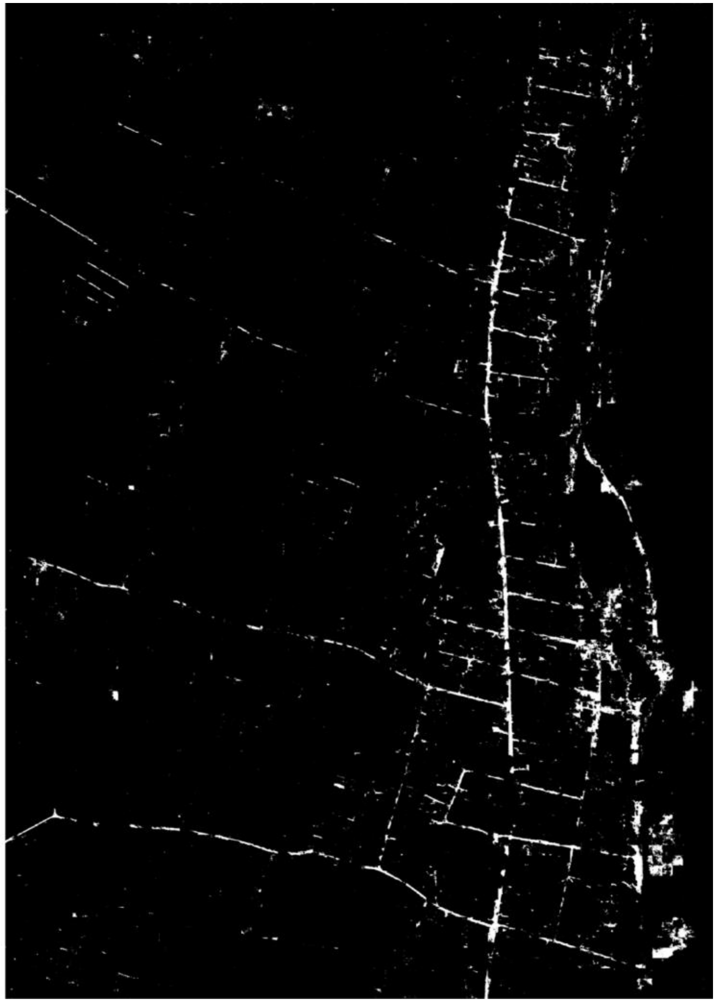
Machine Intelligence and *Architectural Applications*

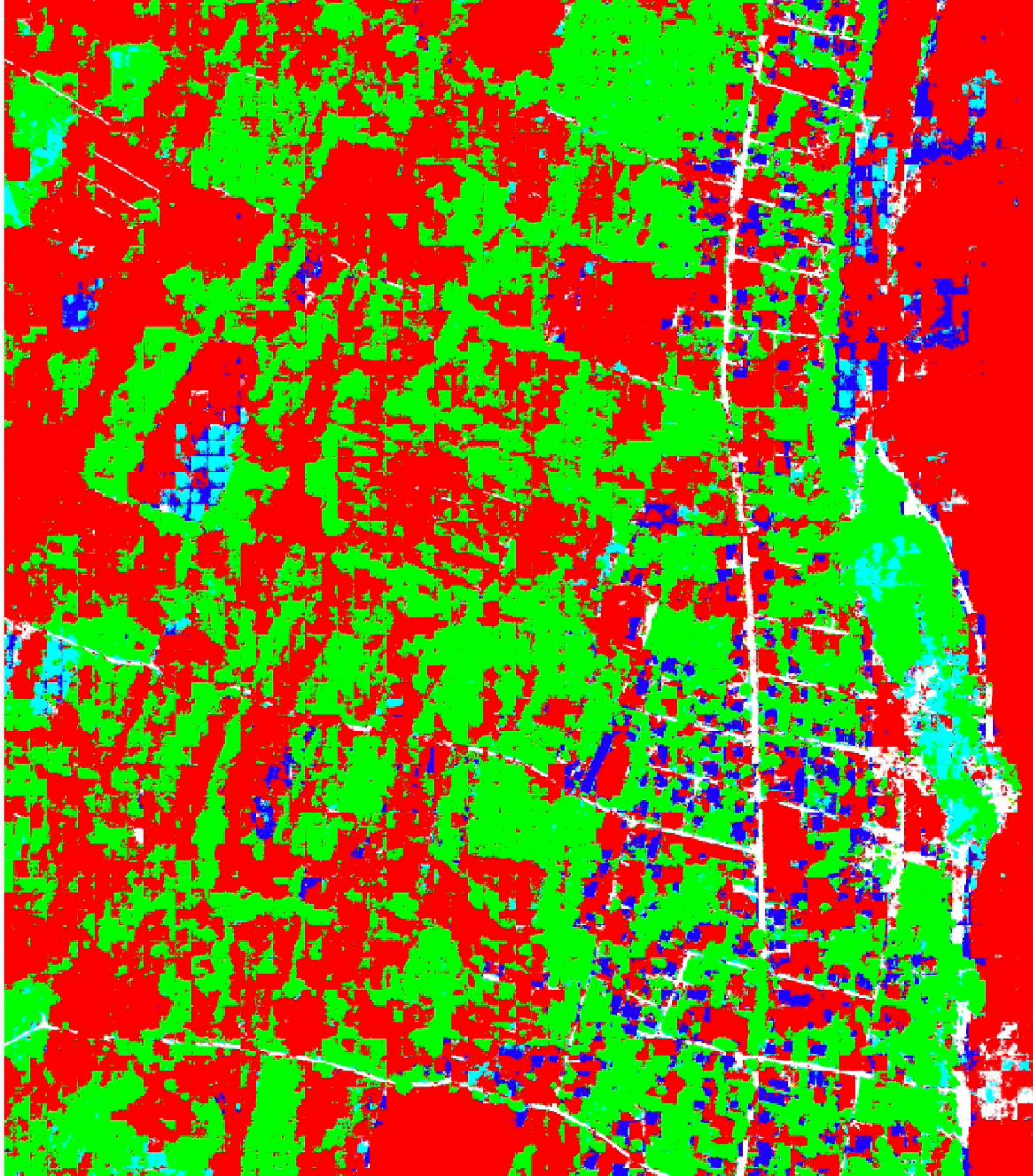
Table of Contents

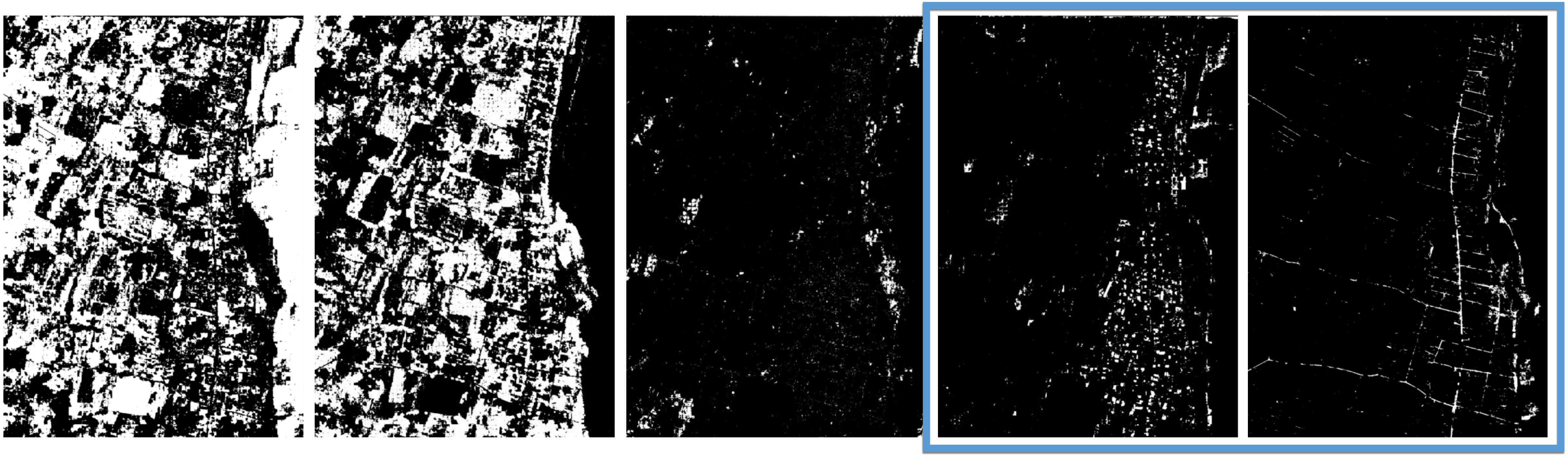
Object Detection of Aerial Imagery

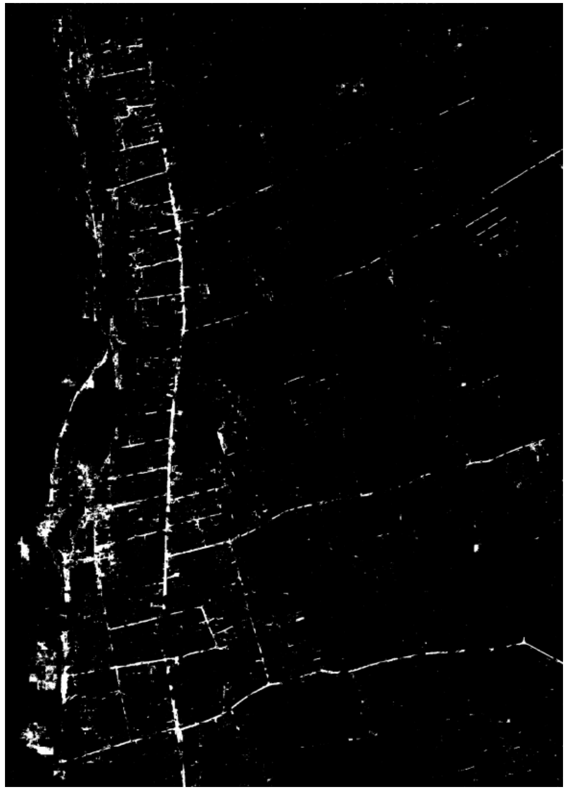
As a start



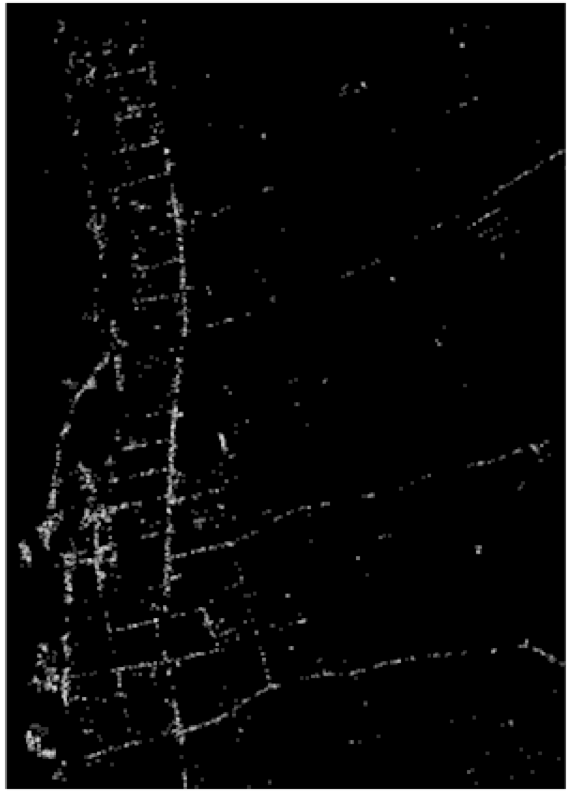
Banana
Coconut
Mango
Papaya





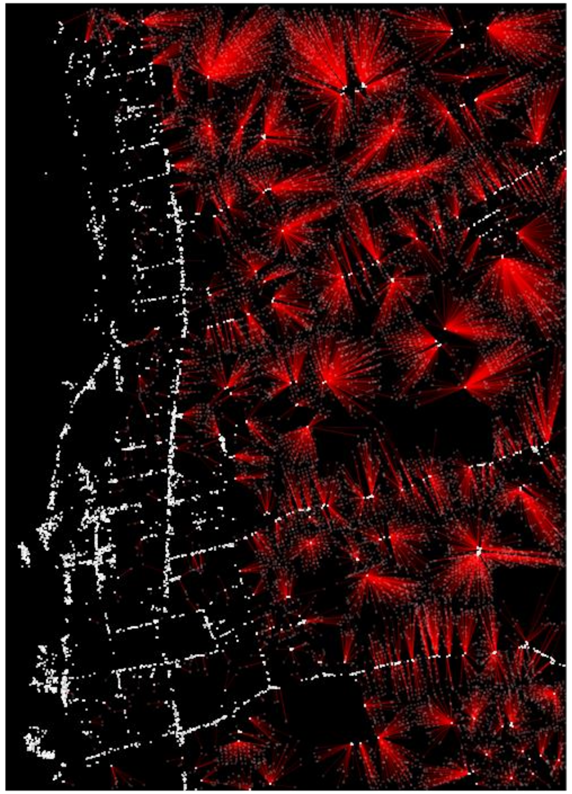


Masking streets



Subsampling

Delaunay Triangulation

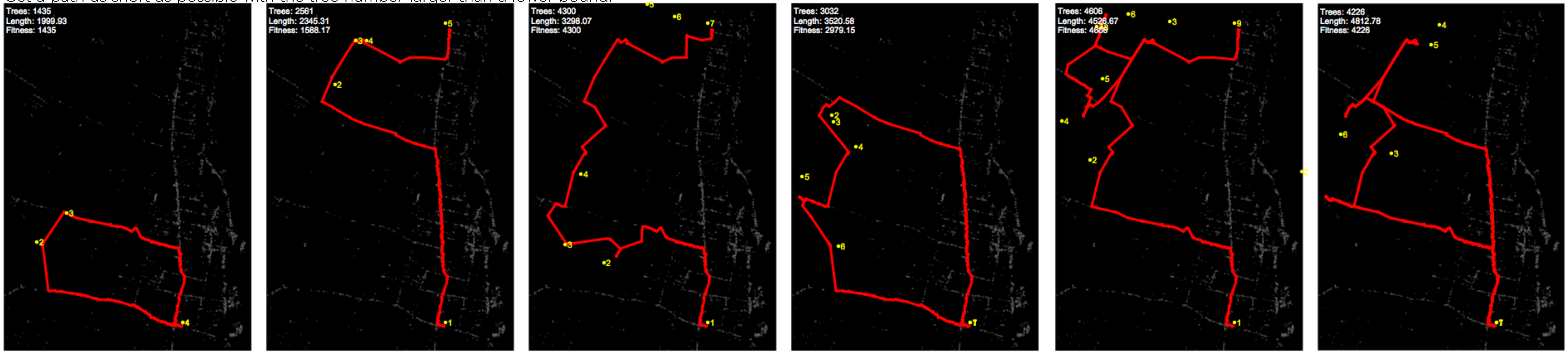


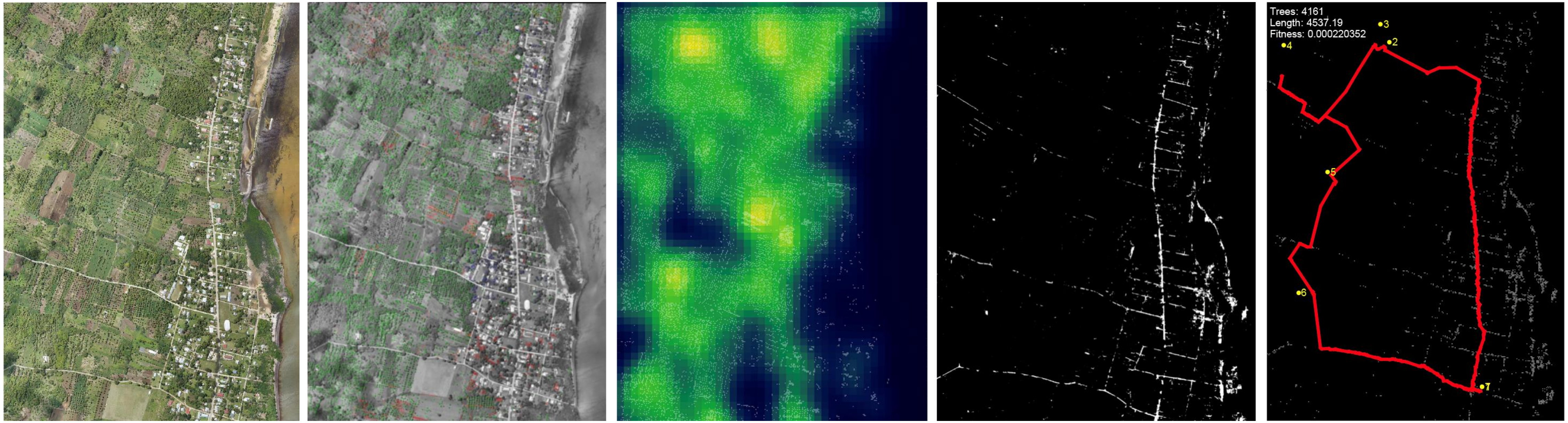
Weighted nodes by the number of reachable trees

Path Optimization

Get a path that contains as many trees as possible with its length below an upper bound.

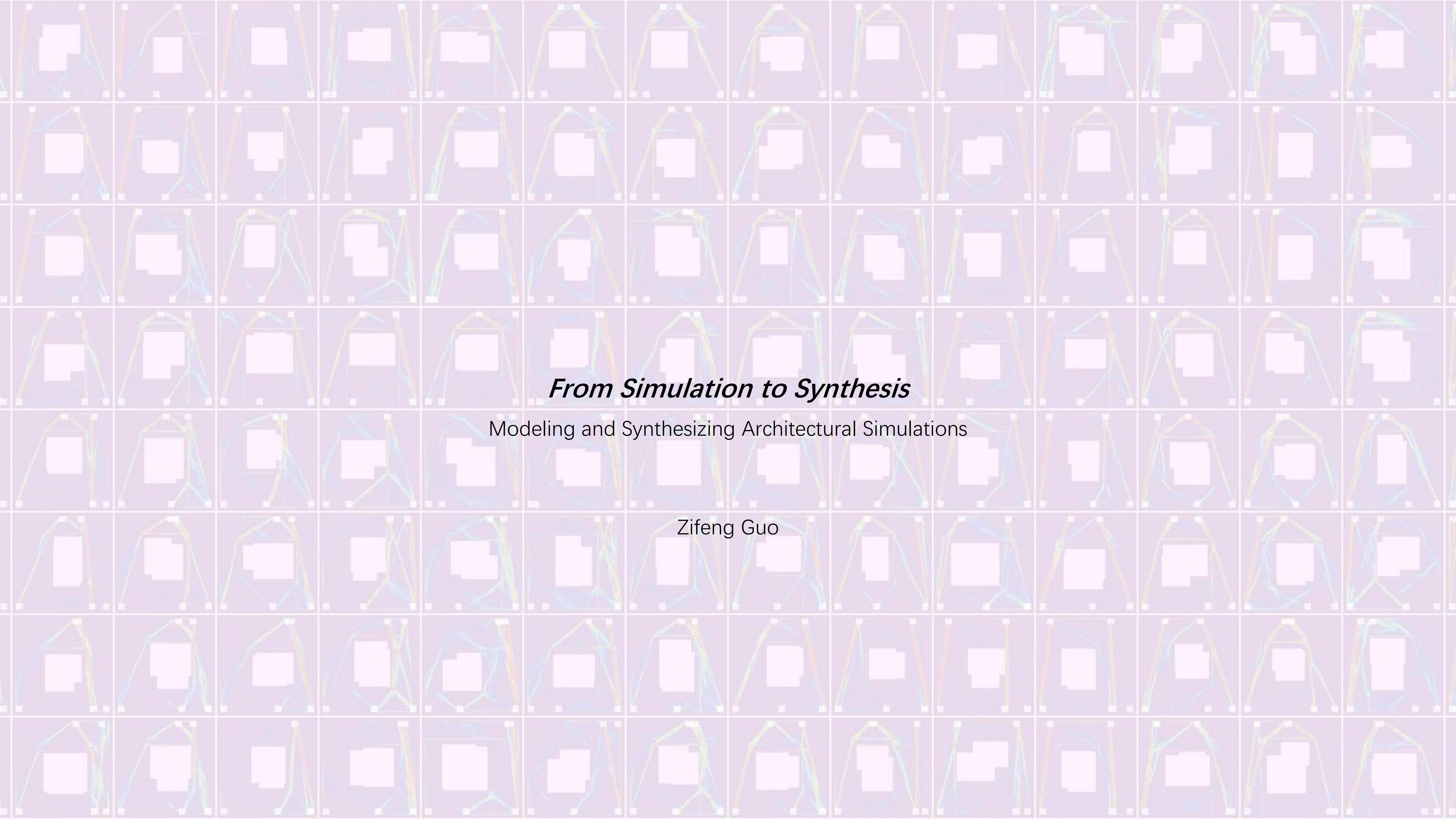
Get a path as short as possible with the tree number larger than a lower bound.





Aerial Imagery | Classification/Localization | Density Maps | Street Segmentation | Path Optimization

The pipeline of the experiment, starting with the collection of aerial imagery, followed by the localization and classification of trees, density maps. Segmentation of the roads to propose a short path based on user’ question to harvest.



From Simulation to Synthesis

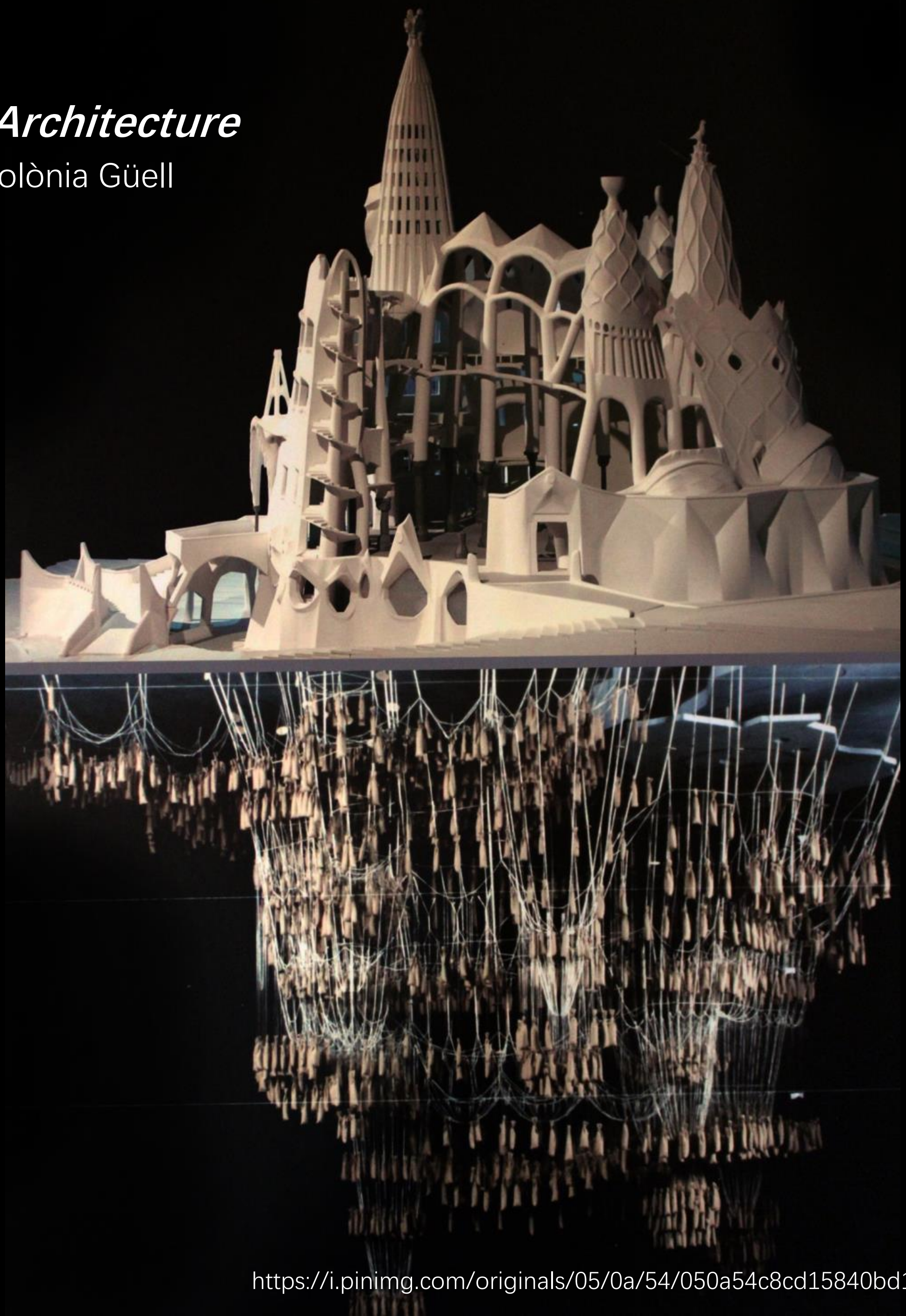
Modeling and Synthesizing Architectural Simulations

Zifeng Guo

Simulations in Architecture

The Church of Colònia Güell

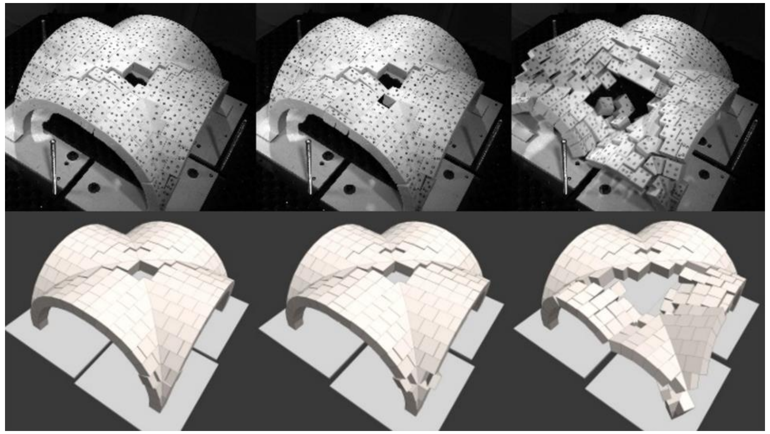
Use a cable system to find the form for an arch system



https://i.pinimg.com/originals/05/0a/54/050a54c8cd15840bd151d5c82b9a8408.jpg

Computer Simulations in Architecture

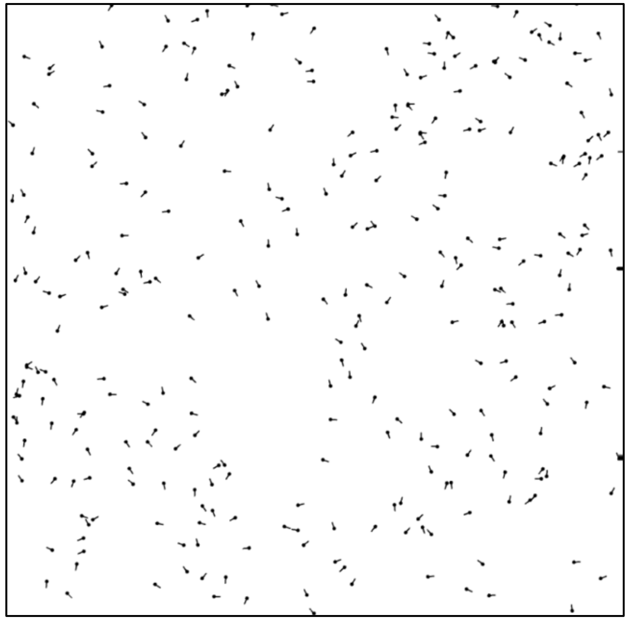
State of the arts



https://ita.arch.ethz.ch/

Obstacles in Computer Simulation

Idealizations regarding the system

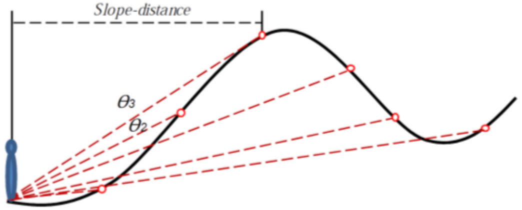


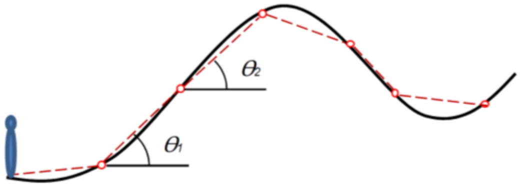
https://www.youtube.com/watch?v=Y-5ffl5_7AI

