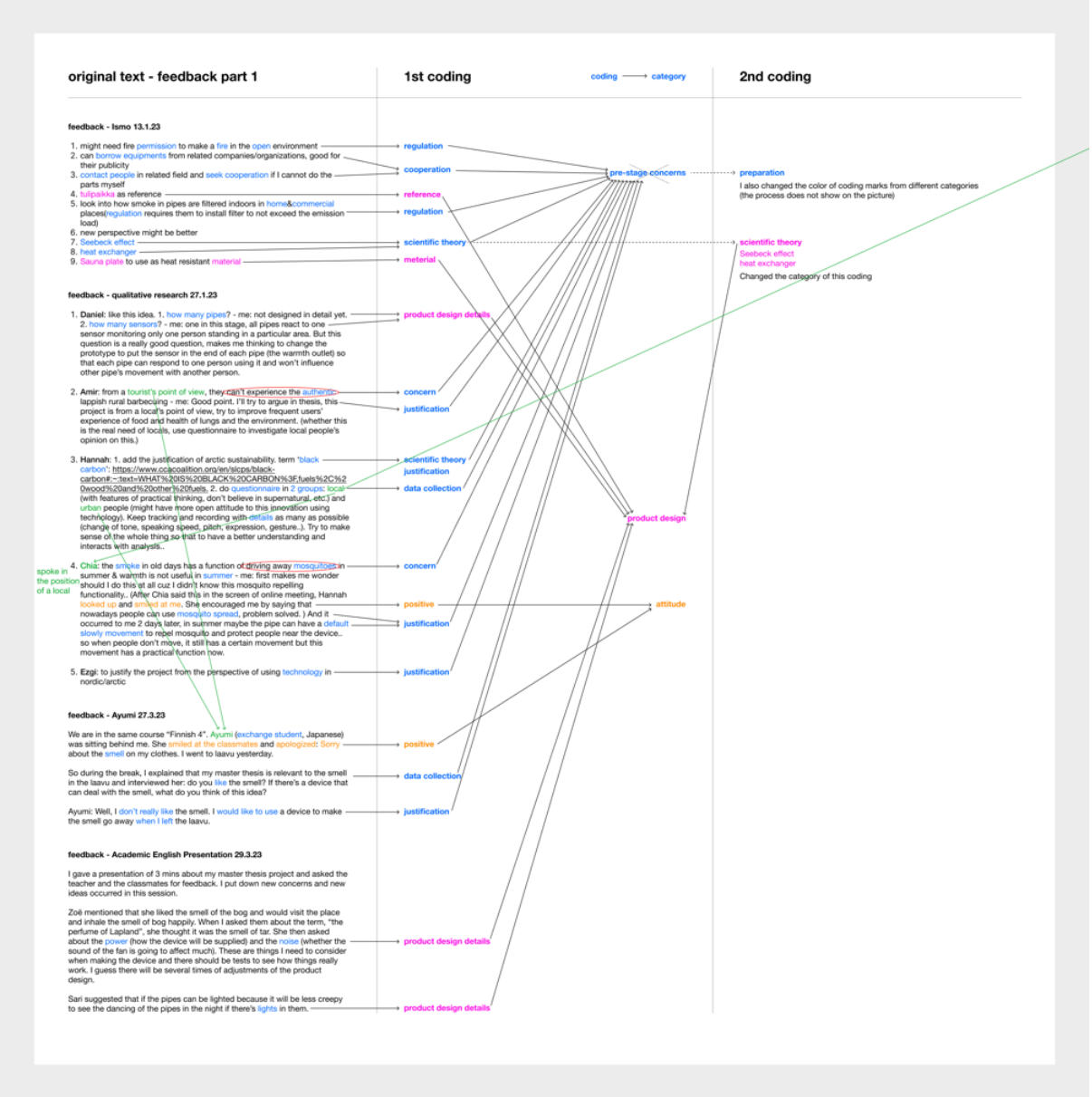


Fig 12. Screenshot of the coding process of the feedback text, part 1. Credit: Fangchen Dai, 2023.

In my process of making the coding, the first and the second phases are not very clearly divided. Small revisions (or correction of small mistakes) happened all the time. When analyzing the part of my own thinking and response to one person's feedback on the second page, the method of directed content analysis is used as there is already a pattern of the codes. I marked this part with codes "negative" from the category "attitude" and "justification" from "preparation". Although it is not rich content, I imagine I will follow the same pattern using the same method if I am going to analyze other texts of my own reflection and ideation in the online link.

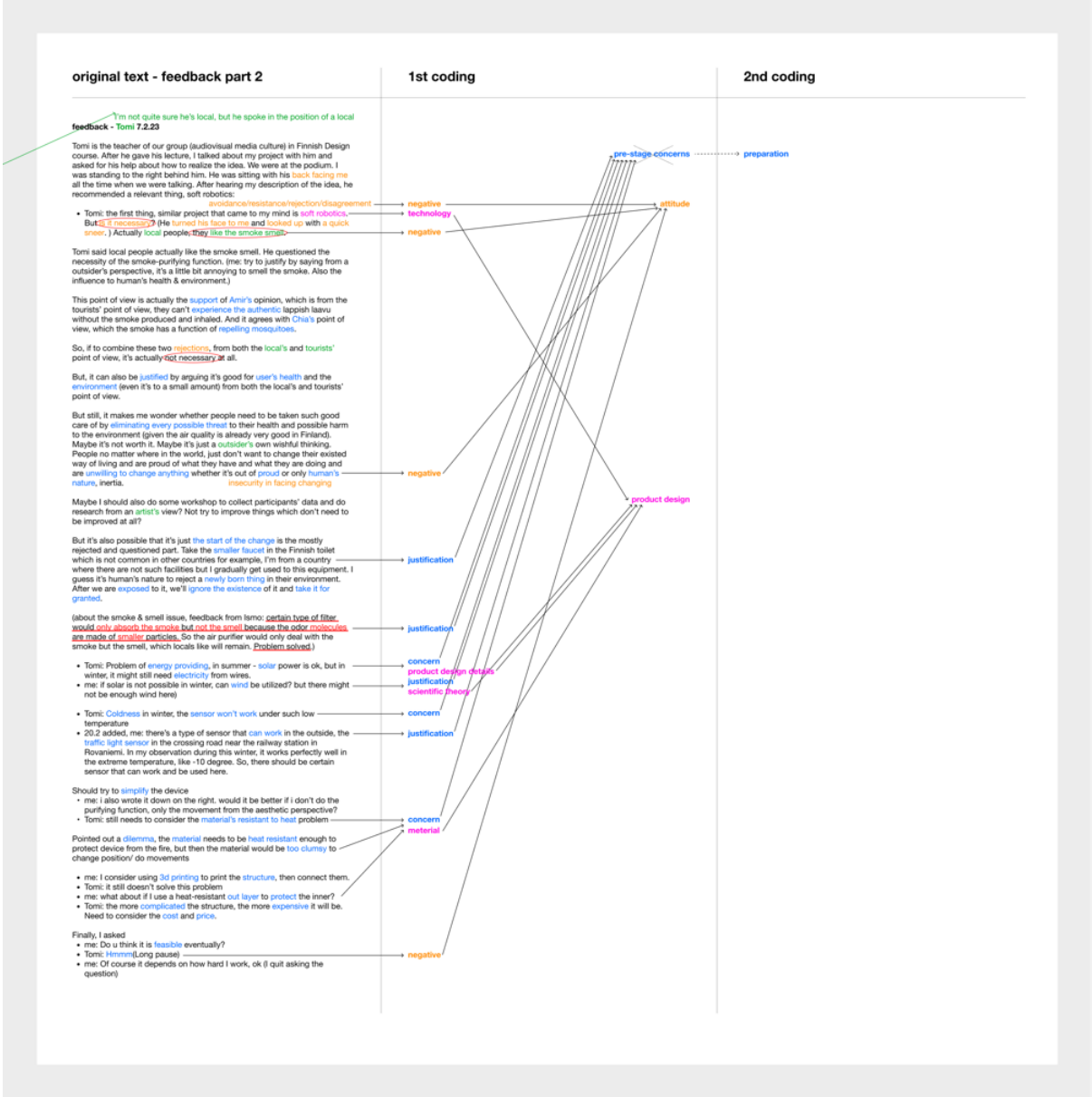


Fig 13. Screenshot of the coding process of the feedback text, part 2. Credit: Fangchen Dai, 2023.

The three categories become clear during the coding process:

Categories	Codes		
preparation	regulation	cooperation	scientific theory
	concern	justification	data collection
attitude	positive	negative	
product design	reference	material	product design details

Fig 14. Table of the categories and codes. Credit: Fangchen Dai, 2024.

There is one interesting data I want to discuss more from one “outsider’s point of view” that “She smiled at the classmates and apologized: Sorry about the smell on my clothes. I went to laavu yesterday”. The word “smiled” accompanied by “apologized” and “Sorry” does not stand for an agreeable or happy mood in this situation. It indicates the annoyance feeling triggered by the lingering smoke smell on her clothes, which I will interpret as a dislike of the smoke smell and a willingness to have a device to get rid of the smell. Thus, I mark it as “positive” in attitude because “attitude” here is an attitude toward the question of whether they want to have a device in the laavu.

The terms “concern” and “justification” can be analyzed together as a pair. Ideally, if there is a justification for each concern or there is more than one justification for one concern, then the conclusion would be easy to draw. But in reality, maybe one or two not-so-serious concerns can be ignored with no equivalent justification is also acceptable for getting a positive answer to the research questions. In this case, there are 5 concerns and 9 justifications. To be specific, the first 2 concerns are related to the first research question, and the other 3 are related to the second question. There are equivalent and sometimes more than one justifications for the first 2 concerns that are often answered beneath them, while there are not-so-solid justifications in regard to the last 3 technical concerns.

3.3 Ethical Considerations

According to the Finnish National Board on Research Integrity TENK (2023), the research for non-medical research that involves human participants in Finland needs to follow the guidelines on ethical principles to ensure no harm to the participants. The research and study in this thesis follow the ethical principles of research with human participants in human sciences in Finland. Consents were asked in written form in the questionnaires when they were given to the participants. There is no physical action involved to intervene in their physical integrity in the form of danger or mental harm. No minors under the age of 15 are included. The questions in general do not contain sensitive issues of personal information. Before the interviews, the nature of the research was always informed to the participants. The interviews were carried in a transparent and honest way with respect to the participants. The data were obtained and recorded faithfully.

In an action, there is always an action executor. Here, I also want to pose the question of who has the right to preserve cultural heritage because as a person coming from outside Lapland, outside Finland, and even outside Europe, am I qualified enough to even talk about the preservation of protecting the historical and cultural heritage here though as an out-and-out "outsider"? Trulsson & Burnard (2016) problematize the insider/outsider relation by pointing out that nowadays community-based researchers often enter the communities as outsiders, no matter whether they are from a university or other academic institutions. The dichotomy of outsider/insider leads to two doctrines. The outsider doctrine believes that outsider researchers are valued for their objectivity, while the insiderism suggests that the outsider researchers will never truly understand the culture and the insider researcher has a unique position to understand the situation, but there is also a risk that the insider might be blind to a phenomenon (Trulsson & Burnard, 2016, p. 4–5).

In my own experience as a researcher in this study, I experienced these two doctrines both, which are more or less reflected in the collected data. However, I believe there is not a definite right-or-wrong conclusion about which is better because people and things are in a constantly fluctuating state. Conflicts are meaningless by insisting on one side, while understanding and empathy are the keys to bridging the cognitive gap, thus propelling the improvement of the situation. An ideal conclusion is easy to form metaphysically, but not in reality, which is uncontrollable.

Trulsson & Burnard (2016) further discuss the ethical challenges in intercultural interviews that it is widely known that the researcher has power over the informants in a qualitative interview (Trulsson & Burnard, 2016, p. 1). Thus, in data collection, power should be made visible in order to avoid entering into a situation where the informants might consciously or subconsciously express in a way that they think the interviewer would want to hear (Trulsson & Burnard, 2016, p. 3). In my case, the data I collected are not private information related but mainly innocent subjective feelings toward a phenomenon or scientific technology. In my observation and viewing from the data collected which shows diversity of opinions, most informants are being honest about their feedback.

4. PROCESS AND PROTOTYPES

4.1 Phase 1 “Discover”

4.1.1 The smell of the smoke as a touchpoint to start with

The Discover stage starts from the day of the first visit on site, Oct 8th, 2022**,** and ends before the second visit, May 3rd, 2023, when the Define stage begins. However, they are not strictly divided due to the inevitable overlapping of the back-and-forth nature of the research process. This is just for the convenience of defining. The Develop stage starts at the beginning of June 2023, while the Deliver stage takes place in March 2024 and ends after the exhibition for the artistic part in May 2024.

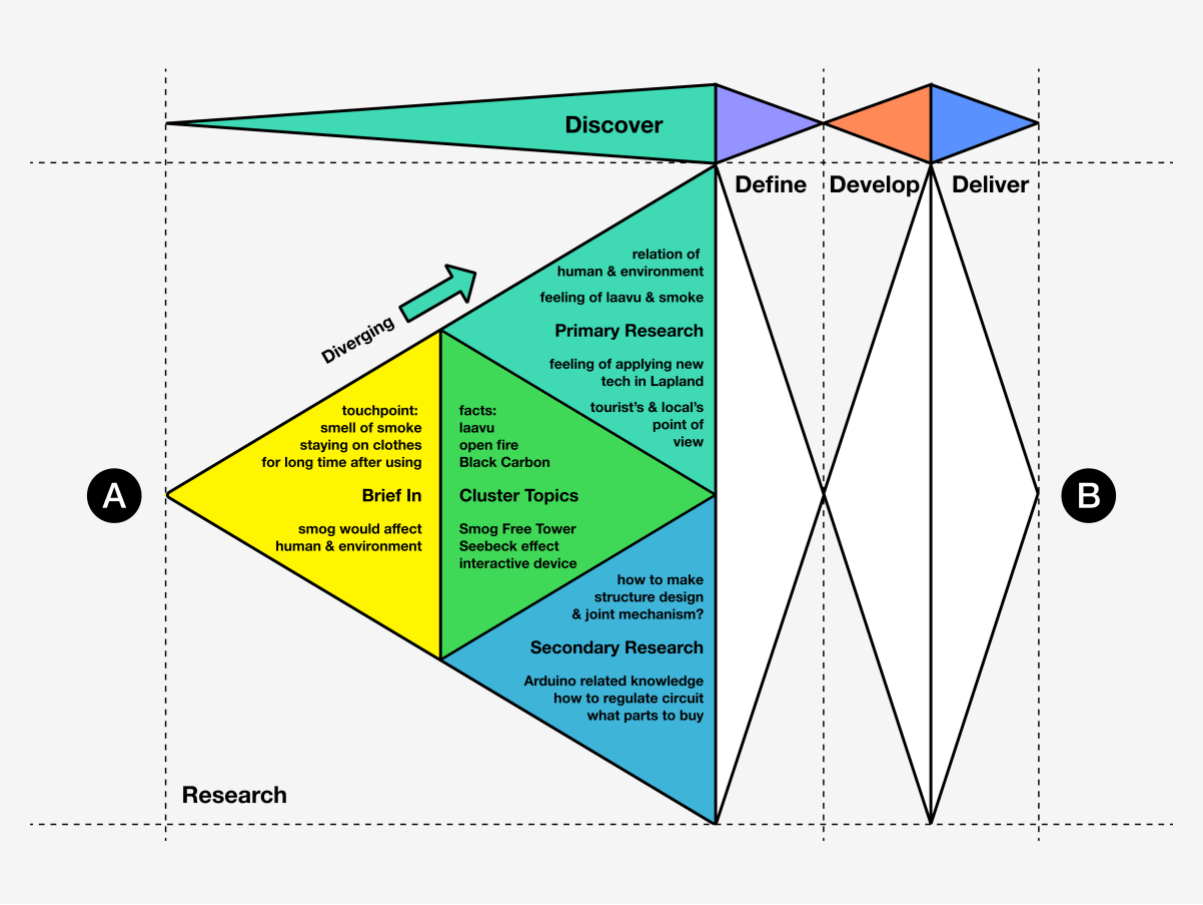


Fig 15. The Discover phase in the double diamond design process in my project. Credit: Fangchen Dai, 2024.

The diagram gives a more detailed explanation of what has been done in the Discover stage. It is divided into Brief In, Cluster Topics, Primary Research, and Secondary Research. In the Brief In session, I start by setting the touchpoint of my research. A touchpoint is defined in the book *An Introduction to Service Design: Designing the Invisible* by Penin (2018) as the medium that the user interacts with a service through, at which moment a service happens (p. 19).

According to Penin (2018), touchpoint stands for the physical feature of the service and constitutes the artifacts of the interactions of a service. Besides the material facet, it is also the key to improving the interactions to make them more efficient, meaningful, and desirable. When the value of a service is established, the moment is acknowledged as "the moment of truth" of a service and the interaction that occurs in this special moment is vital for the users to perceive the quality of the service by getting the results from the provider of the service. Touchpoint, unlike other factors in a service, is one thing that is controlled and designed by the service designer. After the touchpoint encounters, a "consistent delivery of positive moments of truth over time" poses a challenge for the provider who would orchestrate the service by a combination of multiple channels (Penin, 2018, p. 19).

Penin (2018) points out explicitly later that a touchpoint can be anything that is the "material evidence" that "supports the service performance", which can be "anything from physical good, interior and exterior spaces, printed materials, graphic pieces applied to surfaces of objects or architecture, digital interfaces and devices, furniture and light, uniforms and other garments worn by staff", and even including the "smell and perfumes released in the environment", and "background music and sounds" (p. 32).

4.1.2 Analyzing the data collected at the university

From the data collected from people with different backgrounds in the University of Lapland, I find it interesting to notice the more "negative" attitude towards the concept of the device, the more improvement ideas are attributed to the design of the device. Although when I was writing down people's opinions, normally I did not put down their expressions and body gestures when they were agreeable with an open attitude (with a smile on their face in most cases).

Major technical issues toward the realization of the device include “power supply in winter”, “sensors will not function under low temperature”, and “material’s heat resistance problem”. In the long run, technical issues are always solvable technically in one way or another, or by compromising or dialing down certain function’s difficulty levels. They are to be faced and dealt with later in the real-making stage.

The obvious benefit of having a purifying device near the fire is that it is good for people’s health and the environment. The main concerns about the necessity of having a purifying device are that local people like the smell of the smoke, tourists want an authentic Lappish barbecuing experience, and the smoke has the practical function of repelling mosquitoes. However, an argument given by one interviewee also points out that having a device to absorb the harmful particles and enjoying the smell of the smoke are surprisingly not contradictory at all because the diameter of an odor molecule (approximately 1 nanometer or less) is much smaller than PM2.5 (2.4 micrometers), let alone PM10 (10 microns). Needless to say, 1 micrometer equals 1000 nanometres. So, the smell can stay, and at the same time, the harmful particles go away (be captured and sunk). After all, for people like me, who have had an indescribable negative feeling related to the smell of the smoke is only because of the “bad particles” hidden within. As long as I know those parts are taken out, the smell will not bother me anymore. This scientific fact makes the whole thing reasonable and logical, which grants a yes to continuing the research project. From all this, I would say that it is necessary to make a device in the laavu and it is possible to make it technically.

Apart from the technical issues and necessity-related issues (which I define as “hardcore” issues, the whole concept would collapse if not solved), it is surprising to notice that the feedback gives me so much useful information. For example, one concept brought up by one interviewee, “black carbon”, had become a very important keyword for my research. Based on these findings, I continue by composing a written questionnaire (see Appendix A) translated later from English to Finnish which will be given to the smaller group of only local Finns in the village Meltosjärvi to compare with the analytical result I got already from talking more casually with the bigger group of people in the university.

4.2 Phase 2 “Define”

At this stage, I work mainly on converging the scattered information: obtaining a more comprehensive understanding of the necessity and possibility for the “Insights” based on the analysis of the collected data from the questionnaires, and focus on the “Themes” of the environmental protection in the Arctic and sustainable development by applying technologies of all kinds regarding new energy possibilities, and research on as many materials and theories that can be used as possible for the actual realization of the product.

