Optioneering and Optimization Using Generative Design and Evolutionary Solvers

Maciej Wypych

Design Technology Coordinator at BVN

Credits to Matt Wash

Design Technology Coordinator at BVN

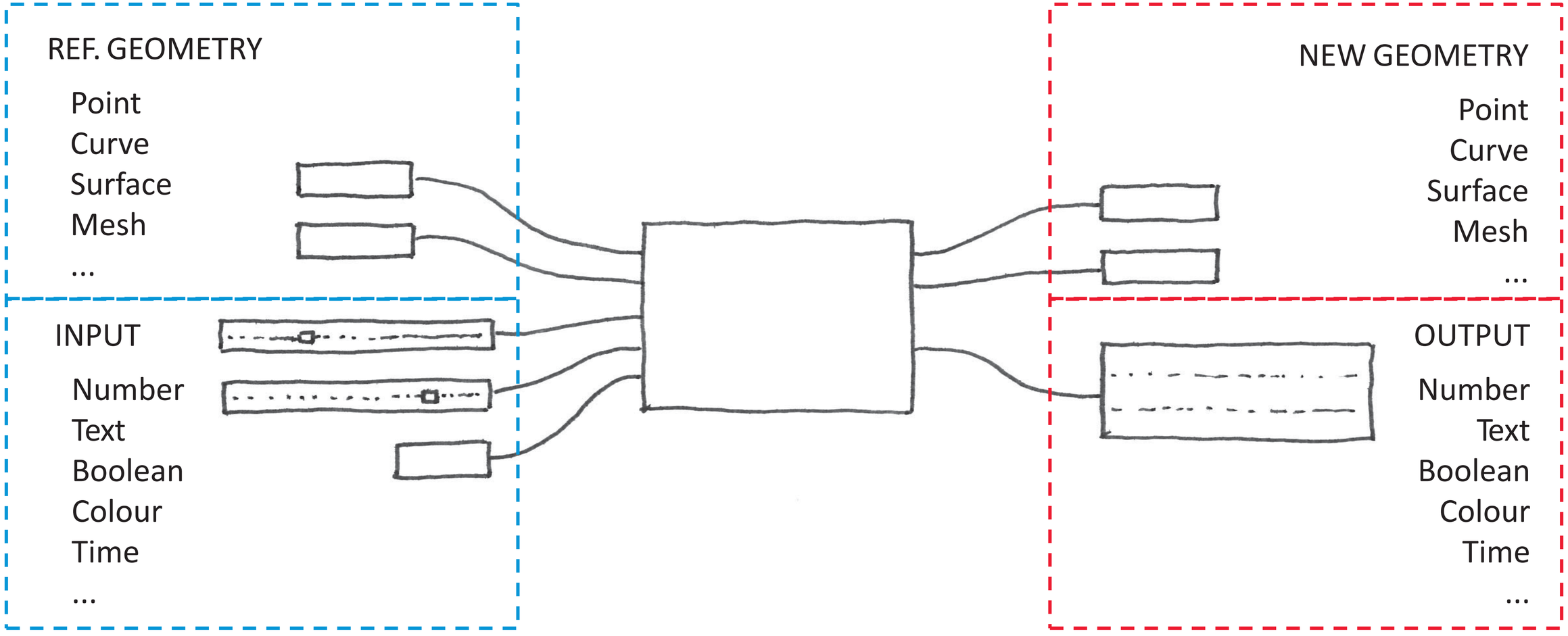
AUTODESK. UNIVERSITY

About the speaker

Maciej Wypych

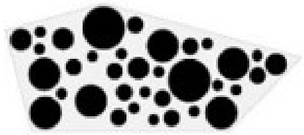
Maciej is a Design Technology Coordinator at BVN, and Design Information Management Sessional Tutor at UNSW. He is a committee member and frequent speaker at Dynamo User Group Sydney as well as BUILT ANZ, Wellington Digital Design User Group and other conferences. He has over 15 years’ experience in the architecture and building industry in Australia and UK. Maciej brings extensive knowledge in architectural design technology, parametric 3d modelling and the rationalization and delivery of geometrical complex designs.

