Digital Design in Sustainable Urbanism - Explorations in computational design strategies

DIGITAL DESIGN IN SUSTAINABLE URBANISM

Explorations in computational design strategies

TAMPERE UNIVERSITY OF TECHNOLOGY

Tampereen teknillinen yliopisto - Tampere University of Technology

Digital Design in Sustainable Urbanism - Explorations in computational design strategies

Course AYS-6106 Digital Design in Sustainable Urbanism

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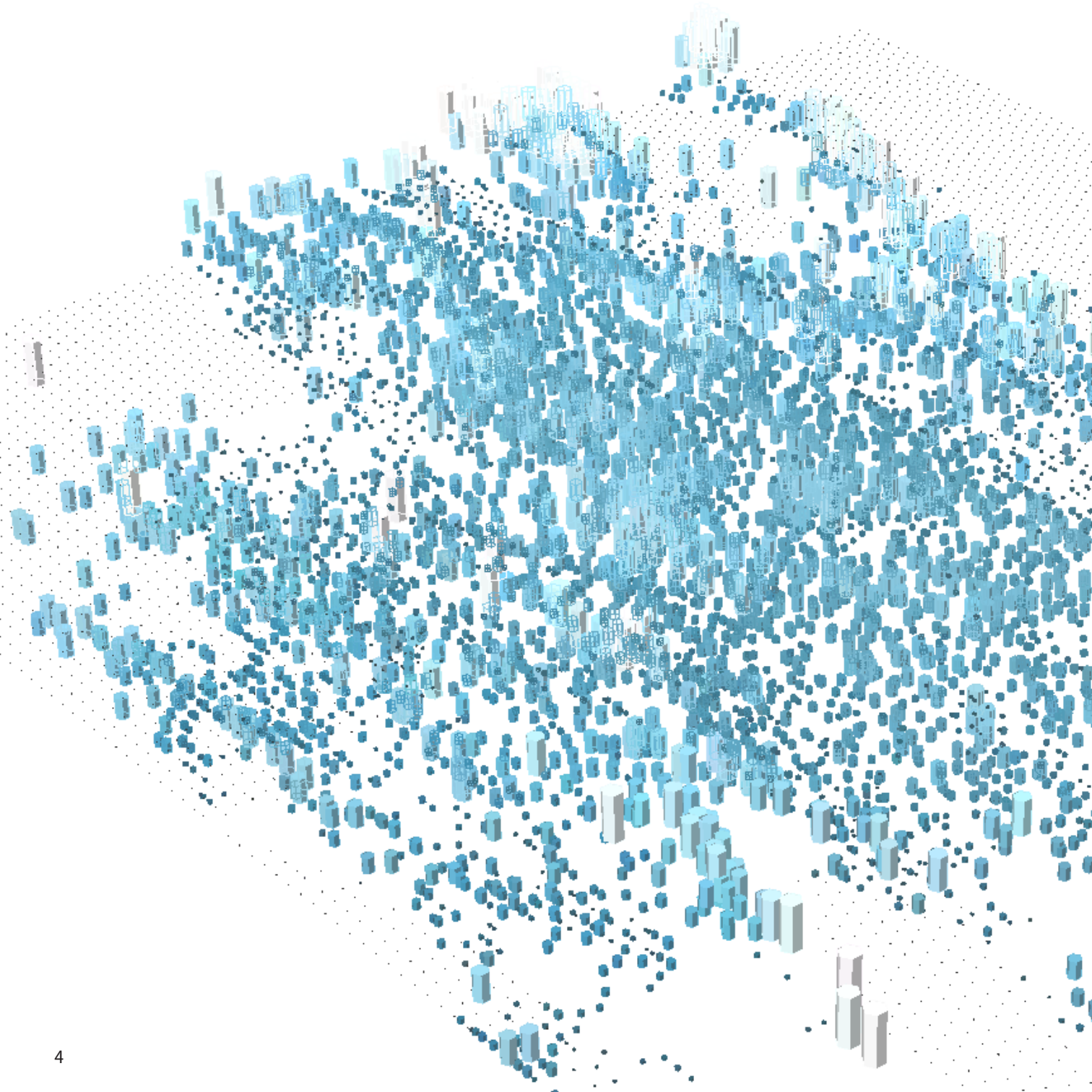
Contents



Introduction

This booklet and the accompanying exhibition represent student explorations in the *Digital Design in Sustainable Urbanism* course, held at the Tampere University of Technology within eight weeks at the beginning of 2013. The course is a new addition to the TUT architecture curricula, but even this very first implementation displays promising results through these inspirational student works.

The goal of the Digital Design in Sustainable Urbanism course was to introduce students into the new world of possibilities in digital design; especially in the shift in thinking design through the use of algorithmic processes and parametric modeling. The task of learning a new parametric design software, within this tight schedule, is no simple task when you combine it with the requirements of testing and analyzing the influence that different design parameters have in the urban design.

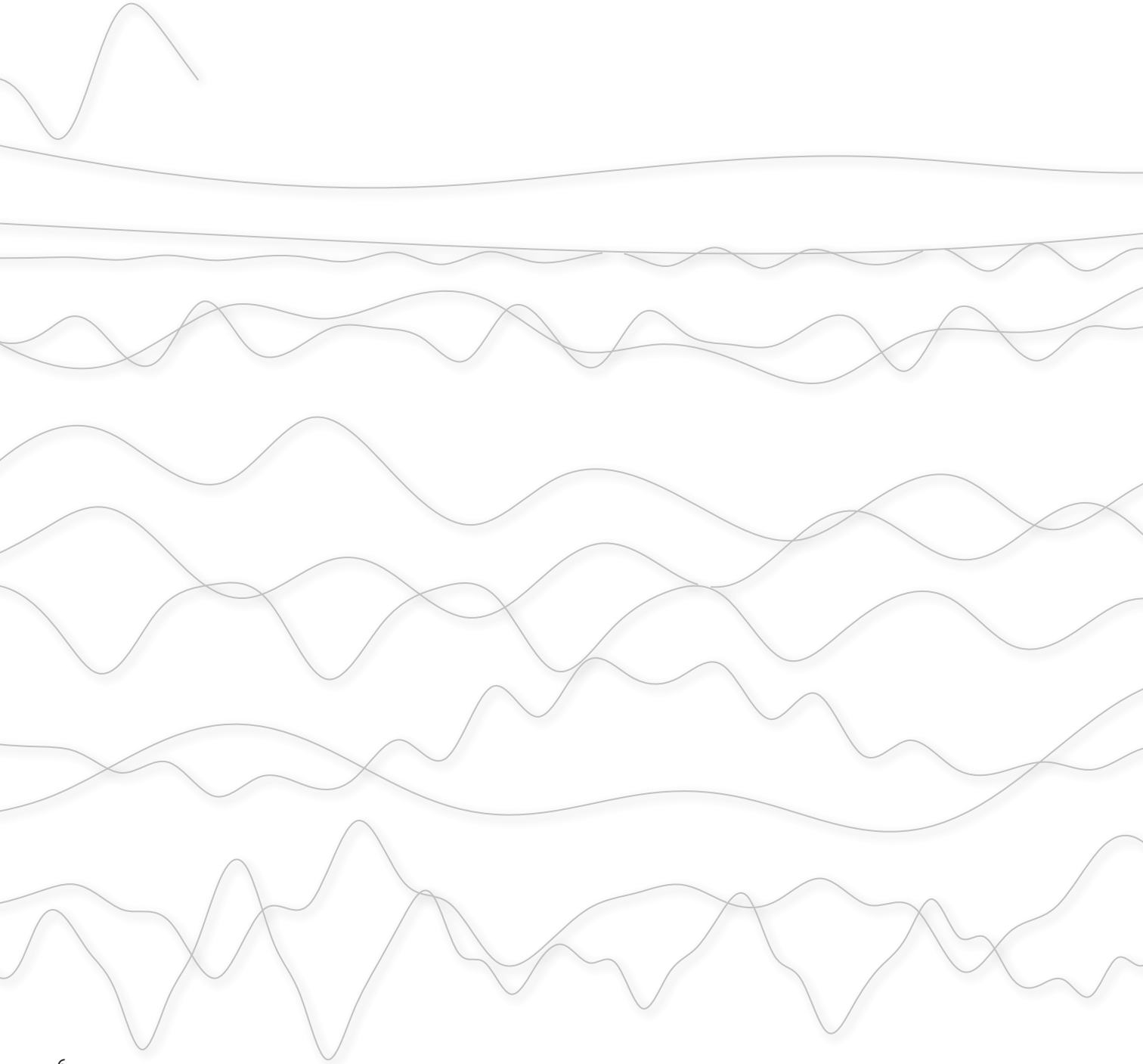
The course demonstrated different analysis and design methods in urban scale and encouraged students to explore the design potential of them. The methods were selected to form a broad scale of analysis and design processes that could be beneficial in urban scale design development. Each week represented a new set of methods and challenges for the students to absorb.

The design explorations presented in this book, represent the student's answers to these different tasks presented to them. Through their work, they demonstrate vast potential and great assimilation of knowledge within this tight schedule.

Courses like these are always a possibility for me to be inspired and also learn from the students. The great interaction with the students challenged me to explore the boundaries of my own knowledge and seek new methods in solving the questions they presented. To me, that is the ideal situation and a thriving force in education in general.

Special thanks to professor Panu Lehtovuori, Jenni Partanen and Elena De Lisio for their support and guidance.

Toni Österlund



Function(al) Urbanism

1. *Mission*

There is elegant beauty in equations and with this exercise you should explore the possibilities of different mathematical expressions and functions as basis for an urban plan.

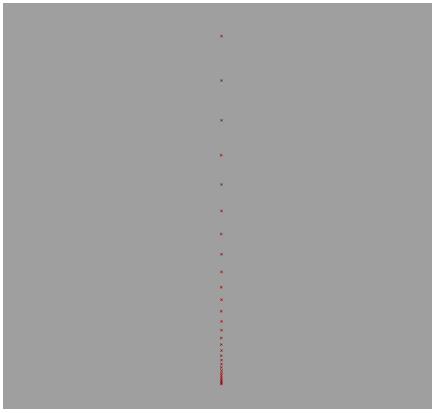
Through experimenting and exploring different functions and combinations, try to achieve interesting results.

Test out different possibilities that the digital tools and equations offers and seek out a solution that satisfies you.

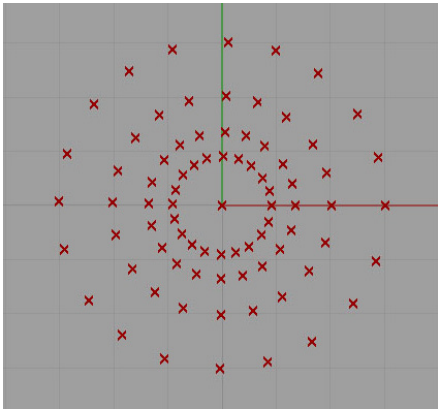
Use coloring to emphasize and clarify your intentions. Be creative, but use math.

The main goal of this exercise is to familiarize you with the possibilities of mathematical equations and how to implement them in design.

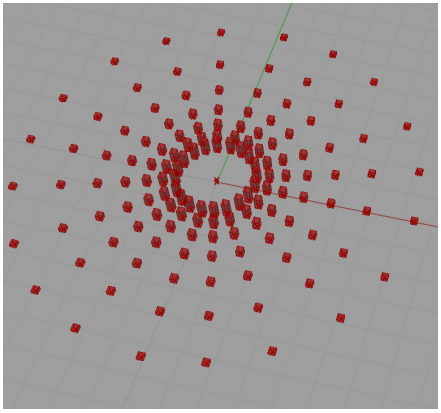
1. Explorations



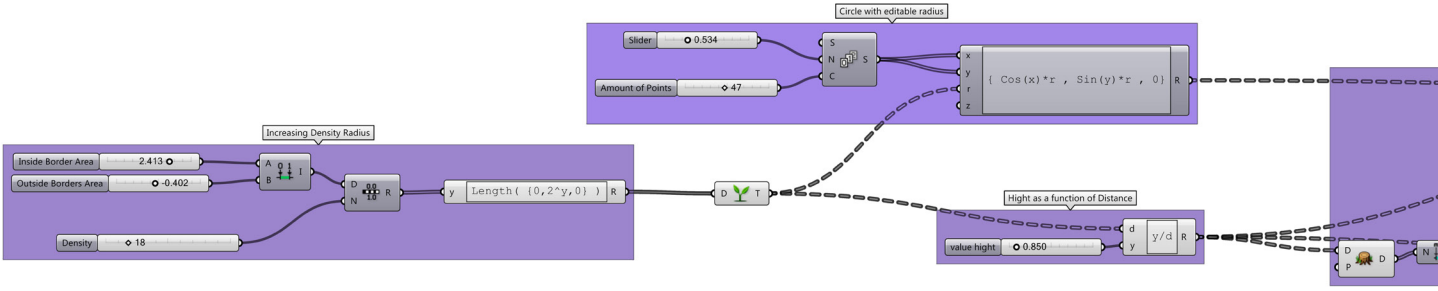
First Step: "Line of Density"



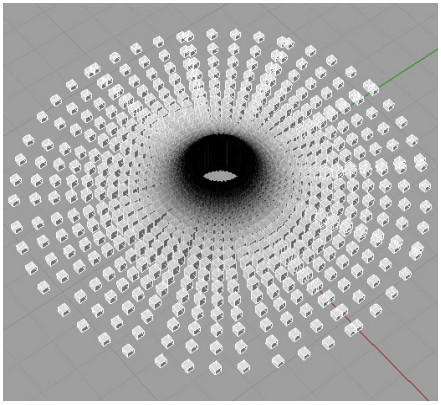
Second Step: "Area of Density"

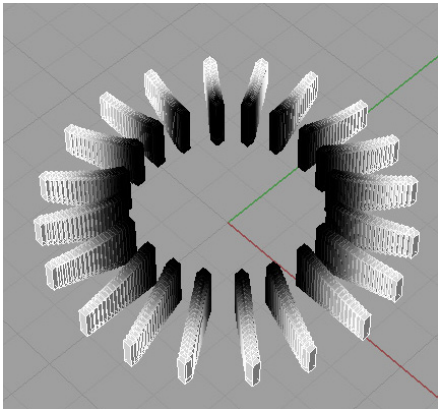


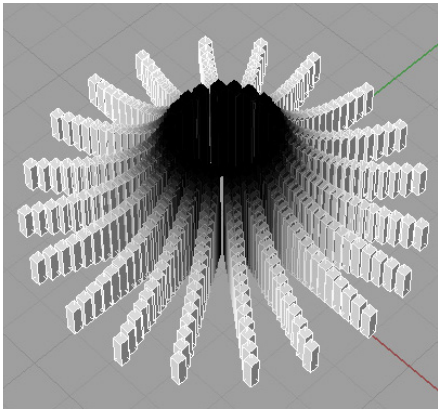
Third Step: Defining Volumes

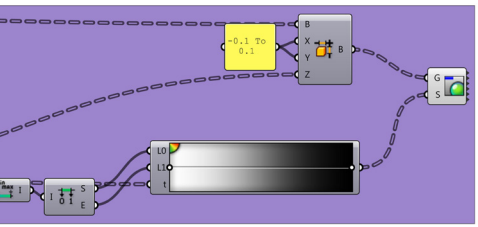


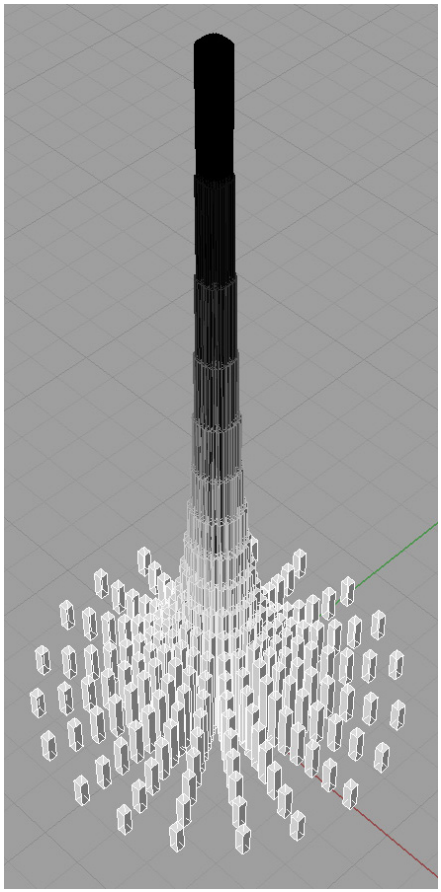
Grasshopper definition

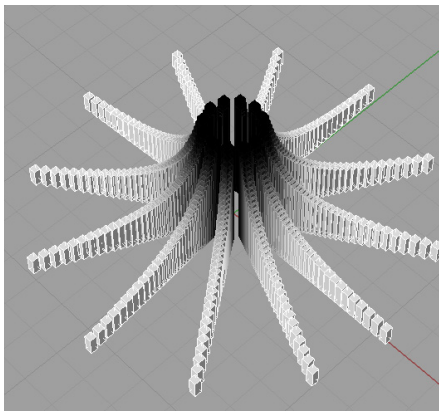


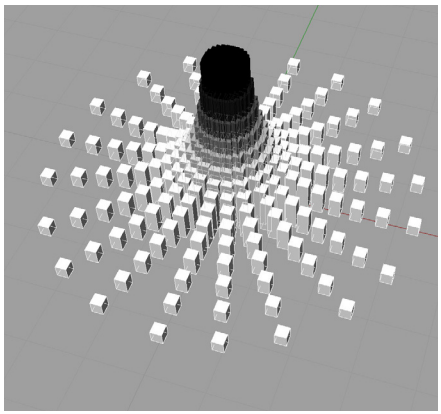












1. Circle of Density

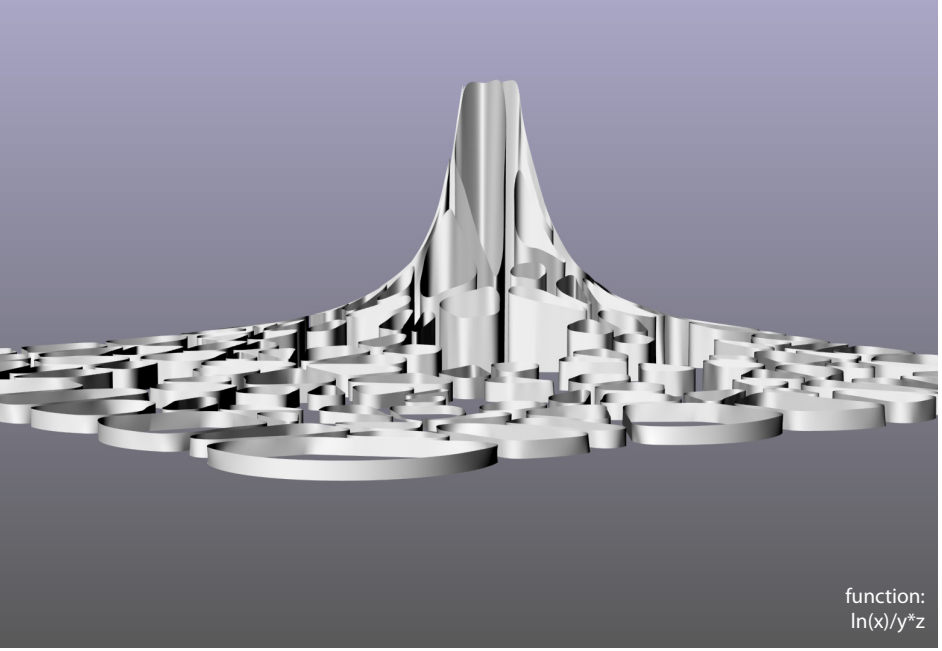
Elisabeth Heinz

Still taking first steps with the Grasshopper tool, this tasks was supposed to be the chance to play with the possibilities of the software.

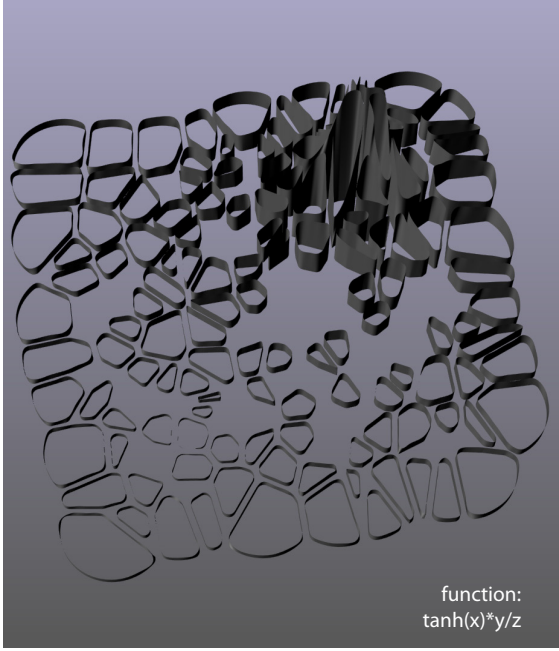
The main idea of the project was to visualize density, which is an component of urban development in general. In the first step a simple row of points was created. The distance of the points decreases fluently the more they get to the end of the row. Every exponential equation can be used for this, but 2^x gave a well floating result.

Based on this thoughts the "Line of density" was simply used as a radius for a circle to create an "Area of Density". The center point of the circle marks the area where the density is the highest - just like in the center region of urban areas.

