Geometry matching by multi-agent systems

Changing GFRP from an environmental hazard to a façade design solution


HUNGERBURGBAHN

Study Motivation

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Due to a lack of recycling solutions for glass fibre-reinforced polymers (GFRP)

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Out of 4500 tonnes of GFRP waste material in the Netherlands, 1400 tonnes is boat hulls and 1300 tonnes of windturbine rotor blades.

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Grossens

Study Motivation

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More complex 3D modelling software

=

More complex shaped designs

Study Motivation

The goal: Creating some program that has the ability to match curved material shapes with curved design shapes automatically

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The goal: Creating some **program** that has the ability to **match** curved material shapes with **curved design shapes** automatically

Study Motivation

The problem: **Difficult** to recycle, **hard** to process material in large amounts

Conflicting design **objectives** for **optimisation**

The goal: Some **program** with an ability to **match curved shapes**

Research Framework

Main research question:

How can a multi-agent system match geometrical properties of curved surfaces?

Sub-questions:

What geometric properties define a curved surface?

How can geometry properties drive the behaviour of agents?

Providing a solution towards solving an environmental problem

Awareness about environmental problems

Contributing towards research concerning (agent) optimisation
for architecture with conflicting objectives

The Design Process

The process on this poster describes how the algorithm created by this research would fit into a real life scenario, from localising the material until the placement of the material on an actual project.

Material location

Analyse Design

Pre-select material

3D Scan

Reality

3D Geometry

Full Surface:
Gaussian curvature data range

x 15

Defender
400 kg/each
Gaussian range

Input

Output

Material list

Transport

Placement on machine bed

Fixing the material in place before processing

Pre-Assembly

Temporary storage

Set Parameters

Analyse panel

Panel

Gaussian curvature data range

Cutting locations

Post-processing

Dis-Assembly

Precise location

Research

Boat builders

Analyse 3D Scans

Architect's plugin

Material selection

Material

Code for machinery

Mass
Amount
Types

Include boatbuilding companies into the process, they can provide 3D models of boats. This could help them with their 'suistainability' image

Gaussian curvature data

- Maximum deviation
- Maximum panel gap
- Size
- Shape
- Curvature continuity

Design plugin using the digital warehouse to create preliminary design solutions based on available shapes.

Material choice from pre-selection

x 1

Defender
400 kg/each
Gaussian range

Probing: Determining the exact location of the material

Dis-Assembly & packaging

Start

3D Digital warehouse

Design

Algorithm

Production

Build

Finish

x 105

x 92

x 631

x 384

Defender
400 kg/each
Gaussian range

Cutting

A robotic arm, instructed by code generated in the algorithm cuts out the panels for the design.

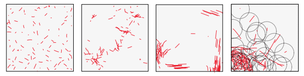
Design Construction

The Algorithm Logic

The logic presented on this poster shows how the algorithm works. How is the data generated, what kind of data adaptations are being made? How are the results ranked? All these things are shown step by step, from raw material to cutting pattern, code generation and a material list.

Furthermore the parts on this poster that are ....

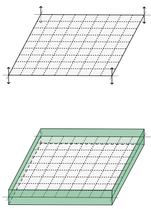
Rules



Separation Cohesion Alignment Attraction

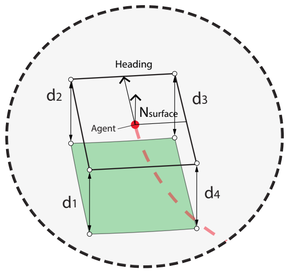
Behavioural system defined by rules

Environment



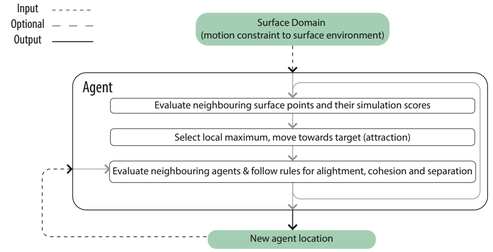
Combination of rules bound by an environment

Information carried by agents



Each agent carries a plat surface with an amount of data points. This can range from 4 (as the example shows) up until any amount. This illustration shows the orientation of the data points in relation to the agents. The heading of the agent is a result of the rules and aligns with the panel's Y-axis.

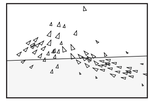
Internal logic



The internal logic describes what the agent does after every calculation/iteration/time-step

Agents

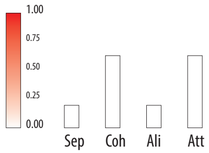
Computer System



"An agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives."

Rule importance

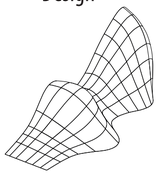
The weighing of each rule



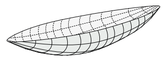
The combination of all the rules are a ruleset that instruct the agent's behaviour.

Input

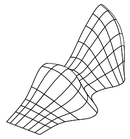
Design



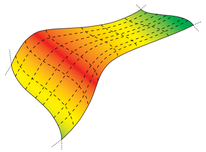
Material



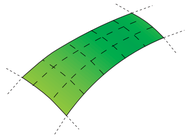
Measuring Full Surface



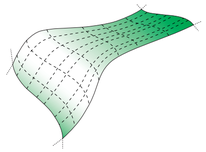
Measuring material input



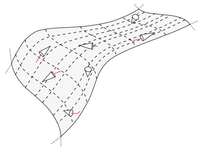
Measuring Panel



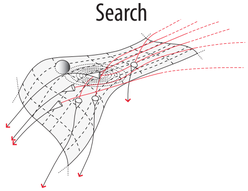
Mapping



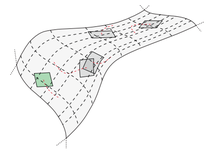
Agent Placement



Search



Solution

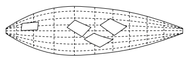


Find panel placement

Output

Material List

Cutting locations



Machine Code

Agents - Introduction

"An agent is a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives."

Wooldridge & Jennings, 1995

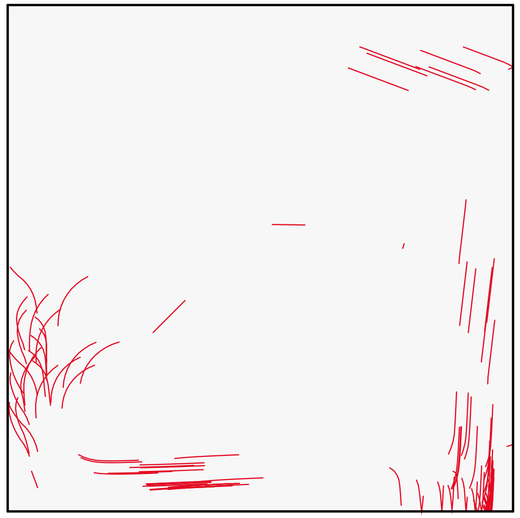
Agents - Behaviour logic

“The aggregate motion of a flock of birds, a herd of land animals, or a school of fish is a beautiful and familiar part of the natural world.”

Reynolds, 1987

Agents - Behaviour logic

Alignment

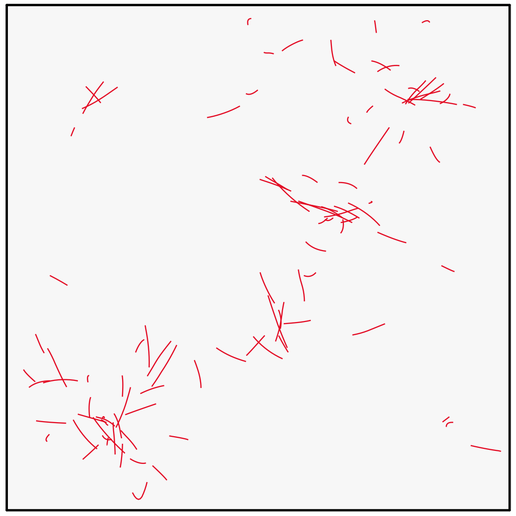


Align Weight Multiplier: 0.6
Separate Weight Multiplier:
Cohese Weight Multiplier:

Current repetition done: 150
Agent amount: 99
Lifespan: 140
History Length: 10

Bounce Contain:	Yes
Contain:	Yes
Radius:	5

Cohesion



Align Weight Multiplier:
Separate Weight Multiplier:
Cohese Weight Multiplier: 0.15

Current repetition done: 150
Agent amount: 99
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History Length: 10

Bounce Contain:	Yes
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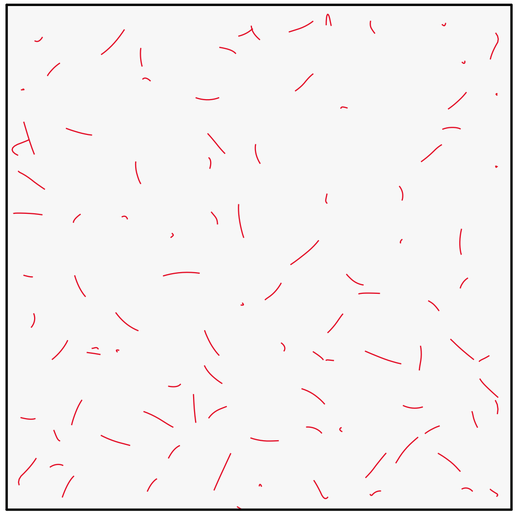
Radius:	5

