INNOVATION INCUBATOR.

CROWD SIMULATION ANALYSIS AND FORM FINDING

PERKINS+WILL

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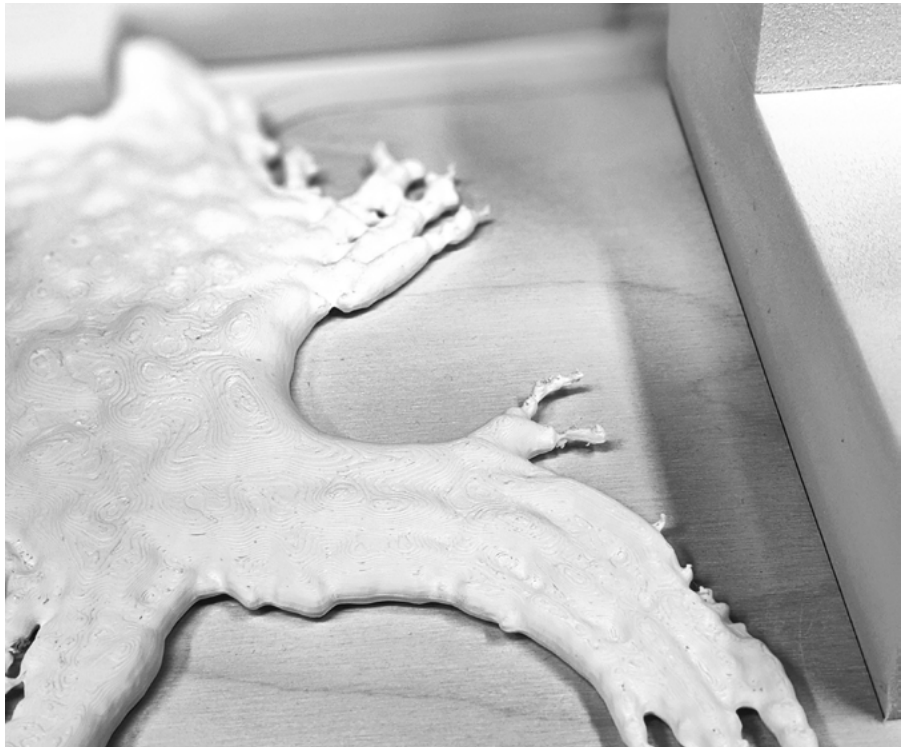
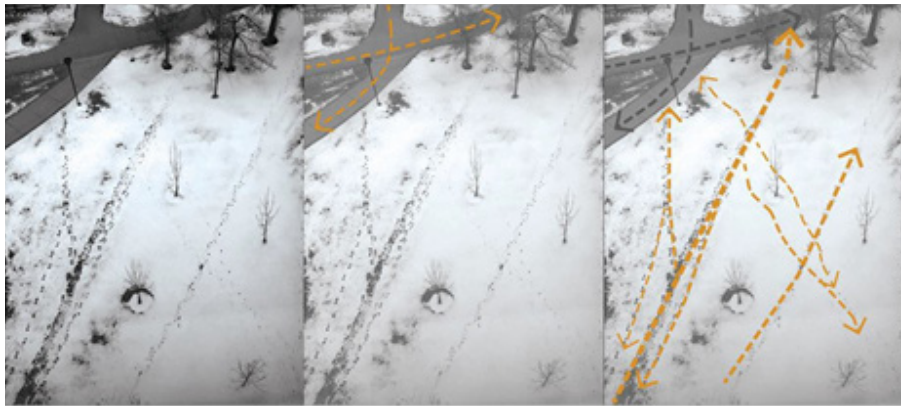
CROWD SIMULATION ANALYSIS & form finding.

INTRODUCTION
PROJECT DESCRIPTION





RESEARCH/PROJECT DESCRIPTION

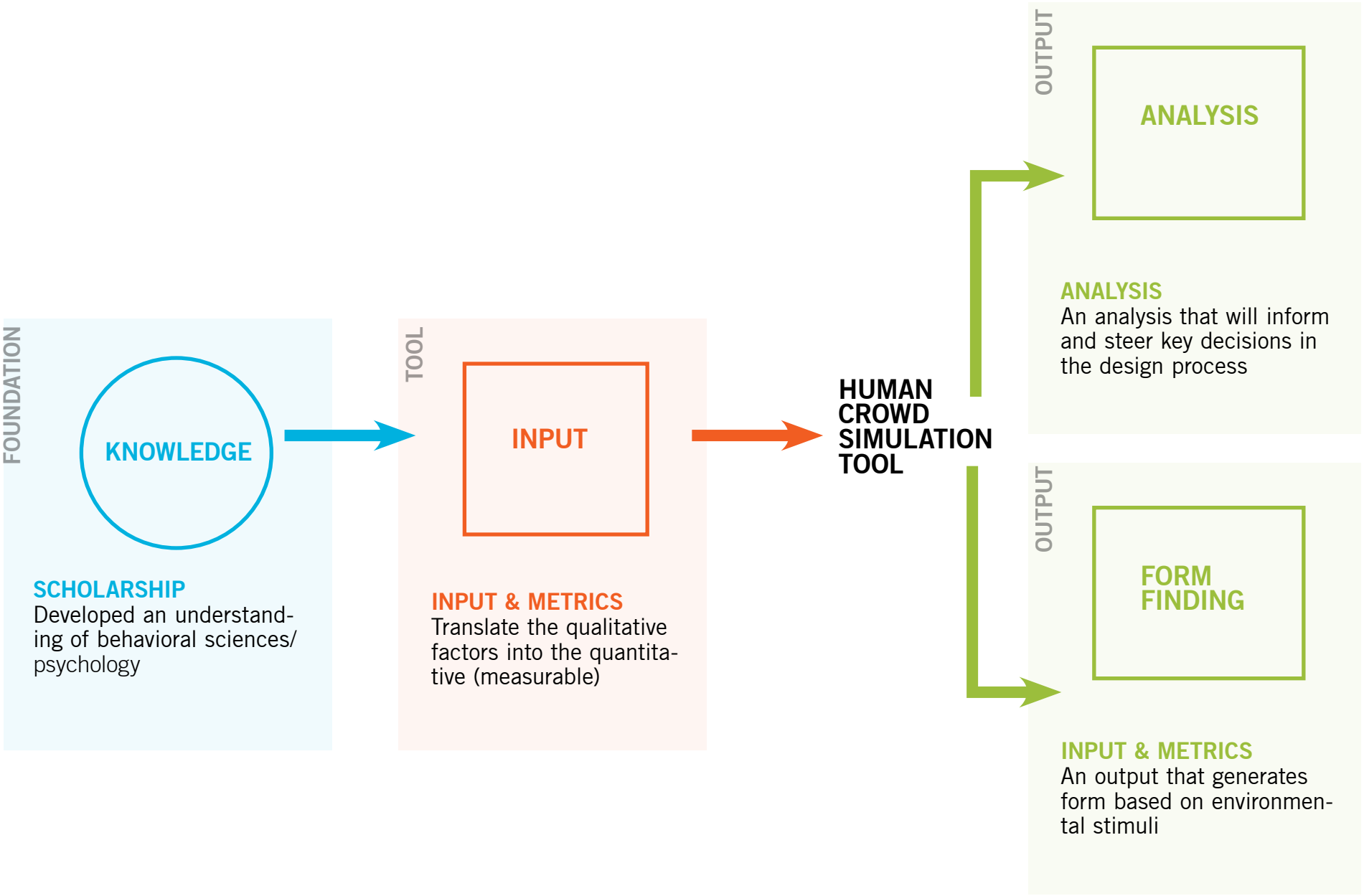
Registration of computational algorithms explores transition of spatial design from a static, pre-planned rigid form to an organic design and geometry. This research explores a design methodology and an analysis technique that uses crowd simulation for production of the organic human circulation patterns, interpretation of those patterns as inputs for design and generation of organic forms based on that algorithm.

Inspiration

Observing the natural swarms and agent-based behaviors in nature has inspired a lot of different simulations and research-based design projects. Agent-based systems and Swarm behavior have the potential for generation of structures in numerous ways. As an example, there are larger structures formed out of single agents; like simulated molecules in Artificial Chemistries. Additive fabrication precess in wasps' nests, where the agents deposit building blocks as a construction technique, or the subtractive process in ant colonies, where the agents hollow out material to form tunnels and chambers as their habitat. Swarms are believed to be capable of creating productive structures based on various meaningful evidences in nature, which can be a proof of concept that swarm configurations or structures built by agent-based systems can produce desirable designs.

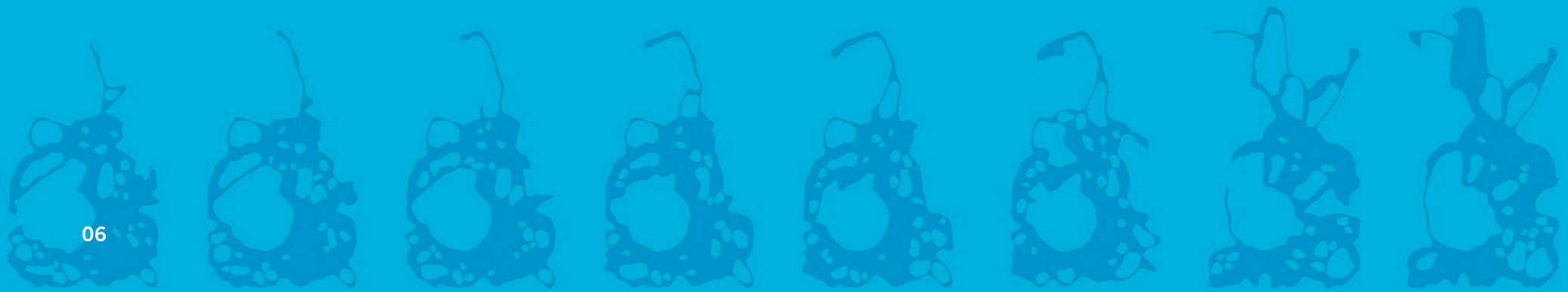
The project's goal is to introduce an algorithm for designing organic forms and dynamic analysis techniques that could define architectural/urban spaces with respect to the form of human body movement in various scales.

In this research also, the exploration is based on a multi-agent natural phenomenon. Similar to the ones mentioned above, which suggests that human crowd simulation could be considered to have environmental effects on its surrounding and could be used as a tool for driving design and form finding processes.


FOUNDATION
KNOWLEDGE
SCHOLARSHIP
Developed an understanding of behavioral sciences/ psychology
TOOL
INPUT
INPUT & METRICS
Translate the qualitative factors into the quantitative (measurable)
HUMAN CROWD SIMULATION TOOL
OUTPUT
ANALYSIS
ANALYSIS
An analysis that will inform and steer key decisions in the design process
OUTPUT
FORM FINDING
INPUT & METRICS
An output that generates form based on environmental stimuli

SECTION 1

LITERATURE REVIEW



SECTION 01

THE PSYCHOLOGY BEHIND SPACE

Privacy, Territoriality and Personal Space- Proxemic Theory

Privacy

Privacy, territorial behaviour, and personal space are closely related to the ability in which individuals or groups control their visual, auditory interactiuons with others. Amos Rapoport (1977) defines privacy as "the ability to control interactions to have option, and to achieve desired interactions". There are several different types of privacy:

1. **Solitude**, the state of being free from the observation of others
2. **Intamacy**, the state of being with another person but free from the outside world
3. **Anonymity**, the state of being unknown even in a crowd
4. **Reserve**, the state in which a person employs psychological barriers to control unwanted intrustion

There is also a cathartic purpose to privacy, it provides for personal autonomy and the release of emotions, it helps self evaluation and it limits and protects communication.

The use of territorial demarcators such as walls and screens are sybolic mechanisims for attaining privacy which the designer of the environment has control over. Threfore privacy is an important idea in terms of the relationships between an individual or group and the rest of society.

Territory

Human beings have innate instincts to protect and control space. Territories or boundaries when overstepped can induce anger, pain and mistrust. People value privacy and personal territory. The characteristics of territory include:

1. The ownership or of rights to a place
2. Personalization, the marking of an area; through photographs or objects
3. The right to defend agaisnt intrusion
4. The service of several functions ranging from the meeting of physiological needs

Terrirotial control is important in that it fulfills several basic human needs such as identity, stimulation, security and provides a frame of reference.

Crowding

The concept of crowding can be stressful, crowding is associated with with a feeling of lack in control over one's environment. It is affected by the individuals perception of the degree of control others have over the intrusions they are making (Rapoport 1977). Crowded conditions can lead to negative behaviours because they are human overload. However Crowding is also a point for curiousity. Human innate nature is to observe and be intruiged by what ever it is other may be interested or occupied by. In social private or public spaces crowds may attract more crowds. Not only do crowds symbolize a sense of security as it is percieved that no harm can occur in places of crowding the opposite can also be said in creating spaces of stressful situations. There is an interesting duality that occurs from crowding.

Primary territories such as homes usually serve this function well since people tend to respect them and since they are easily visable. But secondary and public territories are harder to preserve and define in our built environment.

Jon Lang from the University of Pennsylvania views the urban housing developments in which problems of design of seconday and public territories, such as entranceways, play areas and hallways. When these places were not designed in a way that rendered them distinctive and under control and surveillance of occupants of the building, crime was high and residents felt unsafe.

Carl Jung on behavioural systems states that “people are products of physical environment as well as social environment”. This leads us to believe that it is ever so critical to understand the links created between human psychology and the built environment.

SECTION 01
PROXEMIC THEORY

Proxemics is the study of human use of space and the effects that population density has on behaviour, communication, and social interaction. Proxemics is one among several subcategories in the study of nonverbal communication, including **haptics (touch), kinesics (body movement), vocalics (paralanguage),** and **chronemics (structure of time).**

The cultural anthropologist who coined the term in 1963, was Edward T. Hall, he defined proxemics as *"the interrelated observations and theories of humans use of space as a specialized elaboration of culture"*.In his foundational work on proxemics, The Hidden Dimension, Hall emphasized the impact of proxemic behavior (the use of space) on interpersonal communication. According to Hall, the study of proxemics is valuable in evaluating not only the way people interact with others in daily life, but also "the organization of space in houses and buildings, and ultimately the layout of towns".

The Breakdown of Proxemics:

Intimate is the distance in which is appropriate for touching or whispering, this ranges anywhere between 6-18 inches or closer. When close vision is possible within the intimate range, as with children the image is greatly enlarged and stimulates , much if not all of the retina.

Personal distance for interactions amognst friends or family members range from 4-12 feet. Keeping someone at arms length is one way of expressing the far phase of personal distance. It extends from a point that is just outside easy touching distance by one person to a point. 15 degree clear vision covers the upper or lower face, while 180 degree peripheral vision takes in the hands and the whole body of a seated person.

Social distance for interactions among acquaitances range from 4-12 feet, the head size is percieved as normal; as one moves away from the subject, the foveal area od the eye can take in an even increasing amount og a person. Impersonal business occurs at this distance, and in the

close phase there is more involvement than in the distant phases. People who work together tend to use close social distance. A proxemic feature of social distance is that it can be used to insulate or screen people from each other.

Public distances used for public speaking can range from 12-25 feet, at twelse feet an alert subject can take evasive of defensive action if threatened. This distance may even cue a vestigial but subliminal form of flight reaction.

These metrics are subjective in that they cannot be applied accross all ages, cultures and genders. Personal space changes in relation to upbringing, relationship and to the individual and his/her expectations.

Mapping the Human Body and its Perception of Space

A research report that came out of the Department of Psychology at Lancaster University in 2017, begins to map the perception of the relative body proportions of the self and others. This idea brings us close to understanding how the mind sees our bodies and others. Furthermore this will help us draw conclusions regarding the “bubbles” or spaces

In conclusion, drawing design parameters from this research:

From the literature studies conducted on the psychological definitions of space, pulled from the book Positive Architectural Theory Privacy on proxemics by Edward T. Hall

SECTION 01
TIES TO DESIGN

The Social/Physiological Design Element

Pattern Language

As explored by many sociology centric urban designers, the primary conclusion results in the fact that people feel more comfortable in a space which is at least partly enclosed. This idea may be a resultant of some innate primitive instinct that we all possess that we psychologically still hold on to. Sitting in the open holds us exposed and vunerable to threat, there is an over exposure associated with being placed within the open of spaces. Physiologically our bodies surface area is exposed to more available threat, this is why many studies as explored by William H. Whyte and Clare Cooper describe that in order for "To be comfortable, a person wants a certain amount of enclosure around him/her but not too much."

Studies by architects and sociologists like Christopgher Alexander in 1977 began to produce books and videos as seen in Image 1-3 that helped designers gain a greater understanding of the negative space that a building figure ground would produce and the reprecussions of those decisions on the life and success of urban spaces.

Findings such as these intrinsically meant that humans were reading a physcial pattern language and responding to it. It could now be read, deciphered, mapped and documented.

With this literature and understanding we as designers are obliged to respond to our audiencies requirements in order to best satisfy their needs.

Spaces without walls are just open and people require and enjoy variety in enclosure, Steps create height, a vantage point for people watching, a stage entertaining

SECTION 01
TIES TO DESIGN

"Man will adapt to hydrocarbons in the air, detergents in the water, crime in the streets, and crowded recreational areas. Good design becomes a meaningless tautology if we consider that man will be reshaped to fit whatever environment he creates. The long-range question is not so much what sort of environment we want, but what sort of man we want."

~ Robert Sommer

Psychologists like Robert Sommer in the 1980's produced literature and findings that attempted to quantify the observational found that connected between architecture and behaviours. "the article begins with natural observations of groups of people conversing in natural settings. Certain key principles of spatial behaviour were identified. To control for the effects of extraneous factors, including previous level of contact, experimental studies were subsequantly undertaken in which groups of people were asked to converse at different layouts of tables and chairs. We wanted to determine how group, size, gender and table arrangement would affect spatial relationships.

SECTION 01
ARCHITECTURE AND COGNITIVE PERCEPTION OF SPACE

Tactile Space

Touch and visual spatial experiences are so interwoven that the two cannot be separated. Think for a moment how young children and infants, reach, grasp, fondle and mouth everything, and how many years are required to train children to subordinate the world of touch to the visual world.

The artist Braque distinguished between visual and tactile space thus: “tactile” space separates the viewer from objects while “visual” space separates the viewer from objects while “the visual” space separates objects from each other, Emphasizing the difference between these two types of space and their relations to the experience of space, he said that “scientific” perspective is nothing but eye fooling trick-a bad trick-which makes it impossible for the artist to convey the full experience of space.

James Gibson, the psychologist also relates vision to touch. He satates that if we conceive the two as channgels of information in which the subject is actively exploring with both senses the flow of sense impressions is reinforced. Gibson distinguishes between active touch (tactile scanning) and passive touch (being touched). He reports that active touch enabled subjects to reproduce abstract objects that were screened from view with 95 per cent accuracy. Only 49 per cent accuracy was possible with passive touch.

Therefore this makes it even more important that we are creating spaces that via concept can be read and understood through the act of tactile touch.

Michael Balint, writing in the International Journal of Psychoanalysis, describes two different perceptual worlds, one sight orientated, the other touch orientated. Balint sees the touch orientated as both more immediate and more friendly than the sigh orientated world in which space is friendly but is filled with dangerous and unpredictable objects (people). Man’s relationship to his environment is a function of his sensory apparatus plus how this apparatus is conditioned to respond. Today, one’s unconscious picture of one’s self- the life one leads, the minute-to-minute process of existence is constructed from the bits and pieces of sensory feedback in a largely manufactured environment. A review of the immediate receptors reveals first that Americans who live urban and suburban lives have less and less opportunity for active expereinces of either of either their bodfies or the spaces they occupy.

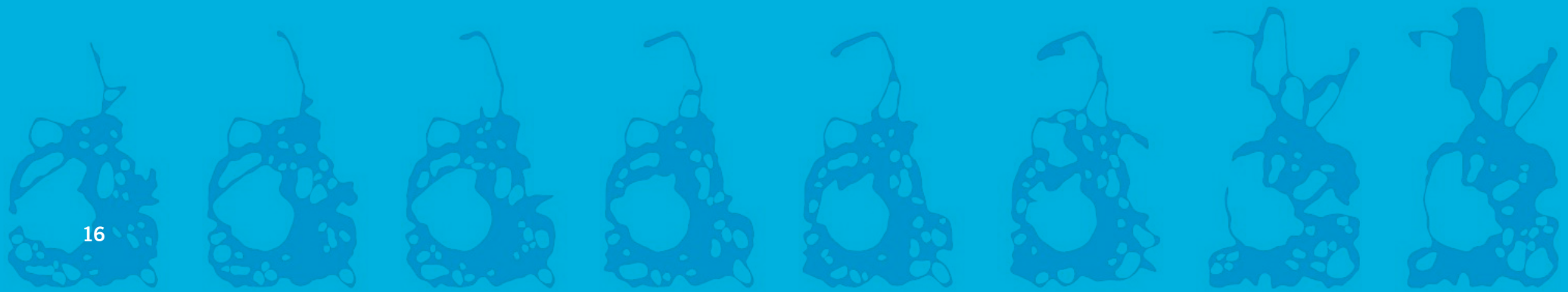
SECTION 01
DISTORTIONS OF PERCIEVED BODY PARTS

The Perception of the human body and space

As we experience our body as a three dimensional form, there are distortions or misperceptions that we experience when it comes to the size of the actual body part and its understanding of volume. This information is extremely intereting in the field of design as objects, artifacts and spaces that we inhabit are constantly being made for the assumed perception of those body parts. Research has found that “The patterns of length and volume misperception across judged segments were determined as their perceived size proportional to their actual size. The pattern of volume misperception paints the representation of 3D body proportions resembling those of a somatosensory homunculus. The body parts with a smaller actual surface area relative to their volume were underestimated more. There was a tendency for body parts underestimated in volume to be overestimated in length. Perceived body proportions thus changed as a function of judgement type while showing a similarity in magnitude of the absolute estimation error, be it an underestimation of volume or overestimation of length” (Cortex, 2019).

SECTION 2

TOOL DEVELOPMENT & UNDERSTANDING PARAMETERS



SECTION 02
CONCEPT

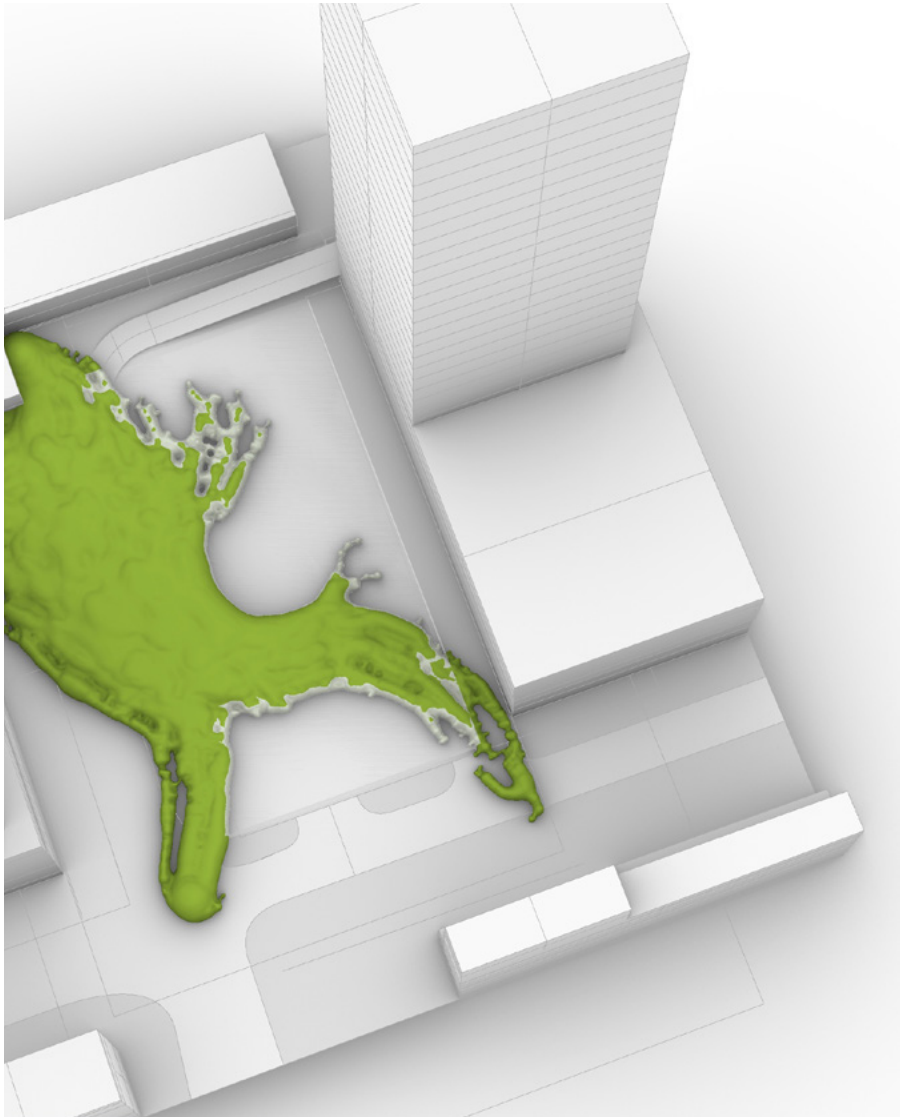
CONCEPT FOR THE DEVELOPMENT OF THE TOOL

What is this tool?

The tool is a way for designers to measure, track and formulate understandings behind human crowd patterns and relationships. It maps and generates human movement patterns based on a series of parameters given to the tool via the script. The tool uses agent based systems, in particular this tool is a multi-agent simulator a class of computational modes for simulating the actions and interactions of autonomous agents (either individual or collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole. The goal of the agent based system is to search for explanatory insight into the collective behavior of agents obeying simple rules and parameters.

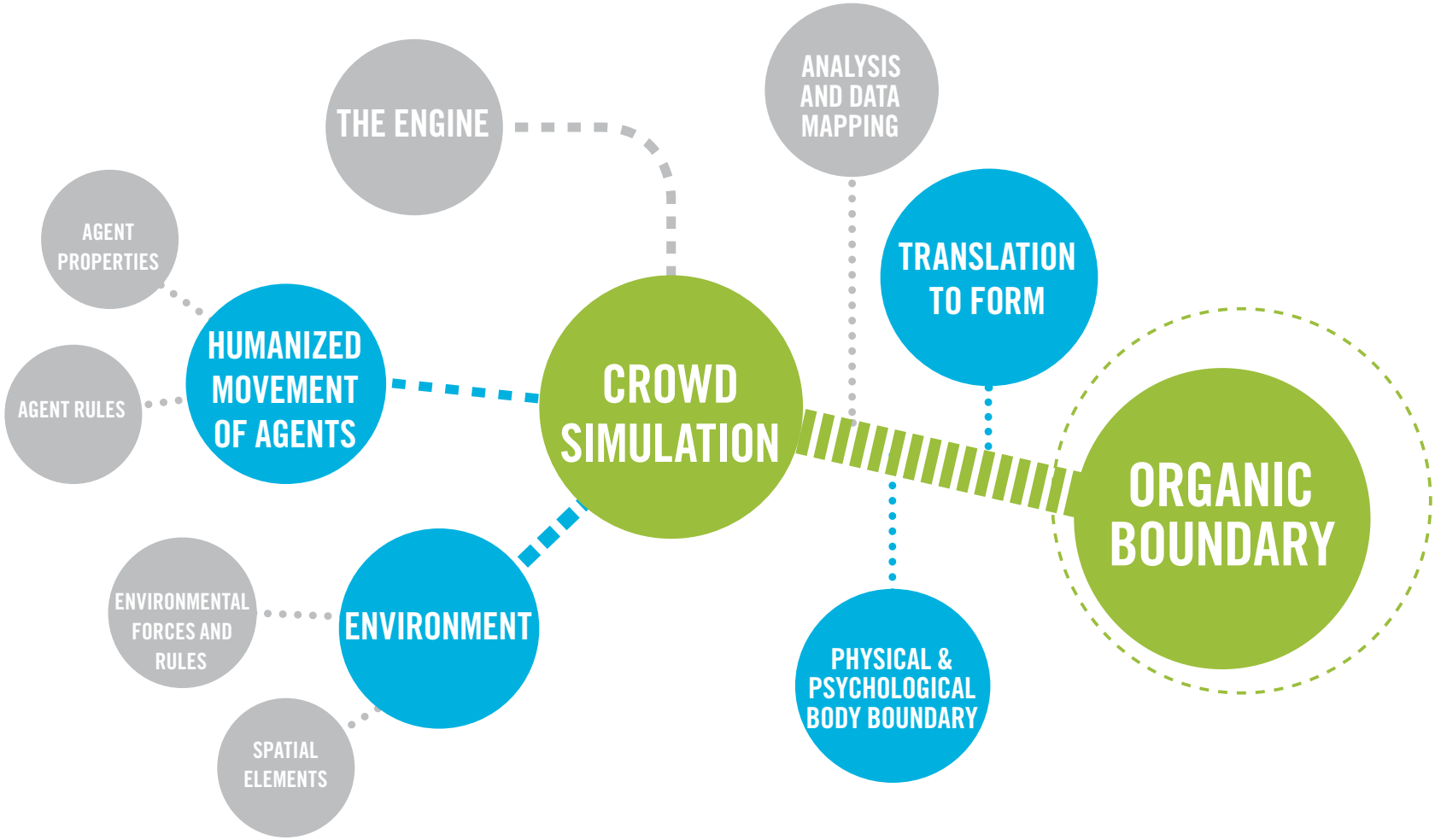
What does this tool do?

This tool is used for mapping and illustrating the human crowd patterns and extent of movement that respond to the set environment. By setting varied environmental parameters and behavioral inputs we are able to develop a better understanding of the real life cases against varied design decisions before the creation of the project. Of course all tests conducted are still subjected to individual bias created by a human being, but based on averaging assumptions about human movement this is the most accurate



screen shot of the crowd simulation model

SECTION 02
CONCEPT



SECTION 02
SCRIPT OVERVIEW

DEVELOPMENT OF THE SCRIPT

How does it work?

The script reads the site information and project requirements from rhino into grasshopper. Based on geometrical inputs and settings the simulations runs in grasshopper to generate circulation paths and volumes.

What Platform does it use?

The tool works in a rhino environment, reads the site and project settings from Rhino geometry, Grasshopper runs the simulation based on the input, The agent based system is created using a grasshopper plugin called Quelea, and the mesh generation tool used for formation of the circulation volume is a plugin called Cocoon.

What are the inputs and outputs of the tool?