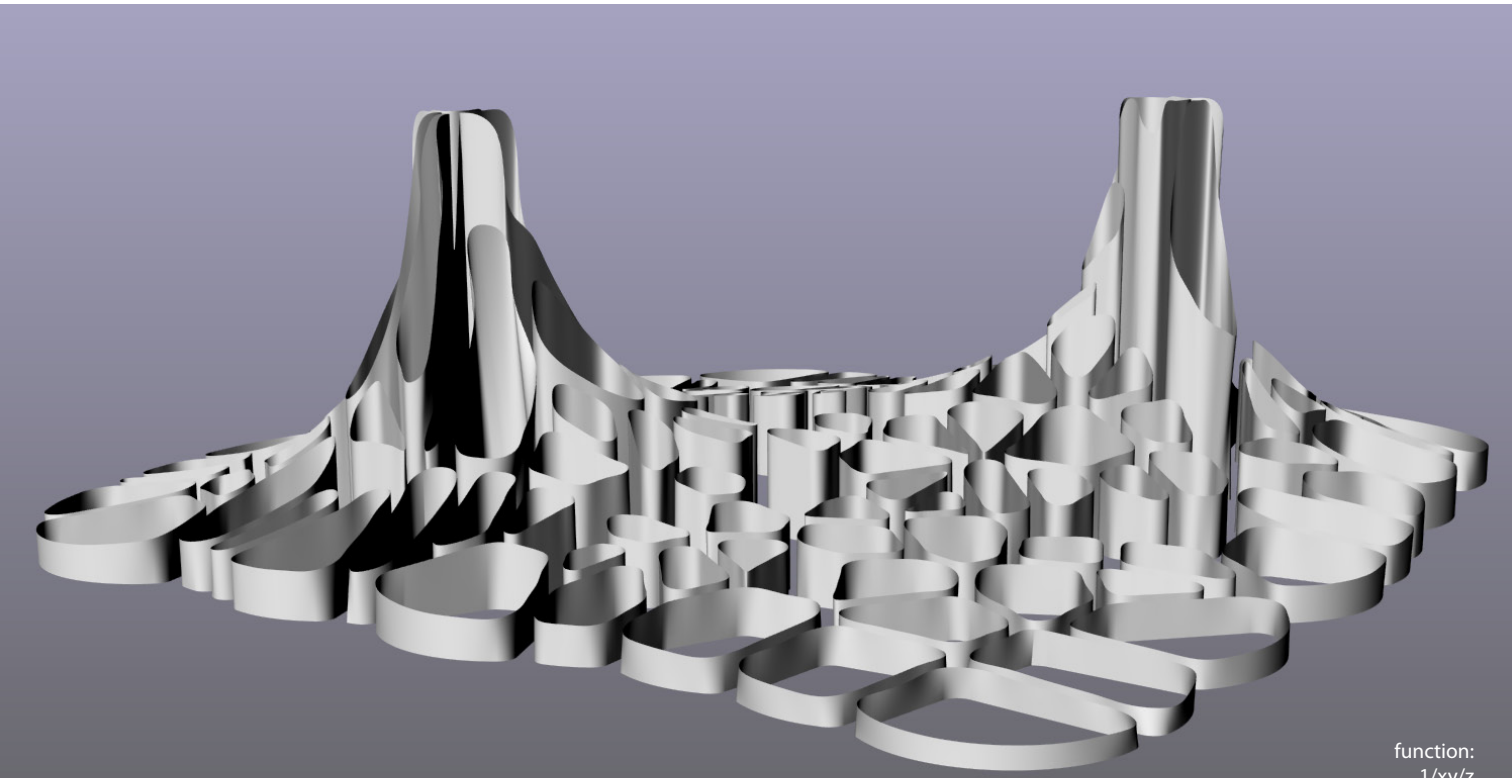
For every point a box is created, whose height depends on the distance to the center point. The final result came out to be changeable since a lot of parameters can be controlled.



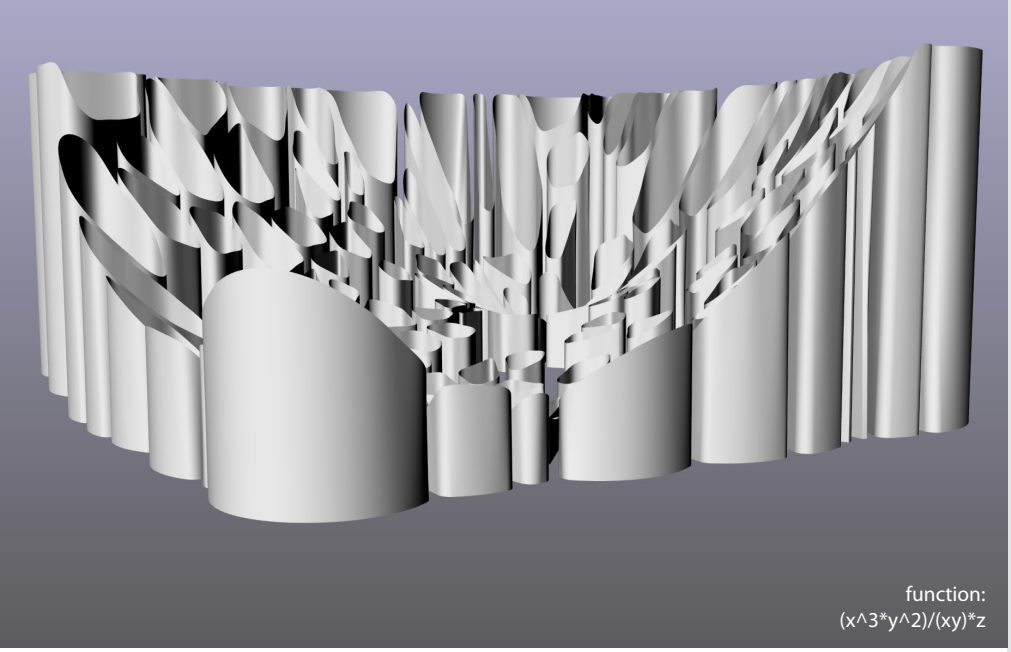
function:
ln(x)/y*z



function:
tanh(x)*y/z



function:
1/xy/z



function:
(x^3*y^2)/(xy)*z

1. Maths city

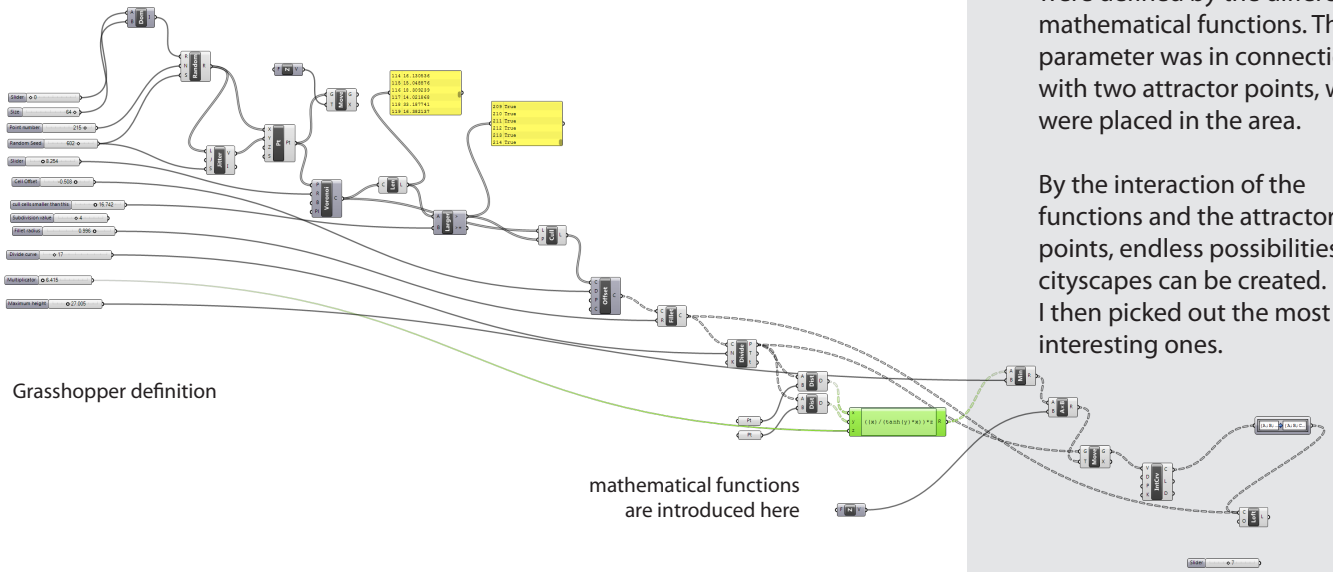
András Botos

The aim of this project was to experiment with different mathematical functions in order to create cityscape structures.

I decided to create a highly variable definition. The base defines random block surrounded by streets, in a streamlined form. By removing the blocks which do not meet a certain size, bigger open spaces were enabled between the blocks.

The height of the blocks were defined by the different mathematical functions. This parameter was in connection with two attractor points, which were placed in the area.

By the interaction of the functions and the attractor points, endless possibilities of cityscapes can be created.
I then picked out the most interesting ones.



Grasshopper definition

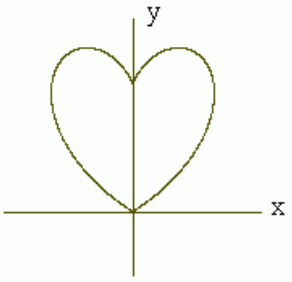
mathematical functions
are introduced here

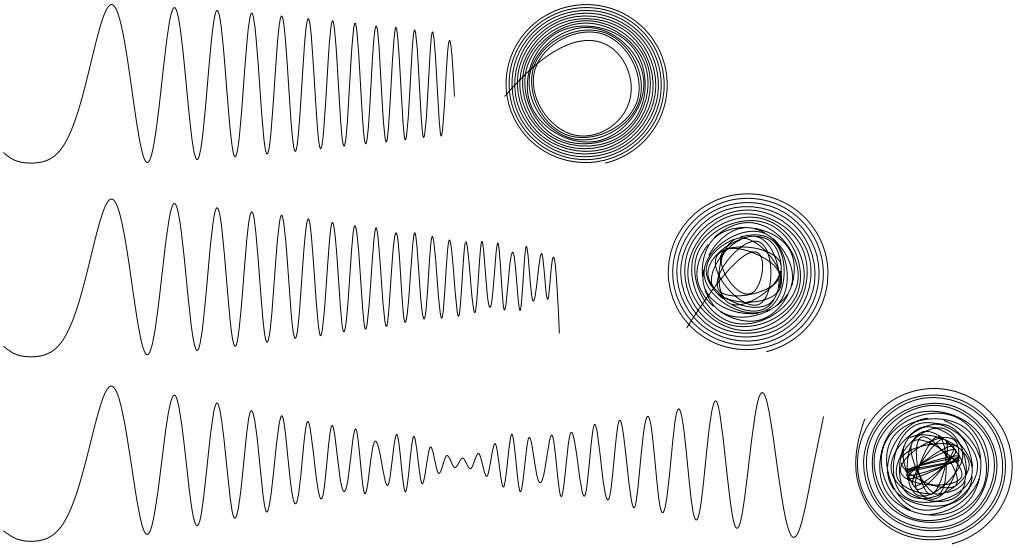
Function 1

$$x = \pm(-3t^2 + 2t + 1)\sin t$$

$$y = (-3t^2 + 2t + 1)\cos t$$

$$0 \le t \le 1$$





Curve - side view

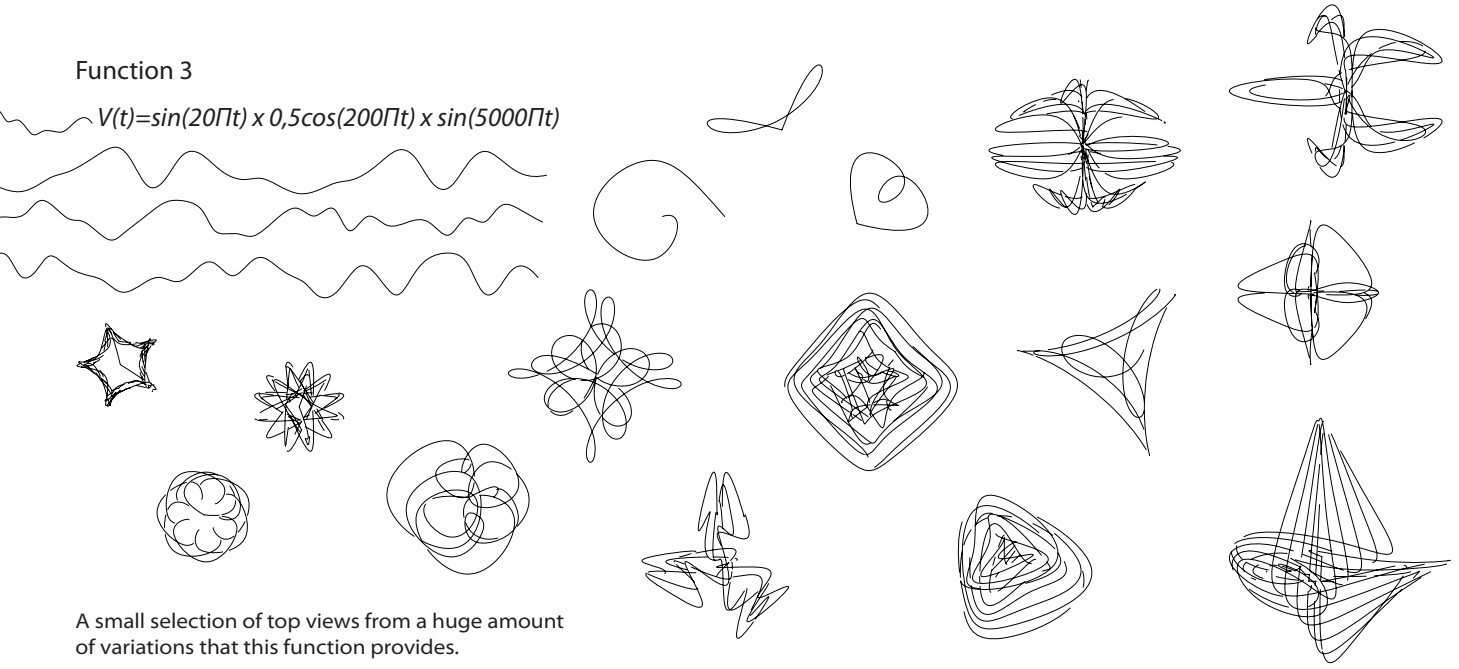
Top views

Function 2

F(x)= cos (z/2)

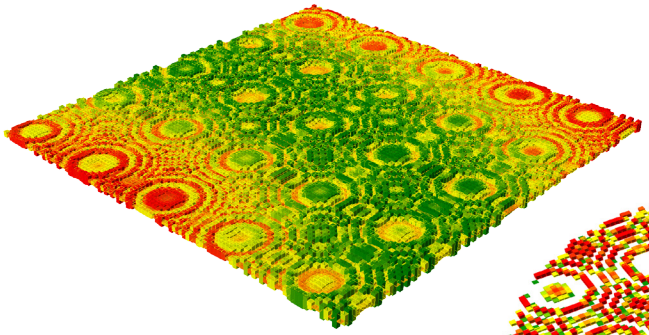
Function 3

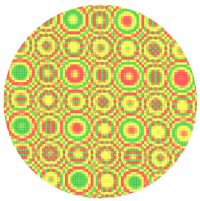
V(t)=sin(20Пt) x 0,5cos(200Пt) x sin(5000Пt)

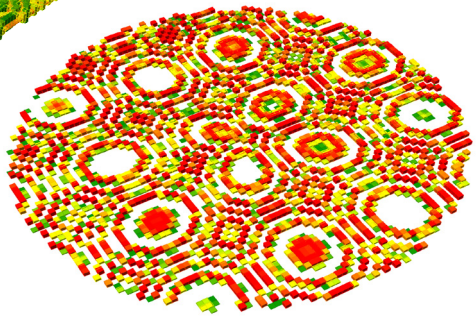


A small selection of top views from a huge amount of variations that this function provides.

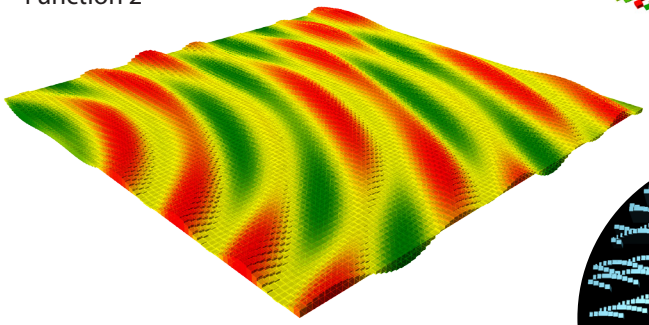
Function 1

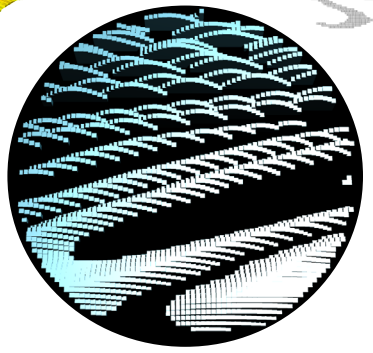




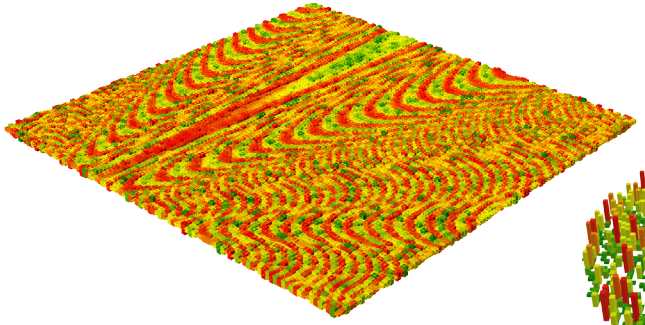


Function 2

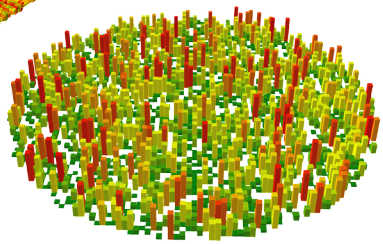




Function 3



Distance as function



Dispatch

1. Sexy Curves

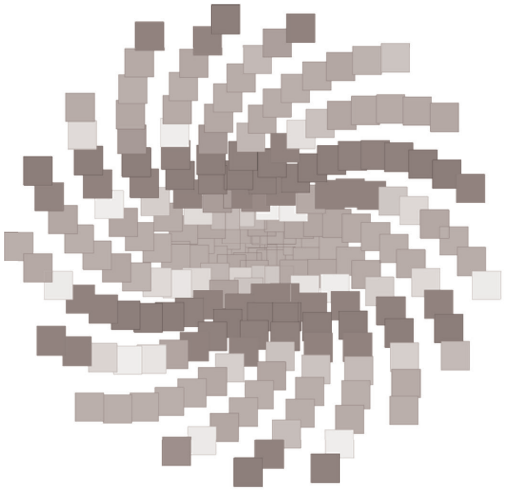
Lisa Voigtländer

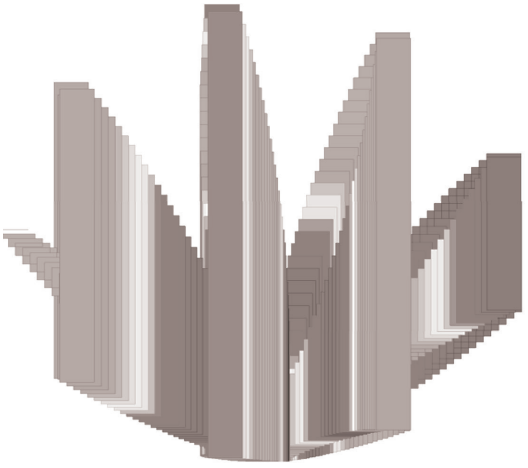
To explore the elegance of math, I searched for few equations. I found the mathematical expression to show love; the equation to form a heart. The other function I used is somehow related to acoustics and waves. The last ones I show here are other Cosinus functions.

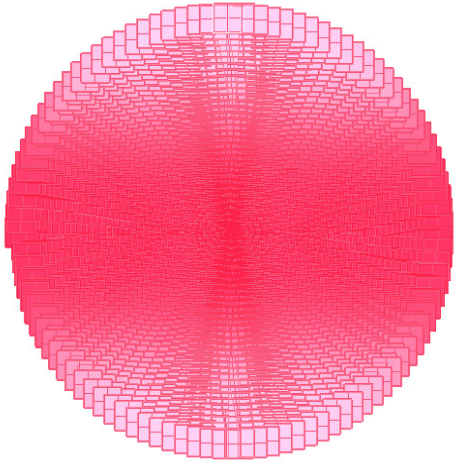
First I just tested them to draw simple line curves in 3D where I could slide through different values of the variable. I was very surprised by the beauty of these lines especially when I looked at the top view. It felt a bit like knitting several symbols.

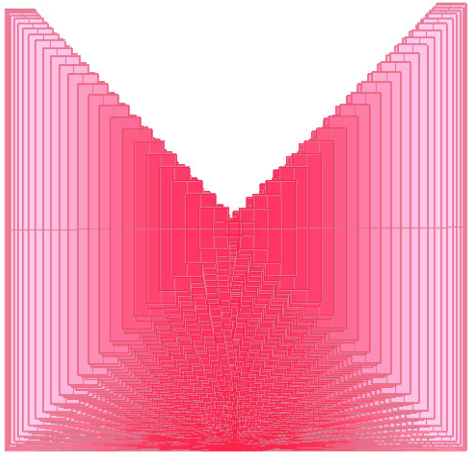
Then I used the same functions in a more complicated definition, we called “distance by function” with the result of getting some surfaces or landscapes, created by a grid of points transformed into boxes. Here it turned out, that the previous more regular, boring “Heart”-function became the most interesting one.

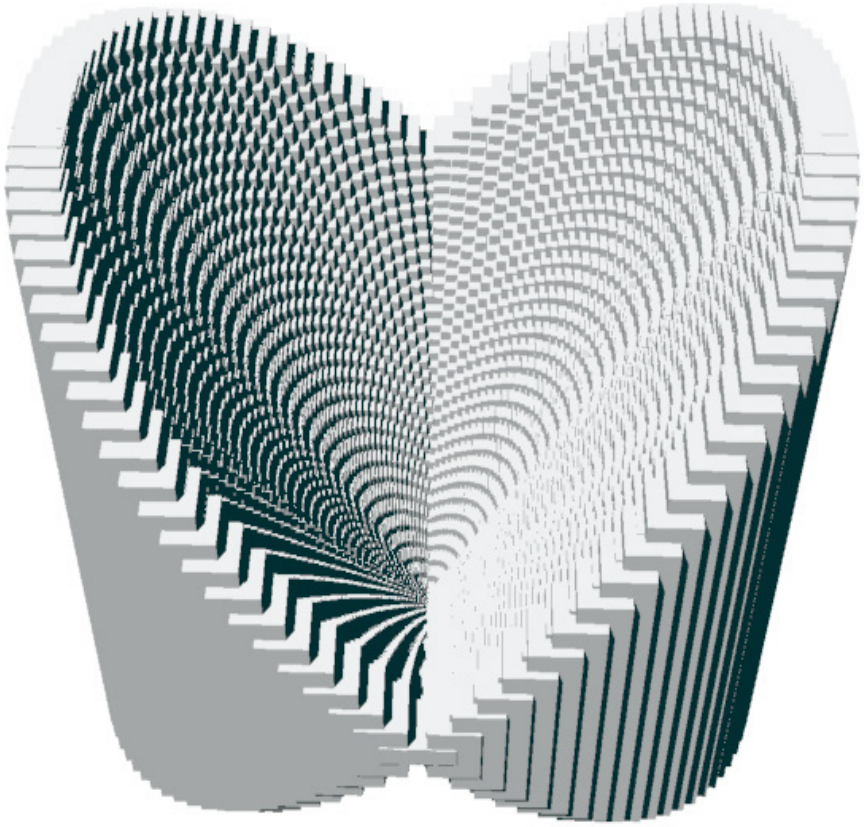
In the last step, with the button-like result, I set a middle point and eliminated everything around a defined radius and below 0.