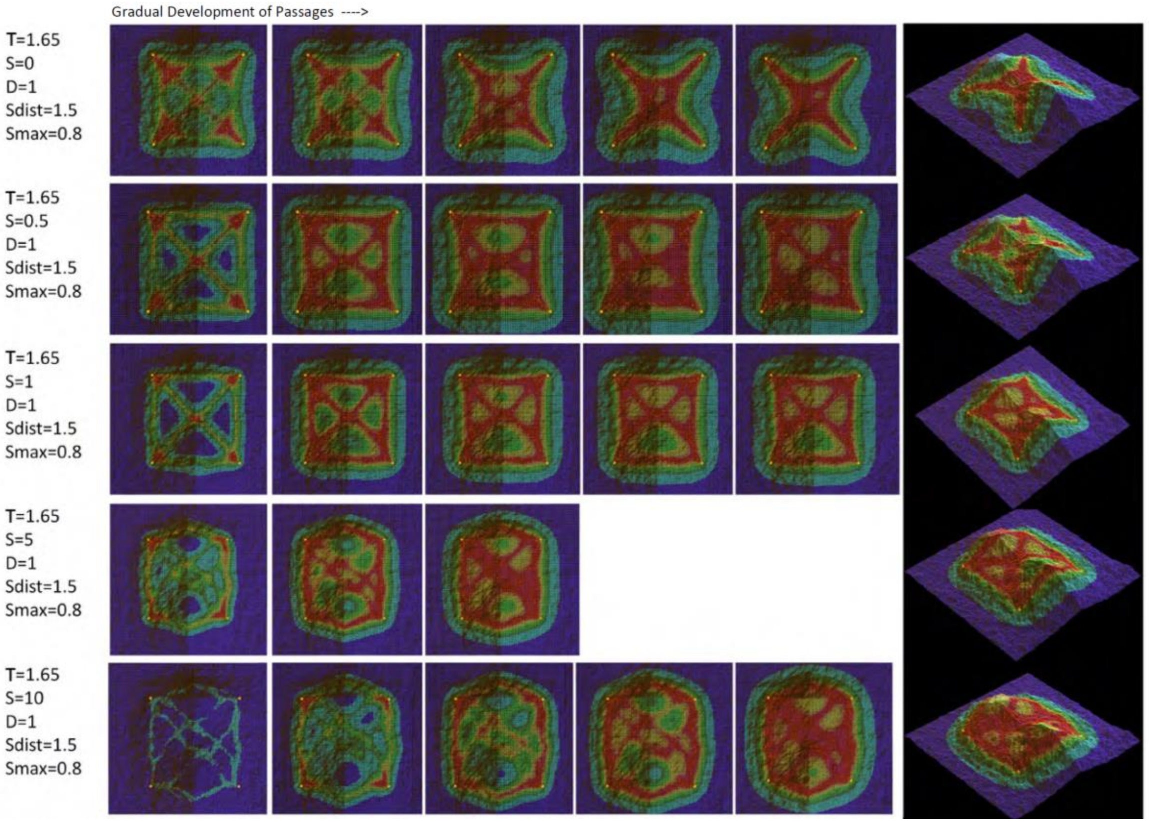
The rules of the system can neither be proved nor disproved

Rule-based Simulation in Design

Agent-based pedestrian simulation



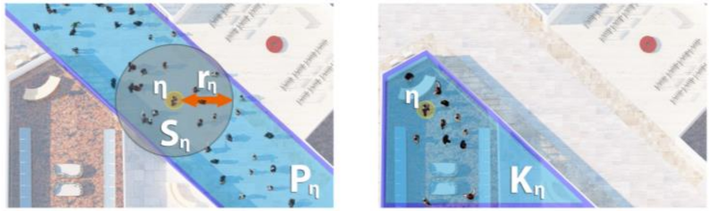




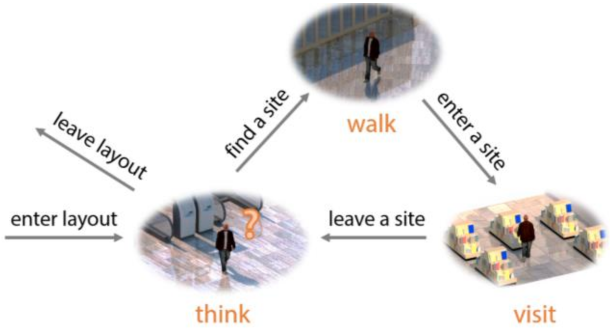
Narahara, T. (2010). Self-organizing Computation A Framework for Generative Approaches to Architectural Design. Harvard University.

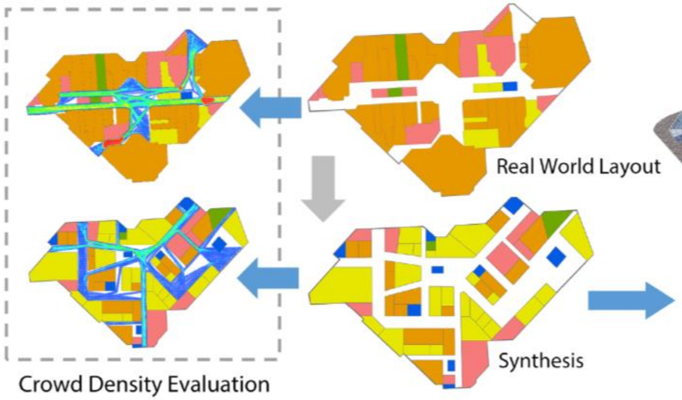
Rule-based Simulation in Design

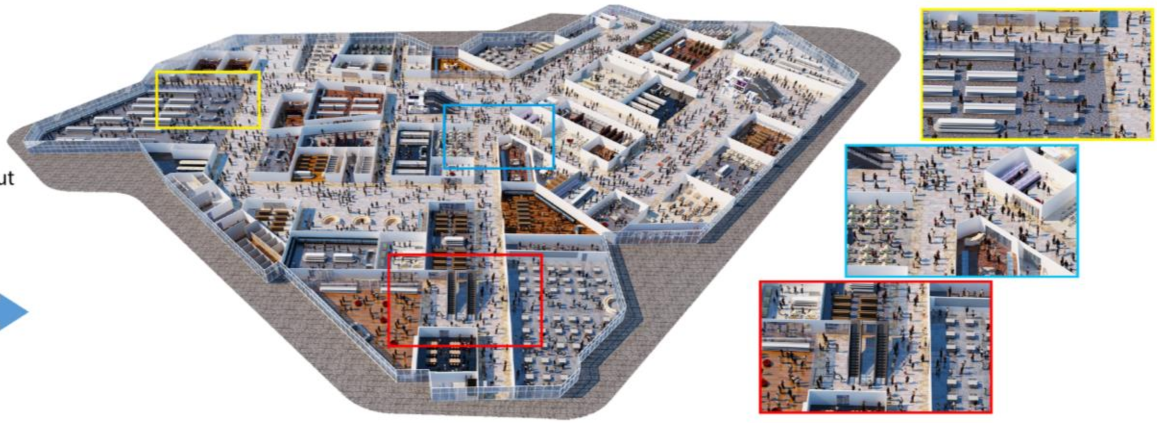
Agent-based pedestrian simulation



(a) *Walking Crowd Density* **(b)** *Visiting Crowd Density*



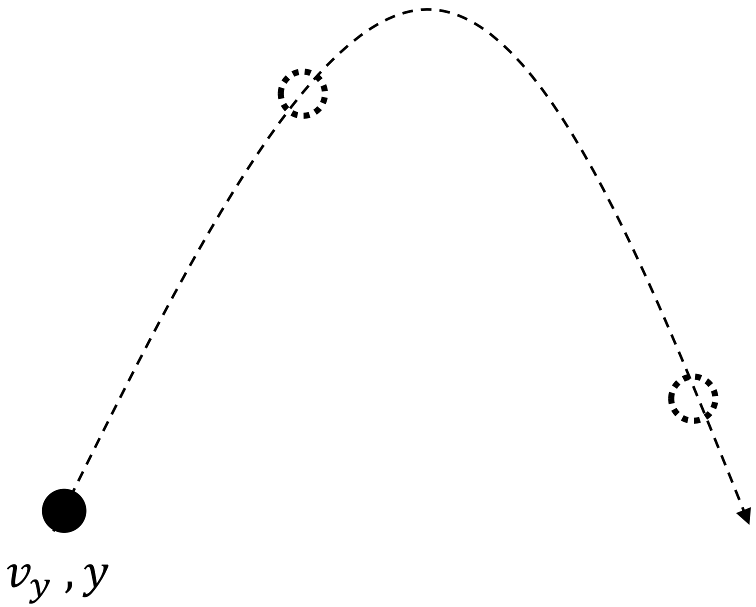




Feng, T., Yu, L. F., Yeung, S. K., Yin, K., & Zhou, K. (2016). Crowd-driven mid-scale layout design. ACM Trans. Graph., 35(4), 132-1.

Obstacles in Computer Simulation

Numerical solution vs. analytical solution



$$y''(t) = -g$$

We observe that the rate of change of speed is a constant

$$y'(t) = -gt + a$$

We then know how speed changes in time

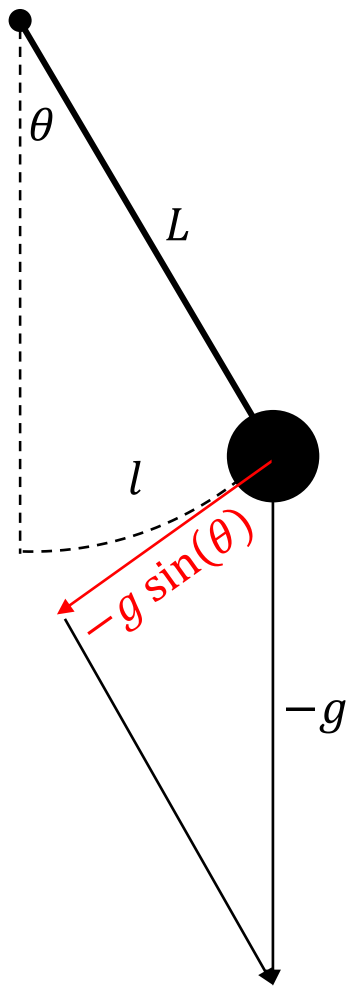
$$y(t) = -\frac{1}{2}gt^2 + at + b$$

We then can calculate the precise positions in time

$$y(t) = -\frac{1}{2}gt^2 + v_0 t + y_0$$

Obstacles in Computer Simulation

Numerical solution vs. analytical solution



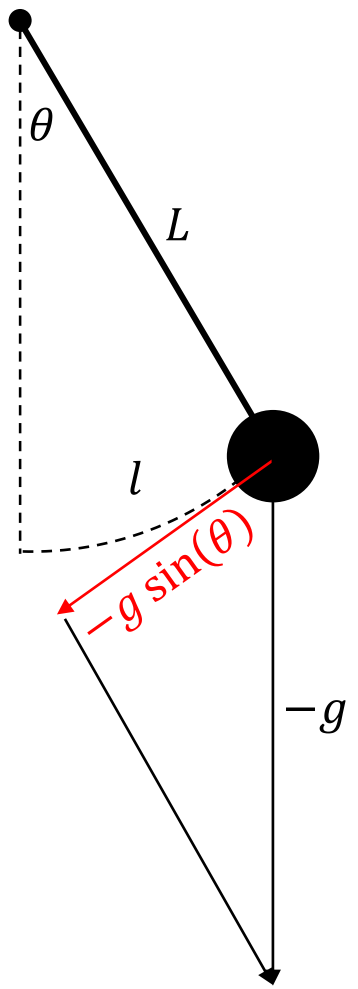
$$l(t) = L\theta(t)$$

$$l''(t) = L\theta''(t)$$

$$l''(t) = -g\sin\big(\theta(t)\big)$$

$$\theta''(t) = -\frac{g}{L}\sin\big(\theta(t)\big)$$

Numerical Integration



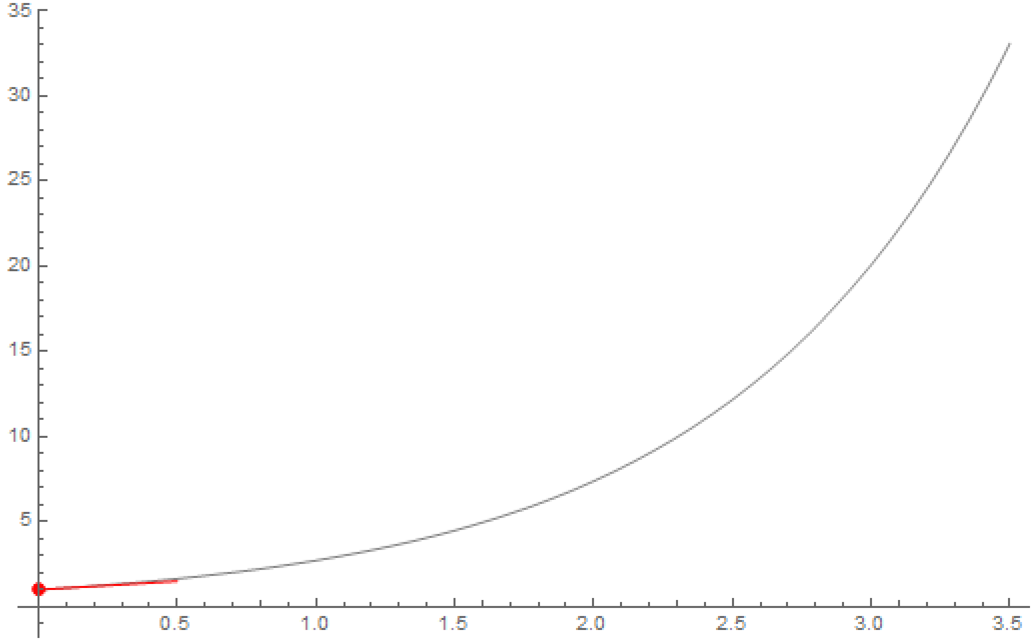
$$\theta''(t) = -\frac{g}{L}\sin\big(\theta(t)\big)$$

$$\theta'(t+\Delta t) = \theta'(t) + \Delta t\theta''(t)$$

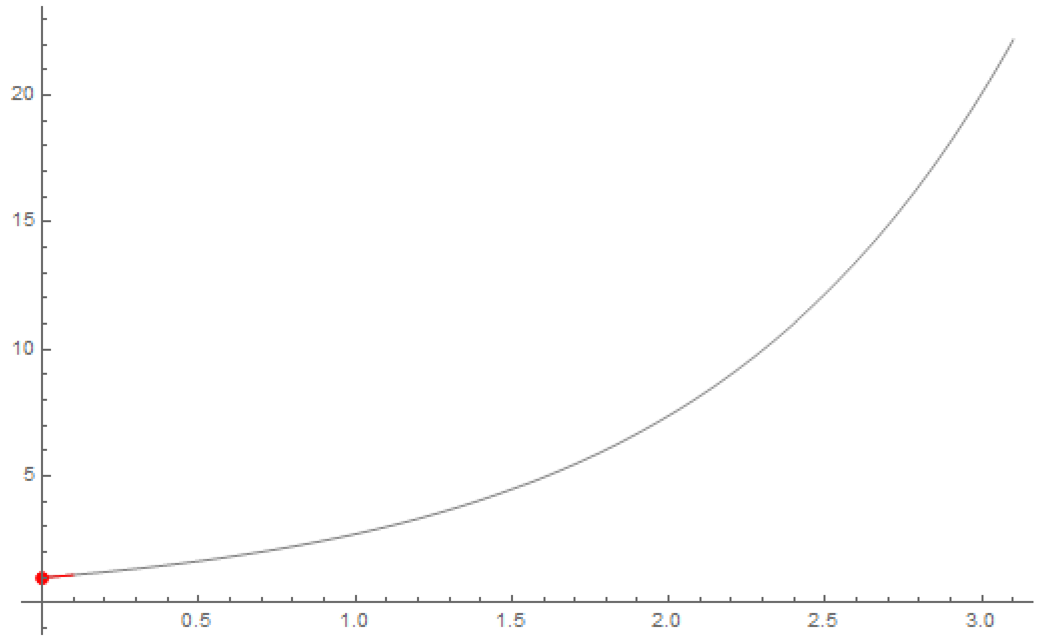
$$\theta(t+\Delta t) = \theta(t) + \Delta t\theta'(t)$$

Numerical Integration

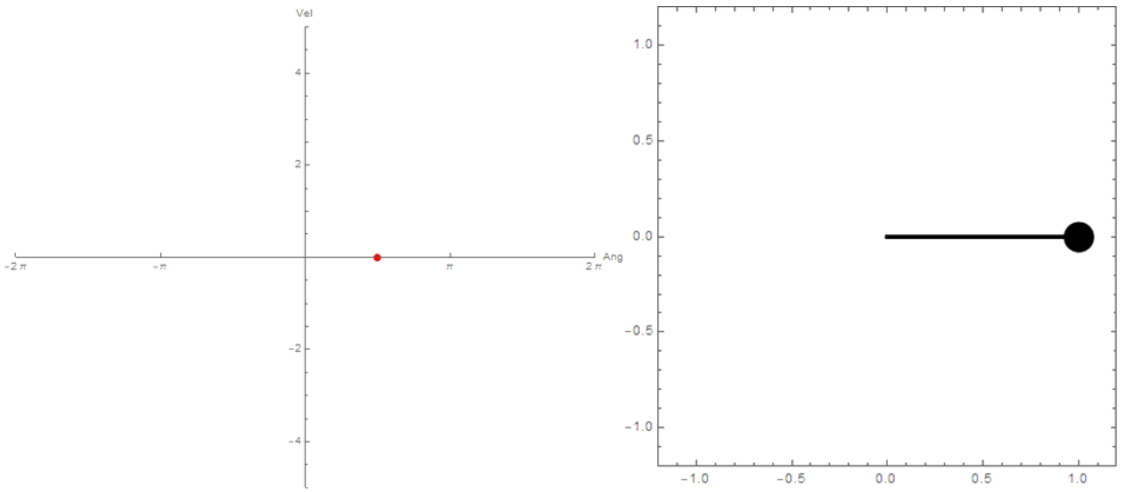
The Exact and Numerical solutions of $y' = y$



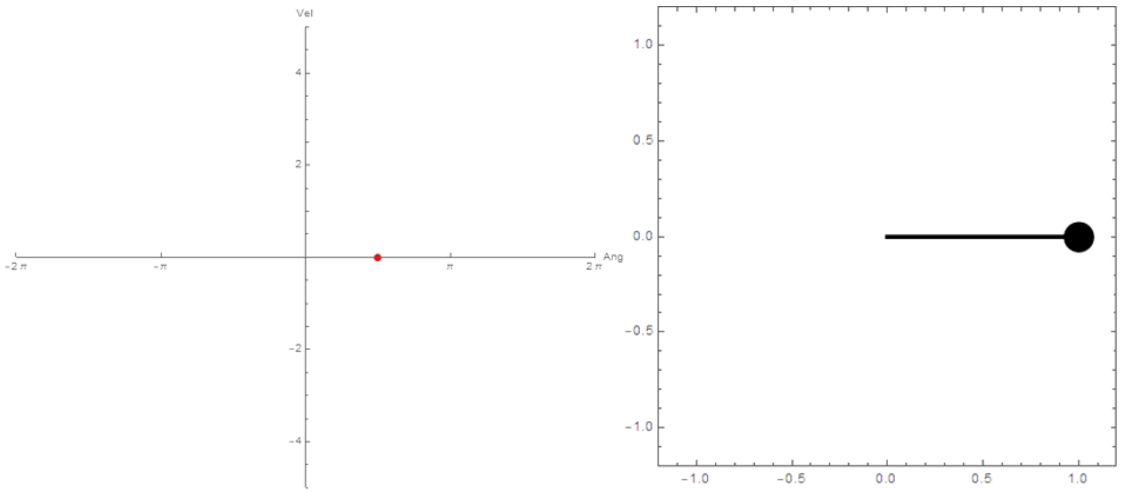
$\Delta t = 0.5$



$\Delta t = 0.1$



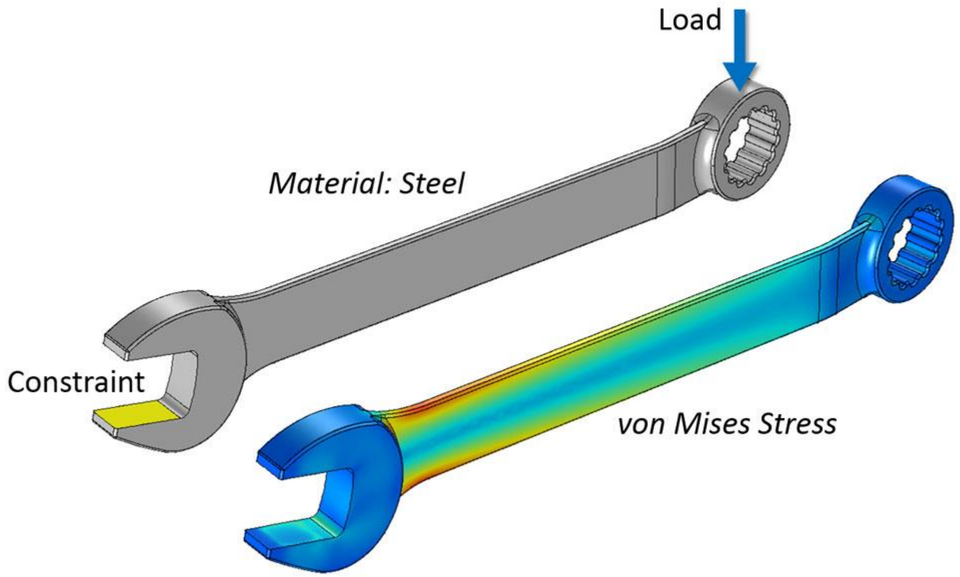
$\Delta t = 0.1$, 120 frames

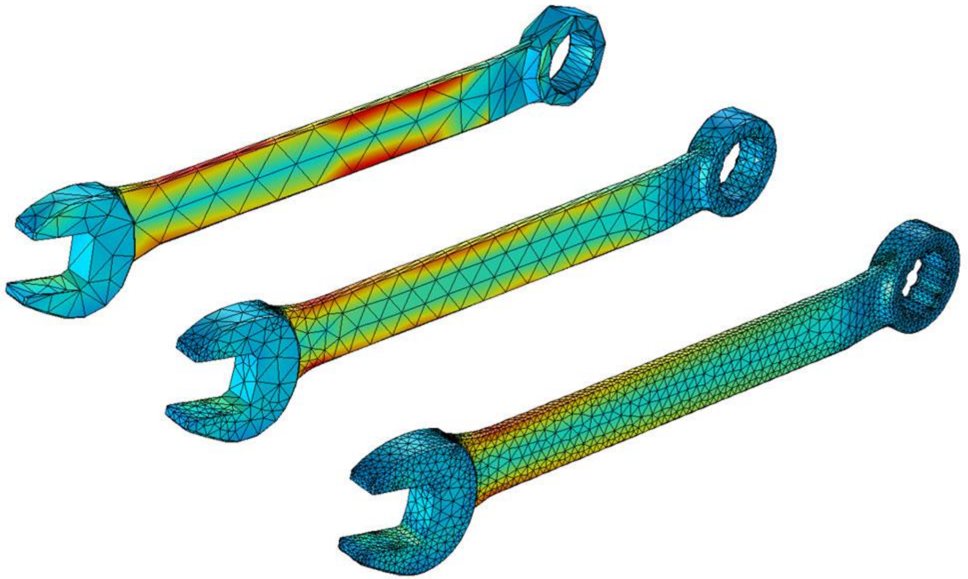


$\Delta t = 0.01$, 1200 frames

The Finite Element Method

Discretization of geometries





https://www.comsol.com/multiphysics/mesh-refinement

Dilemma

Exchange Capacity for Feasibility

Limitations

Huge consumption of computational resources of CPU (speed) and Memory (feasibility)

Too many idealizations for complex phenomena

Despite intensive effort on faster and more powerful simulator, these limitations and not effectively solved

Artificial Intelligence

The same dilemma existed in the history of artificial intelligence (AI)

Symbolic AI

"Good Old-Fashioned Artificial Intelligence"

Logic-based

Knowledge Representation

Combinatory

Theory-driven

"***thinking (intellection) essentially is rational manipulation of mental symbols***"
(Haugeland, 1985)

Sub-symbolic AI

Probabilistic-based

Learning

Approximation

Data-driven

"***representation is the wrong unit of abstraction in building the bulkiest parts of intelligent systems***"
(Brooks, 1991)

Artificial Intelligence

The same dilemma existed in the history of artificial intelligence (AI)

Symbolic AI

The Deep Blue, 1997

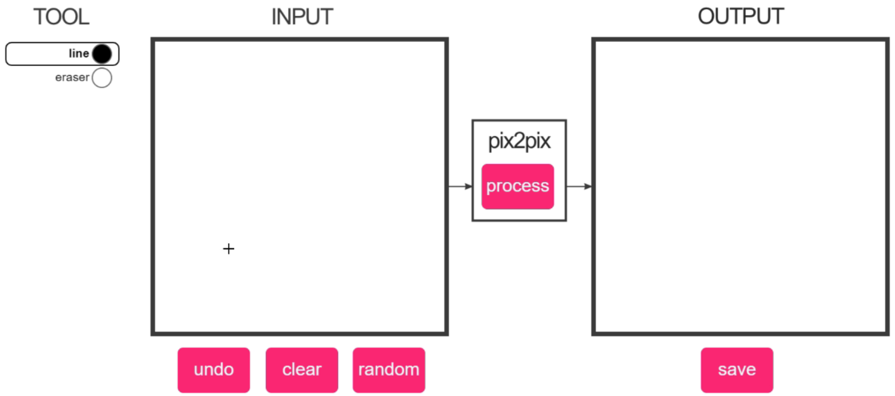
Sub-symbolic AI

The AlphaGo, 2016

Image to Image Translation

From any image to any image

edge2cats



https://affinelayer.com/pixsrv/

semantic segmentation

https://towardsdatascience.com/semantic-segmentation-popular-architectures-dff0a75f39d0

From Simulation to Synthesis?

Any prediction as image to image translation?

Experiment: Topology Optimization

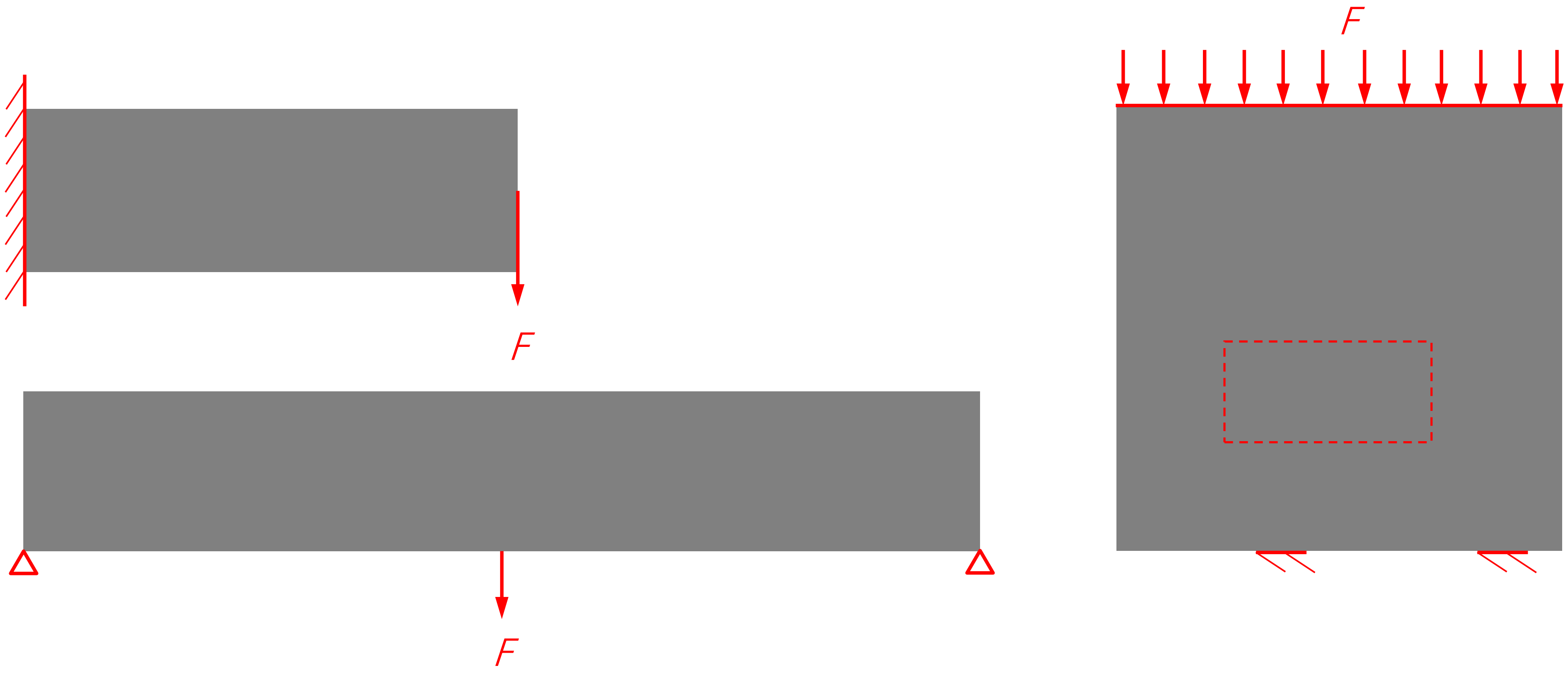
Zifeng Guo
Vahid Moosavi

Topology Optimization

"shape optimization in its most general setting should consist of a determination for every point in space whether there is material in that point or not"

Bendsøe, M. P. (1989). Optimal shape design as a material distribution problem. Structural optimization, 1(4), 193-202.