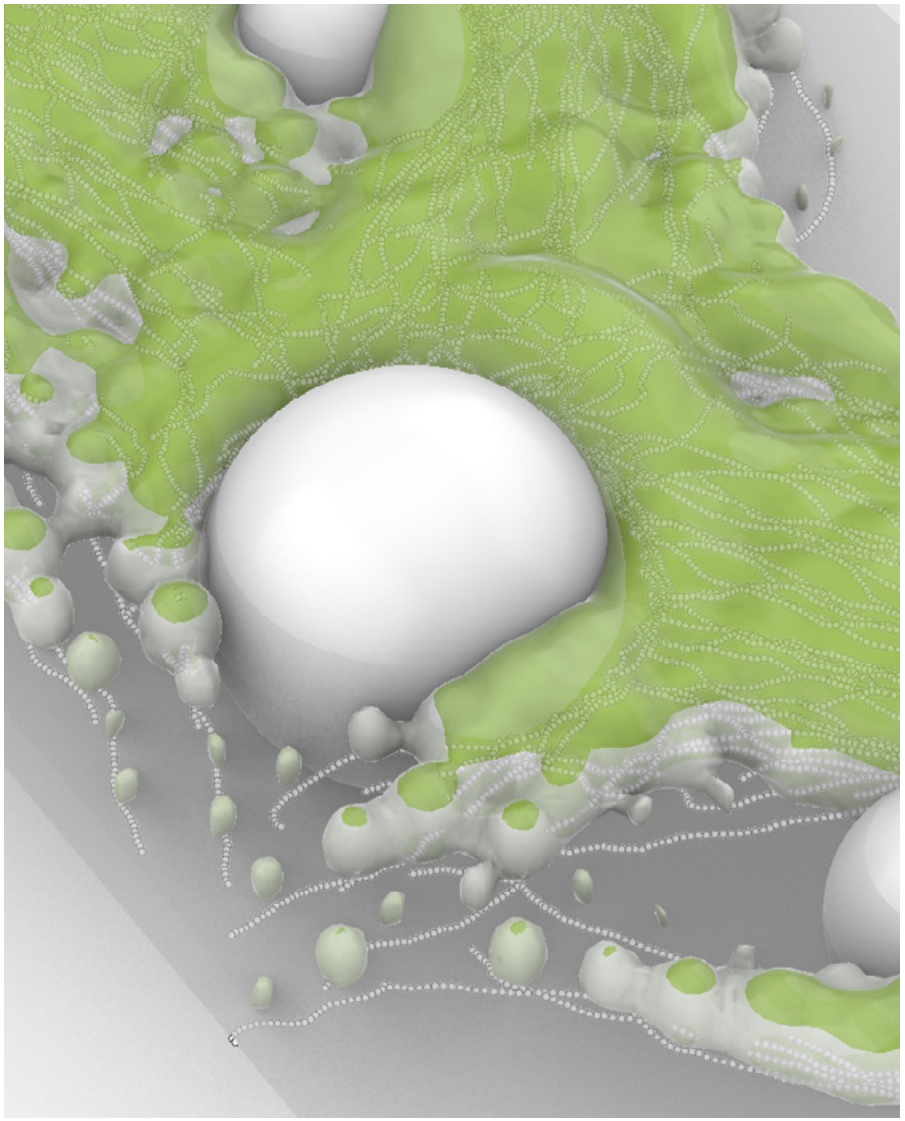
as shown in the diagram, the inputs are defined either under “Setup” section or “Controllers” section where different elements such as emitters and environmental features are defined.

the outputs are generated in the “Form Generation” section, where a corresponding volume for the circulation pattern and its negative space as a boundary for design is generated.

What are the main components of the tool:

The tool has 4 main parts:

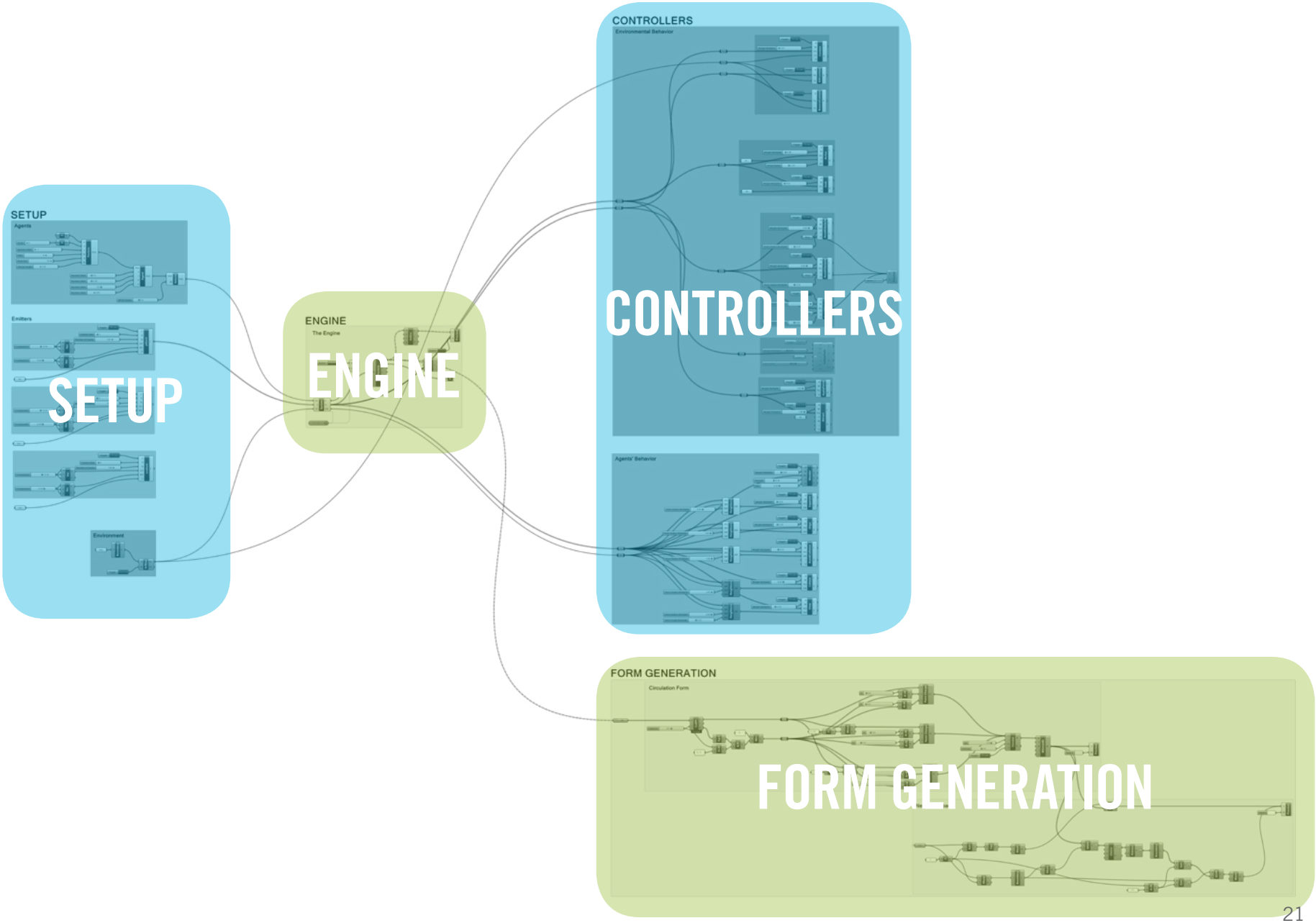
- The Setup - where the agents, emitters and the environment is defined
- The Engine - the engine running the system
- Controllers - Elements controlling environment forces and crowd behaviour
- Form Generation - Generative the positive circulation volume and the negative space



Screen shot of the crowd simulation model

SECTION 02

SCRIPT OVERVIEW/EXPLANATION



SECTION 02
SCRIPT PLUGINS | QUELEA

Simplify Complexity

Quelea is a rule-based design library packaged into Grasshopper components as a free add-on to the 3D modeling environment, Rhinoceros. It allows you to create complex simulations, analyses, and forms through the combination of simple rules. Quelea provides an intuitive interface to experiment with particle systems, agents/boids, braitenberg vehicles, and everything in-between and beyond.

Agent-Based Modeling for Designers

+ A new paradigm for 3D modeling utilizing agents.

+ Assign forces and behaviors to systems of agents to create interactions.

+ Utilize any data to drive the system.

+ Easily debug your system by displaying individual force vectors.

+ High performance, parallel algorithms, spatial data-structures.

+ Write your own custom forces, no coding required.

+ Open source framework for others to build custom behaviors.

+ Boid forces: Cohese, Separate, Align, & View.

+ Contain Agents within Brep, Box, Surface, and Polysurface environments.

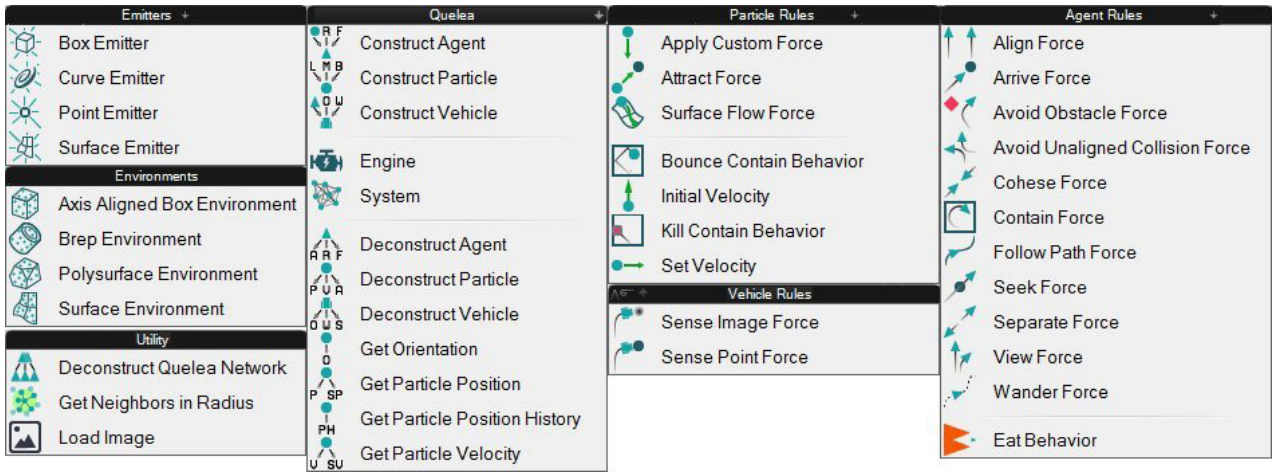
+ Forces: Path Follow, Attract, Contain, Surface Flow, Seek, Arrive, Avoid Obstacle, Avoid Unaligned Collision, Sense Image, Sense Point, & more to come.

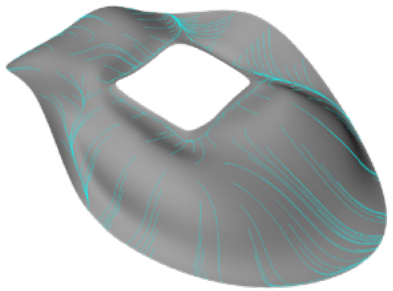
+ Behaviors: Bounce Contain, Kill Contain, Initial Velocity, Eat, Set Velocity, & more to come.

Future work:

+ Behaviors to drive simulations of people and vehicles.

+ Temporal inputs can change the actions of the system over time.

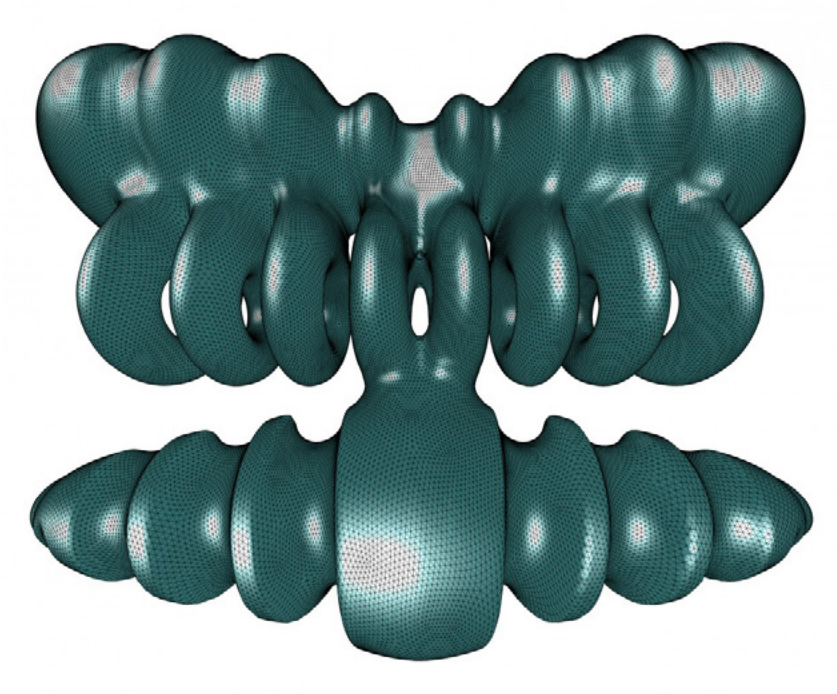




http://quelea.alexjfischer.com/

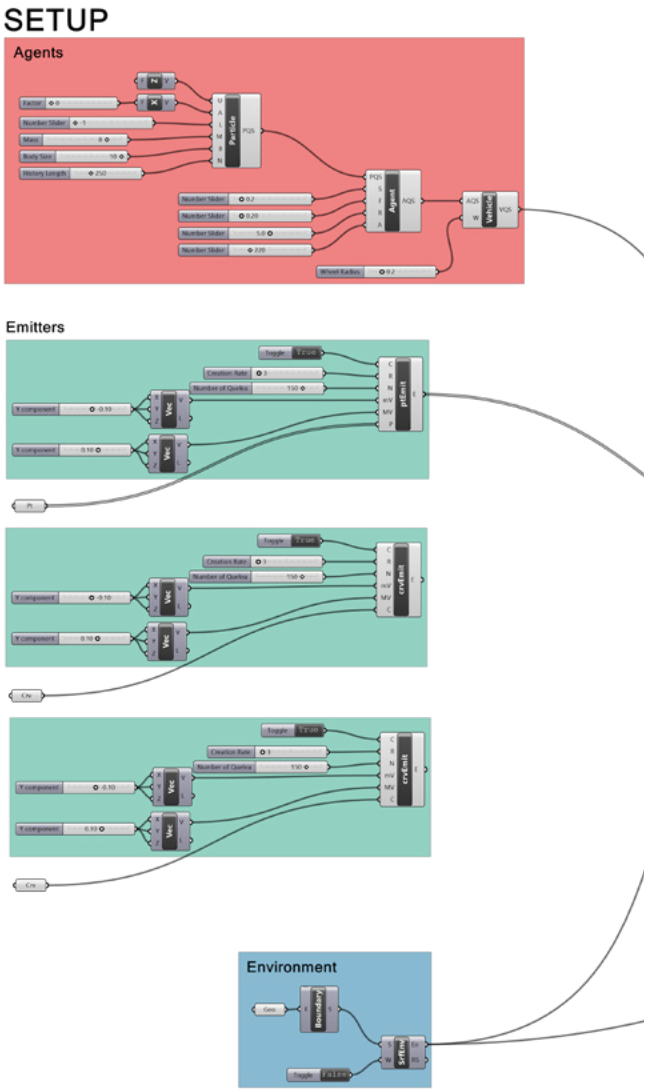
SECTION 02
SCRIPT PLUGINS | COCOON

Cocoon is an add-on to McNeel's Grasshopper visual scripting interface for Rhinoceros. Cocoon is a fairly straightforward implementation of the Marching Cubes algorithm for turning iso-surfaces into polygonal meshes. It is geared specifically toward wrapping existing geometric elements, and works with combinations of points, breps and curves, allowing users to vary a number of parameters that enhance sculptural potentials. It is still rough (and there are definitely a number of other approaches to level sets and isosurfacing that are faster, more robust, more elegant, and/or have more potential) but due to time constraints related to other work I am doing – now and into the near future – I thought it effective and fun enough that it was worth it to make this available to the community. As such, though, general caveats apply: it's probably easy to break, and it will definitely generate some artifacts. But please download and have a play, and feedback on the grasshopper forum is welcome. There's a longer description after the break.



http://www.bespokegeometry.com/2015/07/22/cocoon/

SECTION 02
SCRIPT | SETUP COMPONENT



- **SETUP:**
  - AGENTS / EMITTERS / ENVIRONMENT

The three main components to which we can break down the script set up into are agents, emitters and environment. Agents are the subjects of research, their reaction to environment obstables and forces is what the tool intends to capture and quantify.

Emitters are points/lines/surfaces or boxes of release, they represent and indicate locations of release for agents. Their quantity and speed can be controlled by the designer.

Lastly enviroment controllers are the parameters set by the designer that emulate real life forces or constraints that are evident in replicating the built environment. These controllers can either act as attracting forces to agents or obstacles that steer agents away or around the set points/ geometry.

AGENT PARAMETERS

Agents are the subjects of research, their reaction to environment obstables and forces are what the designer intends to map and quantify. Below is the list pf control factors that can be applied to agent parameters:

Up direction (Vector)

The up direction for the calculation of the initial orientation.

Acceleration (Vector)

The vector of the Quelea's acceleration.

Lifespan (Integer)

Number of timesteps that the Quelea will be alive for. If negative, lifespan will be infinite.

Mass (Number)

Affects how strongly the Quelea reacts to forces. Larger masses will lead to more cumbersome movement.

SECTION 02
SCRIPT | SETUP COMPONENT

Body Size (Number)

The diameter of the extent of the Quelea's bounds. This is used for collision detection among other things.

N -History Length - for the code not the particle(Integer)

The number of past positions to remember for each Quelea.

<u>Feed into</u>

Agents:

Maximum Speed (Number)

Rather than teleporting, the Quelea will move incrementally by this speed towards targets that it seeks.

Maximum Force (Number)

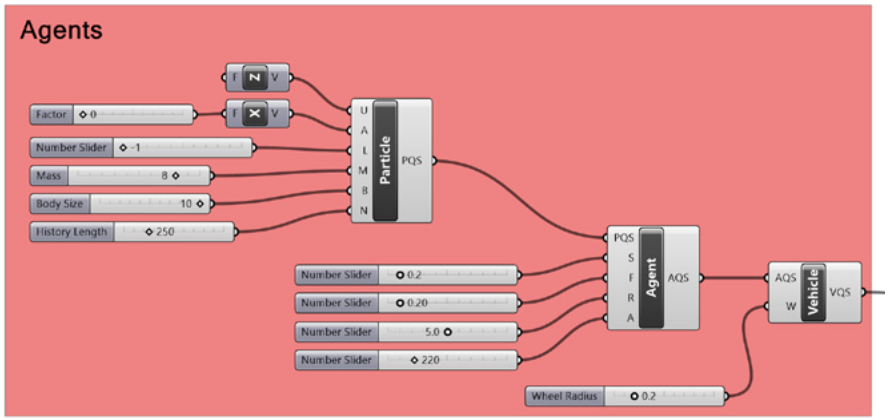
Steering ability can be controlled by limiting the magnitude of the steering force.

Vision Radius R (Number)

The maximum radius around the Agent that it can see.

Vision Angle A(Number)

The maximum angle, taken from the velocity vector, that the Agent can see around it.



Screenshot of the script - Agents Setting/Setup

Various Agent Setup Setting Exploration - Preferred Default Setting

Various Agent Setup Setting Exploration - Increased Braitenberg Vehicles Wheel Radios

Various Agent Setup Setting Exploration - Reduced Agent History Length

Various Agent Setup Setting Exploration - Reduced Agent Mass and Body Size

SECTION 02
SCRIPT | SETUP COMPONENT

EMITTERS

Emitters are points/lines/surfaces or boxes of release, they represent and indicate locations of release for agents. Their velocity, quantity and rate of creation speed can be controller by the designer.

Continuous flow (Boolean)

If true, particles will be emitted every Rth timestep. If false, N particles will be emitted once.

R creation rate (Integer)

Rate at which new Quelea are created. Every Rth timestep.

Number of Quelea/agents (Integer)

The number of Quelea that are allowed to be alive in the system at once.

mV Minimum initial velocity (Vector)

The minimum initial velocity from which a random value will be taken.

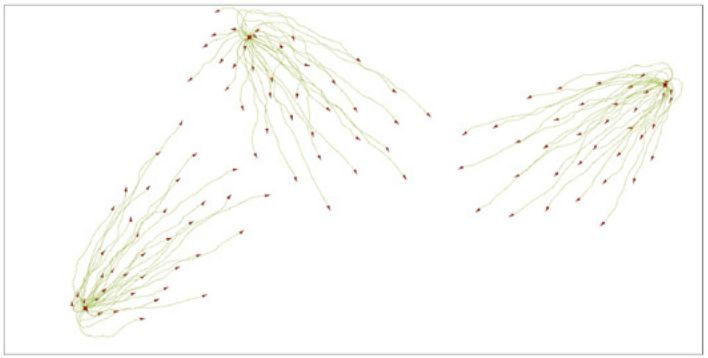
MV Maximum initial velocity (Vector)

The maximum initial velocity from which a random value will be taken.

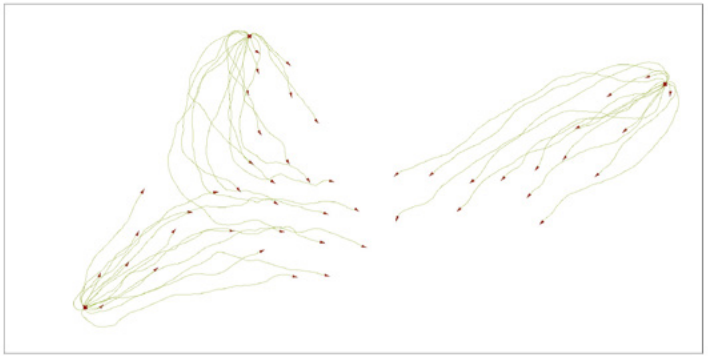
P point where emitter is located(Point)

Base point for Emitter.

Definition of Emitters:
-Box
-Surface
-Curve
-Point



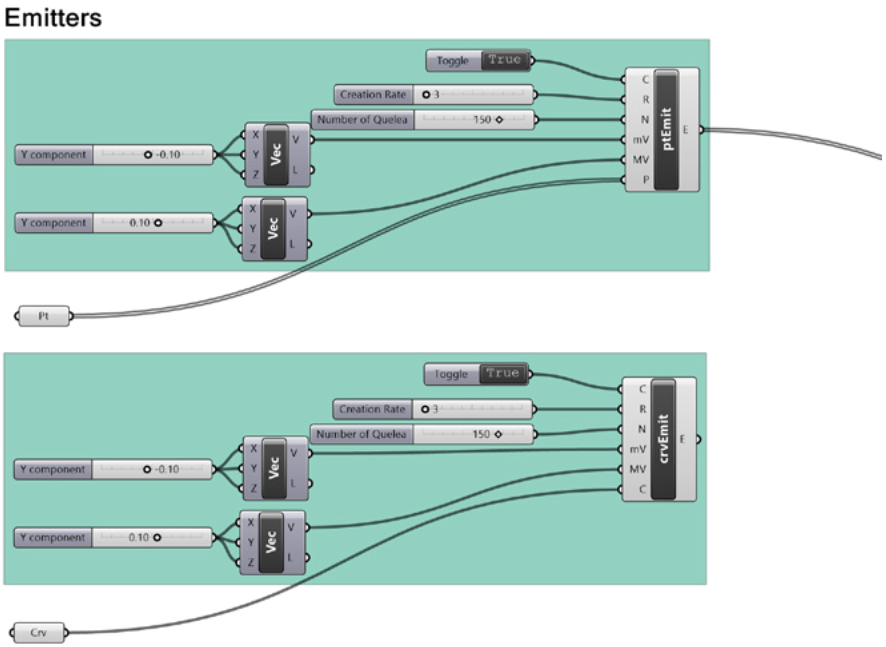
Various Emitter Setup Setting Exploration -
Preferred Default Setting



Various Emitter Setup Setting Exploration -
Reduced Number of Quelea and Creation Rate

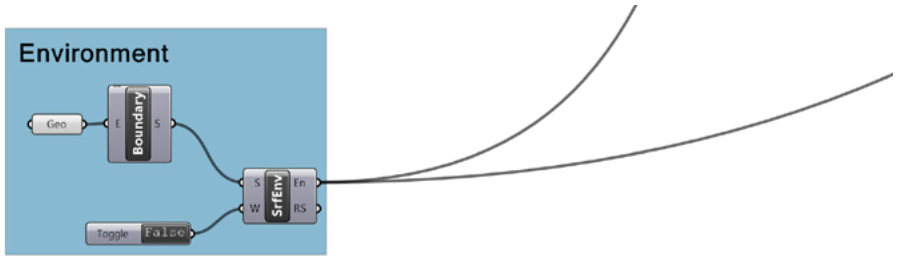
Various Emitter Setup Setting Exploration -
Exploring a Curve Emitter

SECTION 02
SCRIPT | SETUP COMPONENT



Screenshot of the script - Emitters Setting/Setup
Various Agent Setup Setting Exploration - Preferred Default Setting

Various Agent Setup Setting Exploration - Increased Braitenberg Vehicles Wheel Radios



Various Agent Setup Setting Exploration - Reduced Agent History Length

Screenshot of the script - Emitters Setting/Setup

ENVIRONMENT

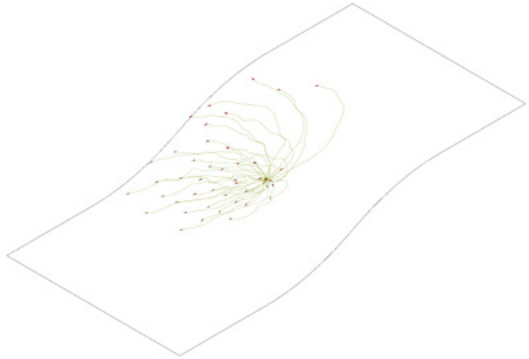
The environment is a location set within the model to test agents against certain behavioral and movement controls. Within the model this space is typically a:

-Surface

-Poly surface 3D

-Brep Volume

Various Environment Setup Setting Exploration - Flat Rectangular Surface Environment



Various Environment Setup Setting Exploration - Sloped Surface Environment

SECTION 02

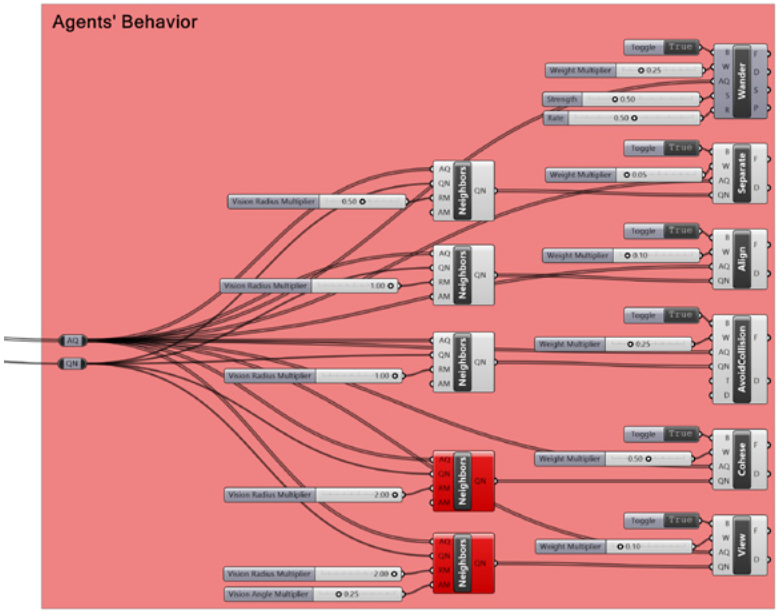
SCRIPT | CONTROLLERS COMPONENT

- **CONTROLLERS COMPONENTS:**

Controllers are parameters within the work/test space that define the rules, behavior patterns of the agents, their reactions can be controlled and defined by the set parameters against movement and environment. There are two types

of controller components that are explored within this tool implementation:

- MOVEMENT BEHAVIOR
- ENVIRONMENTAL BEHAVIOR



MOVEMENT BEHAVIOR CONTROLLERS

Movement behavior controllers determine “behavior” of agents, much like humans there are many forces at play in determining the priorities of movement. Such factors include the force, speed, velocity, direction, separation, the ability to control avoiding collisions, the ability to seek certain locations or destinations and more, these factors are listed below:

Wander Force

Applies a force that causes the agent to randomly steer in a direction that is based off of its previous direction. This produces a seemingly realistic wandering behavior, rather than steering in a completely random direction.

Separate Force

Applies a force to steer to avoid neighbors.

Align Force

Steer towards the average heading direction of Neighbors.

Avoid Unaligned Collision Force

Applied a force to steer the Agent away from a predicted potential collision.

Cohese Force

Steer to move toward the average position of neighbors

View Force

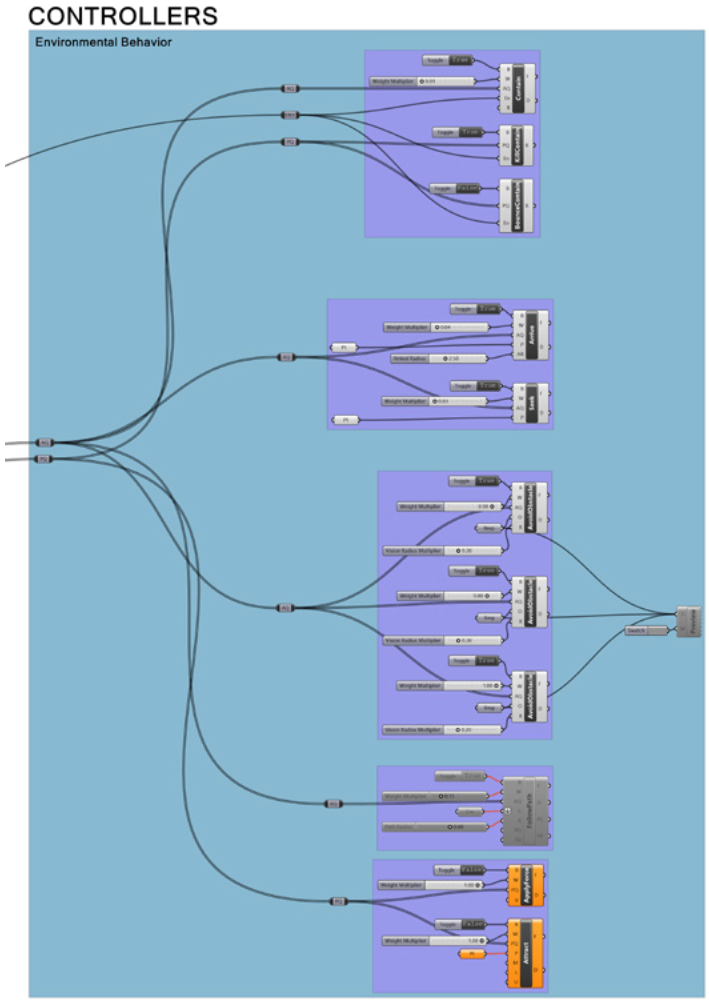
Applies a force to move the Agent laterally away from any Agent that blocks its view.