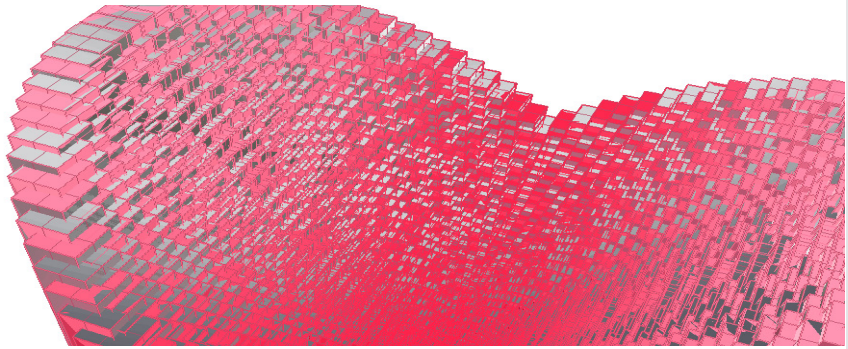












1. Function(al) Urbanism

Xianghe Gao

The "function of urbanism" is about how to use mathematic equations to get different versions of digital desiged models.

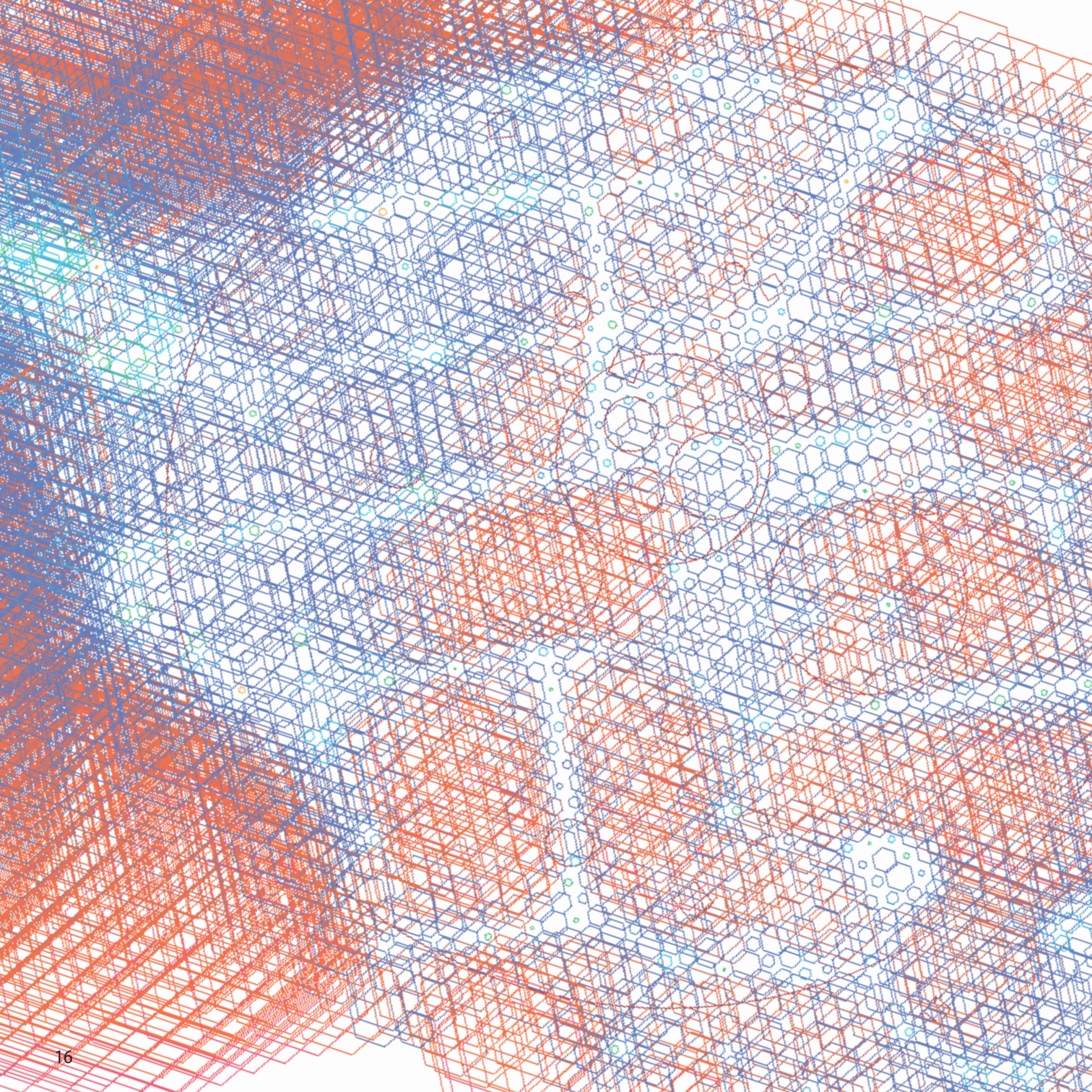
It is a totally new and interesting idea about architecture and design.

In this exercise, my friend Lisa and I tried to get a "heart" shape by using equation. After couple of experiments it was finally gained.

When the number is small, we can get a spiral shape but when the numbers getting lager the model changed.

So, I tried to change parameter in Z-axis to get the "HEART" shape.

This exercise, really broadened my eyes and was a starting point to discover another way of thinking architecture.



Attractive Hervanta

2. Mission

Select a location within Hervanta, Tampere and map out different urban attraction factors it may have. Define those factors either as point or curve geometries on top of an aerial image or map.

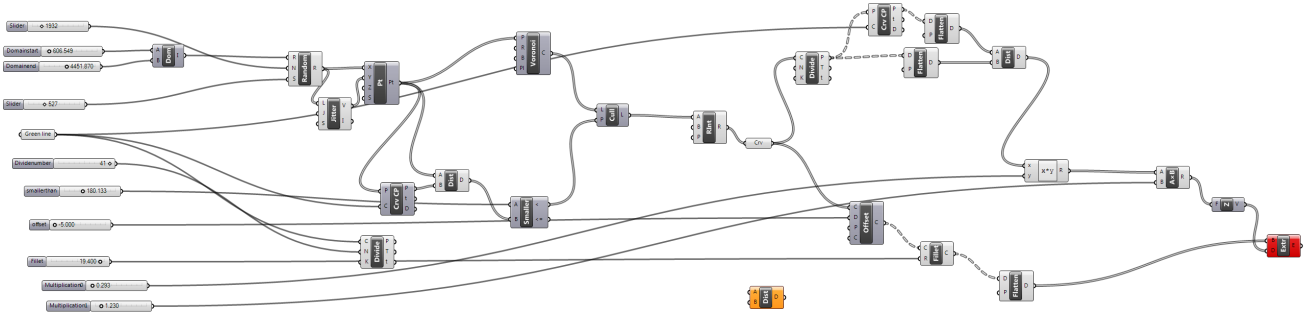
Choose a location within that map and design a small scale urban area that utilizes the attraction field potential. Use the generated field to define density, orientation, height, scale, etc… of your urban plan.
The closeness to a certain point can used to increase or decrease defined parameters (e.g. closeness to parks, roads, etc.).

Your design should be the result of your design intentions and the environmental attraction factors.

The main goal of this exercise is to familiarize you with attractors and their use as urban scale parameters and how to implement them in your design.

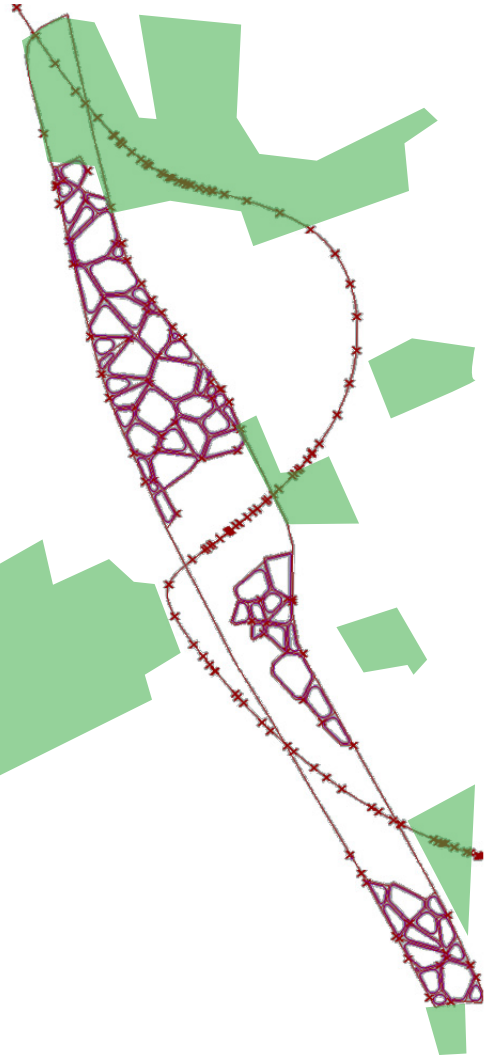
2. Explorations

Perspective view



Grasshopper definition

Concept



Defining green areas, and planning connections

Building zones

2. Hervanta center

András Botos

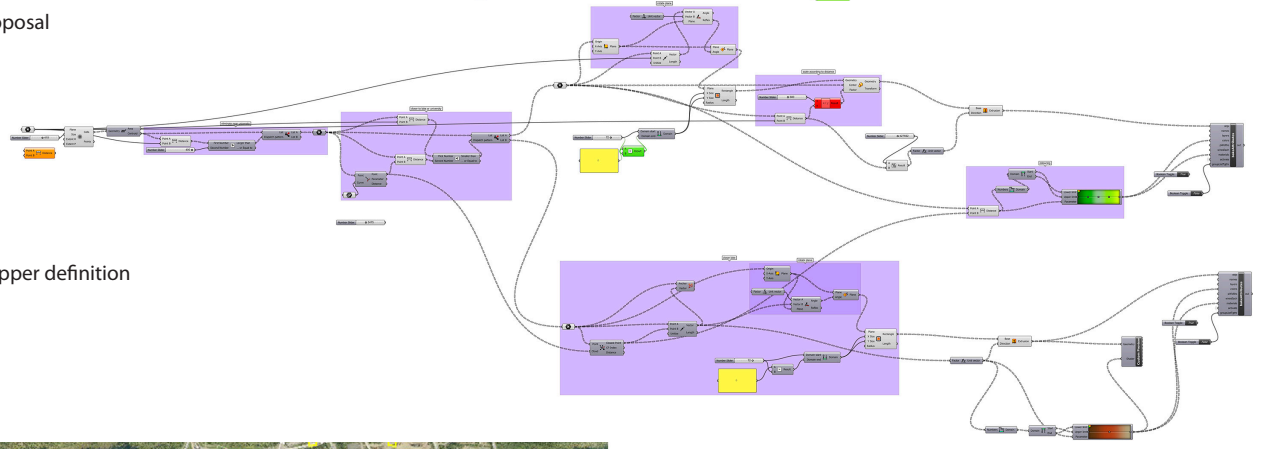
The aim of the project was to create a proposal for an area somewhere in Hervanta. I chose the area between Hervannan valtaväylä and Insinöörinkatu.

At first I traced the green areas with the help of the satelite images. I realised that these areas were scattered and unconnected.

I created a connecting line, based on the location and size of the green areas. The intersection of this line and the area of intervention creating the connecting new green spaces.

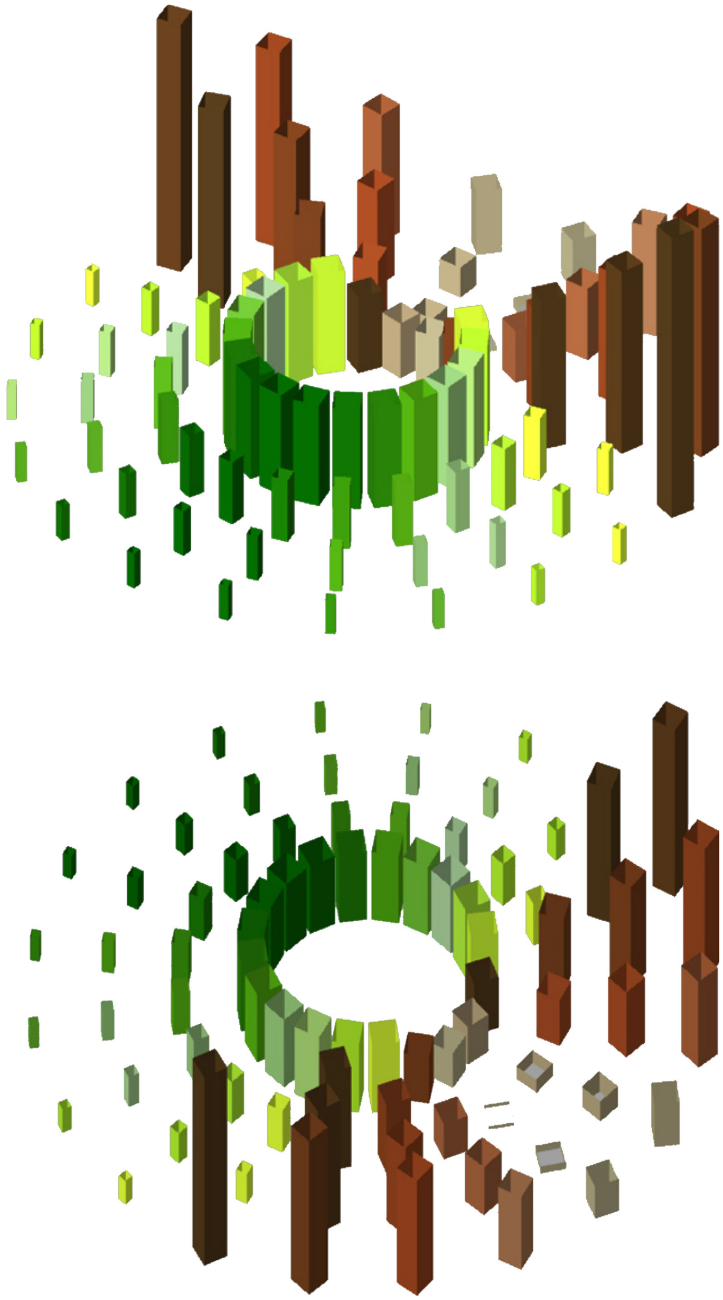
The rest could be used for building. The buildings were placed on a voronoi grid. Their function was based by their nearby buildings, for example next to the university campus there are educational buildings and student housings.
The functions of the buildings were indicated by their height and floorplan area.

New proposal



Grasshopper definition

General plan



Aerial views

2. Attractive Hervanta

Rafael Alonso Candau

The aim of the project was to explore and redesign an area of Hervanta, according to its most interesting points.

Because it is a student neighbourhood, the centre of the new proposal is established in the university, where the streets converge.

From there, the height of the buildings is affected by the distance to the centre, as well as the size, which gives a decreasing intensity result to the area.

For those buildings that are closer to the lake than to the university, the process is inverse. The closer the volumes are, the smaller, so more buildings can see the lake.

These part of the intervention is also rotated towards the lake, to improve the views.

Urban attraction factors

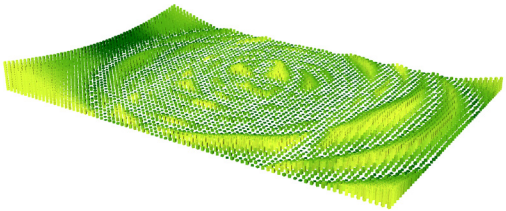
Attraction circles-Urban infrastructure

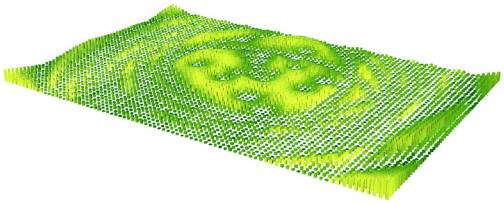
Student housing

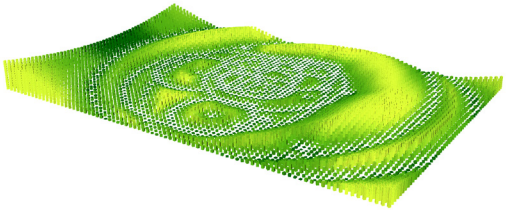
Streets-roads-connections

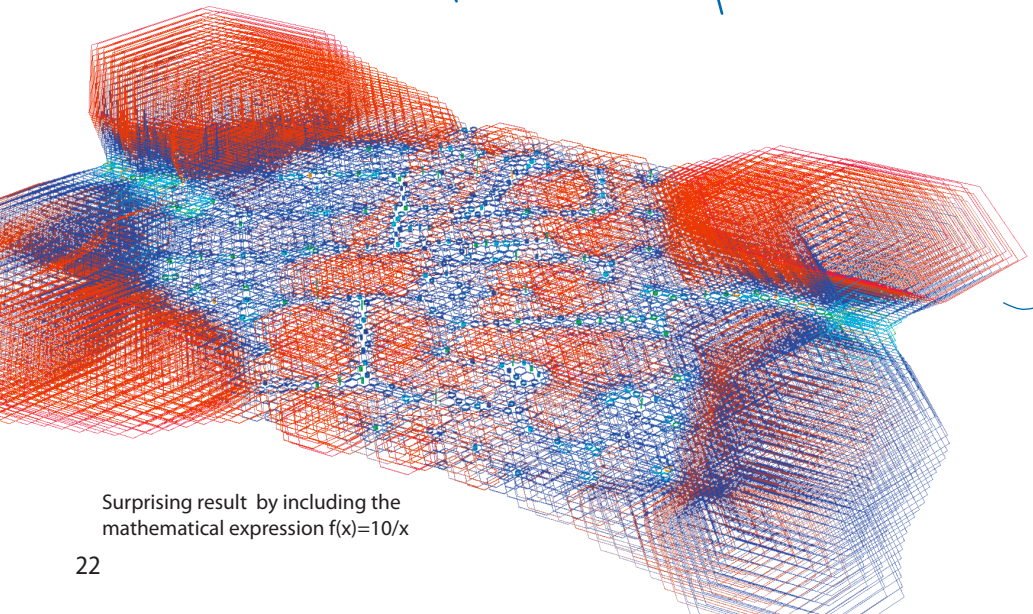
Map of Hervanta

Experiments with calculations of area spaces

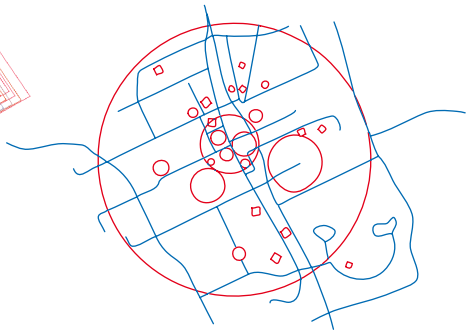




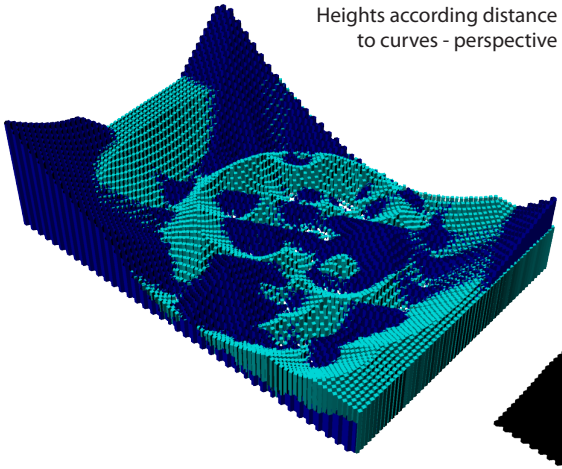




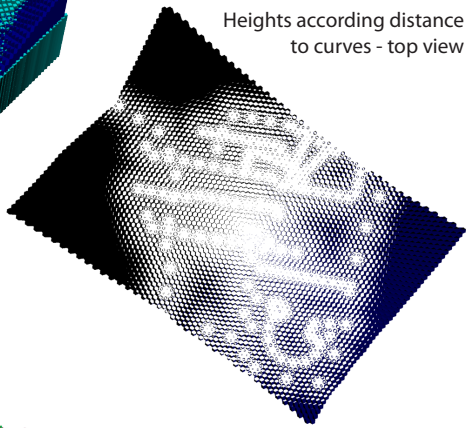
Surprising result by including the mathematical expression f(x)=10/x



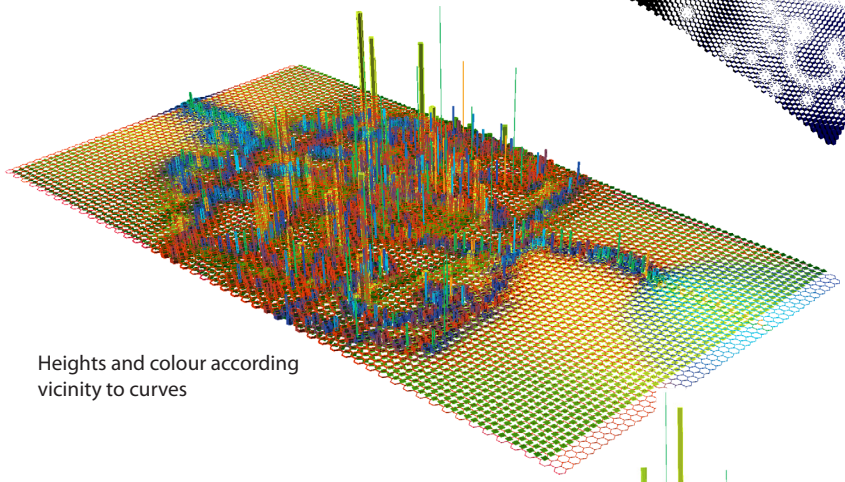
Basic curves



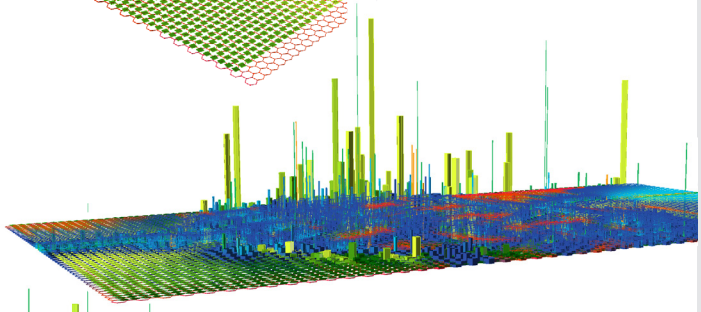
Heights according distance
to curves - perspective