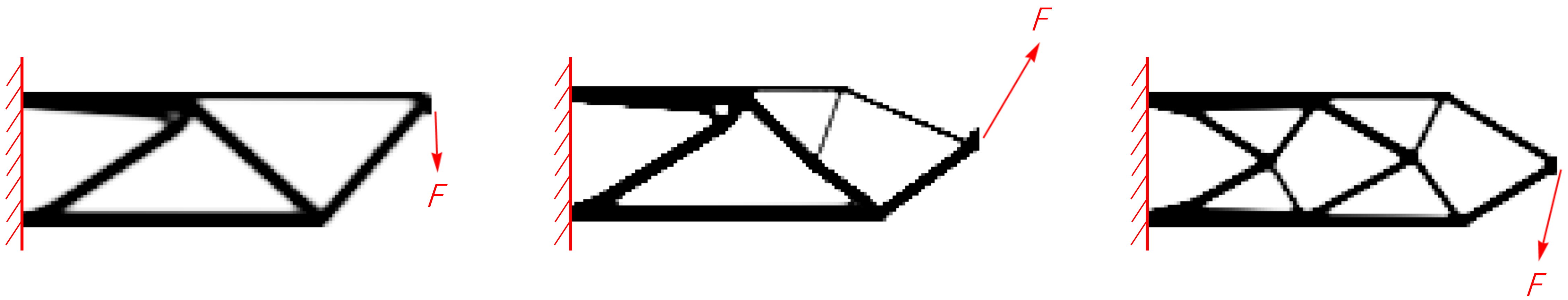
2D Examples

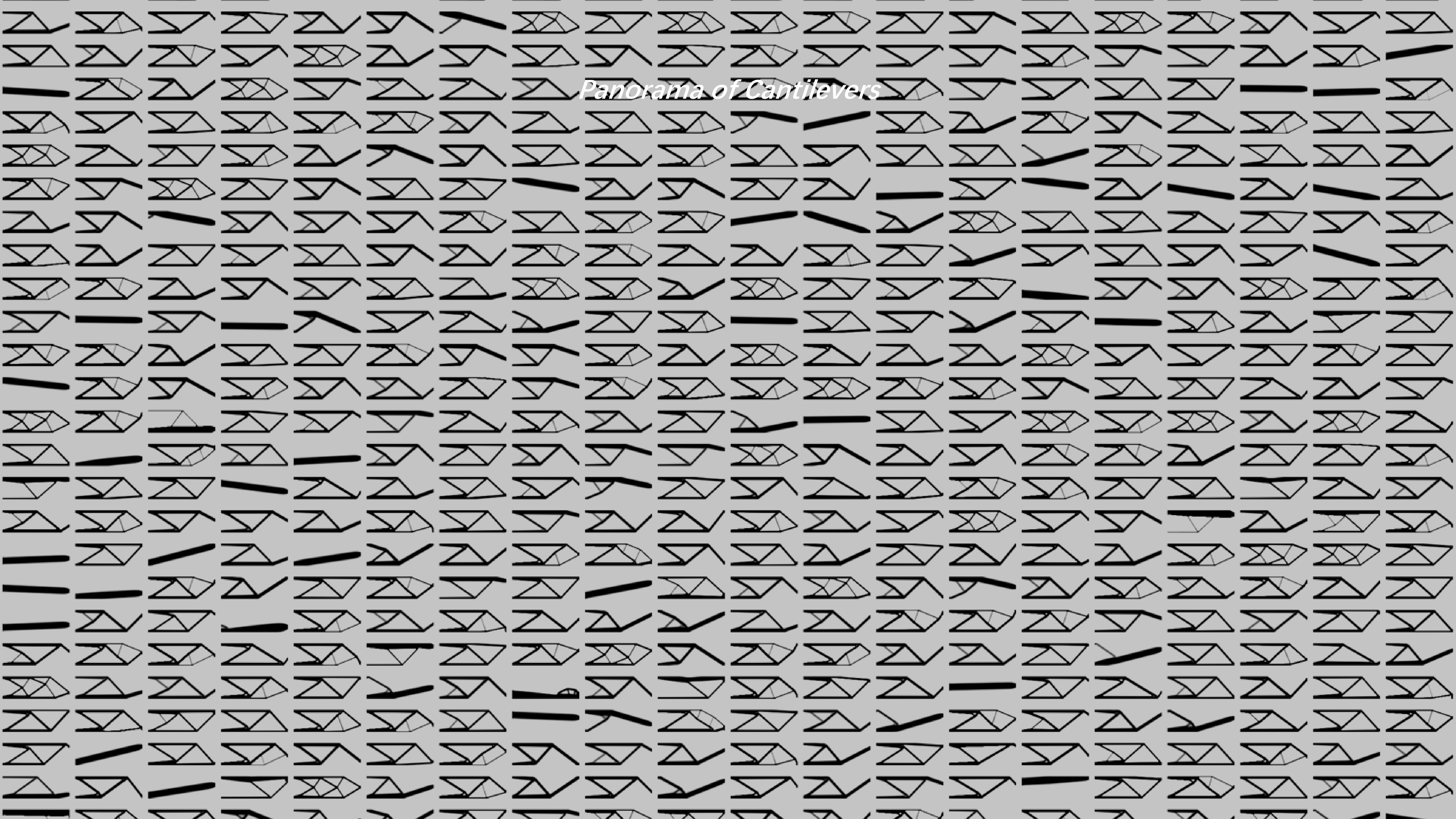


The Smart Slab

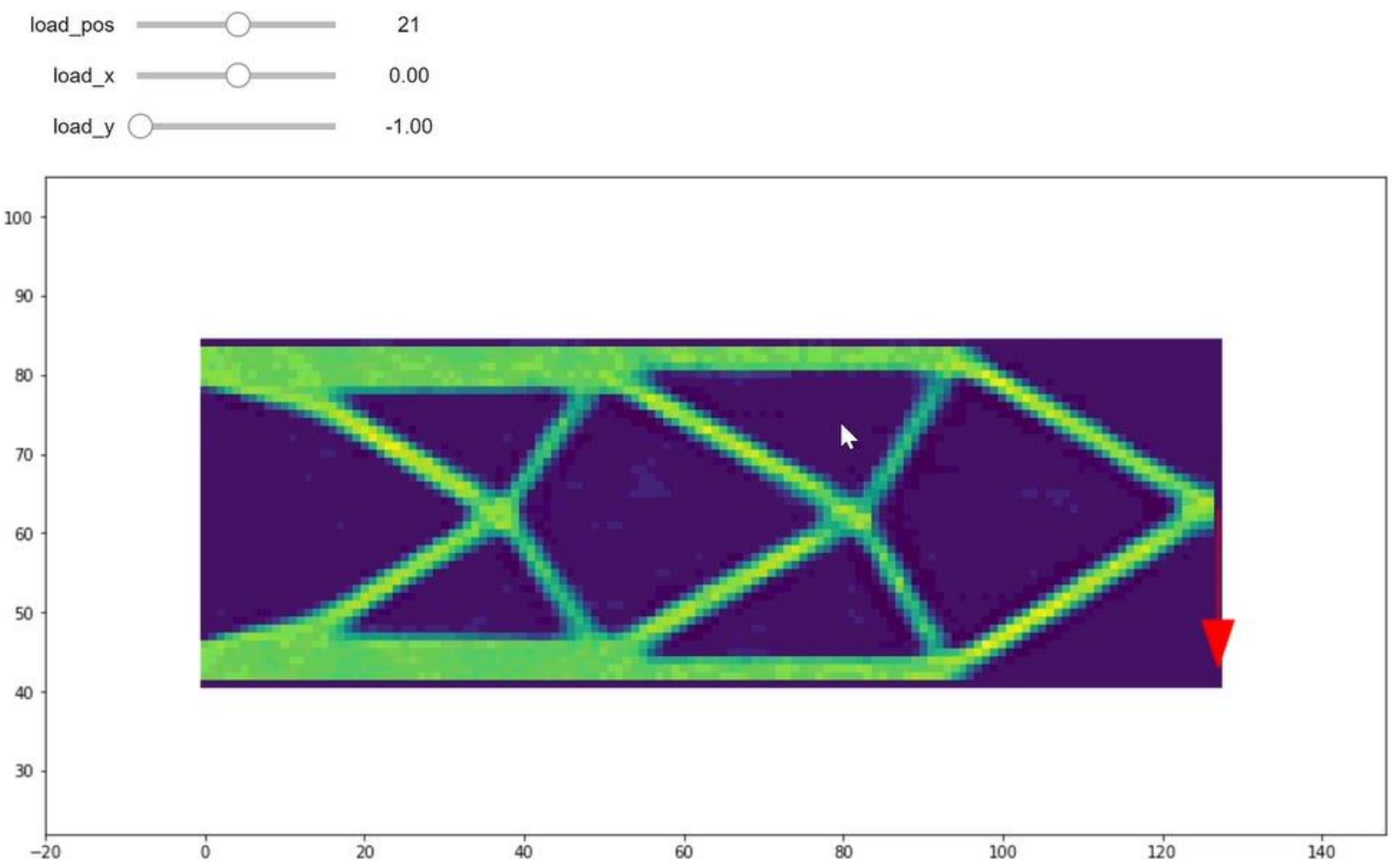
http://dbt.arch.ethz.ch/project/smart-slab/

Experiment: Cantilever

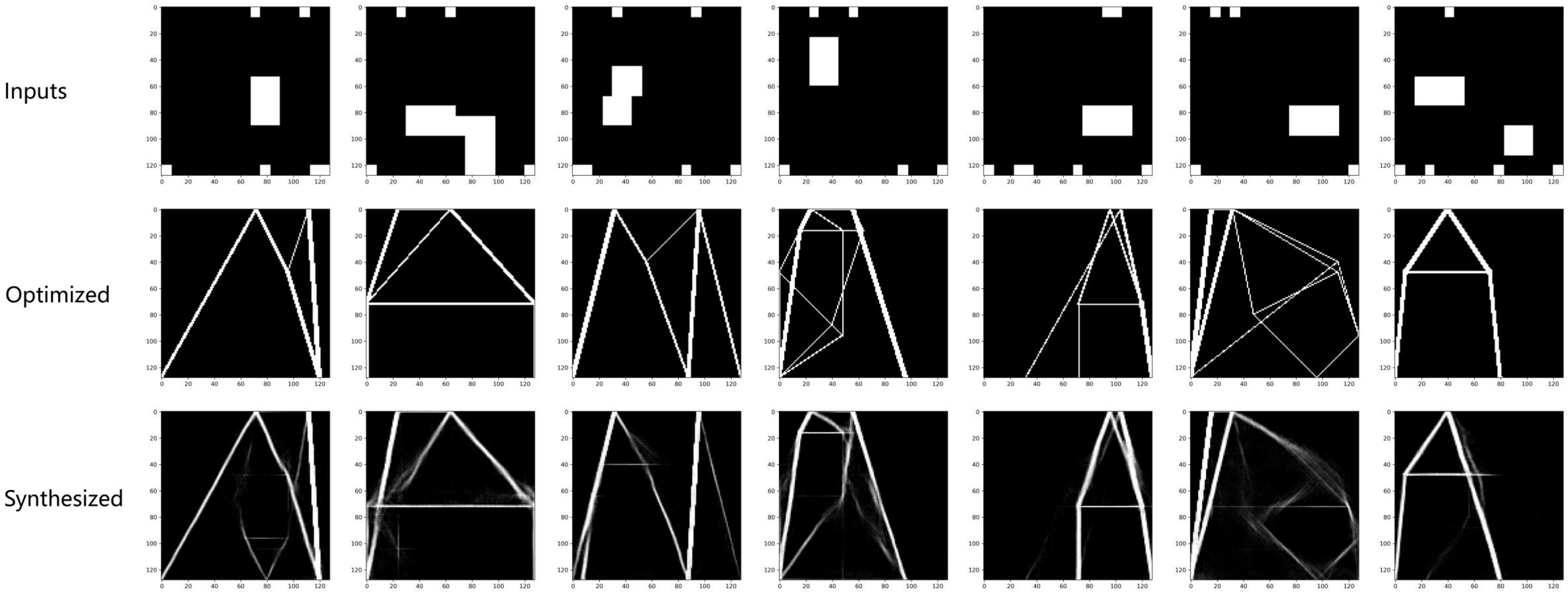


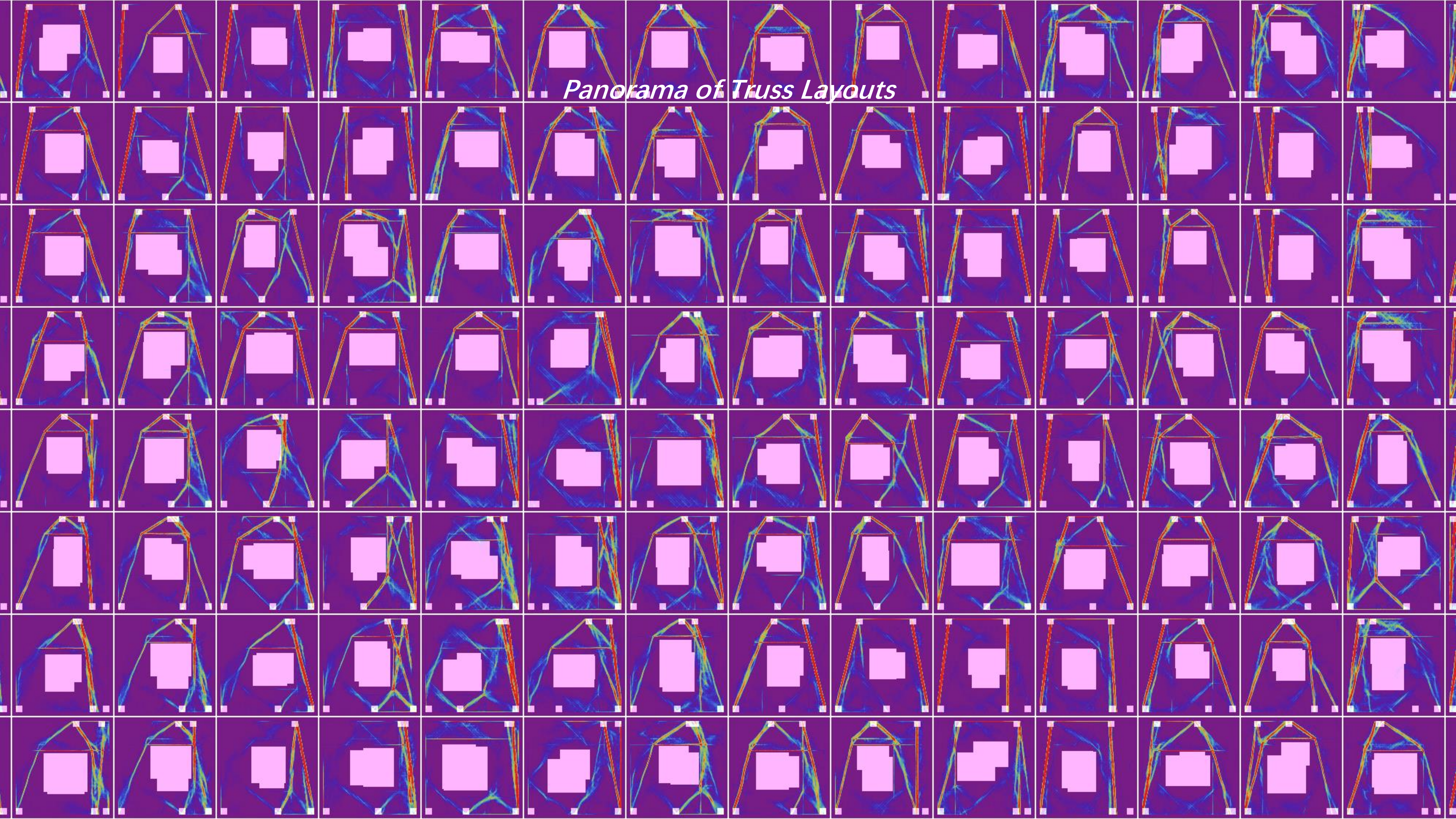

Panorama of Cantilevers

Real-time Prediction



Truss Layout Optimization




Panorama of Truss Layouts

Experiment: Urban Flood Prediction

Zifeng Guo
João Leitão
Nuno Simões
Vahid Moosavi

Flood Simulation

A Dynamic Process

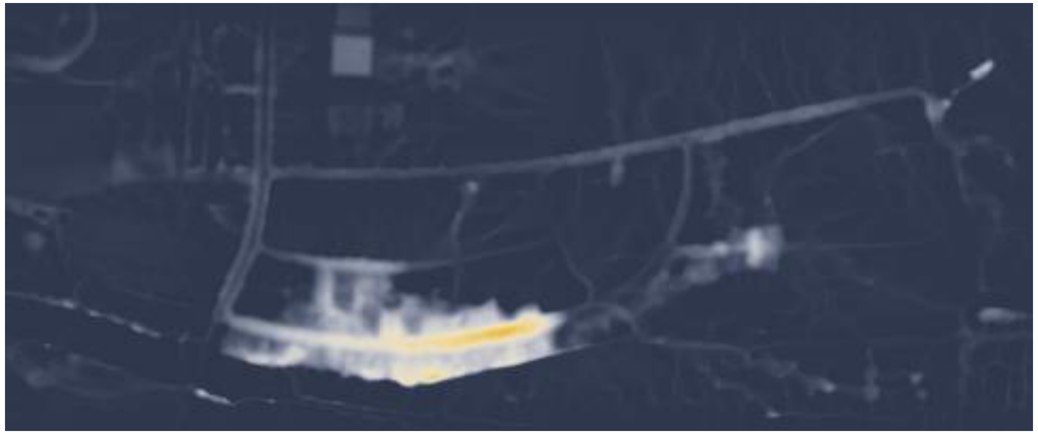
Digital Elevation Model (DEM)

Water Depth

Flood Simulation

Maximum Water Depth

Digital Elevation Model (DEM)



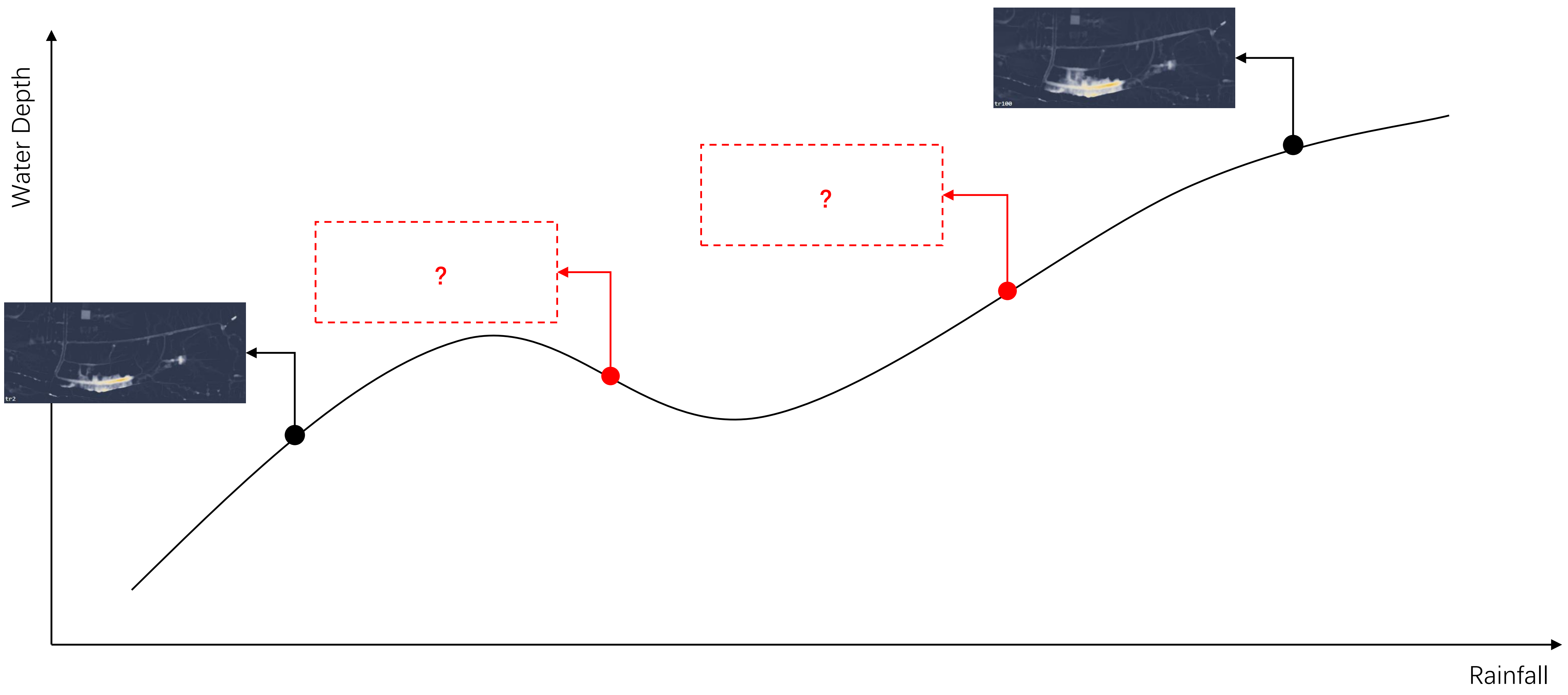
Maximum Water Depth

One

Same Catchment Area with Different Rain Patterns

Areal Sampling

Can we prediction the in-between?