Separation



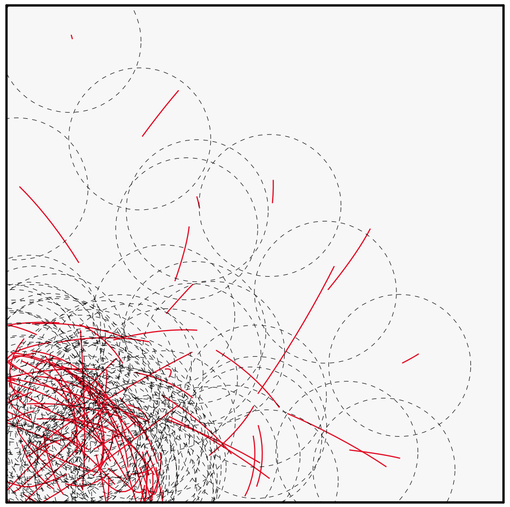
Align Weight Multiplier:
Separate Weight Multiplier: 0.15
Cohese Weight Multiplier:

Current repetition done: 150
Agent amount: 99
Lifespan: 140
History Length: 10

Bounce Contain:	Yes
Contain:	Yes
Radius:	5

Agents - Behaviour logic

Atrraction

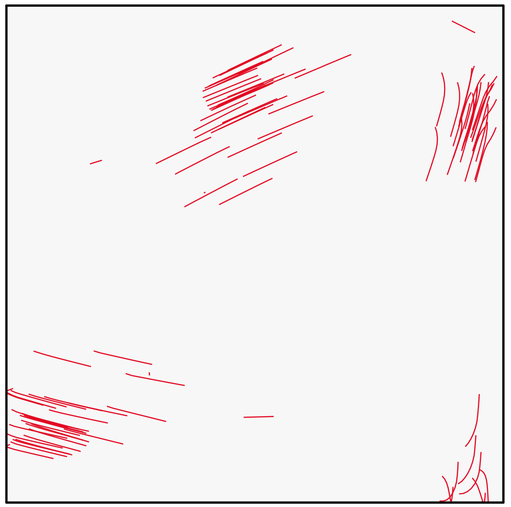


Align Weight Multiplier:
Separate Weight Multiplier:
Cohese Weight Multiplier:
Attract Point Multiplier: 0.6

Current repetition done: 150
Agent amount: 99
Lifespan: 140
History Length: 10

Bounce Contain:	Yes
Contain:	Yes
Radius:	5

Alignment, Cohesion & Separation

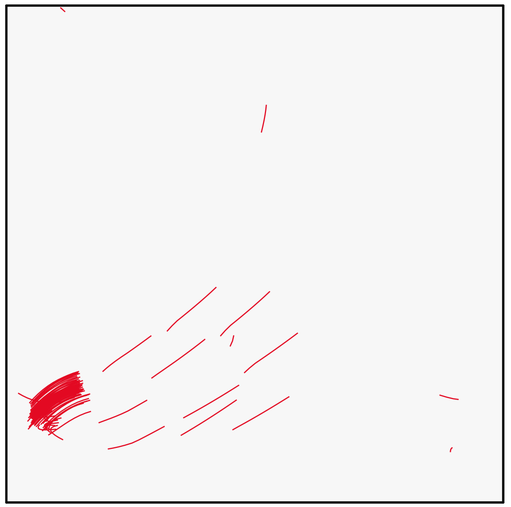


Align Weight Multiplier: 0.6
Separate Weight Multiplier: 0.15
Cohese Weight Multiplier: 0.15

Current repetition done: 150
Agent amount: 99
Lifespan: 140
History Length: 10

Bounce Contain:	Yes
Contain:	Yes
Radius:	5

Alignment, Cohesion, Separation & Attraction

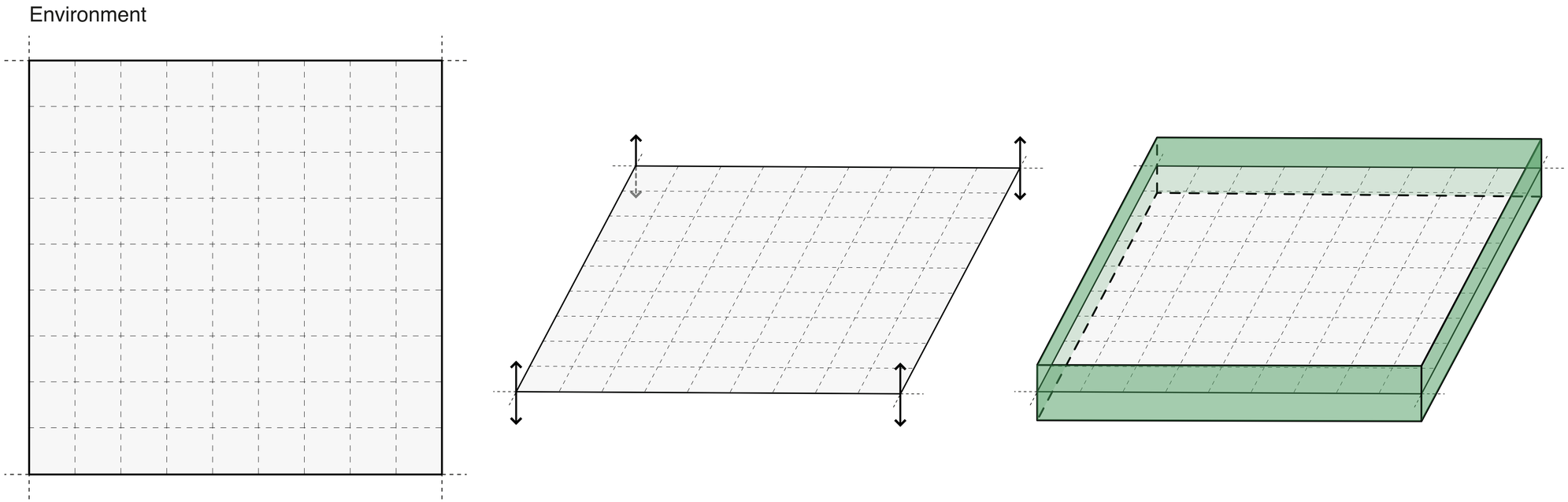


Align Weight Multiplier: 0.6
Separate Weight Multiplier: 0.15
Cohese Weight Multiplier: 0.15
Attract Point Multiplier: 0.6

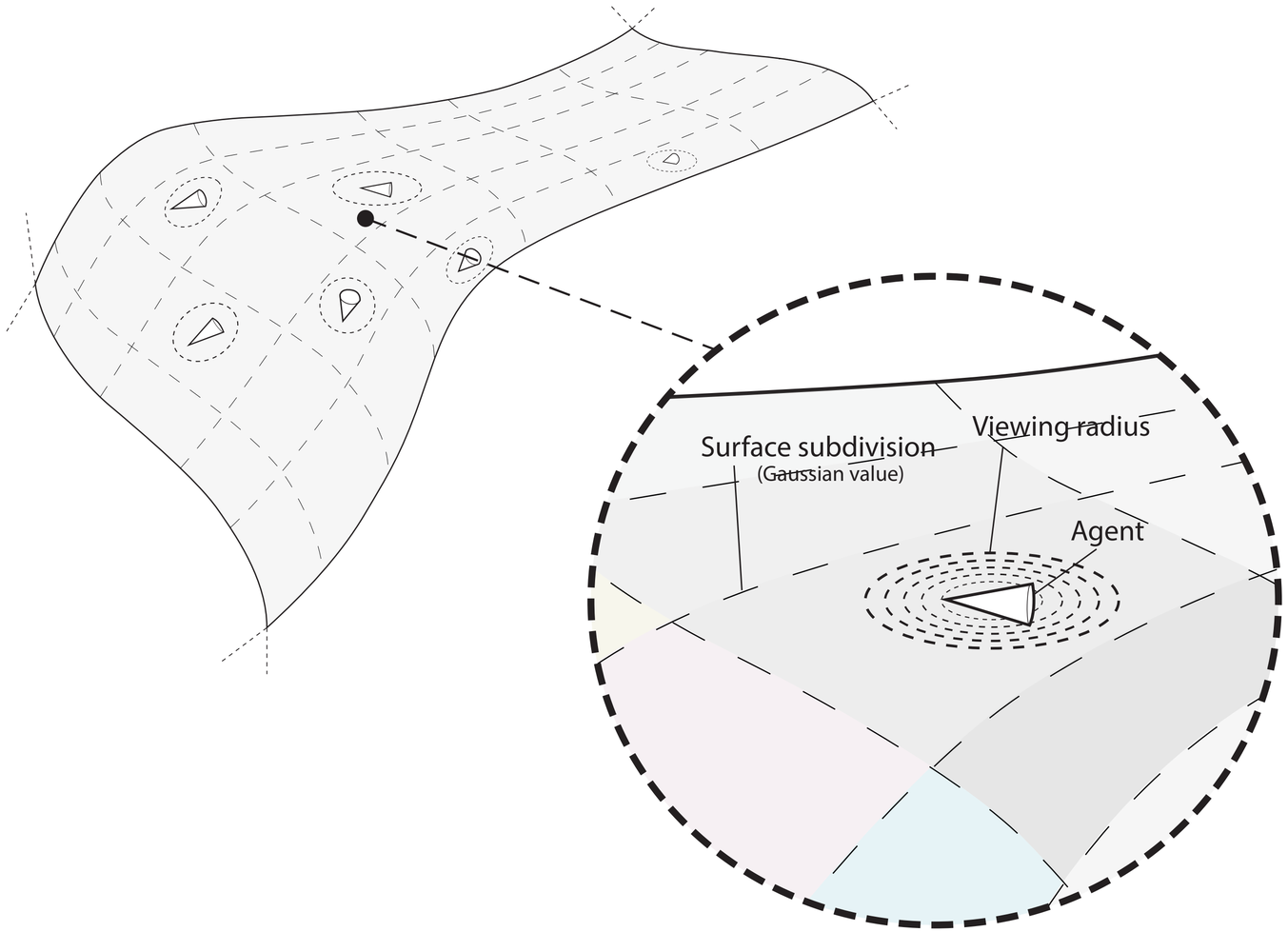
Current repetition done: 150
Agent amount: 99
Lifespan: 140
History Length: 10