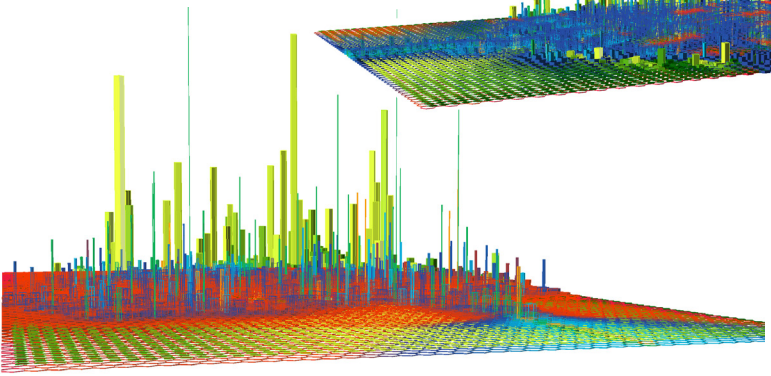


Heights according distance
to curves - top view



Heights and colour according
vicinity to curves





2. Attractive Hervanta

Lisa Voigtländer

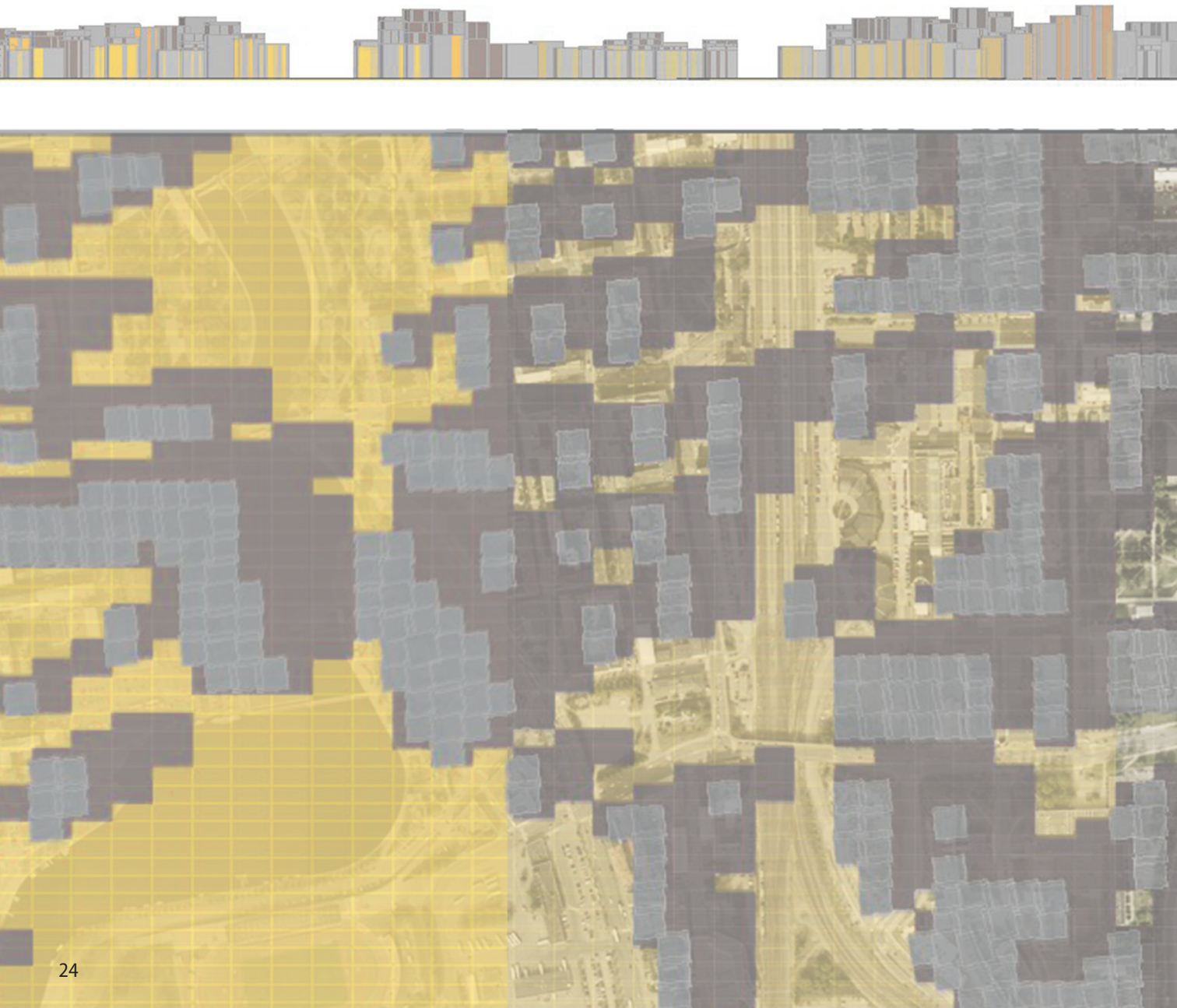
In the beginning, I used the map of Hervanta to define some "attractions" in order to have a basis for testing different Grasshopper definitions and mathematical expressions.

The main streets are drawn as curves, circles for attractions like the Campus, etc. and squares for student houses.

I tested rectangular and hexagonal grids, for example to rotate them towards the attractions or calculate the space of these areas and show as heights and colour.

I also created the heights according to distances, which resulted in this mountain structure where the highest points are furthermost away from the drawn lines.
So I tried to change it to the opposite and have the highest structure at the attractions.

The results are still very experimental and far from an actual building but they show a different kind of analysis and could be a starting point for an urban design.



Sun Analysis

3. *Mission*

Use the solar analysis exercise done during the class and use it to analyze an existing urban design. You may use your design from exercise 3 or you may have an older existing design ready.

If you do not have a suitable design for this analysis, you may create a simple design especially for the analysis purposes.

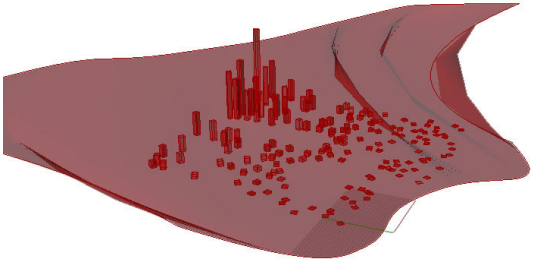
Analyze the solar energy that falls on to the terrain and pathways OR to the buildings. The analysis can be made on a specific day and time or it can span the range of several days/ hours. For instance, what would the solar energy look for an entire year, day by day? Create an animation from that analysis.

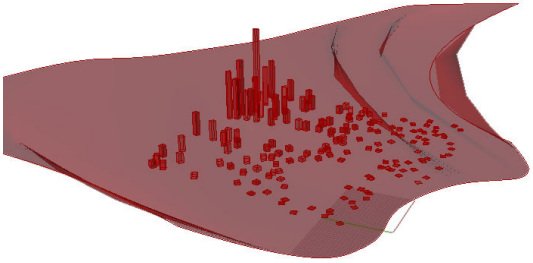
Think of different ways you could use the solar analysis tool for design purposes:

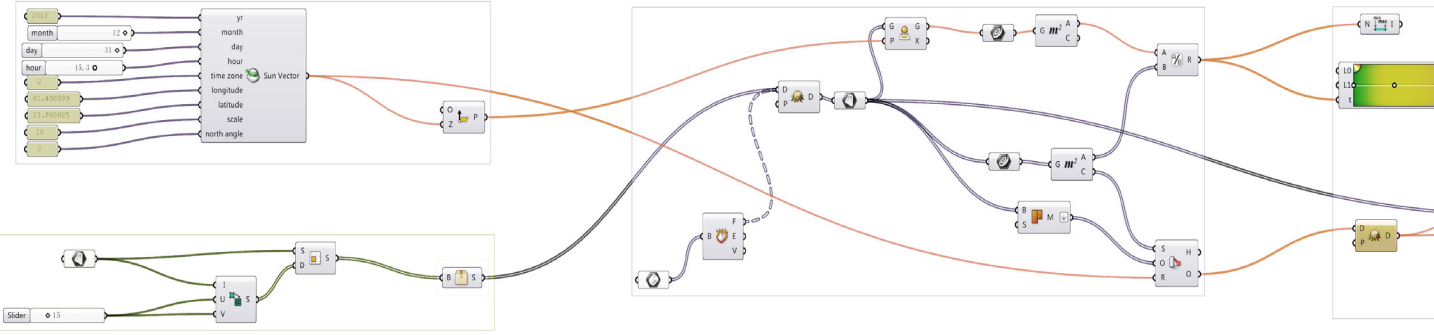
- *orientation*
- *distribution*
- *walkways*
- *shading*
- *etc…*

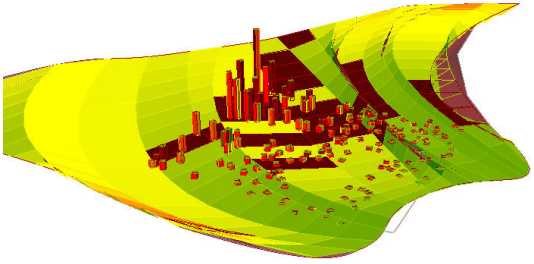
Give out few ideas, how you could implement it in your design.

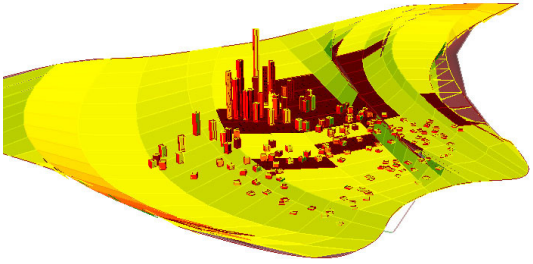
3. Explorations





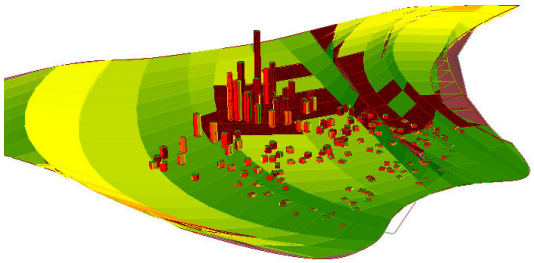

yr
month
day
hour
time zone
Sun Vector
longitude
latitude
scale
north angle
Slider

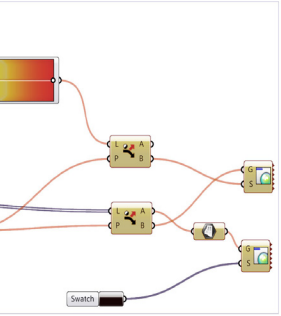


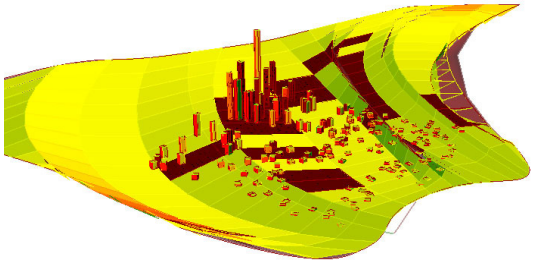


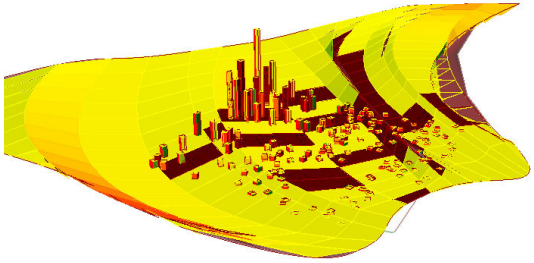
3. Solar occlusion

Xianghe Gao









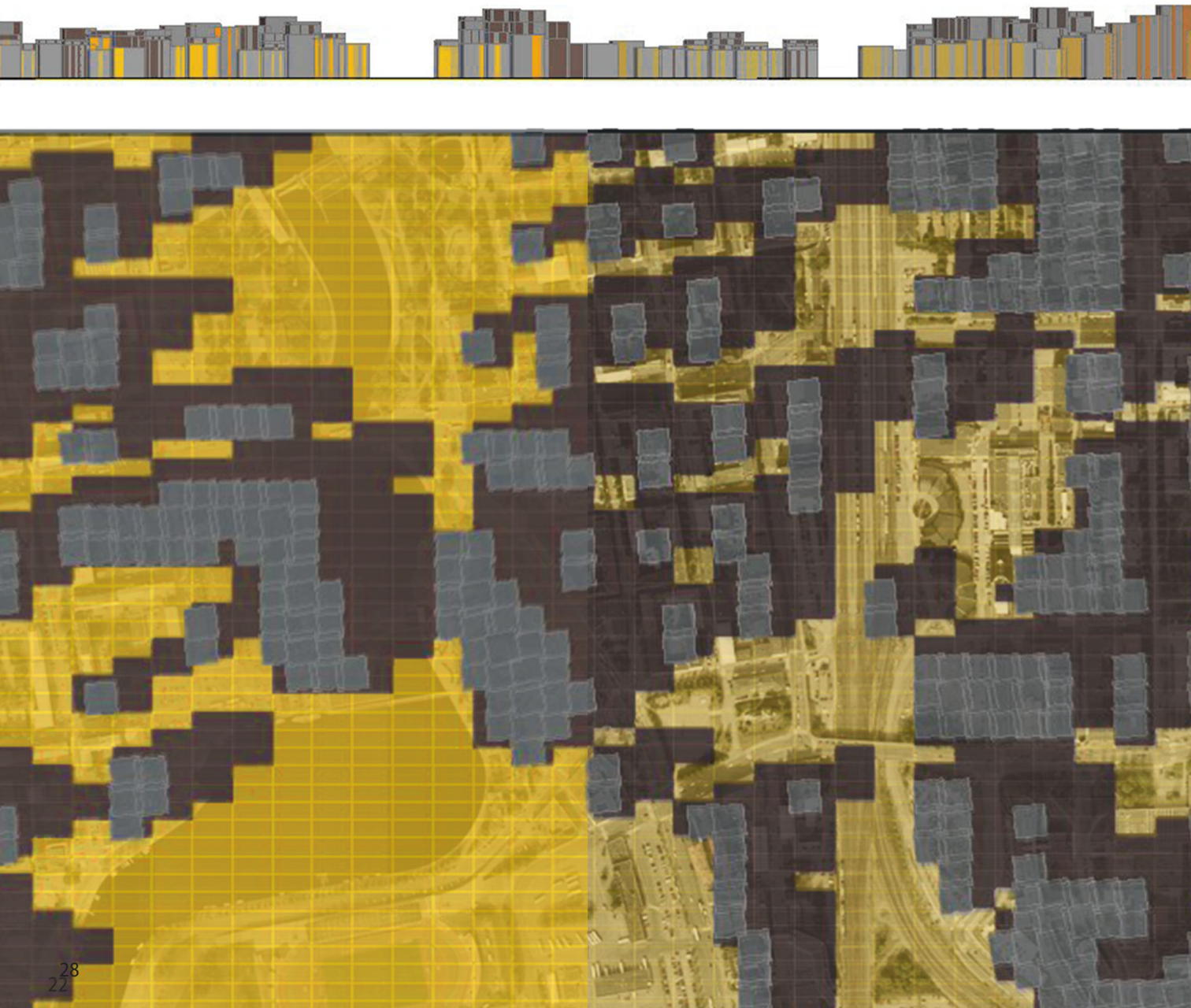
The "Solar occlusion" is a useful tool to analyse the sunshine and solar radiation of a 3D model.

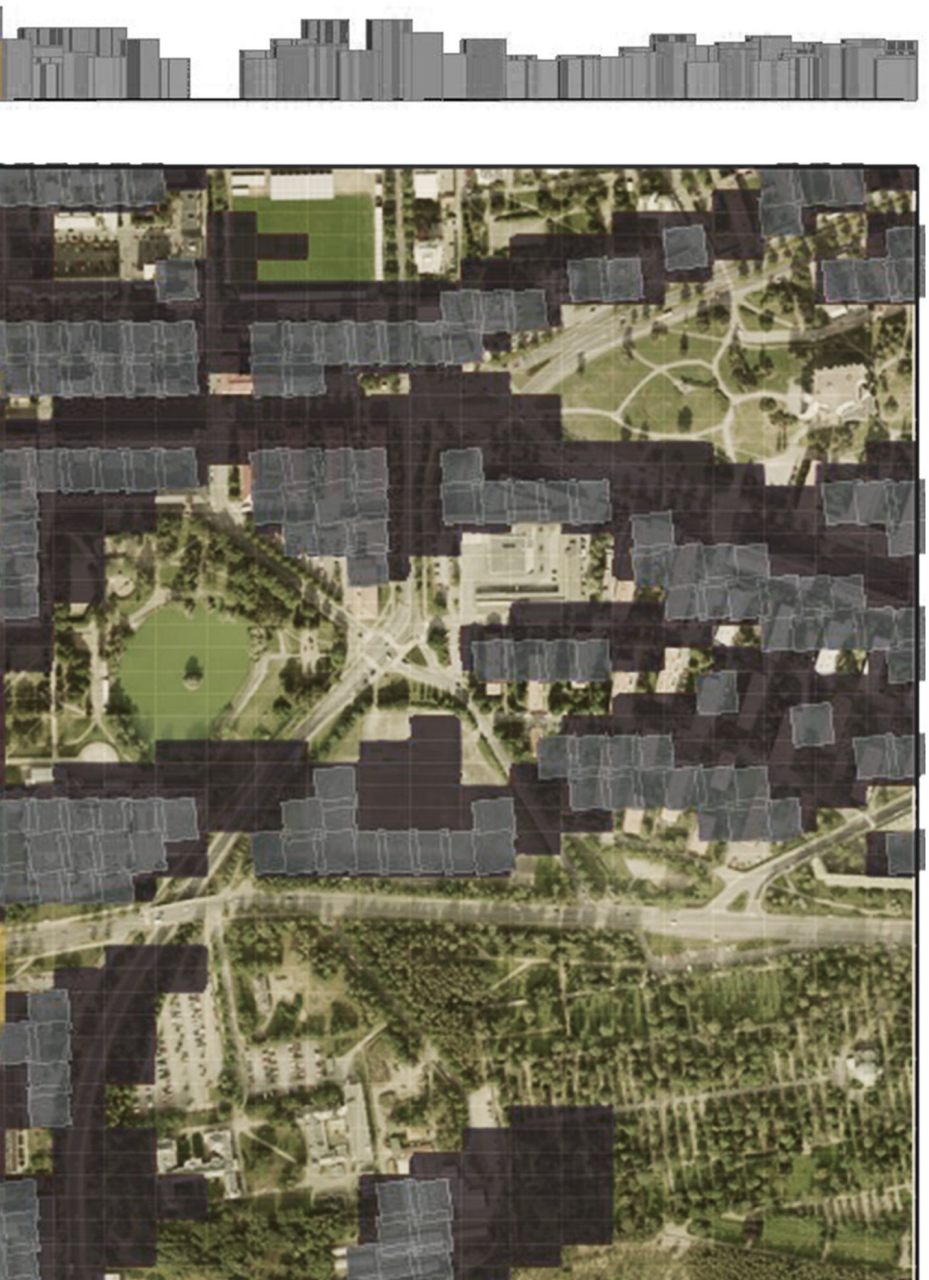
With changing the parameter about "year, month, day and hour" we can even gain different animations, which show the analysis in an intuitive way.

In this page, I set the year as 2013, and we can see the building's shading change by 12 months. Then it is easy to get the conclusion about influnces between buildings.

According to the occlusion command, it is easily and accurately to analysis the sunshine and shading. No matter what the topograpy or the shape of building is.

This method might be used in other fields as well, not only for solar analysis.





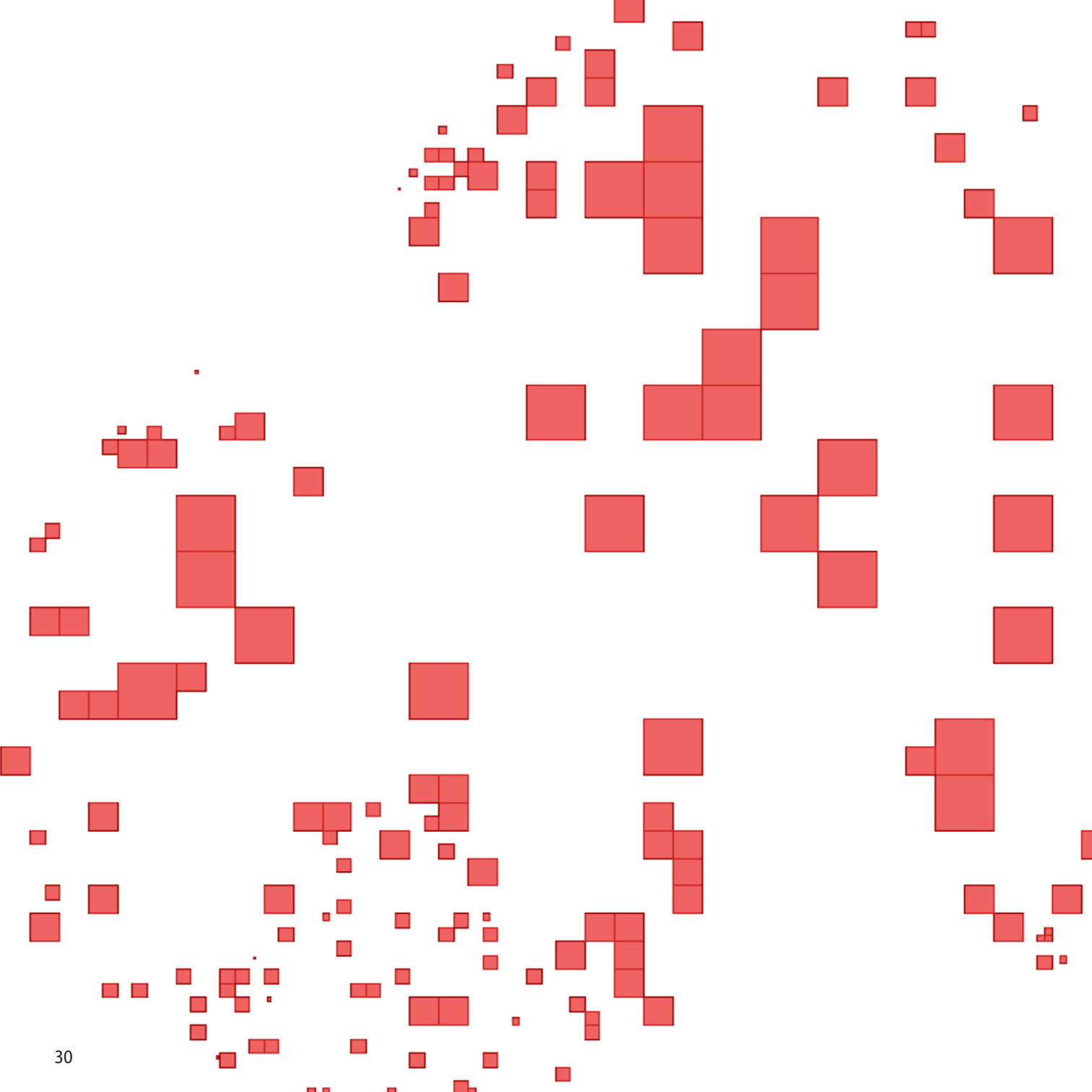
3. Sun Analysis

Nina Hatzitheofilou

The solar occlusion exercise was a very interesting task in discovering a new method and tool for urban analysis. The level of accuracy of the sun path across a terrain as complex as the city is in general very useful.