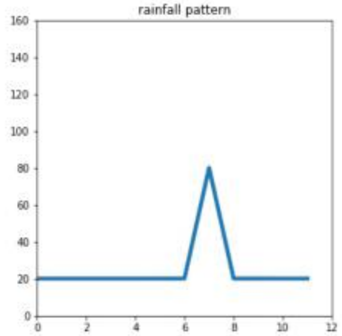
mu 6.00

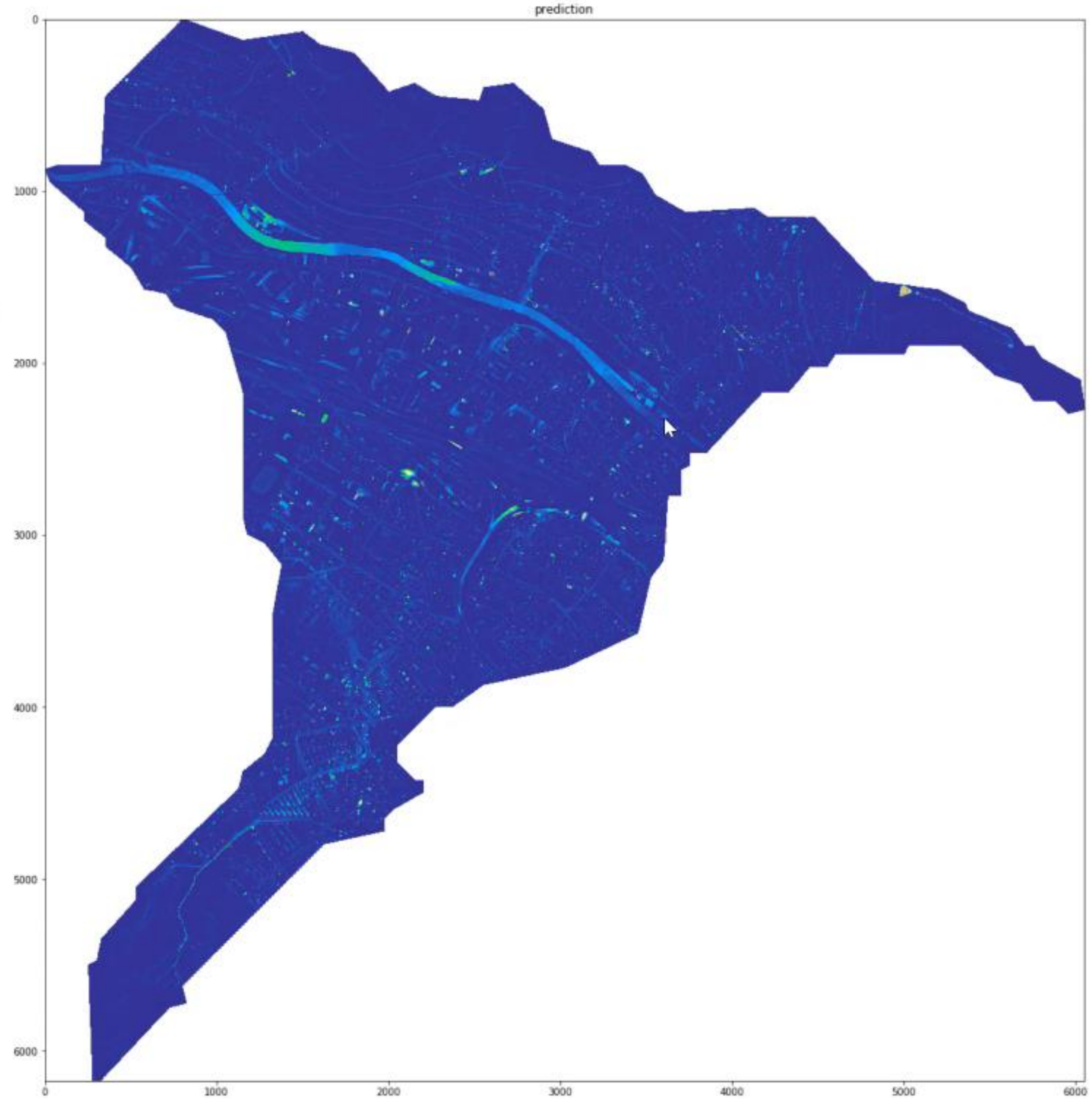
sigma 0.10

minval 20

maxval 80

threshold None





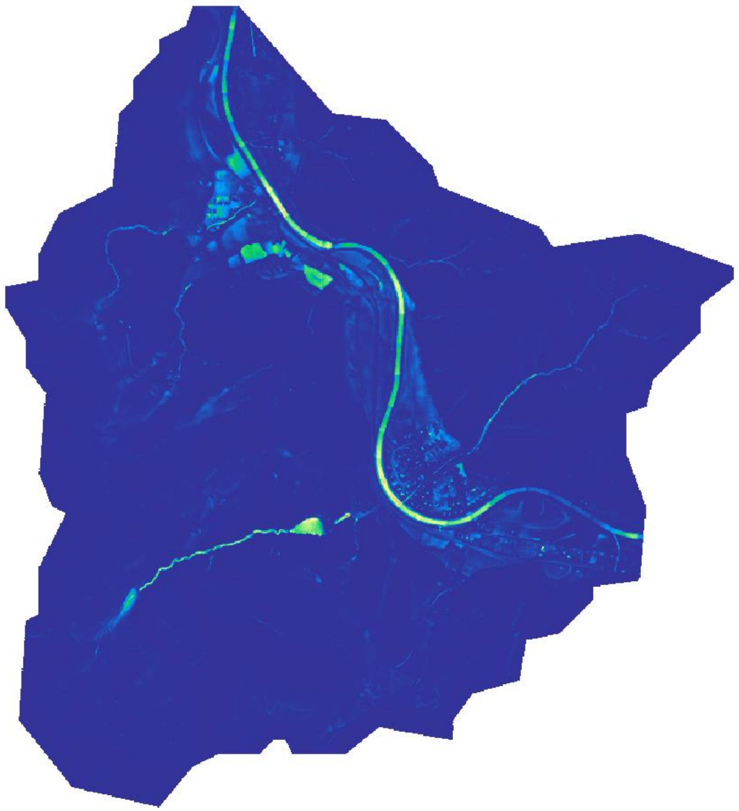
Two

On Different Catchment Areas

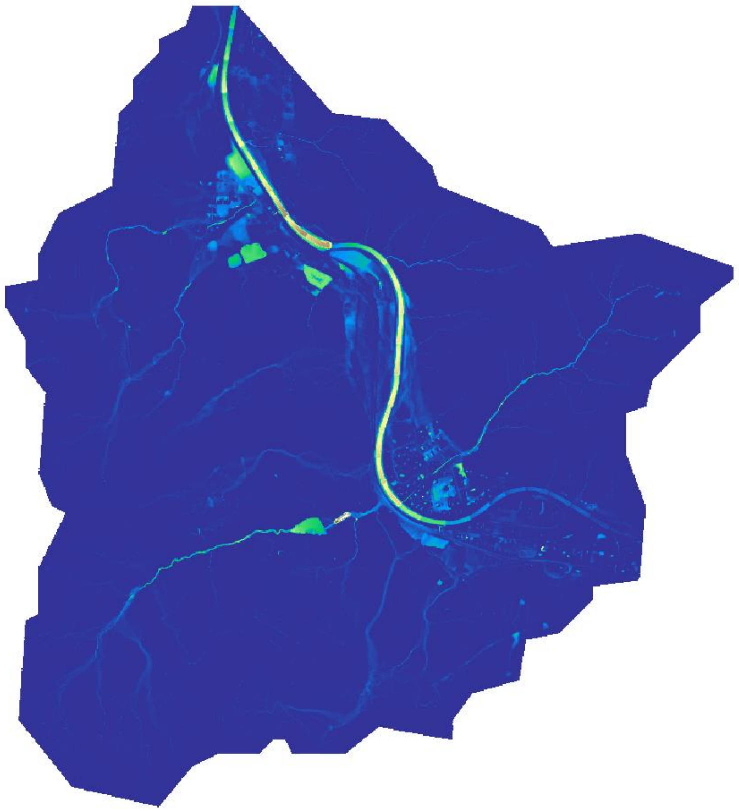

Training Data
All catchment areas

The Prediction Results

Synthesized

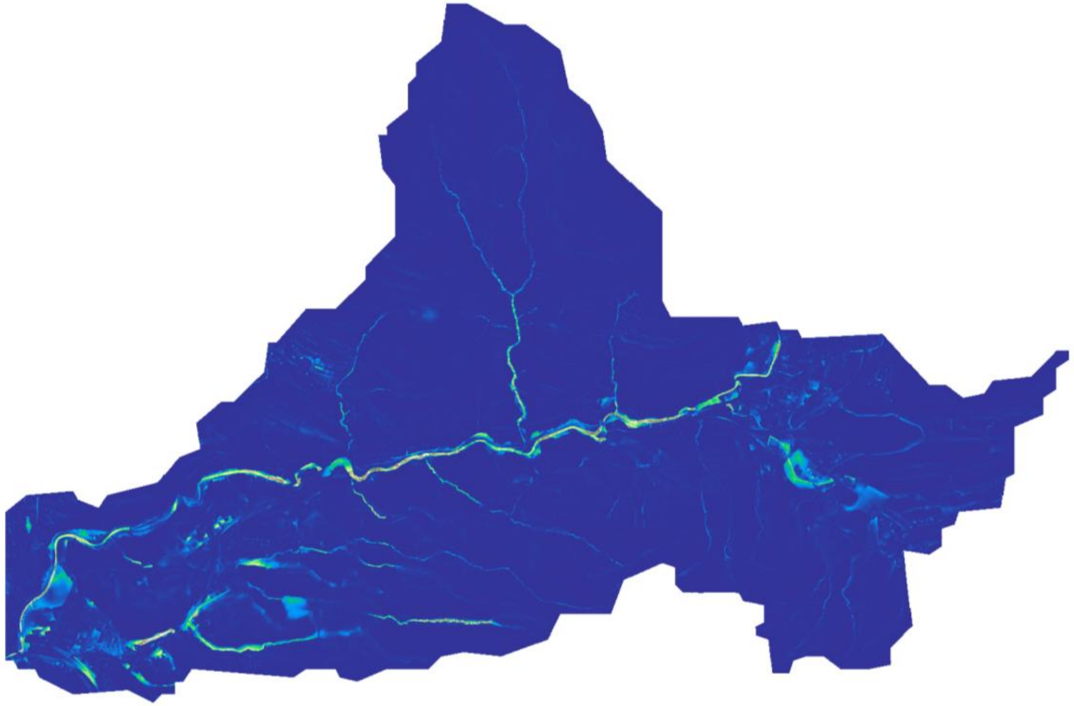


Simulated

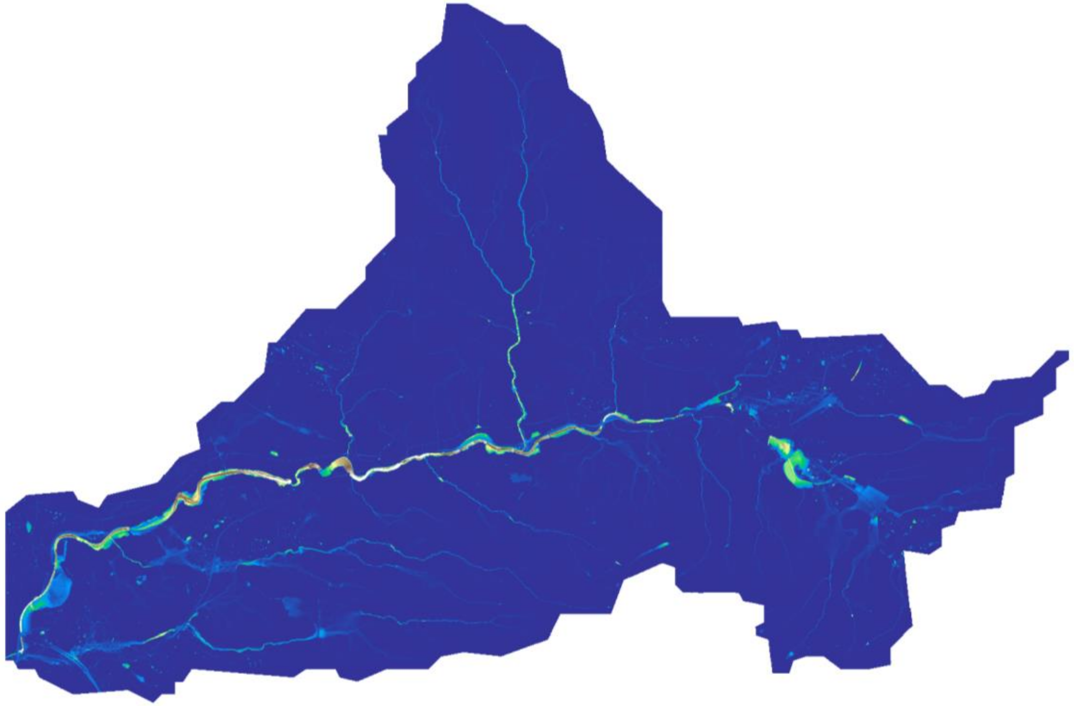


The Prediction Results

Synthesized

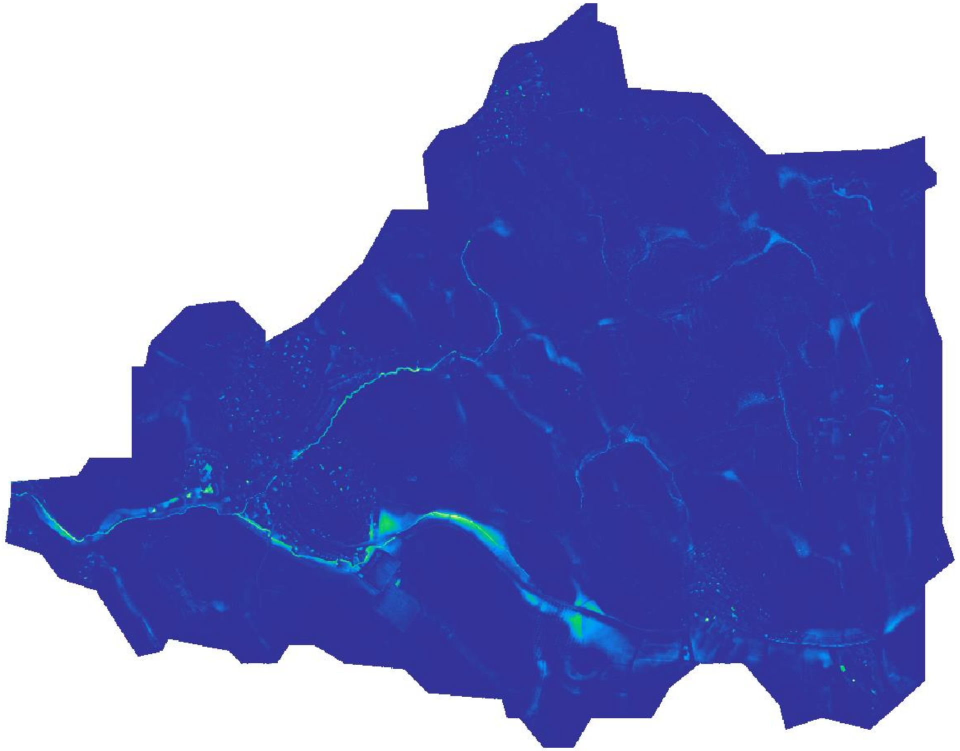


Simulated

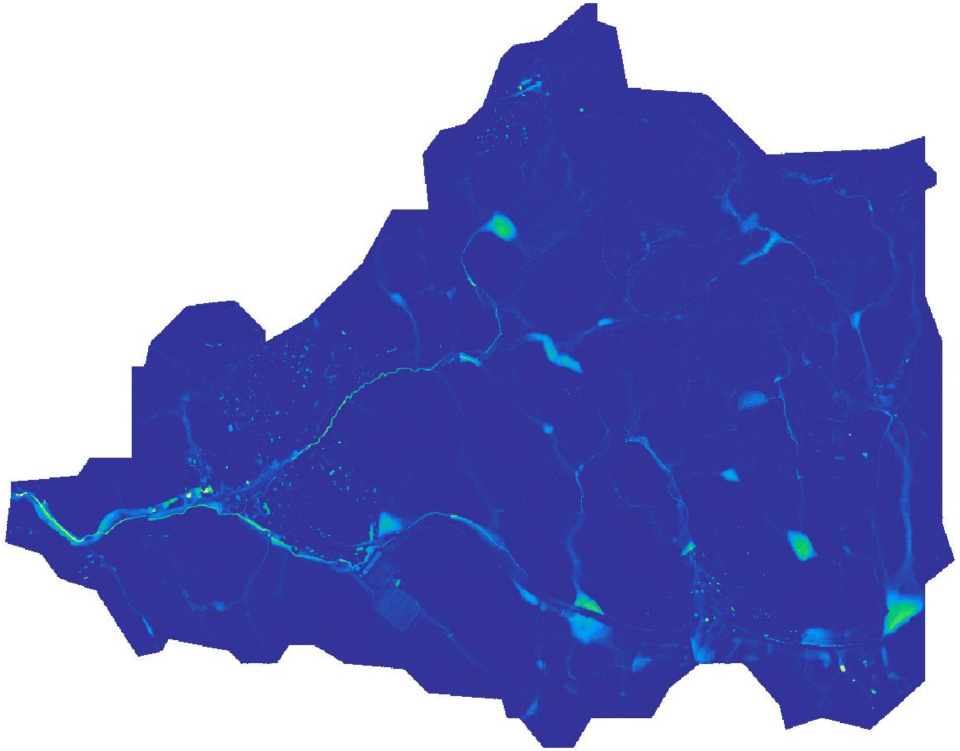


The Prediction Results

Synthesized



Simulated



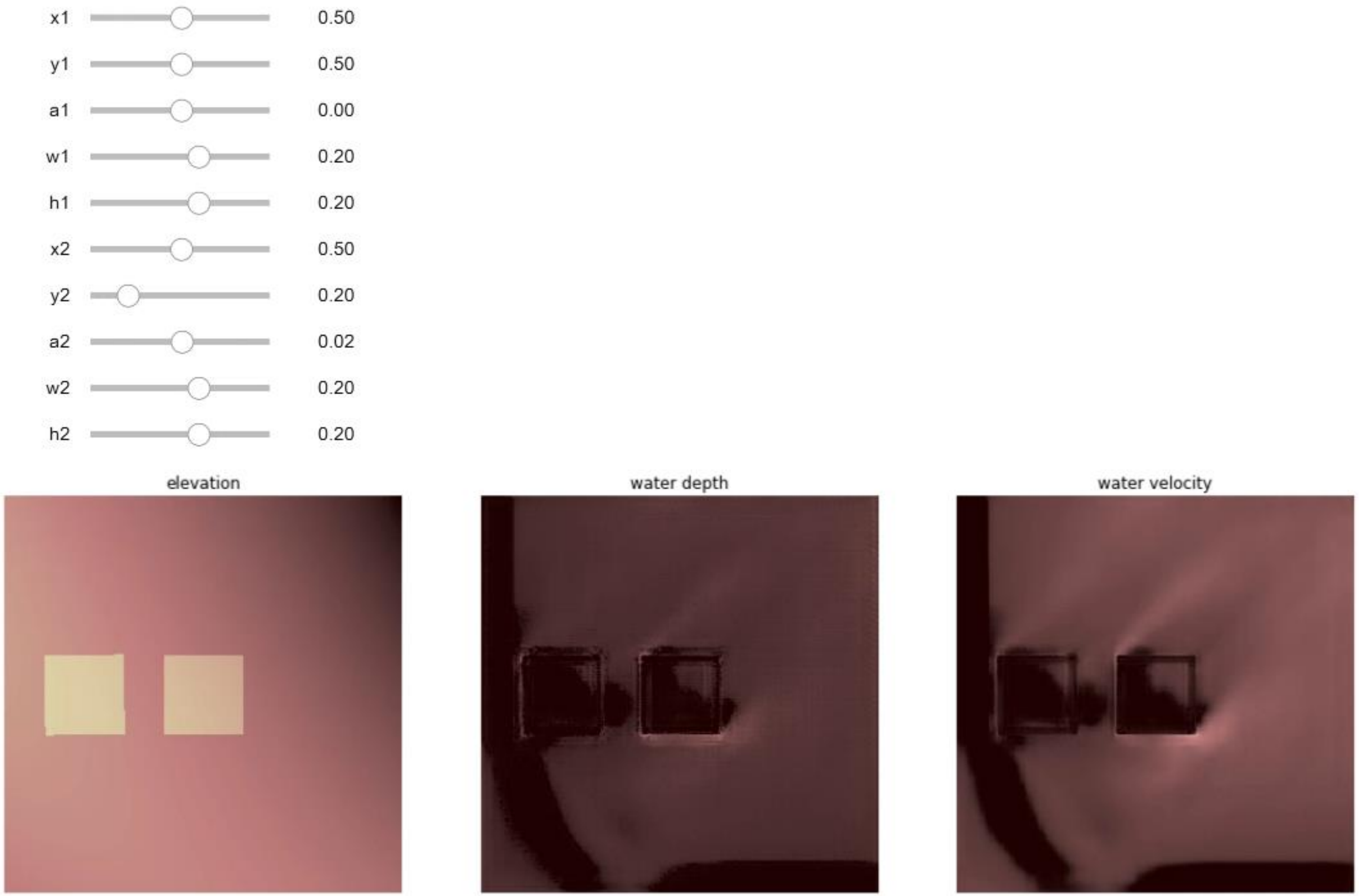
Improvement

4 Hours → 3 Seconds

Three

On Layout Design

Realtime Interactive Predictions



Beyond typologies, beyond optimization

Exploring novel structural forms at the interface of Human and Machine Intelligence

Karla Saldaña Ochoa, Patrick Ole Ohlbrock, Pierluigi D'Acunto, Vahid Moosavi
Eidgenössische Technische Hochschule Zürich (ETH Zurich)

ETH zürich
prof ludger hovestadt
digital architectonics
institute of technology in architecture
DARCH
structural design

- *Introduction*
- *Proposed Technical Framework*
- *Design application*
- *User specific implementations*
- *Conclusion / Outlook*

“Art is solving problems that cannot be formulated before they have been solved. The ***shaping of the question is part of the answer****”*

Piet Hein

1905

"[Structural] art is solving problems which cannot be formulated before they have been solved. The search goes on until a solution is found, which is deemed to be satisfactory. There are always many possible solutions, the search is for the best ***— but there is no best — just more or less good."***

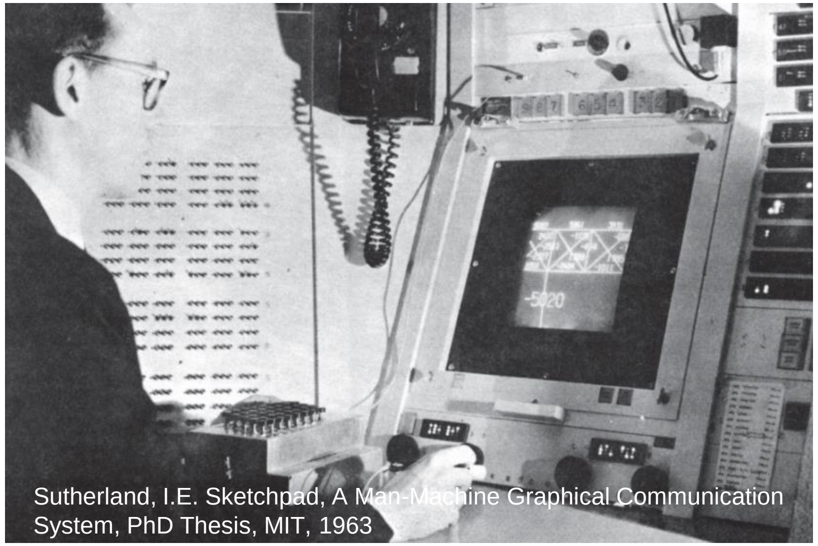
Ove Arup

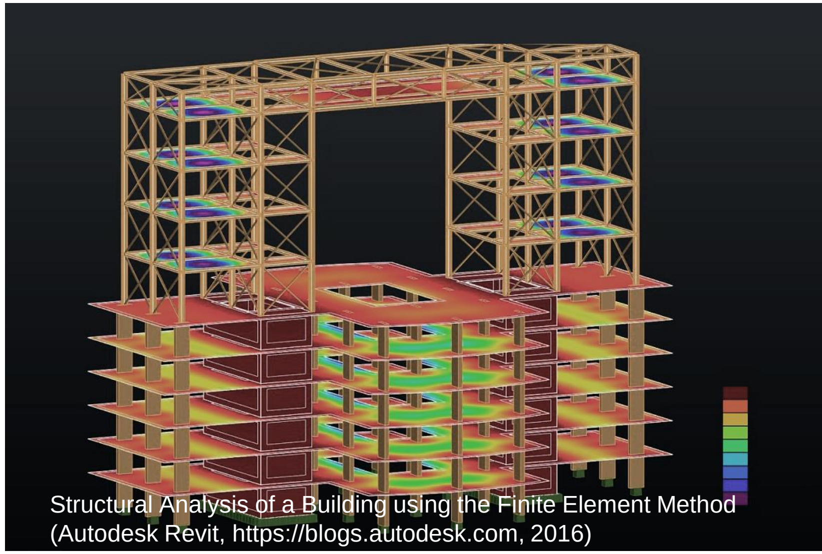
- **Establish a theoretical framework** that allows to **generate** multiple informed forms that go beyond the conventional canon of structural typologies.

- **Create a human-centered design process** to combine the subjective evaluation and selection capacity of humans with the capacity of machines handle large set of quantitative data.

Design Process


Engineers at Inland Steel Building, 1958 (SOM Archive)


Sutherland, I.E. Sketchpad, A Man-Machine Graphical Communication System, PhD Thesis, MIT, 1963

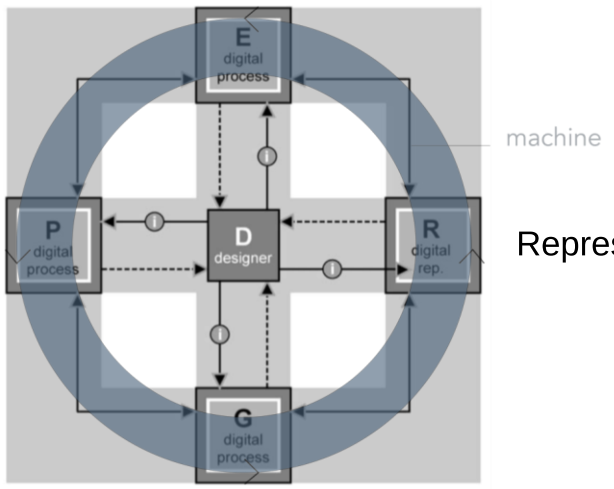

Structural Analysis of a Building using the Finite Element Method (Autodesk Revit, https://blogs.autodesk.com, 2016)

Rivka Oxman, *Theory and design in the first digital age, Design Studies, 27, 3, 2006*

Proposed Technical Framework

Evaluation

Performance



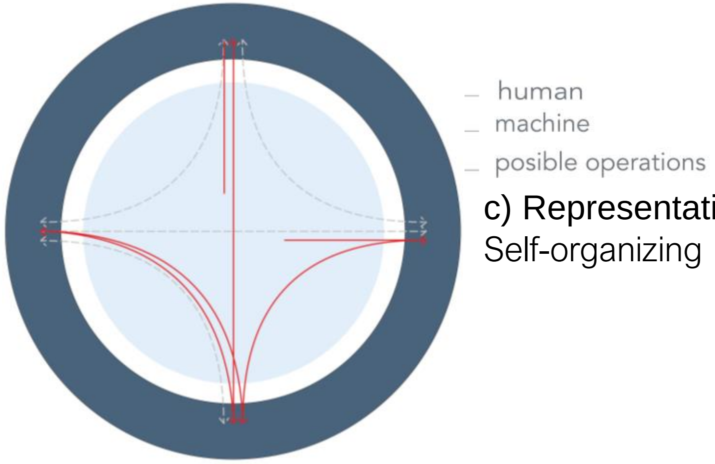
Representation

Generation

- Introduction
- Proposed Technical Framework
- Design application
- User specific implementations
- Conclusion / Outlook

b) Evaluation Quantitative
Higher-order Statistics (HOS)

d) Selection Qualitative
Designer



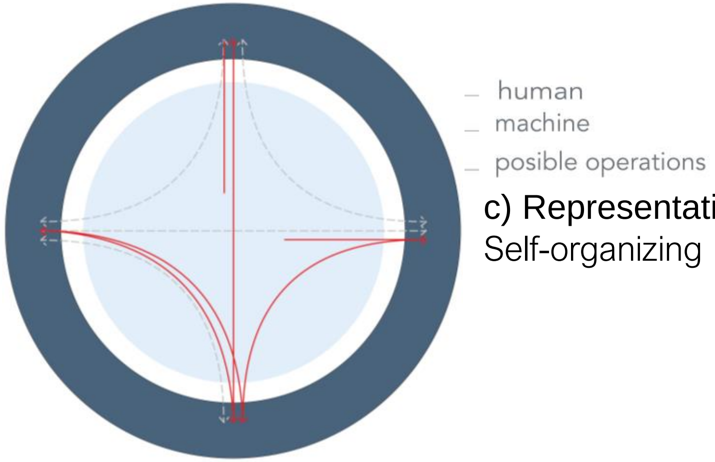
c) Representation/Clustering
Self-organizing Map (SOM)

a)Generation - e) (Re-)Generation
Combinatorial Equilibrium modeling (CEM)
Gradient Boosted Trees (GBT)

Proposed Technical Framework

b) Evaluation Quantitative
Higher-order Statistics (HOS)

d) Selection Qualitative
Designer



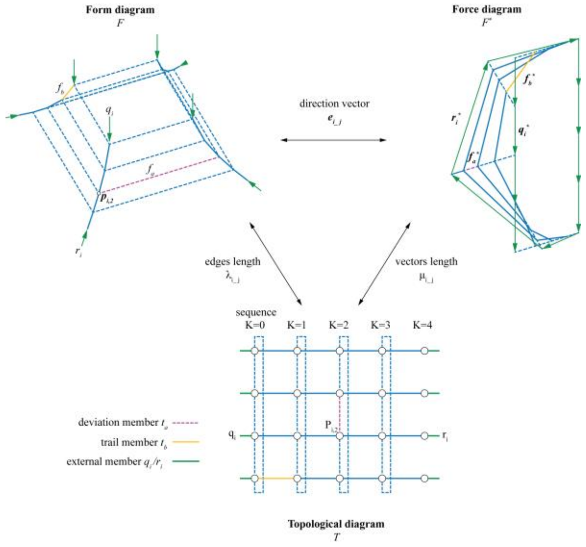
c) Representation/Clustering
Self-organizing Map (SOM)

a)Generation - e) (Re-)Generation
Combinatorial Equilibrium modeling (CEM)
Gradient Boosted Trees (GBT)

a) Generation

Combinatorial Equilibrium Modelling

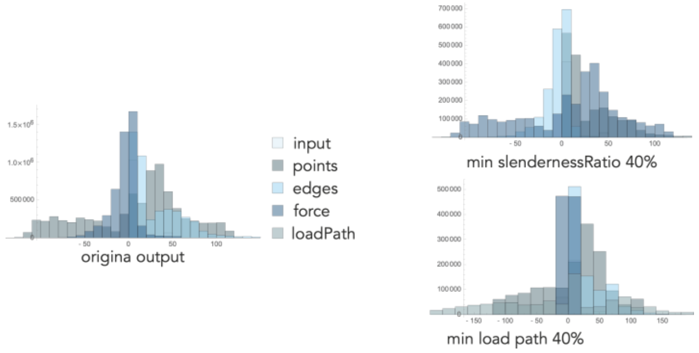
Combinatorial Equilibrium Modelling (CEM), is a method for the design of spatial networks in equilibrium that is based on graphic statics.



b) Quantitative Evaluation and Filtering

Objective Functions

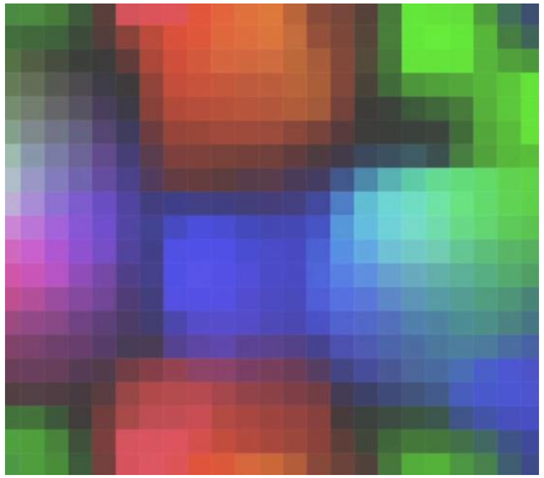
In order to reduce the number of possible solutions, additional quantitative and qualitative aspects can be taken into account. Quantitative criteria addressed through filters and objective functions



c) Representation / Clustering

Higher Order Statistics andSelf organizing Maps

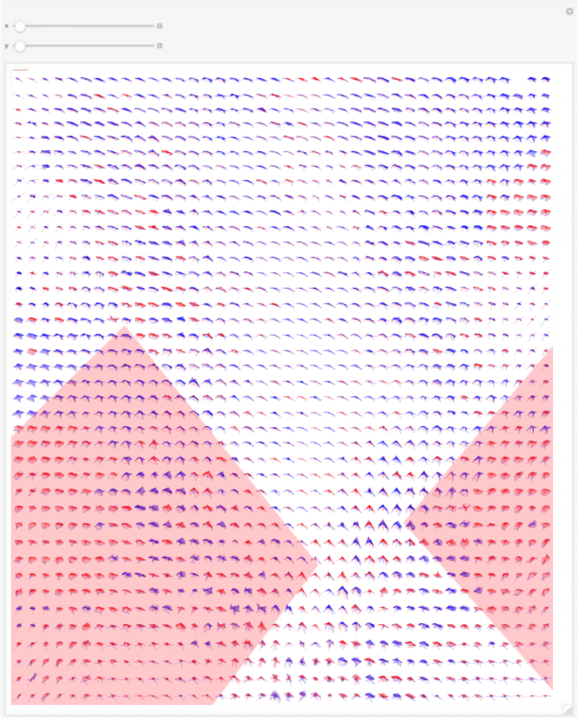
This is an algorithm that learn to classify data without supervision.
It start with a initial distribution of random weights, and over many iterations, the SOM eventually settles into a map of stable zones all cluster

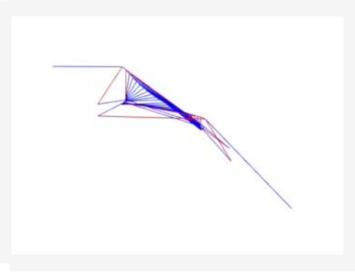


d) Qualitative Evaluation and Selection

Formal characteristics

Based on the 2D grid SOM, the designer can not only get a fast and precise overview of possible solutions but also use this map to give feedback by distinguishing between preferred and non-preferred proposals.