SECTION 02

SCRIPT | CONTROLLERS COMPONENT

EnvironmentAL BEHAVIOR CONTROLLERS

Environmental controllers emulate real life forces or constraints that are evident in replicating the built environment. These controllers can either act as attracting forces to agents or obstacles that steer agents away or around the set points/geometry. Listed below are a set of parameters in which the agents react to:



Contain Force

Applies a force to keep Agents away from Environment boundaries.

Kill Contain

Applies a force that ends and agents path and force once it reaches the boundary/ surface. Like the contain path its an environmental boundary.

Bounce Contain

Applies a force that contains an agents path and force once it reaches the boundary/surface. the agents will bounce off these boundaries to re-enter the space of study.

Arrive Force

Applies a force to steer the Agent towards a target point and slow down to a stop is it approaches the target point.

Seek Force

Applies a force to steer the agent towards the point.

Avoid Obstacle Force

Applied a force to steer the Agent away if it is about to intersect with an obstacle.

Follow Path Force

Applies a Force to an Agent to move along and stay within a specified radius of a curve.

Apply Custom Force

Applies a custom force to steer the agent towards the point.

Attract Force

Applies an attracting force to steer agent towards themselves or towards a point.

Neighbors in Radius

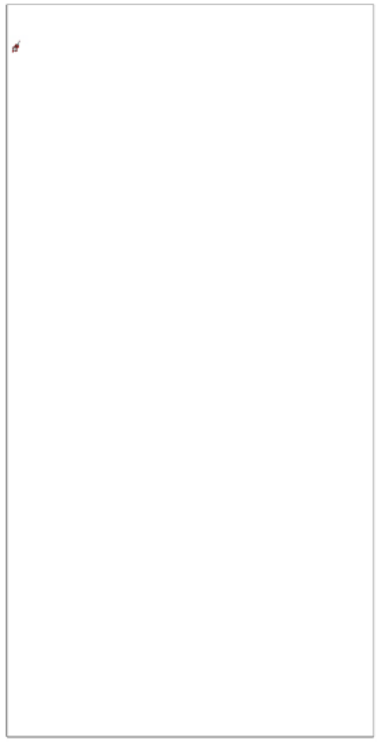
Gets the Neighbors of an Agent within a specified radius.

SECTION 02

SCRIPT | CONTROLLERS COMPONENT

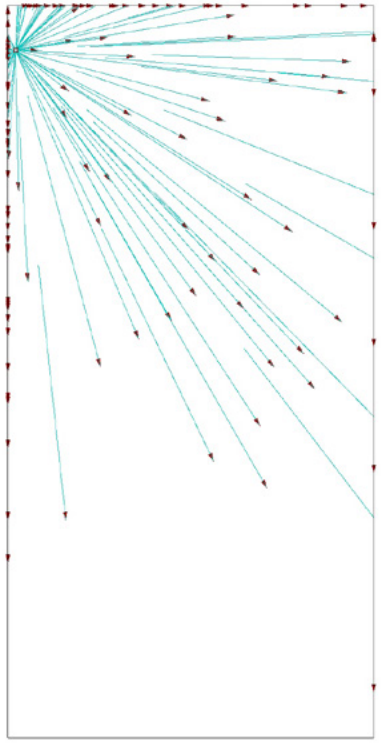
MOVEMENT BEHAVIOR CONTROLLERS EXPLORATION

ENVIRONMENT



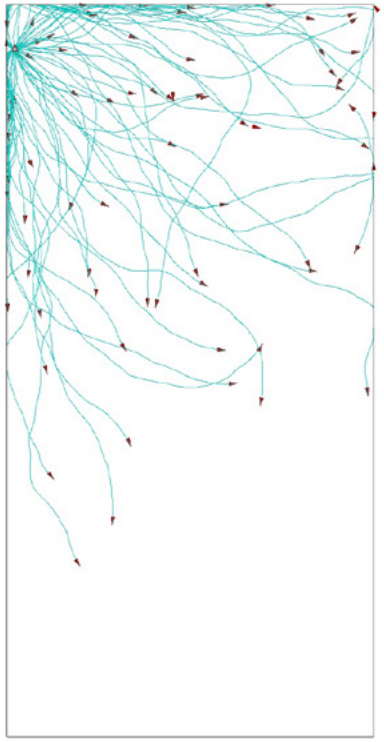
An example of a basic view of the environment constraints/contents.

BASIC



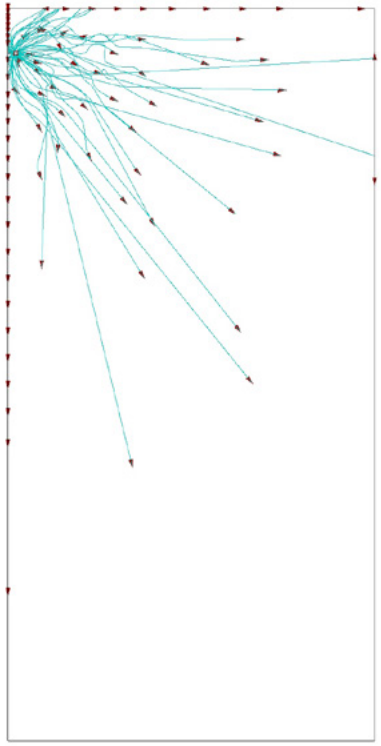
An example of a basic view of the environment and agents with no particular force or constraint set to them.

WANDER



An example of agents set to the controller behavior wander. This applies a force for agents to randomly steer in a direction that is based off of its previous direction. This produces a seemingly realistic wandering behavior.

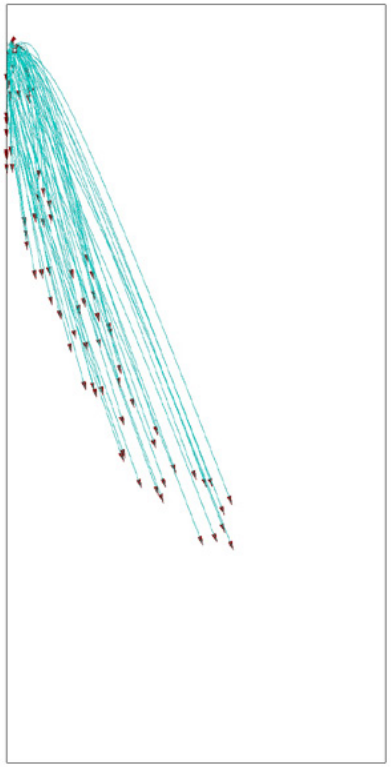
SEPARATION



An example of agents set to the controller behavior separation. This applies a force for agents to steer away from each other at a set measurement.

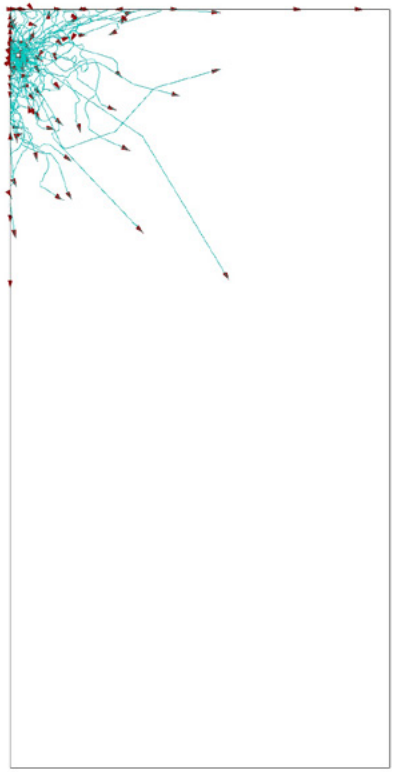
SECTION 02
SCRIPT | CONTROLLERS COMPONENT

ALIGNMENT



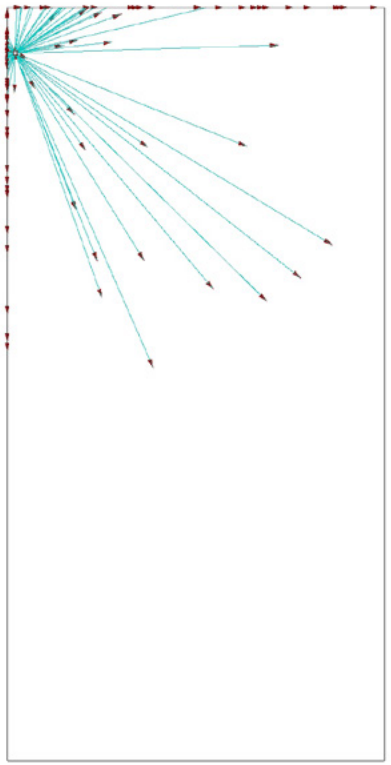
An example of agents set to the controller behavior alignment. This applies a force for agents to steer towards the average heading direction of neighbors.

AVOID COLLISION



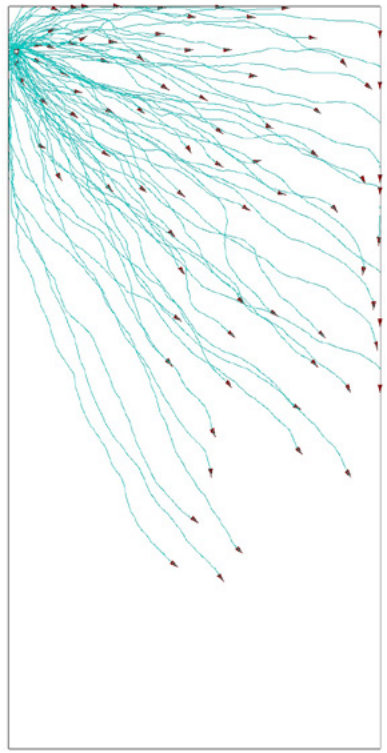
An example of agents set to the controller behavior avoid collision. This applies a force for agents to steer the agent away from the predicted potential collision.

VIEW



An example of agents set to the controller behavior avoid collision. This applies a force for agents to move laterally away from any agent that blocks its view.

COMBINED ALL PARAMETERS



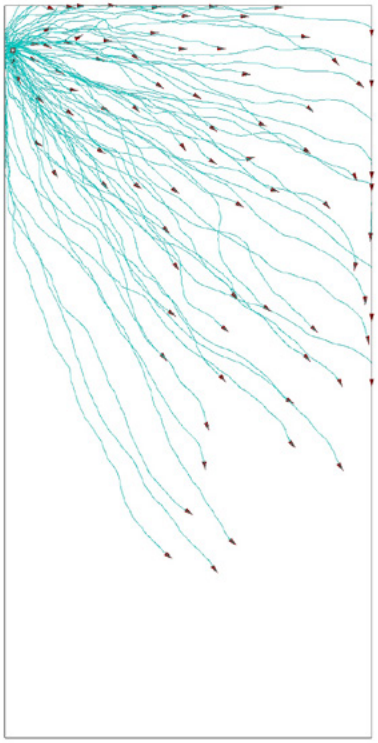
An example of where all of the previous behavior settings are controlling the agents at once.

SECTION 02

SCRIPT | CONTROLLERS COMPONENT

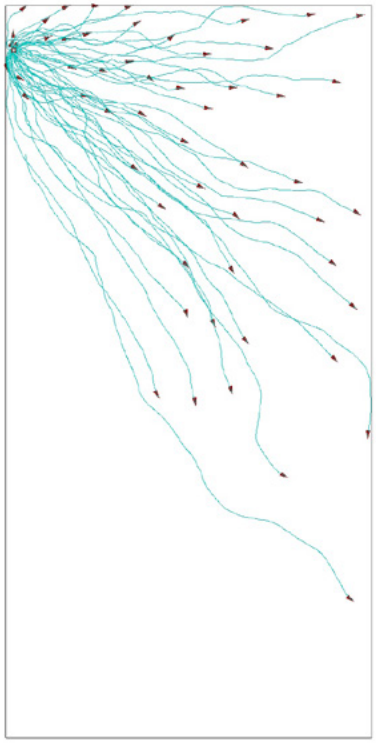
ENVIRONMENTAL BEHAVIOR CONTROLLERS EXPLORATION

AGENTS MOVEMENT



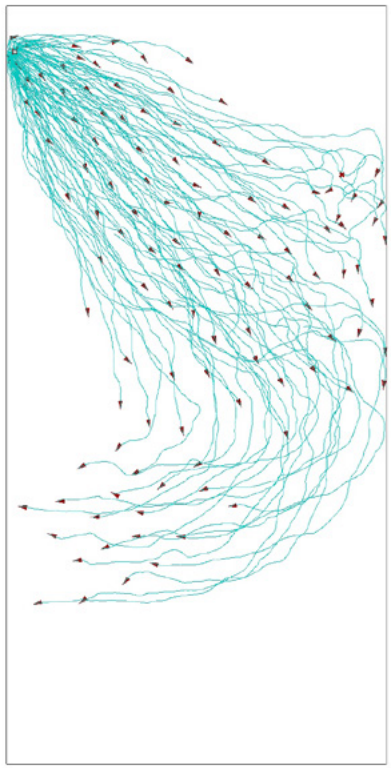
An example of agents set to a basic non instructive setting with no environmental behaviour conditions set.

CONTAIN AND KILL CONTAIN



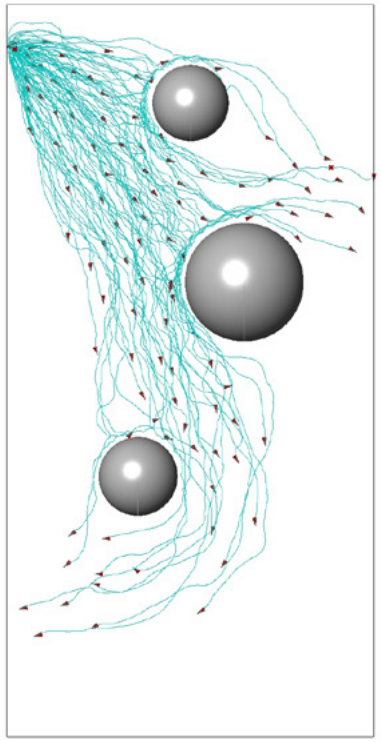
An example of agents reacting to an environmental controller behaviour setting named contain and kill. Here the agents are contained within the environmental boundaries.

ARRIVE AND SEEK



An example of agents reacting to an environmental controller behaviour setting named arrive and seek. Here the agents are steered towards a target point but slow down as they approach the target.

AVOID OBSTACLES



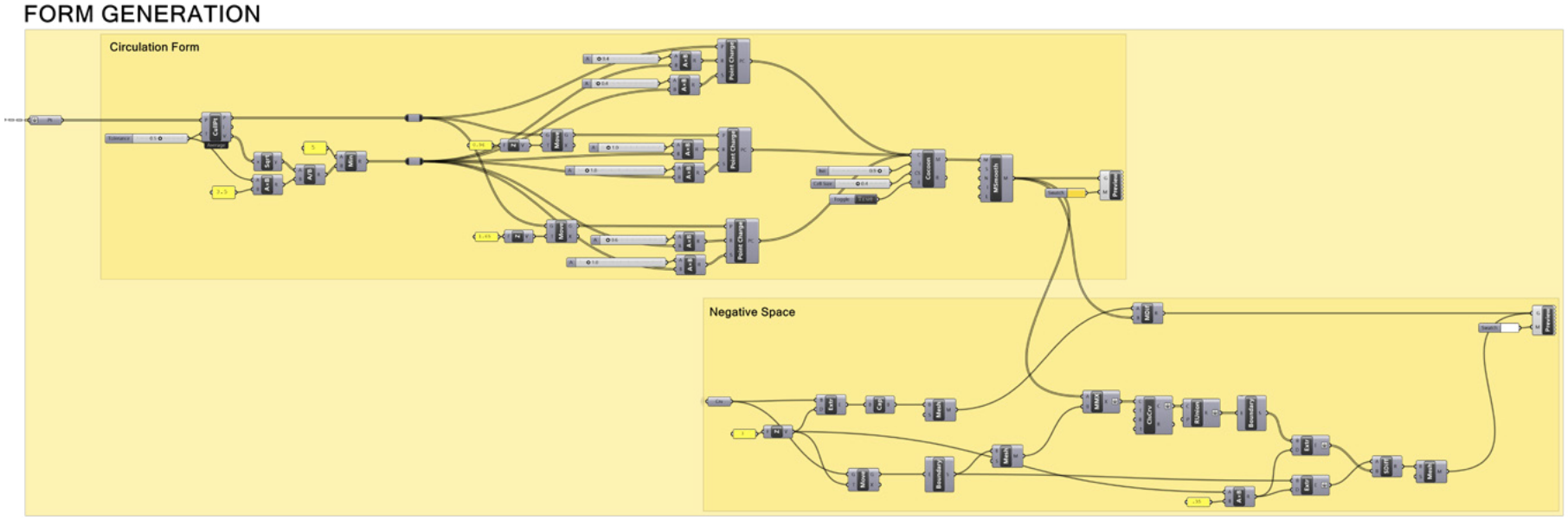
An example of agents reacting to an environmental controller behaviour setting named avoid obstacles. Here the agents adhere to a force that steers them away from the obstacle they are about to collide with.

SECTION 02
SCRIPT | FORM GENERATION COMPONENT

FORM GENERATION

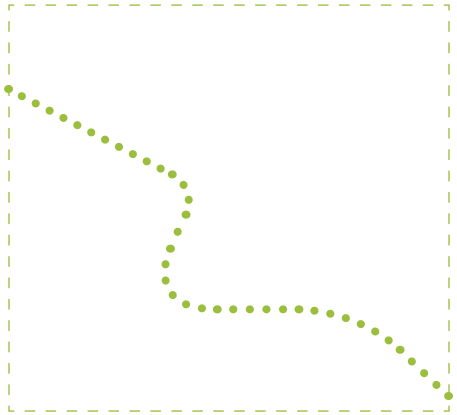
The form generation component of this tool explores creating positive spaces made by the paths of the agents or alternatively can be carved out of the negative space left by the paths of agents.

The aim of the form generator is for the designer to know and set behavioural and movement constraints/parameters for the space. Therefore the form generator is capable to create efficient spaces of obstruction based on singular or collective agent movement paths. These spaces are both efficient and accurate to the user based on environmental stimuli and on data that averages out assumptions regarding human spatial comfort considerations.

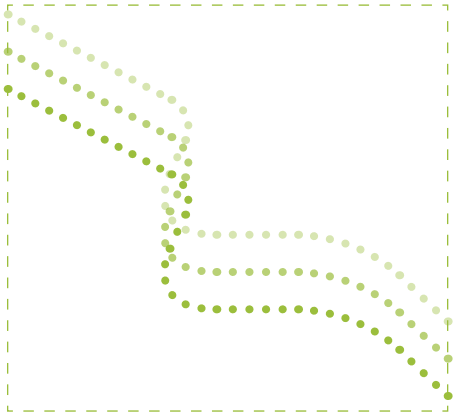


SECTION 02
SCRIPT | FORM GENERATION COMPONENT

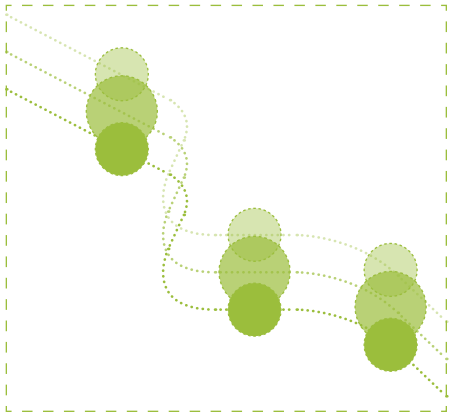
Stage 1 - Crowd Simulation Curves



Stage 2 - Points



Stage 3 - 3D Points



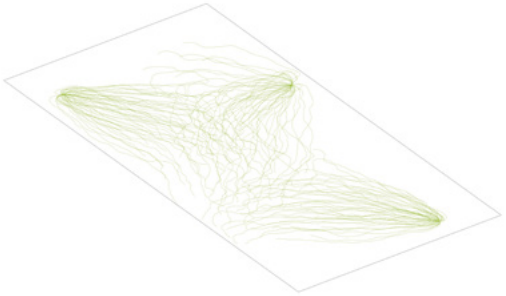
Stage 4 - Sphere Representation Of The Circulation Space

Stage 5 - Positive Volume Required For The Circulation

Stage 5 - Negative Volume of the Leftover Space

Form Generation Stages Concept Diagram

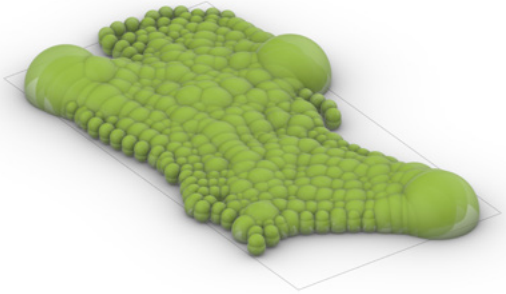
SECTION 02
SCRIPT | FORM GENERATION COMPONENT



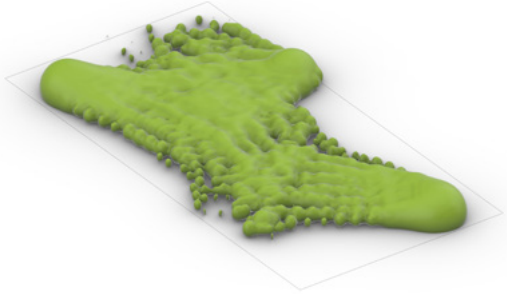
Stage 1 - Crowd Simulation Curves

Stage 2 - Points

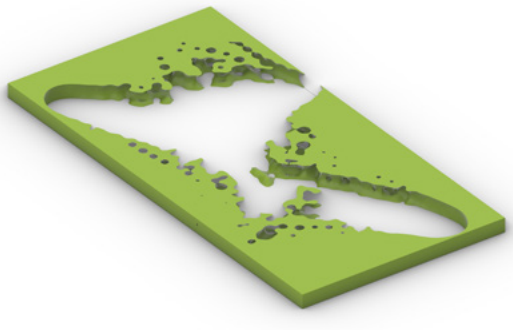
Stage 3 - 3D Points



Stage 4 - Sphere Representation Of The Circulation Space



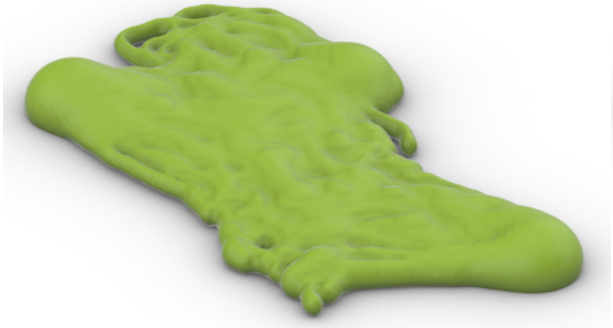
Stage 5 - Positive Volume Required For The Circulation



Stage 5 - Negative Volume of the Leftover Space

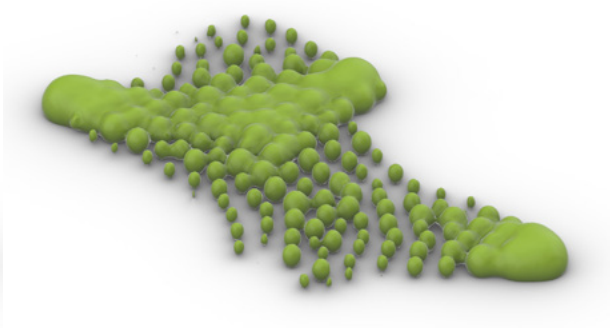
Form Generation Stages Diagram

SECTION 02
SCRIPT | FORM GENERATION COMPONENT

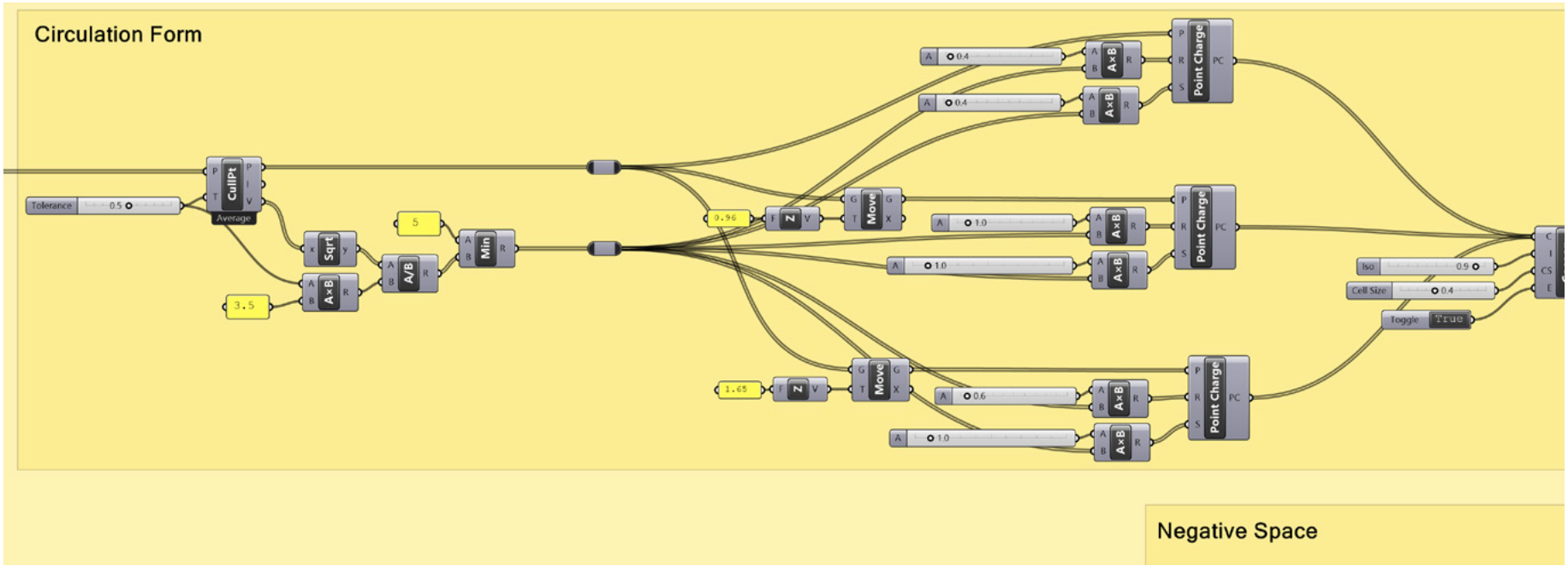


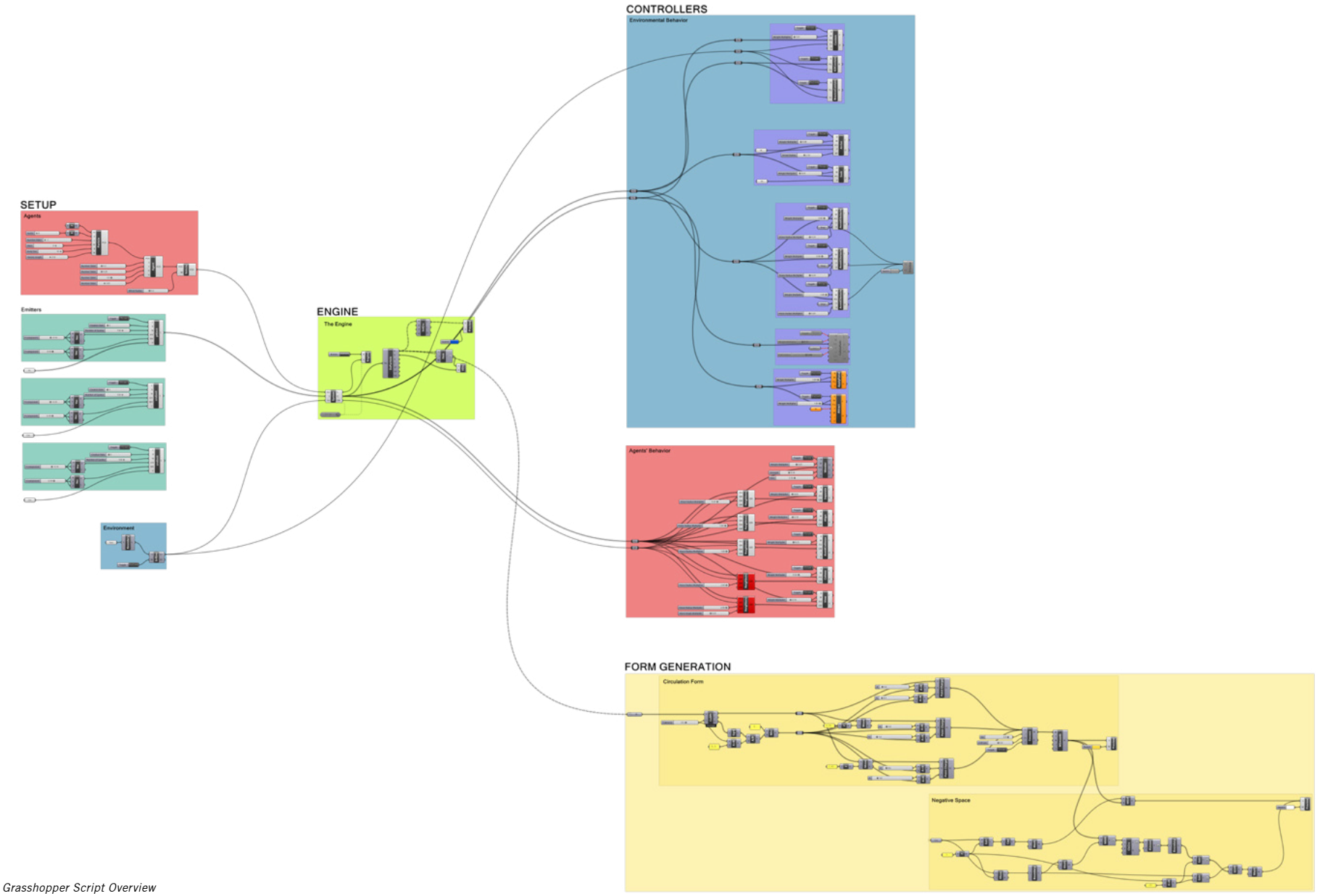
Various Form Generation Setting Exploration - High Resolution and High Density of Circulation Points

Various Form Generation Setting Exploration



Various Form Generation Setting Exploration - Low Resolution and Low Density of Circulation Points





Grasshopper Script Overview

SECTION 3

PROJECT RELEVANCE & CASE STUDIES

SECTION 3
RELEVANCE

What is this tool?