What is even more interesting though is the potential interpretation of this information. The sun, being such an important element to human life, can have a big influence in the design process. Other than shadow, such an analysis can define paths of orientation, distribution and circulation in the urban space.

It would be exciting to take this solar analysis information to a new level of understanding before proceeding in any design task.



Pattern Design

4. Mission

Explore the design possibilities of Voronoi, Delaunay or other patterns in small scale urban design.

Keep in mind the realistic scale of buildings and surroundings. Pick a location of your liking, or you may also use the given location for your design.

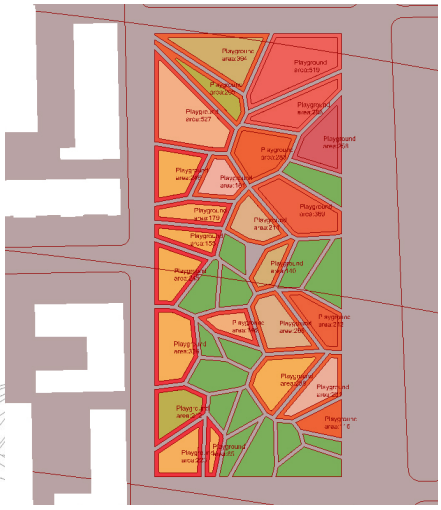
If possible, try to take advantage of the intelligence of the pattern creating algorithms, how they define connections or divide area.

Create algorithms for your design, where you define some of your design characteristics through area, height, location, distance, orientation, etc..

4. Explorations

Pattern design

Tammela square
aerial view



Top view

TAMMELA SQUARE

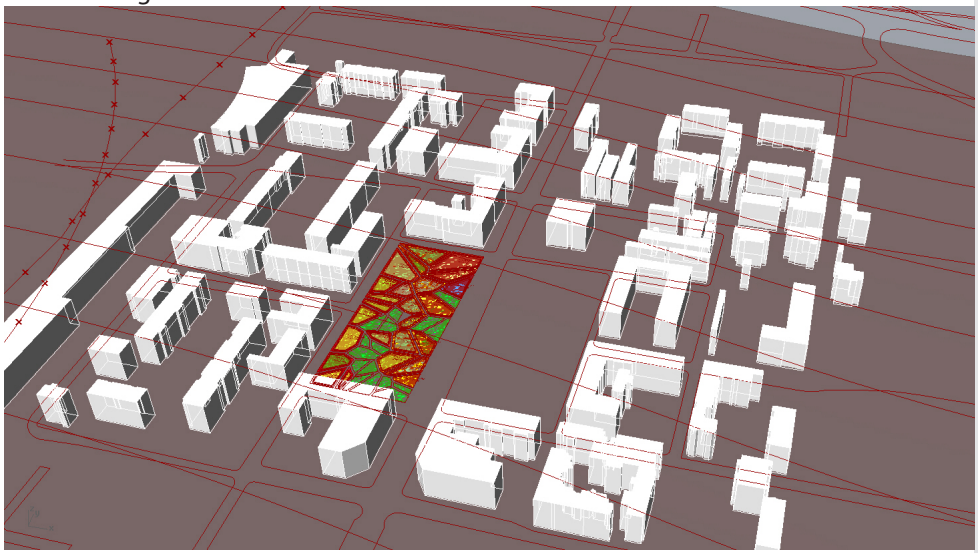
Input data >>> Attraction points

Attraction points >>> Voronoi surface >>> Green + Playground >>> Move to terrain

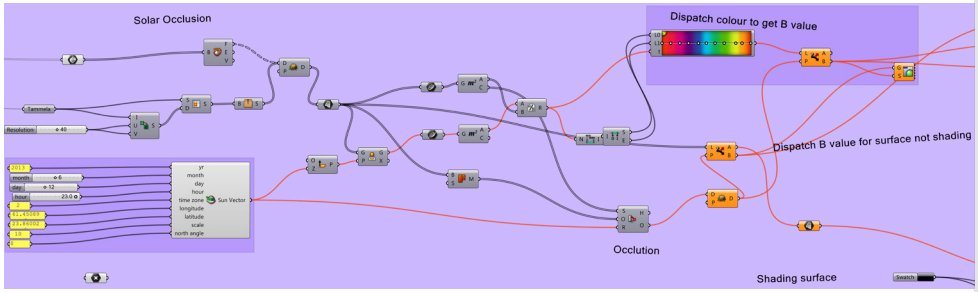
4. Pattern Design

Nguyen Minh-Chau

Pattern design



Final model



Solar Occlusion Analysis

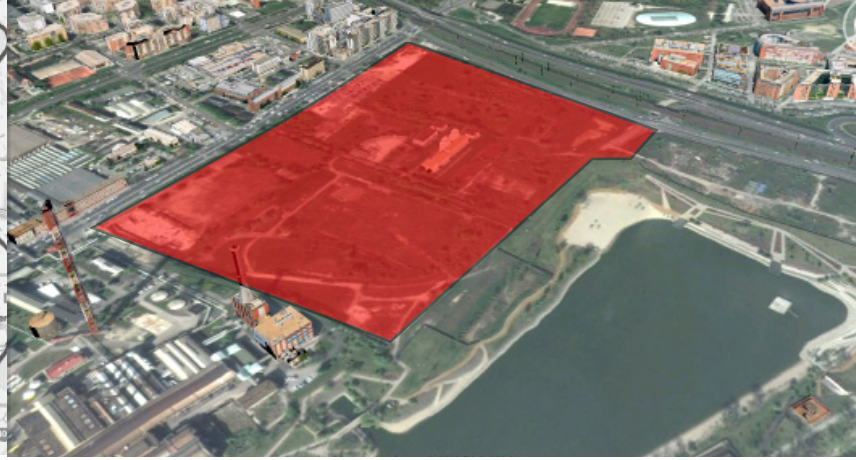
Explore the design possibilities of Voronoi in small scale urban design.

I develop the concept from a landscape project in Tammela Square, Tampere. From the input data, including the nearby railway, existing trees and restricted border, we get the attraction points. Then we create the voronoi pattern inside the border.

I separate the green and playground by their calculated area, the one which is smaller than the minimum value, will be organised as green space.

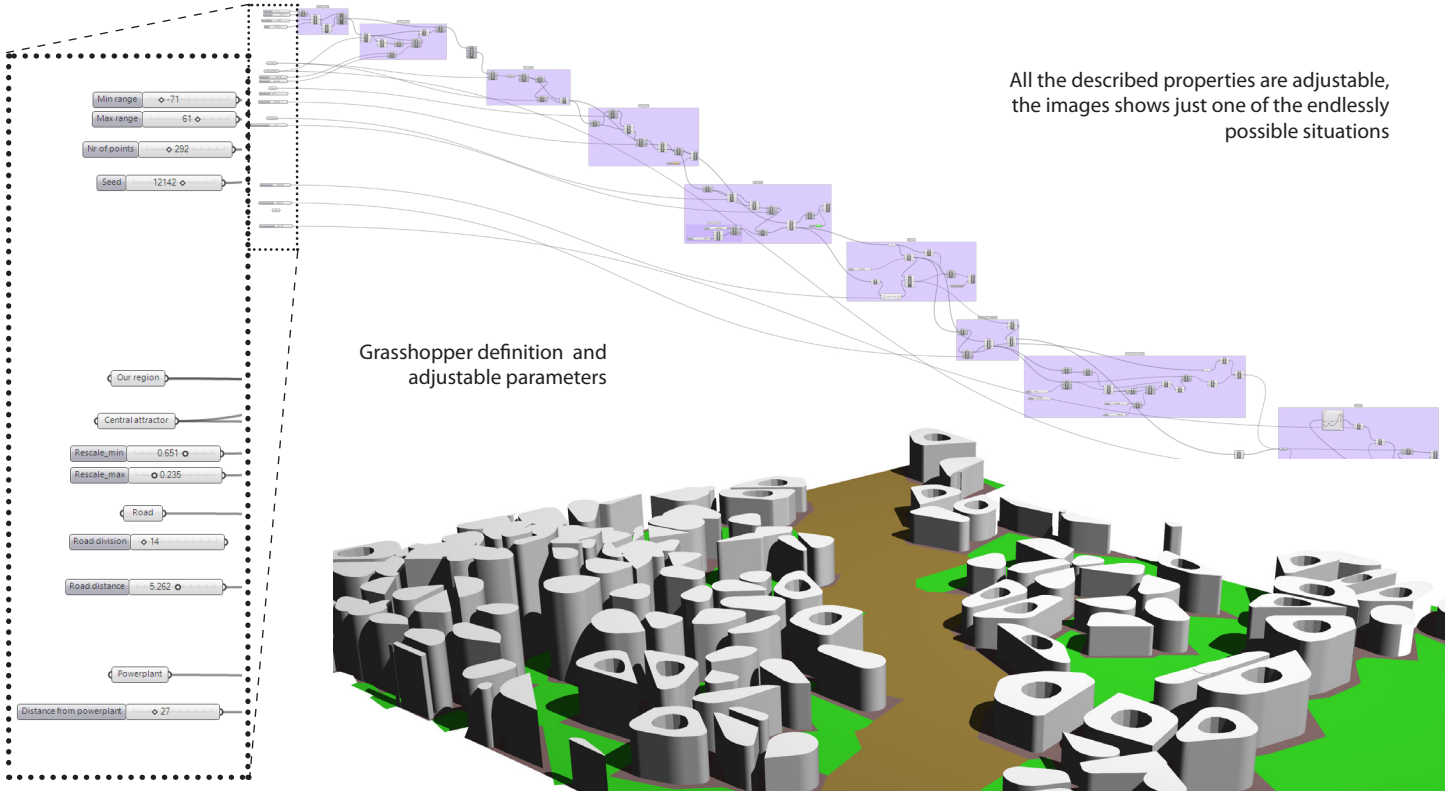
Finally, the patterned landscape design will be moved up. The distance depends on the existing terrain of Tammela Square.

The solar occlusion analysis is animated with the span of 24 hours.

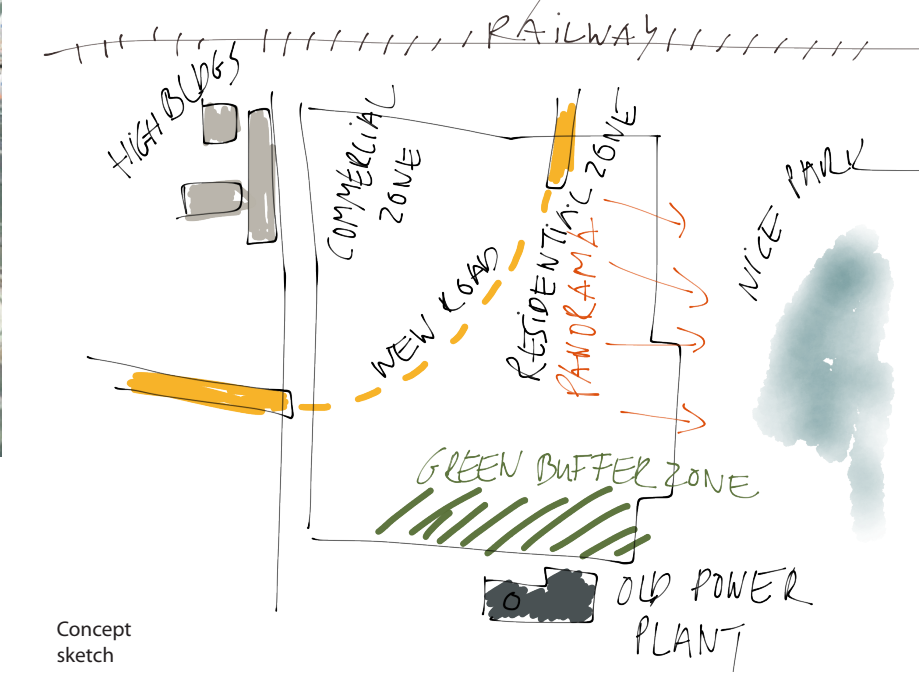


Location of plot

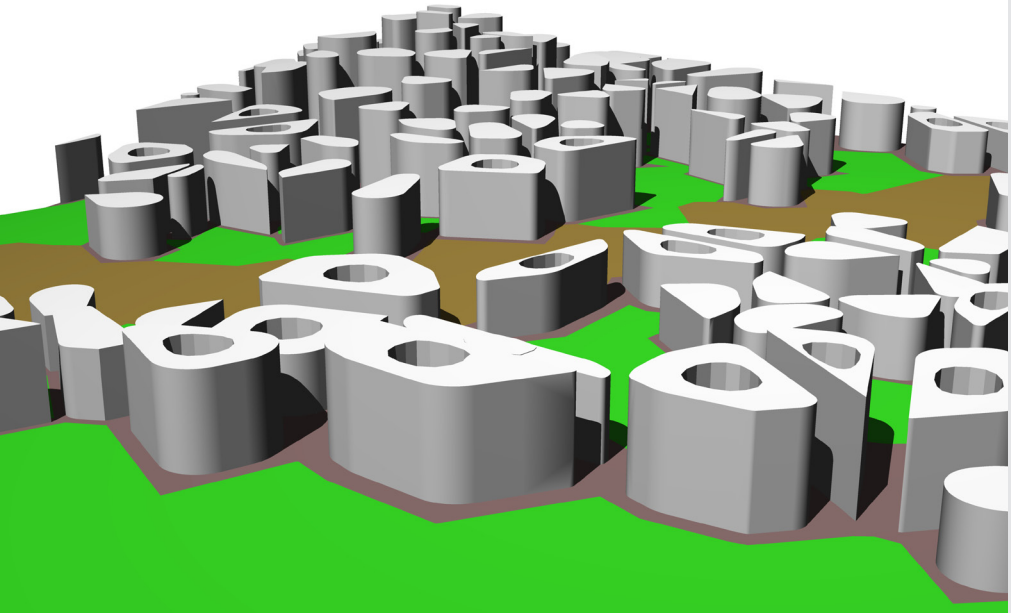
All the described properties are adjustable, the images shows just one of the endlessly possible situations



Grasshopper definition and adjustable parameters



Concept sketch



View from the south

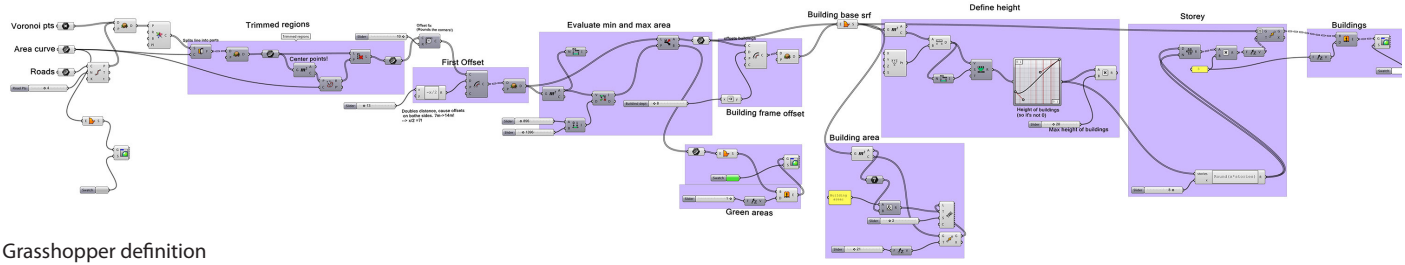
4. Waterfront development

András Botos

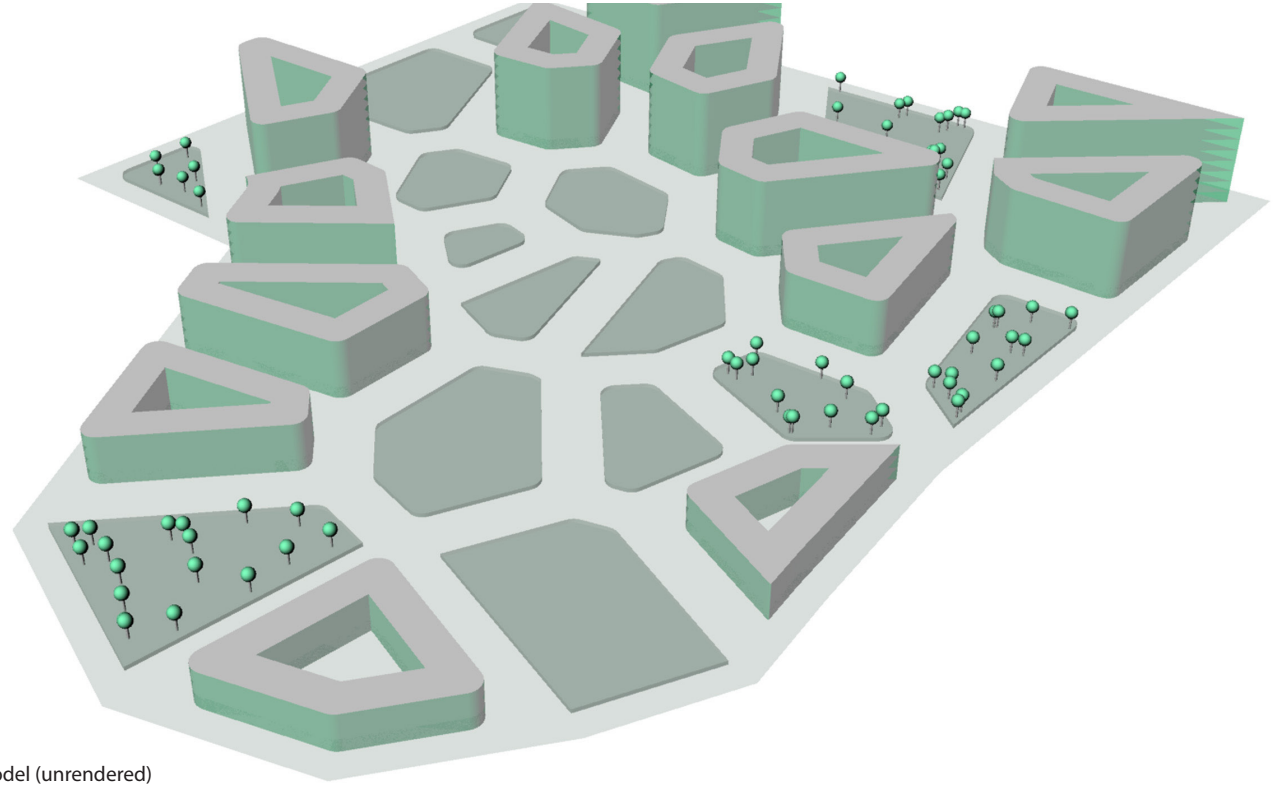
This project was an experiment to create a more complex proposal to react on the different conditions of the chosen abandoned area in Budapest.

The site had challenging conditions. From south there is a power-plant which should be avoided. On the east side there is the river Danube, with a nice park and beach nearby. On the northwest border there are mainly commercial buildings, while on the southwest side residential. Additionally in the north there is a railway line, and there are two unfinished roads on the edges.

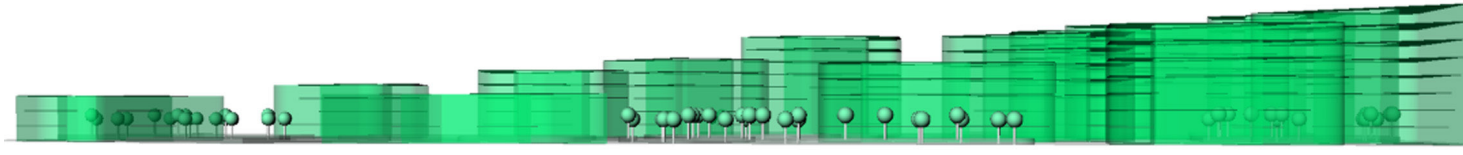
I started by dividing the site, meanwhile connecting the two dead ends of the roads. Then I created a green protecting belt to the power-plant and the northern side. The residential buildings have received an adjustable courtyard. The width of the pavement was also influenced by the functions. I created a gradually increasing height of the buildings, allowing nice views to the river and adjusting to the surrounding buildings.



