

Project Woodwind



Interactive urban furniture

**David Grünewald, Kevin Winiarczyk, Leticija Petrova,
Samuel Slezák, Solkyu Park**

Group 2

1:1 interactive prototype course

Faculty of Architecture and the Built Environment

Delft University of Technology

Abstract

This paper describes the group process for the development of an Interactive piece of Urban Furniture along the watertaxi stops near the Maas in Rotterdam. Therefore parametric design approaches were used to realise an 3D voronoi pattern on macro, meso and micro scale along and within the piece of furniture, by taking into account functional, structural, material and operational aspects. For the realisation of an 1:1 prototype, robotically 3D printing methods were used and wood based biopolymers.

The design focuses on the realisation of a multifunctional bench with regular seating areas, shelters and tribune, which relates oneself with multiple social interactions with users and the surrounding environment. It integrates sensors and actuators into the urban furniture which makes direct and indirect communication possible with users via sound (music), light, web based apps and AI. The final design is an interactive piece of urban furniture respecting the voronoi logic.

Keywords

voronoi, interactive urban furniture, macro, meso, micro

Introduction

The project Woodwind is a design of Urban Furniture, created for the 1:1 interactive prototype course, the group has designed a bench near the water taxi stops in the city of Rotterdam. The furniture is placed in Rotterdam water taxi stop “Willemskade” and functions as a seating area and a shelter where you can wait for the taxi to arrive, as well as it serves as an interactive space where people can create and discover music and socialise during events.

During the design process, the main focus of the project was to design with the concept of Voronoi using parametrically generated point-cloud in the means of functional, structural, material, and operational. The culmination of these processes is the generation of a design, that through the use of robotic systems has emerged exclusively from the connection between the users and the site. The design then is robotically 3D printed using wood-based biopolymers. Through the process and with the guidance of professors, we were encouraged to discover approaches to design and produce in the 4th industrial revolution.

The project was a team-based effort. However, the group was divided into two sub-section; One that predominantly focused on the topic of robotic production (D2RP) and the second, which focused on the topic of robotic operation (D2RO). The final product is a complex project which is an outcome of the team’s common efforts.

Design Goal

The group started out asking a series of original questions: what is a bench? And what is a digitally produced bench? Can a bench be where people can interact more and connect cities and people with new technologies, rather than just a bench as a device for people to sit and rest? The goal was not to create a simple bench with only one-way interaction, rather imagined a bench that correlates oneself with multiple social interactions with users and also to the surrounding environment. The goal of the design was to generate the design through the connection between users, the site, and the bench.

Design Process

Conceptual design phase

The conceptual phase consisted of the exploration of 3 aspects: (1) interesting references (2) options for the potential location and (3) potential key focus points of the furniture either for its function or shape. The outcome of the brainstorming sessions resulted into several conclusions and potential ideas to explore:

Core messages and ideas:

- Addressing an issue either social, environmental or related to data privacy or current pandemic and loneliness.
- Using sensors to educate people on the climate and the environment
- Extension of the public space towards water
- Inclusivity of insects, plants and people
- Voronoi within a voronoi

Location:

Rotterdam water taxi stop Willemskade with a visual connection and interaction with a stop across the river.

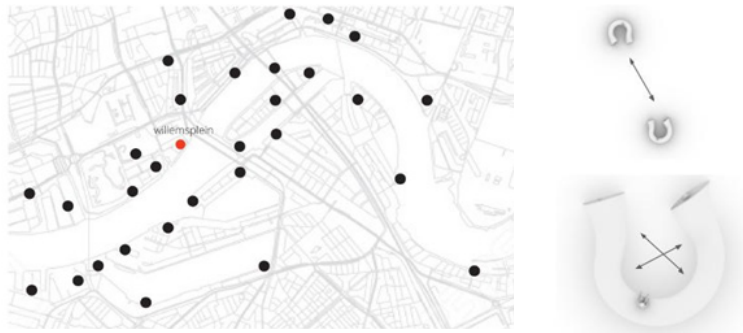


FIGURE 1 Location watertaxi stop Willemskade and interaction with stop accros the Maas