The tool is a way for designers to measure, track and formulate understandings behind human crowd patterns and relationships. It maps and generates human movement patterns based on a series of parameters given to the tool via the script. The tool uses agent based systems, in particular this tool is a multi-agent simulator a class of computational modes for simulating the actions and interactions of autonomous agents (either individual or collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole. The goal of the agent based system is to search for explanatory insight into the collective behavior of agents obeying simple rules and parameters.

Why we think this tool is useful?

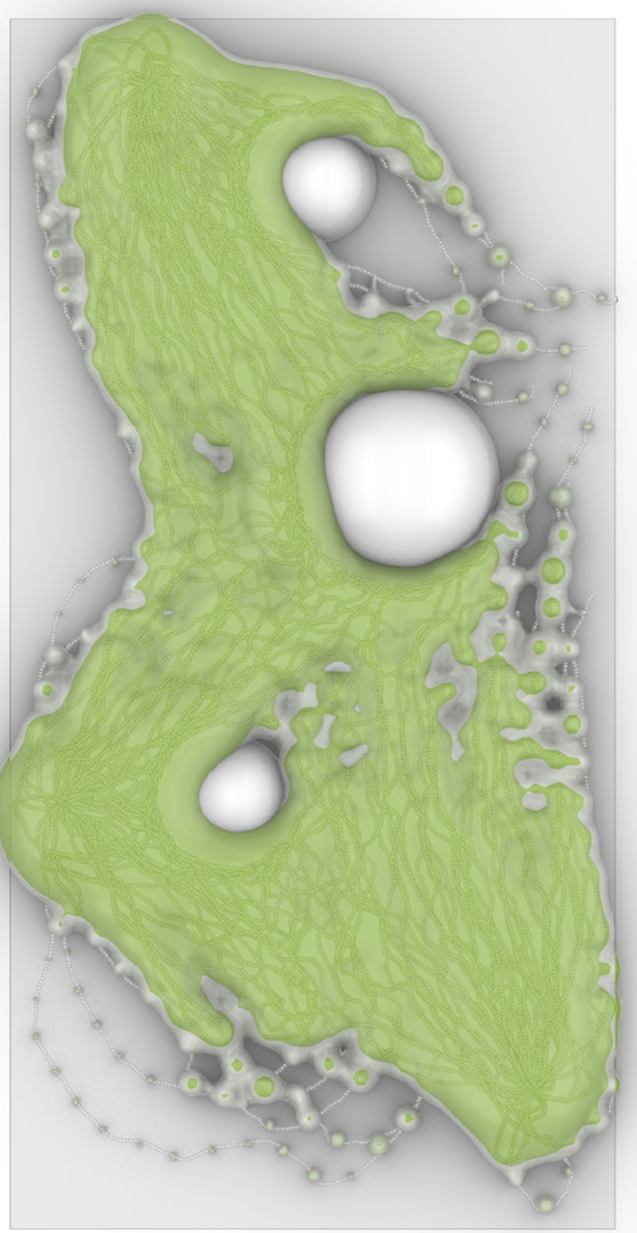
The script parameters run on behavioral movement and science analysis, these parameters have been collected and analysed over a long literature study where an understanding of quantifying the qualitative is possible. A large area to which needed translating was from the data into design metrics and additionally the stimuli language into the computational design metrics in order to create the design platform/condition and environment.

This tool is useful in mapping and illustrating the human crowd patterns and extent of movement that respond to the set environment. By setting varied environmental parameters and behavioral inputs we are able to develop a better understanding of the real life cases against varied design decisions before the creation of the project. Of course all tests conducted are still subjected to individual bias created by a human being, but based on averaging assumptions about human movement this is the most accurate

For example, in relation to land use and program, the script can help inform designers where best to place heavy retail and commercial nodes, based on human movement, crowding and proxemics etc.

How will this make our designs process more efficient?

The tool's output generates solutions and deliverables for both the iterative process and the generation process. The analysis output produces mapped outcomes that will inform and steer key decision making in the design process. The Form finding output will generate form based on the environmental stimuli set by the designer. This design tool will not only streamline our process but additionally add to the accuracy and effectiveness of our design decisions.



Applicability to the Design Field,

Our public urban spaces provide little excitement or visual variation and virtually no opportunity to build a kinesthetic repertoire of spatial experiences. It would appear that many people are kinesthetically deprived and even cramped.

These are the spaces we are hoping to bring based on a thorough analysis and understanding of movement patterns. To achieve the most successful response to human behaviour, instead of affecting it with obstacles.

The range and diversity offered in the plug-in settings of this tool allows us to experiment with a variety of test subjects, people. We understand that humans are variable test subjects and we believe that this tool is specifically programmed to capture the potential large demographic of people we see in our public spaces. These demographics can be categorized by age, sex, culture primarily but are not limited to.

Therefore we see this tool critically assisting in our design processes and the assumptions we make around human patterns created in public space. Another applicable example, in relation to this tool and our environment can be seen in landscaping. There are many examples in our cities today where hardscaped surfaces in an urban setting could be landscaped. Crowd simulation illustrates how the path most travelled in certain high traffic areas pedestrians only use a fraction of the area that is actually intended. Meaning that these unused spaces could actually be for softscaped vegetation, storm water remediation or filtration and park space. Therefore this tool could help provide this information to urban planners and landscape architects within the design process. Better choices that reflect sustainability and resilience, cost efficiency and health.

SECTION 3
RELEVANCE

URBAN/ARCHITECTURE ISSUES TO RUN/TEST SCRIPT ON

Brief description:
We see issues and topics (as identifies in the list below) as opportunity areas to measure and perform human crowd simulation tests upon. The design tool is beneficial in measuring and producing findings that will inform design decisions related to each of these topics:
For example, in relation to land use and program, the script can help inform designers where best to place heavy retail and commercial nodes, based on human movement, crowding and proxemics etc.
The script parameters run on behavioral science analysis, translates into computational design metrics and stimuli from the existing condition/ environment.

-Land uses and program
- -Commercial analysis
- -Educational analysis
- -Civic analysis
- -Retail specific

-CPTED Principles (Crime prevention through environmental design)
- -Natural Surveillance
- -Natural Access Control
- -Territorial Reinforcement
- -Maintenance

-Landscaping & Ecology and nature
- -Urban Run off (storm water)
- -Impervious material locations based on path most travelled
- -Location/design decisions around landscaping/plantings (collective gathering areas under shade)

-Renewable technologies-Self-sufficient communities

-Paving solutions, kinetic energy
-Heat generation
-Energy sharing (building to public spaces)

-Art and play

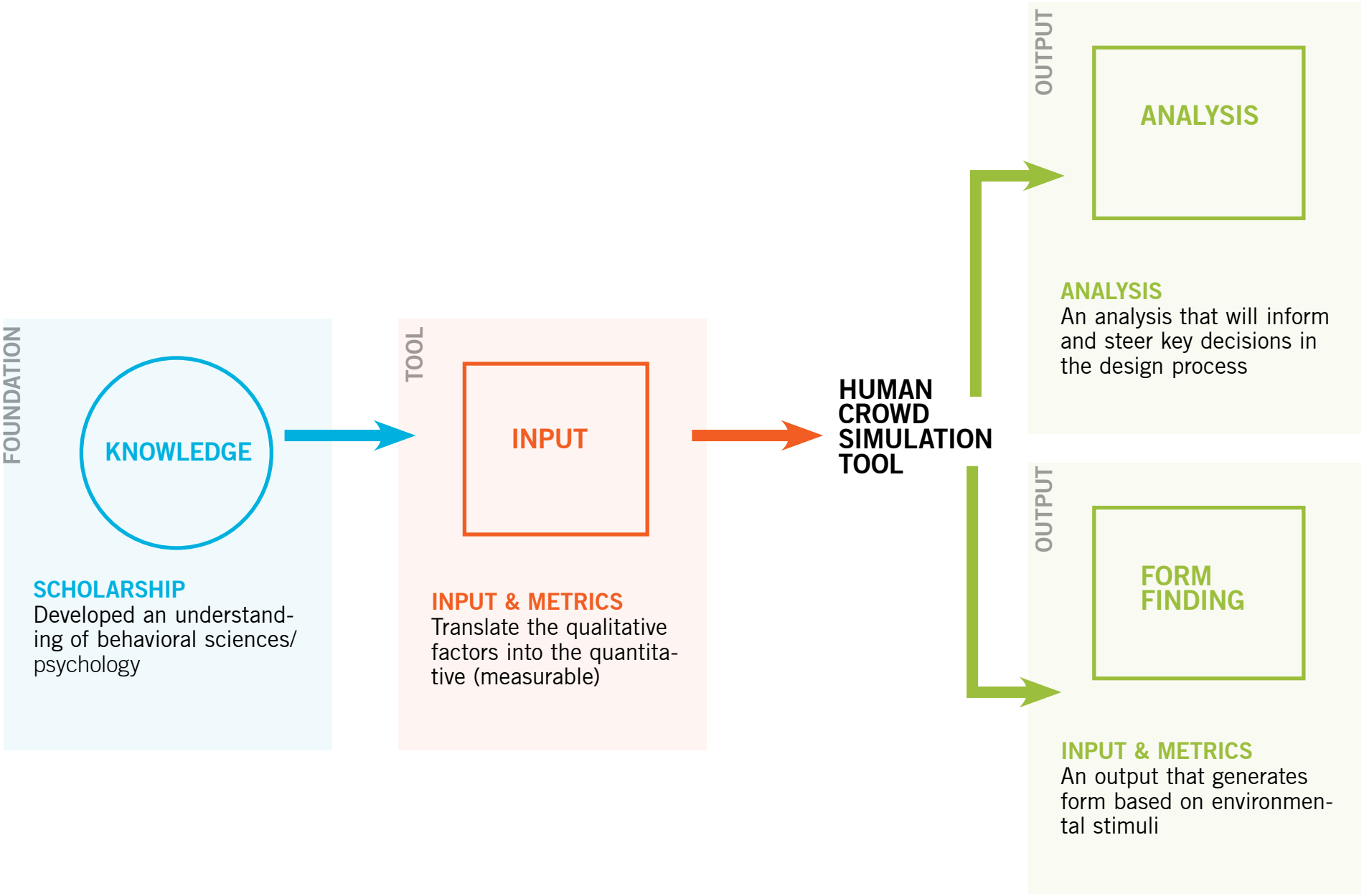
-Physical Sculptural forms based on the human perception of space and movement patterns
-Development of forms based on the understanding and reading of different age groups and mentality
-Platforms for art/play/educational instillations

-Staying Spaces vs Transient Spaces

-24 hour use
-Seasonality
-Programing civic uses
-Flexible spaces for a variety of uses
-Different users, layering narratives

-Psychology and Mental health

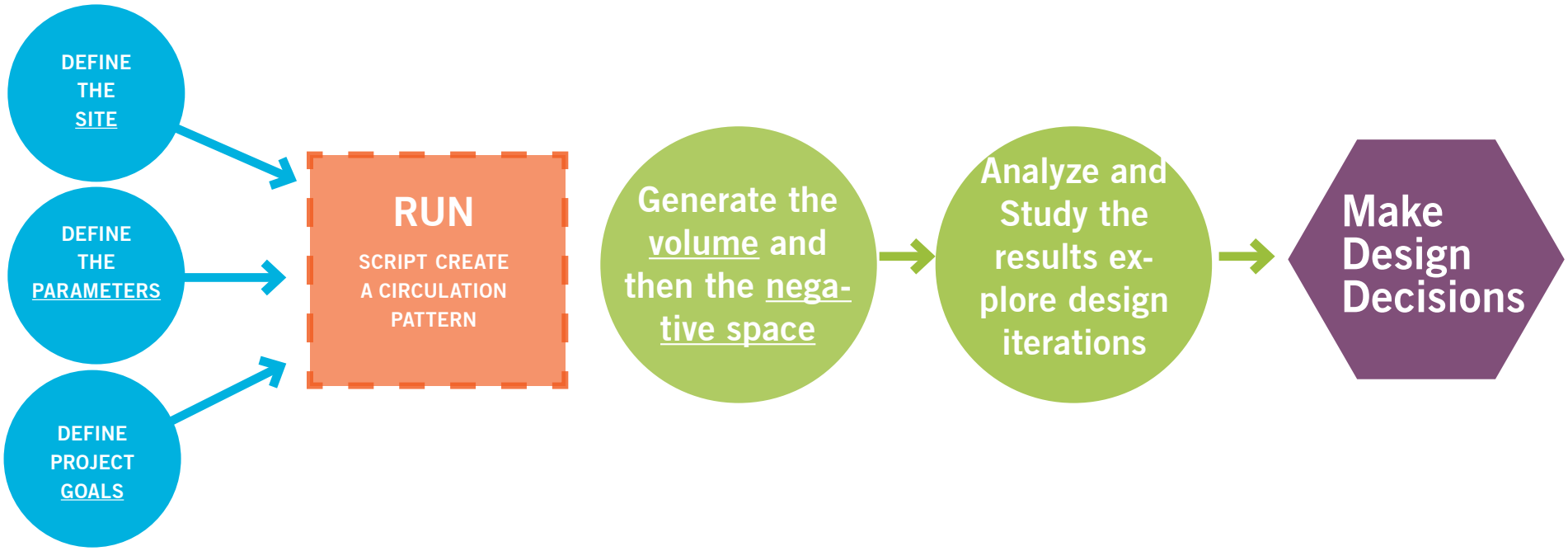
-Understanding the reaction of certain demographic groups, based on the behavioral characteristic inputs we create and define. Within this tool we can start to better understand spaces and behavioral reactions from groups such as:
-Females
-Males
-Children
-The elderly
-The Physically challenged
and much more.


FOUNDATION
KNOWLEDGE
SCHOLARSHIP
Developed an understanding of behavioral sciences/ psychology
TOOL
INPUT
INPUT & METRICS
Translate the qualitative factors into the quantitative (measurable)
HUMAN CROWD SIMULATION TOOL
OUTPUT
ANALYSIS
ANALYSIS
An analysis that will inform and steer key decisions in the design process
OUTPUT
FORM FINDING
INPUT & METRICS
An output that generates form based on environmental stimuli

SECTION 3
DEMONSTRATION OF WORKFLOW

HOW TO USE THIS TOOL:

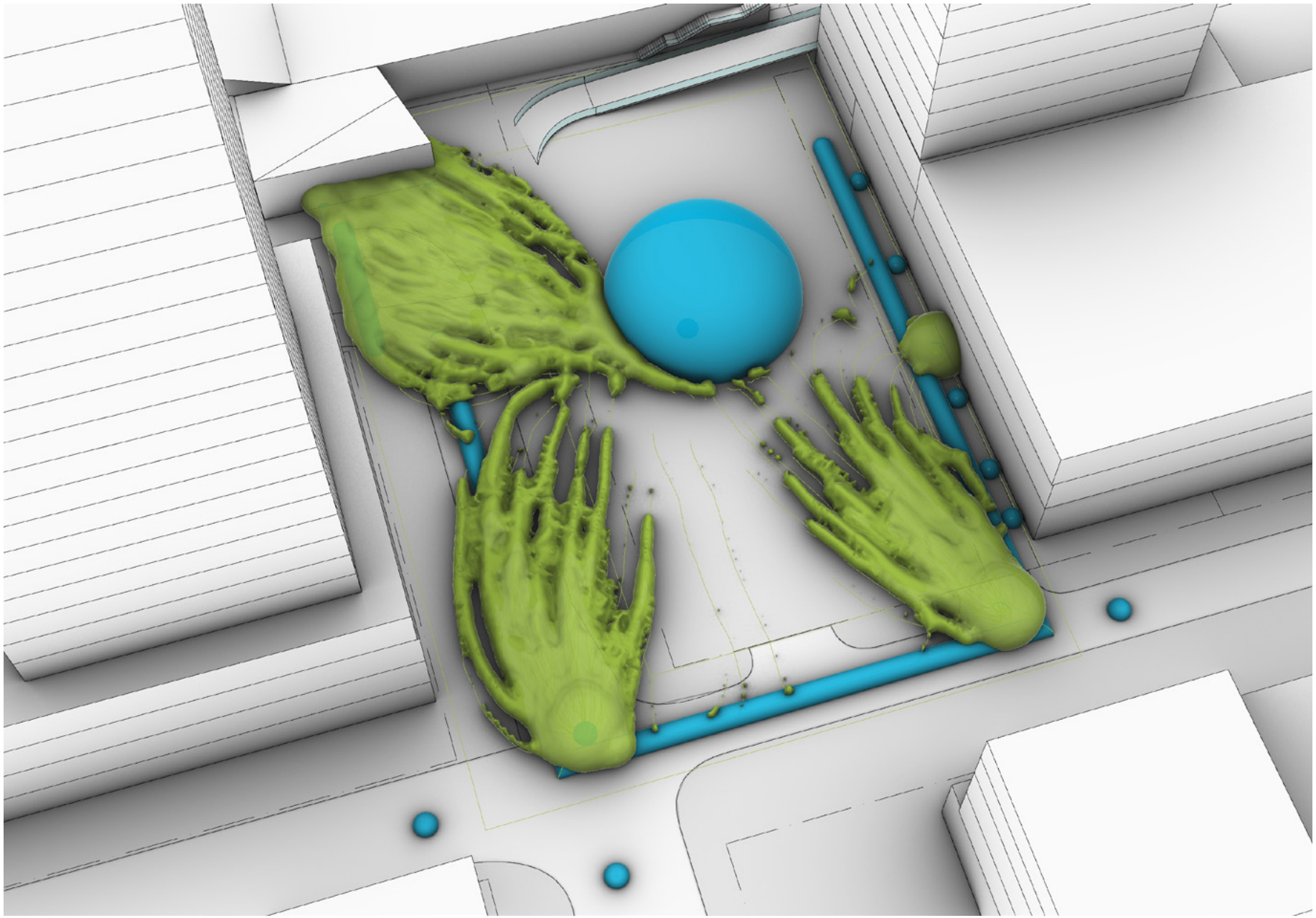
The Following workflow describes how this tool can be used as a part of the design process for defining the boundaries within which the designer can make design decisions regarding the circulation spaces and the programmable volumes.



SECTION 3
TRANSLATING SPACE TO AGENT BASE
GRASSHOPPER LANGUAGE

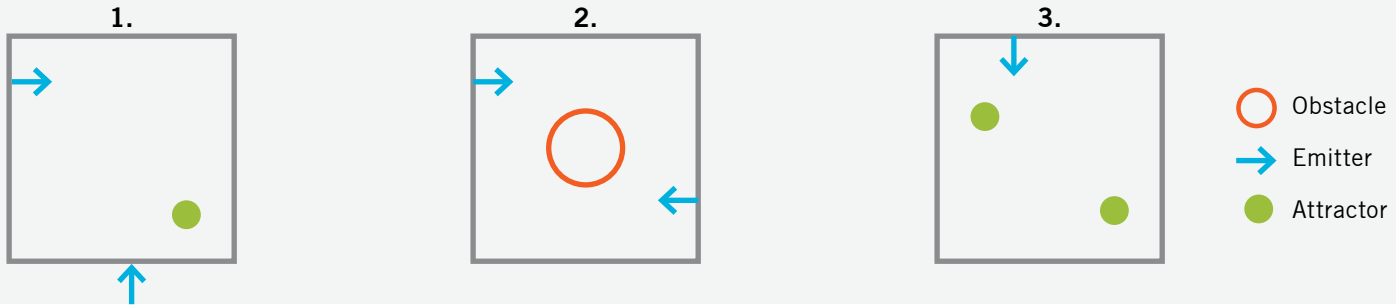
In order to describe urban and architectural spaces in Rhino/ Grasshopper environment for the crowd simulation platform, the activities should be translated into grasshopper components. The following table shows a list of these components. Based on the component's definition and function, the urban or architectural representation could be defined. As an example, emitters point can define a point of entry for crowd, obstacles can represent programmable spaces, etc.

	GRASSHOPPER COMPONENT	GRASSHOPPER DEFINITION OF THE COMPONENT
	AGENT RULES	
CONTAIN	Contain Force	Applies a force to keep Agents away from Environment boundaries.
	Kill Contain	Kills the particle when it leaves the environment boundaries.
	Bounce Contain	Causes Particles to bounce off Environment boundaries.
FORCES AND ATTRACTION	Arrive Force	Applies a force to steer the Agent towards a target point and slow down to a stop is it approaches the target point.
	Seek Force	Applies a force to steer the Agent towards the point.
	Attract Force	Attracts a Quelea within the radius of the point.
	Follow Path Force	Applies a Force to an Agent to move along and stay within a specified radius of a curve.
	Apply Custom Force	Applied a user specified force vector to the Agent.
OBSTACLE	Avoid Obstacles	Applied a force to steer the Agent away if it is about to intersect with an obstacle.
	EMITTERS	
EMITTER	Point Emitter	A point from which Quelea can be emitted.
	Curve Emitter	A curve from which Quelea can be emitted.

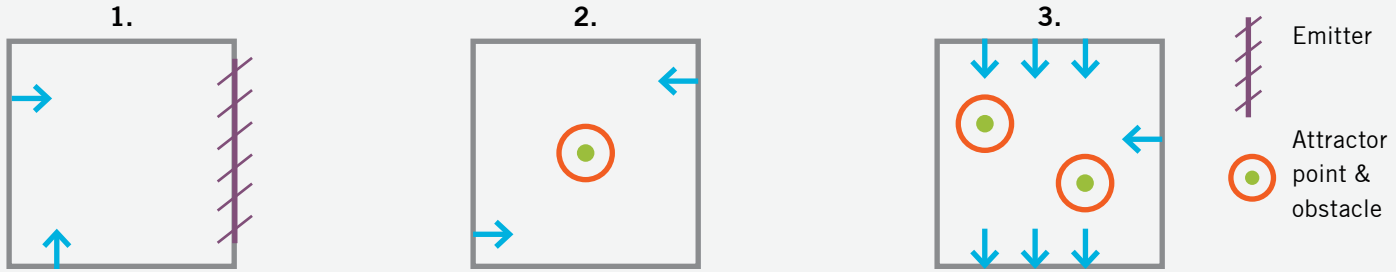


CASE STUDY ANALYSIS DEVELOPING LAYERS OF ANALYSIS

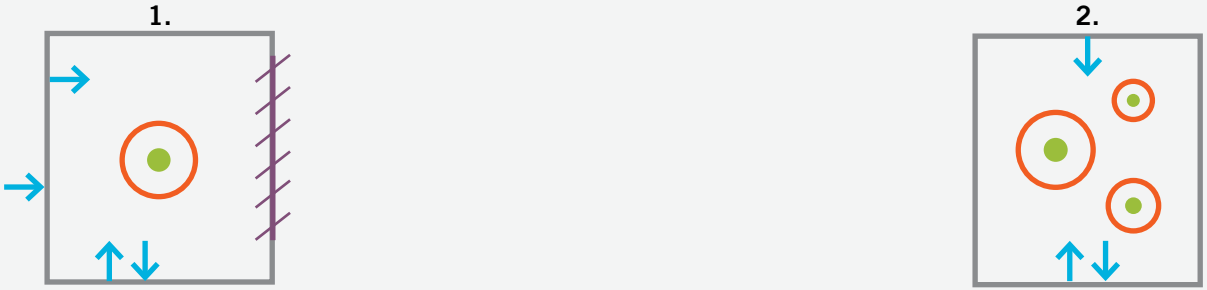
PHASE 01
Base Level Exploration



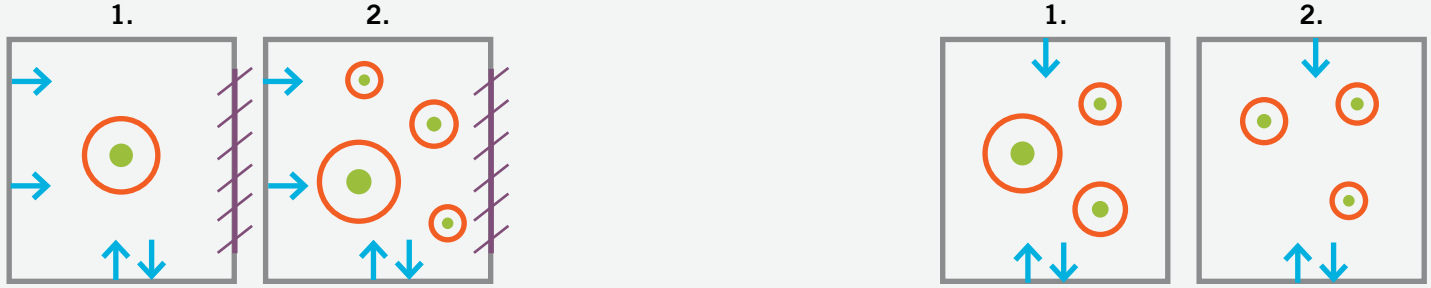
PHASE 02
Advancing Exploration



PHASE 03
P+W Project Case Study Application
Port Moody
Commercial Broadway

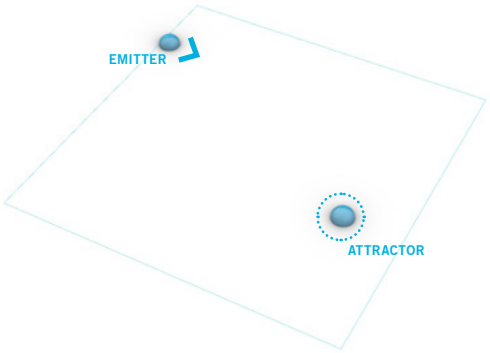


PHASE 04
Variations and Design Options

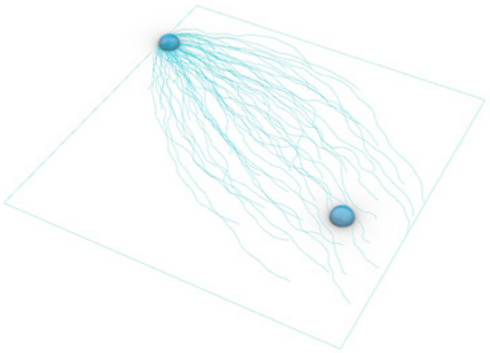


SECTION 03
PHASE 01
Base Level Exploration

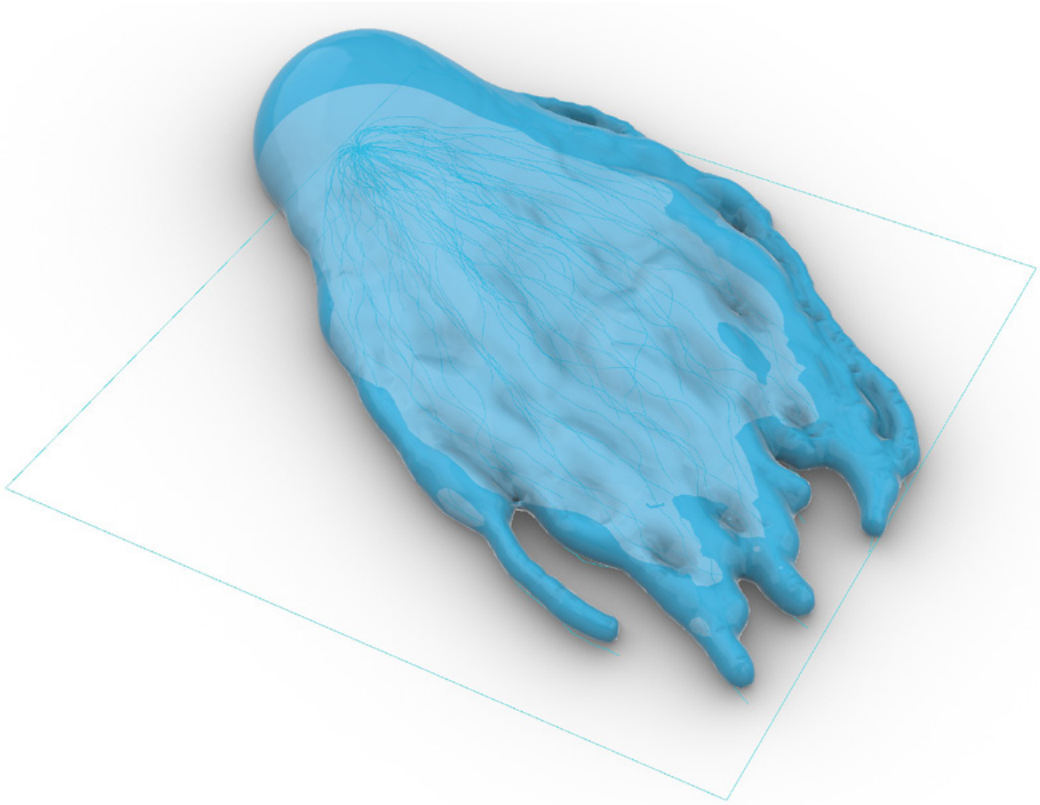
01.1 - Single point emitter and single attractor point