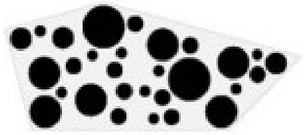
FLOW OF INFORMATION IN A SCRIPT

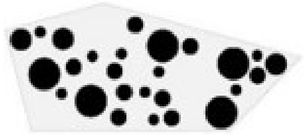


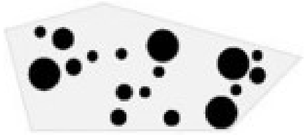
12 CREEK ST. THE ANNEX CEILING, BRISBANE PROJECT

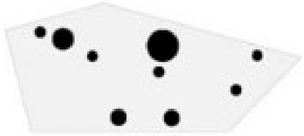
REF. GEOMETRY

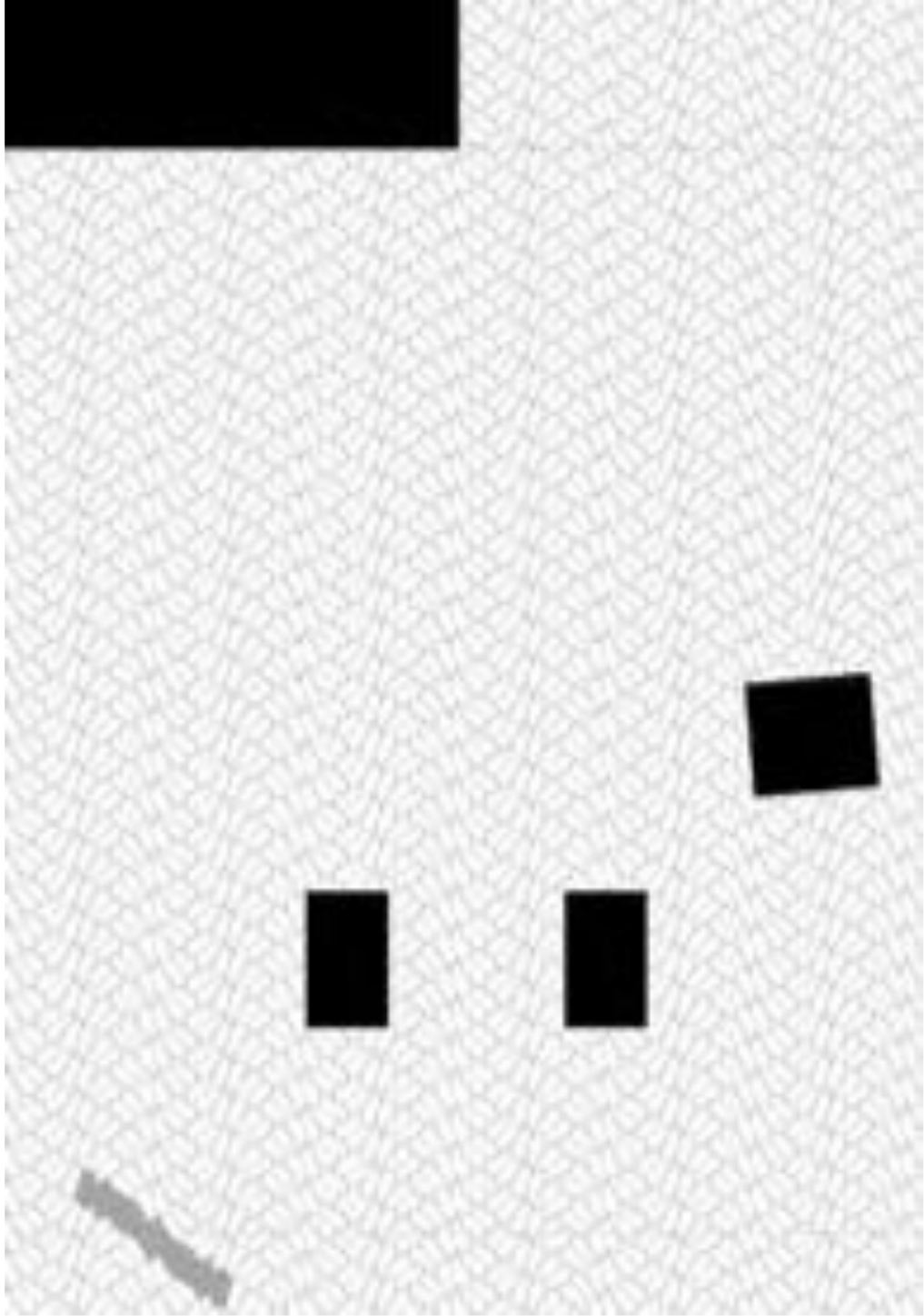