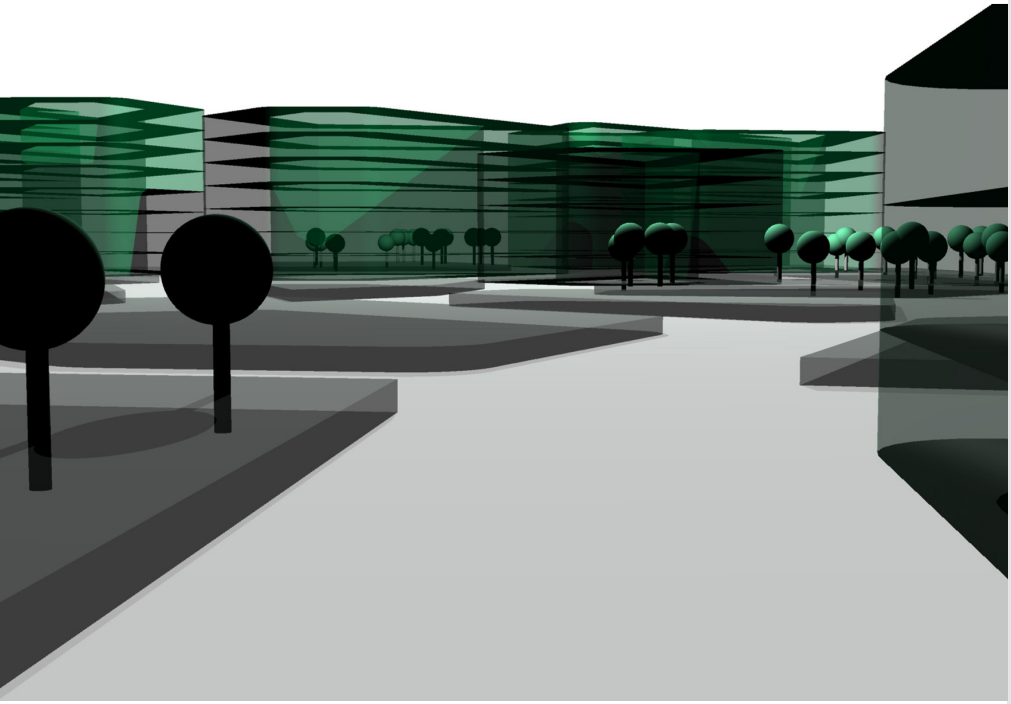
Grasshopper definition



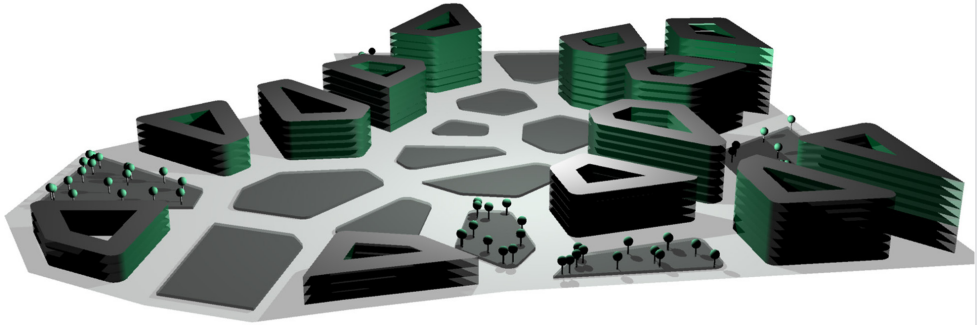
Urban model (unrendered)



Elevation



Perspective view of Hervanta



Render of the urban model

4. Pattern Design

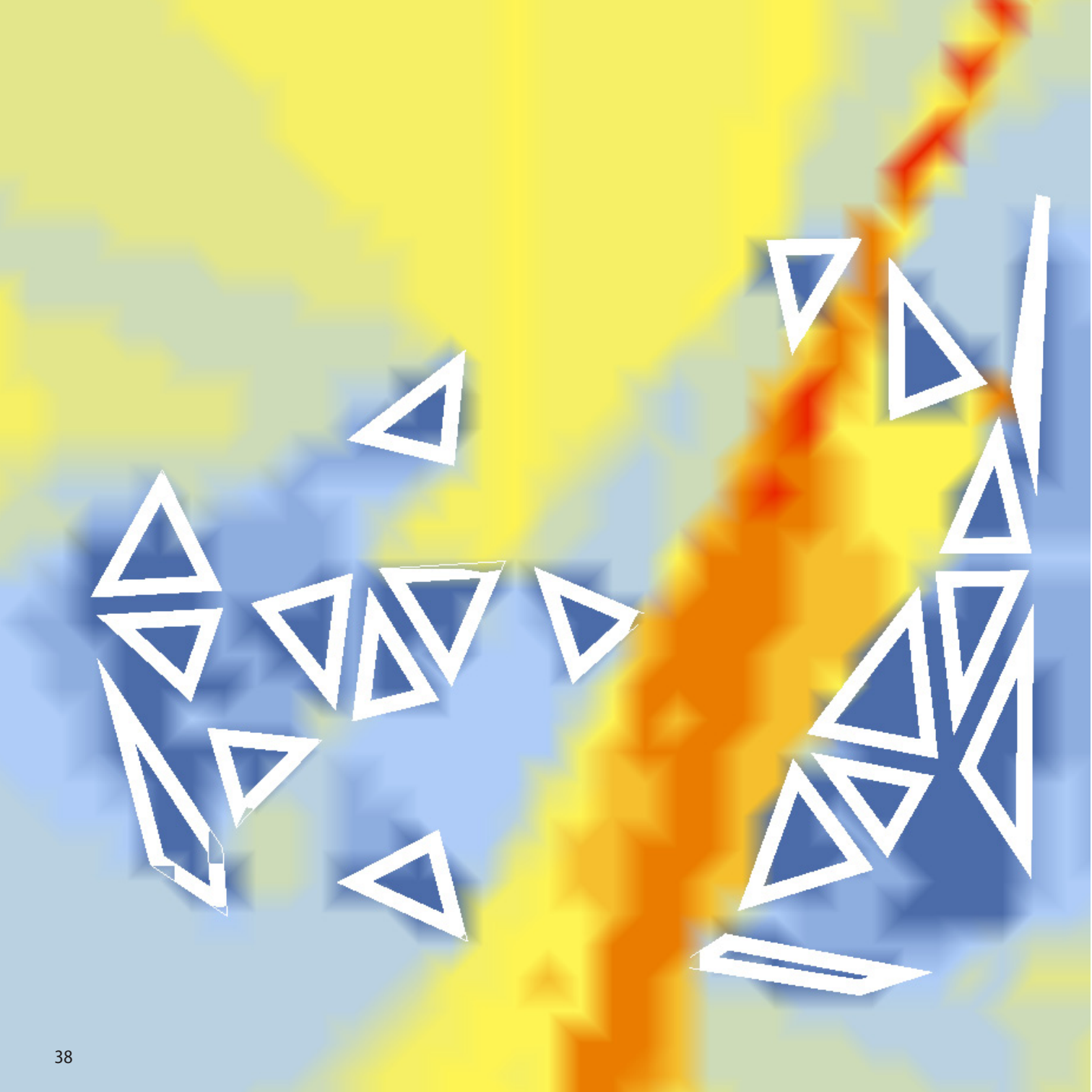
Isabella Pollak

For the task Pattern Design, I designed an urban model for future Hervanta.

The starting point was a rectangular grid, which I lifted up. I used the points to create vectors. The ending point for all vectors is a defined point in Rhino. Perpendicular to those points I created polygoncurves that are extruded in the direction of the vectors. The length of the extrution is controlled through a slider.

Trying to give the polygons a more architectural outlook, floor levels in a height difference of three meters were created. Saving the floors and the hull of the buildings in two different groups in Rhino helped me to colour them differently. The floors are solid grey, while the hull is translucent green.

After rendering the urban model with the light settings of Rhino, the effect of the various material settings is clearly visible.



Isovist Analysis

5. *Mission*

Create a visual three dimensional isovist view analysis of one of your earlier existing urban designs.

Alternatively you can analyze existing urban area from Tampere or other city. Choose a significant open space, public square or pedestrian oriented public street.

Try to imagine yourself in that spot or walking along the route, how does the isovist analyze correlate with your image of that space.

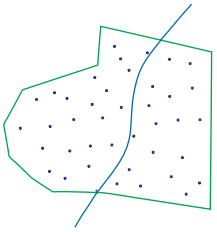
Is there an "optimal" space for views, narrow pathways that offer privacy, etc…

What does the isovist analysis reveal? Can you make some design assumptions from it?

5. Explorations

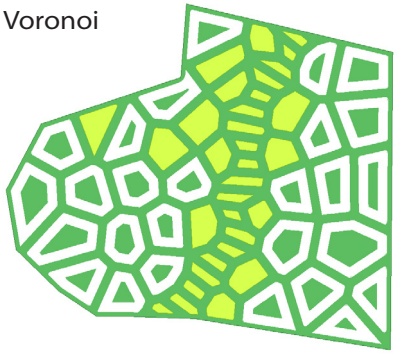
Pattern Design Results

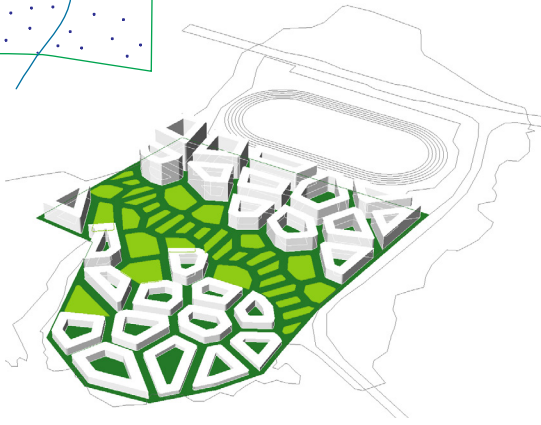
Basic drawing of all designs



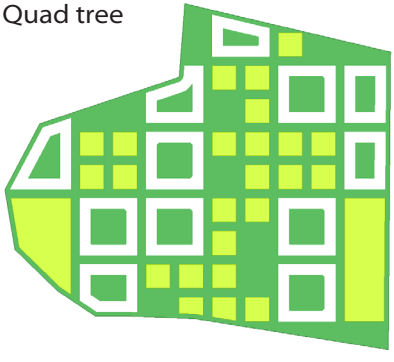
Isovists

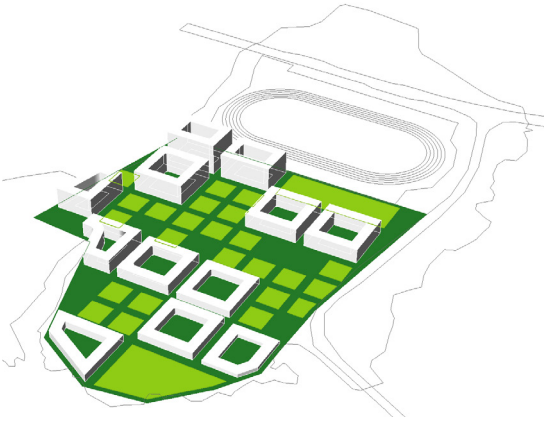
Voronoi

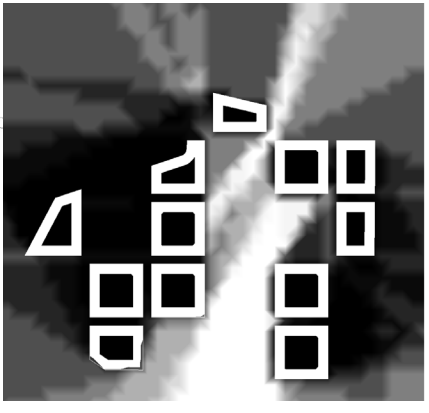




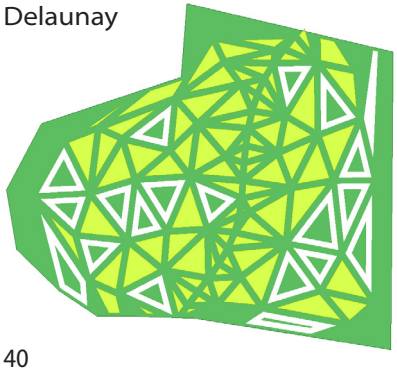
Quad tree

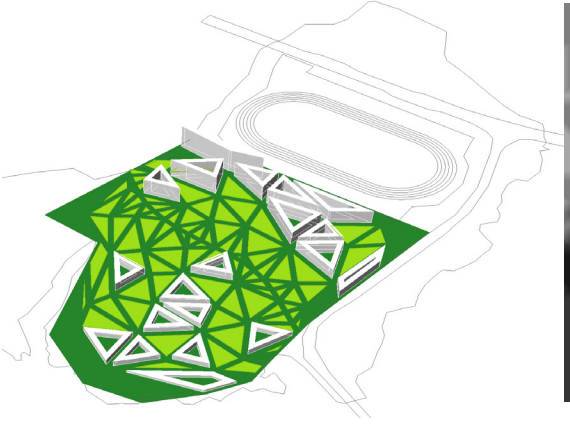


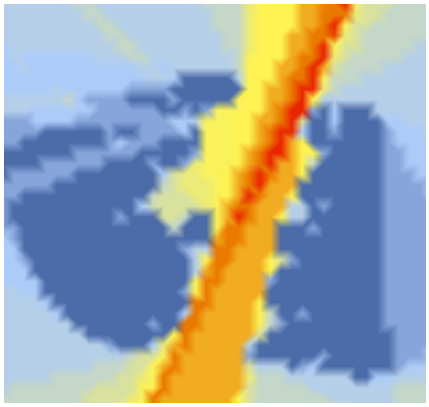


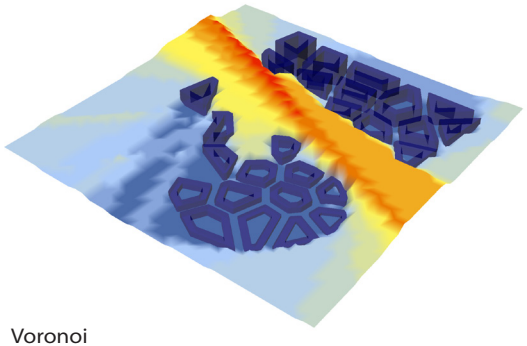


Delaunay

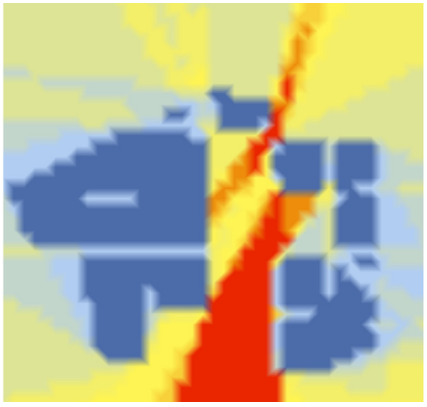


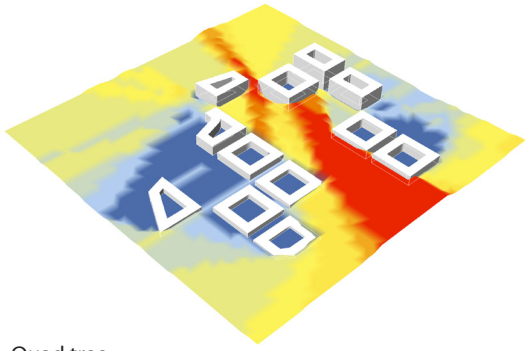




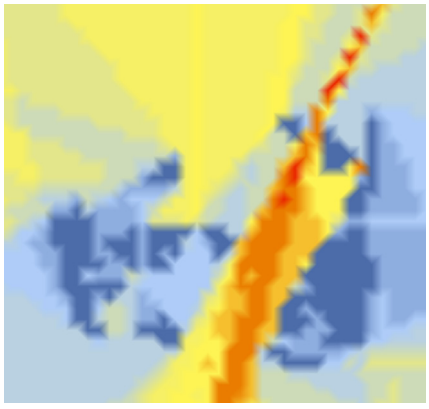


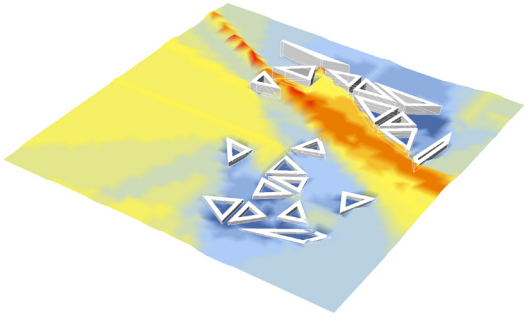
Voronoi





Quad tree





Delaunay

5. Isovist analysis

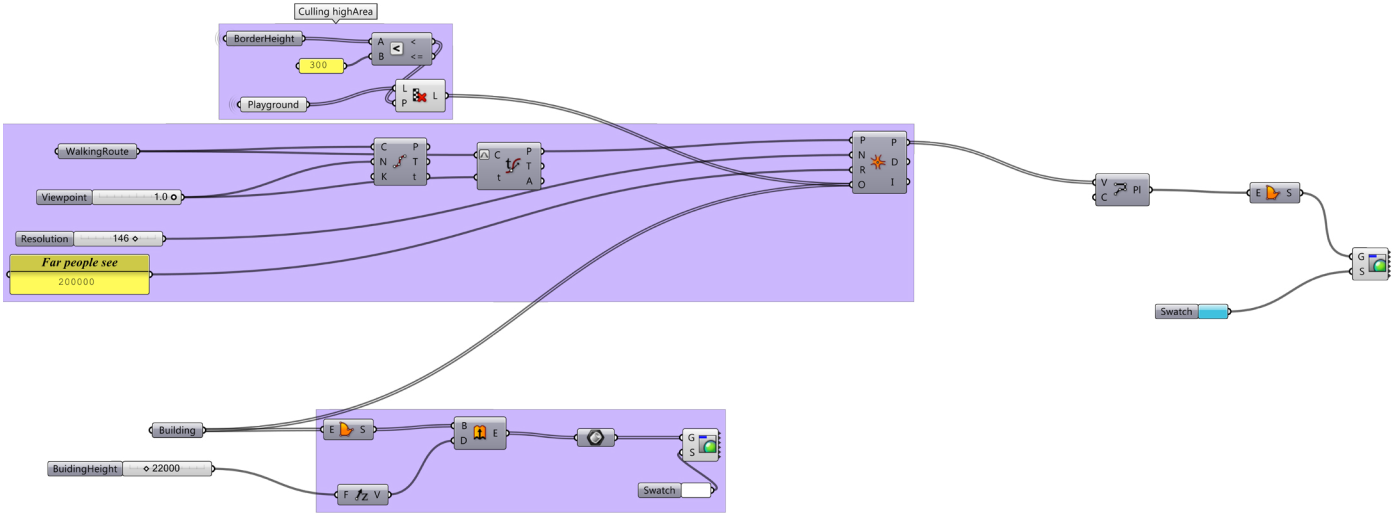
Lisa Voigtländer

For the Isovist analysis I tested three different kind of mesh patterns with the same initial situation, from the previous task. I had to do some adjustments but basically I used the same points for the grid, crossed it with the same curve for a street and same outline as a border. The different grid patterns are called: Voronoi, which results in cell looking like forms. The Delaunay mesh creates triangles and Quad tree creates squares according to an amount of points defined to be included.

The building structure is defined through the size of ground area and the heights are set by a maximum floor amount and controlled with a graph mapper. I wanted to test the variations of Isovists from the street in all three versions. The straightest view is in the Voronoi structure and narrowest turned out to be in the Delaunay structure and the Quad tree seems to have the most open part.

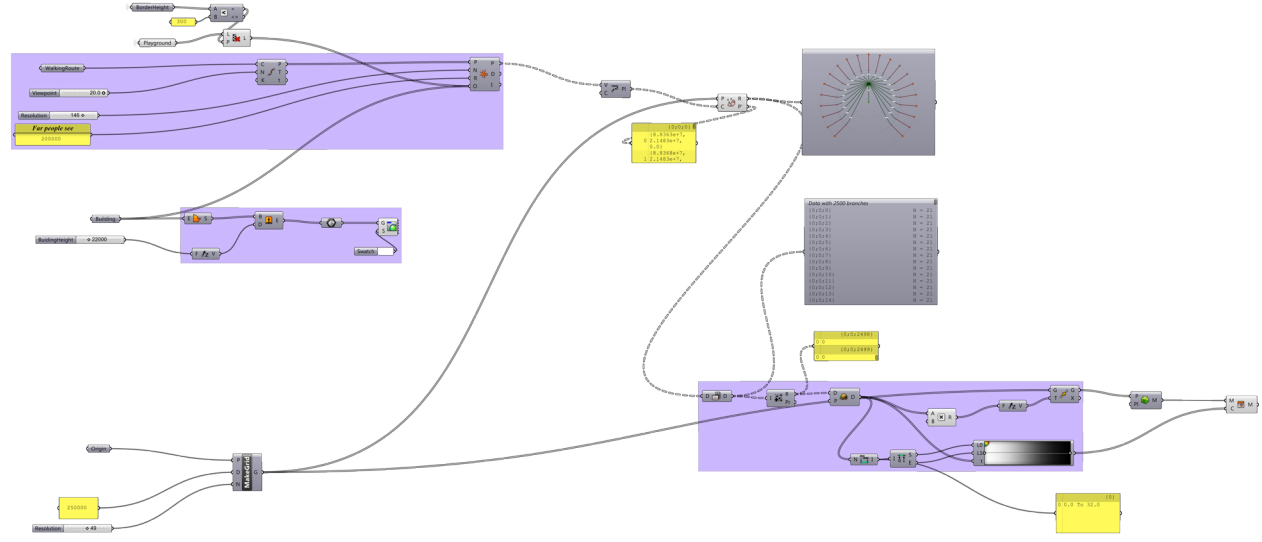
First I used the black and white colouring but I think the colourful Isovists give more information and look beautiful, even like a painting.

Isovist analysis_ Single View

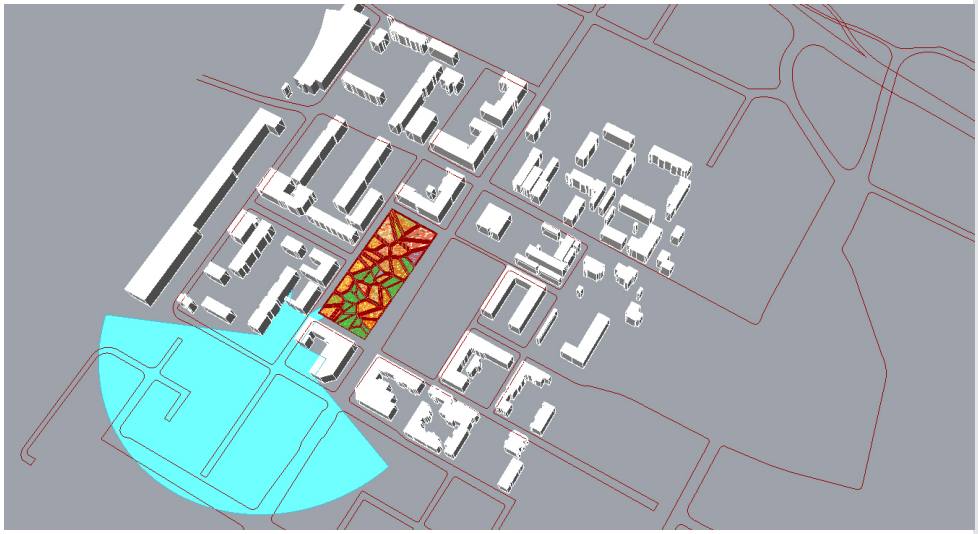


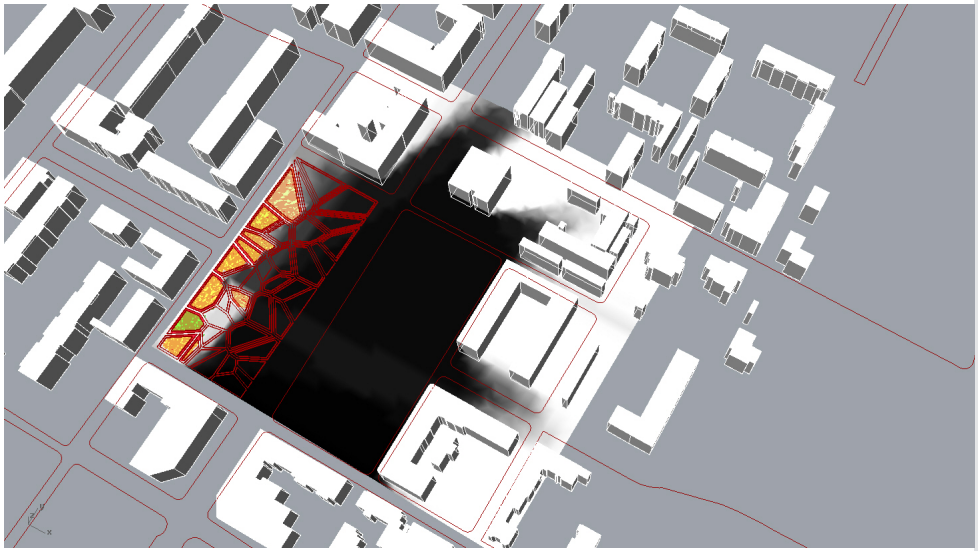
Walking route >>> Viewpoints >>> Isovist analysis >>> Make a closed polyline visualizing the view from one specific viewpoint

Isovist analysis_ Area



Walking route >>> Viewpoints >>> Isovist analysis >>> Make a grid of point >>> Colourize points inside the visible area based on the Isovist analysis





Final works

5. Isovist analysis

Nguyen Minh-Chau

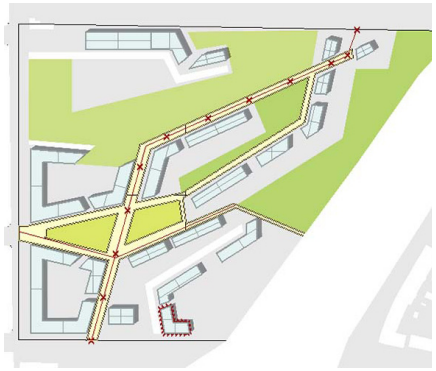
Create a visual three-dimensional isovist view analysis of the earlier existing urban designs.