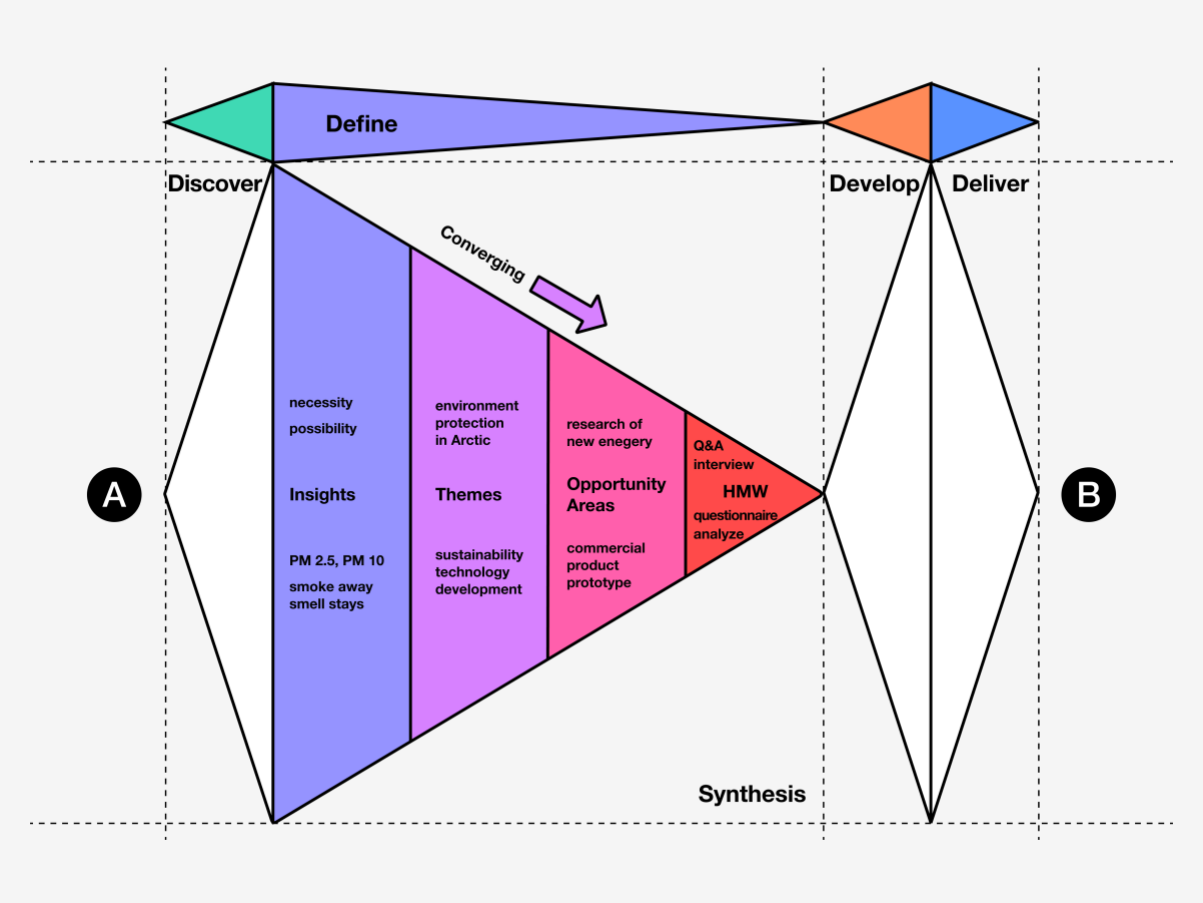


Fig 16. The Define phase in the double diamond design process in my project. Credit: Fangchen Dai, 2024.

I got four answers from the locals. The number of villagers who are still living there is estimated to be around 70–80 (figure given by my supervisor Elina Härkönen). With the help of Elina, the handwritings are recognized and translated into English for further analysis.

4.2.1 Analyzing the data from the locals and comparing it with the previous findings

Statistically speaking, this investigation belongs to the category of a small sample survey. Typically, if the sample size is less than 30 (or 15, even 10 for some cases), the large sample theory (asymptotic theory) is no longer suitable for estimation because the data structure in a small sample does not conform to a normal distribution (Gaussian distribution) anymore (Glenn, 1992, p. 4; Hill, 1998, p. 4).

What needs to be pointed out is that in this thesis, the emphasis is not on analyzing the data strictly statistically because it makes more sense to discuss the subjective interpretation provoked by the answers given the fact that the data is very limited although it can be calculated from a scientific perspective. For a sample of a small size (four observations), the confidence interval is calculated by the t-distribution method instead of the z-distribution (standard normal distribution) used in a large sample (Jones & Faddy, 2003, p. 159).

In the questionnaire, after acquiring consent for data collection the first question inquires how often the respondents use a laavu per year. By designing a question like this, the intention of the research study is to get a basic understanding of the relationship between the user and the laavu setting. The result shows that 2 persons out of 4 use the laavu at a frequency of Option 1 (< 5 times/year), while there is one person each choosing Option 2 (5 – 10 times/year) and Option 3 (> 10 times/year).

4 persons (n) →			scale to →	80 persons
	Frequency	Probability (p)		Estimated number
Option 1	2	2 / 4 = 0.5		0.5 x 80 = 40
Option 2 Option 3	1	1 / 4 = 0.25		0.25 x 80 = 20

4 persons (n) →					interpret →	80 persons
	Confidence Level (z)	Standard Error (SE)	Margin of Error (MOE)	Confidence interval		true proportion range
Option 1	90% (z) ≈ 1.645	$SE = \sqrt{p(1-p)/n}$	$MOE = z \times SE$	$(p - MOE, p + MOE)$		
		$\sqrt{0.5 \times (1-0.5)/4} \approx 0.25$	1.645 x 0.25 ≈ 0.411	(0.5 – 0.411, 0.5 + 0.411) ≈ (0.089, 0.911)		0.089 ~ 0.911 x 80 = 7 ~ 72 persons (rounded)
	95% (z) ≈ 1.96		1.96 x 0.25 ≈ 0.49	(0.5 – 0.49, 0.5 + 0.49) ≈ (0.01, 0.99)		0.01 ~ 0.99 x 80 = 1 ~ 79 persons (rounded)
	99% (z) ≈ 2.576		2.576 x 0.25 ≈ 0.644	(0.5 – 0.644, 0.5 + 0.644) ≈ (-0.144, 1.144) should be between 0 ~ 1, otherwise is not meaningful		beyond valid range, not well-defined
Option 2 Option 3	90% (z) ≈ 1.645	$\sqrt{0.25 \times (1-0.25)/4} \approx 0.19$	1.645 x 0.19 ≈ 0.312	(0.25 – 0.312, 0.25 + 0.312) ≈ (-0.062, 0.562)		beyond valid range, not well-defined
	95% (z) ≈ 1.96		1.96 x 0.19 ≈ 0.372	(0.25 – 0.372, 0.25 + 0.372) ≈ (-0.122, 0.622)		beyond valid range, not well-defined
	99% (z) ≈ 2.576		2.576 x 0.19 ≈ 0.487	(0.25 – 0.487, 0.25 + 0.487) ≈ (-0.237, 0.737)		beyond valid range, not well-defined

Fig 17. The estimated calculation of how many people in a total number of 80 might choose between the three options. Credit: Fangchen Dai, 2024.

As shown in the calculation chart above, the most common way to estimate the number from a portion to a total is scaling up by the same probability, which is a very straightforward way to use in my case. There might be 40 people who would also use the laavu less frequently (less than five times a year). Apparently if one tries to get the Confidence Interval based on the extremely small sample, most of the values calculated by applying the t-distribution method do not make sense. Thus, it is enough to just stay with the values directly scaled from the 4 answers. It is the same with the following questions.

As a result, I will only analyze the data from a qualitative perspective and extend it speculatively and vaguely to a larger group. Although many locals might not use the laavu quite often, they still have a special feeling toward it. Among the additional things related to the laavu using experience, short descriptions with positive feelings such as "'survive' like the cave people in previous times (smiley face)", "outdoor fire and often frying food or sausage and eating outside (translated from Finnish)" are mentioned. What is a surprising finding to me is that 3 out of 4 votes for the option "I like the smell" of the smoke from the stove. However, one person mentioned: "Sometimes I roll from place to place dodging smoke. It's okay. That's the point (translated from Finnish)" and this person is also among those who like the smell. This positive attitude towards the smoke smell is also observed in other Finnish people that I interviewed before in the university.

Another statement "The smell of smoke covers other smells." seems to be a rather neutral one. It can be either a good thing or a bad thing for the smell of smoke to cover all other smells according to my understanding. However, when it comes to the question of whether they like the smell staying on their clothes, 3 out of 4 select "I don't like" and one "I don't care". From this, it is safe to say that even the feeling of smoke is mostly happy memory related, when viewing from a practical perspective people still are troubled by the longevity of the smell accompanying them. I remember when asked about how they deal with this "small issue", some said that one solution to take was to wear a coat specially prepared for this occasion so that other clothes can stay clean away from the open fire. Apparently, this is not possible for everyone.

For the third multiple-choice question, the answers are also distributed evenly like the first one: two persons never thought about "inhaling some harmful particles when burning the woods",

while one chose “I have worried” and one “I don’t think that’s a problem”. In putting this question in the questionnaire, I intended to raise awareness of informing that there might be a health issue related with the smoke, so the last option is “I got interested and now I would like to know more”. Nevertheless, no one was intrigued by this point and got interested. Apart from the questions and answers designed, one person mentioned that when hunting, he also makes open fire and asked whether this can be considered as a setting which is similar to using a laavu and stove. This makes sense, which makes me decide to extend the background to a broader situation of using open fire outside.

4.2.2 Conceptualizing the device

At this stage, a new perspective is brought up. I was wondering if it is possible to collect the heat from the fire and gather it into a pipe structure that can be controlled by people to change its shape and direction of the end that is near the human body. So, when the “pipe” is dragged to them, the heat can be filtered and transferred to warm up the user’s body or at least their hand. The heat, which is purified through the pipe, is cleaned and “recycled” to benefit people around the stove. This idea came up because the day when we first visited the laavu was chilly and the exploration of utilizing the so-called “new energy” is always welcome in this era.

When the smoke is extracted from the heat, it remains a question to be answered later in the Develop stage what kind of purifying technology should be used to make sure the heat is treated well to no longer possess the harmful particles and can be blown to humans directly carefreely? In my plan, one way to do this is to use several HEPA filter screens installed inside the pipe. In order to make the airflow run through the pipe, a ventilator near the end of the fire should be used. The other way is to have a positive ionization (or negative ionization) tunnel accompanied by the ventilator. Other ideas include using an active carbon filter, photocatalyst, ultraviolet sterilization, or electrostatic absorption filter (ideas are planned to be tested in a later stage to see which is the most suitable choice). A combination of multiple materials is also taken into consideration but again it needs to be tested to see whether it is feasible in real making.

As for the interaction, details are revised from “making a set of pipes that can ‘dance’ according to human body movement and the users can grab a pipe and aim the air outlet at themselves to

warm up by cleaned heat" to "each pipe has a sensor at the end which will only capture the body movement of the nearest person".

Besides, a new argument from the perspective of the season is brought up. Although the summer in Lapland can still be chilly sometimes even in the daytime which still needs the heat from keeping a fire, there are also times when there is no need for getting extra warmth or when nobody is moving around with big-scale gestures (resting state), during which state the pipes can have some default movements to repel mosquitoes.

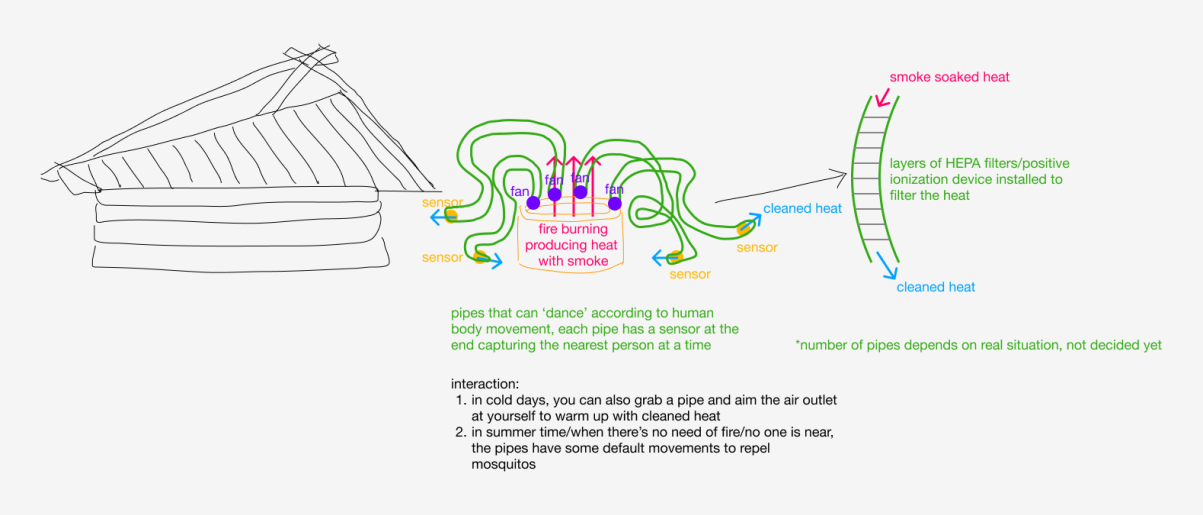


Fig 18. The revised illustration (third version) of the conceptual design of the whole structure. Credit: Fangchen Dai, 2023.

I attempted to simplify the structure as much as needed. As a result, the third version of the illustration is shown in Fig. 18, in which the idea is revised further that instead of using a big fan on the top center above the stove, it is better to use several small fans to absorb in smoke-soaked air in the other end (as one end already is to be installed with the sensor) of each pipe to muffle the possibly loud noises generated by a big central ventilator. Also, it makes it easier to standardize a small pipe as a single-unit module. A smaller unit is easier to install/uninstall and carry around to different places.

About the source of the power supply to the device, my premium choice would always be "green power" like solar power or wind power, which is more environmentally friendly than electricity. But if the context is outdoor conditions with extreme coldness, it is inevitable that sometimes electricity is still needed as a backup option. One thing I learned from reading the

ENS case study is that the advantage of using positive ionization is that it only costs a small amount of electricity to work, rendering the utilization of solar or wind power possible (Jenniskens, 2017, p. 6). As I decided to apply the thermoelectric effect as the power source, more research on what components should be used will be conducted later.

For getting the heat from fire to the human body, there is a concept called a “heat exchanger” which is a device that transfers heat between two or multiple fluids. According to Linquip (2023), heat exchangers are widely used in industrial areas, such as power plants and refrigeration systems (para. 4).

As for the materials to use in the setting, a sauna plate is suggested by an interviewee as heat heat-resistant material. A sauna plate is a board that is used in a sauna to protect the stove and hearths. There are many different brands of producers, who provide various sizes of plates. Another material that could be useful is the fire-retardant coating, which can be used as the outer layer of the product as a fireproof material. It can stop or slow the spreading of fire, reduce the intensity of the fire, and reduce the smoke amount. When I visit the local hardware store, there are products like this that are available if needed.

Regarding the mechanism to realize the function of changing the shape of the pipe structure, another interviewee mentioned a recently developed device, soft robotics. According to the website SOFT ROBOTICS (n.d.), a soft gripper module is used at the end of the robotic arm to pick up the object. This module is ingenious in engineering and with AI-intelligent algorithm to control the grip precisely. This is a very promising direction. However, I do not possess the ability or condition to make it delicate like this.

4.3 Phase 3 “Develop”

With all the feedback I got in the preliminary stage, I began to work on putting everything together and making the real thing piece by piece. I started by doing research about what interactive technology would be the most suitable for the experimental interaction part of my study. After this, I also researched which mechanism from the engineering perspective to use in the structure of the pipe. Then, comes the application of the thermoelectric effect for getting a steady electricity power supply to use for the circuit. The last part is finding the premium

way to realize the purification of the smoke.

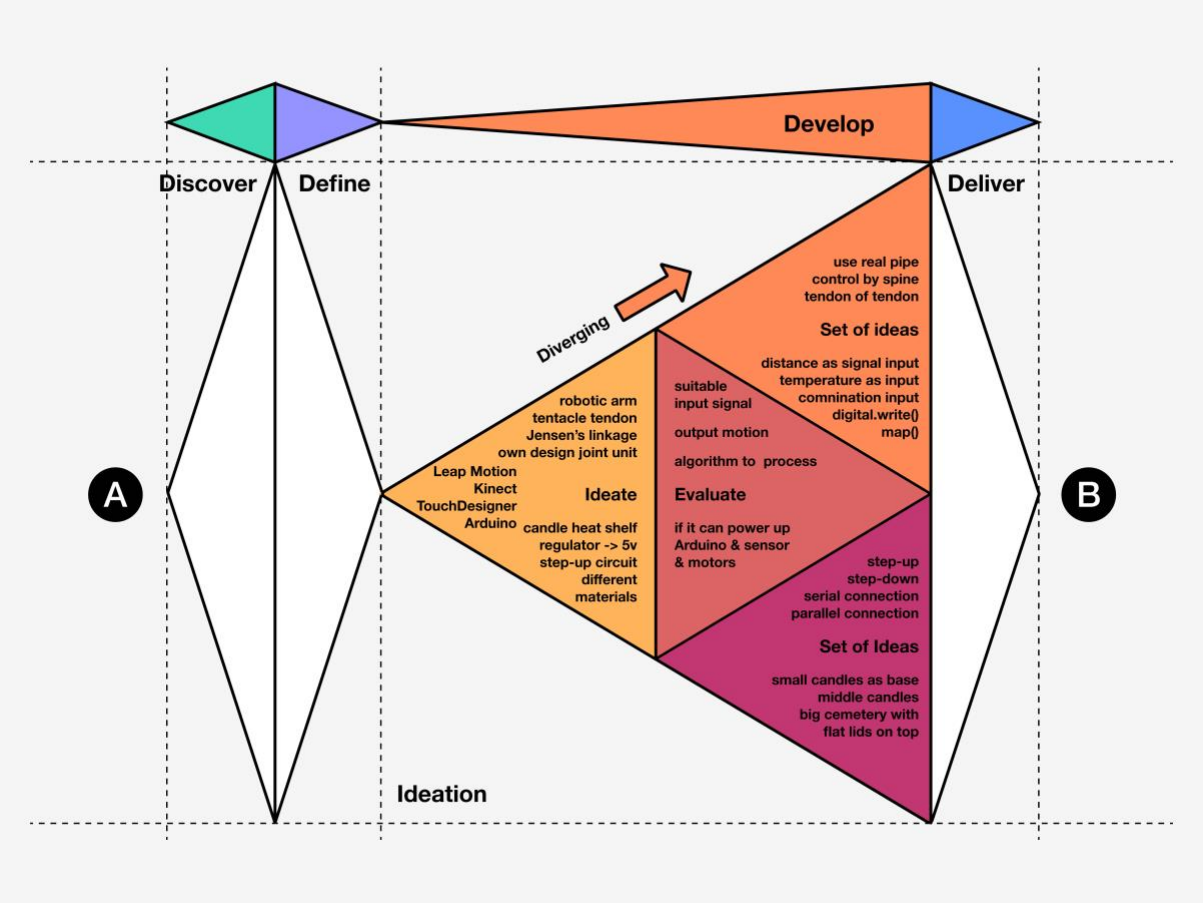


Fig 19. The Define phase in the double diamond design process applied to my research data. Credit: Fangchen Dai, 2024.

4.3.1 Processor, servos, and sensors for the interaction

As a start, I find that there are four technologies used for the interaction between humans and things that might be suitable for my project: Leap Motion (https://www.ultraleap.com), Kinect (https://en.wikipedia.org/wiki/Kinect), TouchDesigner (https://derivative.ca), and Arduino (https://www.arduino.cc).

In my understanding, for Leap Motion, the user needs to wear a headset to experience the XR (extended reality) digital world built virtually. Kinect is a flat cubic box that works with Xbox produced by Microsoft to create an augmented experience but is not in development anymore. TouchDesigner is mostly used in media artworks, with input from a camera to change the visuals and sound on a screen. Arduino is a single-chip microcontroller with code uploaded on

a software platform, which can get in all kinds of signals by attaching various sensors as input to be processed in the chip. As a result, the output can be a multiple-sensory experience (visual, auditory, or olfactory) built into a real thing.

In the end, I decided to use Arduino and related technologies in my project because others are not so suitable. One needs to use a heavy headset for Leap Motion and the user can only experience what happened in a digital world. Similarly, with all due respect, I have always felt that TouchDesigner was merely a more advanced music player desktop application on the PC in the 1990s. The output is always on a screen. For the record, again no offense, this is just my very limited interpretation and purely personal preference.

Maybe because of my previous years of working experience in digital design, I become really tired of the things that only happen on a screen, instead, I am more interested in the things that could make actions in real life. Kinect is nevertheless not an option because it is not a safe choice to use an already abandoned product for possibly unattended management of uncontrollable issues in the process of development. As a comparison, Arduino has both hardware and software that are friendly for beginners, although later I found Raspberry Pi is an alternative that has similar functions to Arduino. However, I did not conduct further research on it because I already worked with Arduino for a while, and it was working well.