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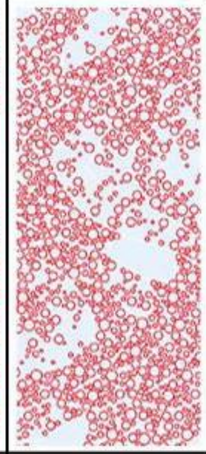
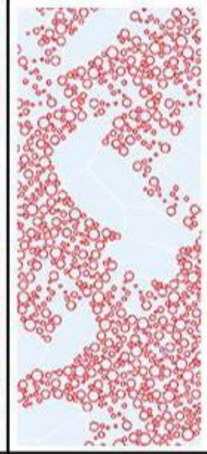
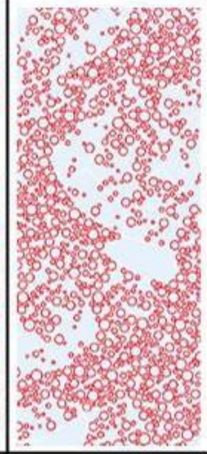
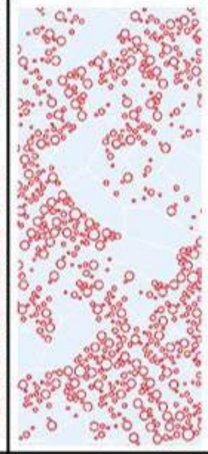
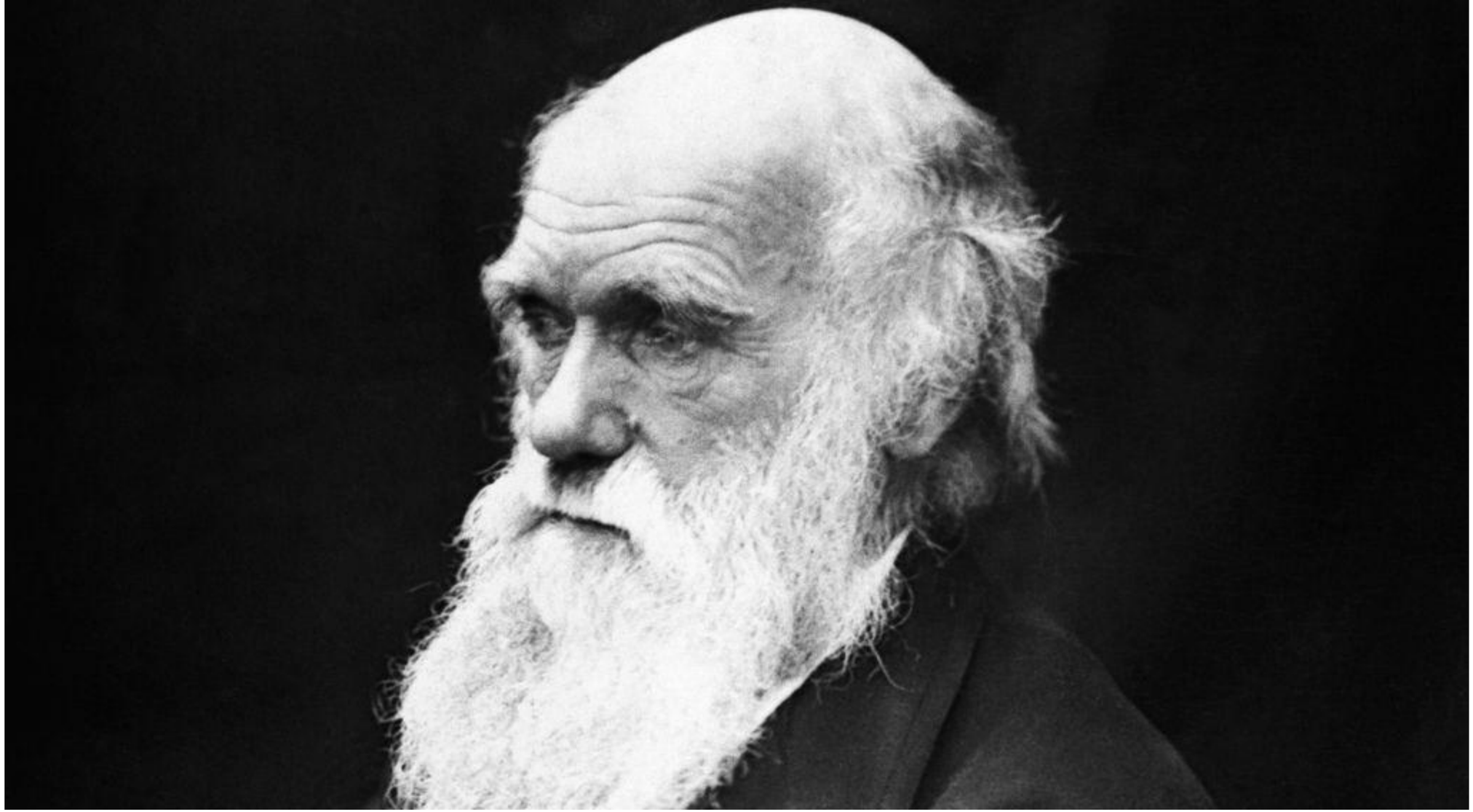
P. 1	7	17	5	29	4	29	3	30	18	0
P. 2	14	17	10	24	4	29	30	3	21	6
P. 3	21	17	14	19	17	17	3	30	24	16
P. 4	35	17	19	14	17	17	30	3	21	25
P .5	21	17	24	10	29	4	3	30	12	31
P. 6	0	17	29	5	29	4	30	3	3	22
RRESULTING GEOMETRY										
HOLES	528.1k	505.2k	353.3k	656.8k	325.4k	684.4k	421.6k	588.8k	613.8k	337.8k
DENSITY	23%	23%	15%	31%	13%	32%	20%	25%	28%	14%