Bounce Contain:	Yes
Contain:	Yes
Radius:	5

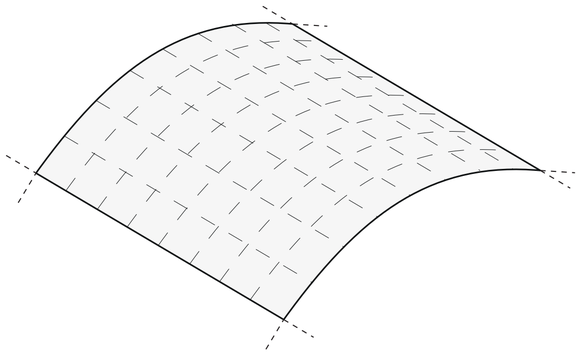
Agents - Environment



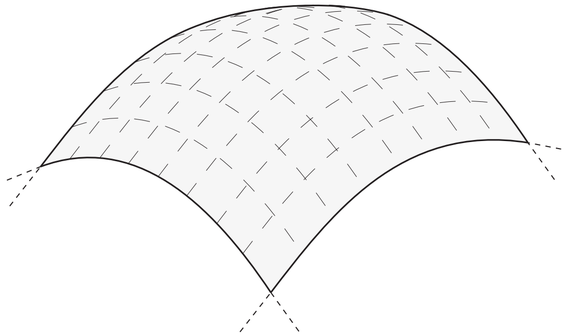
Agents - Local and Global Optima



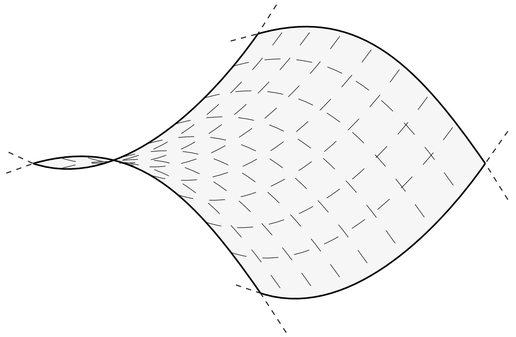
Surface Geometry - Classification



Single curved

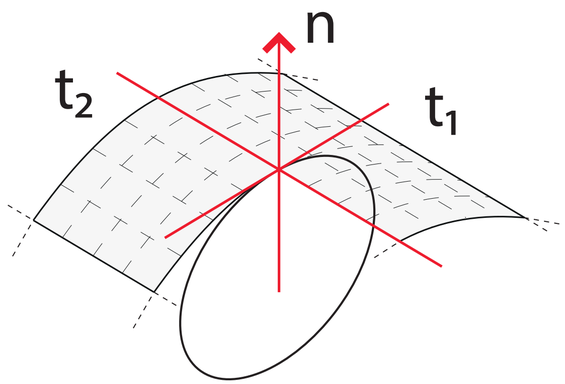


Synclastic

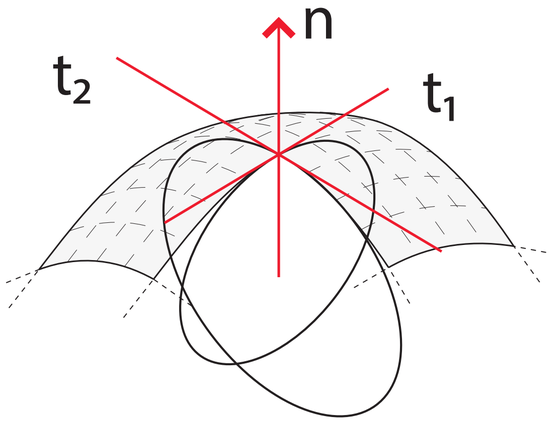


Anticlastic

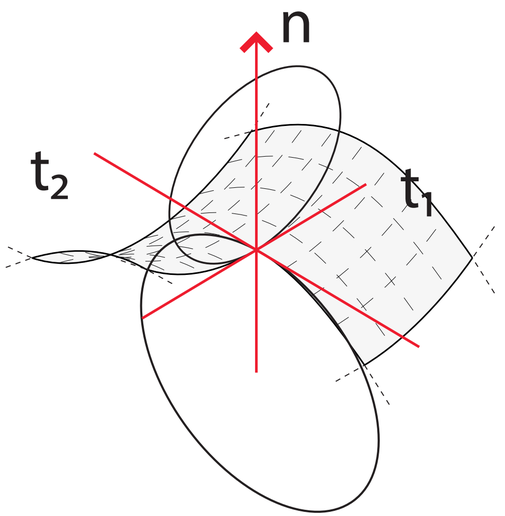
Surface Geometry - Curvature



Single curved

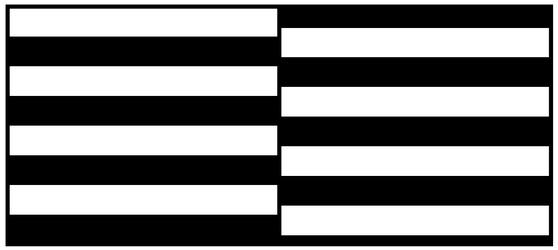


Synclastic

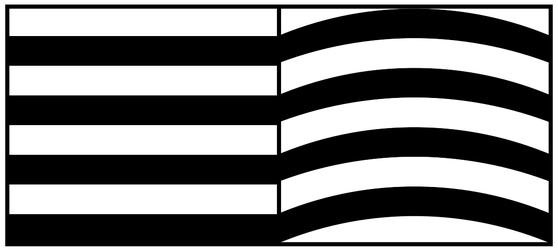


Anticlastic

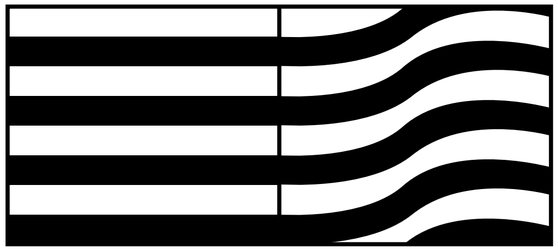
Surface Geometry - Continuity



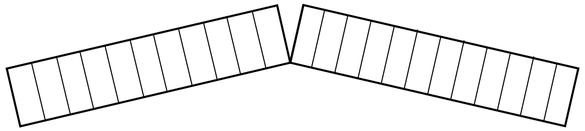
G0. Positional continuity

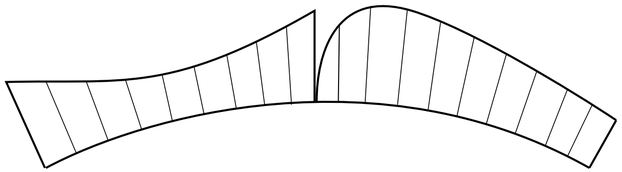


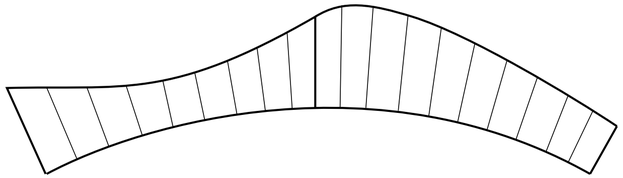
G1. Tangential continuity



G2. Curvature continuity





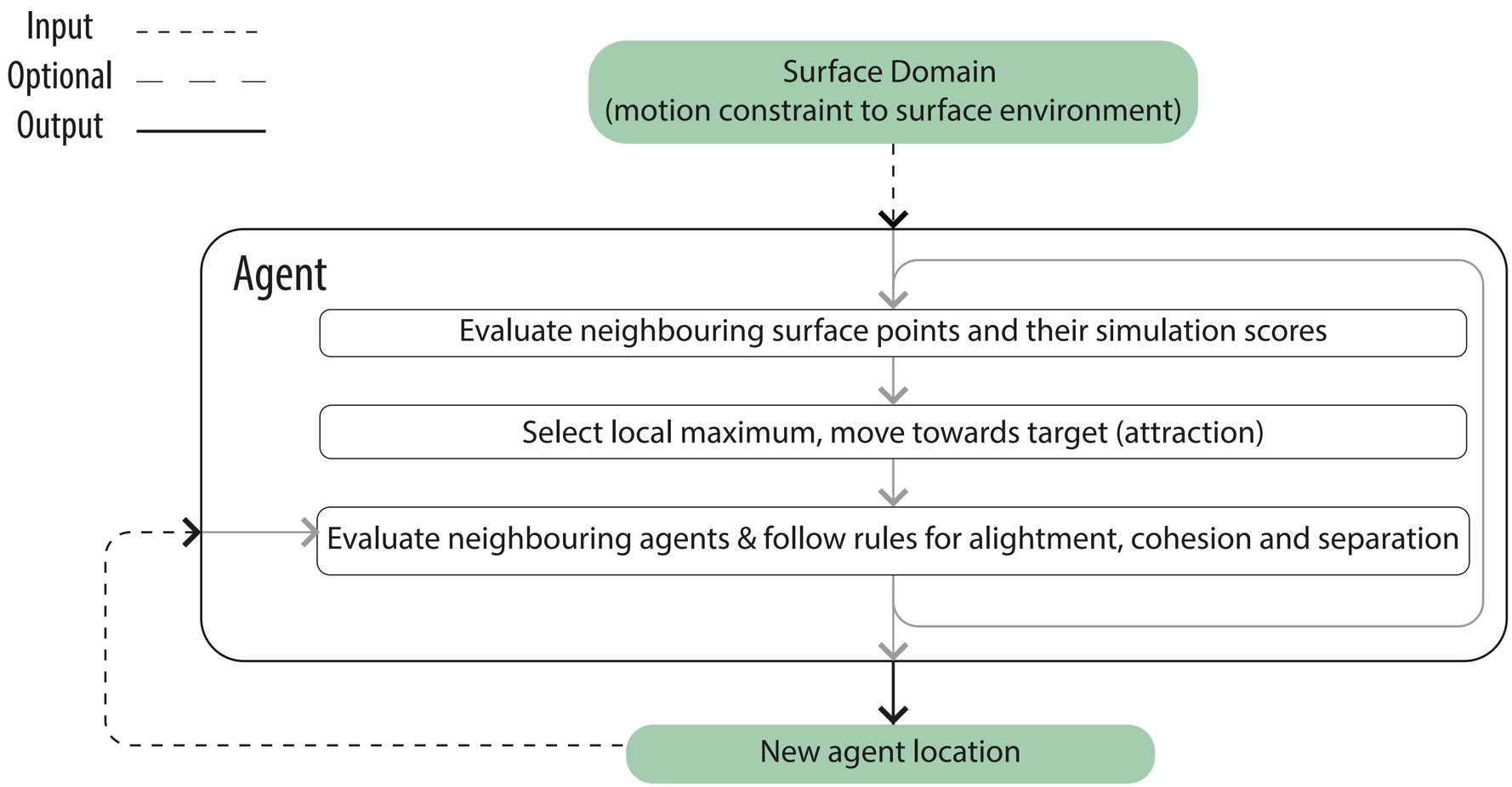


Material

The amount is quantified at 4.500 tonnes a year, out of which 1.400 tonnes are polyester boat hulls and 1.300 tonnes are rotor blades from windturbines. Furthermore the amount of boat hulls is expected to grow up to **4.000 tonnes a year in 2030.**

Ten Busschen et al., 2016

Setup - Rules

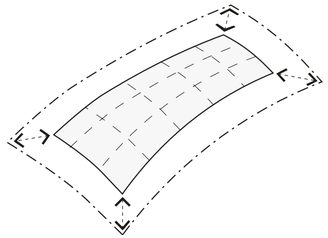

Input
Optional
Output
Surface Domain
(motion constraint to surface environment)
Agent
Evaluate neighbouring surface points and their simulation scores
Select local maximum, move towards target (attraction)
Evaluate neighbouring agents & follow rules for alightment, cohesion and separation
New agent location