Function:

Bench and seating area, weather shelter, place to interact, place to discover and create music (use drum machine concept)

Shape & assembly:

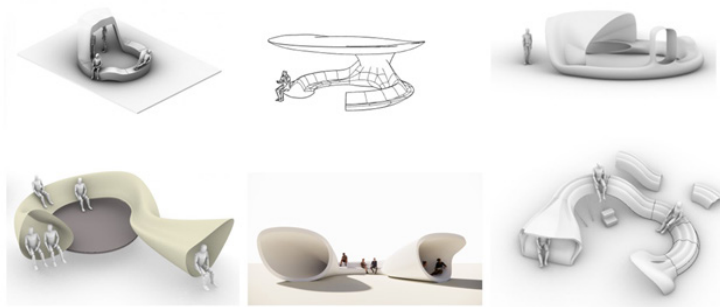


FIGURE 2 Space defining shape design process

Componential logic or divide into parts for printing due to size.



FIGURE 3 Componential logic variations

The main basis for the sensor part of the design was laid down during this phase of the project. The initial ideas included light and sound as the basis of the interactive elements. The concept of interconnectivity between the benches called for a visual dialogue as well and this could be achieved by lights. The acoustic part of the design focused around human interaction with the bench. At this stage of the project a concept of drum machine was introduced for the first time. This idea was then developed further to create one of the main themes for this piece of urban furniture.

In the first weeks the approach was to explore references and brainstorm on the shape, the function, the sensor use without any chosen direction. After a few weeks the core ideas were narrowed down such as the location: Rotterdam water taxi stops, the rough shape (space defining shape such as circle) and the function (bench, shelter). Furthermore, the next design proposals were mostly iterations and improved versions of the chosen key aspects as well as some additional features. Finally, the above mentioned ideas were narrowed down even more for the midterm presentation which will be discussed in the next section.

Midterm design phase

After the conceptual phase the group had to narrow down on multiple aspects to come up with a coherent proposal for the midterm presentation. During these weeks further decisions were made for the following topics: the main ideas, shape, applying voronoi script, assembly method, printing part and types of sensors and actuators needed for interaction.

The idea of using a circle as space defining shape remained by using a ring as starting point and resulted in the development of the base shape by splitting it up, opening up the ends to create shelters and regular seating areas in the middle part of the furniture.

For applying the voronoi pattern on the urban furniture the first concepts for the computational part were made by the use of three grasshopper scripts. The first script was used to create a structural analysis based on the humans placed on the seating areas, which was needed to create a point cloud in the second script. In the final script the voronoi pattern could be created, the density of the pointcloud on the seating areas depended on the placement of humans. Further variations on the voronoi pattern were created by changing several parameters as extrusion, protrusion, void and scale. In order to achieve a logic of the placement of open and closed areas our group experimented with different densities and porosities.



FIGURE 4 Grasshopper structural analysis, point cloud and voronoi pattern

In terms of assembly the bench would be divided in four parts; two benches and two shelters. One of these parts was selected for further development for the integration of sensors and actuators by respecting the printing size limitations of 2x2.5x2m.

The idea for the sensors for the midterm consisted of two parts; the lights and the music that the bench would produce. The lights would be implemented directly into the voronoi cells. The voronoi cells themselves would be buttons which could create sound, similarly to the drum machine. Additionally an application would be created that would further enhance both the sounds and the lights. This app would allow the user to control both of these function, so in theory once could perform a live music performance for an audience, where the bench would be his DJ table.