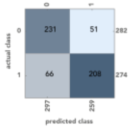
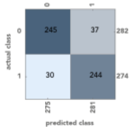
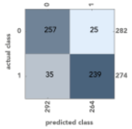




e) Re-Generation

Gradient boosting trees /CEM

In order to reduce the number of possible solutions, additional quantitative and qualitative aspects can be taken into account. Quantitative criteria addressed through filters and objective functions

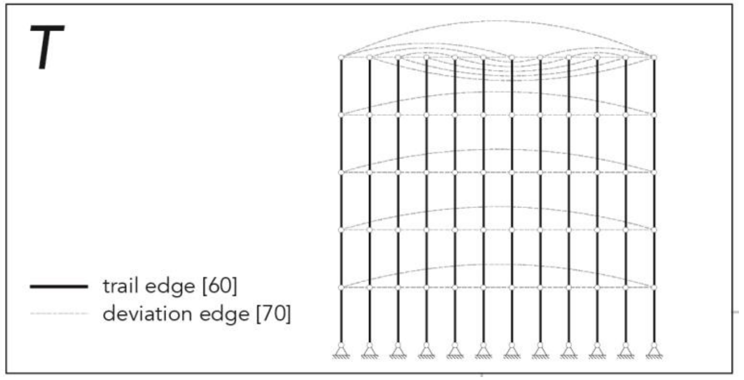
Classifiers	Accuracy	Precision	Confusion Matrix
DecisionTree	0.7904335	0 -> 0.777778 1 -> 0.803089	
Logistic Regression	0.879618	0 -> 0.890909 1 -> 0.868327	
Random Forest	0.89272	0 -> 0.880137 1 -> 0.905303	
Gradient Boosted Trees	0.920364	0 -> 0.9140625 1 -> 0.9266666	

- *Introduction*
- *Proposed Technical Framework*
- *Design application*
- *User specific implementations*
- *Conclusion / Outlook*

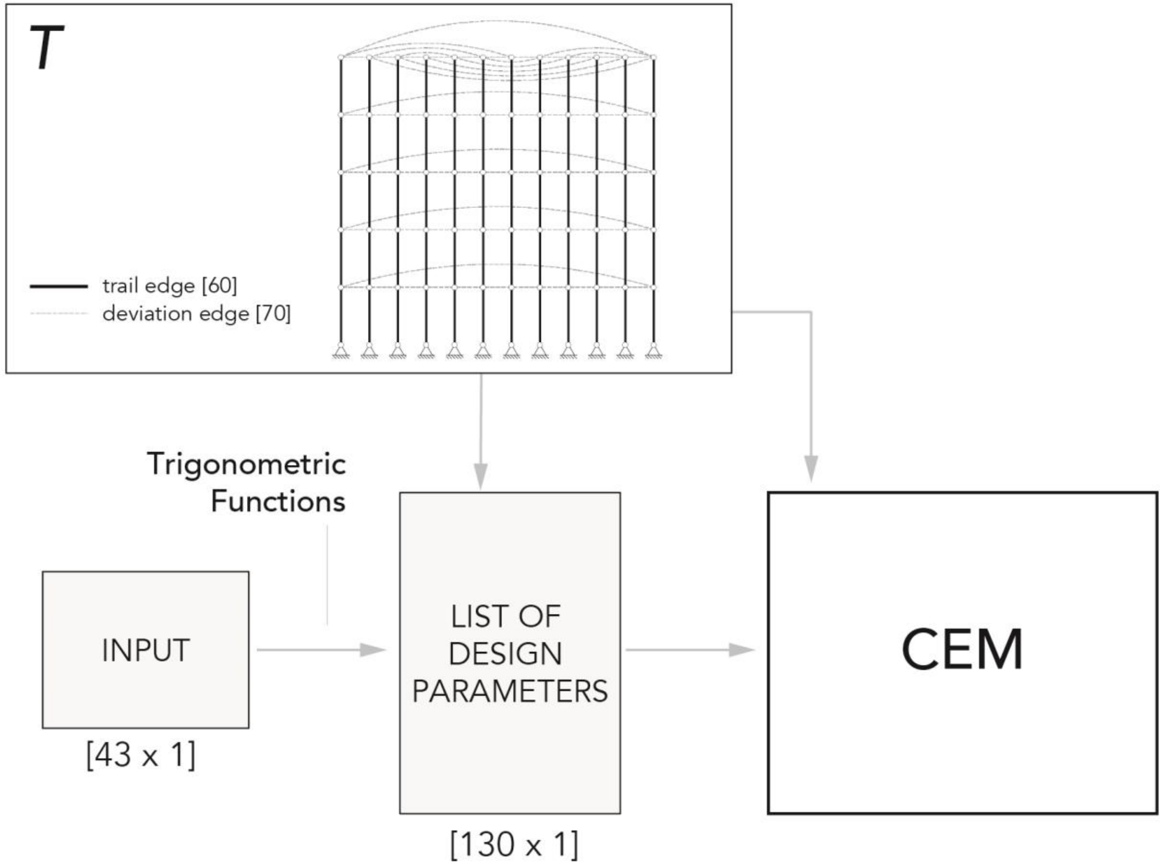
Application

Ullevi Stadium, Goteborg

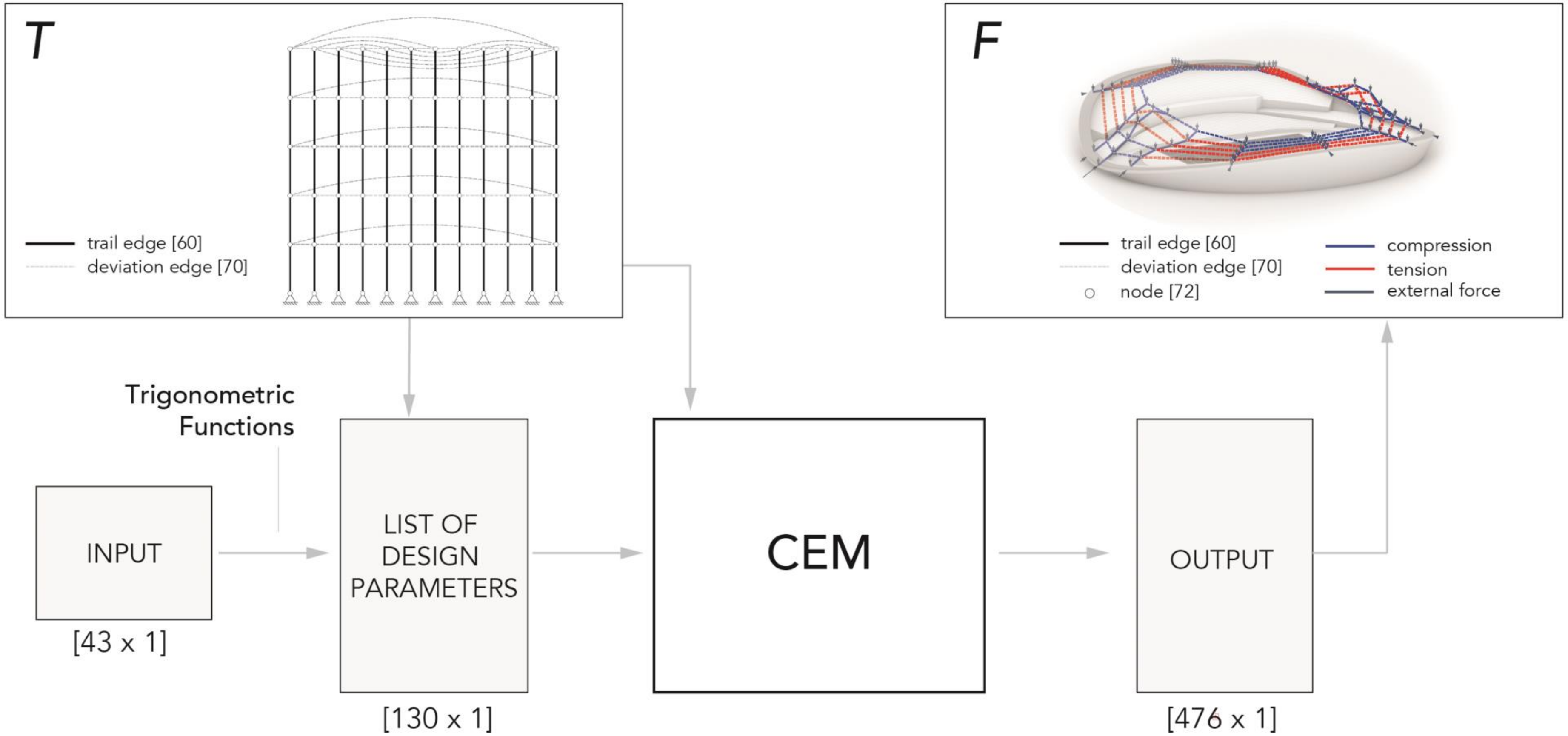
a) Generation



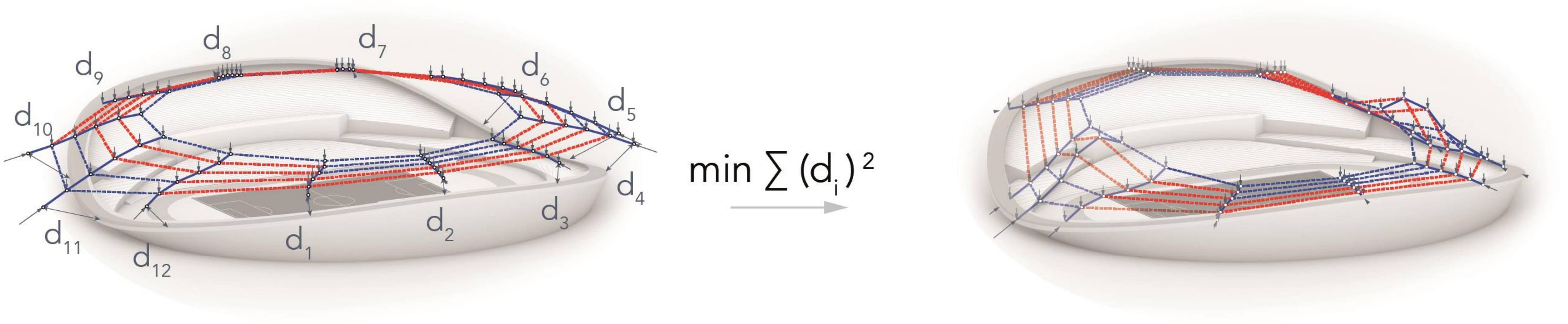
a) Generation



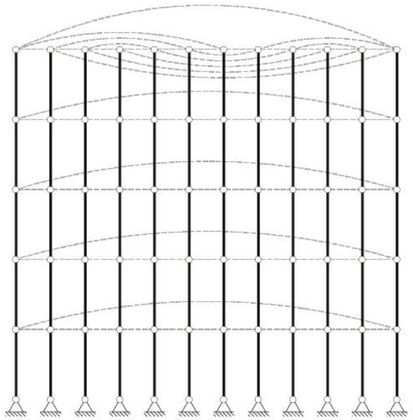
a) Generation



a) Generation



a) Generation



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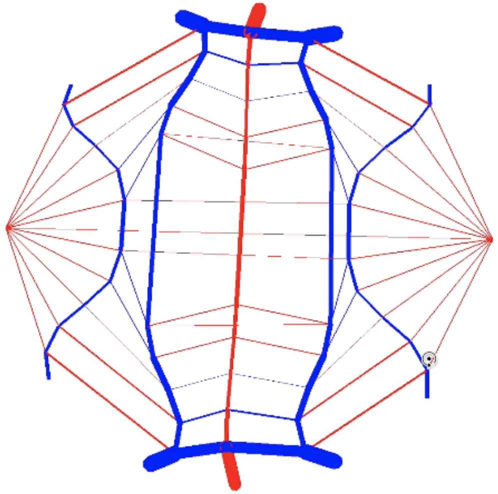

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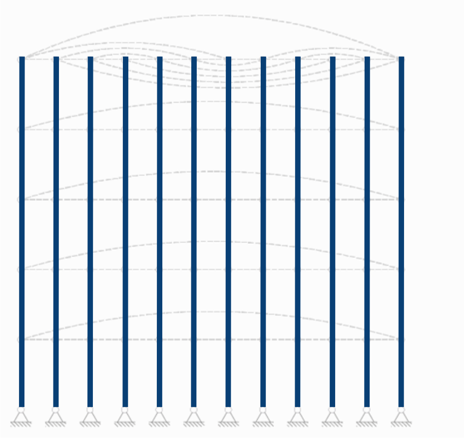
{34.543,-18.7364,50.9361,30.0788,0.278136,39.8596,-20.1227,-60.9853,52.7318,33.3105,19.2516,49.5125,-15.7887,-

2.54,1.2,1.2,2.54,2.54,2.54,1.2,-3.6,0.72,-3.6,1.2,0.72,0.72,1.2,1.2,-3.6,0.72,-3.6,1.2},

a) Generation



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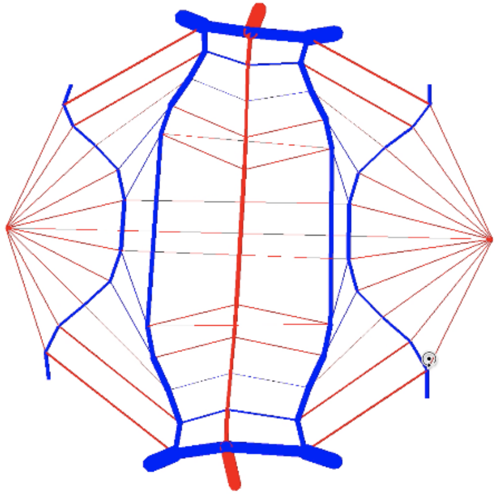

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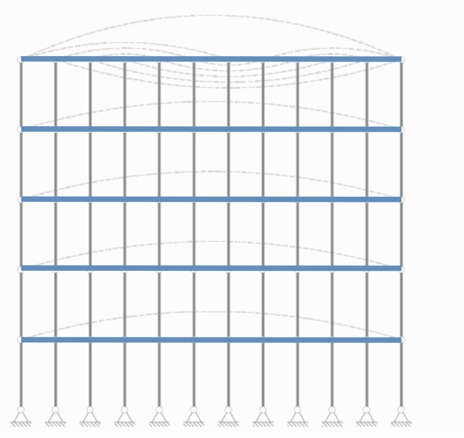
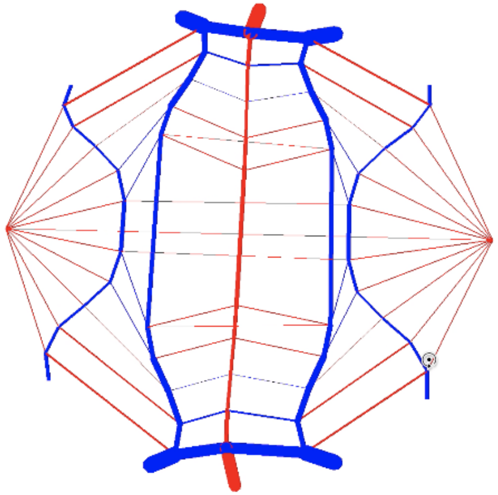
{34.543,-18.7364,50.9361,30.0788,0.278136,39.8596,-20.1227,-60.9853,52.7318,33.3105,19.2516,49.5125,-15.7887,-

2.54,1.2,1.2,2.54,2.54,2.54,1.2,-3.6,0.72,-3.6,1.2,0.72,0.72,1.2,1.2,-3.6,0.72,-3.6,1.2},

a) Generation





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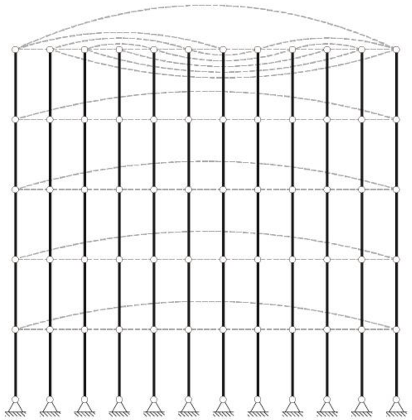
2.54,1.2,1.2,2.54,2.54,2.54,1.2, 3.6,0.72, 3.6,1.2,0.72,0.72,1.2,1.2, 3.6,0.72, 3.6,1.2},

a) Generation



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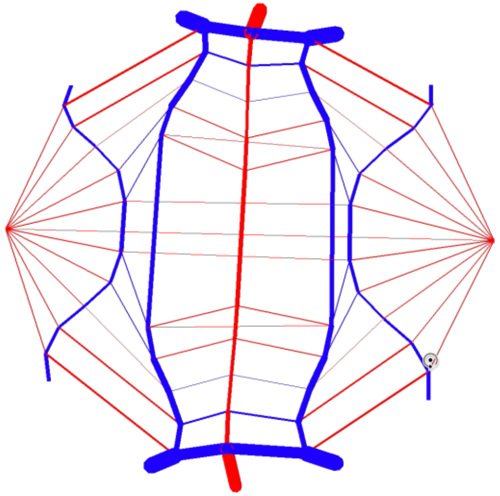

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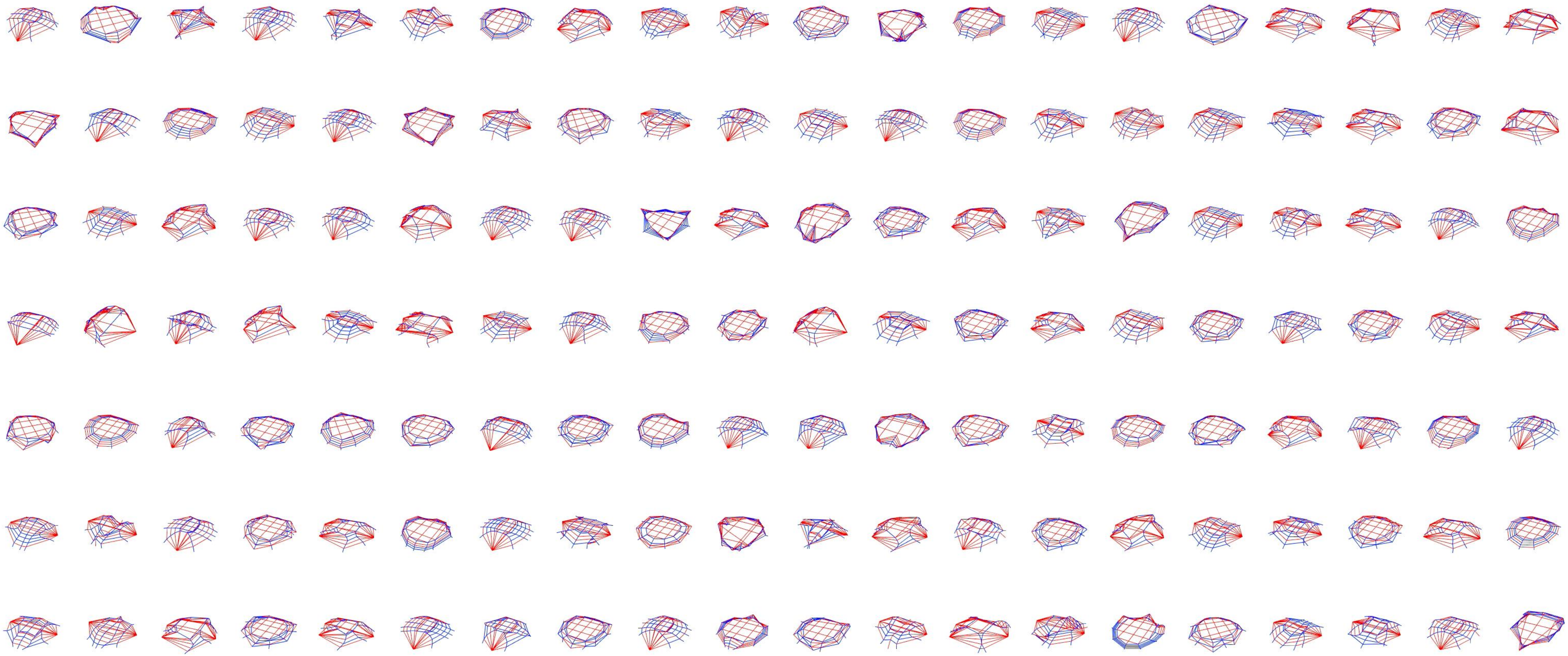
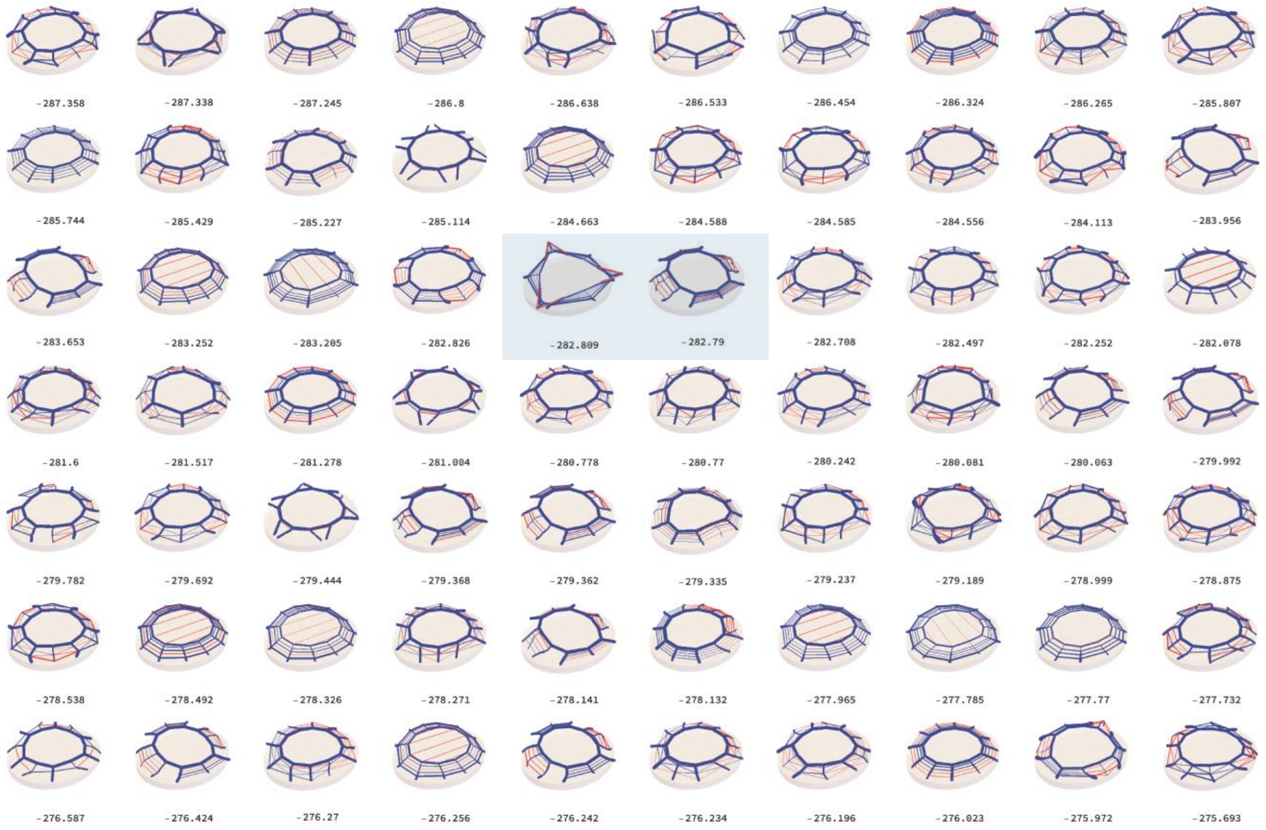
a) Generation

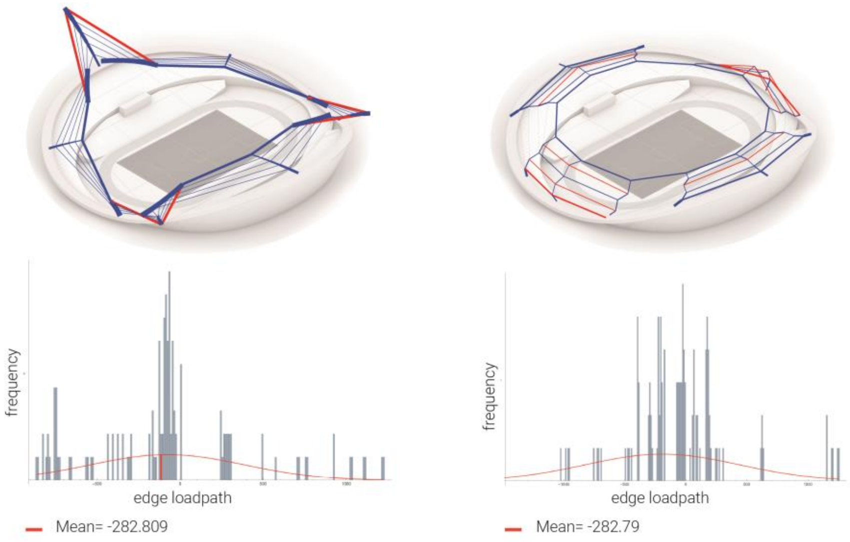


35.200

b) Quantitative Evaluation and Filtering

Objective functions





Load Path

"[Structural] art is solving problems which cannot be formulated before they have been solved. The search goes on until a solution is found, which is deemed to be satisfactory. There are always many possible solutions, the search is for the best ***— but there is no best — just more or less good."***

Ove Arup

b) Quantitative Evaluation and Filtering

Objective functions

Load Path

Minimum Edge load path

$$edgeLoadPath = lenghtElements * force$$

Local stability

Maximum cross section

$$crossSection = 0.5\left(\frac{\frac{force}{maxStress}}{\pi d} + d\right) < max$$

Maximum length of elements

Minimum slenderness ratio

$$inertia = \pi\left(\frac{crossSection^4 - (crossSection - d)^4)}{4}\right)$$

$$slendernessRatio = \frac{lenghtElements}{\sqrt{\frac{inertia}{crossSection}}} > min$$

c) Clustering and Representation

Higher Order statistics.