Setup - Weighting

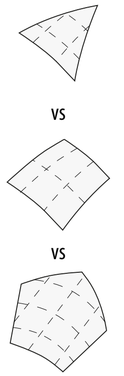
Setup - Example with point attraction

Design and Workflow - Basic Parameters

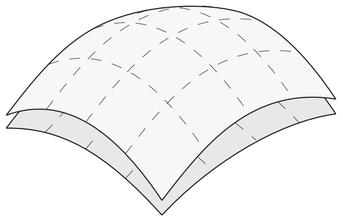
1. Panel size



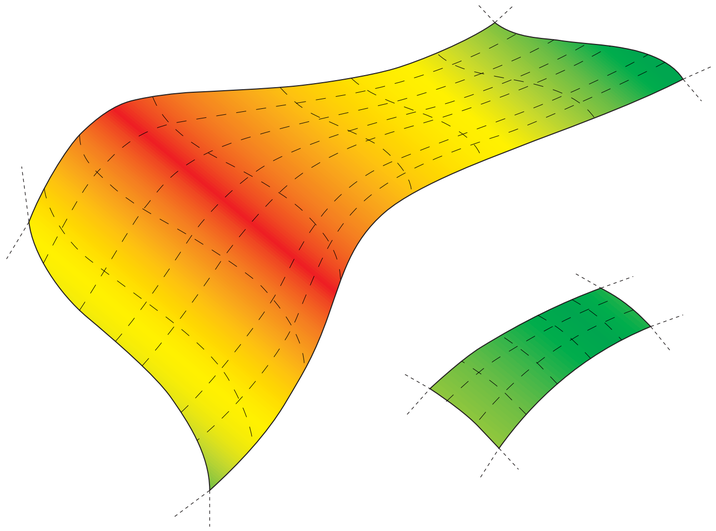
2. Panel shape

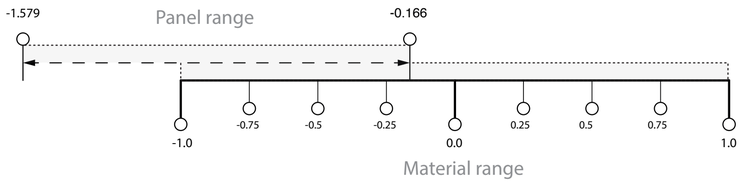


3. Panel curvature deviation
(between source and goal)

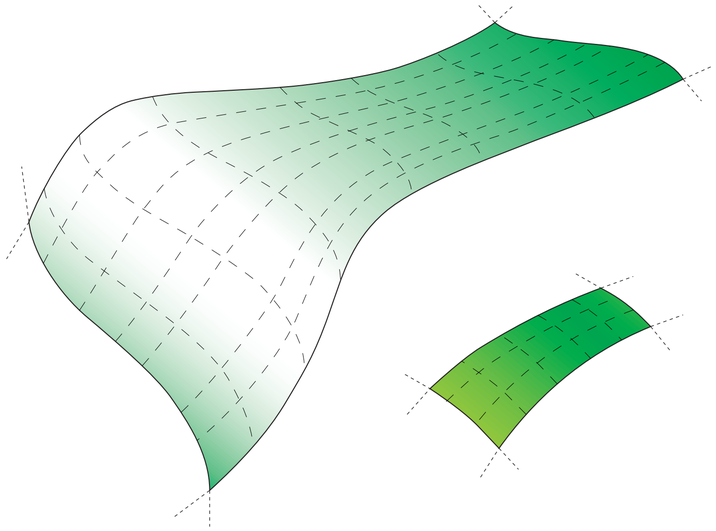


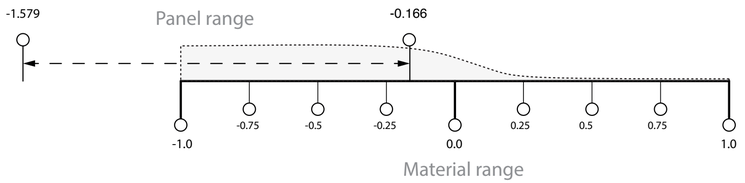
Design and Workflow - Measuring