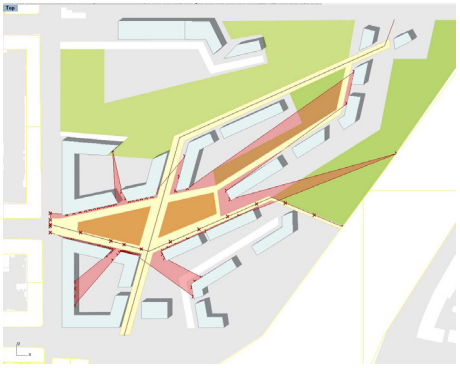
Choose a pedestrian oriented public street. Then imagine yourself walking along the route, the isovist analyze correlate with your image of that space.

From the previous pattern design, with a walking route cross the Tammela square, we figure out the viewpoints from equal distance division.

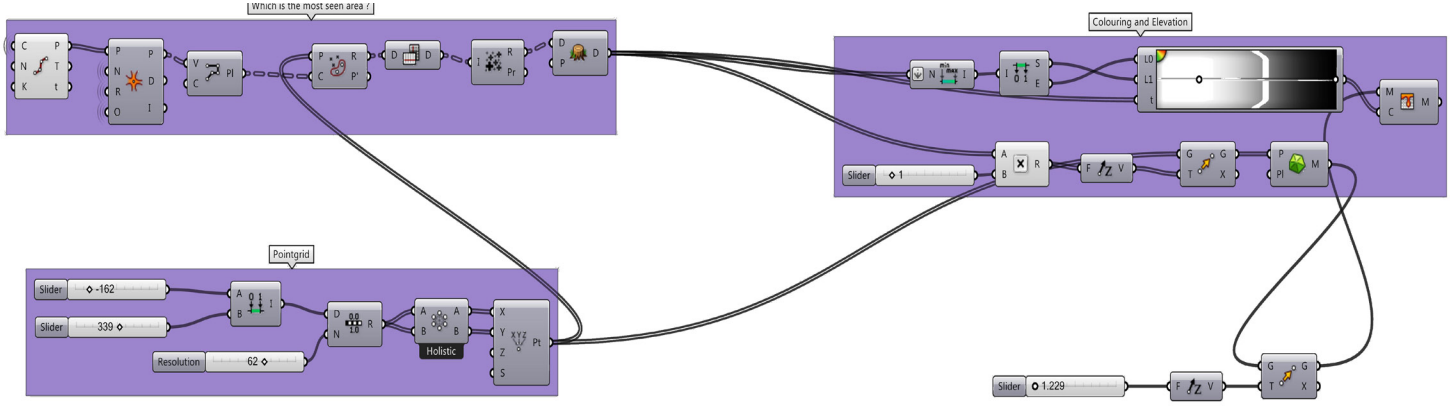
Then we can point out the visible area from each specific point to the surrounding urban context.

The three-dimensional isovist view analysis illustrates the new design with open view to the right side of Tammela Square, which should be strictly conserved with historical buildings.

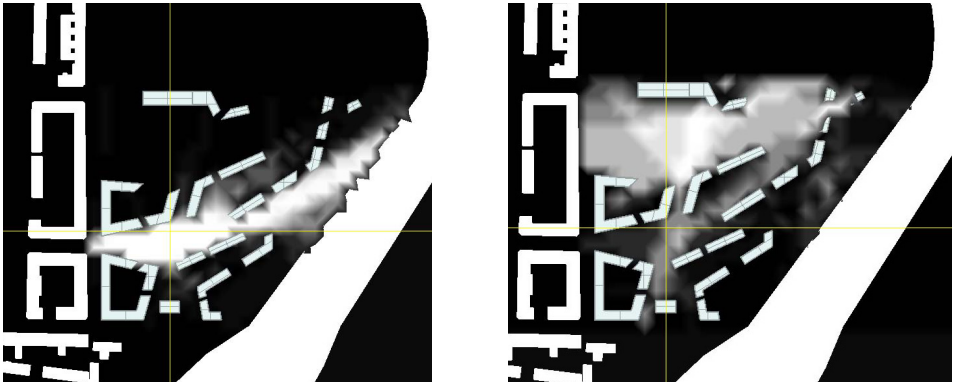




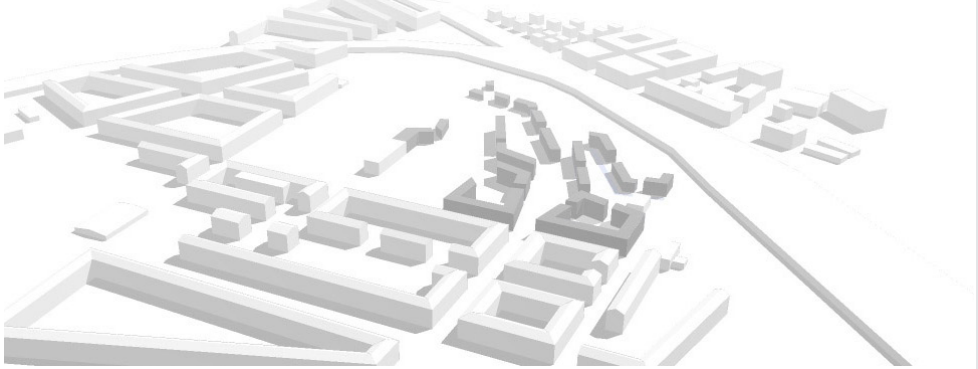
Rhino view from above: unrendered model with defined main routes and isovist



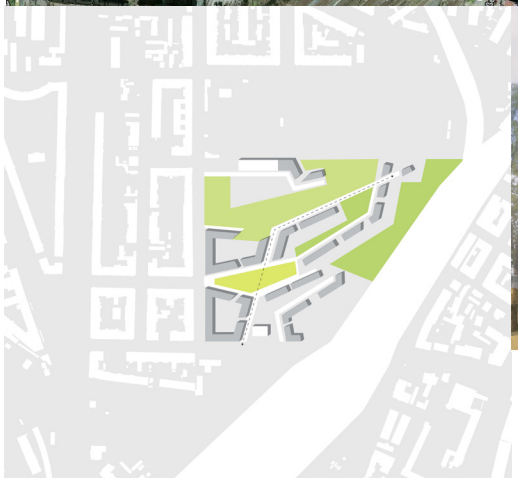
Grasshopper definition: Analysis



Result of the Analysis



Early urban design: Dresden DREWAG Areal, Germany View from above and Site



Siteplan, concept drawing and perspective view

5. Transformer

Elisabeth Heinz

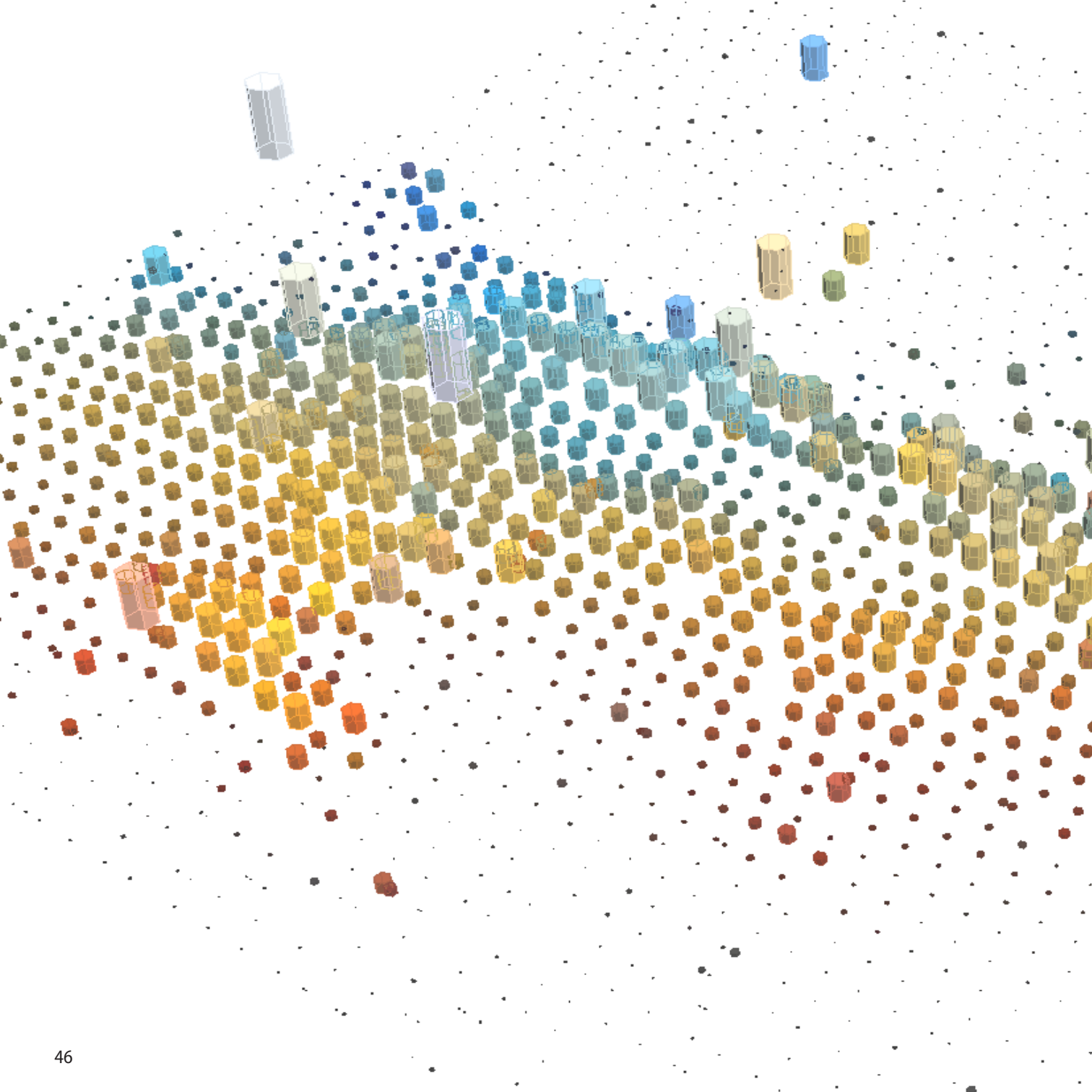
For the analyzing task with the isovist tool I chose my first urban project, which I did in the beginning of my second year.

I found it rather interesting to remember, which were the reasons for developing the design and to get proof from the analysis for the visions that we had at this early unexperienced point of planning - or to find out that the structure is not going to work.

Two main streets are defined and analyzed. The given results in the black and white pictures show that both have in average very different qualities.

One behaves like a corridor and all the surrounding buildings keep most of the views inside of it. In the other street the views are more spreaded and the single building in the north can be spotted from almost every point of the street.

In conclusion the Isovist tool is very useful especially for analyzing your own urban design.



Bitmap Mayhem

6. Mission

Revisit Hervanta to select a location for your urban plan.

Now instead of using attractors, base your design on a visual analysis of the aerial picture and create a set of different bitmaps that you can use to control your design.

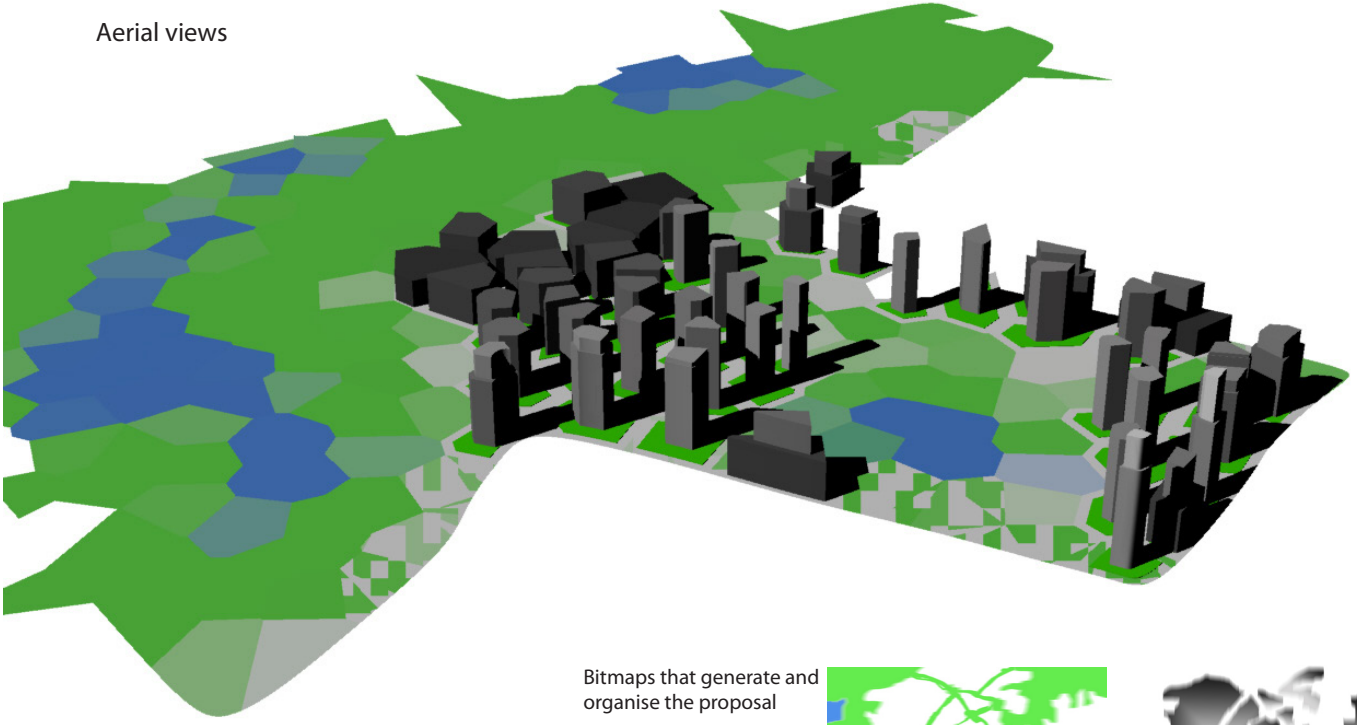
You may also select a different area for your design proposition.

Color different areas with different colors on top of the bitmap, so you can control their size, intensity and distribution.

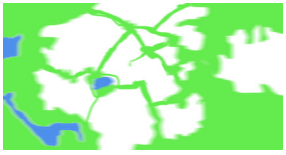
Create different sets of bitmaps as some might affect density, other height, scale, etc..

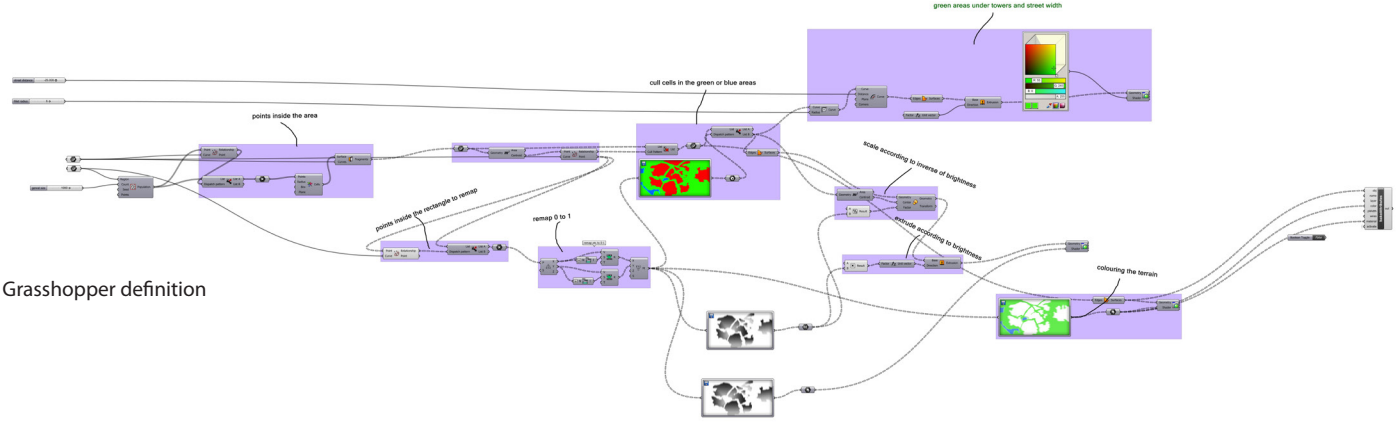
6. Explorations

Aerial views

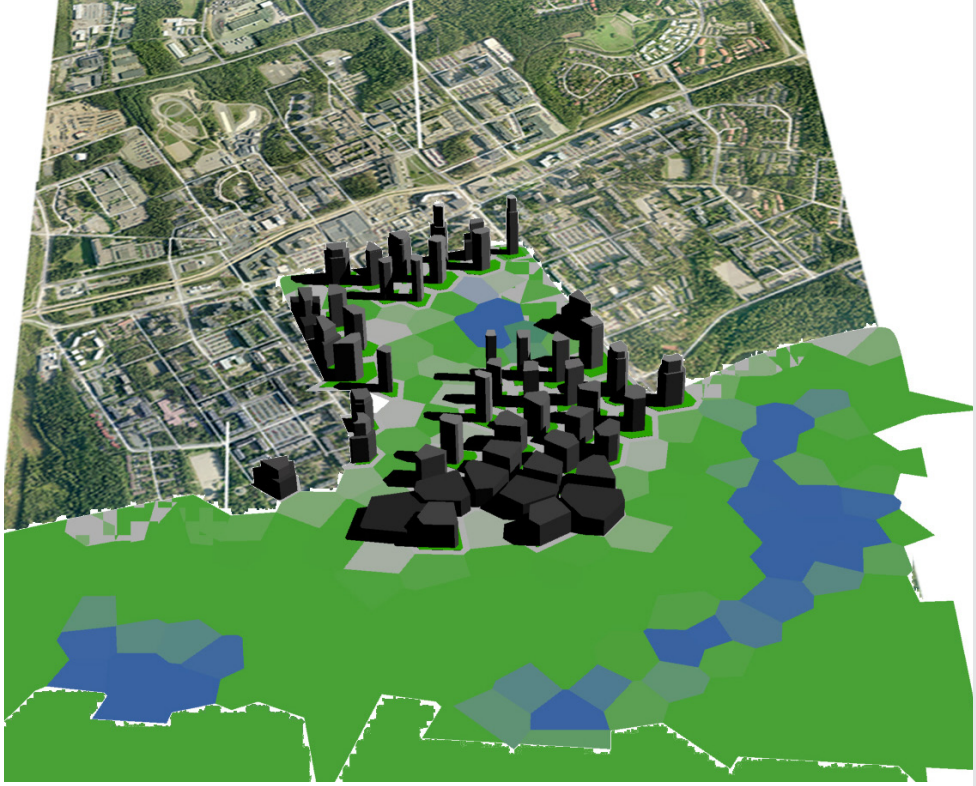


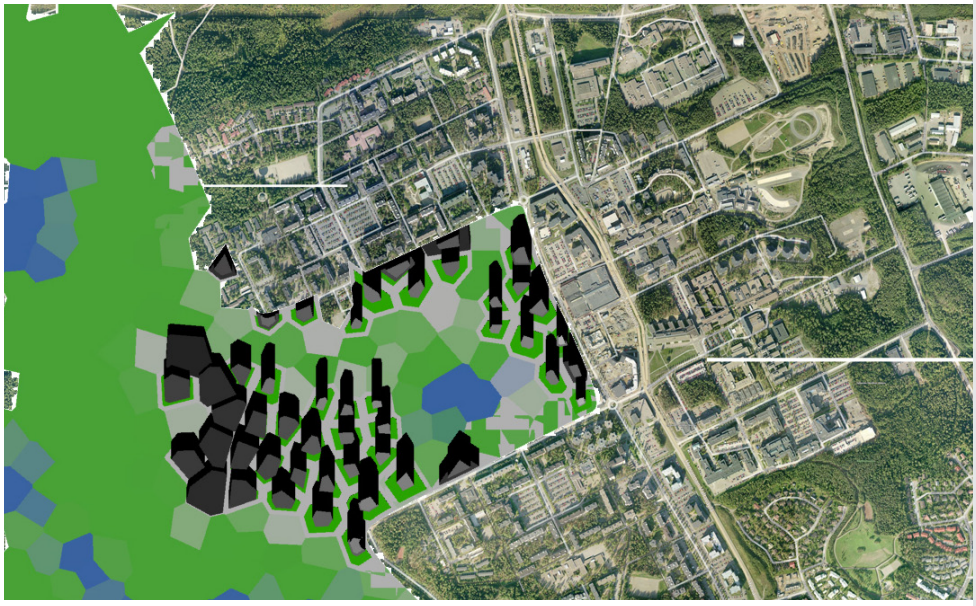
Bitmaps that generate and organise the proposal





Grasshopper definition





General plan

6. Bitmap Mayhem

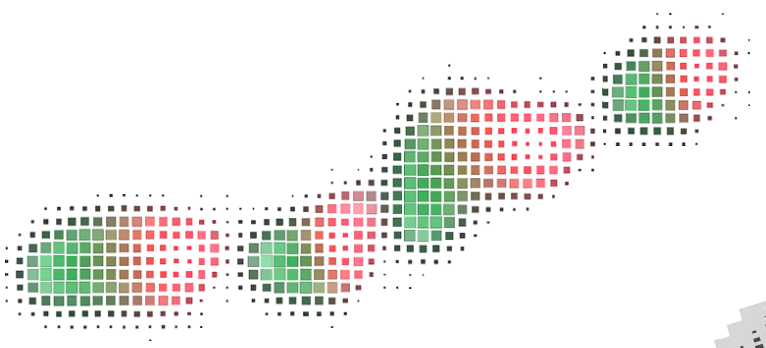
Rafael Alonso Candau

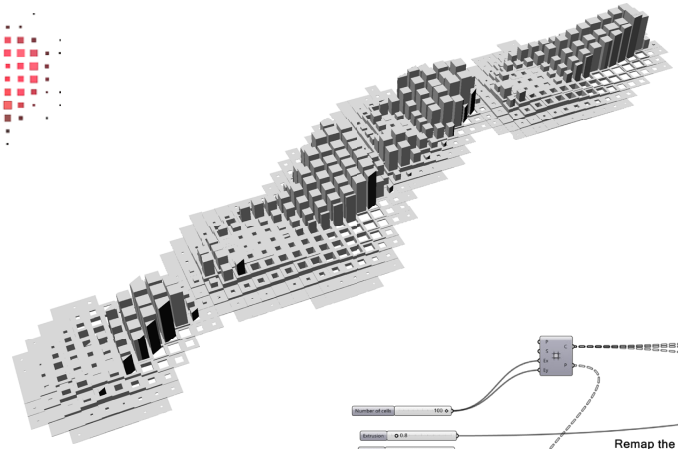
The aim of the project is to design a new residential area in Hervanta, this time working with bitmaps.