As a start, at the beginning of June 2023, I bought components for Arduino and also for the structure from both local hardware stores and online stores. The purchasing of stuff is a continuing journey whenever there are new ideas to test and a lack of materials. While waiting for the online packages to come, even without the parts in hand, plans of how to connect the whole thing are made beforehand. The first version of the whole plan is not in use for the final product after several iterations, but this is how everything can be connected for real as a workable prototype. Although some details do not work in the end, this is quite the natural process of designing a complicated product.

The first workable plan was drawn in Figma, although for many professionals, the choice would be using more professional tools to draw the schematic, such as Fritzing and LTspice. I did try these tools, but I am not comfortable using them although they provide very professional functions which on the contrary are too advanced for me given my limited knowledge of electrics. What I need for my project can be more easily illustrated in Figma by my own

understanding and I do not need to delve too deep into the PCB (Printed circuit board) design at this stage yet.

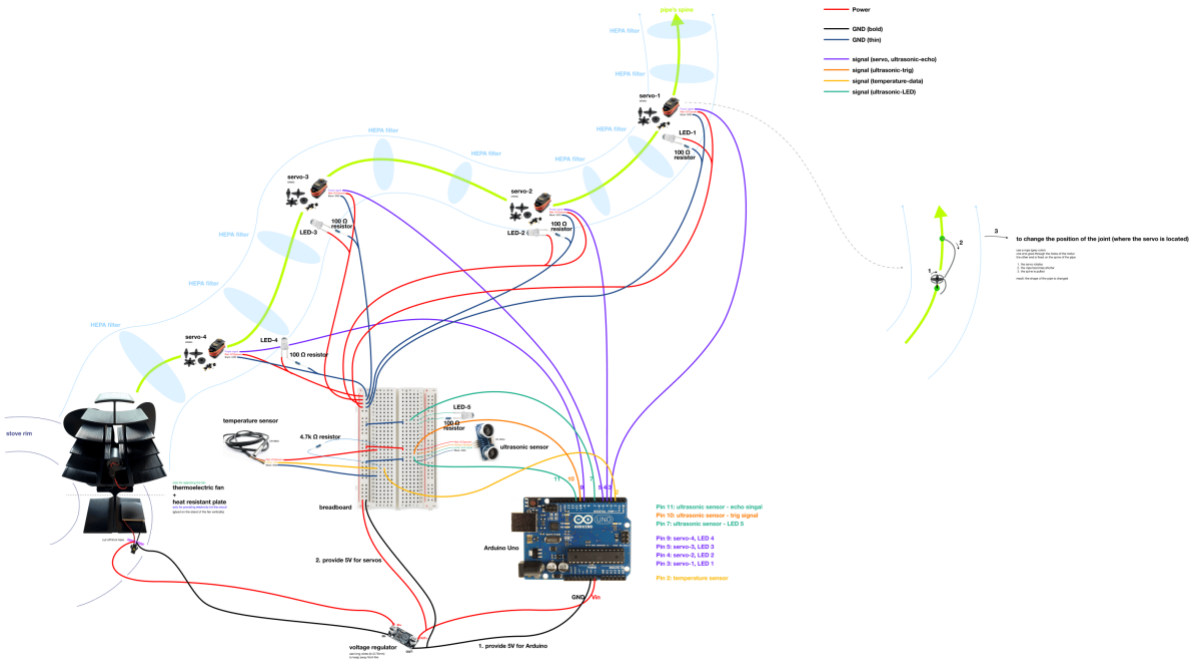


Fig 20. The first workable plan of how to connect the whole thing. Credit: Fangchen Dai, 2023.

For the coding of the Arduino Uno board, which is my choice of processor, ChatGPT plays a big part in writing the code and explains everything that is beyond my capability. In my experience, utilizing AI resources for a project like mine is a really good way for "laymen" to quickly start on a project, especially in which they do not acquire the necessary basic knowledge in another area from their previous skillful ones. It alleviates the shy feeling of the fear of asking "silly" questions if you ask a human expert and artificial intelligence is always giving immediate answers patiently, calmly, and encouragingly. Although it is not perfect in giving the rightest answer, it is close enough to guide me on how to start this project. Thus, I genuinely suggest artists and designers try to use AI to strengthen them in extending their boundaries, combining art and technology in a novel and creative way.

On July 17, 2023, the part of Arduino controlling part reached a milestone, the first version with coding, sensor, and servo motors working together. Video of the connection working can be viewed from https://youtu.be/fQgDUrPSxKE and the video of the input signal detected in the Series Monitor in the Arduino IDE (integrated developing environment) can be watched on https://youtu.be/FxAW_IFS-nw.

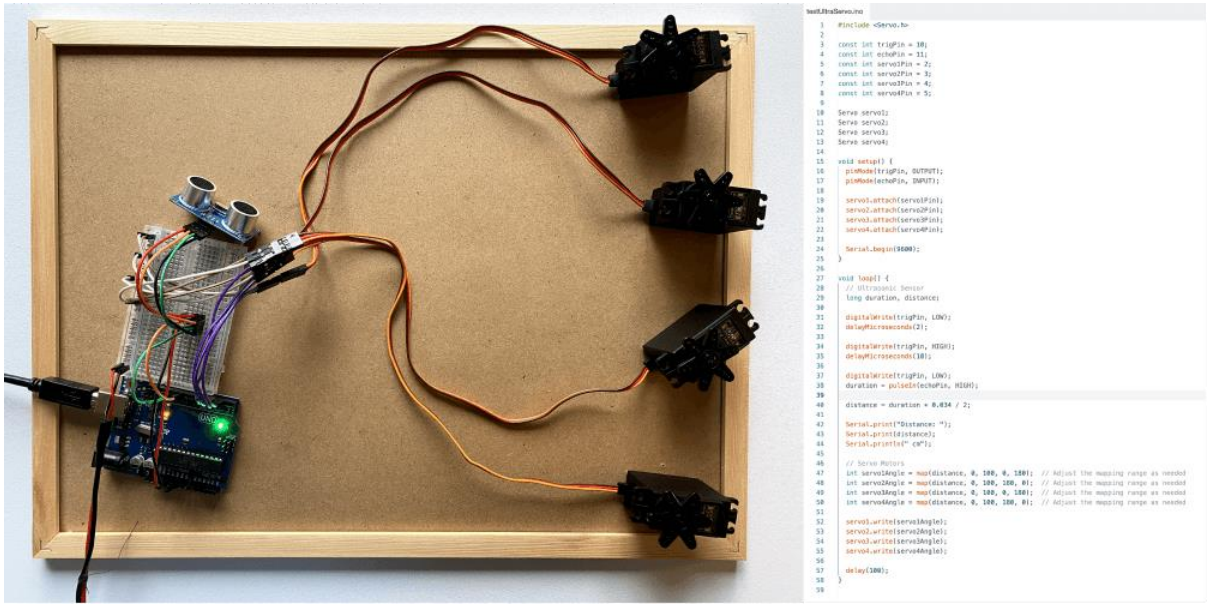


Fig 21. The first version of successfully working Arduino Uno, ultrasonic sensor, and servo motor connected together. Credit: Fangchen Dai, 2023.

The type of microprocessor I use is Arduino Uno. The core of the coding part is set in this stage. The structure design iterations later affect some details in the rotating values and numbers of the servos used, but not the core program. As shown above, the main function is to read the distance value by calculating the time difference of the signal sent by the two ends on the ultrasonic sensor by the formulation “distance = duration * 0.034 / 2” as the speed of sound is approximately 0.034cm/ms. The ultrasonic sensor works by sending a sound wave pulse to the object (obstacle) and the sound wave is bounced back. This real-time changing distance value will be mapped to the rotating angles of the four servos differently: two are from 0 to 180 degrees, and two are from 180 to 0 degrees reversely, with both distance values changing from 0 to 100. The mapping method allows the controlling of the angles of the servos to be very precise.

For the servo motor, I tested two types: SG90 and MG995. The difference between the types is mainly in the torque (lifting ability). SG90 can lift 1.6kg/cm at most, while MG995 is 10kg/cm. To view from another perspective, the SG90 is also lighter, more flexible to be attached to a structure, and as a result will influence the structure less, especially when the structure itself is light in weight. Apart from these two, I wanted to use MG996R (11kg/cm torque) in the beginning but the online seller sent me the wrong type so I had to put up with

what I had (MG995) at the moment because the most urgent thing was to get a quick prototype and details could be optimized later. An interesting thought occurred when this connection was successful, I found the shape-changing could be used as a perk to expel mosquitoes if designed properly and strongly enough. This additional feature needs to be tested later.

The input signal is obtained from the ultrasonic sensor HC-SR04, which detects the distance value between a human and the sensor itself and maps the value by a mapping function to the rotating angle values of the four servo motors MR995. At the beginning of the plan, I considered to use also the temperature sensor DS18B20 as the receiver of the input signal to work as the source of the default gesture changing of the pipe structure, but since I did not get the right resistor (should use a 4.7k Ω resistor, but what I had at the time was a 4.7 Ω one) and I wanted to test everything quickly, I compromised on only using the ultrasonic sensor as the input data source.

Later when I got the right resistor, I tested the temperature sensor in an interactive project "The Beam Bundle" (see Appendix A) to elucidate the idea of transferring the figures of the temperature difference as a trigger to the movement of the structure. The test shows how the LEDs react to the temperature values detected from the temperature sensor with interval delays mapped from the brightness.

Fig 22. The testing of the temperature sensor, DS18B20 in "The Beam Bundle" project. Credit: the left photo is a screenshot from the video taken by Chia-Chen Chang, 2024; the right photo is taken by Fangchen Dai, 2024.

Based on the outdoor test of the temperature sensor, I realize that it is not a suitable input sensor for the pipe project because it does not react as fast as the distance sensors. It takes time for the change of the temperature value to be detected and controlled by the algorithm. Besides, this type, DS18B20, is best for ambient temperature detection instead of rapidly changing temperature, which is also observed in my testing project, in which the sensor seems a little slow in triggering the brightness of the LEDs (although this could also be due to other reasons, such as the over complicated design of the controlling codes). Nevertheless, I decided not to use a temperature sensor in the final project.

Later in 2023 from November to December, I also tested other types of distance sensors apart from HC-SR04 to detect the human body, namely PIR (passive infrared) sensor, and microwave sensor by applying them in different experimental interactive projects with the participants of the group members for the specific project and with the help from my co-researcher Chia-Chen.

The differences between these sensors are firstly on the way they are based. For example, according to the website Core Electronics (2023), distance-based sensors are single-direction detecting sensors that can use the real-time detected distance value for further manipulation of the output action. To be specific, there are two kinds of distance-based sensors: ultrasonic sensors and laser sensors. The former works by sending sound waves and is not good for use in noisy environments because other sound waves may influence, especially ultra-high-pitched noises, but they will not be affected by light, while the latter works by sending light waves, which will be affected by infrared light such as sunlight, so it is best to work indoors. However, the laser sensor is not affected by sound and it is more accurate (up to millimeter accuracy) and has a longer range compared to the ultrasonic sensor, which makes it more suitable for the demand for more precise control (Core Electronics, 2023, paras. 25–32, 36–38). However, since I do not process a laser sensor, I did not test this type of sensor.

Fig 23. The types and the comparison of different human body detecting sensors. Credit: Fangchen Dai, 2024.

PIR sensor monitors the infrared radiation from anything that gives off heat, for example, humans and animals, but it can be affected by the sun, which also gives heat. So, it is better to set in a place without direct sunlight and does not have a fluctuating heat source, such as a fireplace, which makes the PIR sensor not suitable for being used in an open fire outdoors for my research study (Core Electronics, 2023, paras. 16–22).

As for a microwave sensor, it emits signals first at a chosen frequency and then it monitors the changes in microwaves and millimeter wave radiation when the signals bounce back according to the Doppler effect. It is considered better than a PIR sensor in a way of being able to detect through non-metal solid surfaces, which means it can be put in a waterproof container and detects movements of humans through walls and ceilings. One thing to notice is that there should be no metal placed on the front side and there should be at least a 1cm distance away from metal on the back side. The sensitivity and delay timing of some models of microwave sensors can be customize. (Core Electronics, 2023, para. 24–31).

I tested the PIR sensor (model: HC-SR312) in a personal project “The Metal Heart” of an interactive installation to figure out the functioning range of the temperature. In the installation, a servo motor is triggered when the PIR sensor detects a human. At the testing time on that day, the outdoor temperature is around -15°C. I speculate it is because of the low temperature, the battery did not work well anymore. As a result, the reaction of the servo malfunctioned after 7 minutes. As mentioned before, the PIR sensor is affected by the heat given by the sun. At the time of the testing, the sun has already sunk off the horizon, but there might still be influence from the remaining rays of the sunset, which could also possibly affect the functioning of the PIR sensor. Nevertheless, the PIR sensor will not be my premium choice for input signal detection.

Fig 24. From left to right: the testing of the PIR sensor, HC-SR312 in “The Metal Heart”; the testing of the ultrasonic sensor, HC-SR04 in “The Traffic Light”; and the testing of the microwave sensor, RCWL-0516 in “The Bottle Phone”. Credit: the left and the right photos are screenshots from the videos taken by Chia-Chen Chang, 2024; the middle photo is a screenshot from the video taken by Ali Taimour Ali, 2023.

The low temperature affecting the Arduino module functioning is also seen earlier in another interactive installation “The Traffic Light” (see Appendix B). Two ultrasonic sensors (model: HC-SR04) are used on each side facing the coming direction and the leaving direction to detect the human body, which will be triggered when people walk towards them from specific angles within 100cm. In this case, the installation was to be left for the whole day for passersby to interact and to be picked up at noon the next day. Unfortunately, the battery died very soon. The battery was changed at around 8 pm, but not monitored for how long it lasted. The temperature was -5°C to -10°C that day. It is estimated that the interaction was affected by the coldness, although it was not sure that the affected part was just the battery or others as well. In this case, the batteries in use are two AA batteries in a voltage step-up circuit by two 0.9~5V to 5V boosts in series connection, whereas in the former project, there is only one 9V battery in use.

In the third project “The Bottle Phone”, the microwave sensor RCWL-0516 is tested. According to the product specification, it has a detecting range of less than 120° taper angle within 7 meters and a 360° detection angle. This sensor is used to detect humans and trigger a Piezo buzzer to play a tone. The temperature of the testing day is -3°C to -8°C and the 9V battery is in use. There is no malfunctioning of all the parts and all the reactions of the interaction are expected as planned.

In fact, when I am putting everything together and testing indoors, everything works just fine in all the projects mentioned above. Nevertheless, since all these tests are not strictly conducted in a “variable controlling” way and for the last testing project, there is a semi-concealed shell covering all the parts (which is not used in other tests, thus theoretically the slight amount of heat generated by the battery when it is working would possibly warm up the whole inside temperature inside the bottle), I cannot draw a definite conclusion that the temperature is the only reason to influence the performance of all the interaction.

However, based on the comparison of all the tests described above, I assume that it should be receivable to say that the human body detecting sensor with an Arduino Uno microcontroller and output modules functions well in an extreme winter outdoor setting with the temperature higher than at least -3°C ~ -5°C.

The importance of this range is that it can also be used in my thesis project because a part of it is also in the extremely cold outdoor setting. Given that I am not doing research in relatively normal temperatures (higher than 0°C or much higher, such as more than 30°C), I do not discuss the highest threshold of the working range of the Arduino module with an input device of human body detecting sensor and output manipulators. What needs to be pointed out also is that all the data and speculations are totally based on my own specific experiments, in which the condition is very site-specific and confined. The result might be different if the components are replaced with different models. Thus again, every conclusion made in this thesis is only my own estimation from my own observation.

When the core coding part of the controlling function is realized, the structure design is underway. What needs to be pointed out is that this chapter is not written in chronological order of time but in a cyclic iteration order based on the features of the design. The structure design is earlier than the tests of the sensors.

4.3.2 The iteration of the prototypes of a rotating structure

There are four prototypes designed and tested in total. Prototype 1 “Metal Worm” is based on the mechanism of bio-dynamic tendon-operated tentacle robotic arms. Prototype 2 “Brandishing Branches” is a structure composed of environmentally friendly material and designed by using the basic unit of Jansen’s linkage, which is a mechanism invented by Theo Jansen for many of his Strandbeests. Prototype 3 “Scaffold with Arms” is a shelf structure with my own designed basic rotating unit. Prototype 4 “Wiggly Tree Tip” (the final delivery) is a tree structure using the same basic unit discovered by myself which is first carefully and detailedly designed in digital 3D software and then put together using suitable materials in the real world. All the prototypes are displayed in the exhibition (see Appendix D, E).

4.3.2.1 Prototype 1 “Metal Worm”

– An accordion pipe controlled by tendons and robotic arms

As a start, I bought an accordion pipe which was originally used for kitchen ventilation to be the main body of the pipe because it is obviously a ready-made “pipe” structure to pick up. The aim of this first prototype is to realize the function of using the input signal of the detected distance value between the human body and the sensor to apply in manipulating the changing of the shape of the pipe. The detecting sensor is still the same ultrasonic sensor HC-SR04, and the four servo motors are still the same MG995, with Arduino Uno, breadboard, and jumper wires as mentioned before in the core coding part. In order to mimic the real open fire situation, a heavy foldable laptop stand that can adjust the angle of the pointing direction with a hammer to add weight for steadiness is used to make one end (the near-fire end) of the pipe not movable.

The testing video can be seen at: https://youtu.be/U2R-2ZzgR1Y. As shown in the video, there are four sets of threads pulling from the four servos to the rings made of threads also to manipulate the movement of different positions on the pipe. However, although it is working, the movement is not apparent enough to notice. I named it Version 0.1 because it is not good enough be to a workable Version 1.0 yet, but it is a start. The next step is to improve on making the movement more obvious.

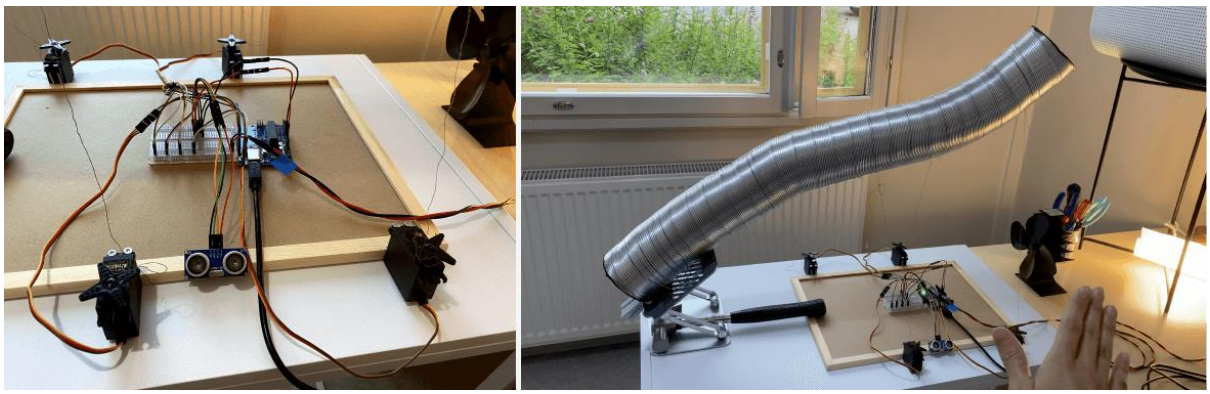


Fig 25. The prototype Version 0.1 of the pipe structure. Credit: Fangchen Dai, 2023.

Thus, I do more research on what can be done to improve the structure. The conclusion is that there are mainly two directions that I can delve into: one is to use “the tendon controlling system” to connect a series of wires between the rings on different positions of the pipe and a central controlling panel near the starting end. This is a biology-inspired method, which is to

mimics the mechanism of the tentacles of an octopus or the nose of an elephant. A similar term “bio-nano dynamics” is used in other cases (see Gear Down For What?, 2018; oomlout, 2009; Vanderbilt MEDLab, 2014).