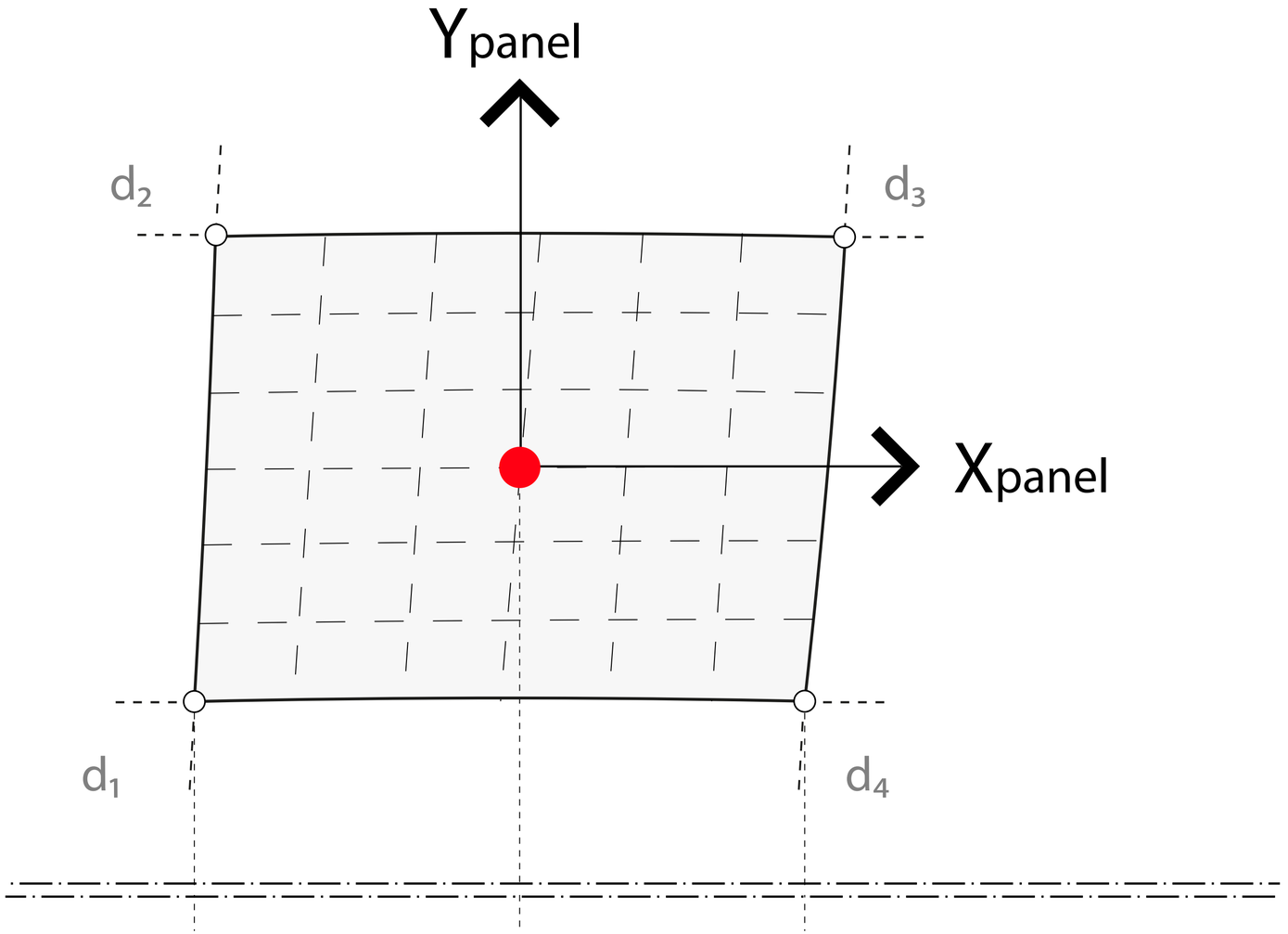


Design and Workflow - Mapping

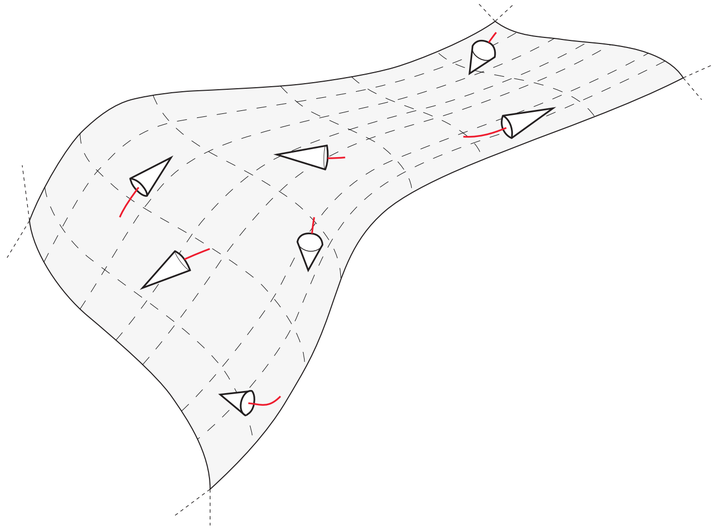




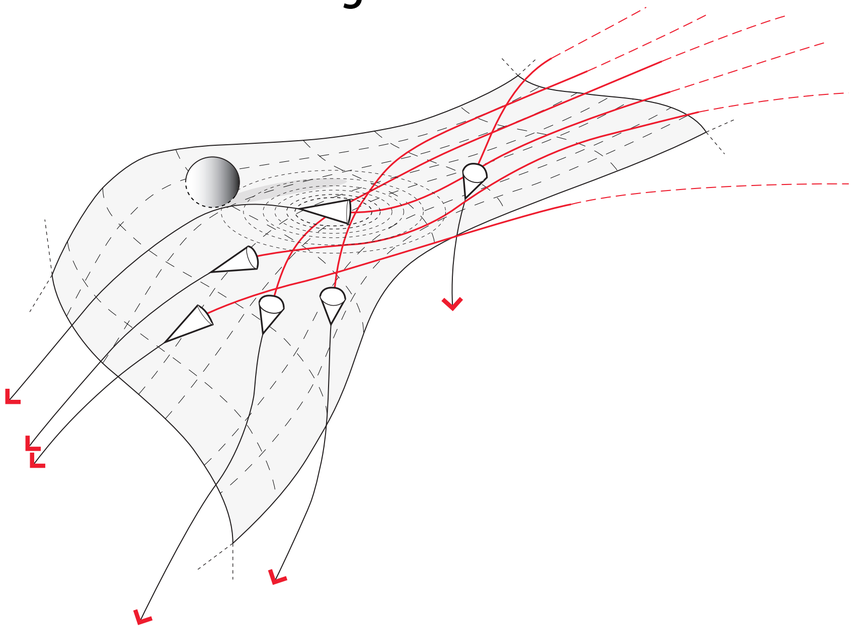
Design and Workflow - Panel Orientation



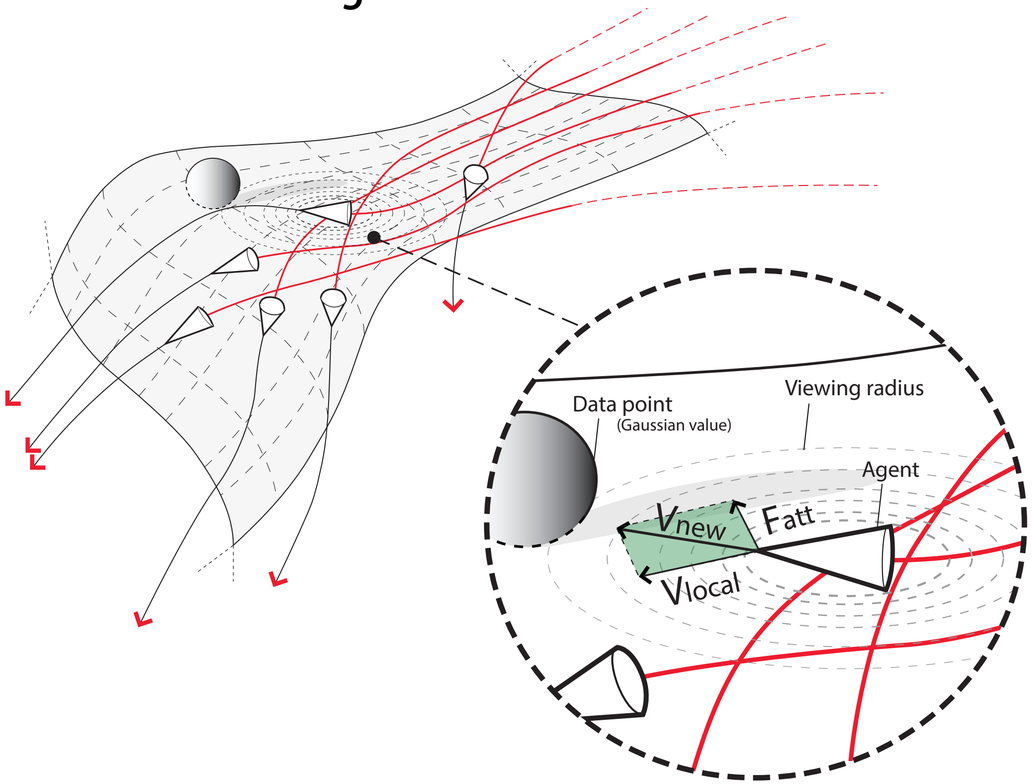
Design and Workflow - Placement



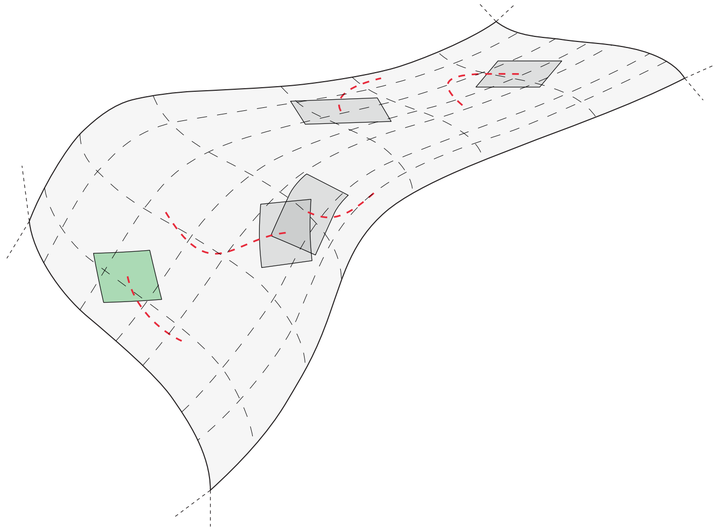
Design and Workflow - Search



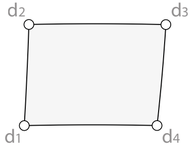
Design and Workflow - Search



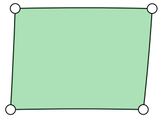
Design and Workflow - Simulation example