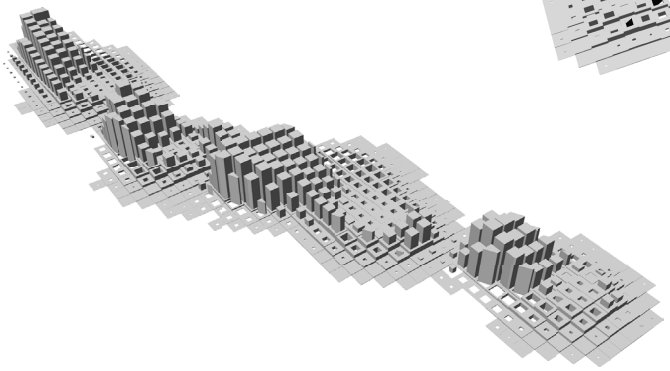
The first bitmap is used to define the building area, parks and to respect the lakes. It also introduces a green connection from park to park.

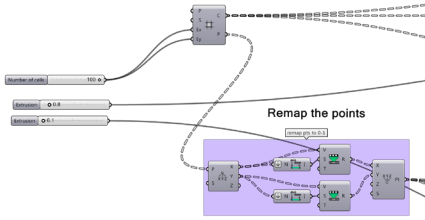
The constructed area is divided according to an organic random pattern, where the too small and too big cells are used as parks or public squares.

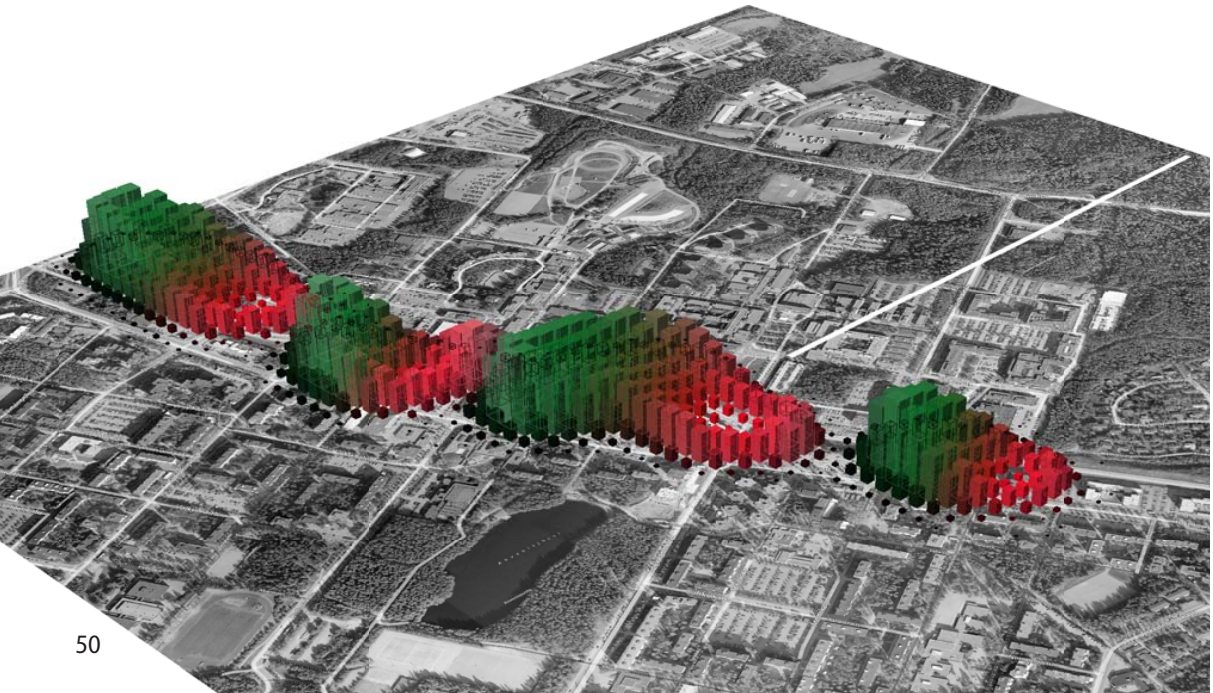
The size and height of the buildings is affected by the second bitmap, where the gradients are defined according to lake proximity, and south orientation, so that the streets get narrower, and the buildings smaller, as you go further from the central lake.



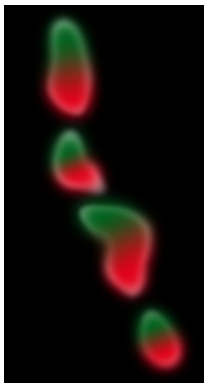


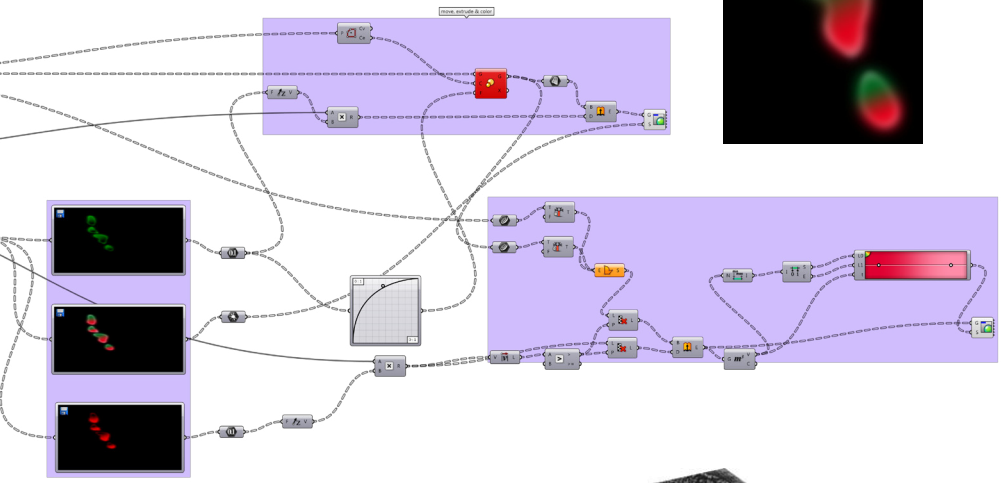


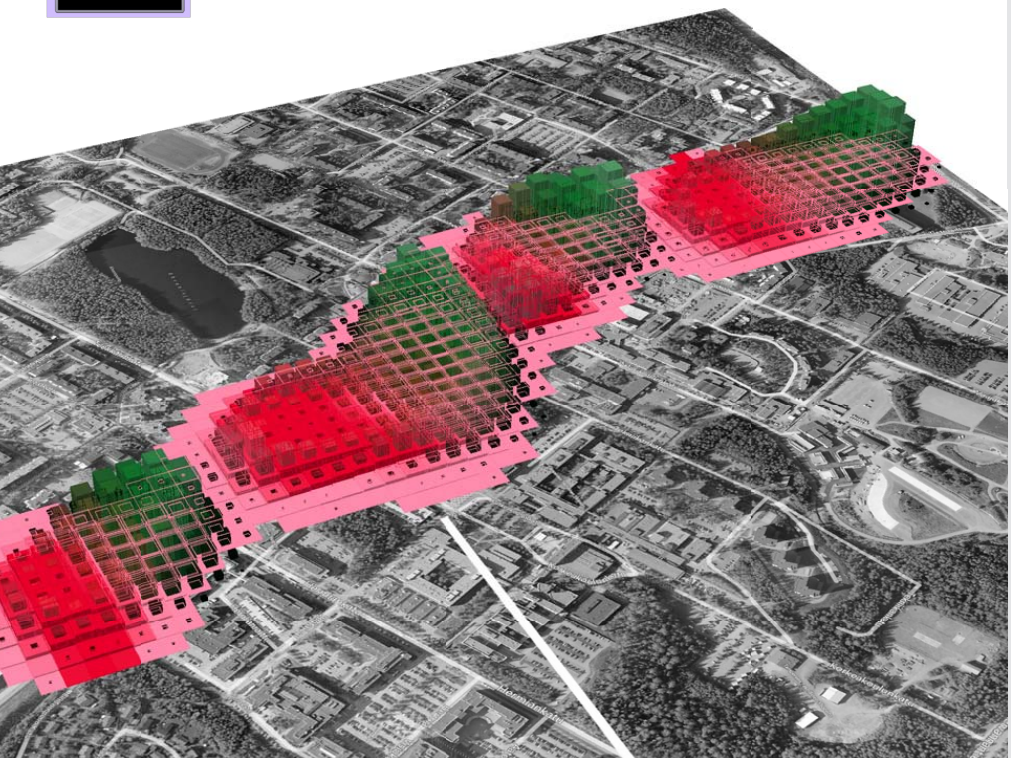

Number of cells
100
Extrusion
0.8
Extrusion
0.1
Remap the points
remap pts to 0-1



Bitmap: the gradient from green to red







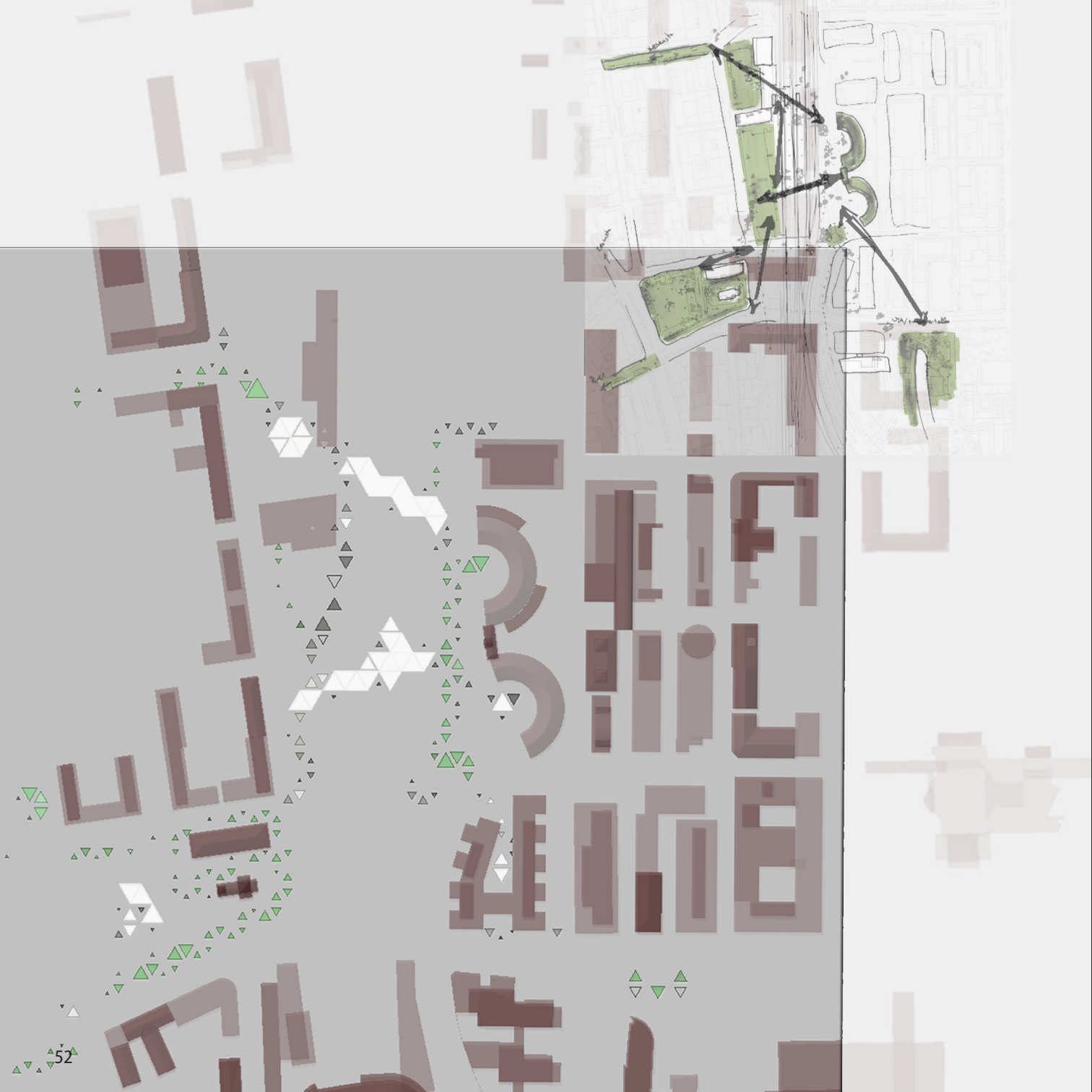
6. Bitmap Mayhem

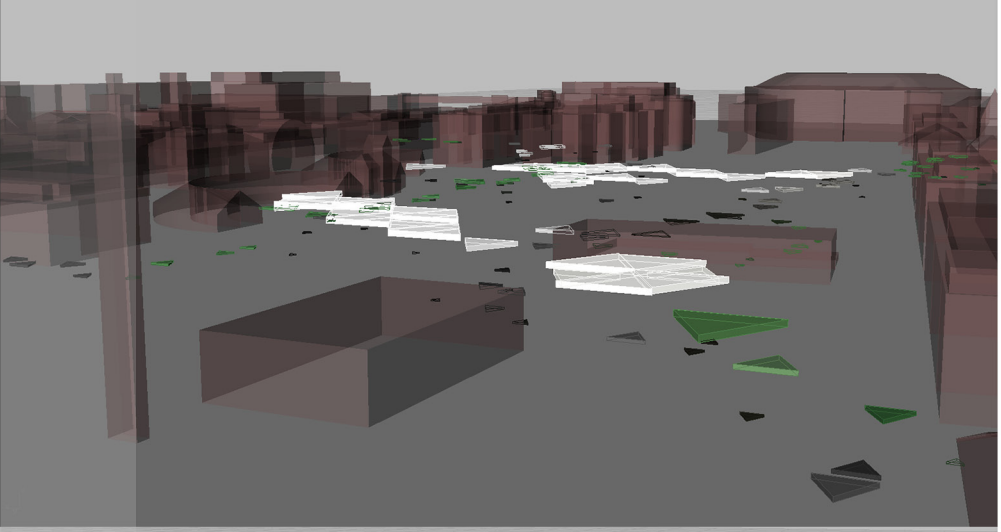
Zimo Zhao

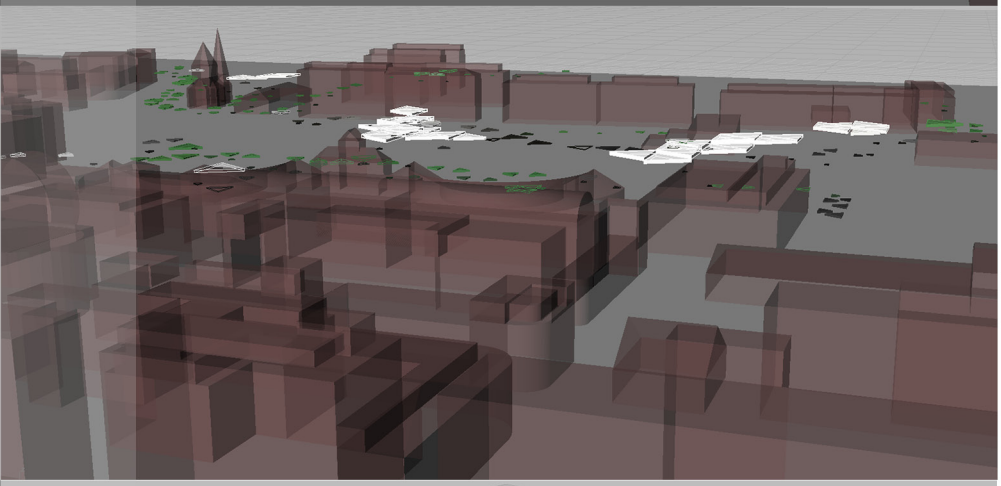
I selected a narrow zone in the centre of Hervanta as my target site. I tried creating four building groups, making each group has an inclined angle to south for getting more sunlight.

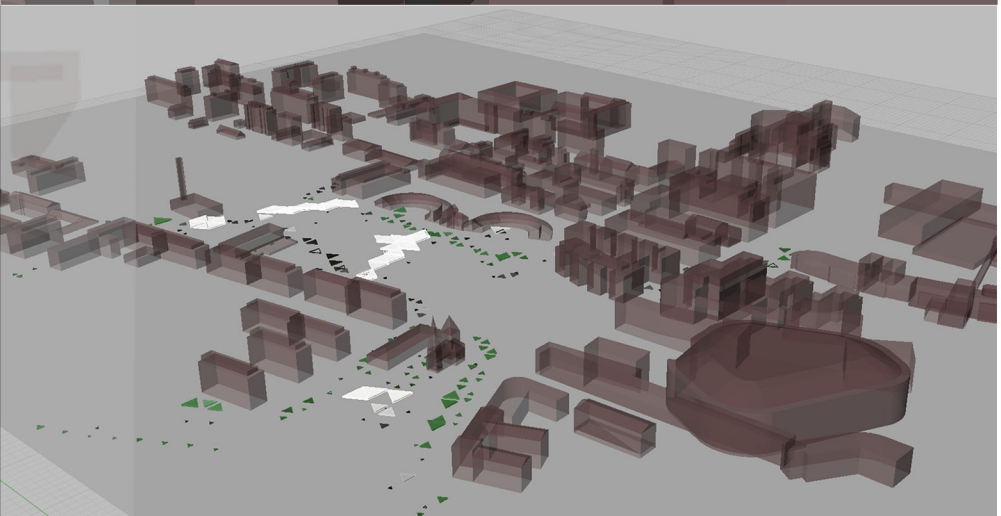
The bitmap is simple, with four dots which have a gradient from green to red. The vibrancy of green controls the buildings' heights and volumes, which means the greener, the higher/ bigger.

In each building group, there is some space among those columns. Landscape architecture is filled within. The vibrancy of red color on bitmap controls the heights of those masses.









6. Bitmap Mayhen

Nina Hatzitheofilou

The aim of this project, which had evolved through the previous tasks, was to find a solution for an existing problem in the heart of Tampere's city center. After analyzing the area, my goal was to find a way through urban and landscape design, to breach the gap that the train tacks form, through the center and to make pedestrian circulation less tricky.

In the design process I decided to use a modular form, and carefully scatter it, in varied form and use, across the area of interest. This module, triangular, square or hexagonal could be designed to serve as anything, from a structure that could form a bridge, to urban furniture like a simple tree pot in the ground.

That was the idea, and my tool to get started was by manipulating a grid, in Grasshopper, using coloured bitmaps that were created after the analysis of the area. Each bitmap image was produced to define a specific parameter of the module. The parameters that I concentrated on, that would then define different uses for the module across the terrain, were it's height scale and density.

Biography

András Botos

Erasmus student in Tampere in spring term 2013.
Has been studying architecture in University of Technology in Budapest, Hungary for 4 years.
Has spent the previous semester abroad in Cyprus.

Rafael Alonso Candau

Exchange student at TUT during 2012/2013.
Has studied in Valencia Polytechnic University since 2008 and is about to graduate next spring.

Nina Hatzitheofilou

Architecture student at the Aristotle University of Thessaloniki, Greece.
Currently studying on exchange at TUT, Finland.

Xianghe Gao

International Master student at TUT since 2011.
Comes from the hometown of the panda.
2013 is the 7th year of studying architecture.
Has been working nearly 3 years in a quite large architecture company in China before she started studying in Finland.

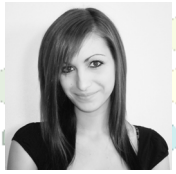
Elisabeth Heinz

Erasmus student in Tampere for the academic year 2012/2013.
Has been studying architecture in University of Technology in Dresden, Germany for 4 years.

Nguyen Minh-Chau

International MSc of Architectural Design at TUT since 2011.

Bachelor of Architecture Engineering in HCMC, Vietnam 2003-2008

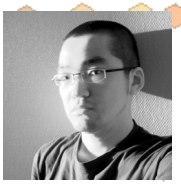


Isabella Pollak

International Master student at TUT since 2012.
2010 Erasmus and 2011 GSP at Aalto Univerity of Art, Design and Architecture, Helsinki, Finland.
Bachelor's degree in architecture from the Vienna University of Technology, Austria.

Lisa Voigtländer

International Master student at TUT since 2011.
In her 6th year of studying architecture.
Bachelor's degree from the university of applied science cologne, Germany.
One semester abroad at Lund University, Sweden.
Vocational training as Joiner before her studies.



Zimo Zhao

International Master student at TUT since 2011.
Bachelor's degree from Central Academy of Fine Arts of China.

Toni Österlund

M.Sc. Architect (University of Oulu 2010).
Digital Design in Sustainable Urbanism course teacher at TUT.
Living in Tampere and currently doing Ph.D. at the University of Oulu.