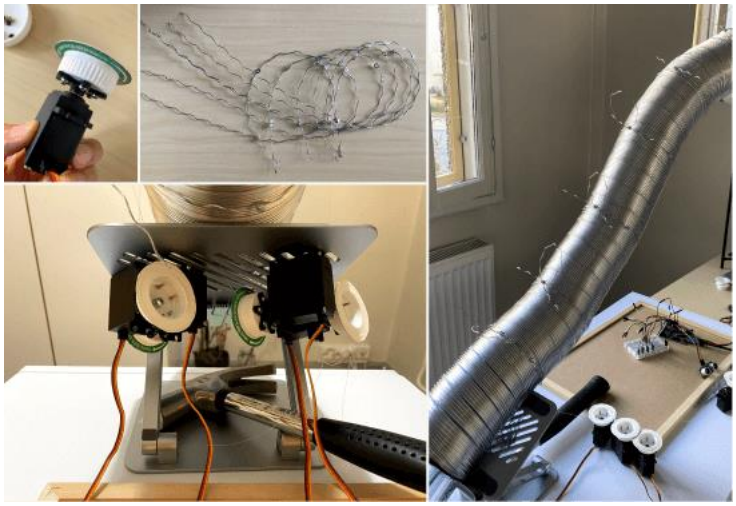
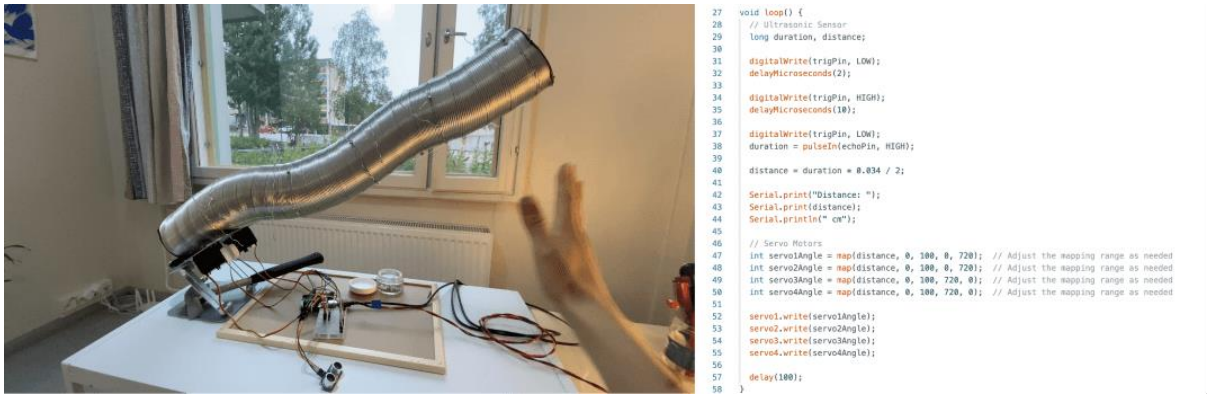


Fig 26. The tendon-controlling system applied on the pipe. Credit: Fangchen Dai, 2023.

As shown above, I use four self-made gear bearings cut from the lids of milk bottles to be screwed with the servo motors, which are placed in the proper positions on the foldable laptop stand to provide the traction force from the right direction. There are five rings made of sets of tangled small-gauge wavy steel wires each with three small round shims evenly attached on different positions and one pair of nuts to close the loop while staying flexible to adjust the tightness when the wires are put on the pipe.

On the pipe, I use fish wires to go through the round shims, and the ends of fish wires are coiled and fixed on the gears on the stand. As I learned from the online cases, I also adjusted the winding mode of the fish wires to make the movement more significant (servo 2 being the longest and its ending point is the farthest on the top; servo 1 being the second longest with ending point one segment shorter on the right side; servo 3 being the third longest and its ending point is on the opposite side than servo 1 with two segments shorter even; servo 4 being the shortest with the ending point on the bottom side with three segments even shorter which makes it only one segment away from the root). I also use different diameters of the fish wires, one is d0.25, and the other is d0.4. Apparently, d0.4 is thicker and provides stronger force than d0.25.



```
void loop() {
  // Ultrasonic Sensor
  long duration, distance;

  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);

  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);

  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);

  distance = duration * 0.034 / 2;

  Serial.print("Distance: ");
  Serial.print(distance);
  Serial.println(" cm");

  // Servo Motors
  int servo1Angle = map(distance, 0, 100, 0, 720);  // Adjust the mapping range as needed
  int servo2Angle = map(distance, 0, 100, 0, 720);  // Adjust the mapping range as needed
  int servo3Angle = map(distance, 0, 100, 720, 0);  // Adjust the mapping range as needed
  int servo4Angle = map(distance, 0, 100, 720, 0);  // Adjust the mapping range as needed

  servo1.write(servo1Angle);
  servo2.write(servo2Angle);
  servo3.write(servo3Angle);
  servo4.write(servo4Angle);

  delay(100);
}
```

Fig 27. The screenshot of the testing video and adjusted coding. Credit: Fangchen Dai, 2023.

There are three testing videos with different adjustments: https://youtu.be/CPMDGfogKYc, https://youtu.be/rgyU0XZ09HM, and https://youtu.be/xZwHoMeQpRk. However, I was still not satisfied with the intensity of the rotation of each section. In my reasoning, when I examined servo 1, I found the reason why there was still not enough torque might be that the thread on the servo was not connected perfectly to the tightest state when it was tensed at 0 degree. When it rotates from 0 to 180 degrees, it goes from half-tight to a loose state and then to half-tight again. As a result, it does not fully utilize the torque that can be provided by the servo. Adjustments were made accordingly on the coding, the angles, and the positions of the servos. Another problem was the rings on the pipe were not fixed tightly enough. So, I dug a hole for each ring for the thread to go through to fix the tendons better.

Besides, I found that the rotating angle is limited for the servo model MG995, while there is a way to modify the SG90 model to be continuously rotating. The SG90 is also quieter than the MG995 when operating. But later in the test using the modified SG90 servos with the continuous rotating ability, it turned out that I misunderstood the functionality of "continuous", by which I expected to rotate several rounds until I demanded it to stop and rotate backward to the original value, but the fact is that it can only rotate in the same direction non-stop. So, this modification turned out to be a dead-end.

Then, I was considering adding a two-section robotic arm as the base so that the whole thing can rotate horizontally with the first joint and "nod" up and down vertically with the second joint. By adding this base, the robotic arm theory can be combined with the tentacle tendon manipulation theory. Here comes another possibly hopeful direction which is to design a robotic arm with several joints, that are placed servos to change the direction of certain spots

on the exact place, instead of being manipulated from the far end as in the first method. The second method is also continued and tested further in prototype 2 with biological materials instead of the already-made pipe.

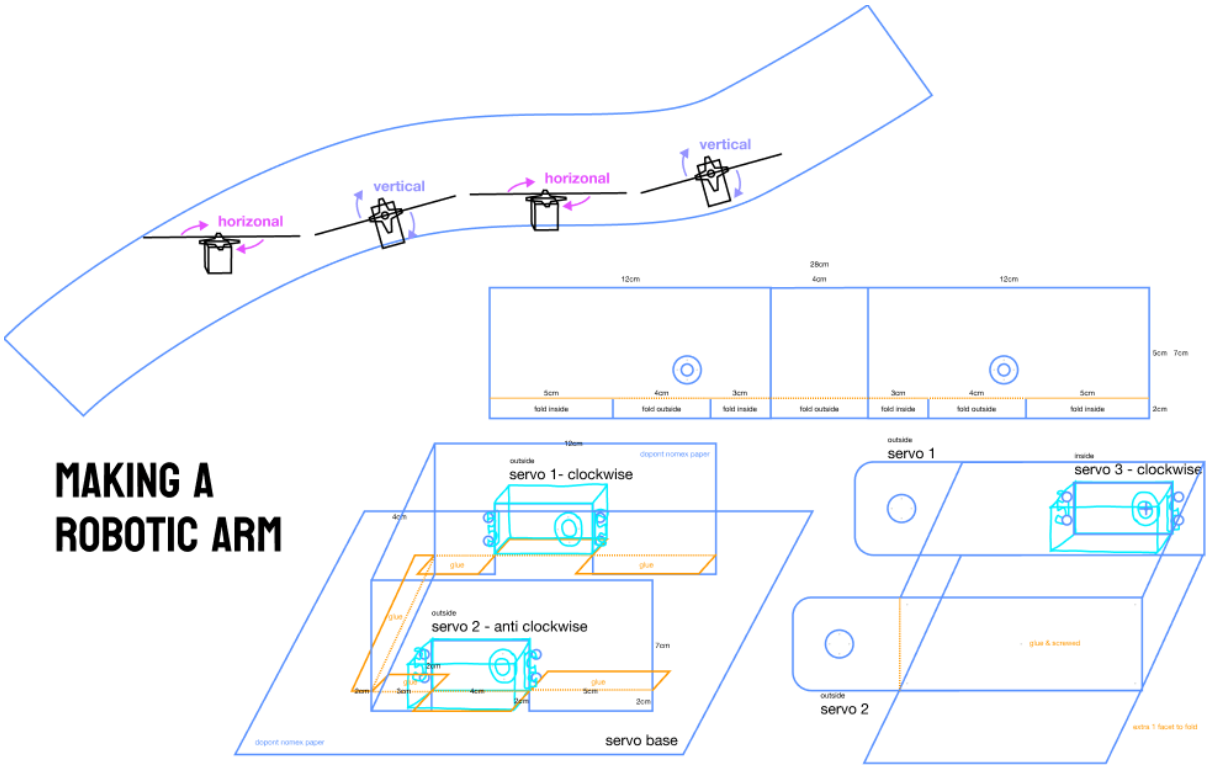


Fig 28. The initial illustration and the specific design of the robotic arm direction. Credit: Fangchen Dai, 2024.

I planned to use a specific type of paper to be the base material. I bought two sheets of the "Nomex Polyester Laminate Sheets, 900 x 200 x 0.46mm thickness" produced by Dupont. The reason I am using this type of paper is from the same consideration at the beginning of the design process to protect the device from fire that the material needs to be fire-retardant so that when it is near heat the whole thing would not be destroyed. However, I found another seemingly more suitable material called "porous vacuum silicon", which is perfect thermal insulation (one can put their hands closely on the other side with this cotton material of a fire whose temperature is up to 200°C) with a very thin layer of 0.6mm and softer to cut and utilize. I gave up getting it in the end since it was invented and only sold in China. So, I have to settle with the relatively old-fashioned Dupont paper. Anyway, it is only a prototype. But for more serious researchers, the premium material plays an important part.

```
void loop() {
  // Ultrasonic Sensor
  long duration, distance;

  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);

  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);

  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);

  distance = duration * 0.034 / 2;

  Serial.print("Distance: ");
  Serial.print(distance);
  Serial.println(" cm");

  // Servo Motors
  int servo1Angle = map(distance, 50, 200, 0, 720);
  int servo2Angle = map(distance, 20, 70, 360, 0);
  int servo3Angle = map(distance, 10, 60, 0, 360);
  int servo4Angle = map(distance, 0, 50, 0, 360);  /
  int servo5Angle = map(distance, 100, 200, 0, 180);

  servo1.write(servo1Angle);
  servo2.write(servo2Angle);
  servo3.write(servo3Angle);
  servo4.write(servo4Angle);
  servo5.write(servo5Angle);

  delay(500);
```

Fig 29. The screenshot from the testing video and the one with a base that can rotate. Credit: Fangchen Dai, 2023.

Prototype 1.3 is the final version of the first cycle of testing the first theory of the mechanism of an accordion pipe structure controlled by tendons and robotic arms. The video can be seen on: https://youtu.be/ol6vD7wYgUY. The reason that I wanted to change the direction from directly using an already-made industrial pipe is that it is inevitable for this structure to look like the male genital system, from which I can imagine some goofy smiles appeared on some people's faces and I hate this correlation and association because we already have enough worship for this in this male chauvinist world. This is totally my personal preference indeed, but since it is my project, I decided to call a stop to this direction.

4.3.2.2 Prototype 2 "Brandishing Branches"

– A branch-section spine connected by Jansen's linkages

In the previous data collection and theoretical preparation stage, one interesting project caught my attention, the Strandbeest project by Theo Jansen, whose work can be seen at https://www.youtube.com/@strandbeestfilm. In his project, Jansen invented a structure with 11 sticks of different measurements that can "walk" like a leg (Jansen, 2007, p. 53–57). This linkage is named after him. Based on this unit structure, he made a series of installations that can be triggered by mechanical controls, such as the Strandbeest which can be triggered by wind to walk on the beach along the seashore (Jansen, 2007, p. 83–91).

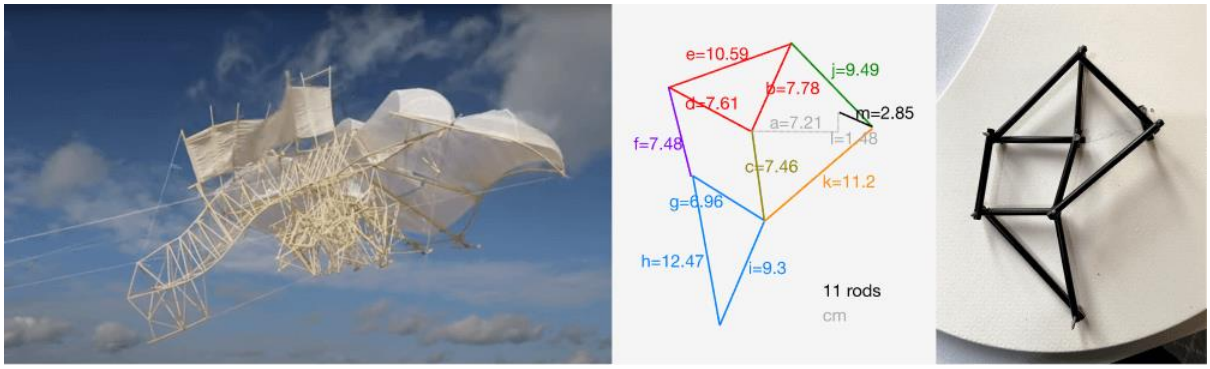


Fig 30. From left to right: The Strandbeest project of Jansen; the illustration of my calculation of the measurements of how to make rods from a plastic straw; the Jansen's linkage I made from plastic straws. Credits: the picture on the left is a screenshot taken from the YouTube video on https://www.youtube.com/watch?v=C97kMKwZ2-g&t=55s, 2022; the illustration in the middle is made by Fangchen Dai, 2024; the photo on the right is taken by Fangchen Dai, 2023.

After calculating the specs based on the material I have, I made several of Jansen's linkages myself. The sticks I use for composing the structure are a type of light but robust black plastic straw, which I bought from a local store at an affordable price. I tried to utilize this basic structure in my pipe idea. A first attempt failed with nails in wrapping the unit inside a semi-transparent soft silicon plate, which has a weak ability to fireproof.

Fig 31. From left to right: the failed first attempt; the second attempt to use branches and straws; the detail of the connection of the second attempt; the spine made of 4 branches and 4 joints. Credit: Fanghen Dai, 2023.

Then, a second idea came to me when I was walking in the woods. I picked up several wasted branches and brought them home. I made a spine with four branches connected by four basic units as the joints. So, the spine can change its posture by the rotation of each joint as shown in the demo video of manually rotating the joints: https://youtu.be/gdpSG0faKkg. The next step is to replace some parts in the manually rotated joints with servo motors, which can react to

the human approach and be controlled by the algorithm coded in Arduino.

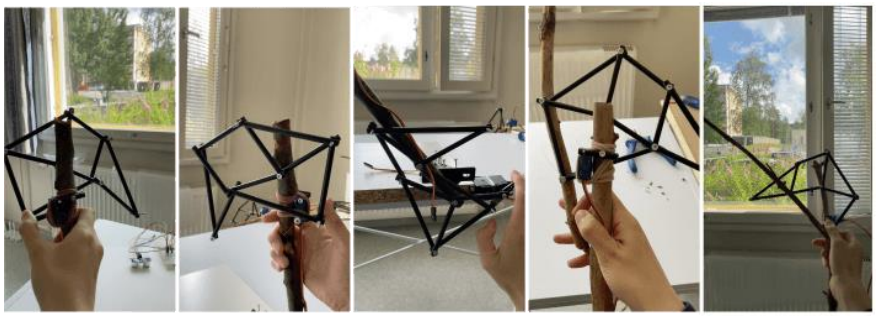
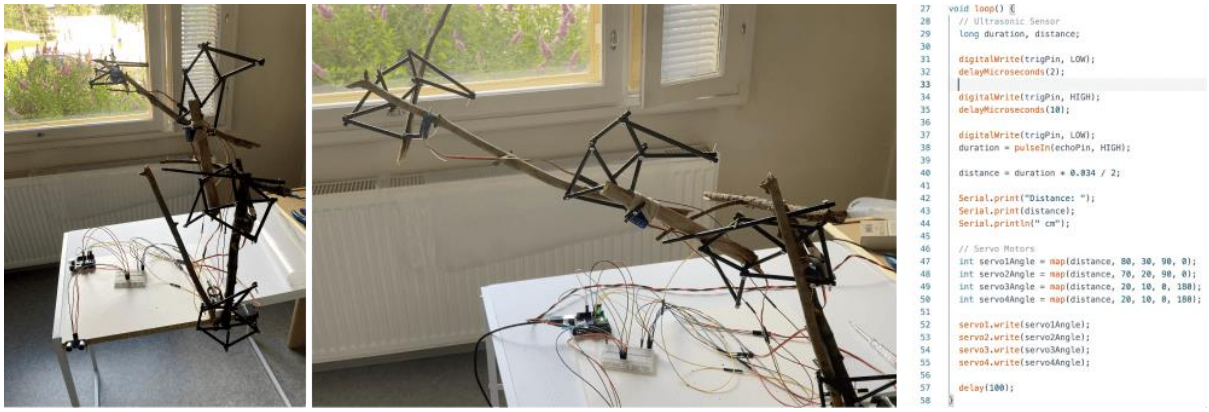


Fig 32. The rotating tests manually on each joint, where certain straws are replaced with servo motors. Credit: Fangchen Dai, 2023.

The videos of the rotating on each joint: https://youtube.com/shorts/SlR44aXIfDM, https://youtube.com/shorts/Z1ZOgzeSuR8, https://youtube.com/shorts/ZoLeNaA71WM, https://youtube.com/shorts/E7Jd7MpbhU0, https://youtube.com/shorts/d5gu5r1HPSQ. After replacing certain straws with several servo motors (four SG90s on the top and one MG996 on the bottom), theoretically, if the torque is enough, they should be able to rotate with the program like how they do now with hand.



```
void loop() {
  // Ultrasonic Sensor
  long duration, distance;

  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);

  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);

  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);

  distance = duration * 0.034 / 2;

  Serial.print("Distance: ");
  Serial.print(distance);
  Serial.println(" cm");

  // Servo Motors
  int servo1Angle = map(distance, 80, 30, 90, 0);
  int servo2Angle = map(distance, 70, 20, 90, 0);
  int servo3Angle = map(distance, 20, 10, 0, 180);
  int servo4Angle = map(distance, 20, 10, 0, 180);

  servo1.write(servo1Angle);
  servo2.write(servo2Angle);
  servo3.write(servo3Angle);
  servo4.write(servo4Angle);

  delay(100);
}
```

Fig 33. The testing of the connection of the Arduino controlling module on each joint and the coding. Credit: Fangchen Dai, 2023.

However, when I connected every wire of the servos with Arduino, only the top two were working: https://youtu.be/58hLlZU0-Mo, https://youtu.be/TSae1P4GxiA. The bottom one and the third one in the middle were not working. I speculate that the weight on the top is too heavy and the bottom ones could not move because there is not enough torque provided by the servo motors I used in this case. From this, I get the conclusion that the branch structure is too heavy, so the base servos could not pull the joints up except for the top two, which are much lighter.

There is also another issue since I was still using the modified servos, which could only rotate clockwise continuously instead of stopping at a certain point and going anti-clockwise, it made the reverse of the position impossible. In this case, the modified servos are not suitable anymore. I need to go back with the model within the 180-degree range type.

Besides, I should be more careful with the "+" and "–" connections because when I got them wrong, one SG90 burned and became useless. As a comparison, the MG995 stronger type must have some kind of error protection, so it was still working after I rectified the circuit connection.

Jensen's linkage is a good starting point and convenient to customize, although after replacing it with a servo, the proportion between each section is slightly different which makes the rotation less easy. The hair bonds used to softly attach the servos on the branch make the continuously rotating possible. Digging holes in damp branches is much easier than in dry ones, which is time-consuming and easy to get fingers injured.

It's a pity that the branch structure didn't work because I made a lot of effort to fix the position and adjust the servos to be compatible with the original static structure, but I guess with more powerful servos, it'll work eventually. Anyway, the movement is not as smooth as I imagined. It's not very precisely controlled – to stop at a specific position as I wish. It makes sudden movements and cannot stay in one position. Nevertheless, if to view from the coding only, one cannot foresee these real-world issues with the structure.

The next plan of improvement is to use only light material, such as plastic straws for the structure. The outer layer of the tube/pipe/tunnel should also be very light in weight. Thus, the silicon plate I tried before will also not be good enough because it is not light enough. I need new materials such as polyester or similar. But the semi-transparent visual effect is what I am satisfied with, so I am still going to stick with this effect, which makes the Dupont paper or the aerogel mat (another material I bought to test), not the premium choice.