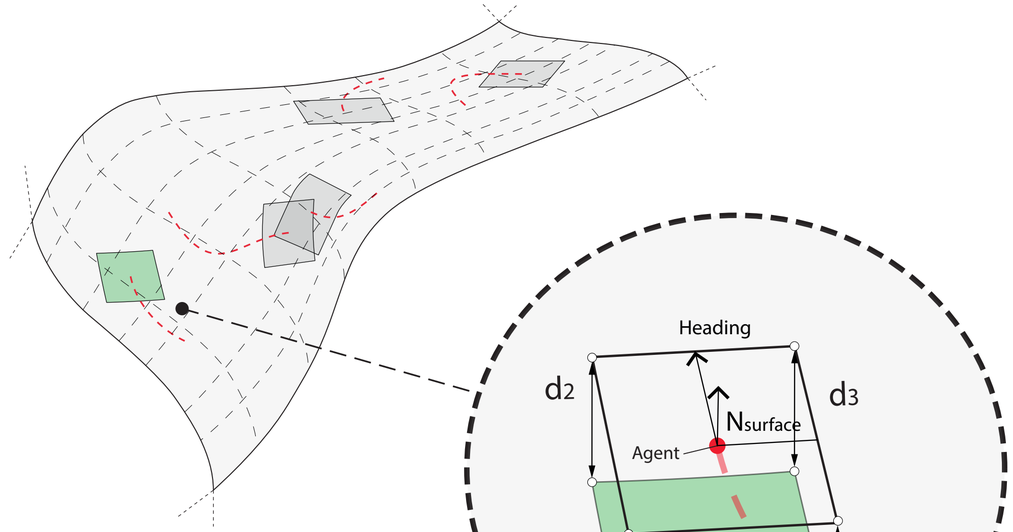
Design Panel



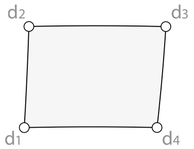
Found match



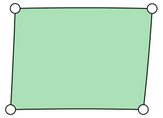
Design and Workflow - Simulation example



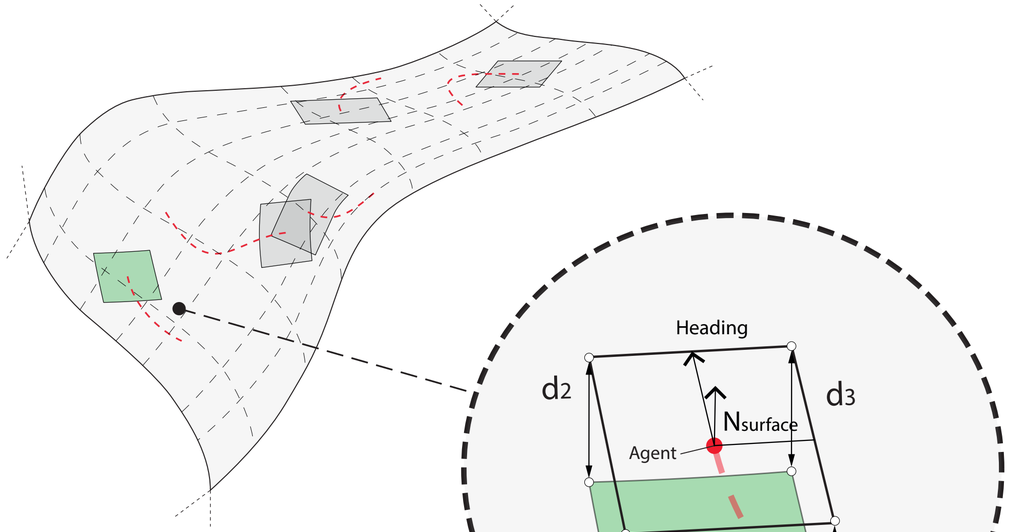
Design Panel



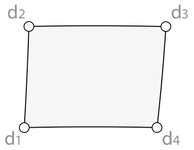
Found match



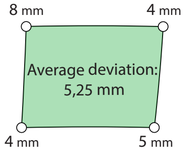
Design and Workflow - Simulation example