CASE STUDY 01.1 - SETUP



CASE STUDY 01.1 - CURVE RESULT

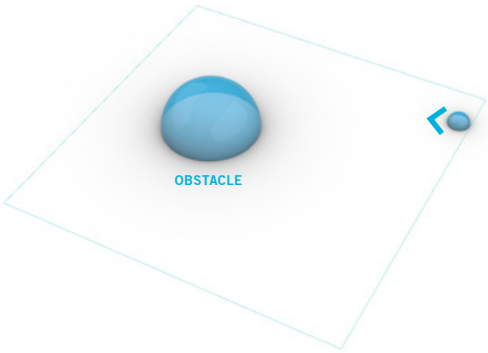


CASE STUDY 01.1 - POSITIVE CIRCULATION VOLUME RESULT

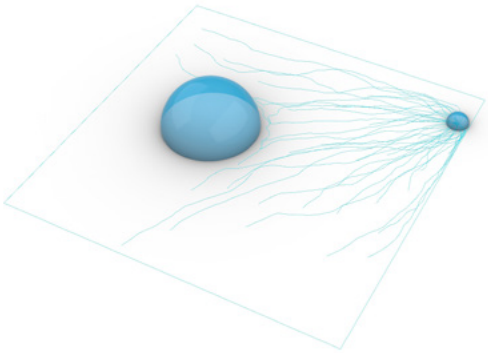
SECTION 03
PHASE 01

Base Level Exploration

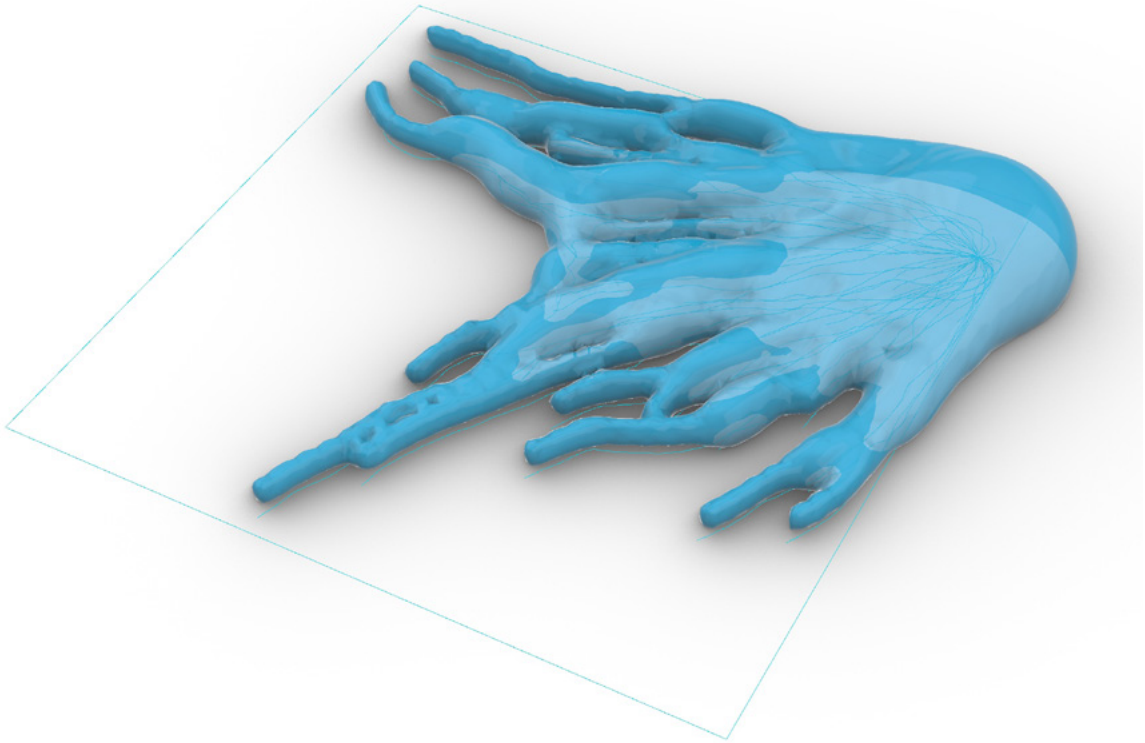
01.2 - Single point emitter and single obstacle sphere



CASE STUDY 01.2 - SETUP



CASE STUDY 01.2 - CURVE RESULT

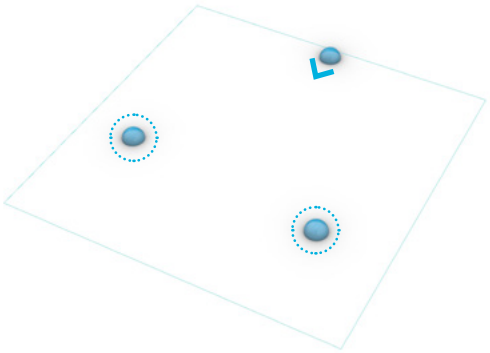


CASE STUDY 01.2 - POSITIVE CIRCULATION VOLUME RESULT

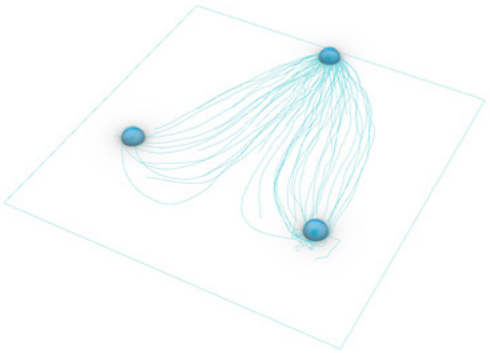
SECTION 03
PHASE 01

Base Level Exploration

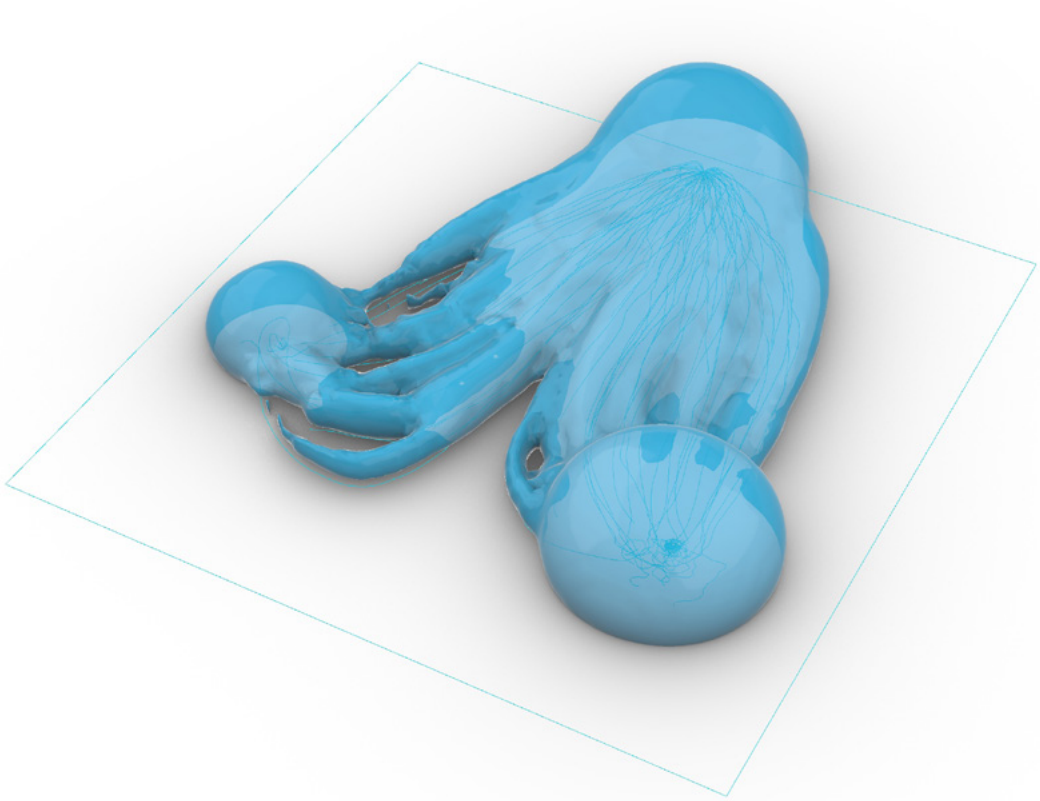
01.3 - Single point emitter and two attractor point



CASE STUDY 01.3 - SETUP



CASE STUDY 01.3 - CURVE RESULT

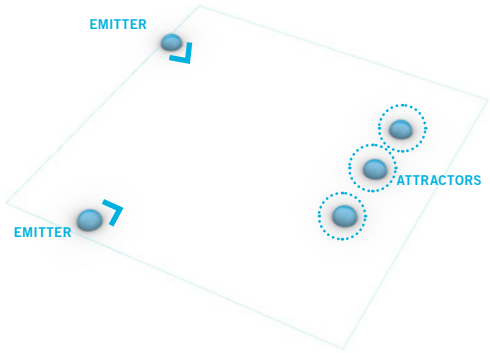


CASE STUDY 01.1 - POSITIVE CIRCULATION VOLUME RESULT

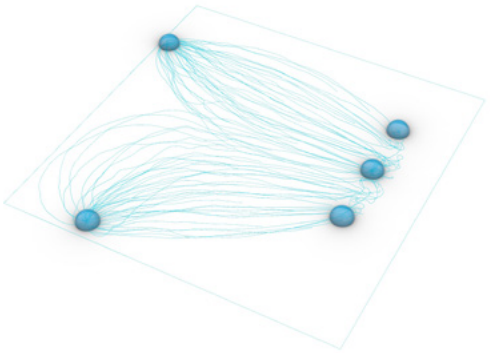
SECTION 03
PHASE 02

Advancing Exploration

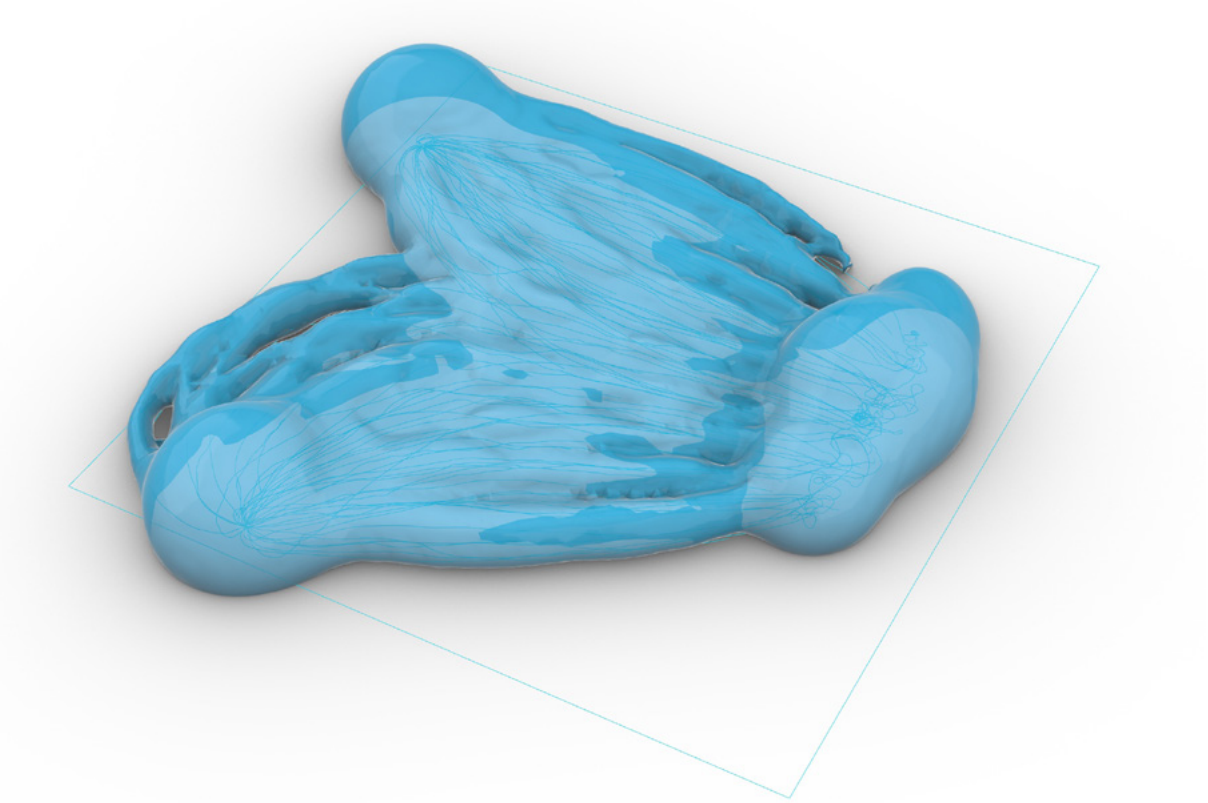
02.1 - Two point emitters and a group of three attractors



CASE STUDY 02.1 - SETUP



CASE STUDY 02.1 - CURVE RESULT

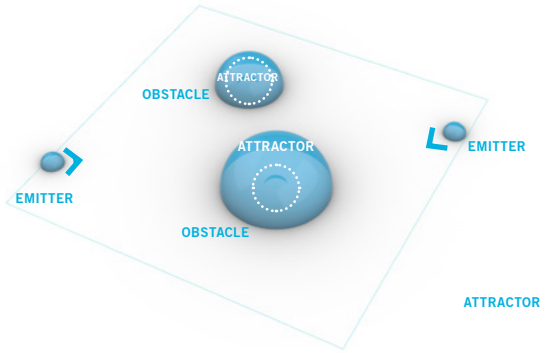


CASE STUDY 02.1 - POSITIVE CIRCULATION VOLUME RESULT

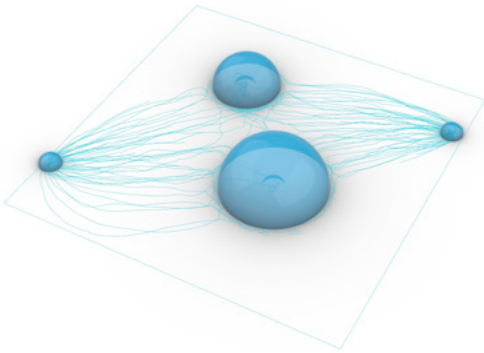
SECTION 03
PHASE 02

Advancing Exploration

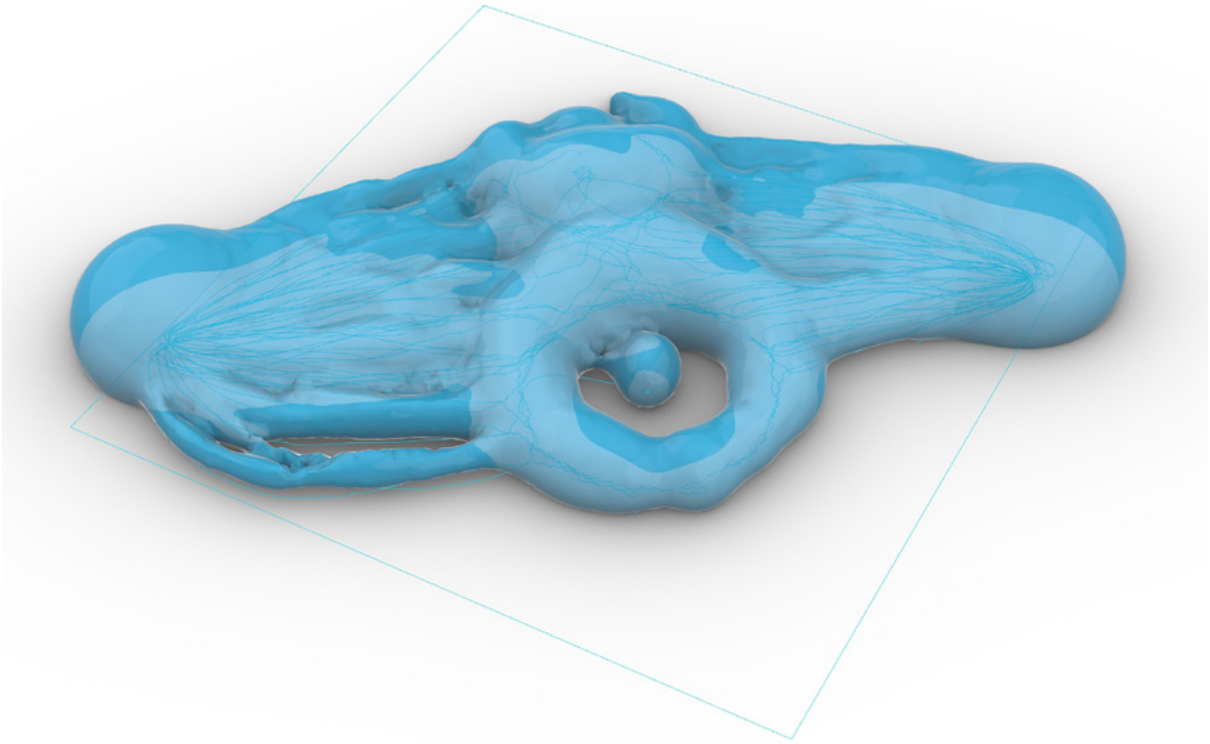
02.2 - Two point emitters, two sphere obstacles with an attractor point in their centre



CASE STUDY 02.2 - SETUP



CASE STUDY 02.2 - CURVE RESULT

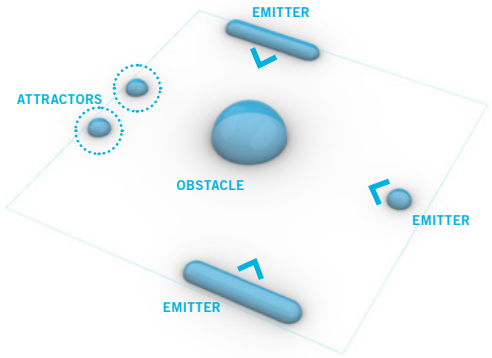


CASE STUDY 02.2 - POSITIVE CIRCULATION VOLUME RESULT

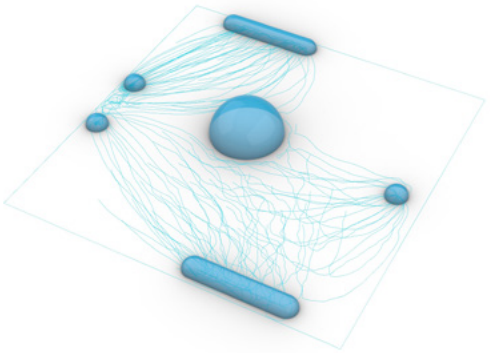
SECTION 03
PHASE 02

Advancing Exploration

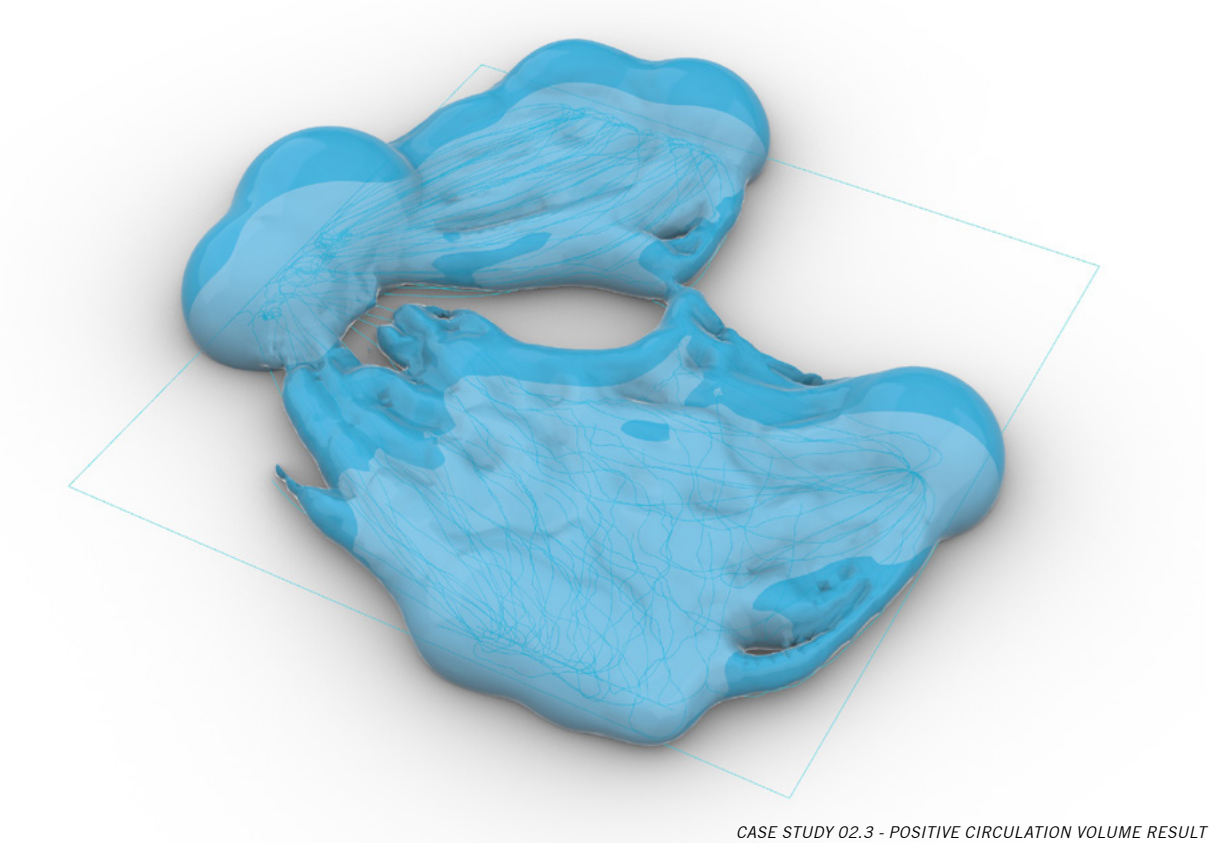
02.3 - One point emitters, two curve emitters, one obstacle sphere in the centre and two attractor points



CASE STUDY 02.3 - SETUP



CASE STUDY 02.3 - CURVE RESULT



CASE STUDY 02.3 - POSITIVE CIRCULATION VOLUME RESULT

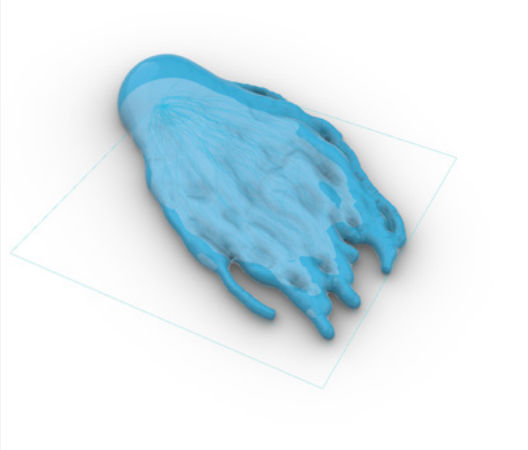
SECTION 03 PORT MOODY PLAZA

Phase 03 **Project Case Study**

PHASE 01

Base Level Exploration

1.



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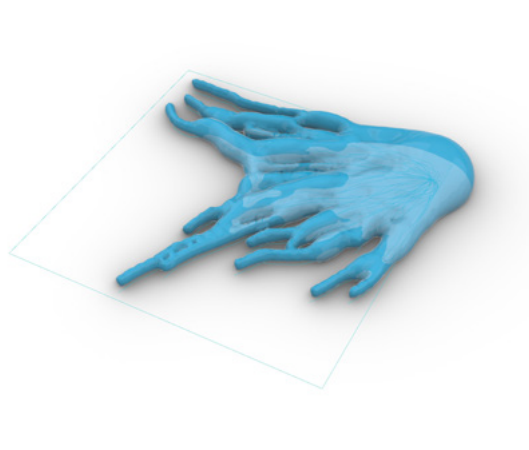

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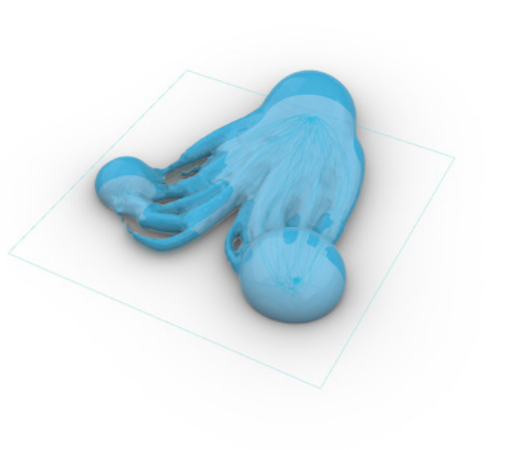
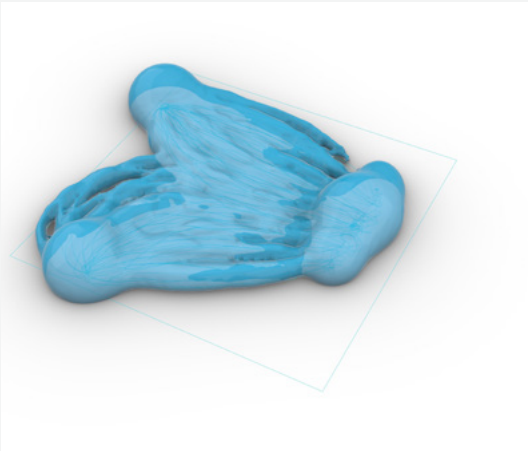


PHASE 02

Advancing Exploration

1.



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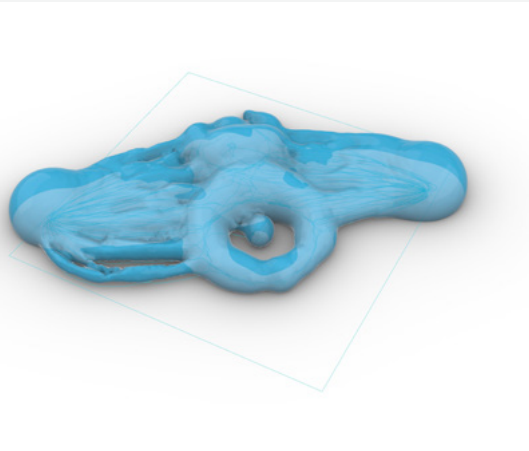

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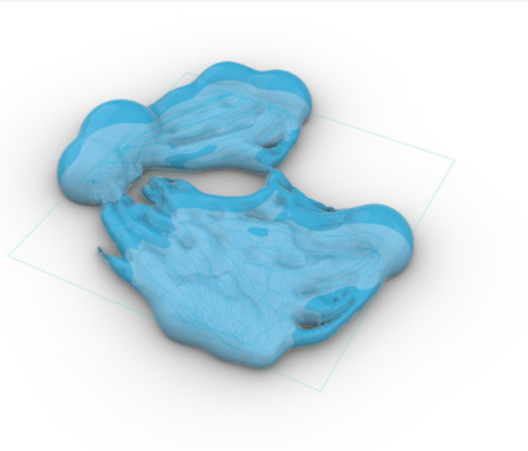


SECTION 03 PORT MOODY PLAZA

Phase 03 **Project Case Study**

P+W Project Case Study Application

CLIENT PCI, Beedie, Translink, BCTFA, Magusta, Anthem, Woodbridge, Colliers, Ranstad, City of Port Moody.
LOCATION Port Moody, British Columbia
PROGRAM Mixed Use, Residential, Commercial and Industrial
SIZE 8.5 HA (914,760 SF/ 21 acres)

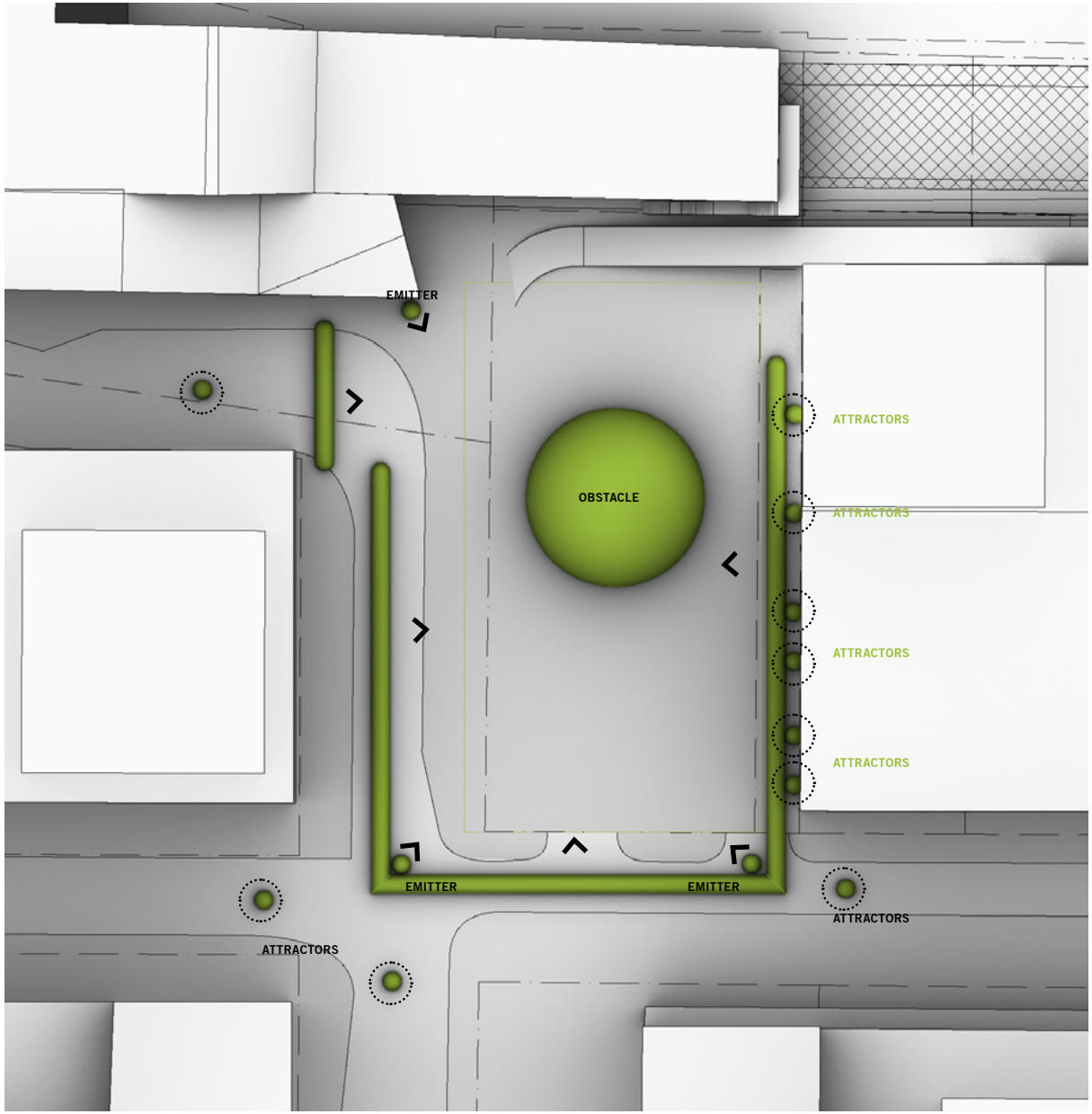
PROJECT 1

Port Moody Plaza (Part of a larger Masterplanning and OCP Amendment Project)

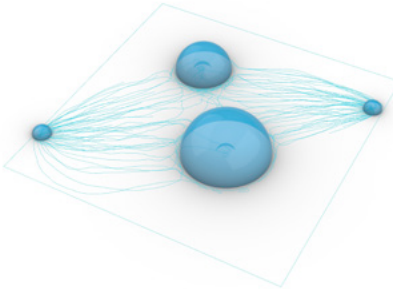
- Creating a compact, walkable neighborhood with a diverse mix of uses that support live, work and play opportunities
- Forming a vibrant mixed use transit orientated development with employment generation and public benefits
- Maximizing solar penetration to public open spaces and street frontages
- Enhancing and connecting the neighborhood to the existing urban fabric while additionally providing a range of amenities and community attractions

Plaza Questions/Project Goals?

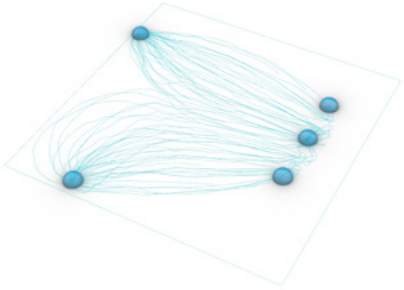
1. What are the best locations for creating art instillations within the plaza?
2. What is the right quantity and size of art/ public realm amenities for the plaza?
3. Where are the “transient vs staying” spaces for people to occupy?