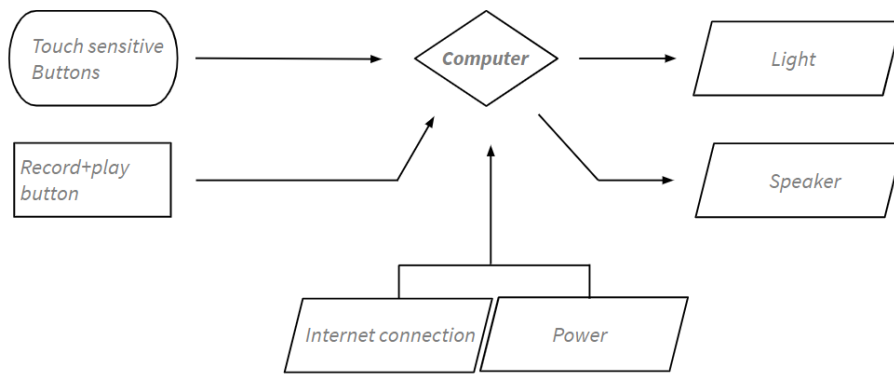


FIGURE 5 Concept sensors and actuators

Post-conceptual design phase

After mid term, the group focused on examining design options based on the concept, therefore, form finding using subD shape was necessary. Since basic design has been agreed, design changes were made to fit more functions.

Macro shaping experiments

Basically, various attempts were made to find a form suitable for macro shaping. The team tried form finding using Voronoi cells, increasing the size of outer skin cells etc. However, It was clear that these methods showed problems in conforming to the preferred function and the basic functions of the bench, so the basic macro form of the voronoi cell was applied to the form made by the SubD method.

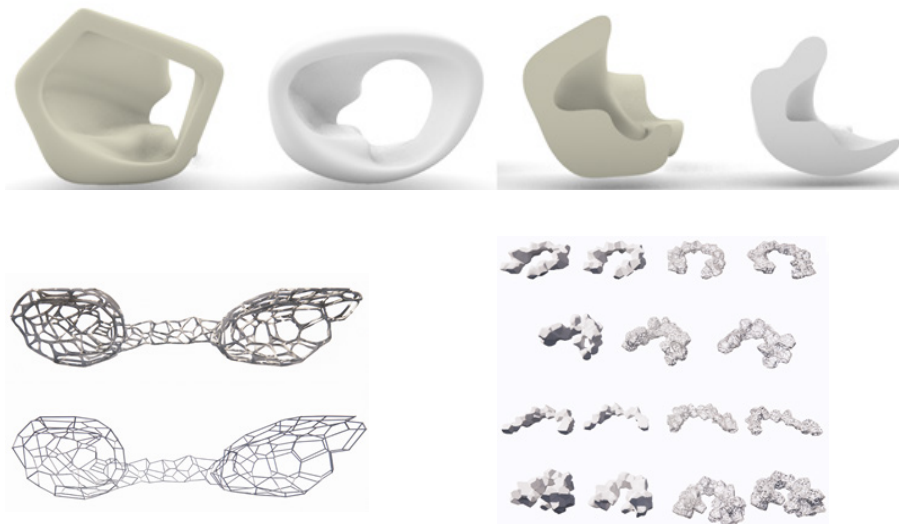


FIGURE 6 Multiple macro shaping experiments

To understand the shape creation of Voronoi cells, understanding the point cloud was the most urgent priority. Therefore, point cloud creation was proceeded through various attempts. In figure 7 an attempt is shown on how to create voronoi cells by making point clouds of different density in different sections and combine them as a single mesh.

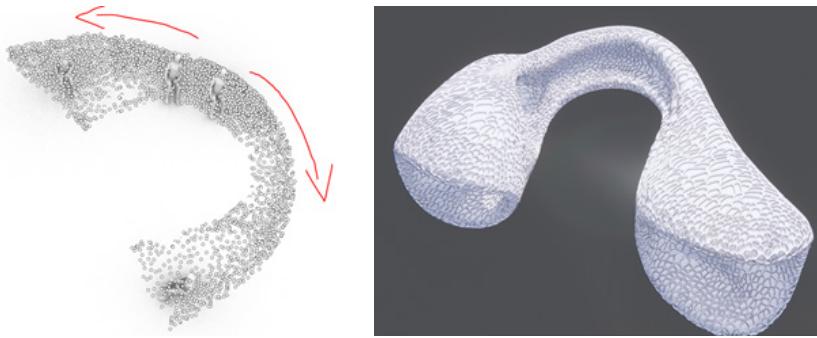


FIGURE 7 Experimenting with different densities of pointclouds

Various attempts were made to understand the tutorial script and point cloud, and experiments were continued to derive the most ideal design based on it.