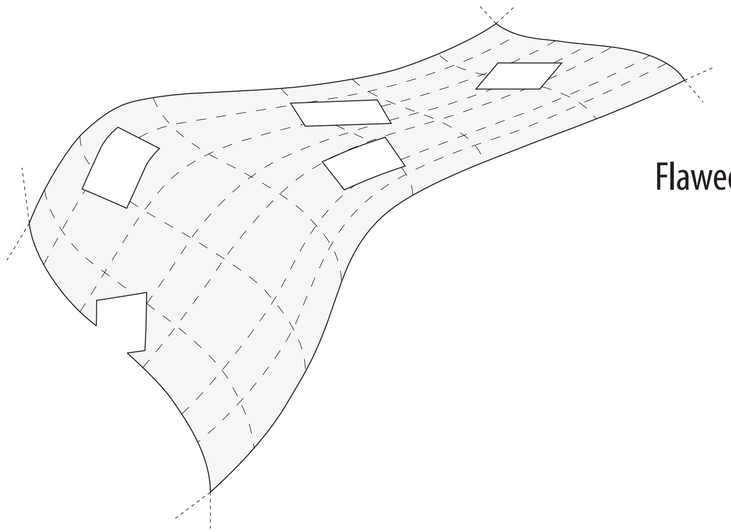
Design Panel



Found match

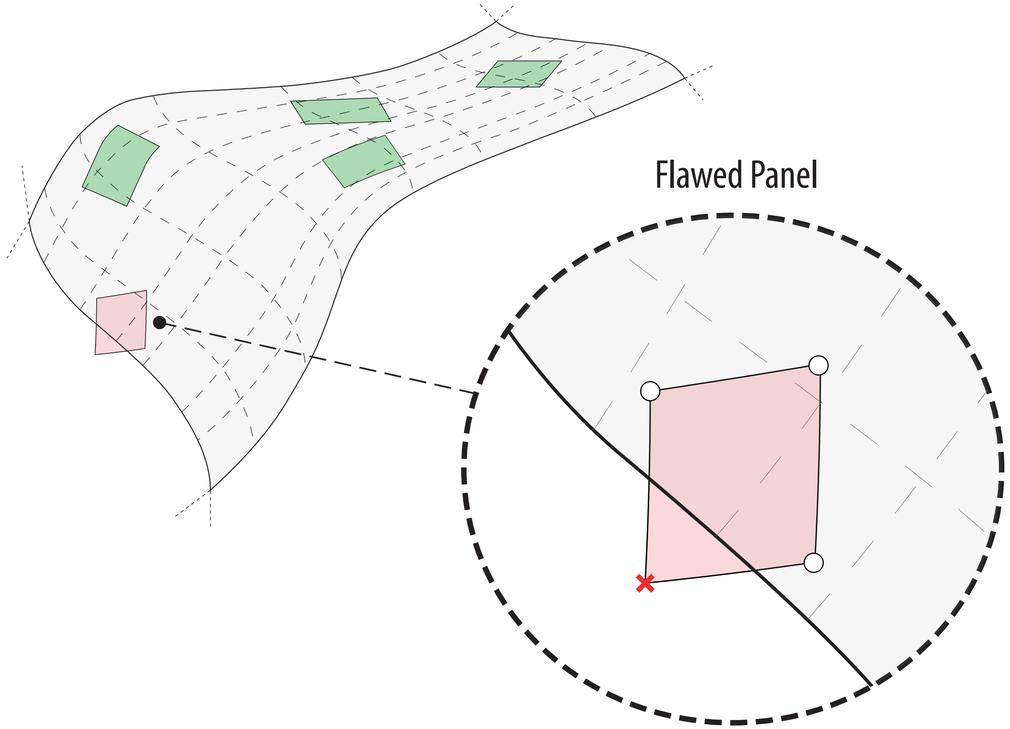


Design and Workflow - Cleaning data & selecting best option



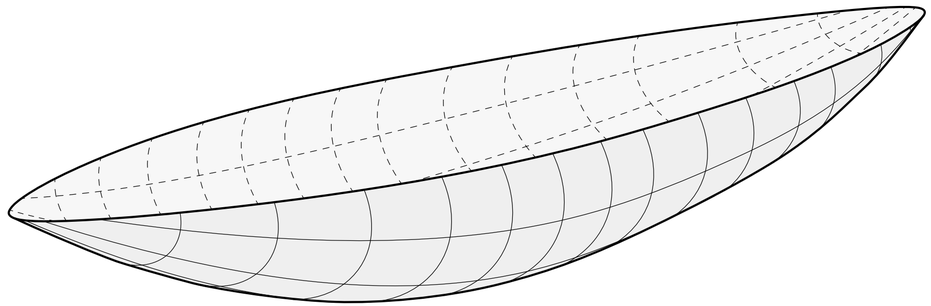
Flawed Panel Placement

Design and Workflow - Cleaning data & selecting best option

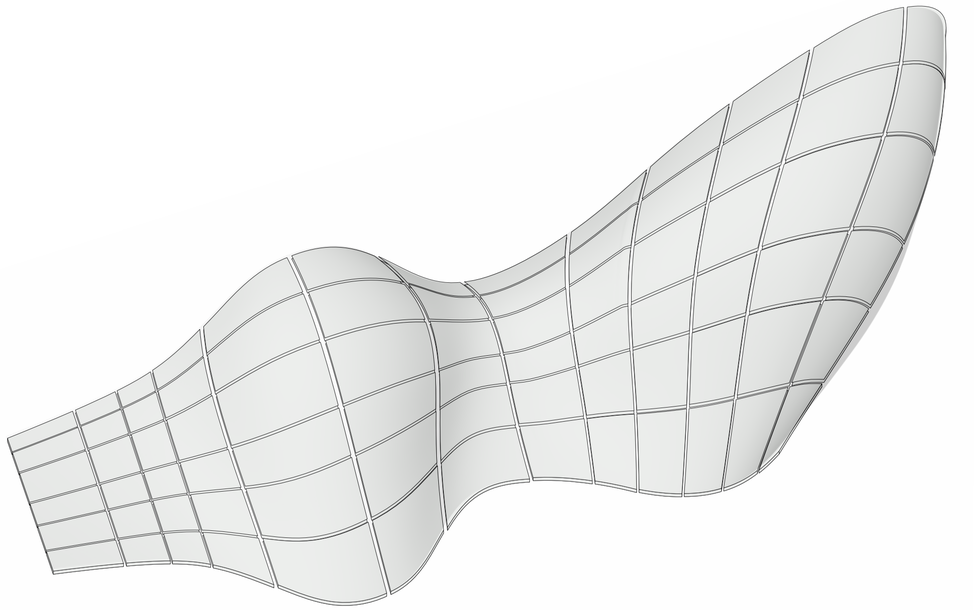


Results - Input

3D boat hull



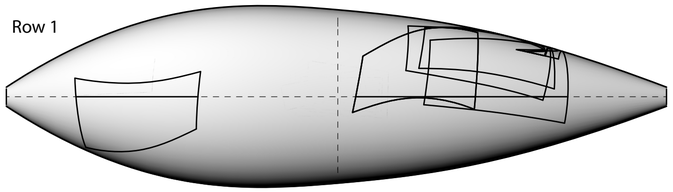
Pavilion

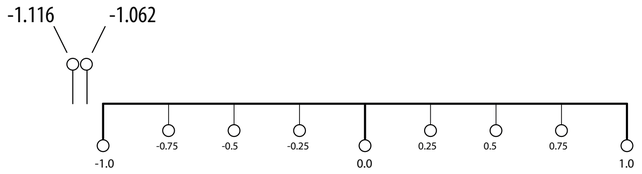


Algorithm

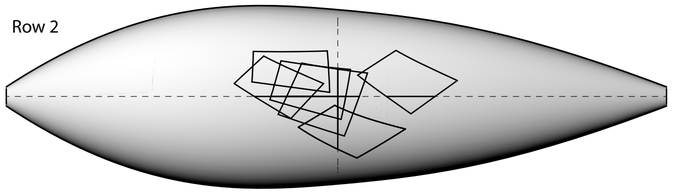
Results - Output

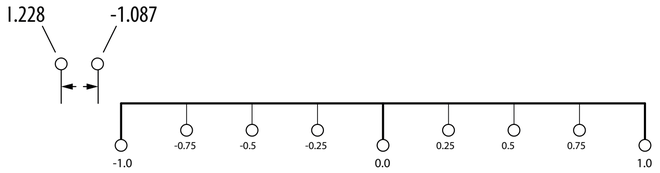
Row 1



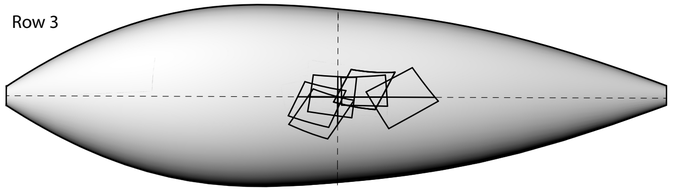


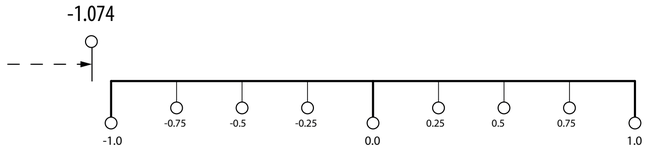
Row 2





Row 3





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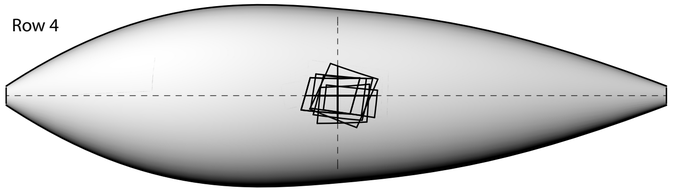
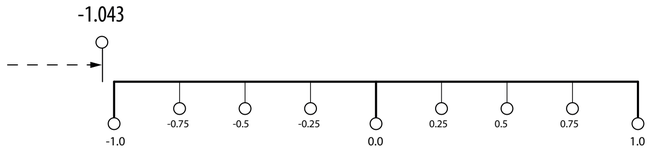
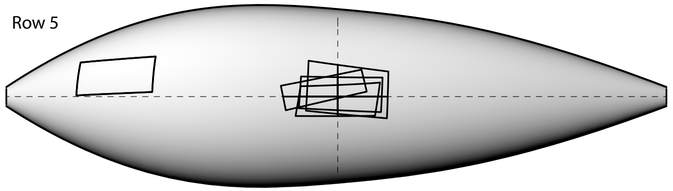