4.3.2.3 Prototype 3 "A Tube with Two Arms"

– A scaffold structure with my own designed basic rotating unit

In the process of assembling a base for the new light structure, I accidentally discovered a direction-redirecting rotation unit. This rotating unit is made of four rods (plastic straws) and four pop rivets / blind rivets intersecting into each other in a way as shown below to support each other and still has the spare space for rotating when one specific rod is pulled up. The important thing for this structure is that the rod cannot be completely rigid but it must have a certain degree of flexibility for making the pivoting possible. See how it rotates from https://youtu.be/euBv5Q2Uzpc.

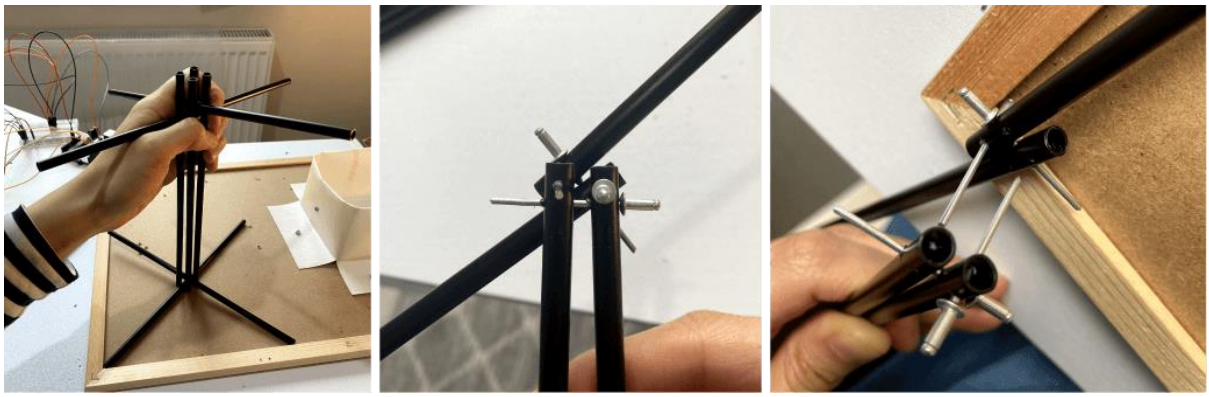


Fig 34. The accidental discovery of the rotating structure and the assembling of it. Credit: Fangchen Dai, 2023.

I made modeling of this structure in 3D software later for designing the tree structure in Prototype 4. But here, I am using this picture with four different colors of the rod to illustrate better how it rotates.

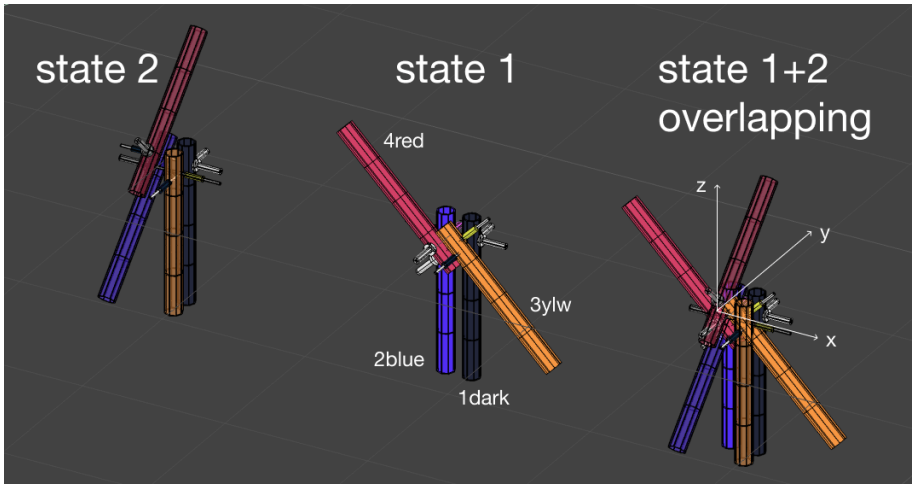


Fig 35. The 3D modeling of the rotating structure and the two states of it. Credit: Fangchen Dai, 2024.

The dark rod, “1dark”, is not moving at all during the whole change. The “2blue” rod is the

trigger rod, which will be picked up from -z(0°) in state 1, the default state to -z(45°)-y in state 2, the rotated state. The yellow rod, “3ylw”, accordingly, will change from x(45°)-z in state 1 to -z(0°) in state 2. And the fourth rod, the red rod “4red”, which I name as the “pointing rod” rotates from z(45°)-x to z(45°)y.

I am using my own 3D location expression if anyone wonders what the figures mean. It is for my own convenience, but in order to make others understand, I will explain it a little bit. Every axis has two directions, positive and negative. Positive has no mark before the axis name, while negative with a “-” before. If the rod is in a direct direction, such as x, -y, -z, it is followed by a (0). If it has an angle, then it ends with an additional axis with the direction mark, which combined with the previous two information can express the plane and the angle it is in.

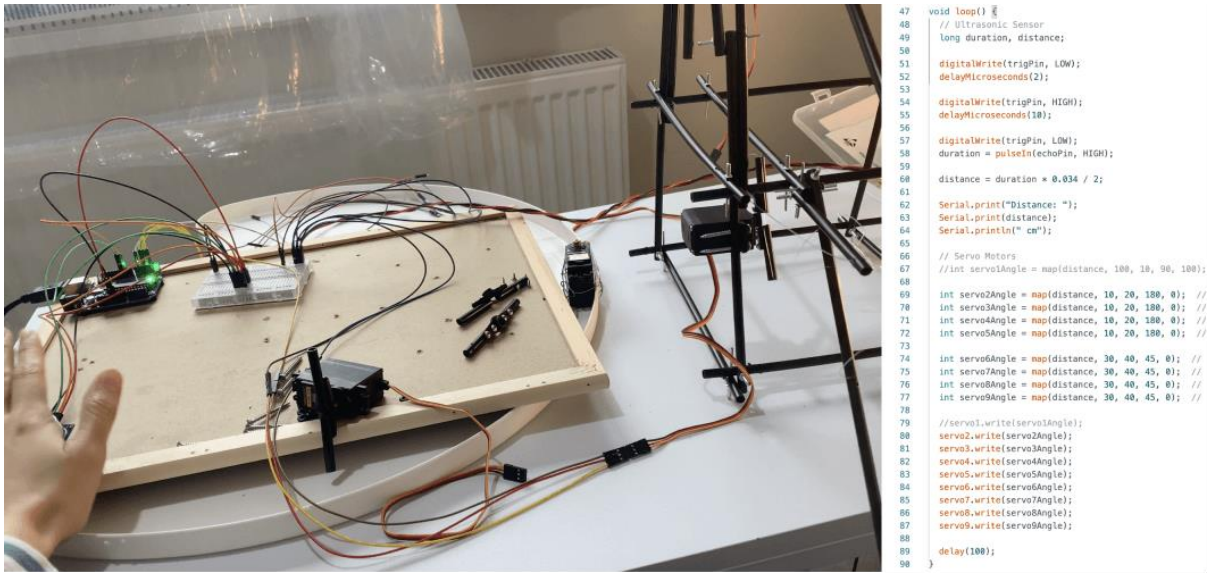
This system is useful when the starting points of all rods are in the same place, traditionally marked in the 3D axis system as (0, 0, 0). Apart from the numerics, the interesting thing about this rotation structure is that the red rod can change to a different plane, which makes it in 3D dimension, although the angle is fixed with a constant 45°. Currently, I do not know what other applications can be used, but I am going to use them in my research in this project.

Fig 36. The process of putting up the scaffold with my own basic unit and the plastic bags. Credit: Fangchen Dai, 2023.

The video of rotating two units by hand: https://youtube.com/shorts/GVzdlbThzgM. The display of one side formed by four units: https://youtu.be/i7dq9iiByqU. The video of rotating the joints of a completed scaffold by hand: https://youtu.be/zaKNoZtgb34. The video of

rotating after cutting the bottom legs: https://youtube.com/shorts/MpLYcAatjks. The video of rotating after putting on the plastic bags: https://youtube.com/shorts/rf48zHFafqg.

In this version, I use the basic rotating unit to make a multi-layer scaffold structure with plastic bags to demonstrate the outer shell of the pipe. After assembling the static scaffold, I start to put on the servo motors so that they can interact with humans. The servos in use on the top horizontal layer are SG90, and the ones on the vertical side are MG996R, which I finally got by post. This model is stronger than MG995 and has smoother rotation with fewer noises when operating, which can be observed clearly in the test videos. For the base, I have to choose between whether to make it be able to rotate. It is possible to rotate if to use an MG996R servo motor and I did test this idea, but in the end, I gave up on a rotating base because it seems to be a little bit hard to control and "messy" when all the other servos on the shelf are rotating together.



```
void loop() {
  // Ultrasonic Sensor
  long duration, distance;

  digitalWrite(trigPin, LOW);
  delayMicroseconds(2);

  digitalWrite(trigPin, HIGH);
  delayMicroseconds(10);

  digitalWrite(trigPin, LOW);
  duration = pulseIn(echoPin, HIGH);

  distance = duration * 0.034 / 2;

  Serial.print("Distance: ");
  Serial.print(distance);
  Serial.println(" cm");

  // Servo Motors
  //int servo1Angle = map(distance, 100, 10, 90, 100);

  int servo2Angle = map(distance, 10, 20, 180, 0);  //
  int servo3Angle = map(distance, 10, 20, 180, 0);  //
  int servo4Angle = map(distance, 10, 20, 180, 0);  //
  int servo5Angle = map(distance, 10, 20, 180, 0);  //

  int servo6Angle = map(distance, 30, 40, 45, 0);  //
  int servo7Angle = map(distance, 30, 40, 45, 0);  //
  int servo8Angle = map(distance, 30, 40, 45, 0);  //
  int servo9Angle = map(distance, 30, 40, 45, 0);  //

  //servo1.write(servo1Angle);
  servo2.write(servo2Angle);
  servo3.write(servo3Angle);
  servo4.write(servo4Angle);
  servo5.write(servo5Angle);
  servo6.write(servo6Angle);
  servo7.write(servo7Angle);
  servo8.write(servo8Angle);
  servo9.write(servo9Angle);

  delay(100);
}
```

Fig 37. Putting the servo motors on the scaffold to make it interactive and the screenshot of the coding. Credit: Fangchen Dai, 2023.

The video of testing the distance sensor (HC-SR04) with an SG90 servo motor on the scaffold structure: https://youtube.com/shorts/qoc06YxyrHM. The video of testing the sensor with one MG996R servo motor: https://youtu.be/1KmZNHZbHZQ. The video of making the base rotatable: https://youtu.be/MNTCoiLCA9k. The video of a rotating base with plastic bags on the shelf: https://youtu.be/gvgMO9QCQpY.

Feedback from the data collection stage suggests that if there was light, the whole atmosphere would be better. As a result, I took this advice and tried to add some LEDs to the structure. I use two sets of LEDs to match with the two different sets of servo motors, so when each set is triggered, the LEDs of this set will be lit at the same time (as an indicator as well). The materials for each set of LEDs are one LED and a bundle of four long optic fibers to make the light scatter.

```
digitalWrite(trigPin, LOW);
delayMicroseconds(2);

digitalWrite(trigPin, HIGH);
delayMicroseconds(10);

digitalWrite(trigPin, LOW);
duration = pulseIn(echoPin, HIGH);

distance = duration * 0.034 / 2;

Serial.print("Distance: ");
Serial.print(distance);
Serial.println(" cm");

// LEDs
if (distance > 10 && distance < 20) {
  digitalWrite(LED1Pin, HIGH); // Turn on LED1
} else {
  digitalWrite(LED1Pin, LOW); // Turn off LED1
}

if (distance > 30 && distance < 40) {
  digitalWrite(LED2Pin, HIGH); // Turn on LED2
} else {
  digitalWrite(LED2Pin, LOW); // Turn off LED2
}

// Servo Motors
int servo2Angle = map(distance, 0, 30, 180, 0);
int servo3Angle = map(distance, 0, 30, 180, 0);
int servo4Angle = map(distance, 0, 30, 180, 0);
int servo5Angle = map(distance, 0, 30, 180, 0);

int servo6Angle = map(distance, 40, 70, 45, 0);
int servo7Angle = map(distance, 40, 70, 45, 0);
int servo8Angle = map(distance, 40, 70, 45, 0);
int servo9Angle = map(distance, 40, 70, 45, 0);
```

Fig 38. Adding two sets of LEDs with the two sets of servos and the coding. Credit: Fangchen Dai, 2023.

The video of testing with the pipe outer layer: https://youtu.be/iUsc6TqUzoY. The test video with the LEDs in the dark: https://youtu.be/BAEkQAnwzNs. The Prototype 3 went into a pause for the time being. One feedback I got when I demonstrated this to a small group of people in the university is that “it looks a little bit shaky”. I also felt the same way.

The way I built Prototype 1 to 3 is “from bottom to top”, which means that I did not plan everything carefully in advance but went where it took me when I put things together and adjusted with reflection in the process freely. The benefit of this free-willing process of making is that I do not confine myself to the uncertainty, which also provides possibility. I consider it a good way of learning by making in a hands-on way, especially when I do not possess many skills and knowledge in the area. After I go through three cycles of iteration, the final delivery will be designed from top to bottom.

4.4 Phase 4 “Deliver”

I make a plan for the final delivery of the rotating structure. First, I set up the code because all the functions needed are clear. Second, I make a 3D model in the 3D software, Cinema 4D (my personal preference) to design the structure before actually drilling straws to form the pipe structure. Third, I make the structure according to the digital design. Fourth, I draw an illustration of how everything functions for the exhibition (see Appendix E).

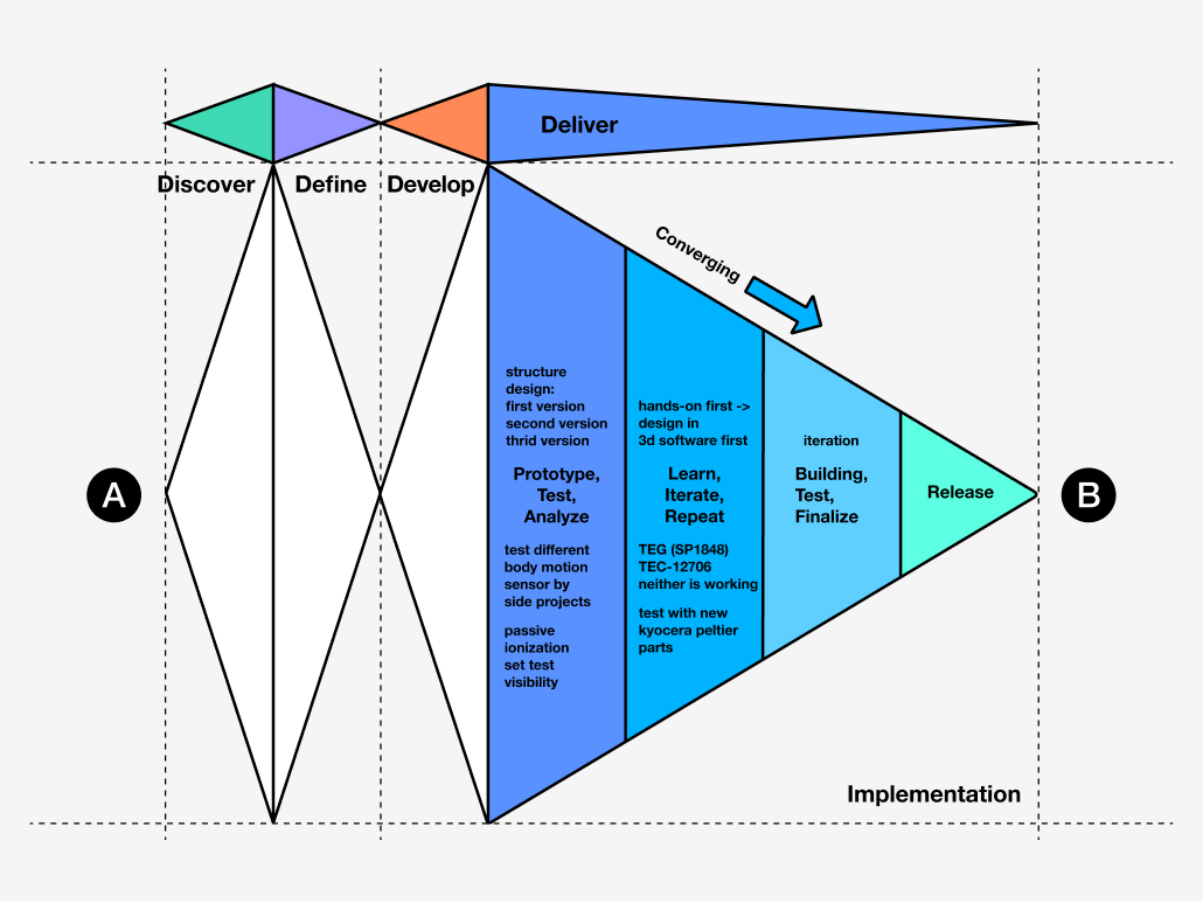


Fig 39. The Deliver phase in the double diamond design process applied to my research data. Credit: Fangchen Dai, 2023.

4.4.1 The final rotating structure – “Wiggly Tree Tip”

From the previous prototypes, I find that it is more difficult to control too many servo motors. I decided to simplify the structure even further to only use one servo, which would consume less electricity as well.

Step 1. The code prepared for the final product is shown as follows:

```
#include <Servo.h>

const int trigPin = 8;
const int echoPin = 9;
const int LEDPin = 7;
const int servoPin = 3;

Servo servo;

void setup() {
pinMode(trigPin, OUTPUT);
pinMode(echoPin, INPUT);
pinMode(LEDPin, OUTPUT);

servo.attach(servoPin);

Serial.begin(9600);
}

void loop() {
// Ultrasonic Sensor
long duration, distance;
digitalWrite(trigPin, LOW);
delayMicroseconds(2);
digitalWrite(trigPin, HIGH);
delayMicroseconds(10);
digitalWrite(trigPin, LOW);
duration = pulseIn(echoPin, HIGH);
distance = duration * 0.034 / 2;
Serial.print("Distance: ");
Serial.print(distance);
Serial.println(" cm");

// LED
if (distance > 20 && distance < 80) {
digitalWrite(LEDPin, HIGH); // Turn on LED
```

```
} else {
digitalWrite(LEDPin, LOW); // Turn off LED
}

// Servo Motor
int servoAngle = map(distance, 20, 80, 0, 90); // Adjust the mapping range as needed
servo.write(servoAngle);
delay(1000);
}
```

Step 2. The 3D model designed digitally can be seen at https://youtu.be/rtak8goRI6A. It starts by enumerating the possible combination of the states of the knots on the joints:

Knots							
1.1				**1.2**			
1–1				1–2			
2.1	**2.2**			**2.3**	**2.4**		
1–1	1–1			1–2	1–2		
2–1	2–2			2–2	2–1		
3.1	**3.2**	**3.3**		**3.4**	**3.5**	**3.6**	
1–1	1–1	1–1		1–2	1–2	1–2	
2–1	2–1	2–2		2–2	2–2	2–1	
3–1	3–2	3–2		3–2	3–1	3–1	
4.1	**4.2**	**4.3**	**4.4**	**4.5**	**4.6**	**4.7**	**4.8**
1–1	1–1	1–1	1–1	1–2	1–2	1–2	1–2
2–1	2–1	2–1	2–2	2–2	2–2	2–2	2–1
3–1	3–1	3–2	3–2	3–2	3–2	3–1	3–1
4–1	4–2	4–2	4–2	4–2	4–1	4–1	4–1

Fig 40. The enumerating of the states of the knots. Credit: Fangchen Dai, 2024.

The number indicates the principle that the end of the joint activates the whole set, meaning it is the first to change, and then the next one to it will change. It feels a bit like after being "affected" or "contaminated", a pile of cards is "flipped". One knot in the middle cannot start the rotating process, only the end one can because it is the nearest to human and detects first.