THIS IS OPTIONEERING!!

HOW CAN WE USE THIS INFORMATION TO REACH BETTER SOLUTIONS?



Charles Darwin (1809 - 1882)

I have called this **principle**, by which each slight **variation**, if useful, is preserved, by the term of **Natural Selection**.

EVOLUTIONARY ALGORITHMS SELECT THE BEST OPTIONS
TO GENERATE MORE OPTIONS

GENERATION AFTER GENERATION, THE ALGORITHMS HELP US TO UNDERSTAND THE NATURE OF THE PROBLEM AND FIND OPTIMAL SOLUTIONS TO IT

PRINCIPLES OF BIOLOGIC AND ALGORITHMIC EVOLUTION

VARIATION

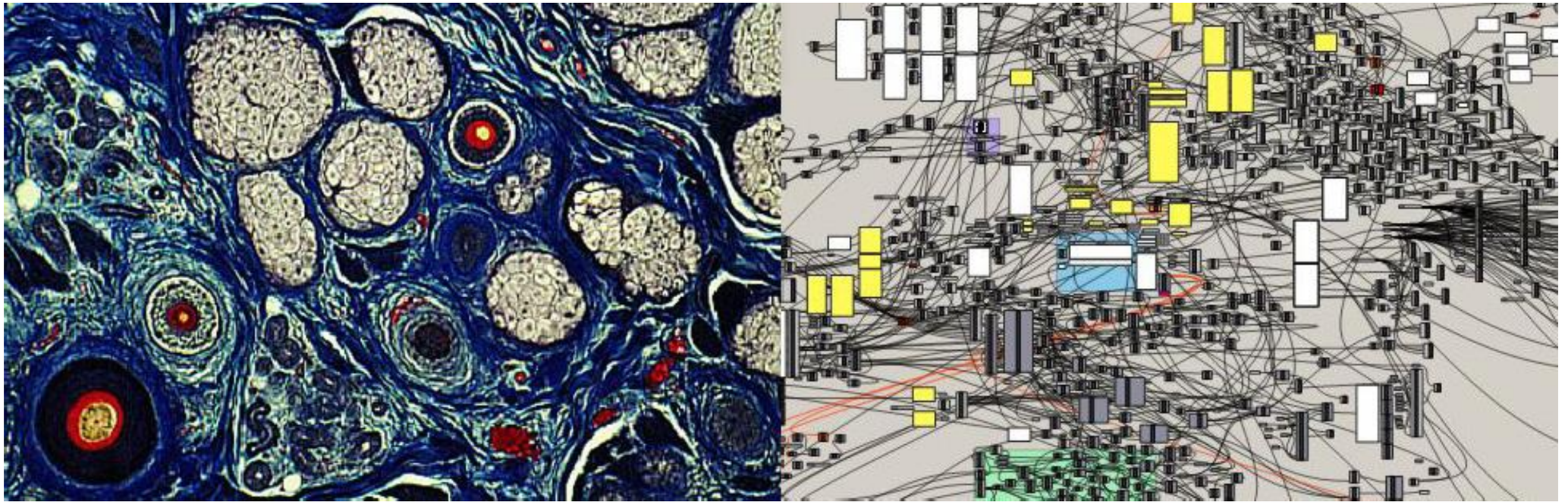
Without it, wouldn’t be possible to pick something that is better than something else

INHERITANCE

Qualities of the individuals are transmitted to the next generations

SELECTION

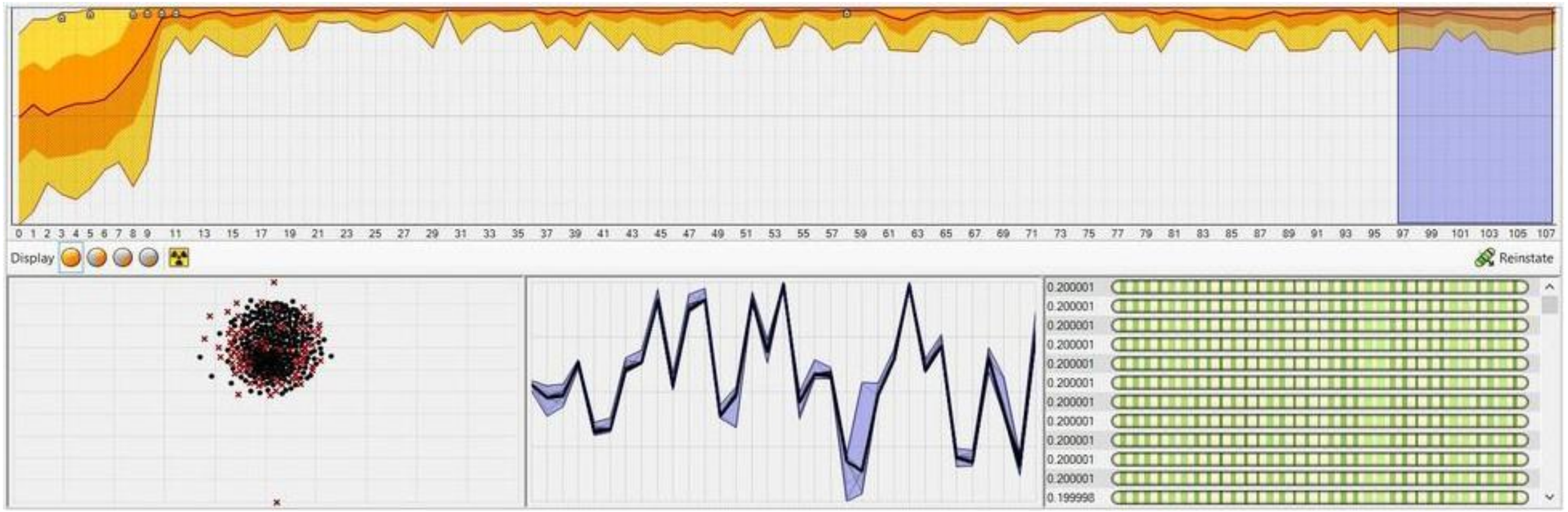
The fittest individuals are likely to survive and have offspring