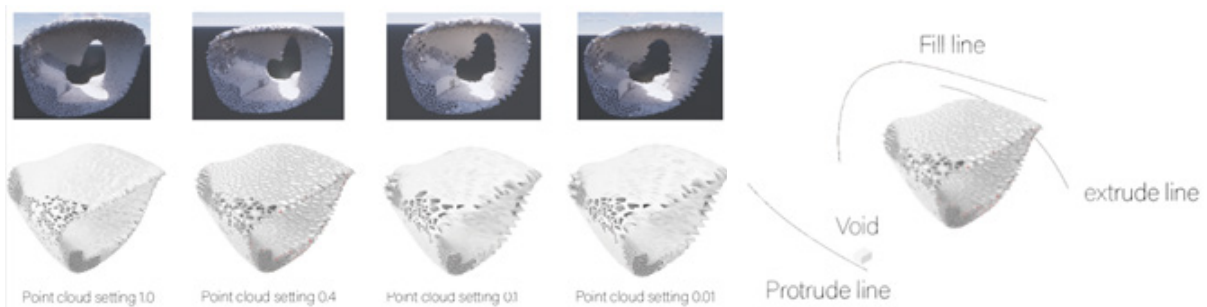


FIGURE 8 Experimenting with tutorial scripts

Final design phase

The final furniture proposal “Woodwind” is called after the definition of wind instruments other than brass instruments including flutes, oboes, clarinets, and bassoons. The name itself consists of the words “wood” and “wind” and the definition of it relates to music, therefore it includes the 3 key points of our design: (1) wood - the production material (2) wind - the environmental aspect and relation to the Dutch windy weather (3) music - the interactive element.

Location & Function

The furniture is placed in Rotterdam water taxi stop “Willemskade” highlighted in red in the diagram below, it functions as a seating area and a shelter where you can wait for the taxi, as well as it serves as an interactive space where people can create and discover music and socialise. However, the goal would be to place different versions of this type of furniture in each stop highlighted with black dots in the diagram below. The last diagram showcases the regions mapped using a voronoi diagram and it highlights in which locations events will be held.

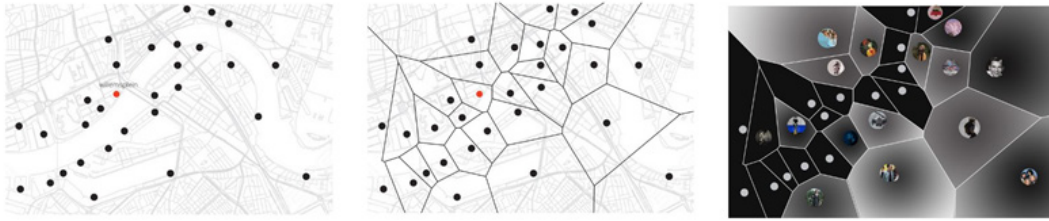


FIGURE 9 Water taxi stops - regions around stops - events per region

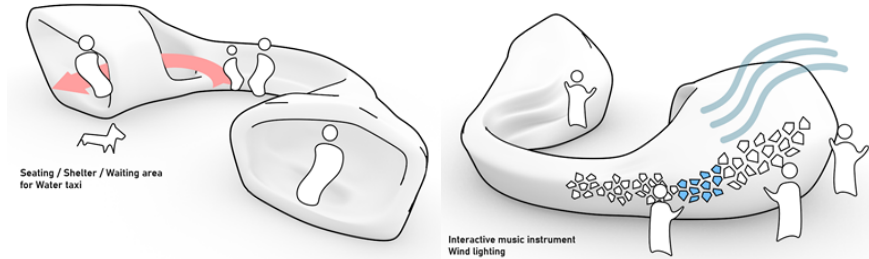


FIGURE 10 The different uses: seating, shelter, waiting area, interactive music instrument, awareness of environment (wind)

Shape macro & meso level

The initial idea of the shape of our furniture was taken from splitting a ring shape and opening it up as well as adapting it to the human body and different functions. The final shape was changed even further and it was adapted towards a voronoi section on a macro and meso scale. On the exterior you can find clear voronoi sections and in the interior the shape merges into a volume that has been adapted to the human body.