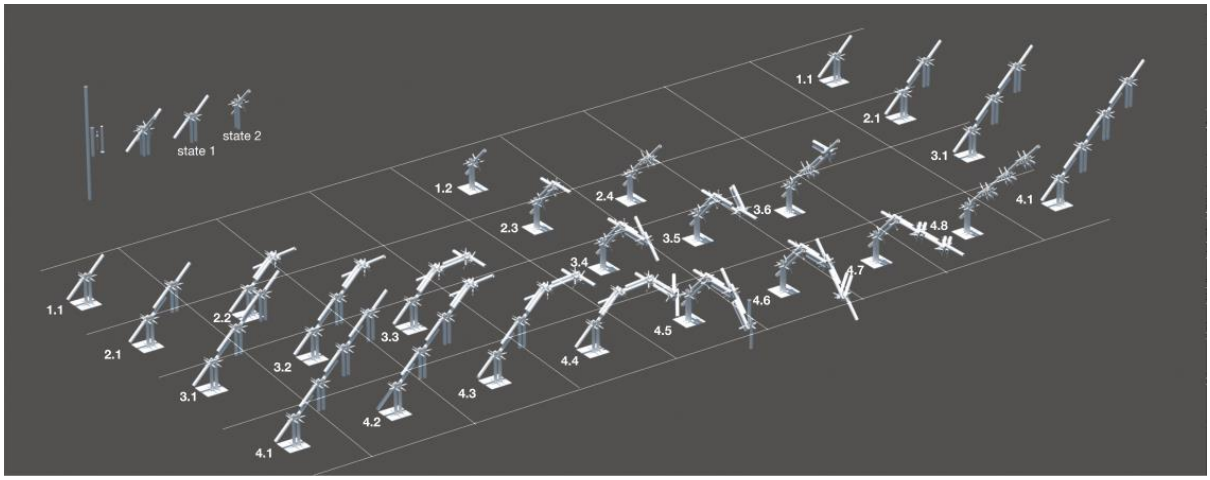


Fig 41. The combination of the knots' states visualized digitally corresponding the enumeration. Credit: Fangchen Dai, 2024.

Step 3. Assembling the structure based on the digital model:

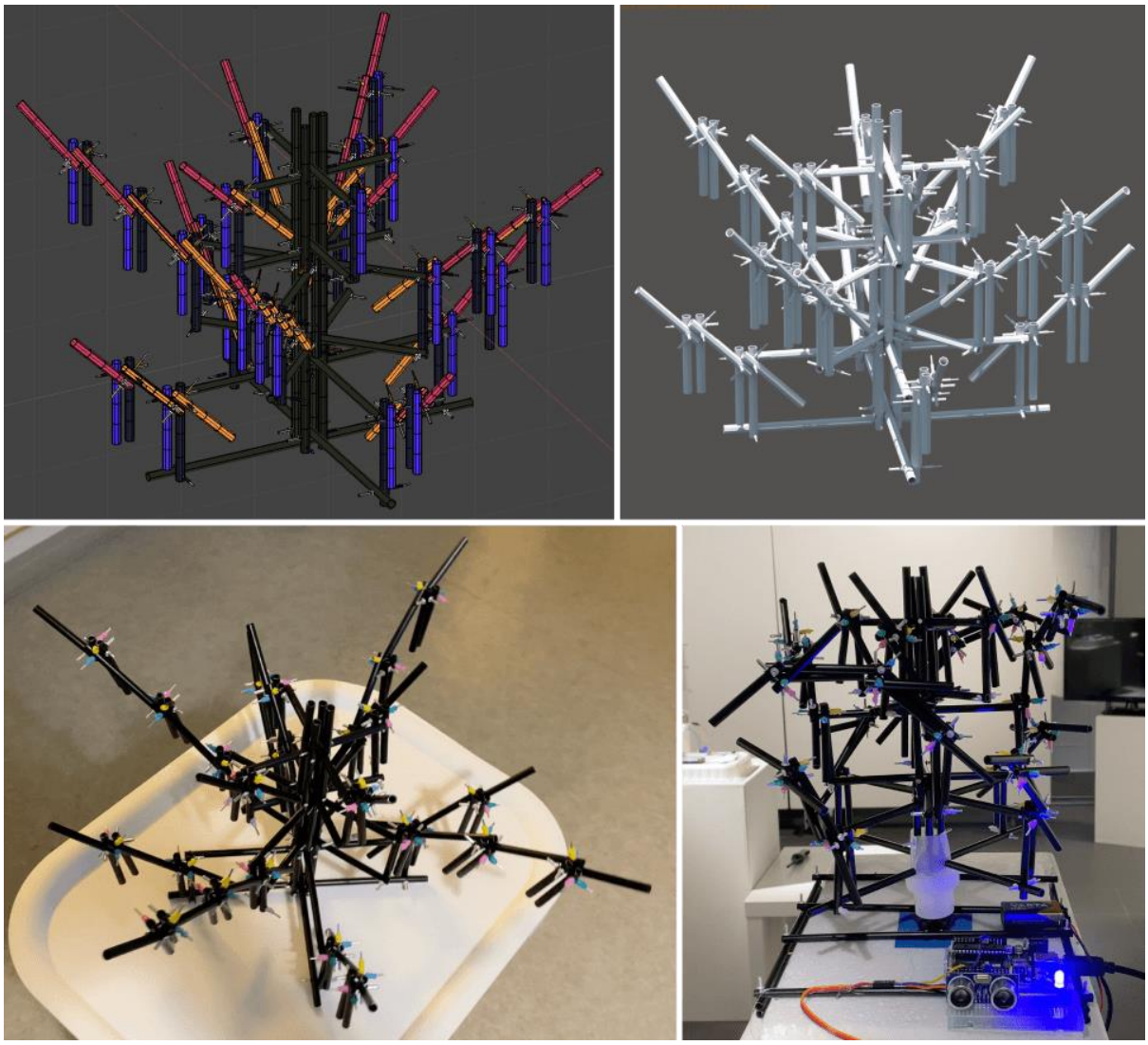


Fig 42. Top two: the digital modeling and rendering of the tree tip structure. Bottom two: the

actual realization of the two states. Credit: Fangchen Dai, 2024.

The measurements in the 3D software are accurate so that the figures can be used in real making for higher precision. However, in the execution, the final assembly will never look as perfect as the digital model because my handmade skill is rather amateur, and adjustments are always needed. For example, the original plan was to make a four-layer structure with as many as four joints the most in one branch, but in reality, I had to delete one layer to make it easier to control.

Although theoretically the possible states can be many, in the real making, I did not manage to manipulate the rotation of every joint, instead only the center of the bottom is installed a servo motor (MG996R) to rotate the whole thing at once. If people are within the range of 20~80 cm of the device, the blue LED will be triggered to light and the structure will start to rotate. The rotating angle is also mapped from 0 to 90 degrees according to the distance value of 20~80 cm. The interaction of the “Wiggly Tree Tip” can be found in the recording video of the exhibition among other interactions: https://youtu.be/covKTLkLcdA.

4.4.2 Trials to power the processor (Arduino) from fire

I was obsessed with the idea of getting rid of all the traditional electricity supplies from cable and from batteries when I got to know the theory of the thermoelectric effect. I was hoping to use only the temperature difference from the fire in the stove to power all the components that need electricity. Thus, I made many models and did a lot of tests to see if I could make it happen.

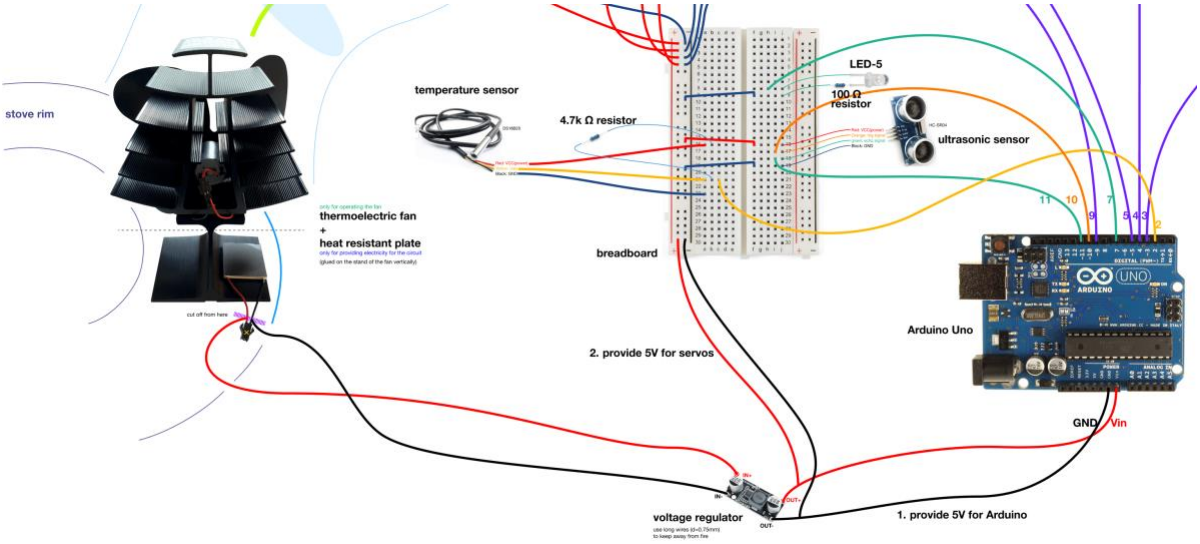


Fig 43. The original plan of how to get electricity from a stove. Credit: Fangchen Dai, 2023.

Ideally in the original plan, there would be two circuits of electricity provided from the thermoelectric components: one to power the Arduino Uno board, and the other to power the servos. The generation of electricity is realized by a stove fan which I bought from the local store whose original usage was to spread the heat from a fireplace chimney in houses by a fan, a heat sink (the top metal "leaves" on both sides), and a TEG (thermoelectric generator) plate installed between the top part and the base which absorbs the heat from the hot side of a chimney or other heated pipes.

I assumed that if the electricity generated from the TEG part could power the motors of the fan, then I could use another TEG installed beside it in the same structure to generate electricity for the Arduino module so that I do not need to make my own structure, which seemed very convenient and efficient. So, I dismantled the stove fan and planned to add two more thermoelectric parts to it.

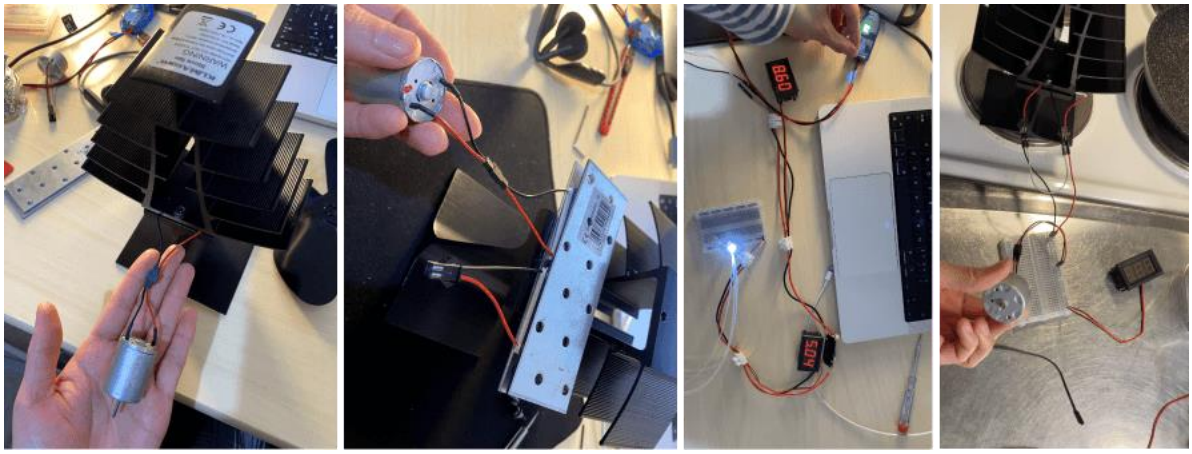


Fig 44. Dismantling the stove fan to add more TEGs, testing a regulator circuit to read the before and after voltage values, and testing the modified stove fan circuit on the electric stove in the kitchen. Credit: Fangchen Dai, 2024.

Then I assembled a line to connect the TEGs and the circuit with two voltmeters, one before a voltage regulator and one after to display the voltage values. The voltage regulator functions to make the voltage steady. Based on the feedback of the technical part I gathered in the pre-stage, I bought a step-down regulator, which reduces the voltage from an adjustable range of 2~60V to a range of 2-34V. In my case, the input volt value can be various, but the output value needed is a steady 5V, which is the minimum volt needed by the Arduino Uno processor to operate.

Normally, one does not need to pay too much attention to the ampere value because Arduino only draws 50-60 mA (milliamps). Thus, I was focusing on getting a steady 5V first. The video https://youtu.be/MXSsrmQOMj8 demonstrates how the voltage is decreased by a regulator. The light indicates that the line is working.

Then, I tested it on one electric stove in my kitchen https://youtu.be/ItSJmoP7MvE to see whether the TEGs in the modified stove fan circuit could provide enough 5V. The result is that one TEG on the stove in the fan structure cannot provide enough voltage to make the circuit work; two TEGs together can only generate about 1.2V, tested by a multimeter. Although the brushless motor separated from the stove fan is working, the LED is not lit up, and the voltmeter is not showing any figures.

The reason for this is that the motor can work under a very small current which does not need

to be steady even, but the LED and voltmeter cannot. The way I can think of improving is to use more TEGs (at least eight in series connection) and to design my own structure using a more efficient heat sink to cool down the hot side and an aluminum plate to transfer the heat better. I started to make different self-made structures to try to get as high voltage as I could on different sources of heat.

Fig 45. The tests to get a steady 5V from different structures. Credit: Fangchen Dai, 2024.

The first photo from the video https://youtube.com/shorts/4x4PqkGvyGg shows that with one bottle of candle, three TEG parts, and a steel bottle, the max voltage can reach 0.2~0.3V. The second https://youtu.be/a-R27jxTZqs shows that with the TEGs glued with thermal paste and the electric stove being the heat source, the max voltage can reach 2~3V. The third https://youtube.com/shorts/4JvkLY-5anE shows that with ten small candles, three TEG parts, two heat sinks, and an ice cube, the maximum voltage can reach 2.2V. The fourth https://youtu.be/62uR_ROACeY shows that with ten taller candles with my self-made fan ventilator shelf and two heat sinks with an ice cube, the max volt can reach 3.2V.

Apparently, the heat difference provided by the burning of the candles and the ice melting working on three TEG parts, SG-HOT 40*40mm with a maximum temperature resistance of 200°C, in series connection cannot provide enough voltage I need, no matter what extra components I add to work with them. There are several reasons and resolutions that I can think up of, not enough TEG parts (buy more parts or change part model), hot side not hot enough (change candles type), cool side not cool enough (change heat sink model), not enough temperature difference (use a fan to ventilate the air to take away heated air and bring cool fresh air and improve the structure by using a semi-concealed tunnel), etc. Besides, the indoor and outdoor settings can influence the result. At the time, I was testing it first indoors. So, I improve the module one by one to see if anything helps.

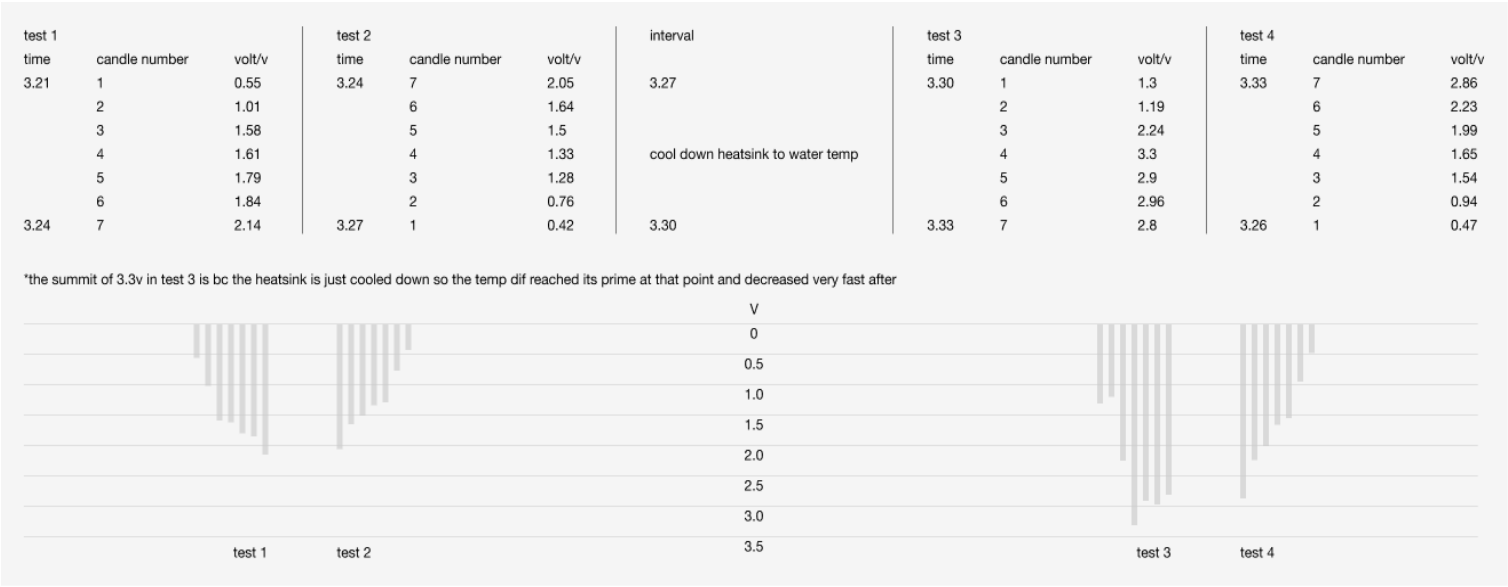
After several other failures for getting a higher voltage by changing the structure, I finally got a max volt of 5.6V (see https://youtu.be/M5nKaZt8ZSA, the last two photos in Fig. 45) with one structure and more new parts (model: TEC-12706SR) but it is not steady enough as a power supplier because the ice melting destroys the Peltier circuit easily by leaking water on it.

The best result I can get from all the improved structures with shields to form a tunnel for the air to flow is a voltage of around 5.6V, but it is not stable. It is only a summit value that can only last a short period. One big issue is that the two sides of the Peltier parts are too close, so when the underside is heated, the temperature of the top side will rise very quickly. As a result, the difference in temperature decreases along with time.

Even within the short period of getting the highest voltage, another problem occurs when two voltmeters are used to display the volt figure before and after the step-down regulator, the first meter only shows 4.07V while the second nothing: https://youtu.be/_0cG2Neescs. The reason is that the voltage regulator consumes 1V itself, so the before meter shows 5–1=4V. Although the LED is lit, which means that the circuit is working well, there is not enough voltage for the after meter to display anymore.

The conclusion is that the voltage generated should exceed at least 6V to provide sufficient input if I am to use a step-down regulator. I decided to use the voltmeters only when testing the regulator circuit from a laptop power supply, so it can still work as the indicator of the line but not be used in the circuit with the heat so that it will not take up voltage consumption.

In order to get a clearer idea of the relation between the number of TE parts in use and the voltage generated, I experimented using the structure that was the most efficient at the moment. After analyzing the data above, it is clear to see the increasing and decreasing of the voltage from the visualization.



test 1			test 2			interval	test 3			test 4		
time	candle number	volt/v	time	candle number	volt/v		time	candle number	volt/v	time	candle number	volt/v
3.21	1	0.55	3.24	7	2.05	3.27	3.30	1	1.3	3.33	7	2.86
	2	1.01		6	1.64			2	1.19		6	2.23
	3	1.58		5	1.5			3	2.24		5	1.99
	4	1.61		4	1.33	cool down heatsink to water temp		4	3.3		4	1.65
	5	1.79		3	1.28			5	2.9		3	1.54
	6	1.84		2	0.76			6	2.96		2	0.94
3.24	7	2.14	3.27	1	0.42	3.30	3.33	7	2.8	3.26	1	0.47

*the summit of 3.3v in test 3 is bc the heatsink is just cooled down so the temp dif reached its prime at that point and decreased very fast after

Fig 46. The experiment on figuring out the relation between the number of the TE parts in use and the voltage. Credit: Fangchen Dai, 2024.

The voltage is very sensitive and changes very fast, which makes it very unstable in this case with 3 TEGs and 4 TECs at the room temperature of 22°C and with 6 to 8 candles. No matter how I tried, it's very hard to get a voltage over 3V. Not to mention if to test outdoors, the value could be even unstable as I imagined.

It occurs to me that maybe I should use only TEG (thermoelectric generator) parts, leaving all the TEC (thermoelectric cooler) parts out because the latter's main function is to cool components when supplied with electricity. The structure of the heat sink also seems to be not efficient enough, so maybe I should also buy new ones with better heat dissipation ability.

However, the most important improvement is that I change my mind about using a step-down voltage regulator if the voltage I can get is very minimal. I should use a step-up boost instead. I found that a 0.9~5V to 5V or a 2~24V to 5~28V might be the best choice to work together as a combination in one circuit. The former boost makes sure to get a 5V from a tiny current with less than 1V and the latter boosts the 5V from the previous one to a higher 9V, which is higher than the required 5V by the Arduino Uno board but ensures extra consumption with other components such as sensors and servo motors. This theory is to be tested.