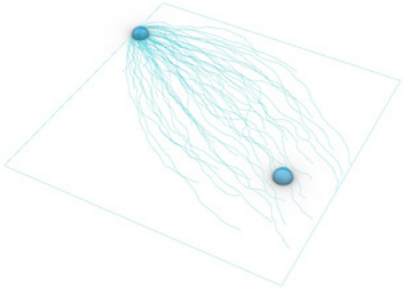
Port Moody Plaza - Crowd Simulation Setup



Case Study 02.2 - informing simulation



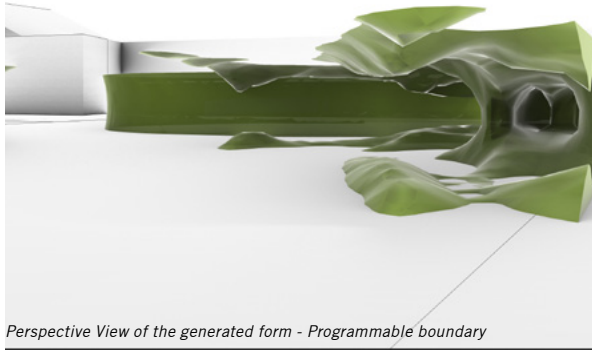
Case Study 02.1 - informing simulation



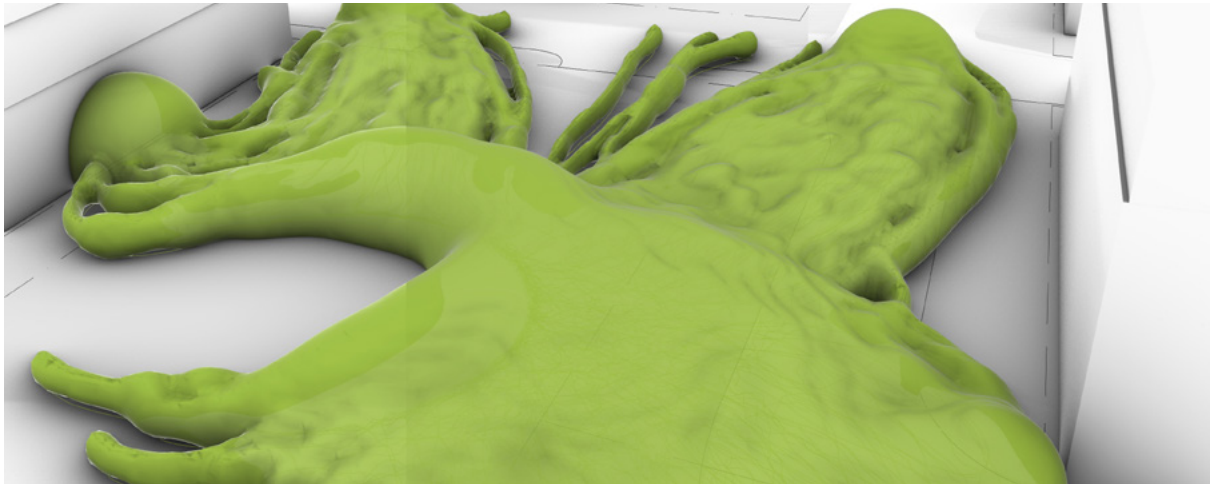
Case Study 01.1 - informing simulation

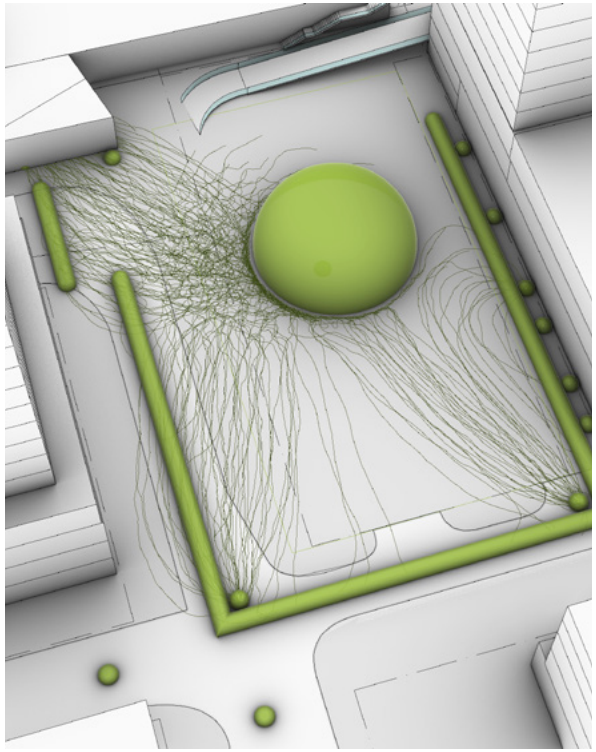
SECTION 03 PORT MOODY PLAZA

Phase 03 **Proiect Case Studv**

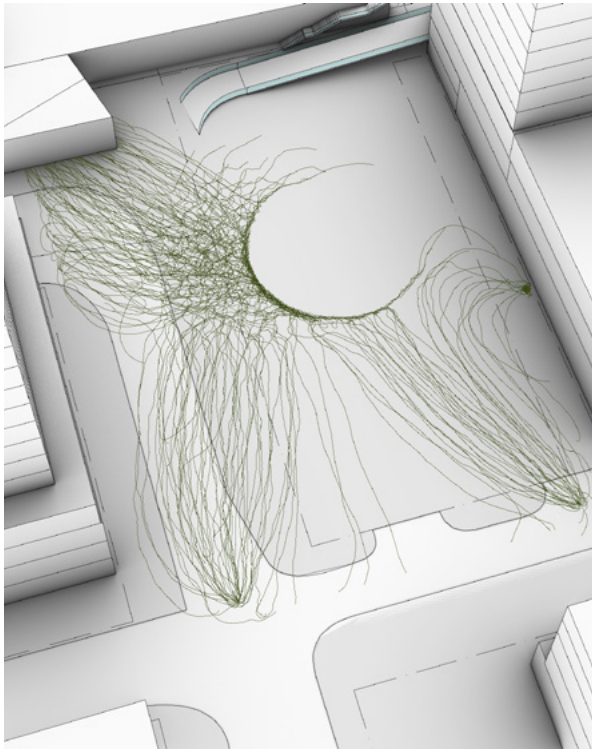


Perspective View of the generated form - Programmable boundary

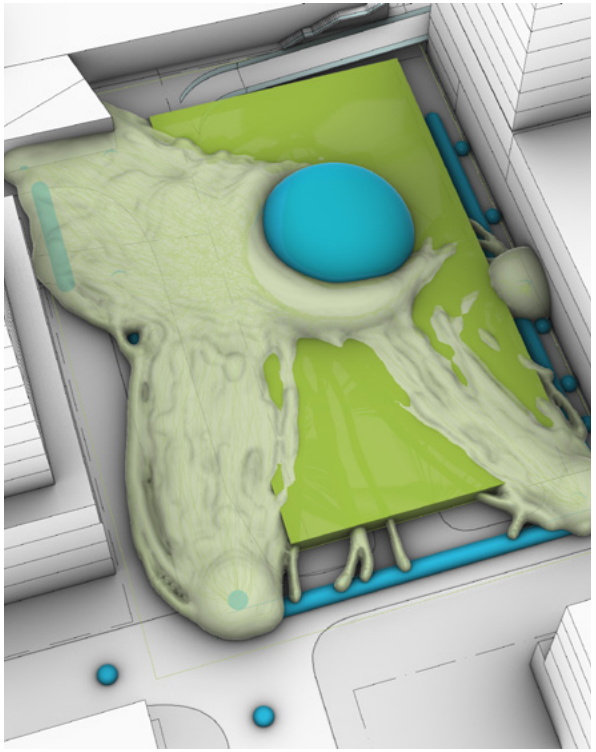




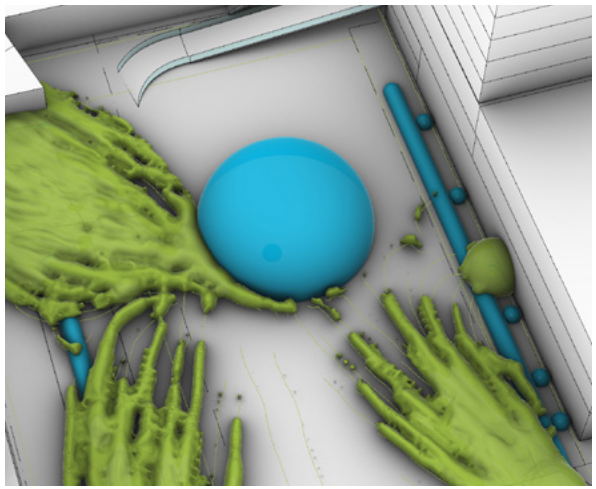
Port Moody Plaza - Environments Setup and Circulation simulation curves

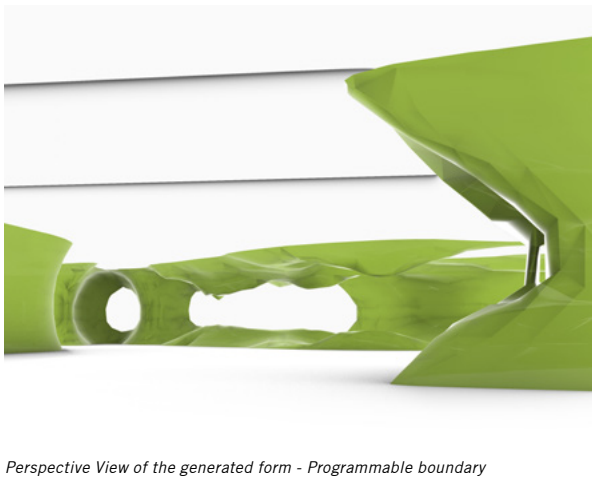


Port Moody Plaza - Crowd Simulation Curve Result

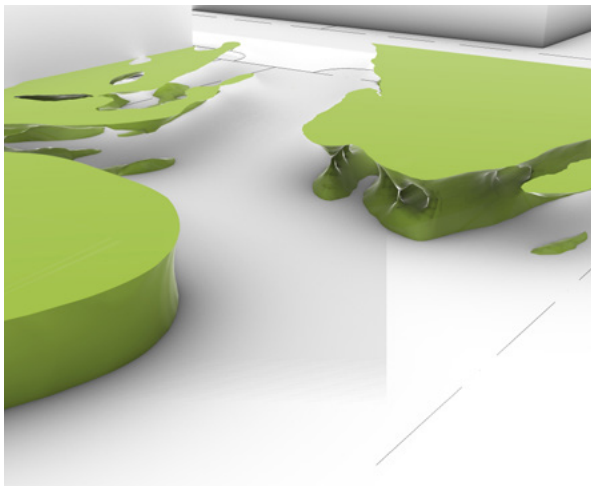


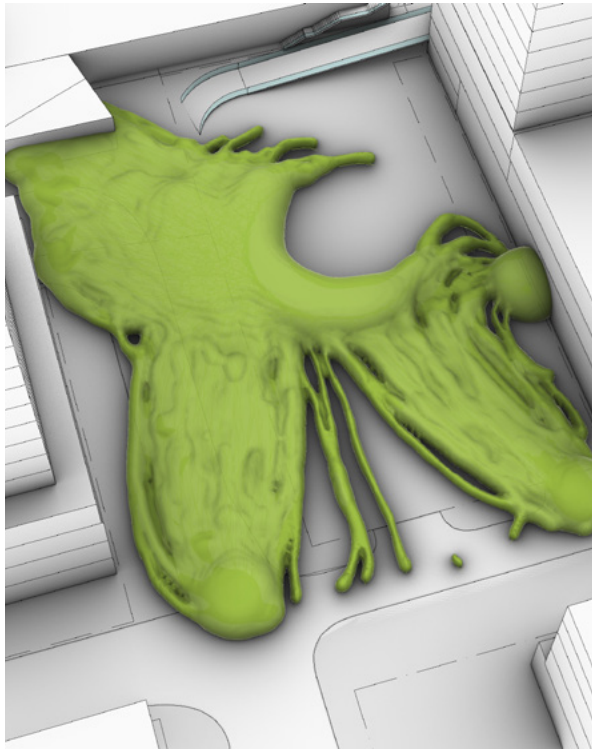
Port Moody Plaza - Crowd Simulation Setup and Volumetric result





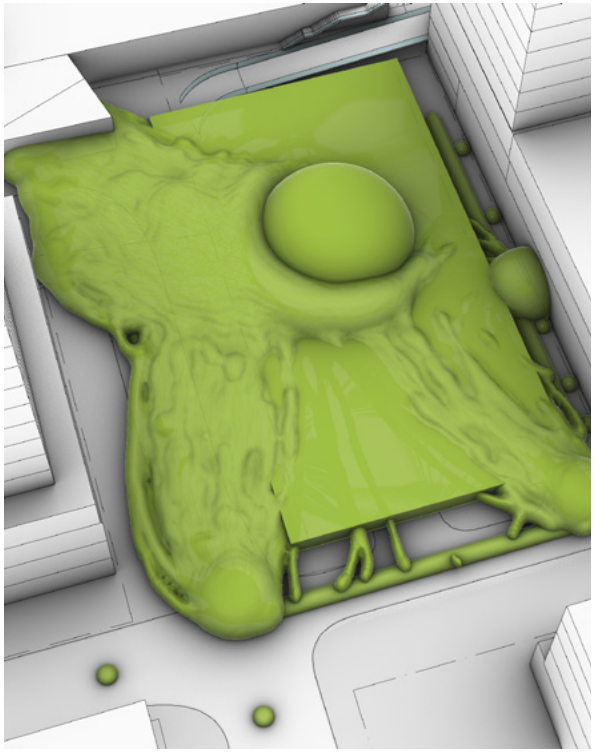
Perspective View of the generated form - Programmable boundary





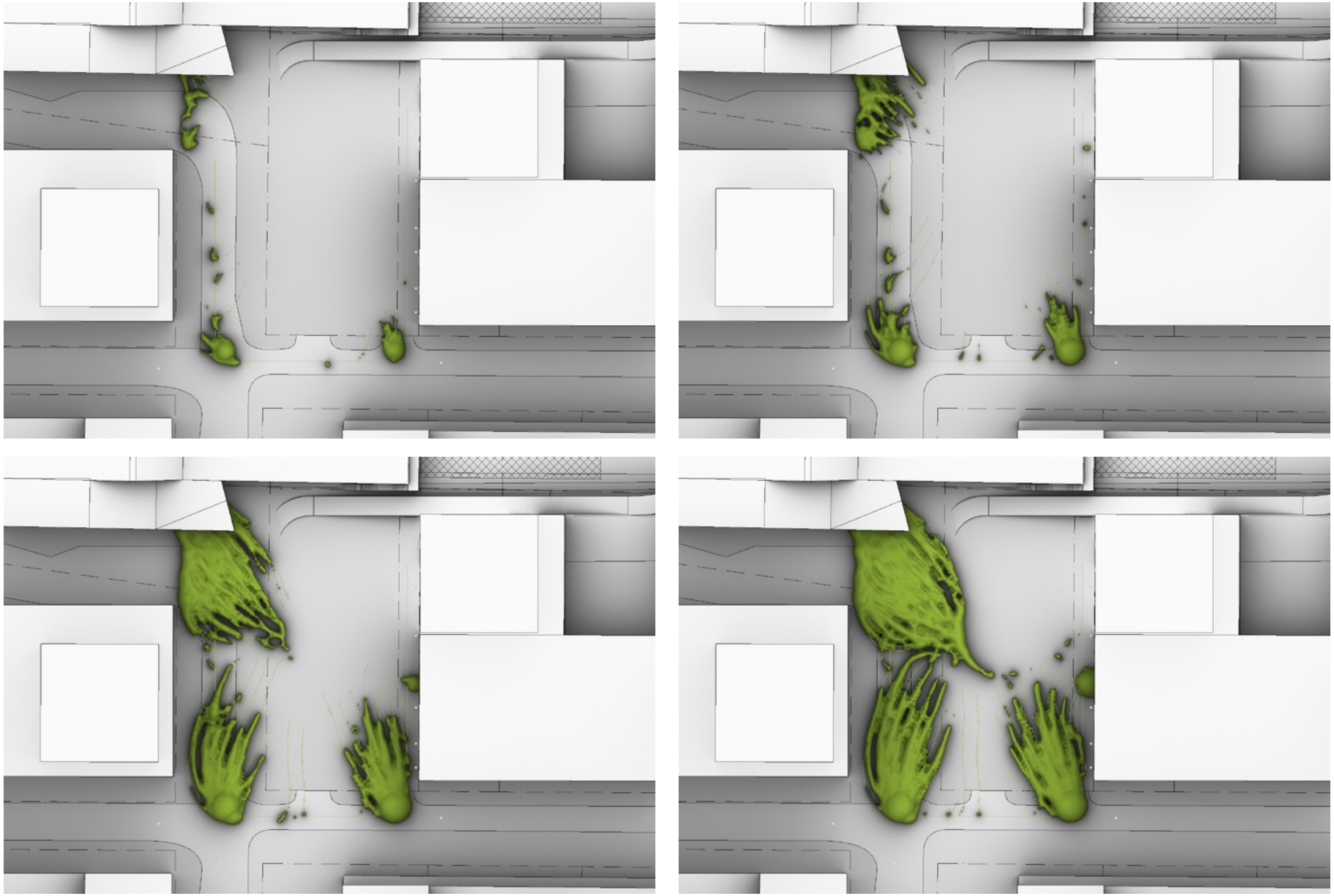
Port Moody Plaza - Crowd Simulation Circulation Volume