Original output:

Position of nodes
Length of edges
Magnitud of the forces
 Load Path

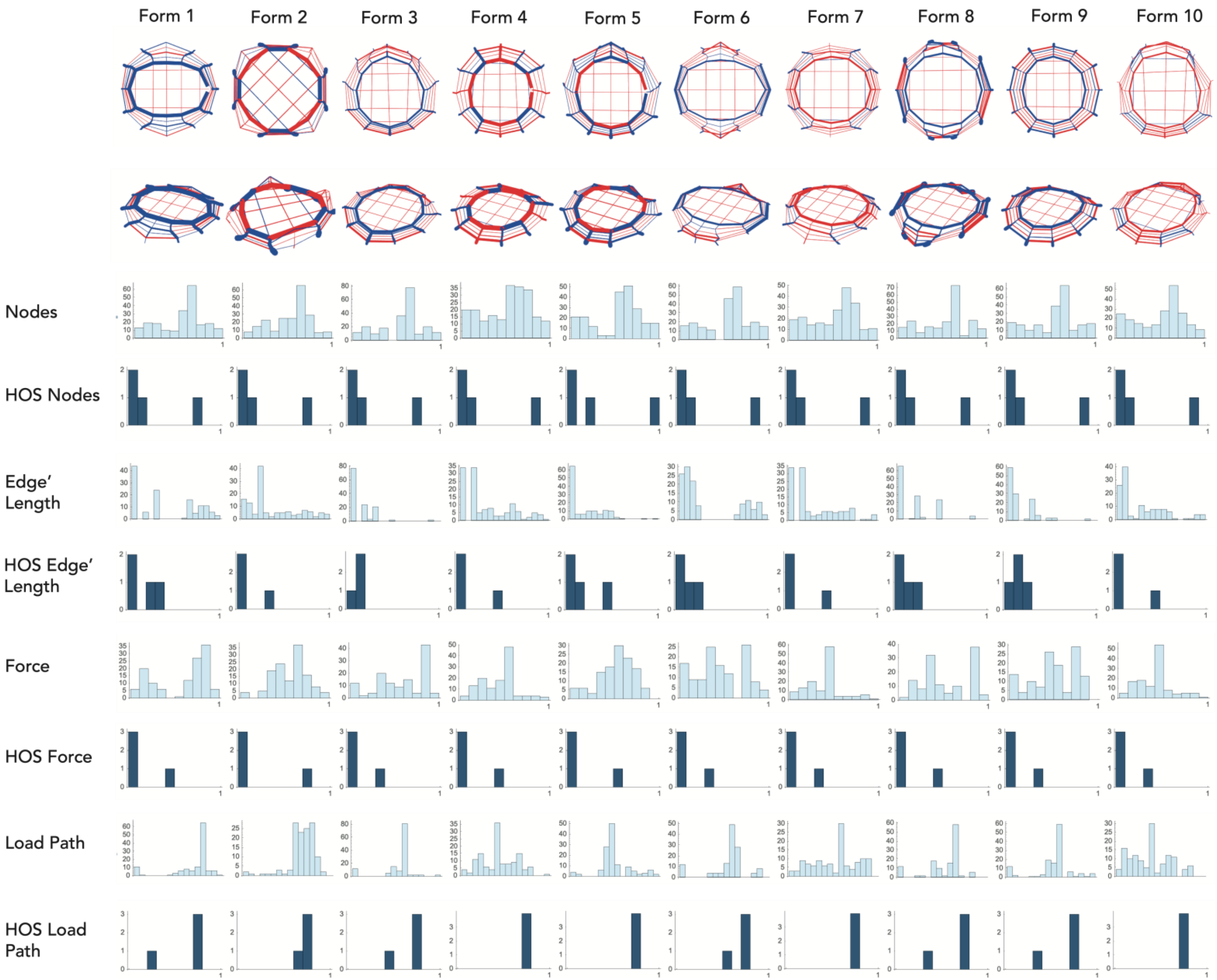
Higher Order Statistics:

Mean of Length of Edges
Mean of Position of Nodes
Mean of Force Magnitude
Mean of Load Path

Variance Length of Edges
Variance of Position of Nodes
Variance of Force Magnitude
Variance of Load Path

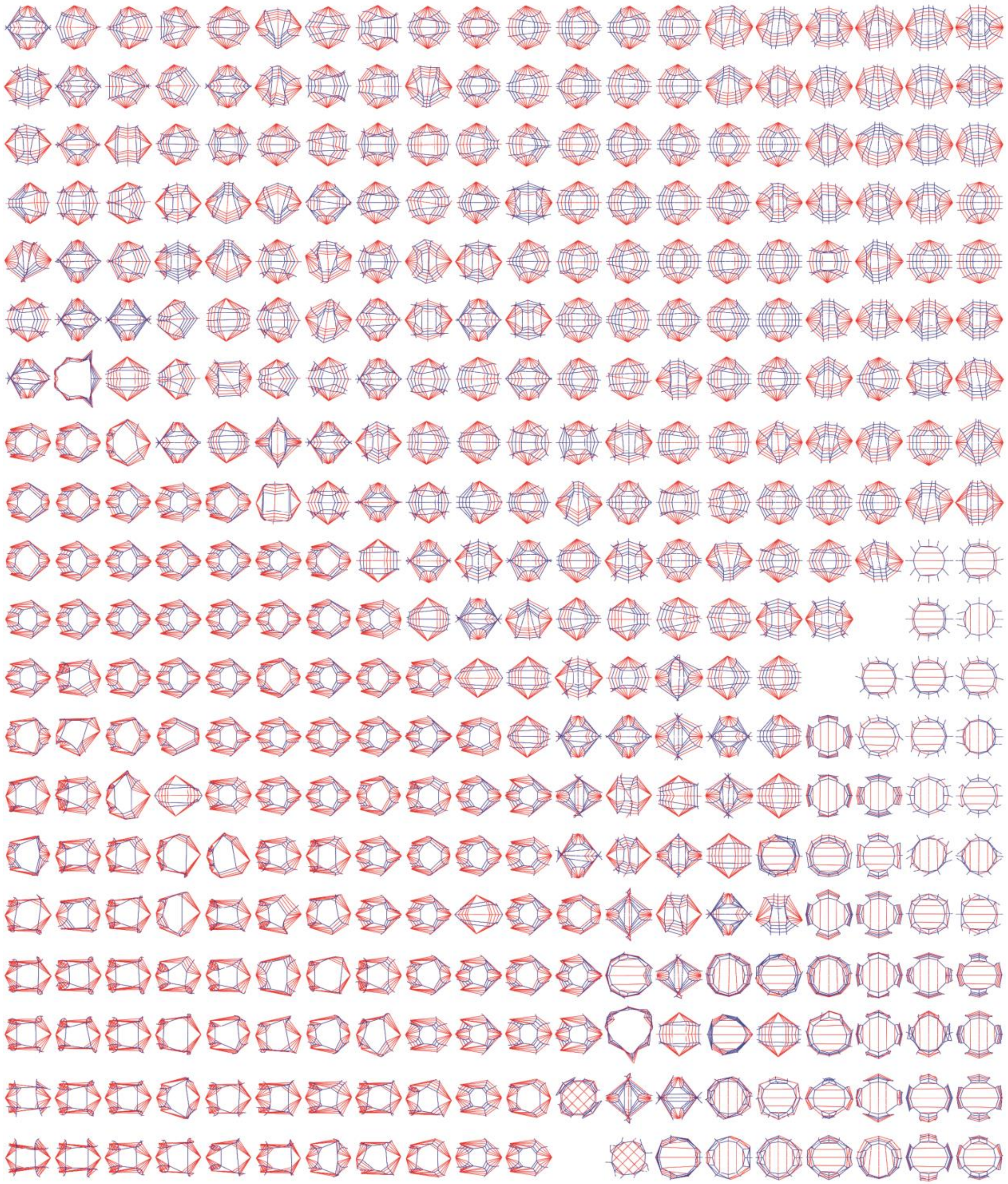
Skewness Length of Edges
Skewness Position of Nodes
Skewness of Force Magnitude
Skewness of Load Path

Kurtosis Length of Edges
Kurtosis of Position of Nodes
Kurtosis of Force Magnitude
Kurtosis of Load Path