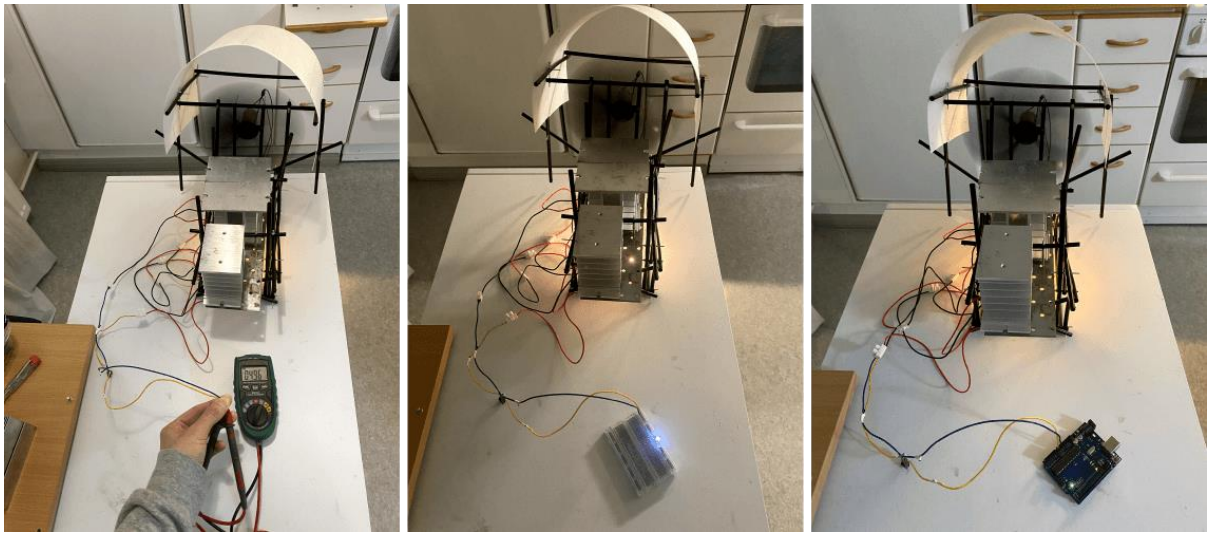


Fig 47. The tests with new heat sinks, step-up voltage boost with voltmeters, LEDs on breadboard, and Arduino. Credit: Fangchen Dai, 2024.

After using one step-up voltage boost (lifts from 0.9~5V to 5V), the voltage reaches 4.96V steadily and it can light up the LEDs on the breadboard and the Arduino Uno board. Although the green light indicates the "power is on" of Arduino, it is still not able to make the coding run. Thus, I need to figure out why. So, I made other tests on how much electricity Arduino Uno needs.

Testing how much it needs to light up Arduino: https://youtu.be/bqM5ebyDBOA. The video is not very clear with the lights interfering with each other, but the minimum voltage to light up Arduino is 3V, and when it reaches 4V the orange signal LED flashes. According to another test, it is also possible to power Arduino with one AAA battery (1.5V) by using one step-up boost.

While with two boosts in series connection in one line, the voltage fluctuates from 5.2V to 5.7V: https://youtu.be/DboV0Cd94f8, and it can light up LEDs with no doubt: https://youtube.com/shorts/tjI1UmcBjAM, and also with the Arduino Uno board: https://youtu.be/QRvPfiSd2P0. In the test, the orange light flashed for once in the beginning and went out immediately. In my guess, the reason might be the voltage is not steady from the two step-ups circuit and it is not enough although quite close (4.96V) to the one step-up boost circuit. So, I bought another step-up, which can lift from 2~24V to 5~28V and I plan to use it after one 0.9~5V to 5V step-up and set the output value to 9V (which I found out later is wrong).

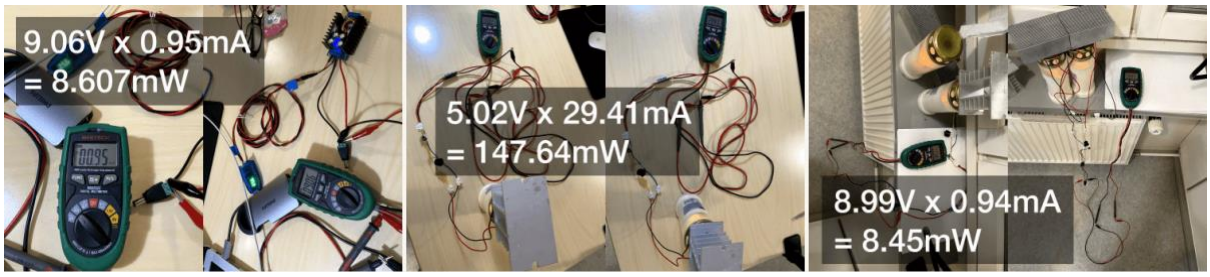


Fig 48. Calculating the power (P) of three circuits, in which the voltage values are boosted differently by different components. Credit: Fangchen Dai, 2024.

At this point, it occurs to me that maybe there is another reason – maybe the ampere is not enough. So, I started to find ways to increase the current value by buying new thermoelectric modules (Kyocera Thermoelectric Heating Cooling Module #12016896A). I even went in the wrong direction of making a circuit to boost the voltage first and then convert the voltage to current by a DC Adjustable 0.2-9A 300w Step Down Buck Converter 5-40V to 1.2-35V Power Supply Module LED Driver 300w XL4016. The mistake I made is that I forgot the principle of conservation of energy which I learned in middle school, which means that in a given circuit the power (P) = voltage (V) × current (I) is constant. If I increase the voltage, the current will inevitably decrease.

In a circuit powered by only some candles using thermoelectricity, the P value is quite small as calculated in Fig. 48. The more voltage lifted, the more consumption of the original power, and the smaller the output P value will be. Reluctantly, I had to give up on using the thermoelectricity to power the Arduino to manipulate the mechanism.

However, it is always possible to make a brushless motor operate as it is already widely used and tested commercially in the market, which I can utilize to make my structure rotate. In this way, I will be able to bypass the control by the Arduino module. This is a part that I have to compromise with, although my initial idea is to completely leave batteries out. I still have to use batteries or cables to power Arduino directly.

4.4.3 A negative ionizer to detect the human body without a processor

The purifying function is realized by a negative ionizer. I made the first prototype to test with

a cigarette to see whether it can be observed by the naked eye without qualitative equipment to measure because I do not have any and this research is not a strictly scientific one.

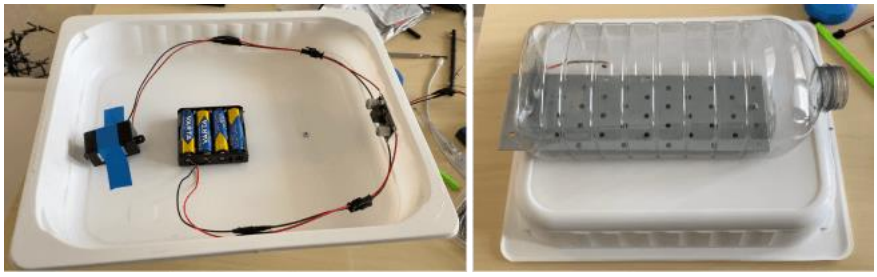


Fig 49. The first prototype of the ionizer. Credit: Fangchen Dai, 2024.

I used a chicken legs package to be the base of the device. In the first prototype, the ionizer, the 5V regulator, the battery set of 4 AAs, and the wires are all hidden inside the box, while there is only the sealed space provided by a softener bottle on the outside top layer with a steel plate to collect the particles. The emitting end of the ionizer comes through a small hole in the box.

Fig 50. The test of the ionizer to purify the smoke from a cigarette. Credit: Fangchen Dai, 2024.

A cigarette is put inside the bottle to test the purifying ability of the ionizer: https://youtu.be/4s0xB0Sv01c. It is obvious to see that the air near the tip of the emitter is cleaner than the part near the cigarette. The test did not last long, so the collected particles were not accumulated enough for further testing and usage.

Then, I added a microwave sensor RCWL-0516 with an LED as the indicator and put everything outside for the exhibition so that it is more obvious to see the components and the connections. The motion detection of the human body is realized without a processor such as

Arduino in this case (see Appendix F).

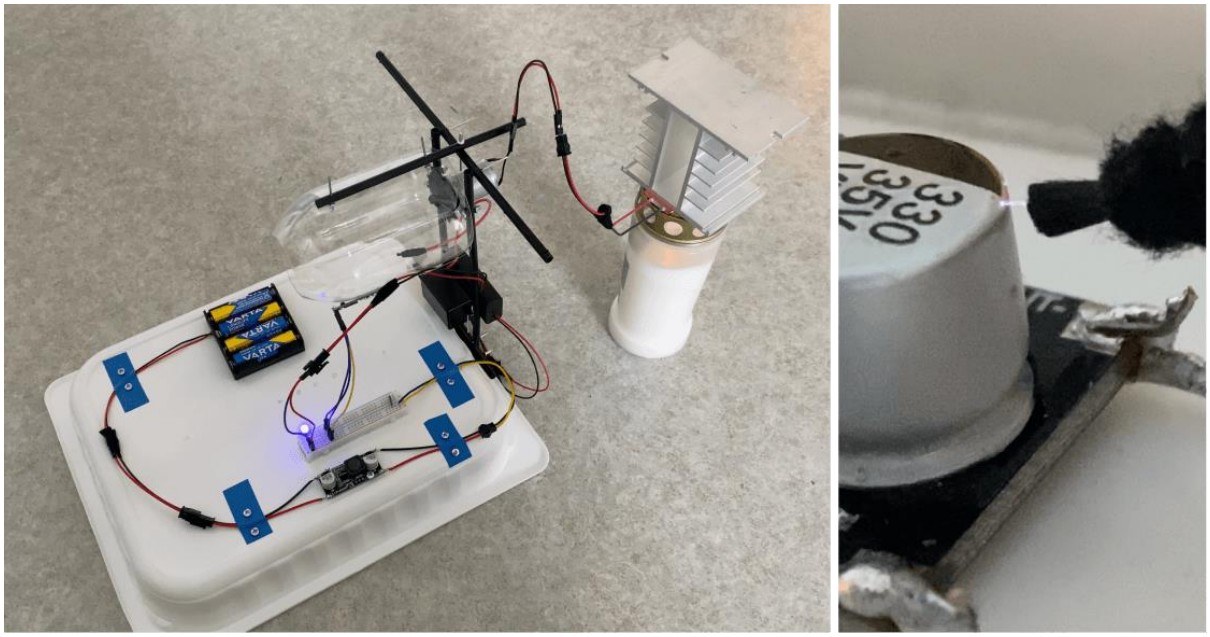


Fig 51. The negative ionizer with the ability to detect the human body without a processor and the ion beam captured. Credit: Fangchen Dai, 2024.

Apart from the thermoelectric power supply via the Kyocera Thermoelectric Heating Cooling Module #12016896A, there is also an alternative 1.5V battery supply for the safety of display indoors. Although there are millions of ions emitted from the tip per second, it is not seen with the naked eye normally. However, if the tip is placed really near the regulator, beams of ions become visible and hearable when they hit the surface of the energized electronic component, accompanied by shiny dots also sometimes: https://youtu.be/S8YJ2-kyrro. I find it quite fascinating to be able to observe a scientific phenomenon like this.

5. REFLECTIONS AND VISIONS

5.1 The Testing Session in a Laavu and Reflection

A data collection of the testing of the Wiggly Tree Tip and the negative ionizer within a small group is conducted on April 17, 2024, in a laavu in Rovaniemi. Native Finnish and international students are included in the participants. Besides, I also have some thoughts from my own observations and experiences. The analysis is conducted in a self-reflective way.

Fig 52. The testing of the two interactive devices in a laavu. Credit: the left photo is taken by Chia-Chen Chang, 2024; the right one is taken by Fangchen Dai, 2024.

For the negative ionizer, participants in the laavu testing session suggested that it would be better to have a structure to hook up onto the pole next to the barbecuing shelf because the current structure cannot be placed near the pollutant center, the fire in the stove. I agree and I did research using the fire-retardant paint on the bottom of the device at the very beginning of the study. Somehow as the research going, I forgot about it completely until this actual installation in a real laavu. The structure now is designed most suitable for the exhibition. However, if I were given more time to continue in the future, improvement for fireproofing would definitely be considered and solved as the first thing.

As for myself, I felt that after I got home from the laavu, the smell of smoke seemed to not linger for that long time and the smell did not bother me that much anymore. Maybe it is due to the placebo effect, I had this implication that the negative ionizer worked on reducing the

harmful particles that stayed on my clothes and I was protected more or less. Because no qualitative figures were measured, the actual effect was not quite sure. I wonder if another reason might be my attitude toward the smell of the smoke has been altered unknowingly during the process of the research. In the end, I did not solve the problem but solved the problem originator.

For the Wiggly Tree Tip, I noticed that when it was powered by a 9V battery outdoors, there were hiccups during the rotation but it was always smooth when it was connected by cable indoors. I guess it is because the servos need more power, which is why they are often powered by an extra supply from the Arduino. Different settings need different power solutions.

5.2 The Artistic Part and the Thoughts from the Exhibition

Fig 53. The Fire, Fan, and Negative Ionizer (left top), the Wiggly Tree Tip (left bottom), the Brandishing Branches, and the Metal Worm (right) in the exhibition. Credit: Fangchen Dai, 2024.

The students of my master's program had a group exhibition to display the work of our thesis projects from April 9 to 25, 2024 in Gallery Kilo at the University of Lapland, from which the artistic part of our work was evaluated. Feedbacks were also gathered by the researcher (myself) casually during the exhibition by talking with people and from the words left on the guest book.

I made two posters (see Appendix G, H) and brought five installations that are informative to explain my research from the process to the exhibition, namely "Fire, Fan, and Negative Ionizer", "Wiggly Tree Tip", "Metal Worm and Brandishing Branches", "Traffic Light", and "Beam Bundle" (see Fig. 53, Fig. 54, Appendix B–F).

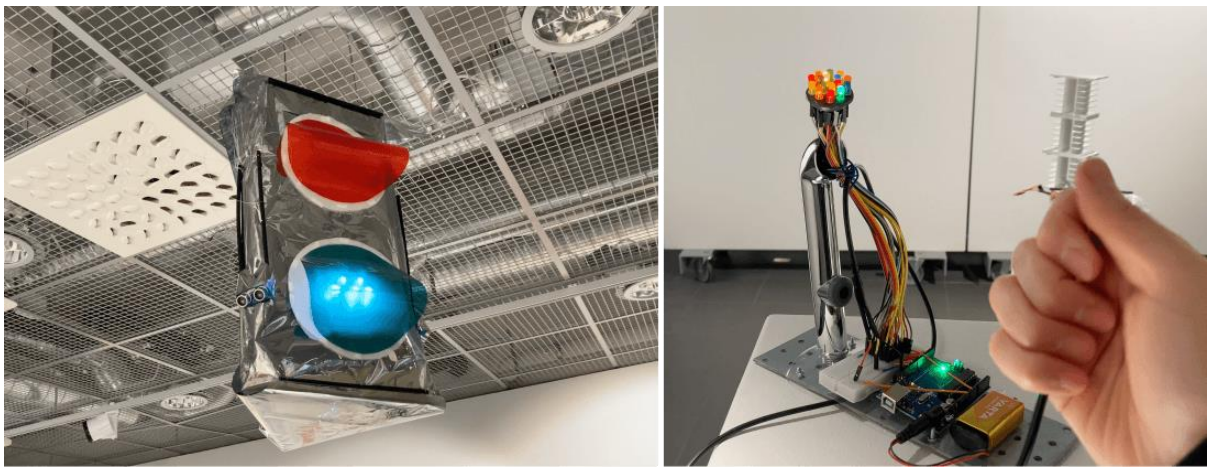


Fig 54. The Traffic Light and the Beam Bundle in the exhibition. Credit: Fangchen Dai, 2024.

One suggestion for the Fire, Fan, and Negative Ionizer mentioned that it would be nice to have multiple colors of the LED, which had only one blue light at the time. Compared with the Beam Bundle, which has both "dark blue" and "dim blue" among other colors, the lonely blue LED is not that exciting. She also suggested a solution if multiple LEDs a]were not possible, then changing the color of the single LED every day would also make it more interesting. I appreciate her consideration and will consider doing so for future development.

One viewer of the exhibition told me that she always felt sad when she saw the Wiggly Tree Tip rotating and that it should be freed outside in the wild. I was intrigued by this emotion. It makes me ponder the meaning of making normally static things able to "move". Another visitor also mentioned that she was afraid that the Tree Tip might run away because it was moving

little by little by each rotation from the original position, but more in a joking way instead of sadness.

When a thing can “make a move”, it will be seen more as a living being. It reminds me of my previous work in the UI/UX field an animation will immediately add another layer to the user experience by exceeding their expectation, rendering the experience more enjoyable. Here also comes an interesting reflection – how do we define “living”? Can the giving of life be totally artificial even when it has no “thinking” ability? What if it is also combined with the recently greatly improved AI? Then how will the boundary between human beings and silicon beings be defined in the future? These are all fascinating reflections to me.

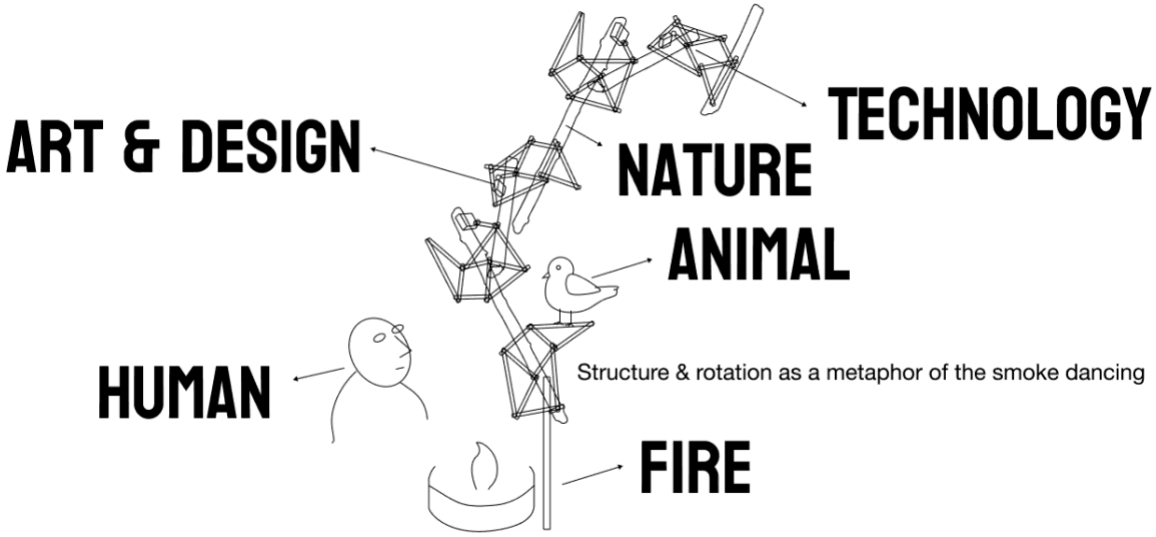


Fig 55. The illustration of the aesthetical metaphor of Prototype 2. Credit: Fangchen Dai, 2024.

The Brandishing Branches from Prototype 2 was given positive feedback by quite a few audiences and its aesthetical perspective was inquired. The aesthetical consideration of this structure is that I wish to use the rotation from a combination of biomaterials (branches) and manmade mechanical components (servo motors) to imply the dynamic dancing shape of the smoke in the open fire of a laavu. It is also a metaphor for the co-existence of nature, human beings, animals, art and design, and technology.

During the opening of the exhibition, a friend pointed out that the kids loved playing with the interactive “toy” (the Wiggly Tree Tip). I also noticed that compared to the braver and always

curious young children, adults seemed to be very “well educated” to “respect” the installations and did not “dare” (or were afraid of making a fool of themselves) to touch the temperature sensor in the Beam Bundle. But it is needed in this piece to actually touch the component to make the interaction happen. I went to the gallery every morning to change the battery. There was only one time I had noticed that the position of the temperature sensor was changed – on the steel plate, instead of its default place – with the tip hanging down onto the guidebook. As for the Wiggle Tree Tip and the Traffic Light, which are less demanding – without the need to touch anything, it is easier for the interaction to take place because it is passively activated by the presence of humans. For an exhibition whose audience might not know the nature of the work, a passive way of interaction (such as by a distance sensor) seems to be more accessible and playful for the visitors.

The exhibition also gave me a chance to test the consumption of the battery on each device. I was over-positive about the lasting time of all the devices that used batteries. I already knew that the servo motors would draw a lot of power, so I used a cable for the Wiggly Tree Tip. When I checked the volts remained of each work in the evening on the second day after the first 24 hours, the Traffic Light (with a 9V) and the Beam Bundle (with a 9V) had both stopped working. The negative ion circuit (with 4 AAs of 1.5V) and the small fan (with 1 AAA of 1.5V) barely made it. After calculation, I decided to change the power supply of the Beam Bundle to cable and all the others needed a new battery in the morning.