FIGURE 11 Split ring - open up the created space - macro voronoi - final shape

Shape micro level

On a micro level the voronoi porosity adapts to the function: shelter and seating- closed cells, sides of the shelters as well as spaces where light sensors are integrated are more porous.

Computational design use for the final 3D voronoi

The final shape was achieved by:

- Firstly, creating a Subd shape adapted to the human body and with voronoi sections.
- Secondly, generating the structural analysis mesh and a structural analysis field (point cloud) where people's weights were added
- Thirdly, generating a 3D voronoi by including the limitations of the printing as well as manipulating the porosity and scale of the voronoi cells.



FIGURE 12 Grasshopper structural analysis, point cloud and voronoi pattern for final design

- Finally, the prototyping of this design was achieved by creating a continuous toolpath within Grasshopper for a 60x60x60 cm prototype.

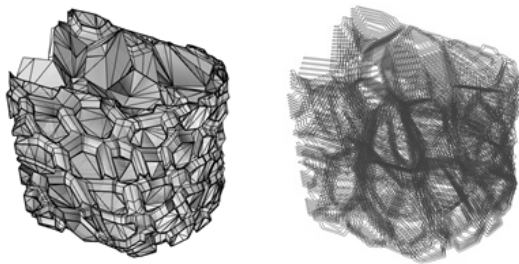


FIGURE 13 Toolpath for 60x60x60cm prototype made in grasshopper

Sensor integration & interactivity

The main challenge in integrating the sensory part into the design was the consideration of the Voronoi. The goal of the design was to develop a design that would revolve around the voronoi logic. The chosen approach is focusing on condensing the concepts that comprise a Voronoi. Voronoi was reduced to its main three components; Point, volume (or a surface in case of voronoi projected on a 2d plane) and a line - a representation of the boundaries between the vertices of voronoi. Based on this simplified concept of voronoi the design split the sponsor logic into three sections; Context, location, and interaction. The context can be understood as the volume of a voronoi; It is the element that occupies the space and area. The location can be understood as the place where the bench is placed. The interaction is the connecting line that brings together and gives definition to the boundary - the boundary can be breached thanks to the interaction. Each of the three elements is represented by its interaction. The context - Volume - Cluster of voronoi cells reacting to its context by creating an atmosphere of the place. The Dots - Location - Point lights react to wind blowing around the river Maas. The line - Interaction - Strips of LED that visualize music in horizontal patterns travel from one bench to the other even through space.

The app was created as an extension of the bench. The main use of the application is to encourage social interaction and facilitate social gathering. The content of the application is to create and share music with others. The original principle for the implementation of music comes from the drum machine. The application is the second part of this integrated drum machine, with the first part being the bench itself. The app is meant as a connecting point between an intimate object and the human seeking social contact. Lastly, an AI is implemented to extend the function of the bench even further; To animate an inanimate object and bring it to life to ease its implementation within its environment. The AI plugins shall also encourage people to interact and experiment with all of the features the bench has to offer.



FIGURE 14 Visualisation showing ambient lights integrated in the urban furniture

Conclusion

Respecting the voronoi logic on macro, meso and micro scale is an important aspect that needs to be taken into account when designing with the voronoi shape. In this way the object can be logically divided into components on the different scales, which makes it more suitable for 3D printing using robotic printing methods. In the first place the design was more based on the human body, resulting in organic shapes of the bench, in this way the voronoi pattern was only visible on micro scale. Therefore the design developed during the weeks by experimenting with the macro scale, which made the division of the whole furniture in meso scale possible. Resulting in a furniture respecting the voronoi logic on macro, meso and micro scale.