Port Moody Plaza - Crowd Simulation leftover programmable volume

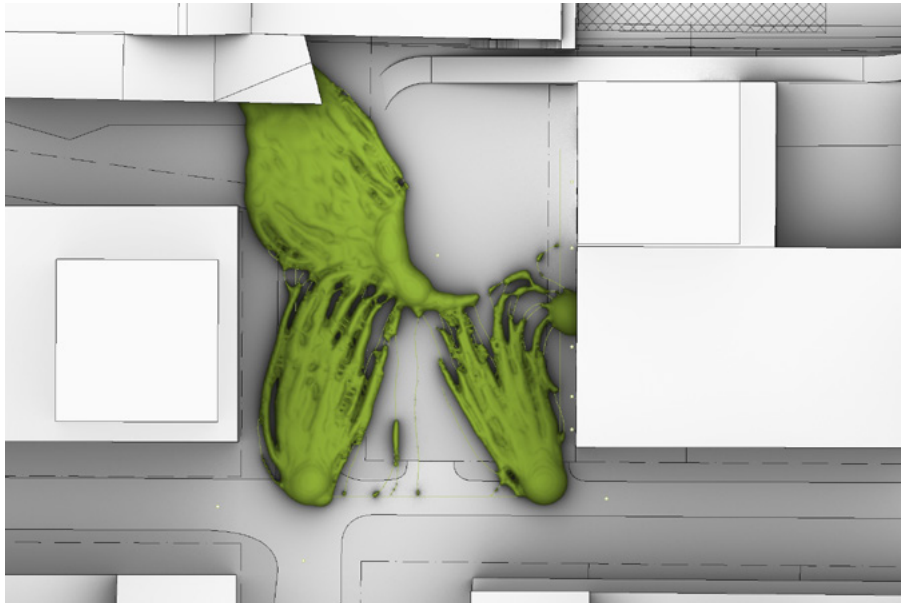


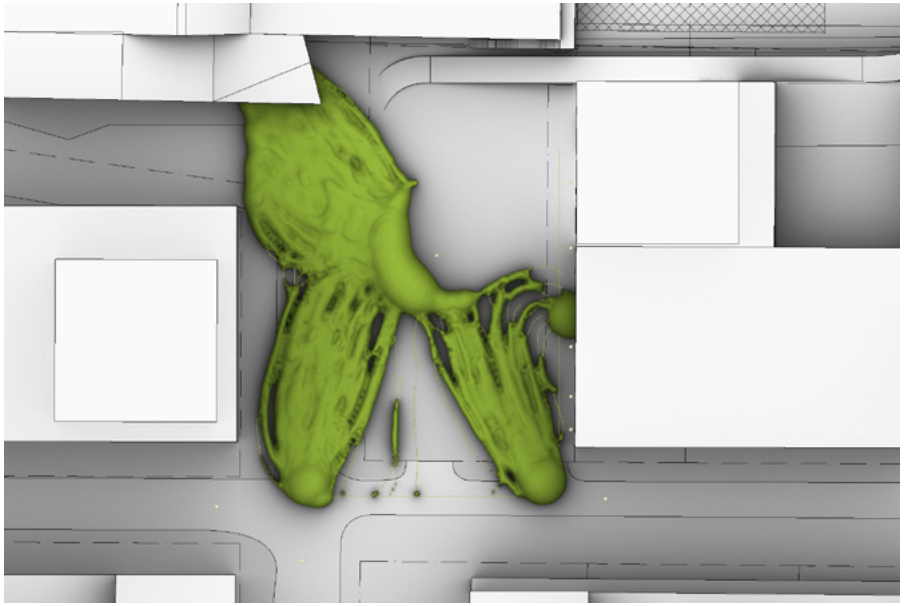
SECTION 03 PORT MOODY PLAZA

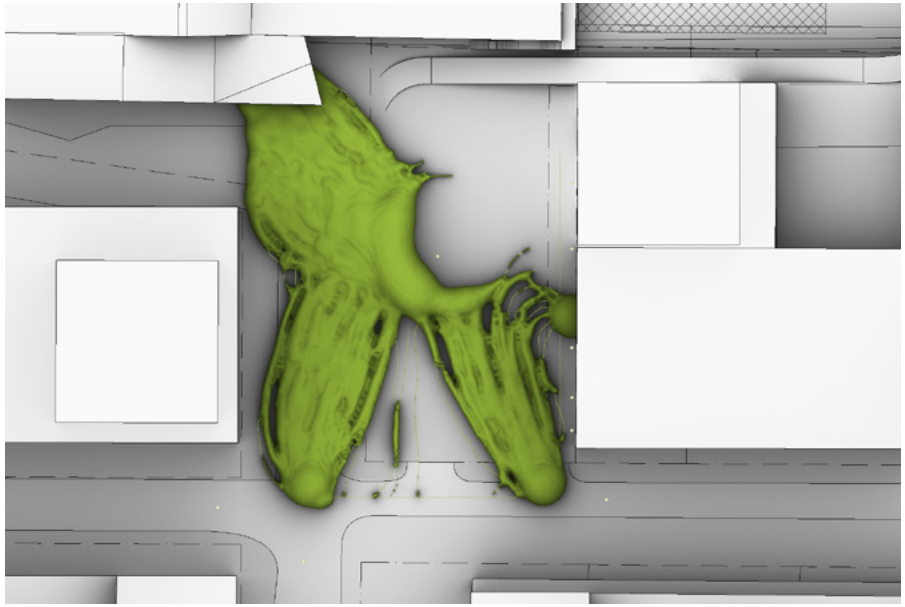
Phase 03 **Project Case Study**

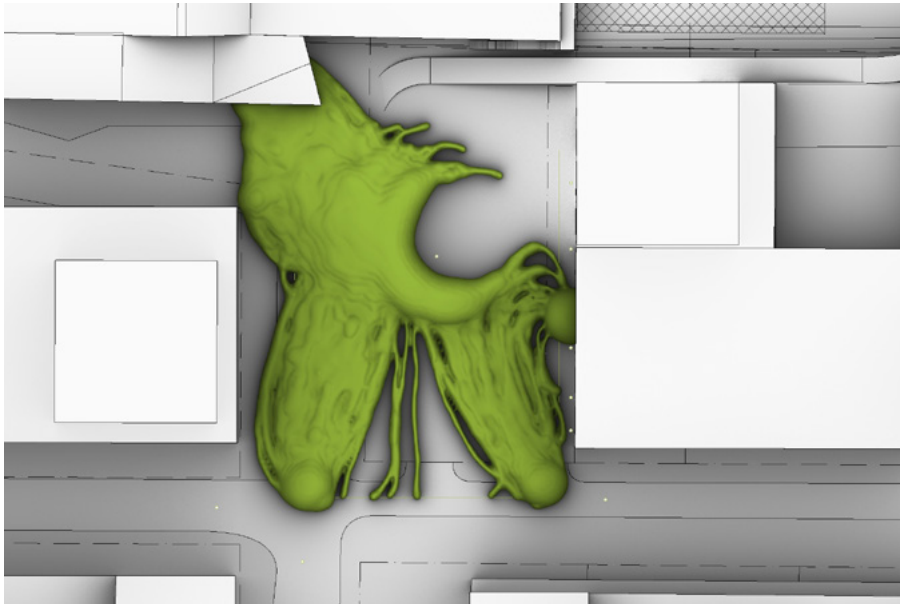


Port Moody Plaza - Form Generation Sequence



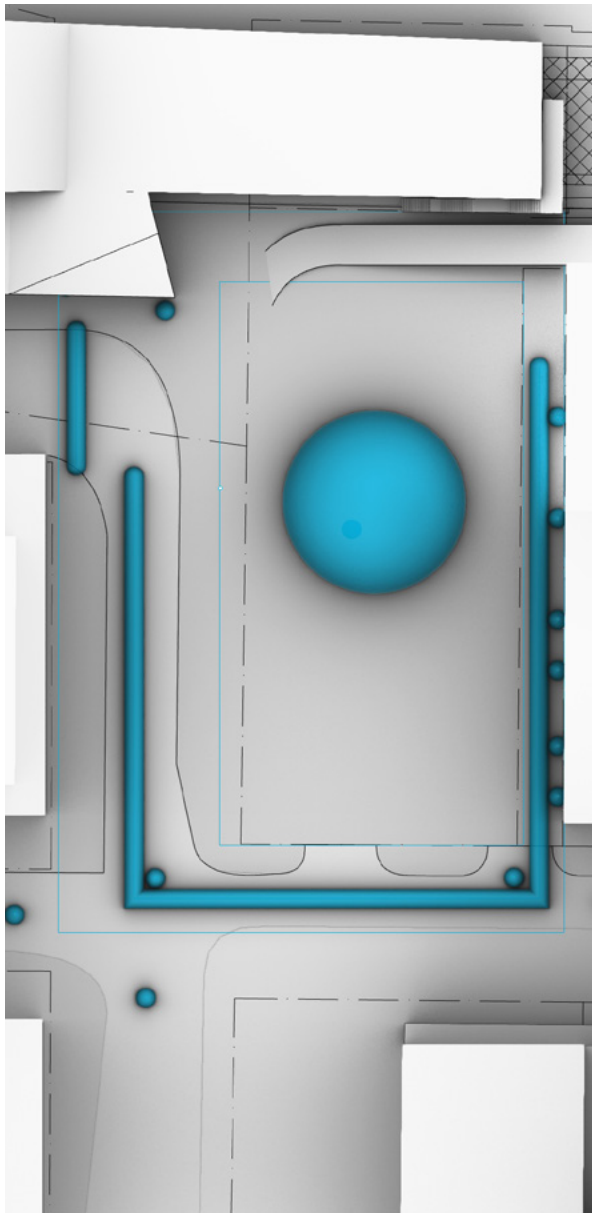


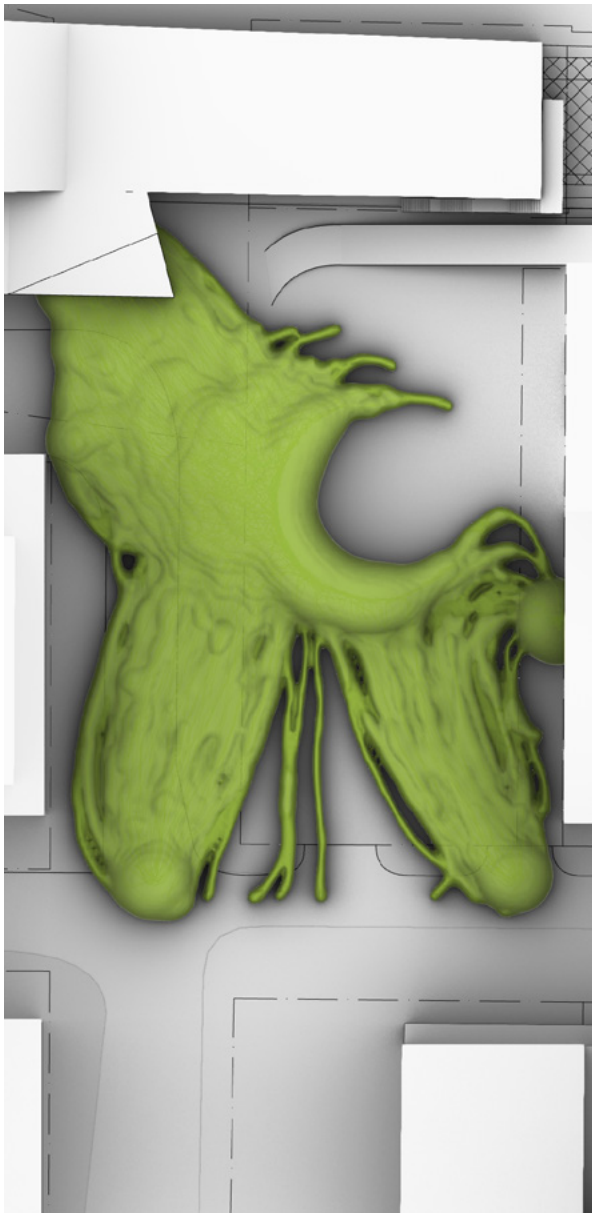




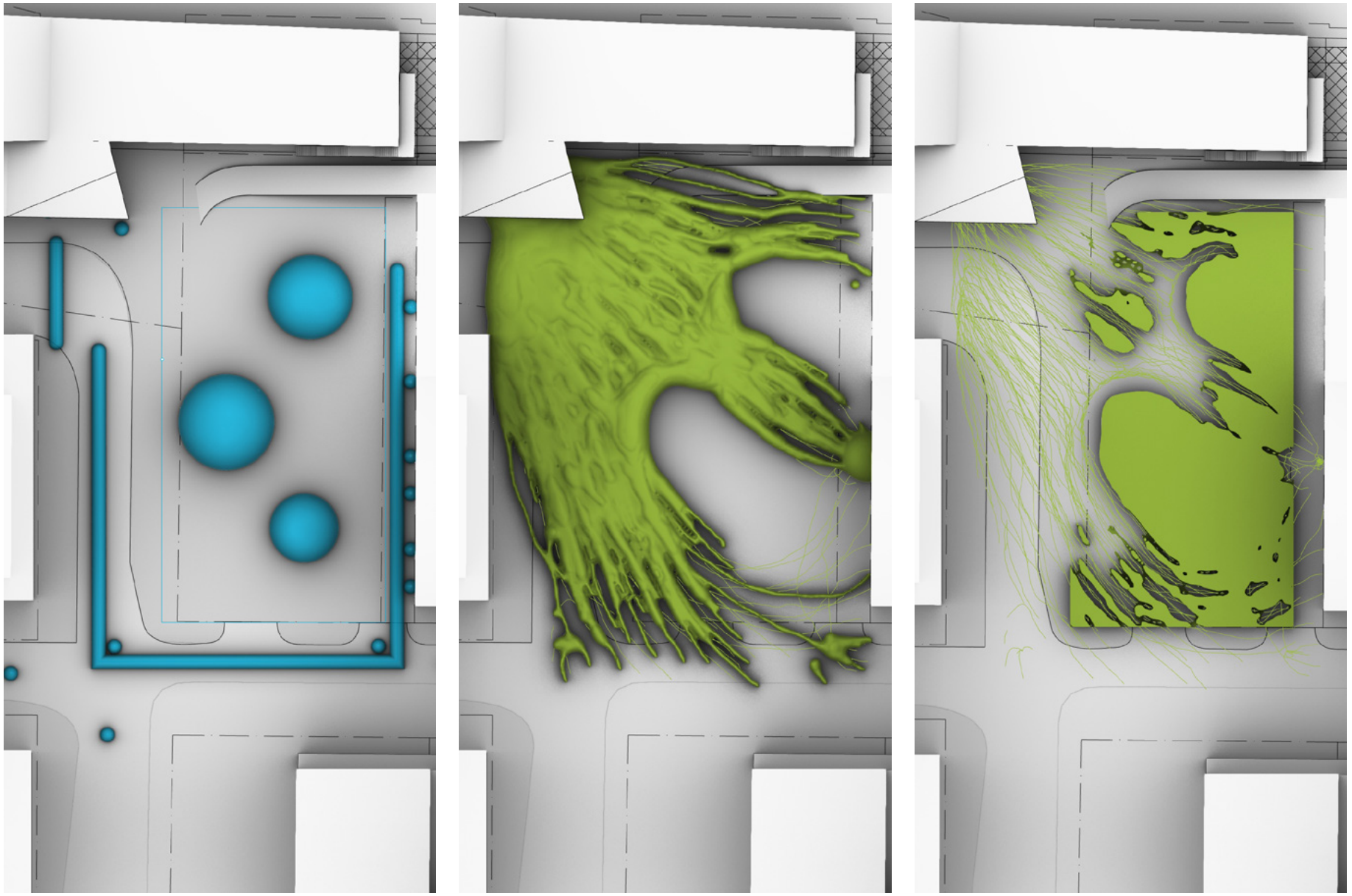
SECTION 03 PORT MOODY PLAZA

Phase 04 **Variations and Design Options**





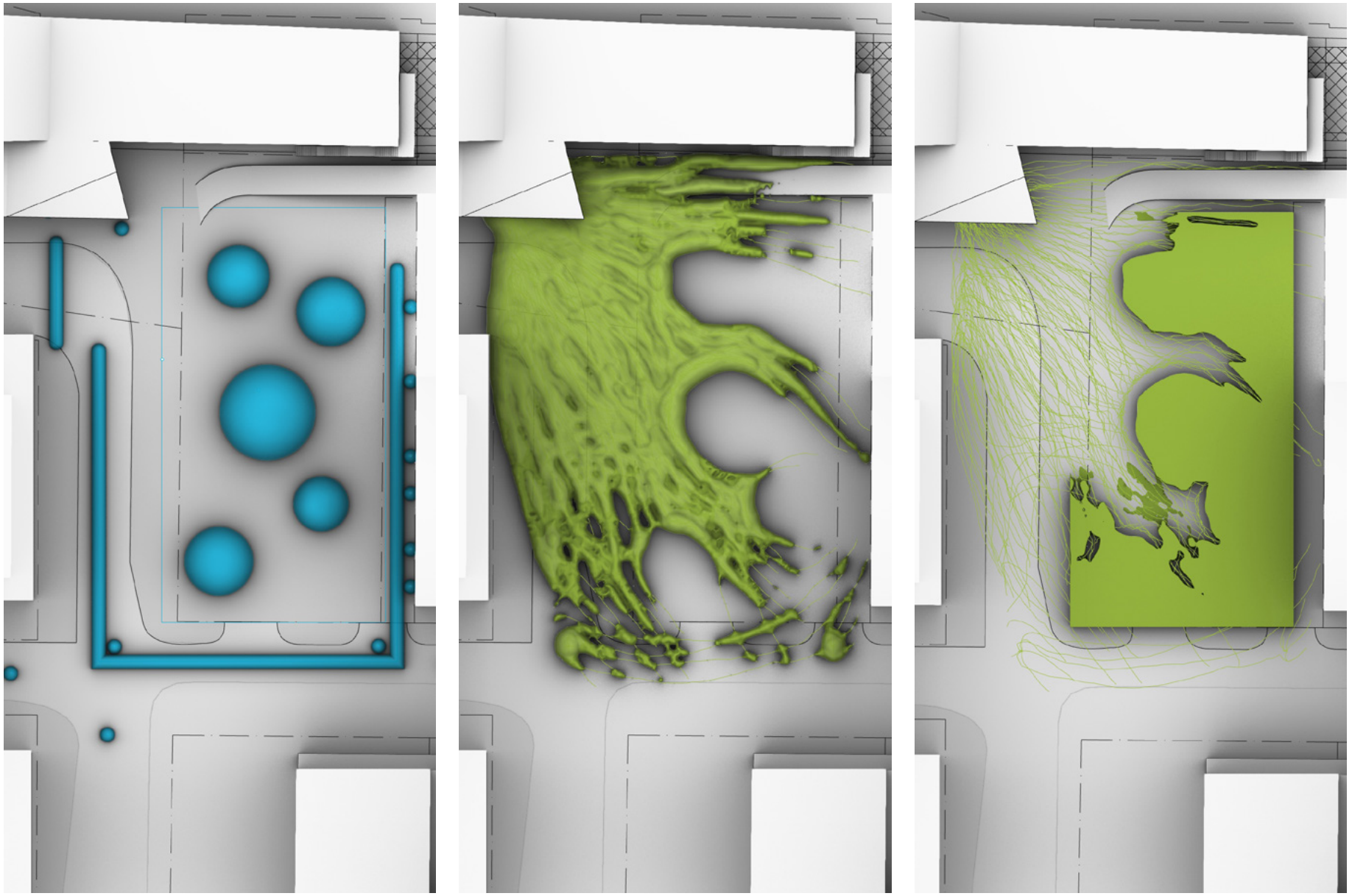
Port Moody Plaza - Option 1 - Single central Obstacle



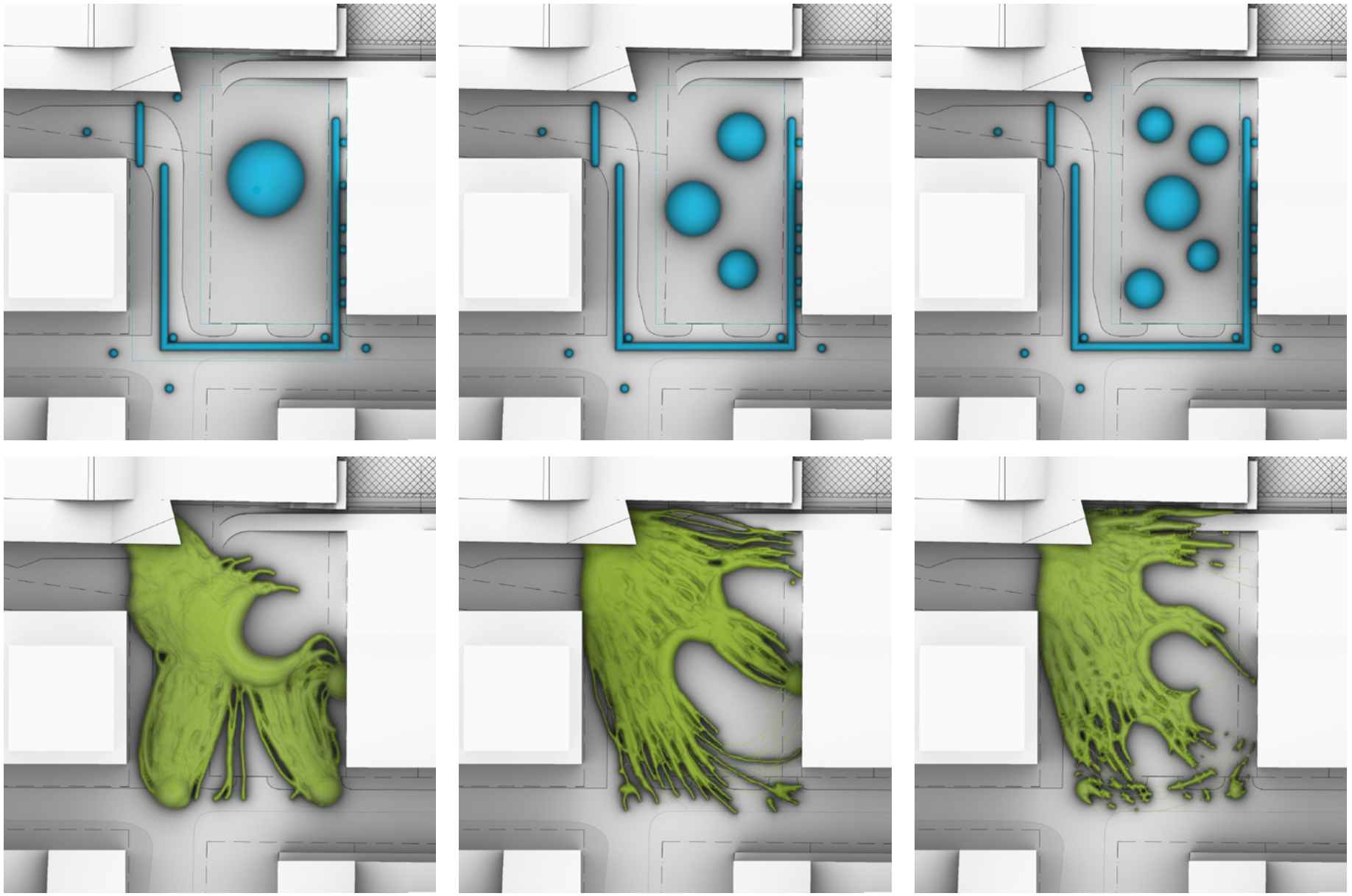
Port Moody Plaza - Option 2 - three obstacles

SECTION 03 PORT MOODY PLAZA

Phase 03 + 04 **Variations and Design Options**



Port Moody Plaza - Option 3 - Five Distributed Obstacles



Port Moody Plaza - Comparison of design variations - Option 1, Option 2 and Option 3

SECTION 03 BROADWAY COMMERCIAL PLAZA

Phase 03 **Project Case Study**

P+W Project Case Study Application

CLIENT Westbank and Crombie
LOCATION Vancouver, British Columbia
PROGRAM Mixed Use, Residential, Commercial and office
SIZE 58,266 sqm (626,736 sqft)

PROJECT 2

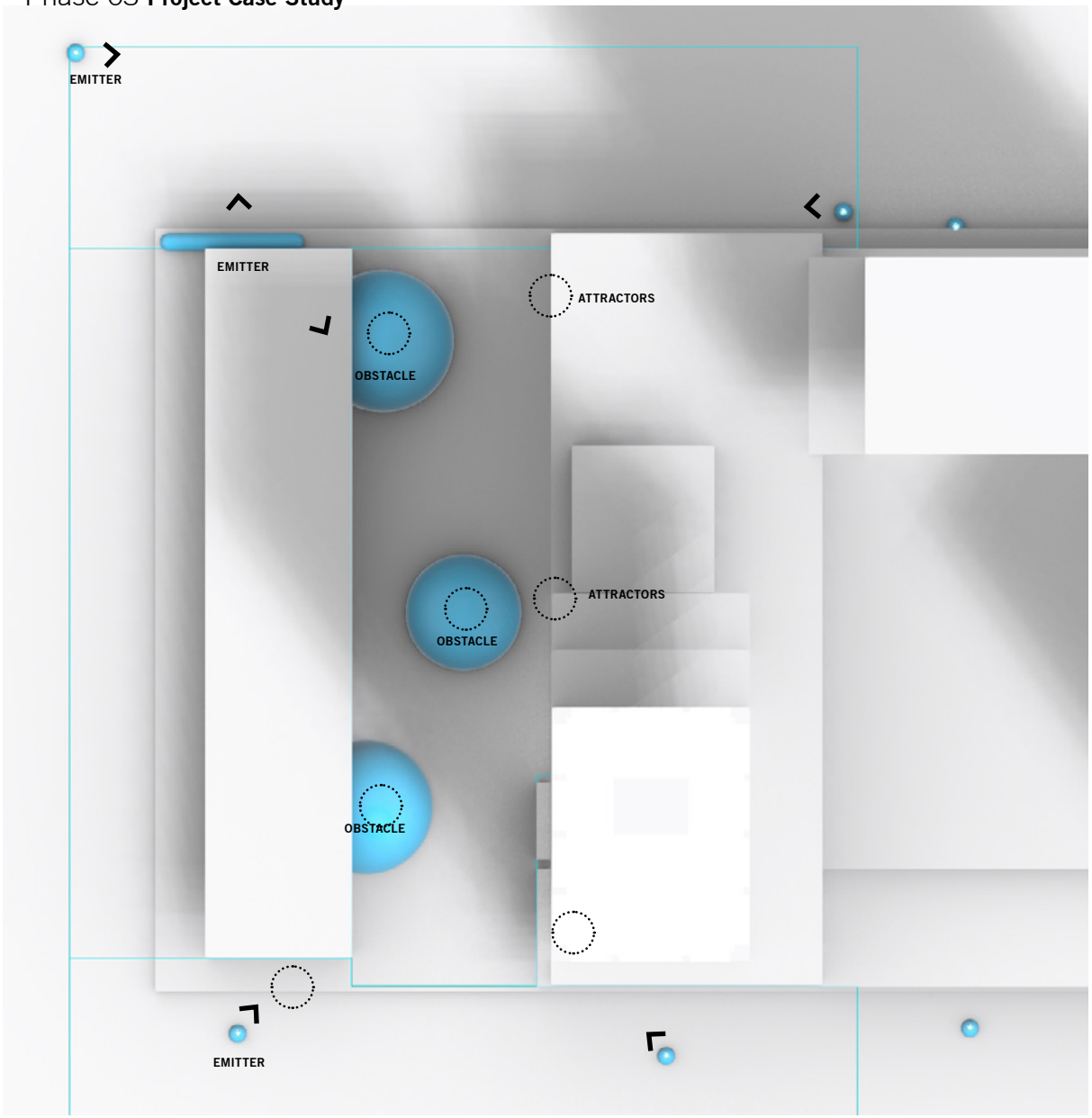
Broadway + Commercial Plaza (Part of a larger Development Project)

- Public Plaza - programmable space for circulation and pause
- Built amongst the busiest transit hub in western Canada, the plaza at Commercial and Broadway will need to manage diverse pedestrian flows. The plaza will act both as a thoroughfare and as a place to linger and must therefore accommodate and provide for a variety of paces and patterns of movement.
- Significant volumes of people will flow to and through the plaza. Their destinations will be diverse, moving between transit connections, Safeway, residences, fitness, daycare, office, and retail options along the developments edges. The design must reflect the needs of the occupants and accommodate diverse uses seamlessly.

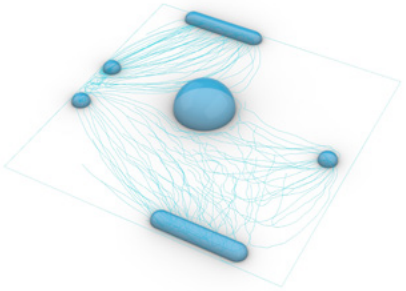
Broadway Commercial Plaza- Project Site

SECTION 03 BROADWAY COMMERCIAL PLAZA

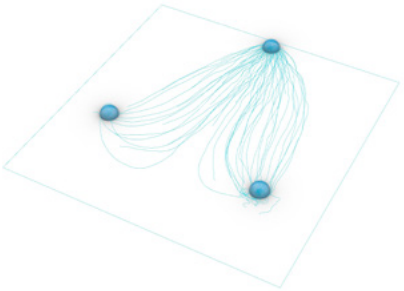
Phase 03 **Project Case Study**



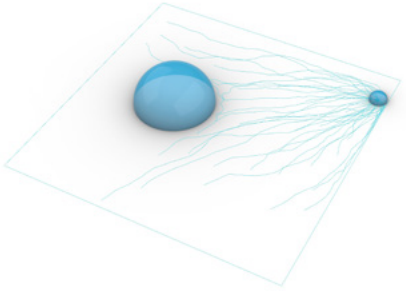
Broadway Commercial Plaza - Crowd Simulation Circulation Volume



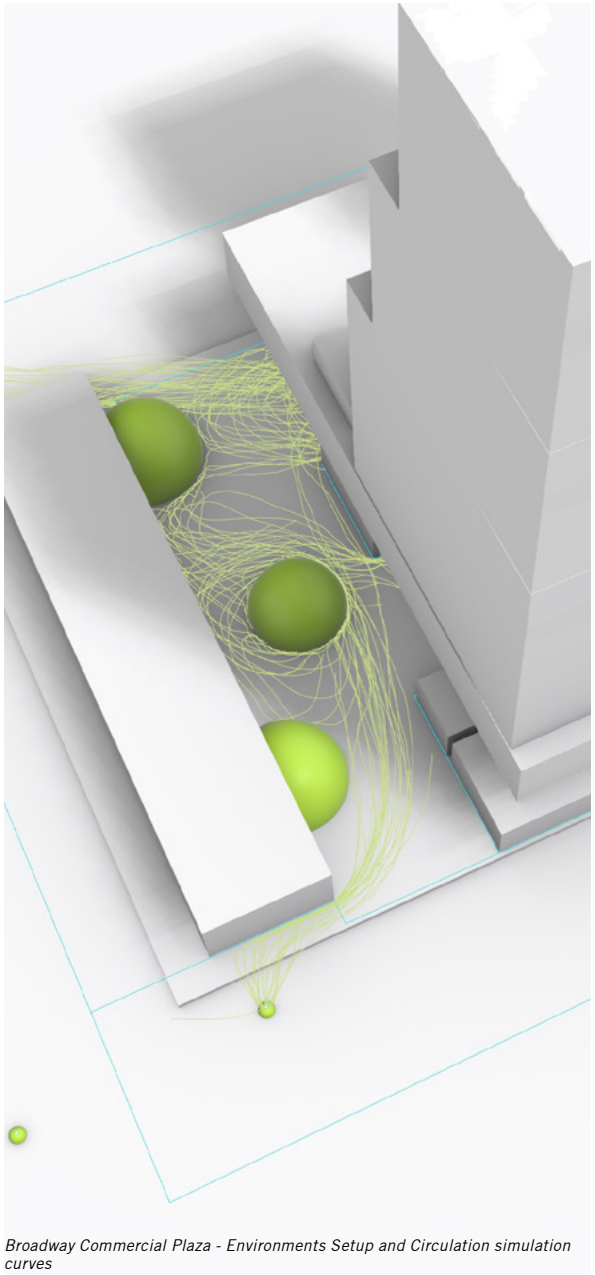
Case Study 02.3 - informing simulation



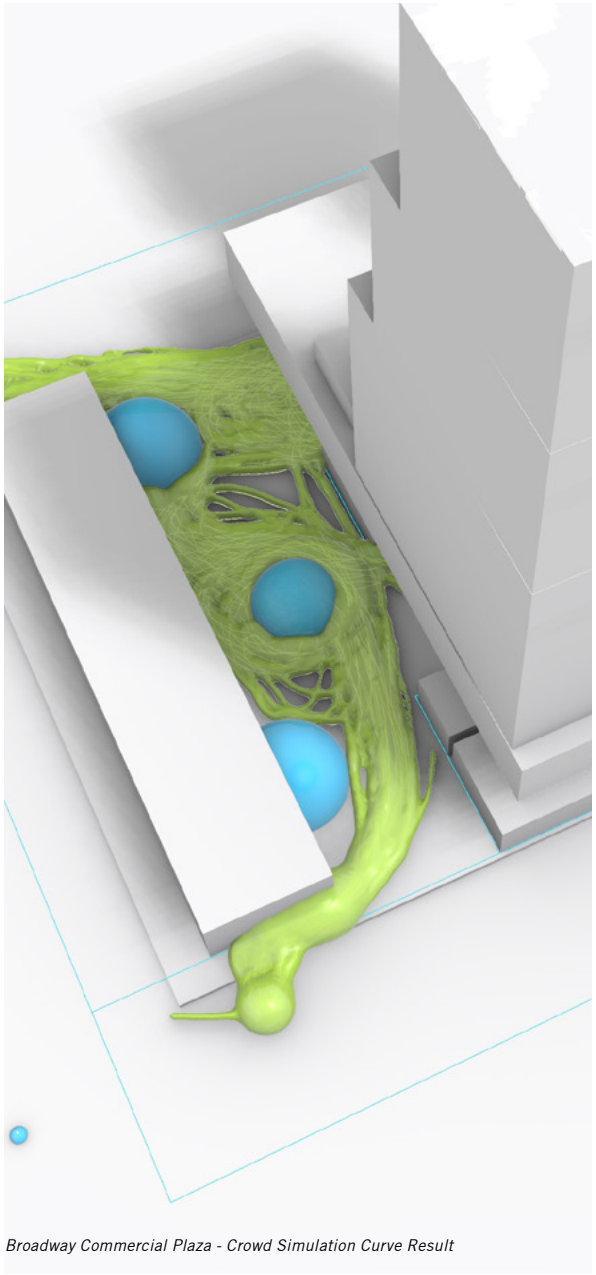
Case Study 01.3 - informing simulation



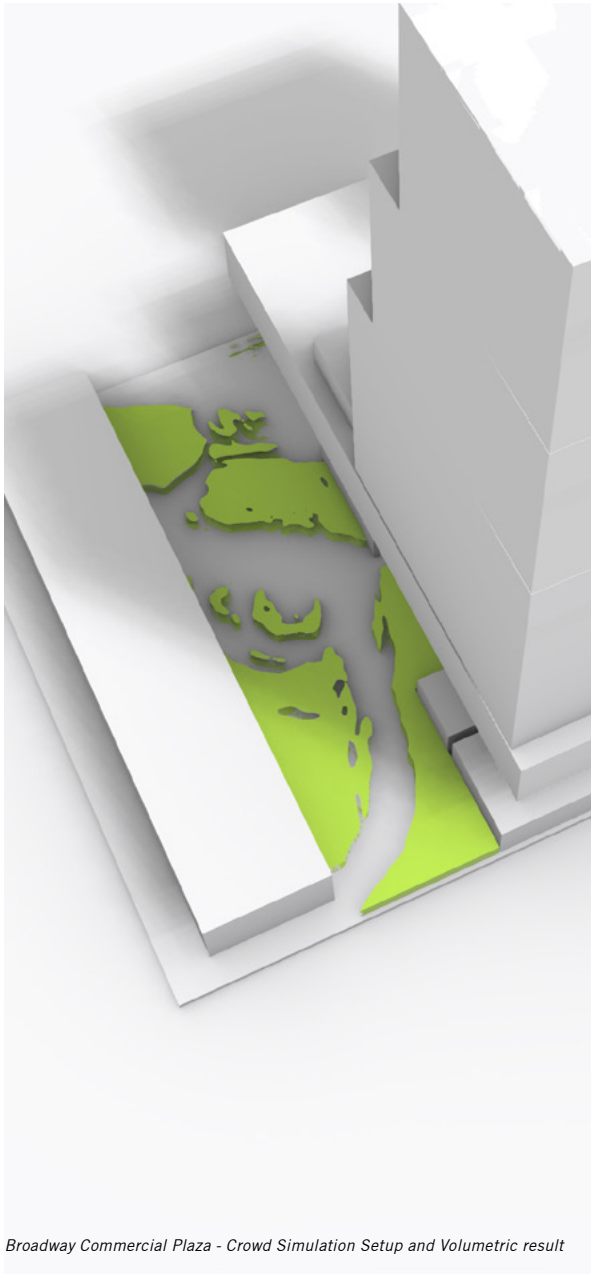
Case Study 01.2 - informing simulation



Broadway Commercial Plaza - Environments Setup and Circulation simulation curves



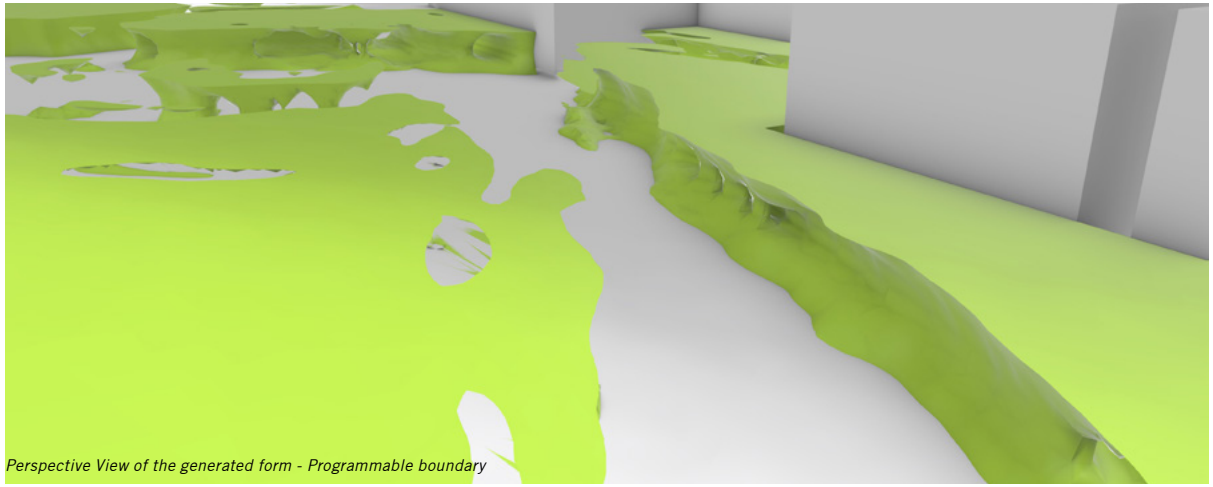
Broadway Commercial Plaza - Crowd Simulation Curve Result



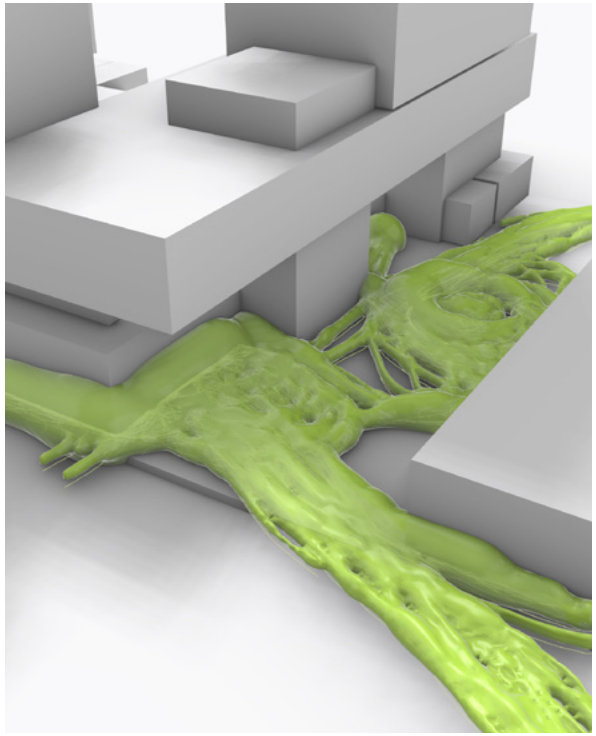
Broadway Commercial Plaza - Crowd Simulation Setup and Volumetric result

SECTION 03 BROADWAY COMMERCIAL PLAZA

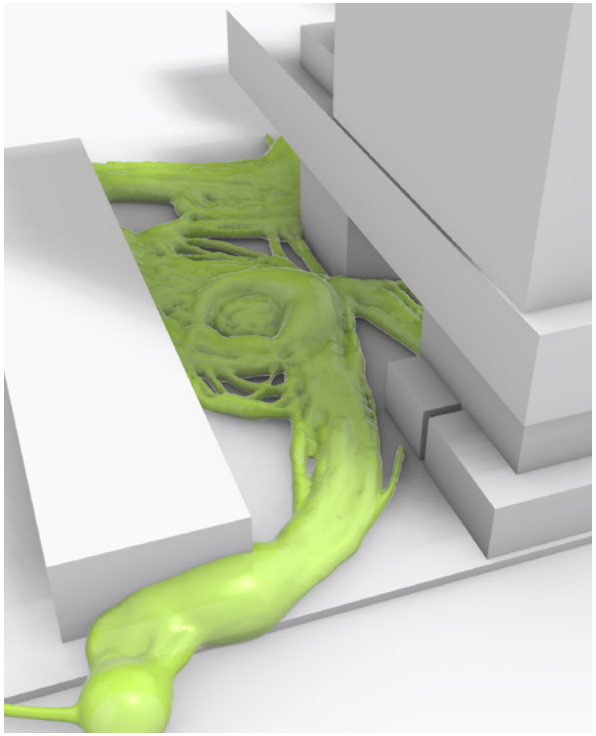
Phase 03 + 04 **Variations and Design Options**