DIFFERENCES BETWEEN BIOLOGICAL AND ALGORITHMIC EVOLUTION

- **Changing** environment
- **Complex** interactions
- **Complex gender** reproduction processes
- **High degree** of arbitrariness
- **Millions** of variables

- **Stable** environment
- **Limited** interactions
- **No gender**
- **Simulated** arbitrariness
- **Limited** variables



PROS AND CONS OF EVOLUTIONARY SOLVERS

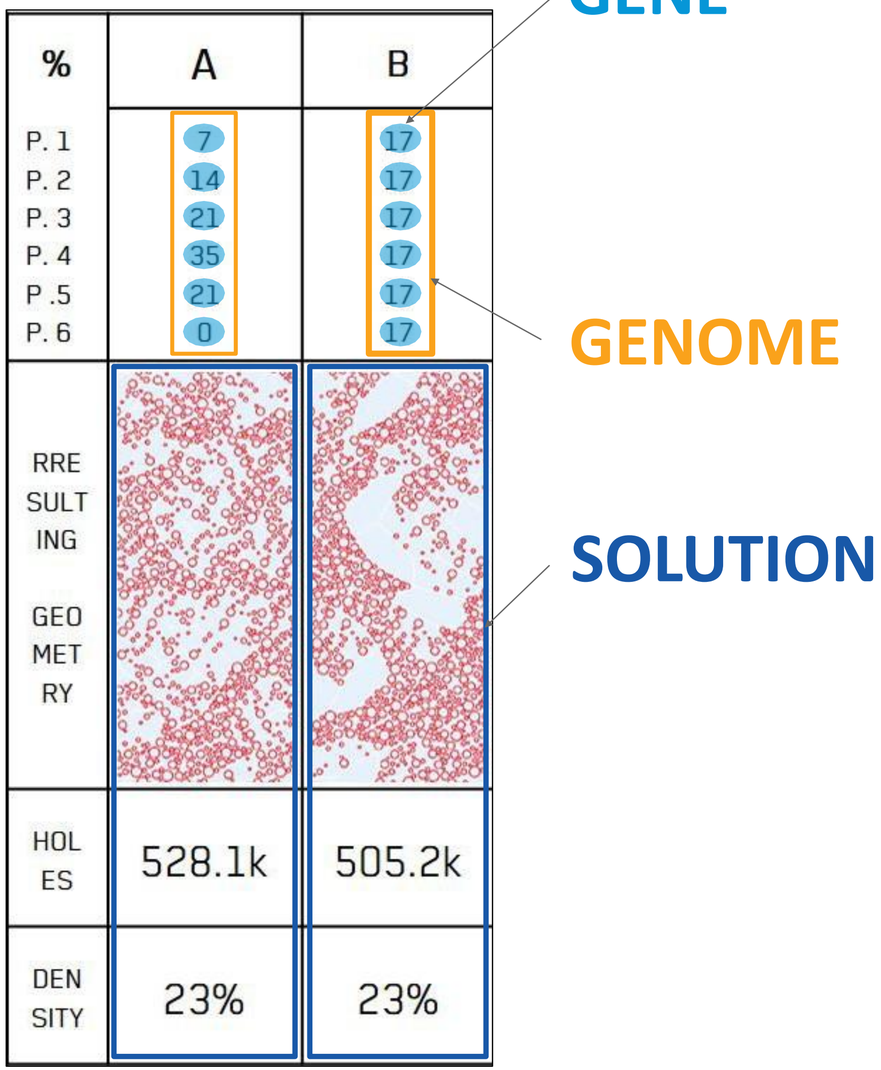
- Flexible
- Progressive
- Forgiving
- Interactive

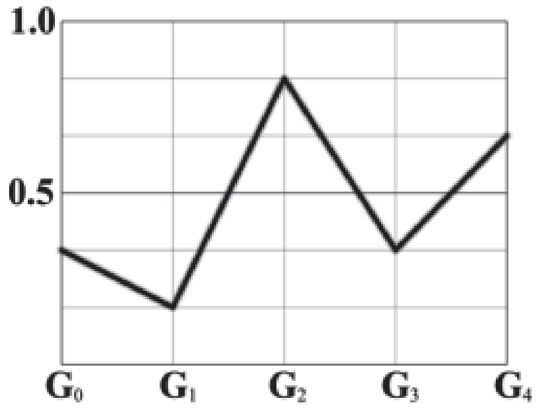
- Slow
- No Guaranteed Solution

WHAT IS A GENE AND A GENOME?