c) Clustering and Representation

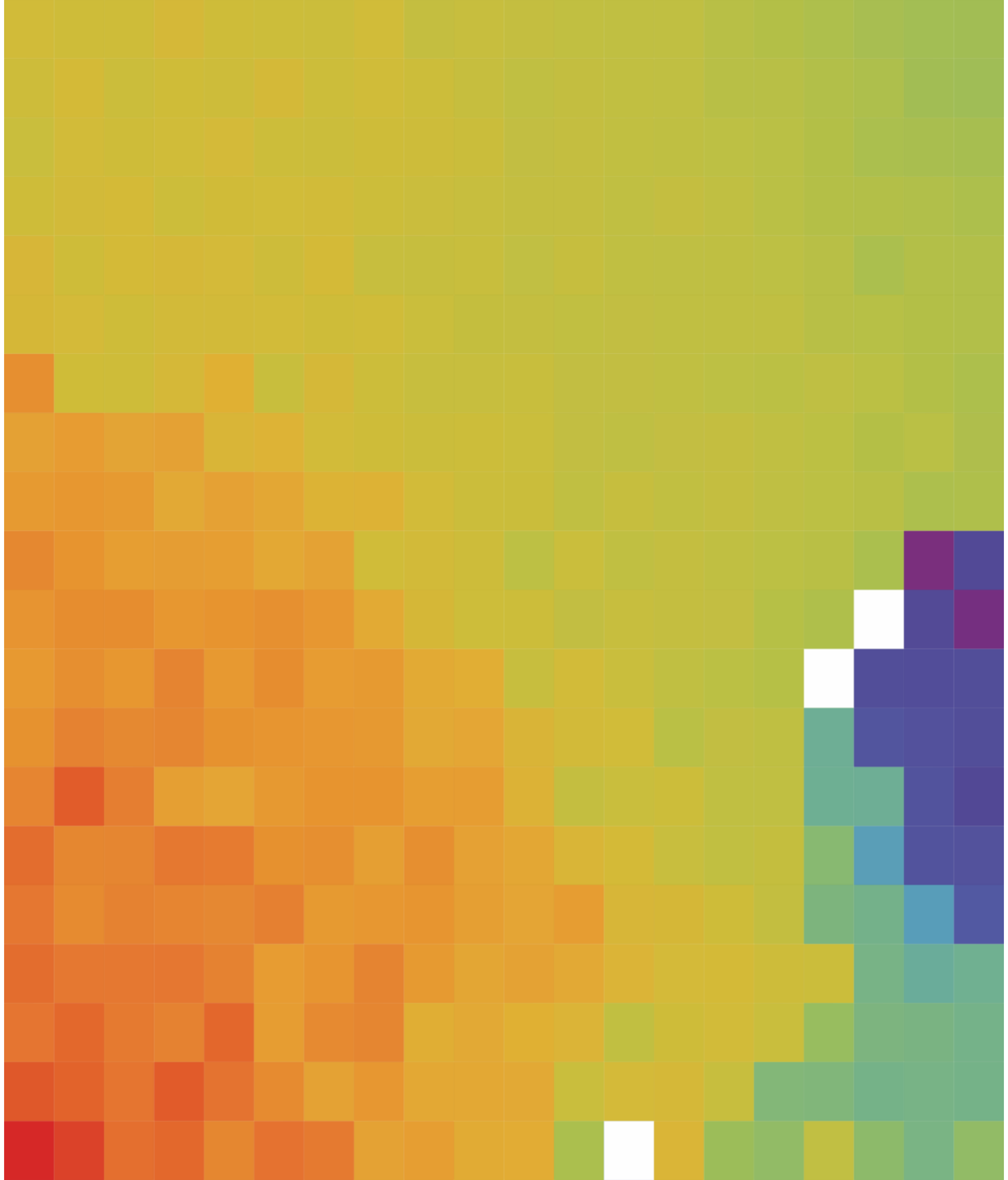
Self Organizing Map



Cluster by edge length

c) Clustering and
Representation

Self Organizing Map

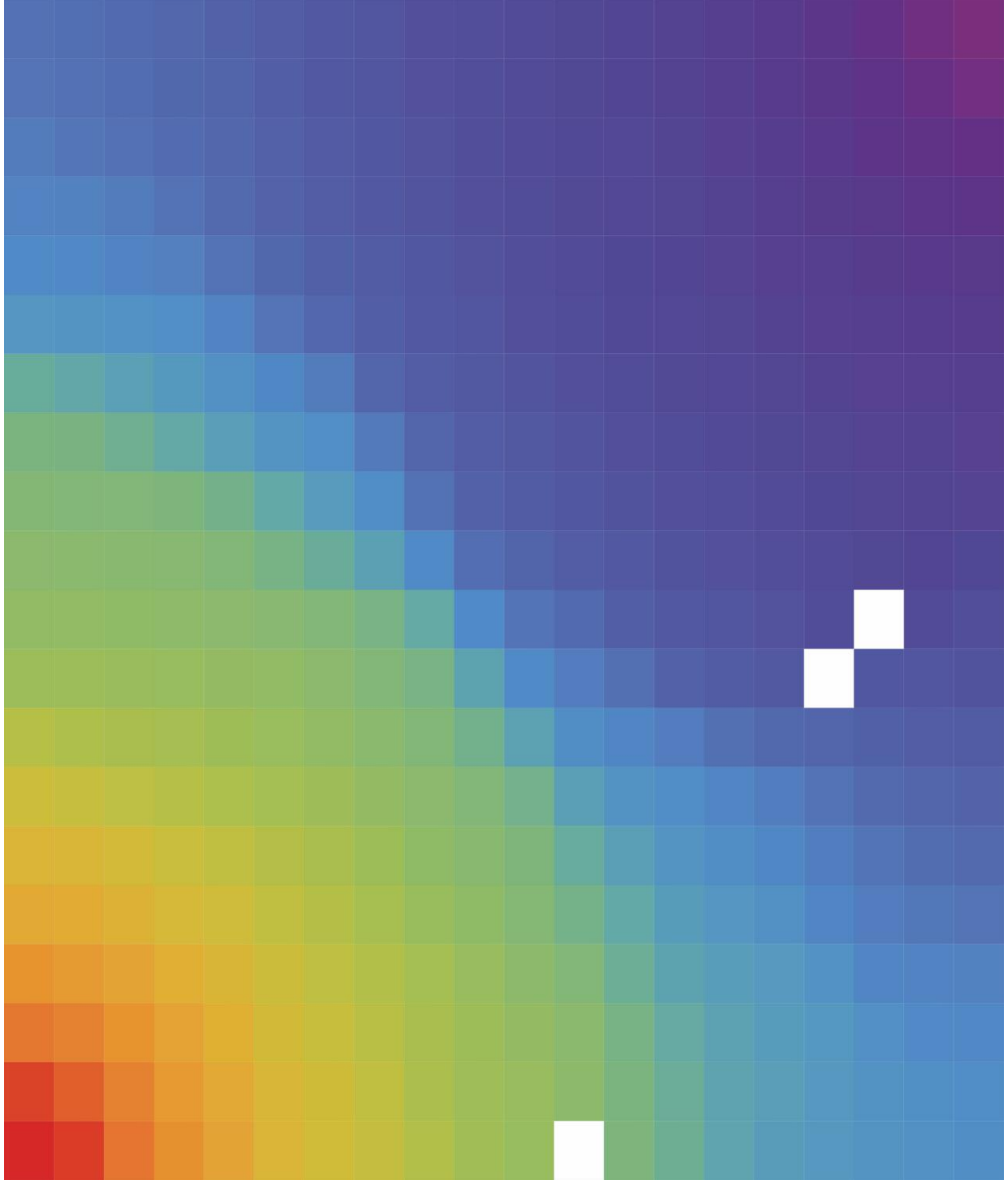


Mean value of edge length

14.490

c) Clustering and
Representation

Self Organizing Map

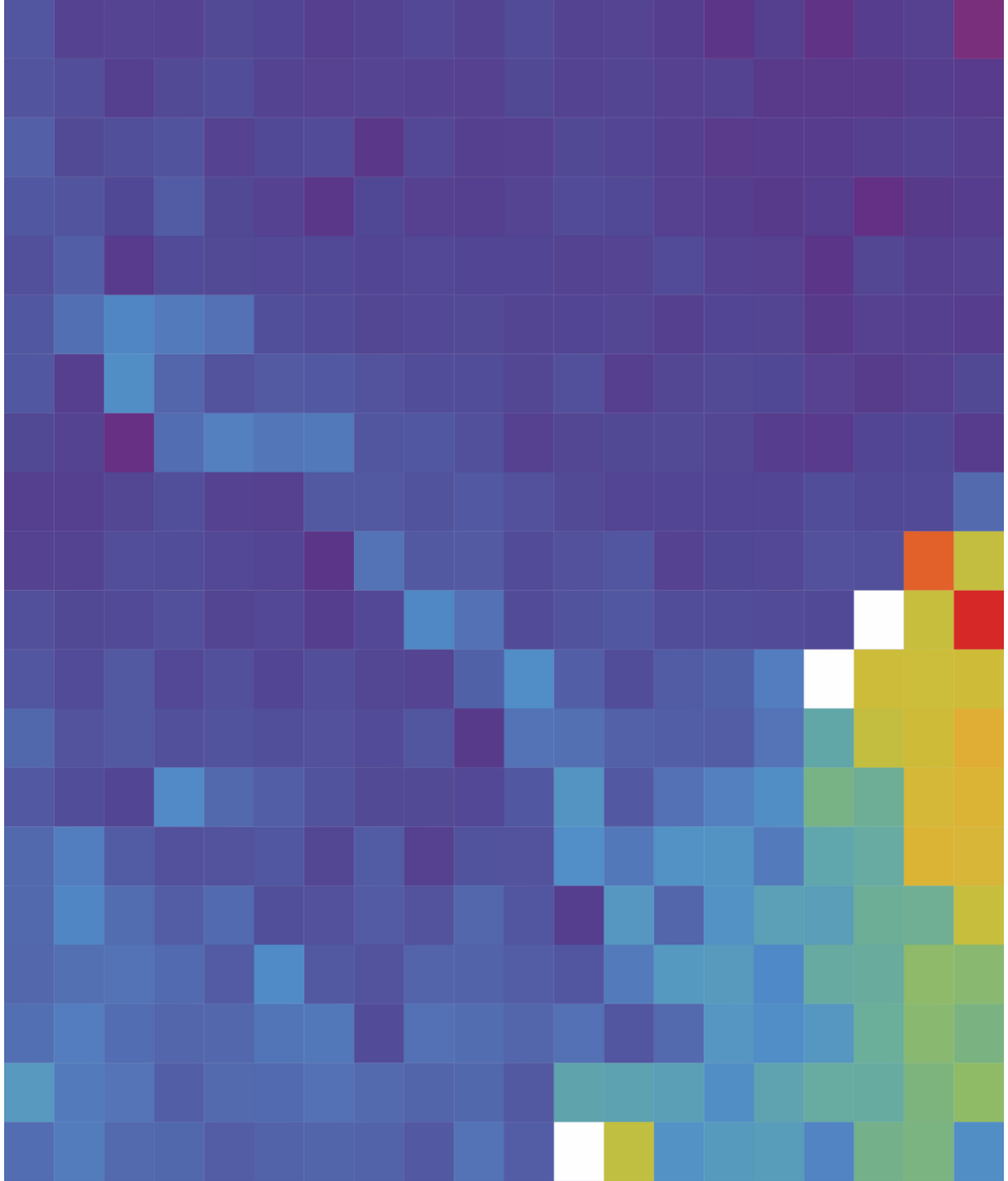


Variance value of edge length

14.490

c) Clustering and
Representation

Self Organizing Map

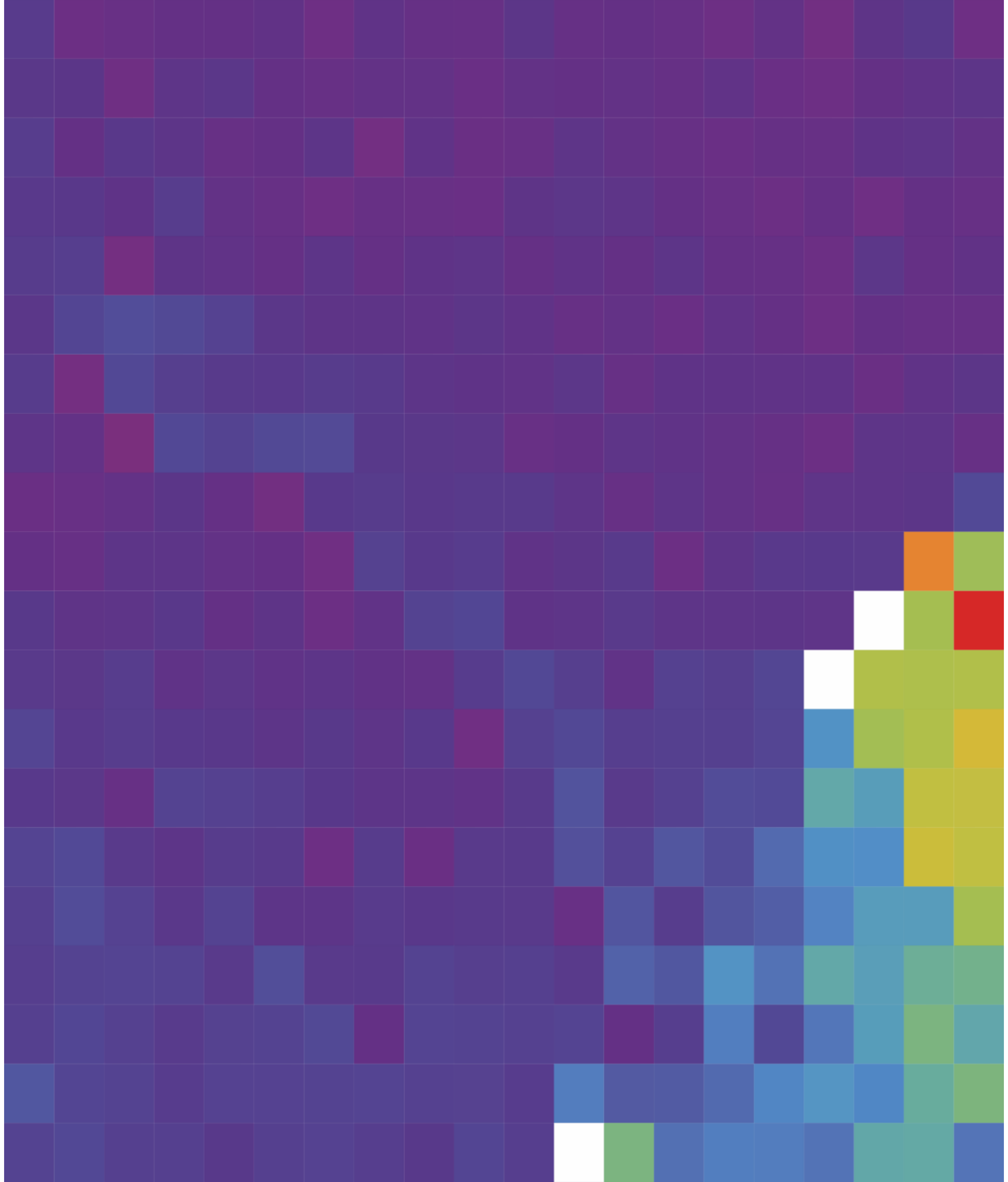


Skewness value of edge length

14.490

c) Clustering and
Representation

Self Organizing Map

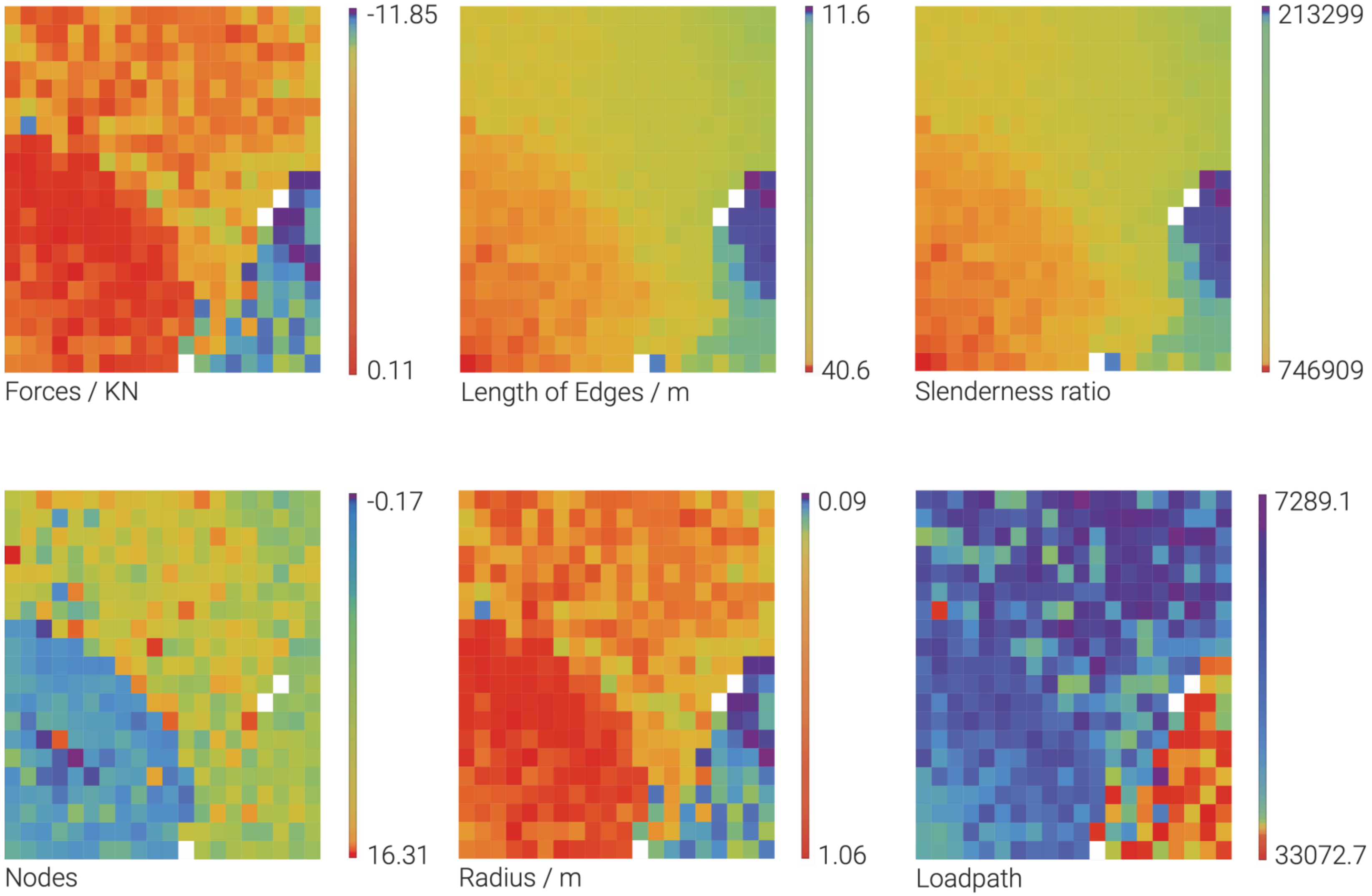


Kurtosis value of edge length

14.490

c) Clustering and
Representation

Self Organizing Map

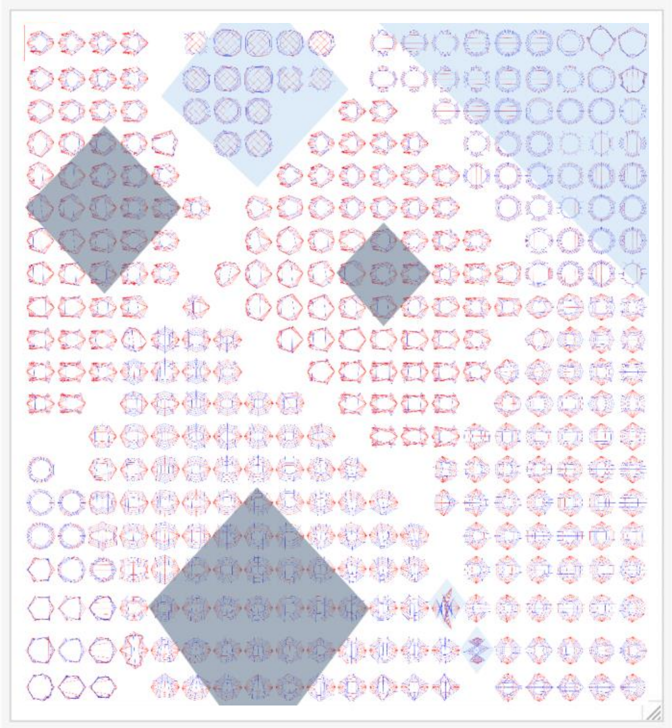


Mean value

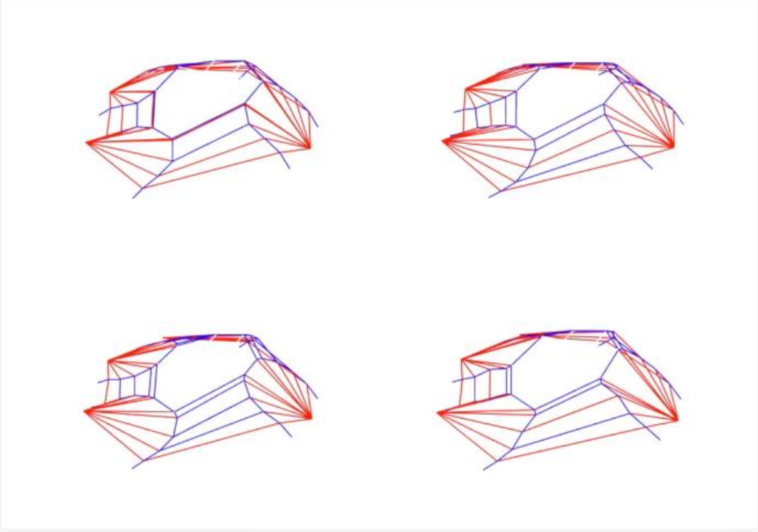
d) Qualitative Evaluation and Selection

Designer preferences

SOM 20x20



Group of representative forms for each cell

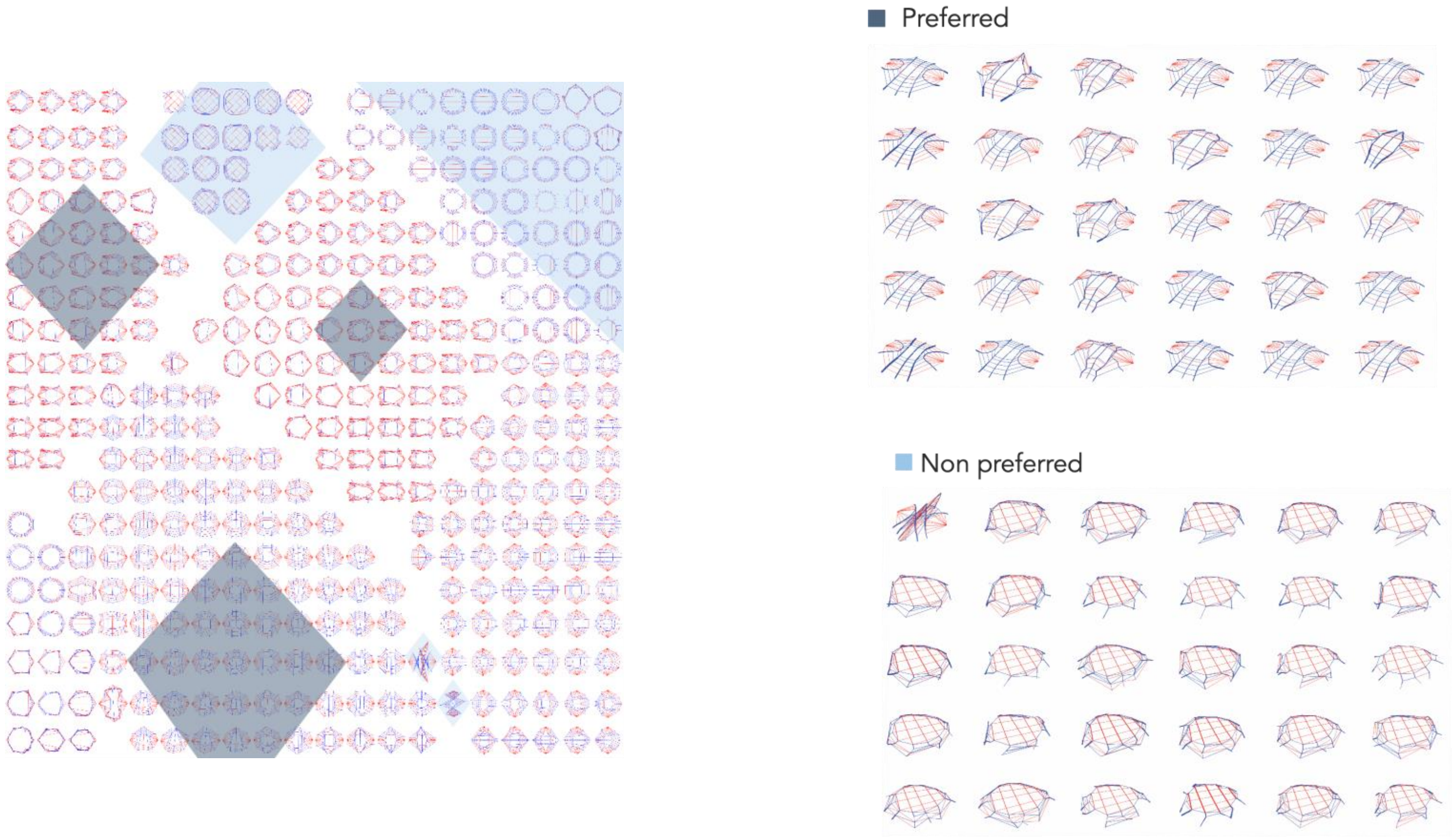


cell N = 1 forms in cell = 60

Cluster by position of nodes

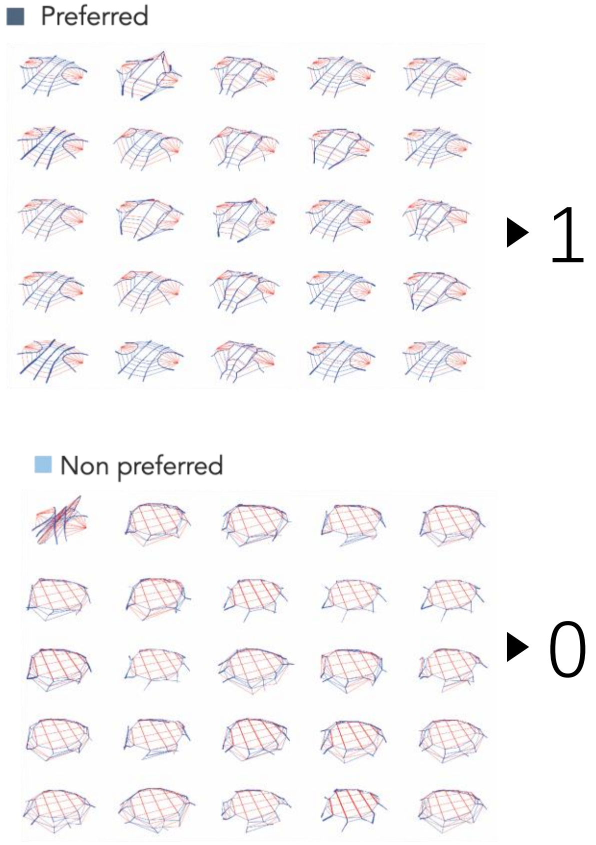
d) Qualitative Evaluation and Selection

Designer preferences



e) Re-Generation

Label data



Input to label

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{30.,2.,90.,0.,6.,0.,-1.2,-2.,6.,0.,-2.4,-3.,6.,0.,2.4,6.,0.,-2.4,6.,0.,2.4,0.4,0.,0.,-7.,6.,0.,1.2,2.,0.,0.2,2.,0.,1.6,2.,0.,1.7,0.,3.,40.,40.,500.,3.} **-> 0**

{40.,2.,0.,0.,0.,0.,-0.7,-1.,0.,0.,-1.,-1.,0.,0.,-1.,0.,0.,-1.,0.,0.,-1.,0.6,0.,0.,-1.2,2.,0.,-3.2,2.,0.,-5.3,2.,0.,2.5,2.,0.,1.,1.,2.,40.,14.,800.,4.} **-> 1**

{30.,2.,90.,0.,1.,0.,-4.,-10.,1.,0.,-1.8,-6.,1.,0.,-1.8,1.,0.,-1.8,1.,0.,-1.8,0.4,0.,0.,-7.,1.,0.,-2.9,1.,0.,-0.1,1.,0.,2.7,1.,0.,-1.7,0.,3.,40.,40.,500.,0.} **-> 0**

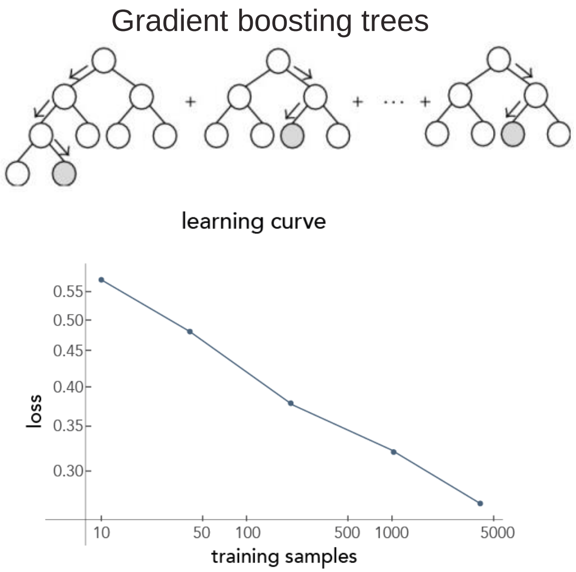
{30.,2.,90.,0.,2.,0.,-4.2,-7.,2.,0.,-1.1,-11.,2.,0.,-1.1,2.,0.,-1.1,2.,0.,-1.1,0.4,0.,0.,-7.,2.,0.,-0.2,2.,0.,0.3,2.,0.,-0.2,2.,0.,1.1,0.,3.,40.,40.,500.,0.} **-> 0**

{30.,2.,90.,0.,1.,0.,-1.6,-8.,1.,0.,-6.,-10.,1.,0.,-6.,1.,0.,-6.,1.,0.,-6.,0.4,0.,0.,-10.,1.,0.,2.5,1.,0.,1.2,1.,0.,-2.4,1.,0.,-4.8,0.,3.,40.,40.,500.,0.} **-> 0**

{30.,2.,0.,0.,6.,0.,-2.4,-6.,6.,0.,-1.1,-11.,6.,0.,-1.1,6.,0.,-1.1,6.,0.,-1.1,0.4,3.,0.,-4.,6.,0.,-0.6,6.,0.,-1.5,6.,0.,-1.6,6.,0.,-0.6,2.,3.,40.,40.,500.,1.} **-> 0**

→

Classifier



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Random Inpu

{31.7004,1.95258,75.4383,0,5,0,1.7606
8.53543,-2.22924,0,0,-5.15774,4,0,-
8.06515,4,0,0.956659,0.447817,2,0,0.69
11.0796,6,0,-2.74024,4,1,2.27955,1,1,-
5.99889,2,1,37.3191,33.155,521,3}

{37.7186,1.95511,65.1791,0,0,0,-0.409
6.48681,-3.70395,6,0,-4.64075,6,0,-8.20
9.67388,0.432731,1,0,-0.946617,0,0,-7.
2.74343,4,1,2.30956,2,1,3.41206,2,2,32

{34.1612,1.94711,16.5273,0,4,0,5.7606
4.92791,-2.37722,0,0,-3.09339,4,0,-9.9
10.0908,0.449276,3,0,-3.77359,2,1,-7.0
2.91664,4,0,-4.79404,4,1,-0.8238,2,1,20

{36.2507,1.95232,45.2289,0,0,0,-0.780
4.27408,-9.89226,0,0,2.25393,2,0,-3.78
9.98175,0.595623,1,0,-2.92354,4,0,-
7.40239,6,0,1.12848,0,1,-3.06993,0,1,-
5.09253,1,0,38.6744,17.055,789,2}

{38.6181,1.99975,69.9351,0,3,0,-1.0317
7.26265,-4.94582,6,0,-5.41421,2,0,-
5.44706,5,0,0.183436,0.427209,1,0,-
0.430016,2,1,1.78398,4,0,-
0.128091,4,0,0.150396,6,1,2.41255,0,0,
,4}

{31.8534,1.93862,64.6778,0,5,0,2.5962
2.69748,-10.1341,4,0,-3.9415,0,0,-
4.39635,1,0,2.5443,0.496435,1,0,-2.40
10.2459,5,1,0.868431,2,1,-
2.11791,2,1,5.51321,0,2,21.7704,37.15

{38.0062,1.97964,24.2896,0,0,0,0.7385
2.33477,-7.32023,4,0,-1.6671,2,0,-
9.07272,0,0,3.19792,0.586746,3,0,0.39
6.77132,1,0,1.28317,3,1,-
1.8156,4,0,3.41661,3,1,28.105,33.0263,

{39.8521,1.99013,16.7108,0,2,0,7.8373
2.22954,-6.6361,0,0,-3.66743,0,0,-3.60
2.0674,0.474582,0,0,-2.56787,1,0,-3.40
3.02895,3,0,2.82892,5,0,2.71254,0,0,37

First Training a machine learning algorithm

Second Gen

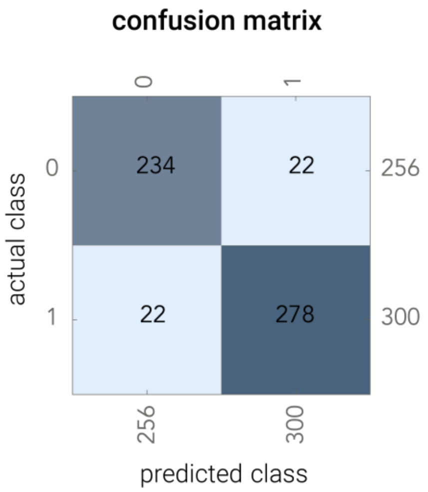
uts

21.0262,2,0,-
9338,0,0,-
305,-10.0768,5,0,-
0661,2,0,-
83671,0,1,-
.5624,33.5049,552,3}
1,-9.84755,4,0,-
1877,3,0,-
1304,2,0,-
.1195,18.2262,629,2}
396,4.81845,4,0,-
443,5,0,-
76,-11.1122,0,0,-
33.2831,14.4356,606
9,20.5884,2,0,-
318,6,0,-
22,509,5}
2,0.289754,6,0,-
5001,4,0,-
540,2}
4.61936,1,0,-
647,3,0,-
803,5,0,-
.466,29.865,576,2}

→

Trained Classifier

Based on users preferences



→

Classified data

{32.709,1.92236,20.7891,0,0,0,4.1737,13.1791,2,0,-4.60392,-3.25911,3,0,-3.53896,6,0,-7.43506,1,0,0.994046,0.431442,0,0,-1.08748,4,1,-4.274,4,0,0.846389,1,1,-1.32083,4,0,-3.25967,3,0,20.5569,14.3004,665,4} **-> 1 (99.9243%)**

{31.6033,1.99855,36.7378,0,4,0,-0.604303,-10.0509,2,0,-4.18794,-6.64236,1,0,2.88324,4,0,-7.49975,1,0,-6.0594,0.424513,0,0,6.55737,4,1,-6.08007,3,0,3.23182,2,1,5.06745,6,0,-1.71971,2,0,31.5574,39.7436,768,0} **->0 (99.9266%)**

{33.8839,1.92742,71.1421,0,6,0,2.295,9.19651,4,0,-10.5094,-10.5067,1,0,-10.5287,3,0,-3.01153,1,0,-5.20941,0.51292,2,0,6.49537,5,1,-6.27142,0,1,-2.25551,1,1,-0.796136,0,1,1.0436,1,1,35.1928,23.499,599,2} **->1 (99.9448%)**

{31.7973,1.93468,10.1377,0,6,0,-5.81181,38.933,4,0,-0.5629,-1.63411,1,0,-0.388363,0,0,-6.56066,1,0,-3.32825,0.442369,2,0,6.69548,5,0,-5.69921,1,0,5.5168,0,0,-2.68969,4,0,0.431611,2,1,24.1778,32.562,578,1} **->0 (99.9448%)**

{30.3566,1.93511,30.1212,0,6,0,0.907838,14.4282,2,0,-6.04254,-4.04241,2,0,-7.91578,1,0,-6.14707,4,0,-0.10778,0.469205,1,0,0.402954,3,0,-1.16862,2,1,0.663736,4,1,2.92581,6,0,-1.08582,0,2,24.5691,26.1762,585,1} **->1 (0.99994%)**

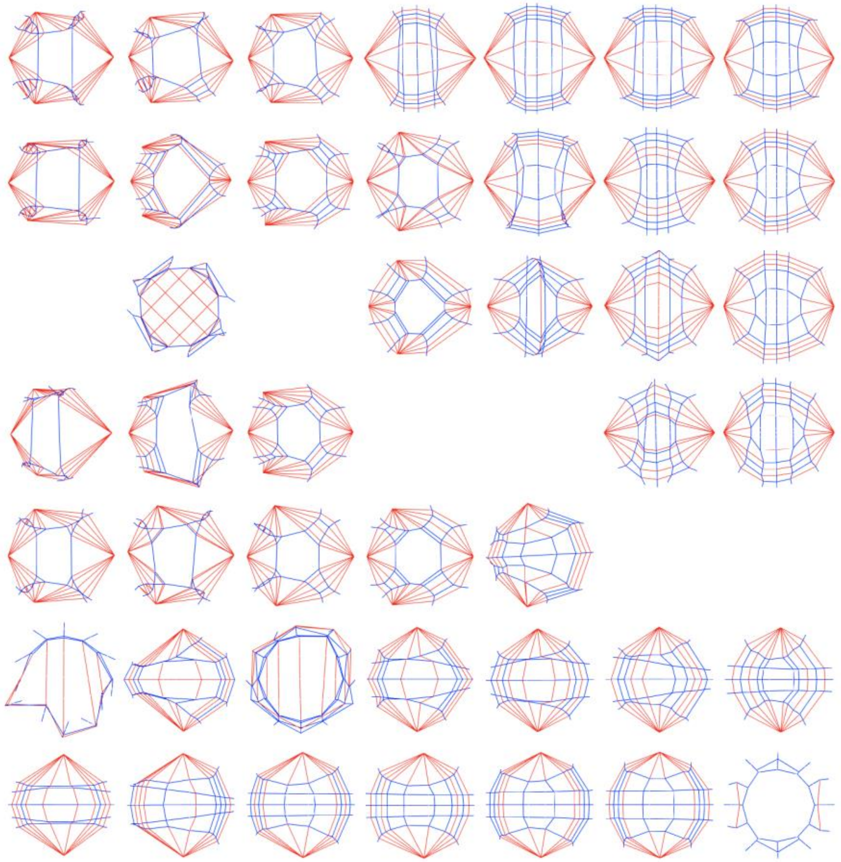
{30.5361,1.96557,29.8152,0,2,0,-2.73107,-4.6429,4,0,-8.03933,-4.35336,6,0,3.38563,2,0,-9.14164,5,0,-7.64957,0.59164,1,0,-5.07847,6,1,-5.86651,1,0,-0.564151,6,0,-5.87093,0,0,1.98507,2,3,31.8755,25.0096,569,1} **->0 (99.996%)**

{35.3154,1.99217,20.7123,0,6,0,3.39089,-8.5296,1,0,-6.89611,-6.19843,0,0,-8.62052,0,0,-10.0493,1,0,-5.34887,0.568105,2,0,-3.07016,4,1,-5.2056,0,0,-2.96831,0,0,-3.25082,6,1,-1.09355,2,1,25.7826,25.9543,790,3} **->1 (99.9266%)**

{33.011,1.98111,17.6824,0,2,0,4.3446,27.4604,4,0,-1.18025,-11.2675,1,0,-4.15671,1,0,-7.18707,6,0,-2.75978,0.433088,2,0,-4.6134,6,1,-0.722242,6,0,3.21735,2,1,2.6081,0,0,-4.12382,0,2,27.0503,15.1917,568,6} **->1 (99.9867%)**

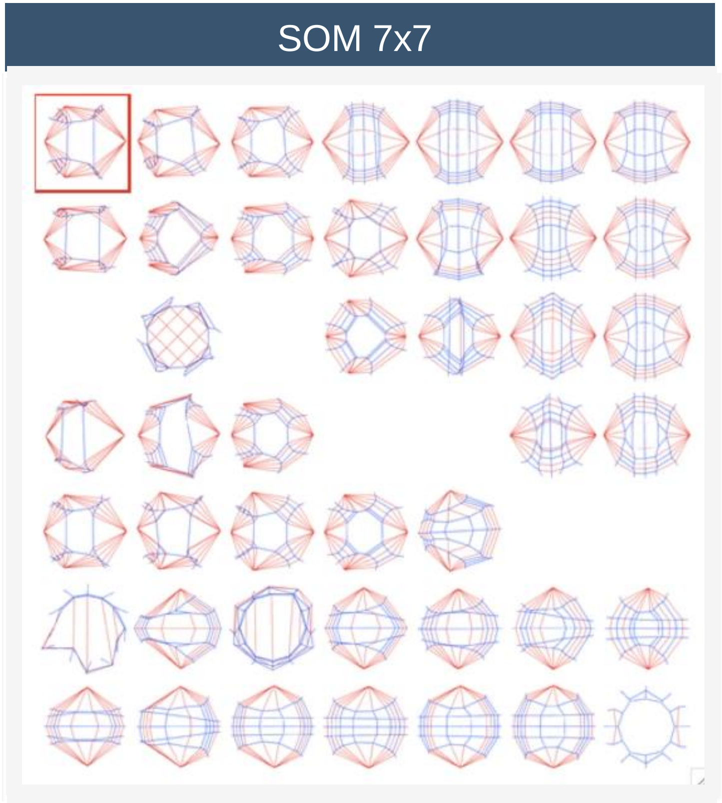
→

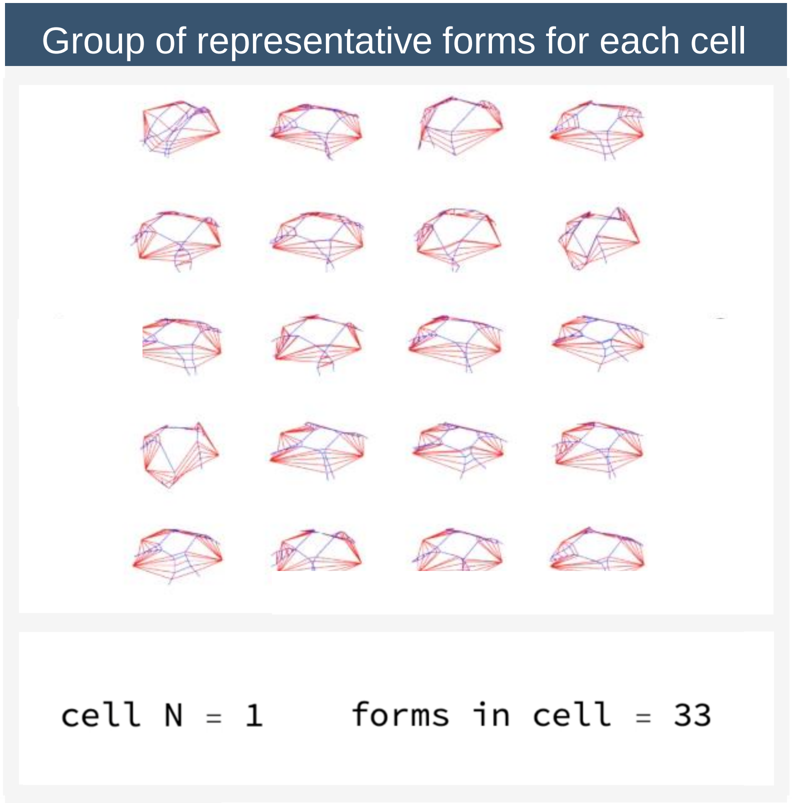
a) Generate/ b) Encode/ c) Cluster



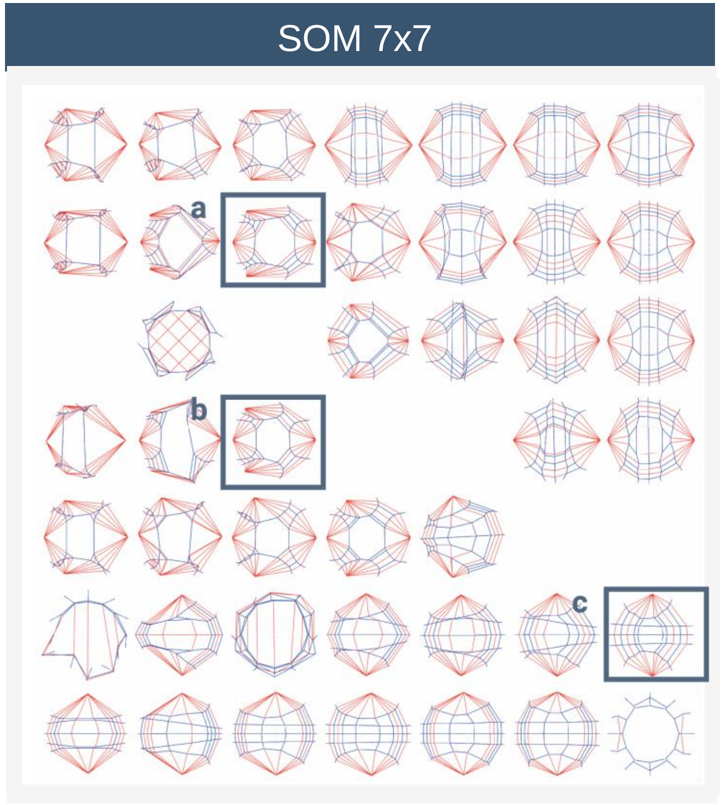
erating preferred forms

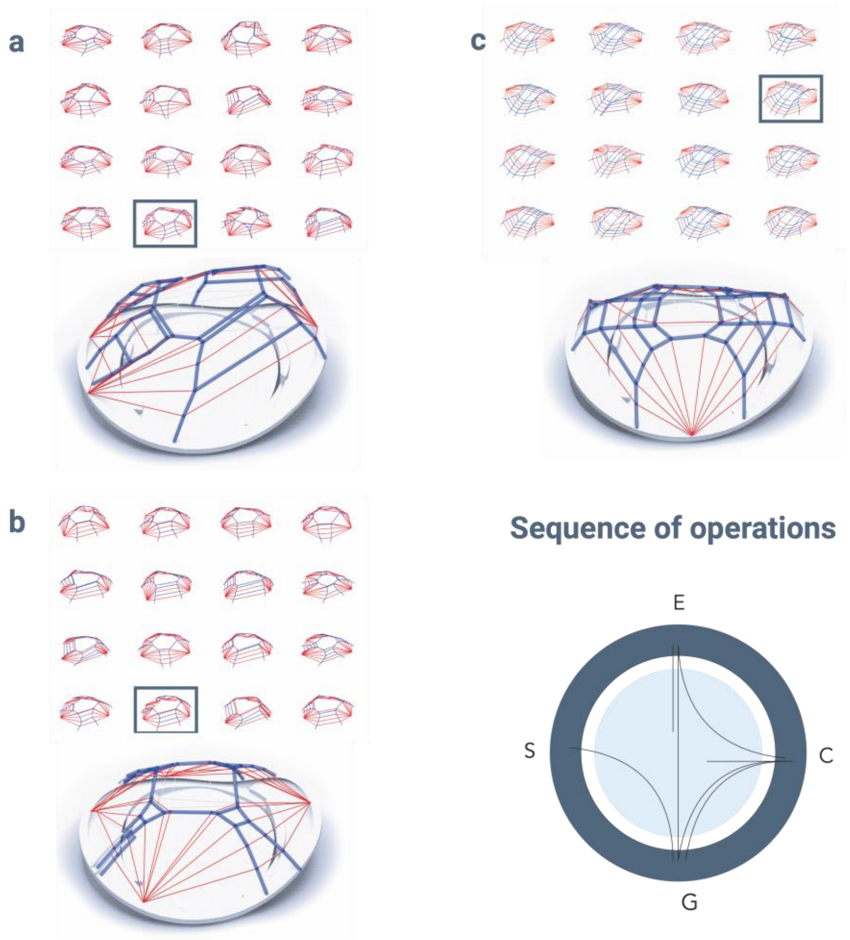
c) Qualitative Evaluation and Selection





c) Qualitative Evaluation and Selection





- *Introduction*
- *Proposed Technical Framework*
- *Design application*
- *User specific implementations*
- *Conclusion / Outlook*