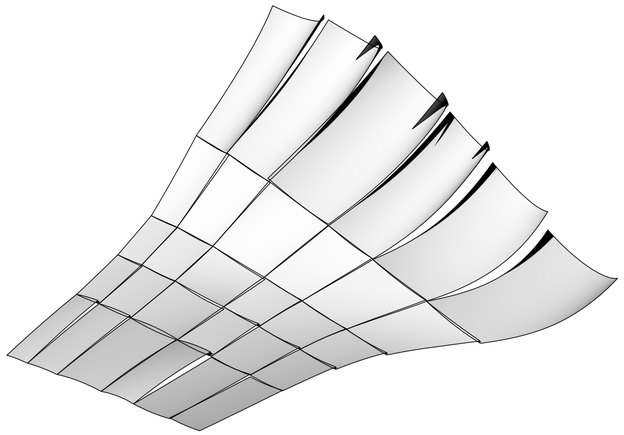
Row 5



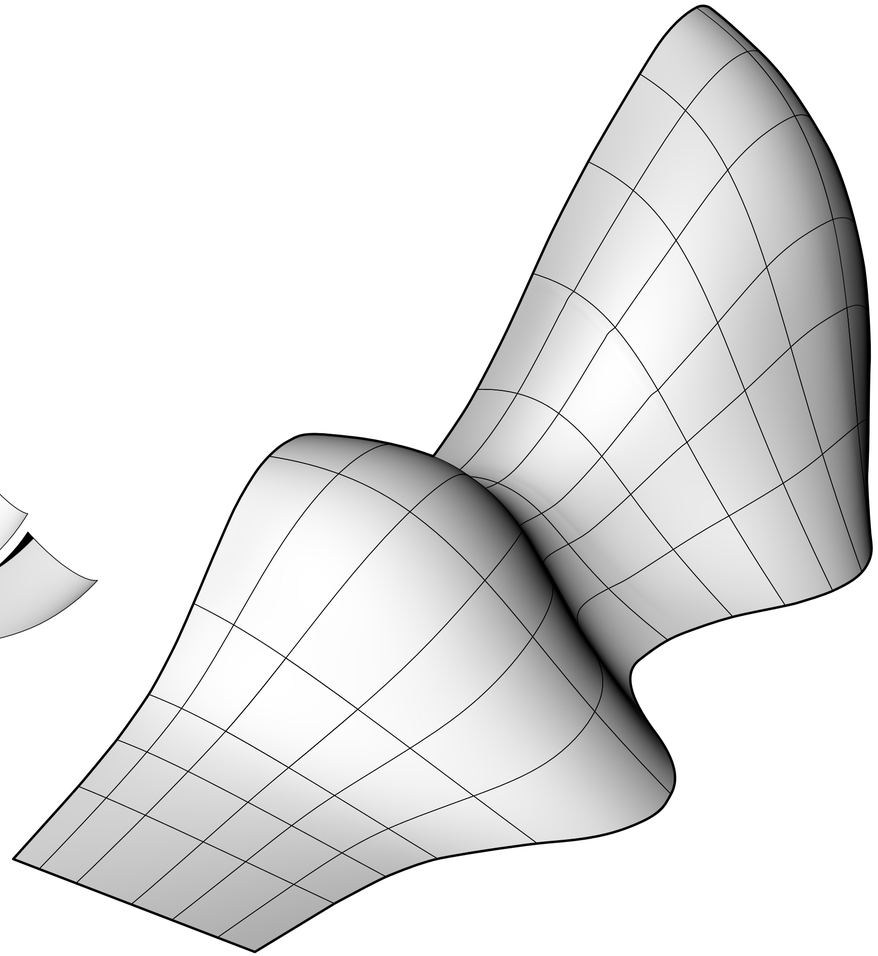
-0.166

Results - Output

Matched panels

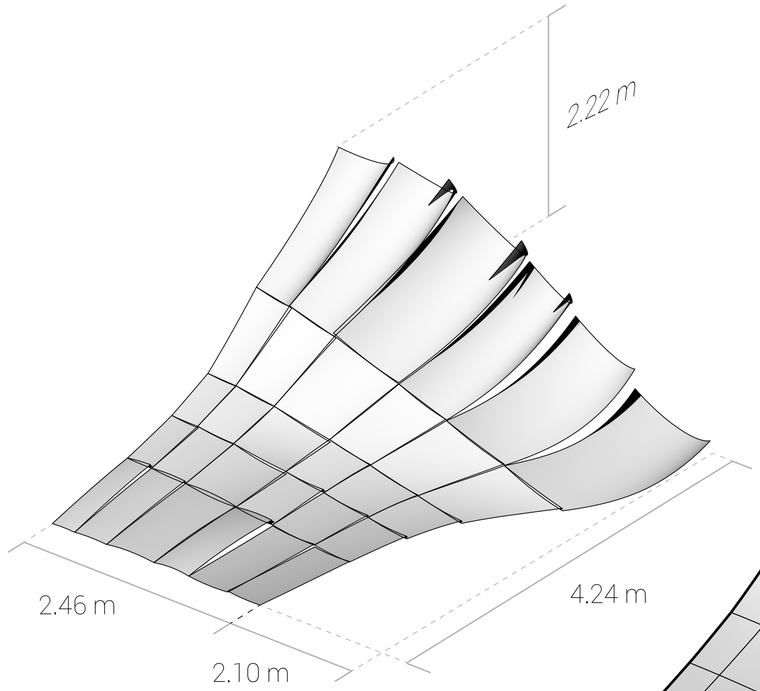


Design panels

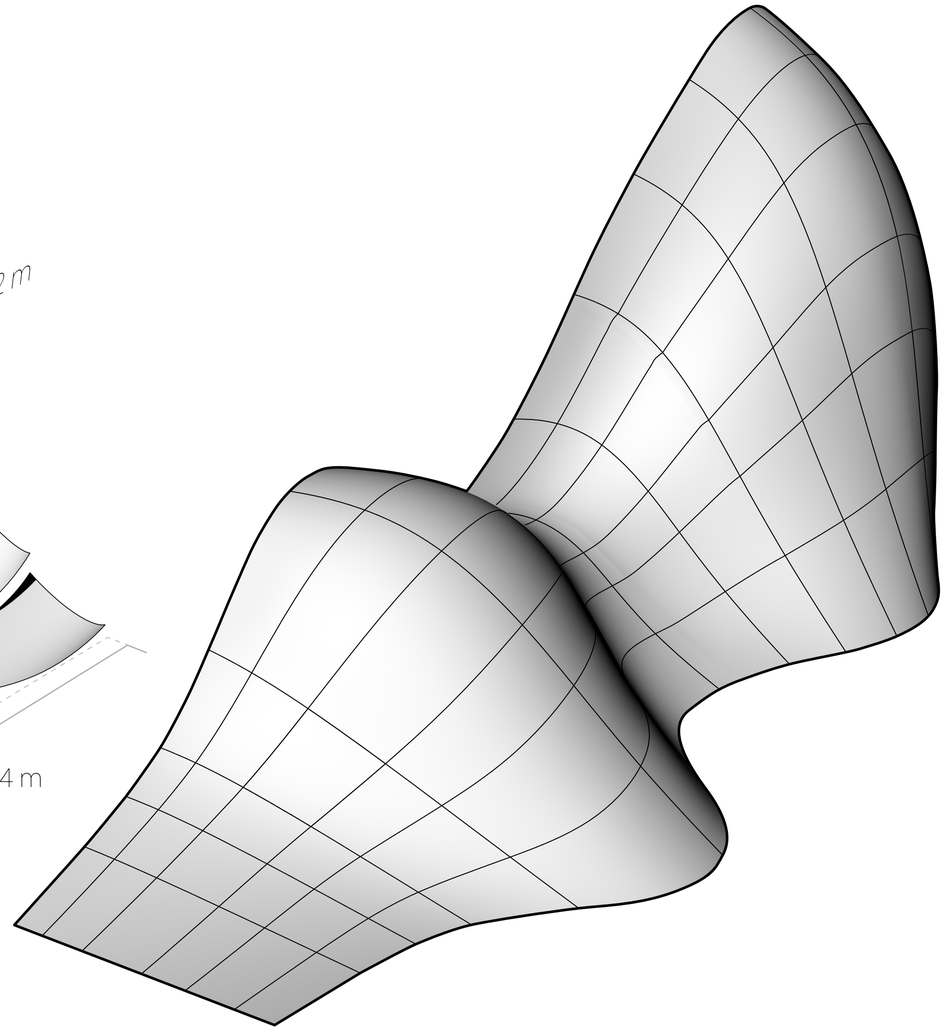


Results - Output

Matched panels



Design panels



Conclusion

Summary

Gaussian curvature values can be used to influence agents towards generating matches between curved surfaces

Conclusion

Type & relative weight of the rules used to influence the overall agent behaviour are important

Amount of data points carried by agents heavily influences computational time

Iterative process per panel and material environment, neglects already ‘used’ space on material

Gaussian curvature per data point/sub division works, more delicate solution might be available

Comparison to other optimisation techniques

Coding in dedicated software pacakge (‘Processing’)

Change iterative process towards multiple agents, or agent groups, solving the ‘used’ space problem

Inclusion of intelligence into the agents behaviour

Improvement in Gaussian value display

Recommendation

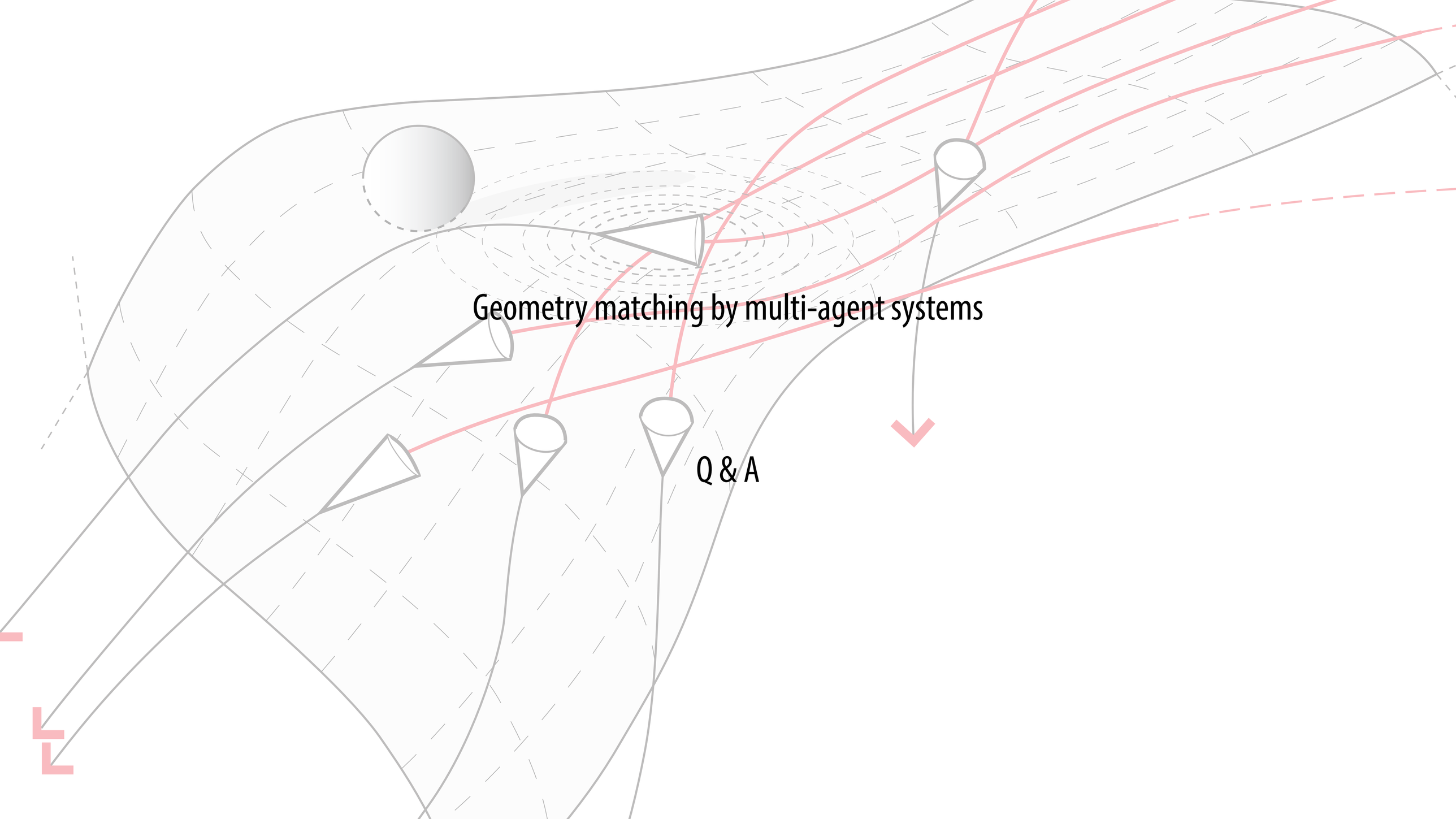
Cutting techniques

Surface treatment(coating)

Adaption towards other materials

Development towards a fit into an overal building method, including, but not limited to:

- 3D scanning
- Possible mesh adaptions that result from 3D scanning
- Pre-selection of material from library (most likely match)
- Generation of code for machinery for production (g-code)



Geometry matching by multi-agent systems

Q & A