Volt remains of	**4.10**		**11**	**12**	**15**	**16**	**17**	**18**	**19**	**22**	**23**	**24**	**25**
	Wed		Tue	Fri	**Mon**	Tue	Wed	Thu	Fri	**Mon**	Tue	Wed	Thu
	8.30	19.22	8.30	9.50	7.51	7.55	7.51	8.30	8.45	8.49	9.06	8.50	8.30
Traffic Light	6.79V	6.48V	4.98V	6.4V	5.7V	6.84V	6.65V	6.51V	6.59V	4.19V	6.63V	6.53V	6.66V
Negative Ionizer	1.6V	1.43V	1.38V	1.4V	1.28V	1.42V	1.42V	1.41V	1.42V	1.24V	1.41V	1.41V	1.43V
Small fan	0.75V	0.72V	0.62V	1.07V	0.93V	1.17V	1.17V	1.17V	1.15V	320mV	1.18V	1.15V	1.17V

Fig 56. The records of the voltage remained of the device every day during the exhibition. *The irregular remaining value of 320mV of the small fan’s battery is possibly due to the dropping of the stopper of the fan’s rotor. Credit: Fangchen Dai, 2024

The working voltage threshold for each component varies. In the end, the replaced batteries still have some energy inside, but it is hard to utilize the remaining separately. I could not help thinking it would be so much better if each remained value could be put into one big container,

it would be more convenient to utilize and better for the environment. I consider this as the disadvantage of battery, but maybe it could be a touchpoint as the starting for new research.

At the opening of the exhibition, the word “IKEA” was frequently mentioned by the audience when they saw the guidebook (see Appendix B–F) illustrated for each work. I admit it was indeed my intention for the resemblance, but when I was drawing it, I did not search for any IKEA product books for reference. However, the black-and-white color minimalist aesthetics and the outline stroke style of the axonometric illustration of the product seem to be deeply embedded in the mind of the masses (me included as a designer), making this style the “IKEA style”. I adapted this style intentionally in the exhibition with the interactive installations because I wanted to see how the audience received this combination. From what I had observed, most people were amused by the association.

Now I think about it, it would also be an interesting way to discuss how commercialism invades our perception. It leads also to the conflict between the pride of some artists and the commercialization of their artwork, in other words, the practical reflection on cost and resource issues. In my observation, people in academia tend to apply for funding first before they can start a project. A previous co-worker of mine reminded me to think about the cost of doing research and making a device which was out of my ability at the time when I asked about his opinion in the preliminary stage of the project. There is nothing wrong with people working in industry thinking practically. Luckily, I still have some money to research what I am interested in. But for those who do not, it would be a hindrance to possible breakthroughs. Anyway, it is a dilemma for those who try to be innovators.

5.3 Limitations, Gains, and Future Considerations

The time limit for a project is always something in the way of the pursuit of perfection. I always feel my product is not ready no matter how many cycles of iteration I have made. In the beginning, I was planning to make something commercially ready, but in the end, it was of course not realized. I wish I were given more time to improve.

During the process, I have learned a lot of new technologies and knowledge, which are beneficial for my artistic expression on other personal projects and I have developed a new

way of visualizing a feeling by experimental interactive gadgets to explore interpersonal relations via tangible objects. I was a little frustrated when I found out that the project was going more technical than artistic in the middle of the research, but I guess it is also necessary to go through this process so that I can fix it later by trying to balance.

In the end, I hope I do provoke some thinking on future projects that also intend to discuss the relationship between human, environment, sustainability, technology, art, and design in protecting the cultural heritage in the context of the Arctic through the medium of experimental interactive devices. The whole journey was not easy indeed, but I wish to encourage those who were as bewildered as I was in the beginning that no matter how complicated the goal seems to be if you split it small enough, there is always a solution. If it is not solvable, it is not small enough. I really enjoy exploring possibilities from the impossible, even when I fail now and then (in fact, quite often). In some sense, maybe the final production is only a by-product of the sense of achievement one could obtain from completing the jigsaw puzzle. In that case, one can focus on the process of making without worrying about how it may look in the end.

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7. APPENDIX

Appendix A

The questionnaire for the locals (English version)

Questionnaire - about the smoke smell in the laavu

Name: _____

(If you do not want to give your name, it can also be anonymous.)

☐ I give consent to allow the data to be collected and used in the researches conducted in the University of Lapland.

1. How often do you use a laavu?

☐ < 5 times / year

☐ 5 - 10 times / year

☐ > 10 times / year

Other, please give the exact number: ☐

2. How do you feel about the smoke smell when using the stove in the laavu?

☐ I like the smell. ☐ I don't like the smell.

Others: _____

3. Do you mind the smell stay on your clothes for a while after you leave the laavu?

☐ I like to have it on my clothes as long as it takes.

☐ I don't like the smell staying on my clothes.

☐ I don't care.

4. Have you worried about inhaling some harmful particles when burning the woods?

☐ I have worried.

☐ I don't think that's a problem.

☐ I never thought about it.

☐ I got interested and now I would like to know more.

5. Other things I want to say about the smoke smell of the laavu:

_____

_____

_____

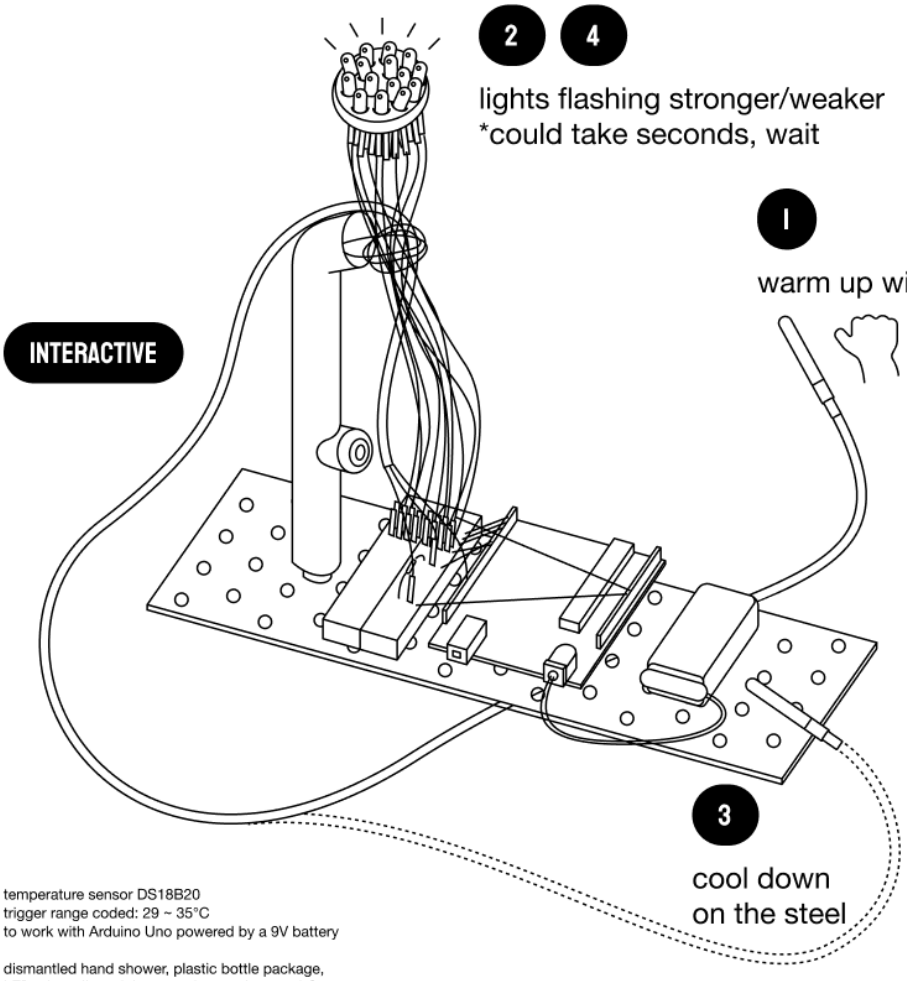
_____

Appendix B

The guidebook of “BEAM BUNDLE” in the exhibition

BEAM BUNDLE

The LEDs react to the temperature values detected from sensor
with interval delays mapped from the brightness.



temperature sensor DS18B20
trigger range coded: 29 ~ 35°C
to work with Arduino Uno powered by a 9V battery

dismantled hand shower, plastic bottle package,
LEDs, breadboard, jumper wires, resistor 4.7kΩ,
steel plate, screws and nuts

24 × 8 × 24 cm

If something is not working,
please contact me.
I'll come to fix it.

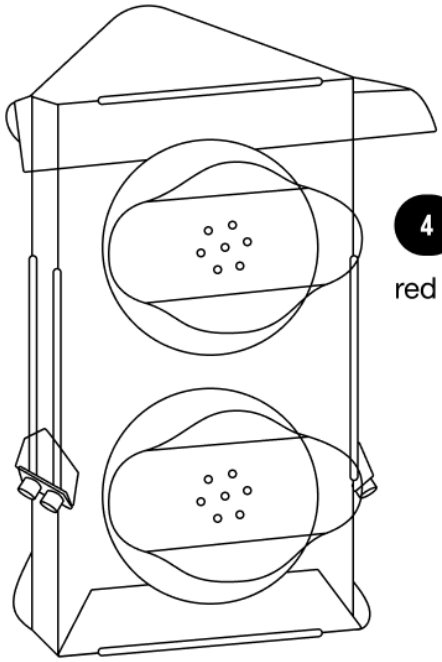
Fangchen Dai fcd.cargo.site fdai@ulapland.fi

Appendix C

The guidebook of “TRAFFIC LIGHT” in the exhibition

TRAFFIC LIGHT

When the ultrasonic sensor detects human,
each triggers its corresponding light.



INTERACTIVE

4
red light flashes

2
green light flashes

1
walk from left

3
walk from right

ultrasonic sensor HC-SR04, trigger range coded: <100cm
to work with Arduino Uno powered by a 9V battery

one-way perspective window film, plastic straws, nails, foam layer, lens filters, plastic bags, plastic threads,
wire connectors, LEDs, breadboard, jumper wires, resistor 4.7kΩ, 22 AWG wires, electrical tape

30 × 30 × 50 cm

If something is not working,
please contact me.
I'll come to fix it.

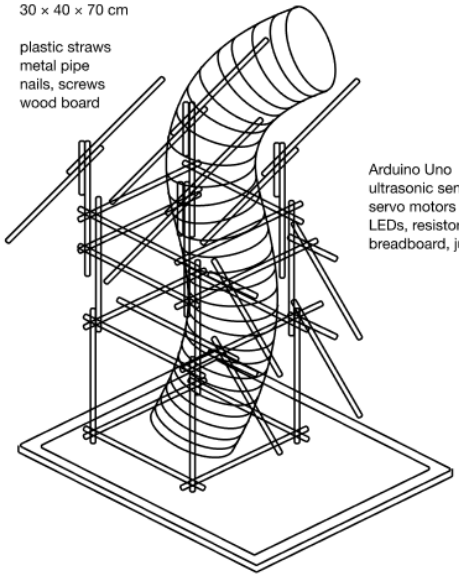
Fangchen Dai fcd.cargo.site fdai@ulapland.fi

Appendix D

The guidebook of "METAL WORM AND BRANDISHING BRANCHES" in the exhibition

30 × 40 × 70 cm

plastic straws
metal pipe
nails, screws
wood board

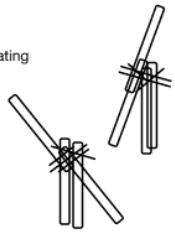


Arduino Uno
ultrasonic sensor HC-SR04
servo motors SG90, MG996R
LEDs, resistor 4.7kΩ
breadboard, jumper wires

METAL WORM

Prototype 1.0 & Prototype 3.0
of a rotating structure

with my own accidentally discovered unit for rotating



NOT INTERACTIVE NOW

see when the components were interactive:

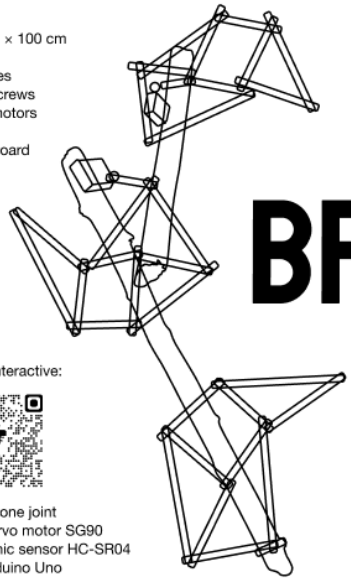
pipe controlled
by tendon

scaffold structure
with LEDs

AND

30 × 45 × 100 cm

branches
nails, screws
servo motors
fixation
wood board



NOT INTERACTIVE NOW

BRANDISHING BRANCHES

when interactive:

test on one joint
with servo motor SG90
ultrasonic sensor HC-SR04
and Arduino Uno

Prototype 2.0 of a rotating structure

with "Jansen's linkage" as the joint
ref https://en.wikipedia.org/wiki/Jansen%27s_linkage

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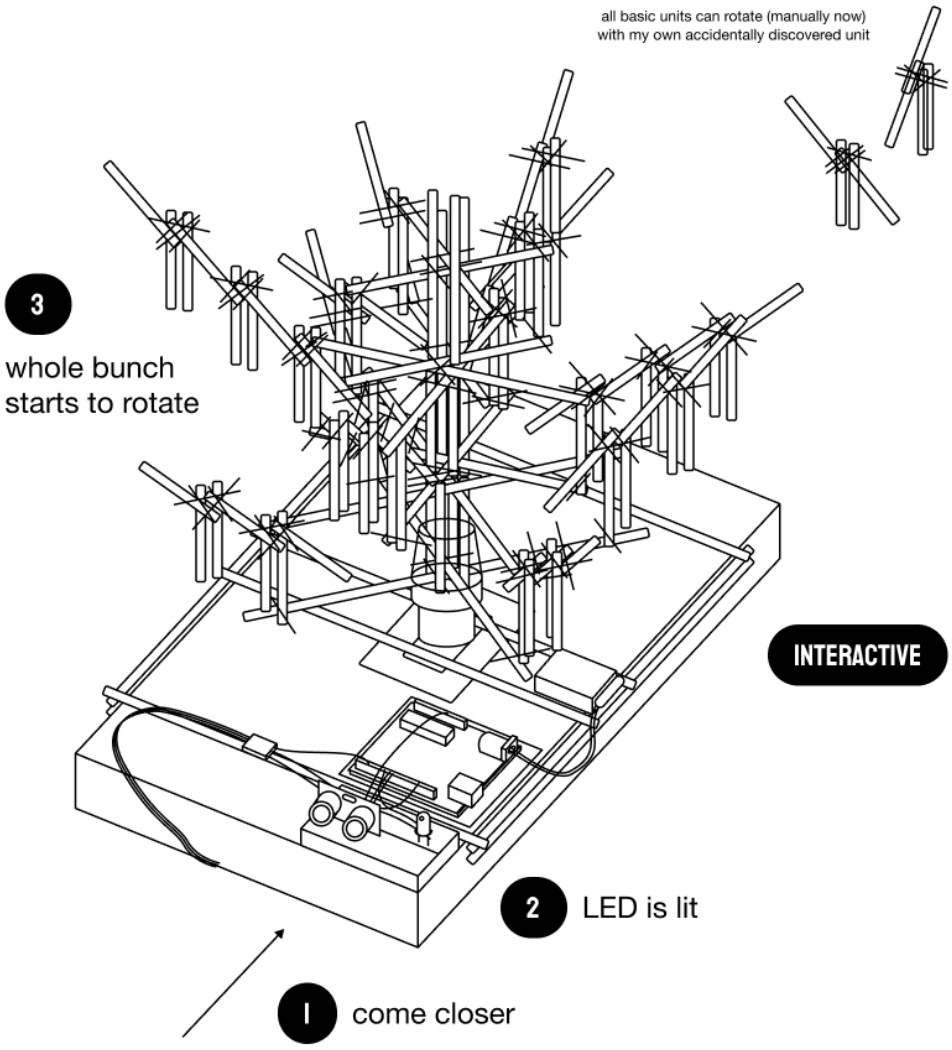
Appendix E

The guidebook of "WIGGLE TREE TIP" in the exhibition

WIGGLY TREE TIP

all basic units can rotate (manually now)
with my own accidentally discovered unit



ultrasonic sensor HC-SR04
trigger range coded: 20 ~ 80 cm
to work with Arduino Uno powered by cable, alternatively a 9V battery

foam board, softener bottle lid,
LED, breadboard, jumper wires,
nails, screws and nuts, hair bands

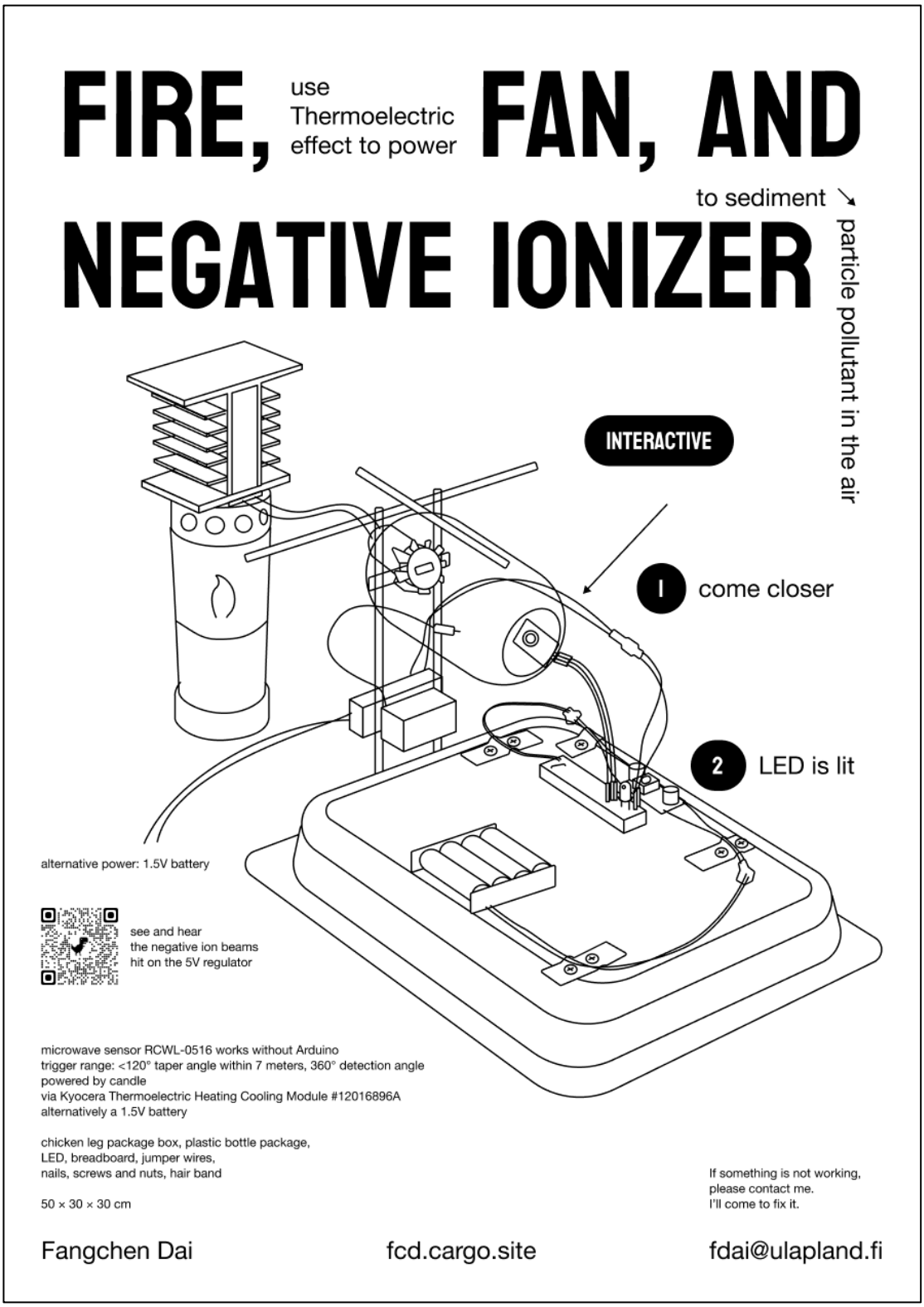
30 × 30 × 30 cm

If something is not working,
please contact me.
I'll come to fix it.

Fangchen Dai fcd.cargo.site fdai@ulapland.fi

Appendix F

The guidebook of "FIRE, FAN, AND NEGATIVE INOIZER" in the exhibition



Appendix G

The Poster (dark version) for the Exhibition

Appendix H

The Poster (light version) for the Exhibition