Generation CEM

trail lengths

deviation forces

origin nodes

Evaluation / Filter

min loadPath

max lengths elements

min crossSection

min slenderness

fromal evaluation

Clustering SOM / Vectors

nodes

lengths edges

force

loadpath

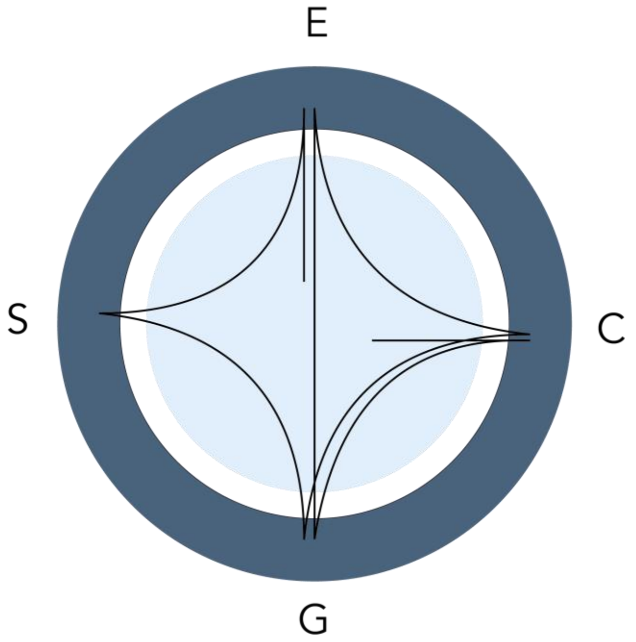
HOS nodes

HOS length edges

HOS force

HOS loadpath

Designer 1



Generation CEM

trail lengths | deviation forces | origin nodes

Evaluation / Filter

min loadPath | max lengths elements | min crossSection | min slenderness | formal evaluation

Representation & Clustering SOM

nodes | lengths edges | force | loadpath | HOS nodes | HOS length edges | HOS force | HOS loadpath

Evaluation / Filter

min loadPath | max lengths elements | min crossSection | min slenderness | formal evaluation

Selection

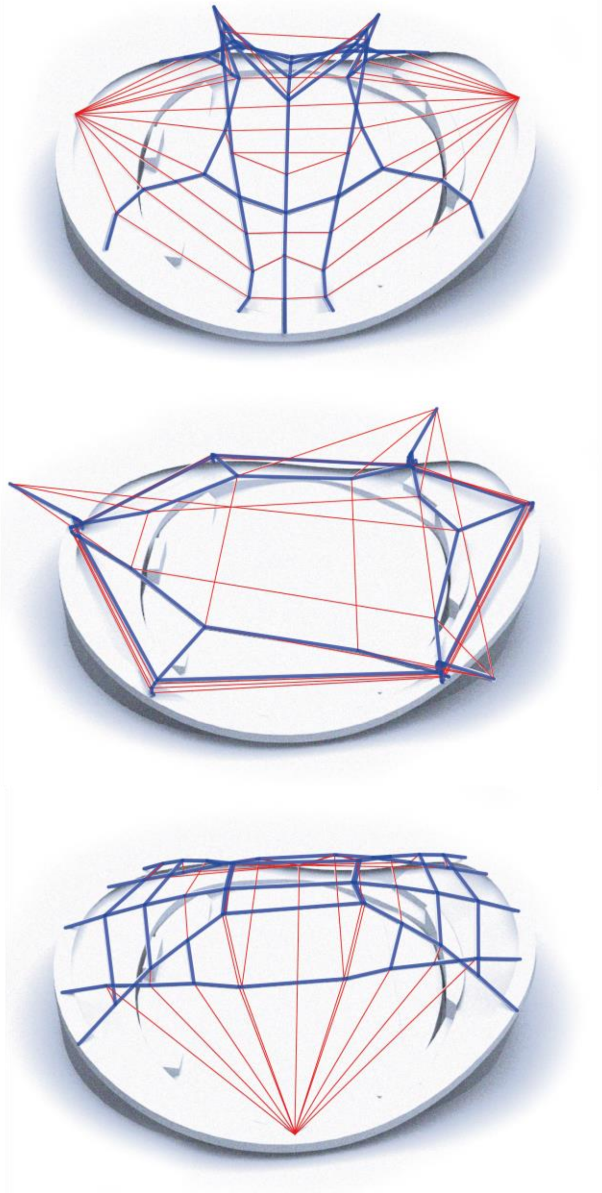
Re-Generation GBT - CEM

trail lengths | deviation forces | origin nodes

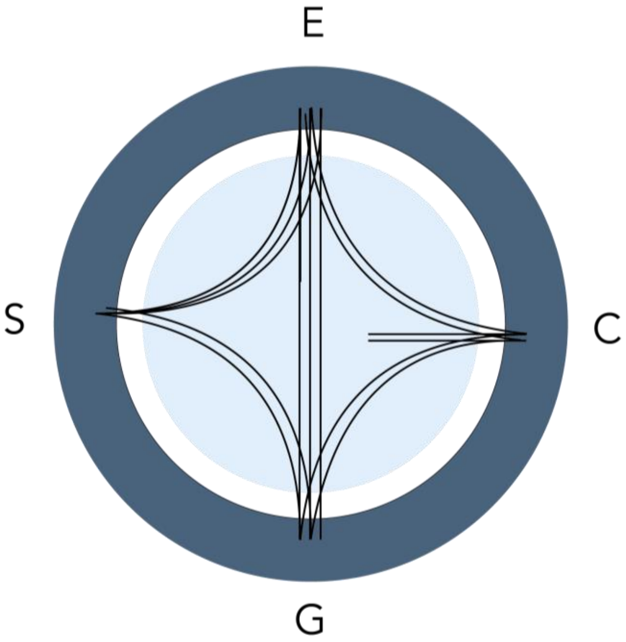
Representation & Clustering SOM

min loadPath | max lengths elements | min crossSection | min slenderness | formal evaluation

Selection



Designer 2



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S
C
G

Generation CEM
trail lengths
deviation forces
origin nodes
Evaluation / Filter
min loadPath
max lengths elements
min crossSection
min slenderness
formal evaluation
Representation & Clustering SOM
nodes
lengths edges
force
loadpath
HOS nodes
HOS length edges
HOS force
HOS loadpath
Evaluation / Filter
min loadPath
max lengths elements
min crossSection
min slenderness
formal evaluation
Selection
Re-Generation GBT - CEM
trail lengths
deviation forces
origin nodes
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HOS length edges
HOS force
HOS loadpath
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Generation CEM
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min loadPath
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min crossSection
min slenderness
formal evaluation
Representation & Clustering SOM
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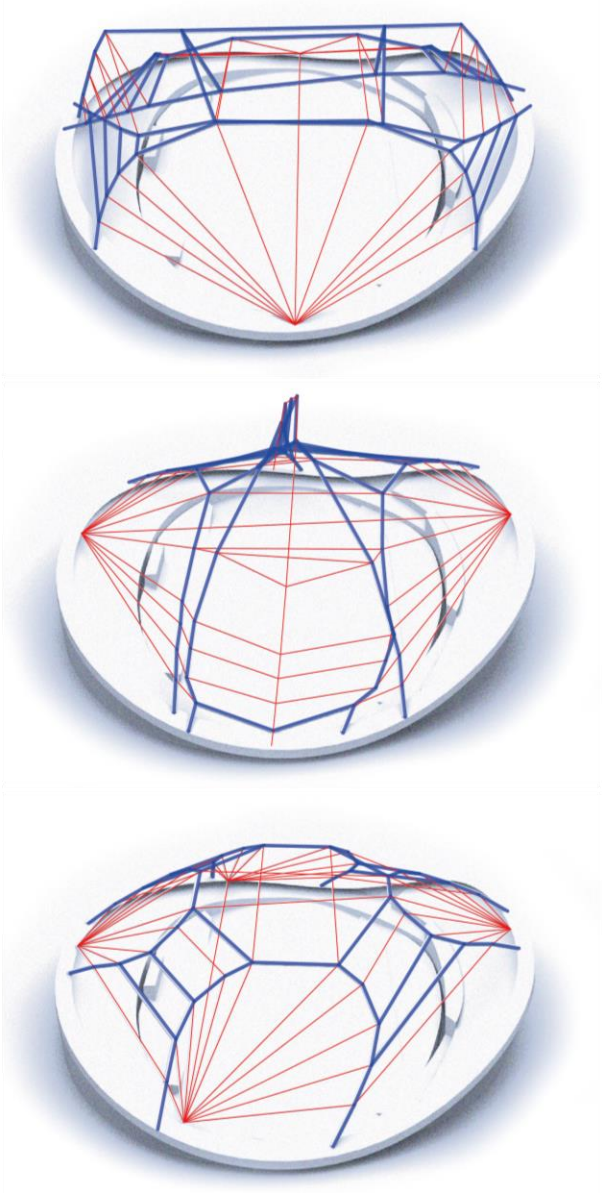
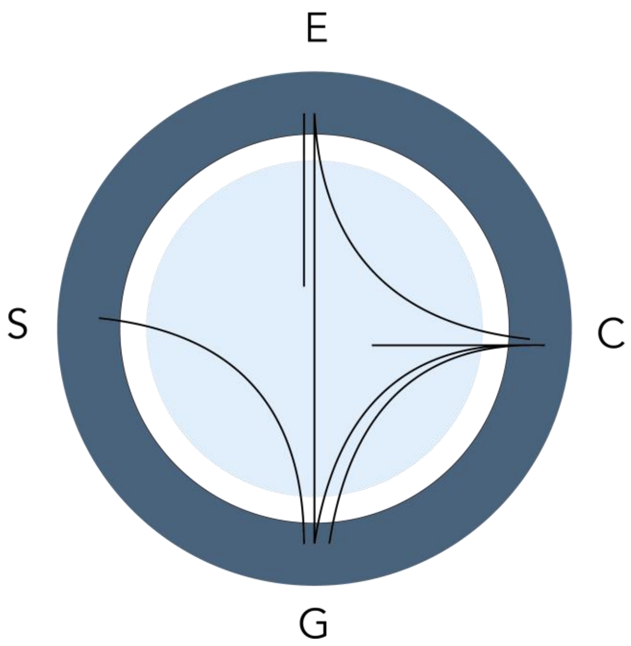
lengths edges
force
loadpath
HOS nodes
HOS length edges
HOS force
HOS loadpath



Designer 3



Generation CEM

trail lengths | deviation forces | origin nodes

Evaluation / Filter

min loadPath | max lengths elements | min crossSection | min slenderness | formal evaluation

Representation & Clustering SOM

nodes | lengths edges | force | loadpath | HOS nodes | HOS length edges | HOS force | HOS loadpath

Evaluation / Filter

min loadPath | max lengths elements | min crossSection | min slenderness | formal evaluation

Selection

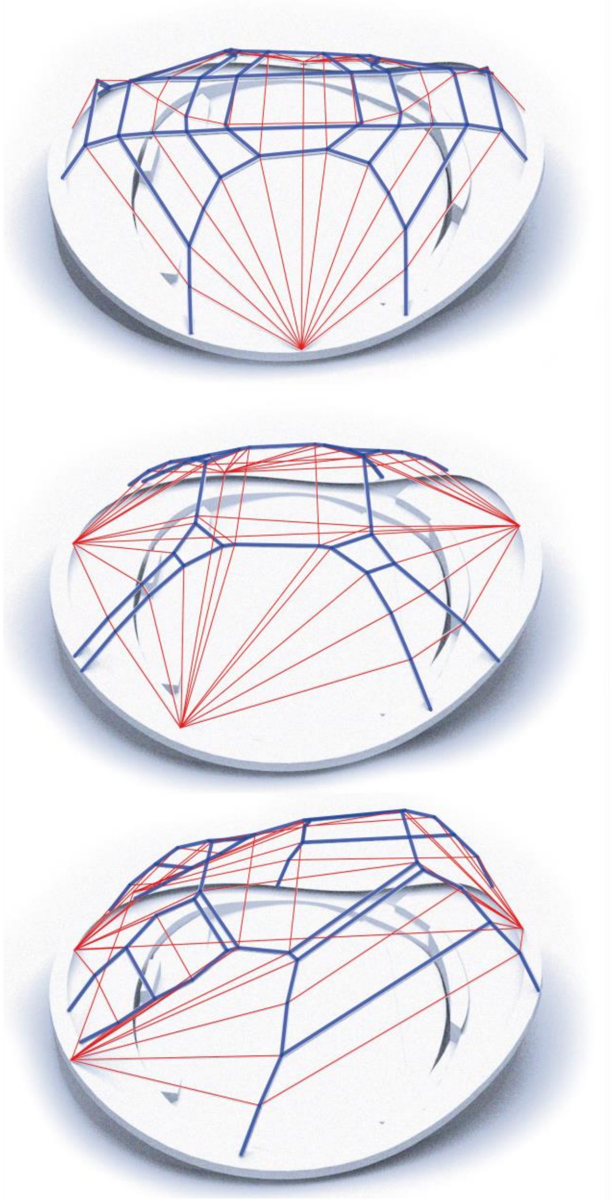
Re-Generation GBT - CEM

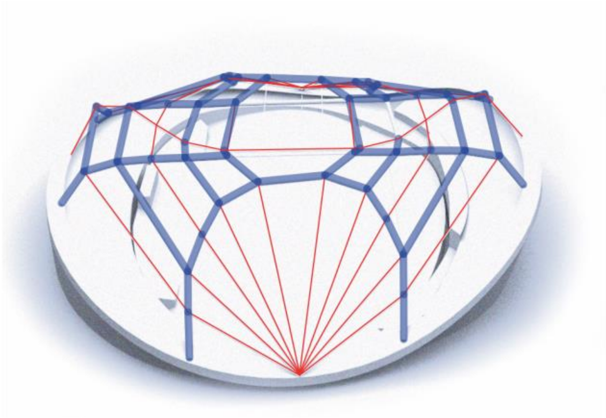
trail lengths | deviation forces | origin nodes

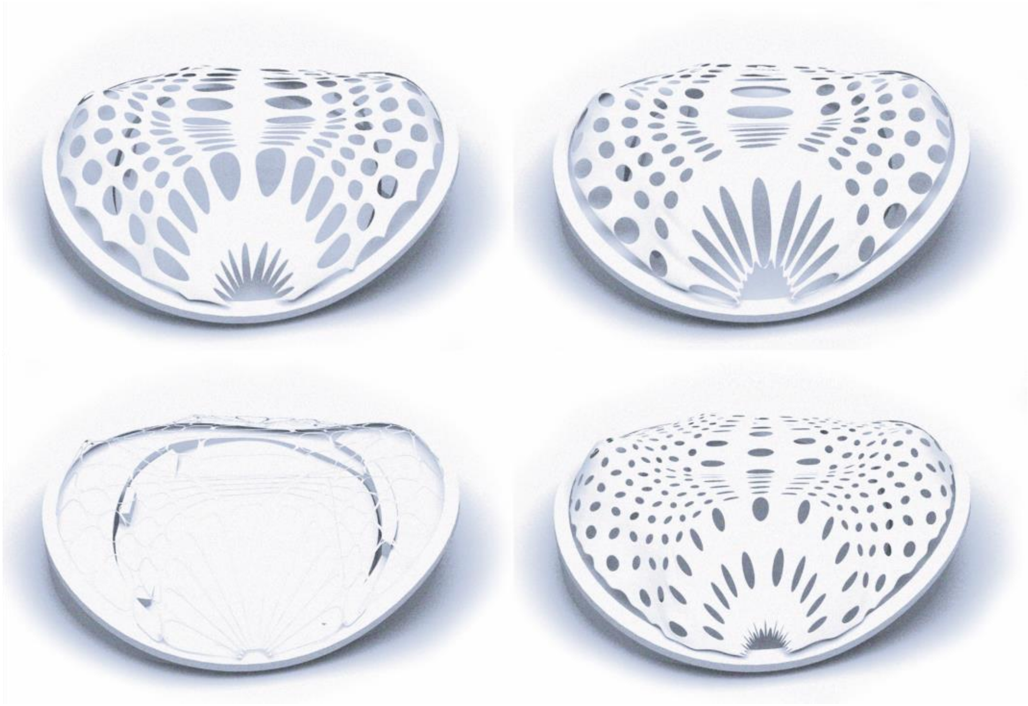
Representation & Clustering SOM

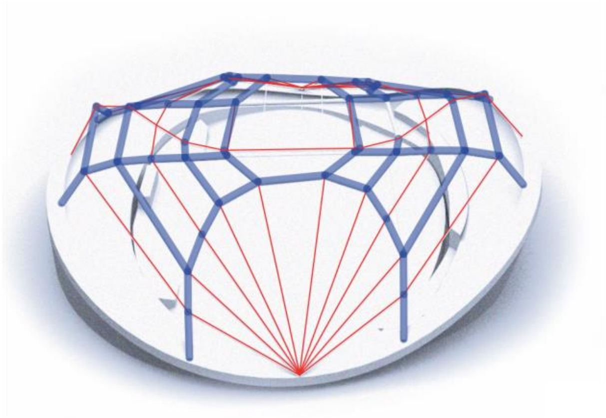
nodes | lengths edges | force | loadpath | HOS nodes | HOS length edges | HOS force | HOS loadpath

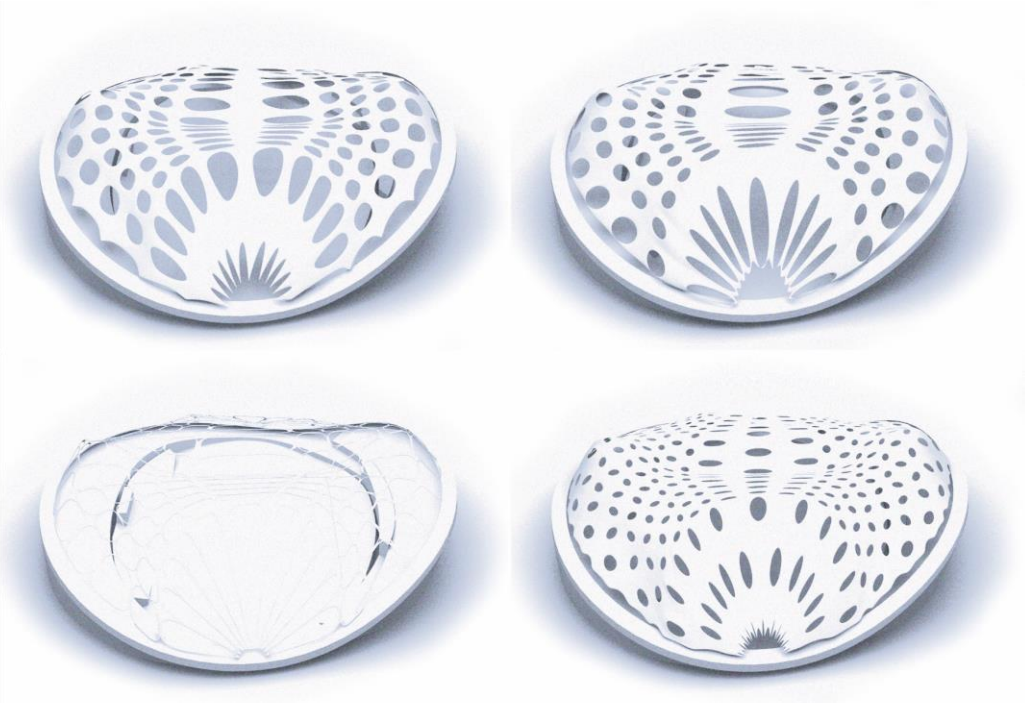
Selection

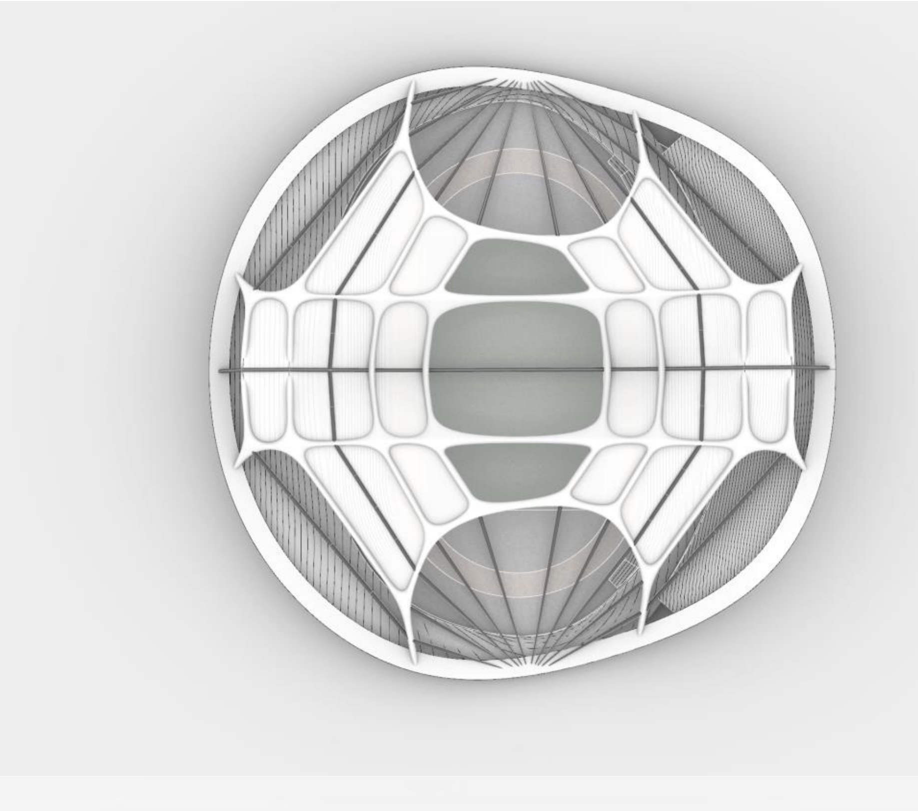












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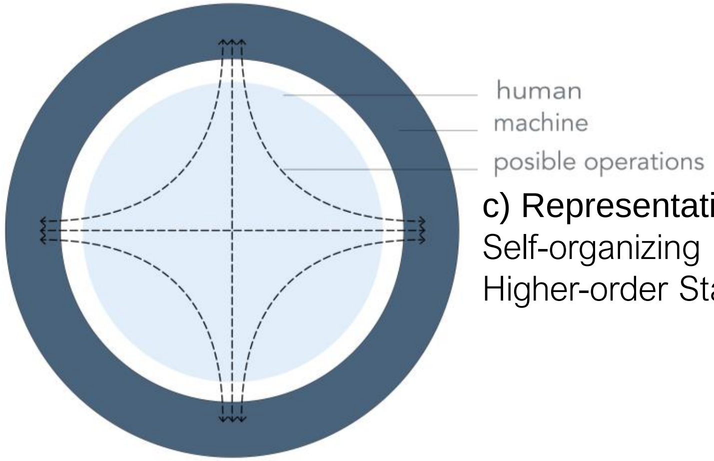
Conclusion

b) Evaluation Quantitative
local stability

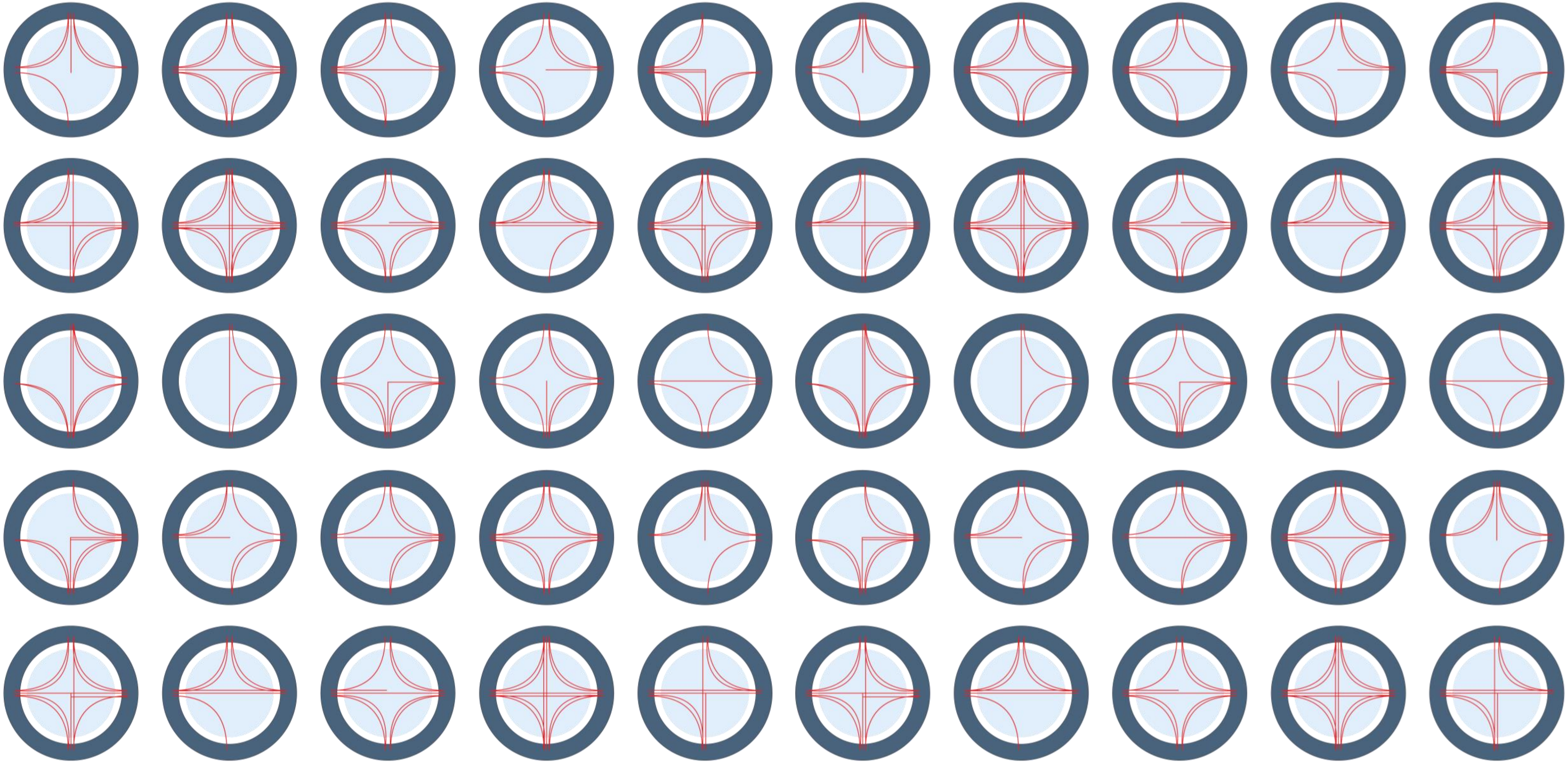
d) Selection Qualitative
Designer



c) Representation/Clustering
Self-organizing Map (SOM)
Higher-order Statistics (HOS)

a)Generation - e) (Re-)Generation
Combinatorial Equilibrium modeling (CEM)
Gradient Boosted Trees (GBT)

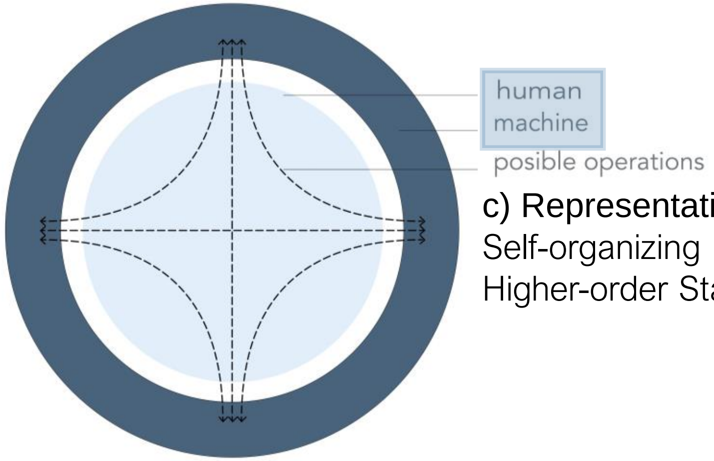
Conclusion



Conclusion

b) Evaluation Quantitative
local stability

d) Selection Qualitative
Designer



c) Representation/Clustering
Self-organizing Map (SOM)
Higher-order Statistics (HOS)

a)Generation - e) (Re-)Generation
Combinatorial Equilibrium modeling (CEM)
Gradient Boosted Trees (GBT)

“Architecture is the art of jointing things together”

Vitruvius

The knowledge of the architect is *furnished with many disciplines and various kinds of learning. Judiciously exercised, it demonstrates everything the other arts achieve. It is* ***brought into being by fabrica and ratiocinatio****.* ***Fabrica*** *is the continuous and routine practice of the activity the hands accomplish out of matter; its off spring* ***is a work whose form is in keeping with its intended purpose. Ratiocinatio is what can show how****, and explain to what degree, things have been made with skill and calculation.*

Vitruvius

Thanks