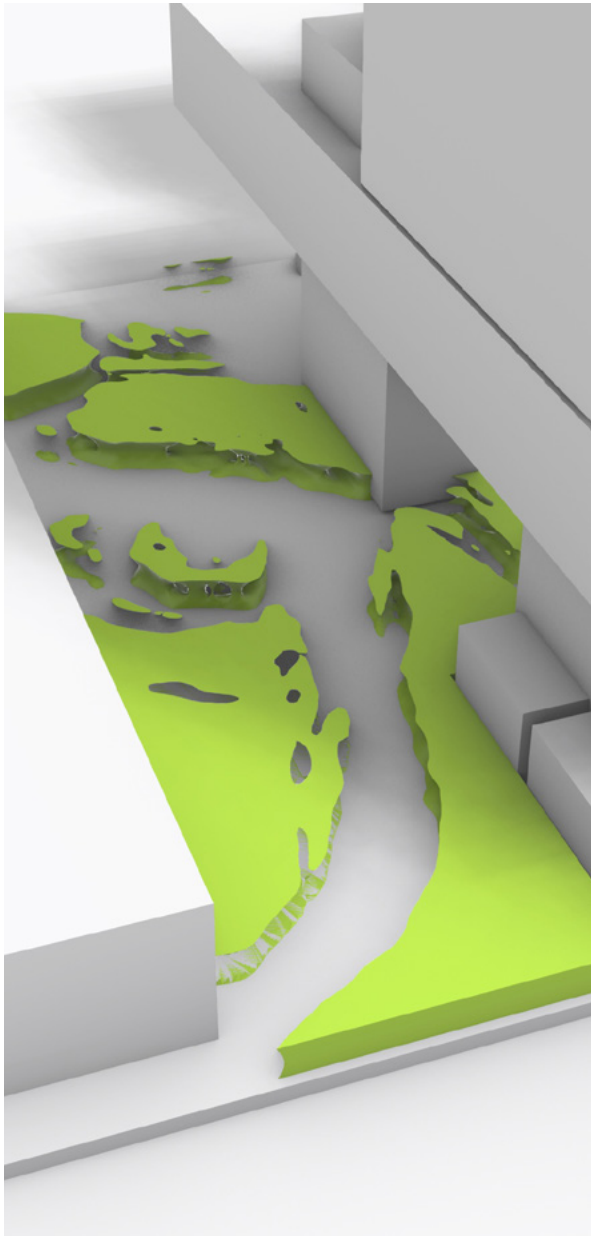
Perspective View of the generated form - Programmable boundary



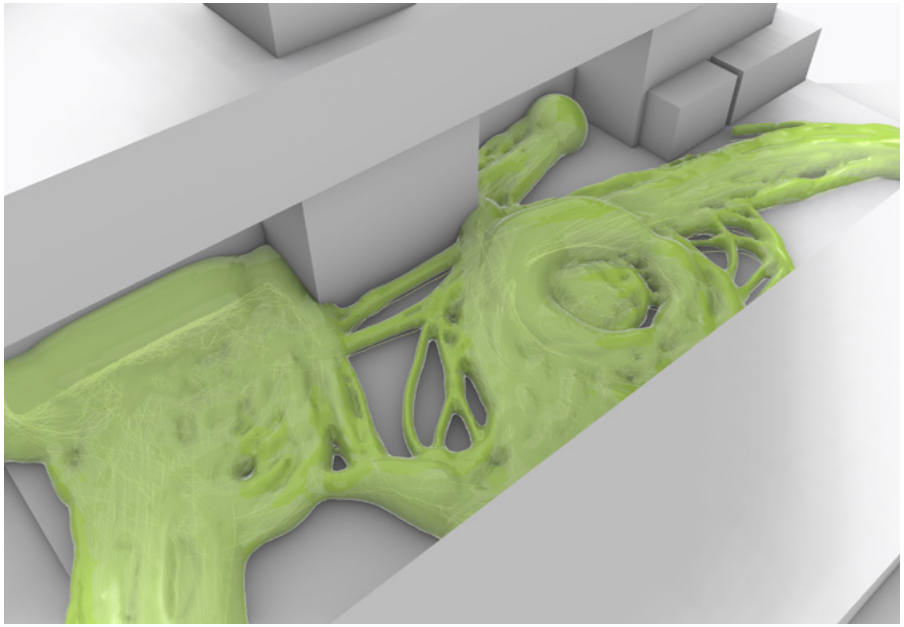
Broadway Commercial Plaza - Crowd Simulation Circulation Volume

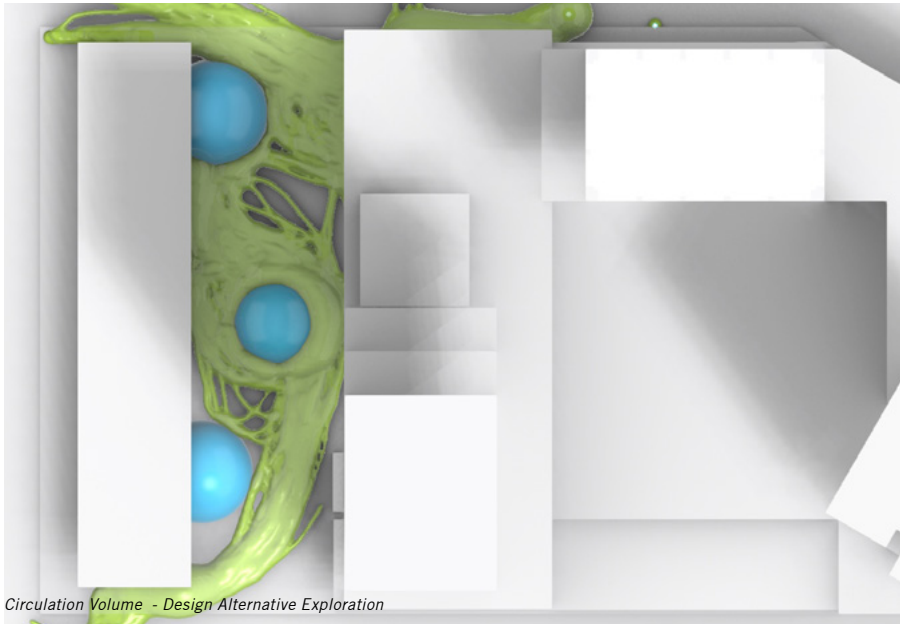


Broadway Commercial Plaza - Crowd Simulation Circulation Volume

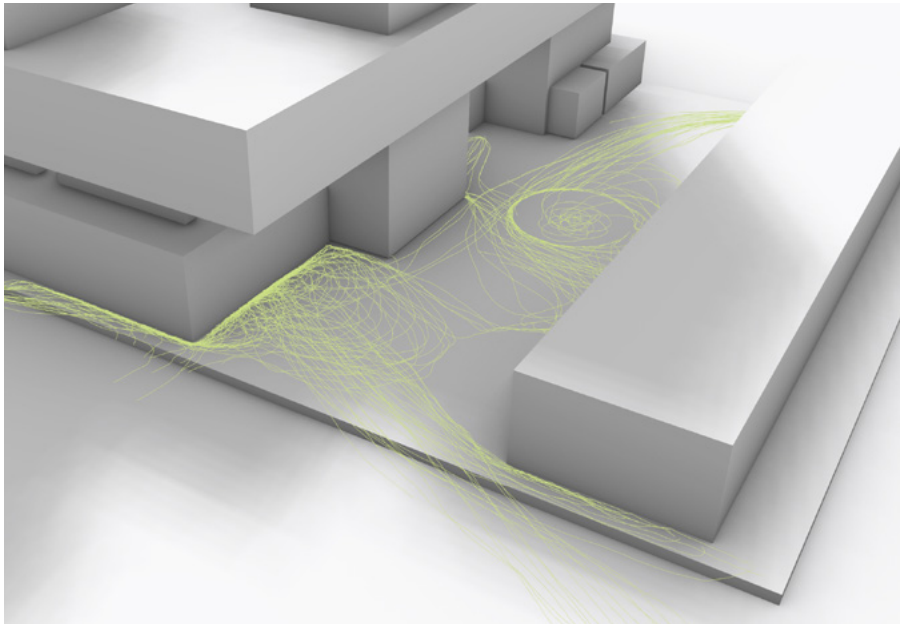


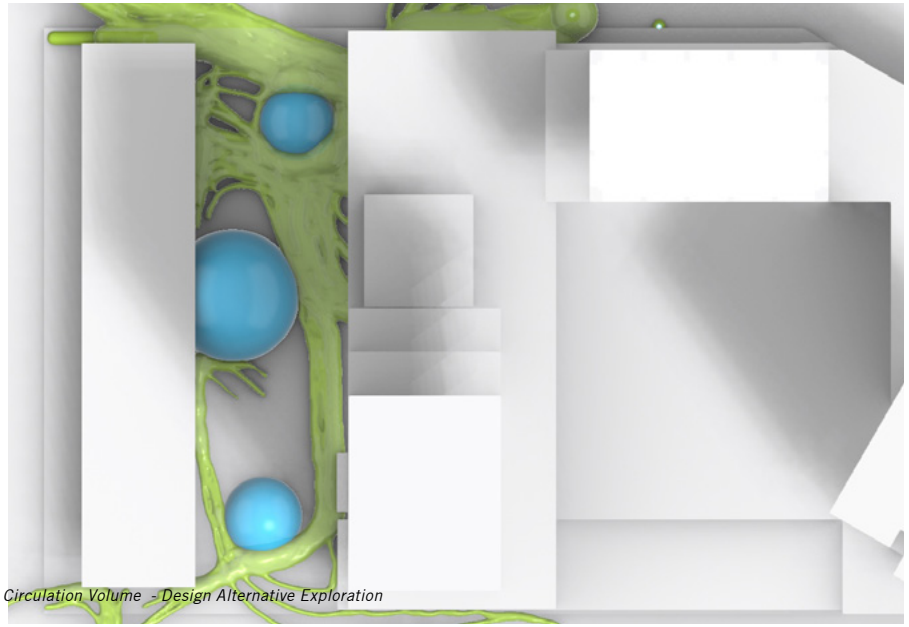
Perspective View of the generated form - Programmable boundary





Circulation Volume - Design Alternative Exploration





Circulation Volume - Design Alternative Exploration

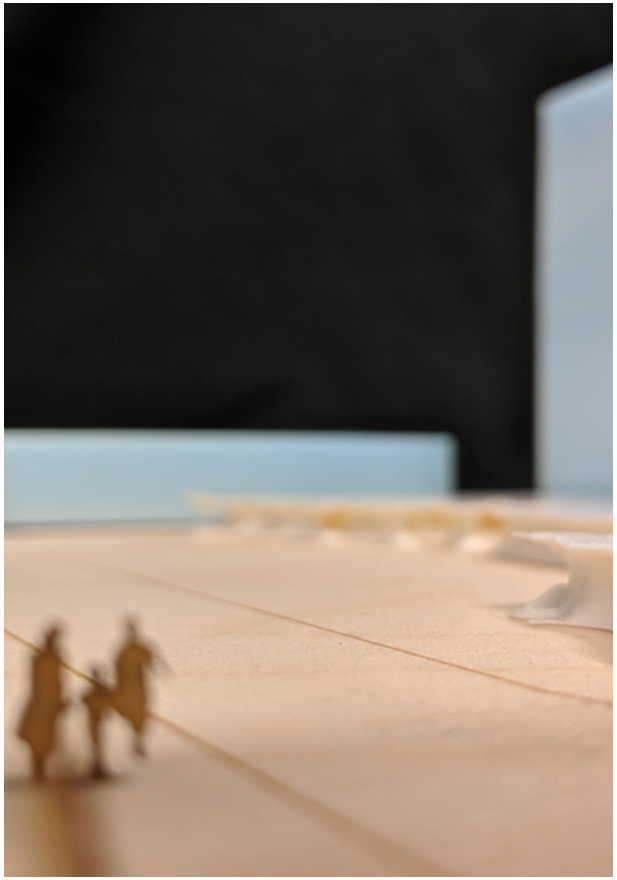
SECTION 4

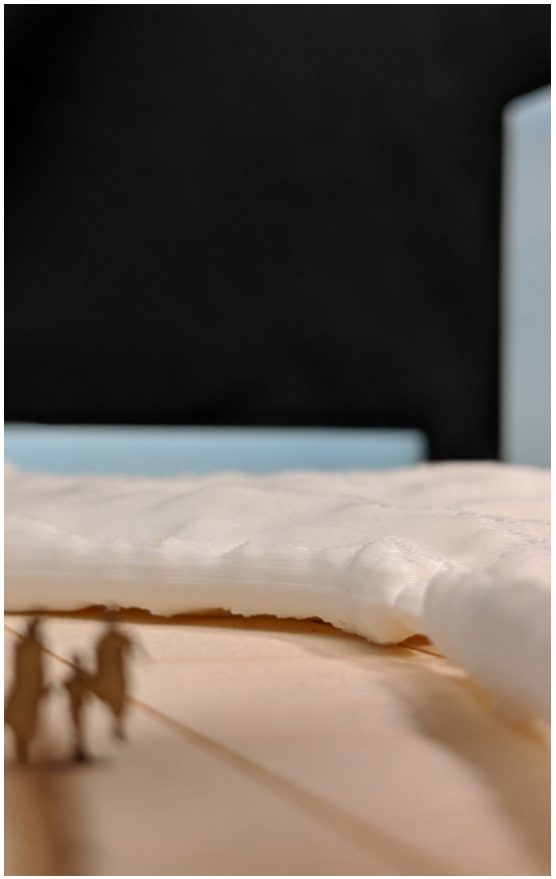
SUMMARY & FINDINGS

SECTION 04
SUMMARY & FINDINGS

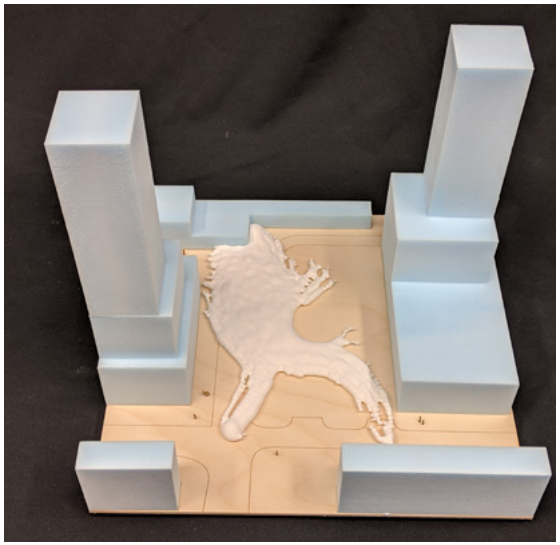
Summary

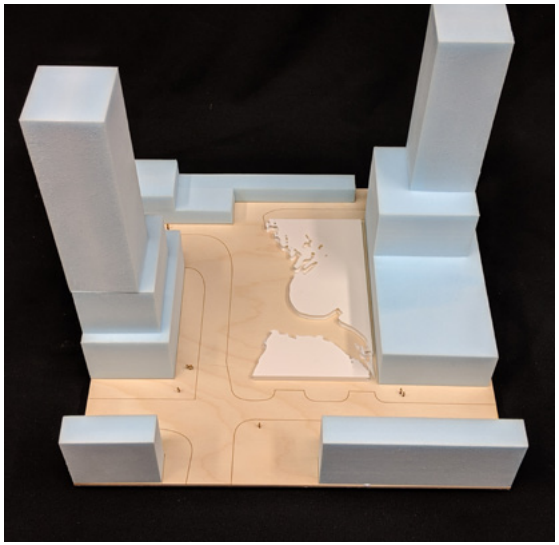
The tool is a way for designers to measure, track and formulate understandings behind human crowd patterns and relationships. It maps and generates human movement patterns based on a series of parameters given to the tool via the script. The tool uses agent based systems, in particular this tool is a multi-agent simulator a class of computational modes for simulating the actions and interactions of autonomous agents (either individual or collective entities such as organizations or groups) with a view to assessing their effects on the system as a whole. The goal of the agent based system is to search for explanatory insight into the collective behavior of agents obeying simple rules and parameters.





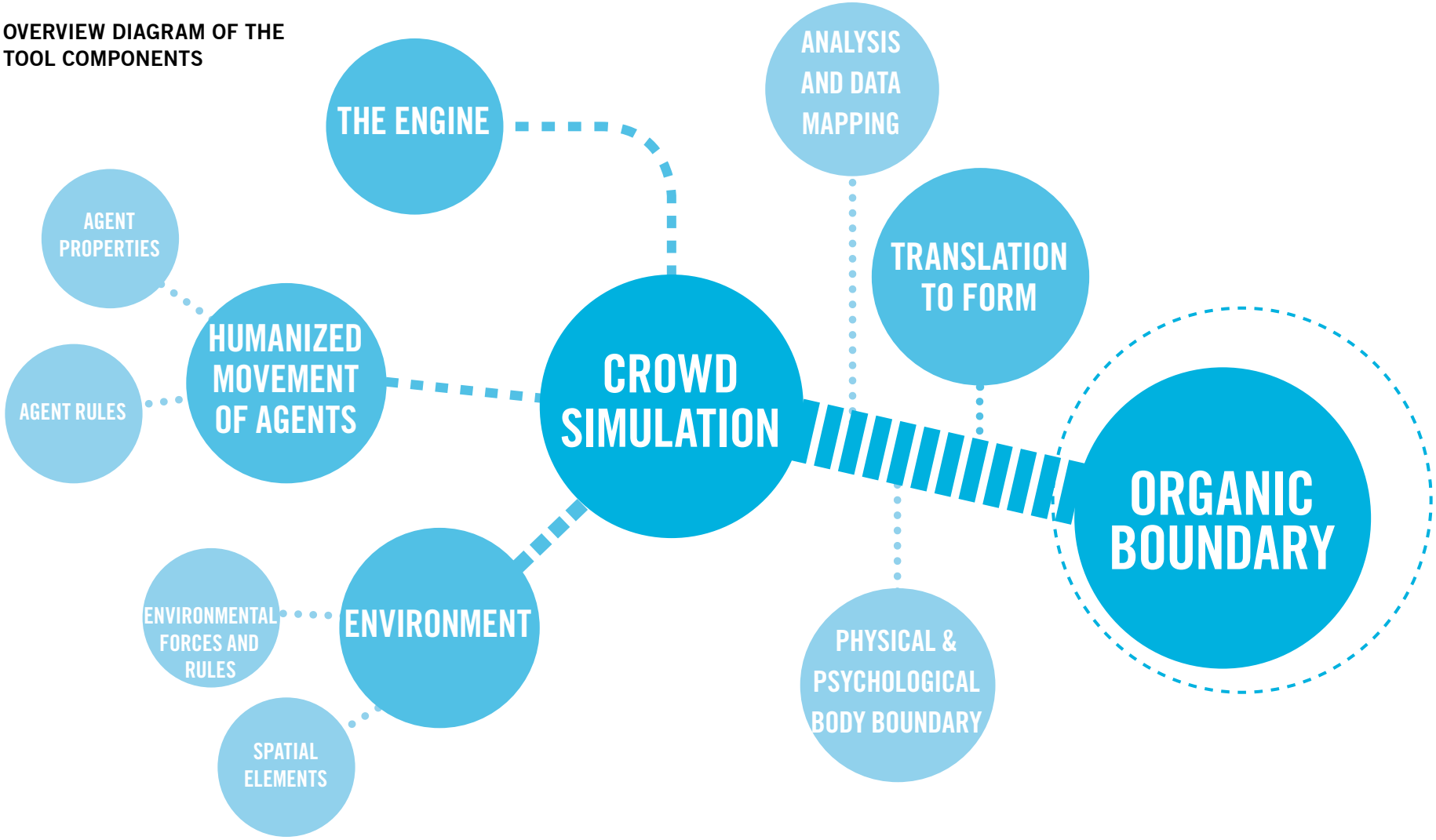
SECTION 04



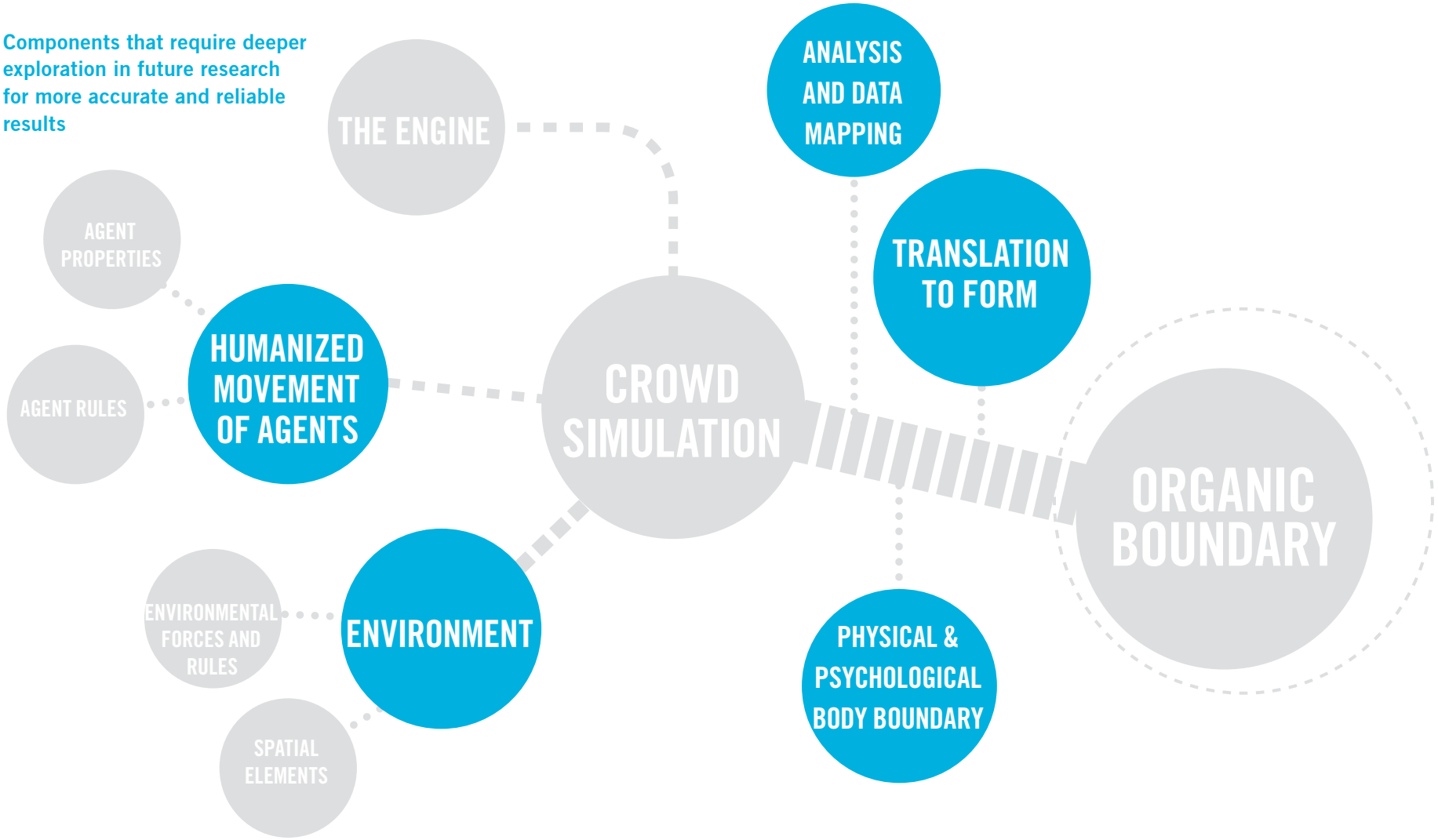


SECTION 04
SUMMARY & FINDINGS

OVERVIEW DIAGRAM OF THE TOOL COMPONENTS



Components that require deeper exploration in future research for more accurate and reliable results



SECTION 04
SUMMARY & FINDINGS

Future Steps / Existing Challenges

- Translating the urban/architectural environment forces to grasshopper

  The project could benefit from a deeper understanding of the forces shaping the results, and the corresponding digital representation of those forces in grasshopper. It is a challenging task to setup each project accurately towards getting the expected results while respecting the design intent. a deeper understanding and exploration of this translation process and the available components within the tool would significantly improve the tool and its results.

- Humanized movement of the agents and comparison of the crowd simulation with actual human movement

  There are a large number of factors involved in defining the movement and the decision making process of the agents in the environment. A deeper understanding of these elements, a more accurate simulation approach, and a comparison to real life situation would be beneficial for a higher accuracy in the process.

- Form generation and human psychology of space

  The form generation methodology used in the script, is currently mainly a result of reading the density of the agents and the 3d volumetric body comfort bubble assumption, made based on a preliminary literature review done at the beginning of the process. The accuracy of this physical and psychological bubble at an individual level or as a group/crowd level could improve the outcome of the system and promise a more realistic and successful solution.

- Analysis of the results and the process in physical world in order to test/evaluate the results for accuracy also the hypothesis of the expected behavior toward the generated volumes.

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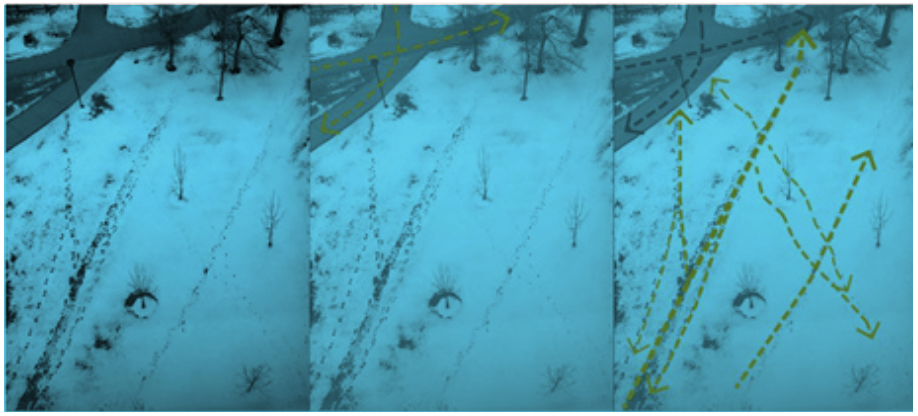
APPENDIX
PROPOSAL



Snow Field Effect" diagram, analysis of human behavior as an agent-based system

"Snow field effect" is a term used to describe a phenomenon that takes place in nature and urban environments. The phenomenon happens when snow covers a large surface and creates a neutral field. Then the traces of people's natural movement through this field will create an organic circulation path that may or may not relate to the existing designed path ways hidden under the field of snow.

RESEARCH MEMBERS

Intermediate Designer, Mahdiar Ghaffarian

Junior Urban Designer, Hannah Gibson

OFFICE

Perkins+Will Vancouver

DISCIPLINES

Urban Design

Architecture

Landscape Architecture

Computational Design

RESEARCH/PROJECT DESCRIPTION

Registration of computational algorithms explores transition of spatial design from a static, pre-planned rigid form to an organic design and geometry. This research explores a design methodology and an analysis technique that uses crowd simulation for production of the organic human circulation patterns, interpretation of those patterns as inputs for design and generation of organic forms based on that algorithm.

Inspiration

Observing the natural swarms and agent-based behaviors in nature has inspired a lot of different simulations and research-based design projects. Agent-based systems and Swarm behavior have the potential for generation of structures in numerous ways. As an example, there are larger structures formed out of single agents; like simulated molecules in Artificial Chemistries. Additive fabrication precess in wasps' nests, where the agents deposit building blocks as a construction technique, or the subtractive process in ant colonies, where the agents hollow out material to form tunnels and chambers as their habitat. Swarms are believed to be capable of creating productive structures based on various meaningful evidences in nature, which can be a proof of concept that swarm configurations or structures built by agent-based systems can produce desirable designs.

The project's goal is to introduce an algorithm for designing organic forms and dynamic analysis techniques that could define architectural/urban spaces with respect to the form of human body movement in various scales.

In this research also, the exploration is based on a multi-agent natural phenomenon. Similar to the ones mentioned above, which suggests that human crowd simulation could be considered to have environmental effects on its surrounding and could be used as a tool for driving design and form finding processes.

RELEVANCE

We find this project extremely scalable and related across multiple fields within the design practice. The design tool can be applied across small scale projects from an interior scale to architecture and even applied within an urban design scale.

Fields that interest us delve into the various environmental and behaviors groups or demographics that have not been explored to date. Some examples of these unexplored environments are the effects of time on the behavioral crowd simulations as well as the effects of light, studying how these patterns of movement occur under different variables.

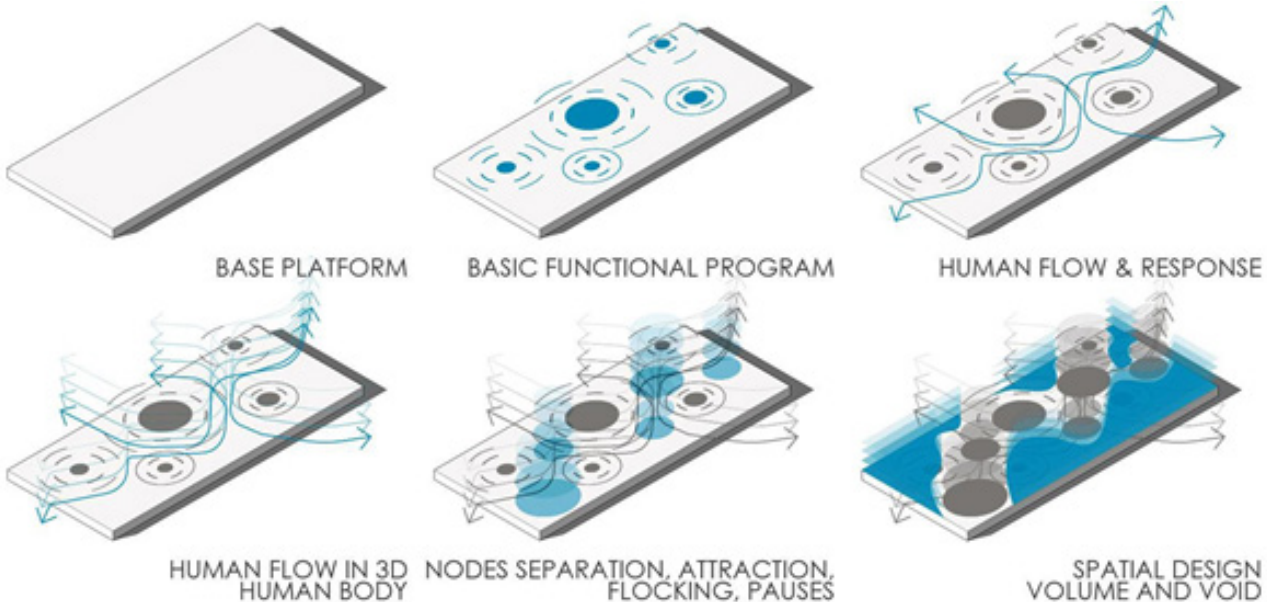
Additional factors that have not been tested within this agent based crowd simulation design tool are testing human subjects from different demographics. Such demographics test groups could include looking into various age groups from children to young adults and the elderly. These tests can create informative results that allow us as designers to better design for a wider spectrum of users.

We hope to see this tool being used within the many areas of our projects, for both context driven background analysis as well as influencing the generation of form for differently sized projects.

Project Relevance

This tool can potentially inform and guide a wide range of project in any of the following phases/scales:

- Development study & site analysis
  - as a site analysis tool
- Preliminary massing for architectural projects
  - informing the perimeters of a massing
- Details of how buildings meet streets
- Design of urban elements and urban design patterns and Landscape design
  - could inform the boundaries of elements that would occupy an urban space
- Small scale architectural projects
  - Pavilions, Monuments and Installations
- Interior design
  - could inform the boundaries of elements that would occupy an interior space



Design Concept Diagram