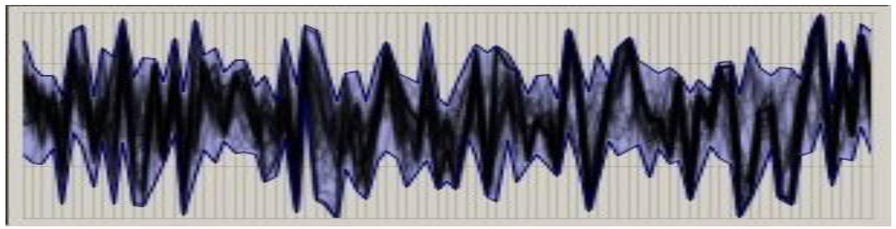
A GENE IS A VARIABLE

A COMBINATION OF GENES IS A GENOME, WHICH OUTPUTS A UNIQUE SOLUTION





Representation of a genome



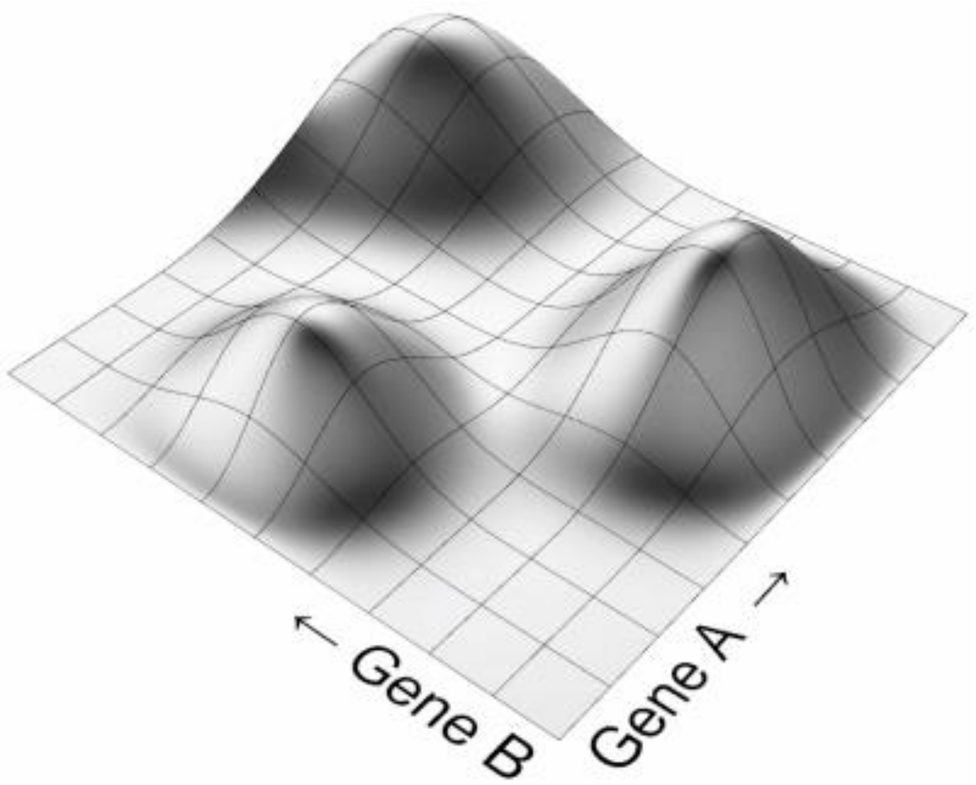
Combination of genomes

WHAT IS A FIT GENOME AND A FITNESS LANDSCAPE?

FITNESS is whatever we want it to be.
We are trying to solve a specific problem, and therefore we know what it means to be fit.

A **FIT GENOME** outputs a better solution to a problem than other genomes.

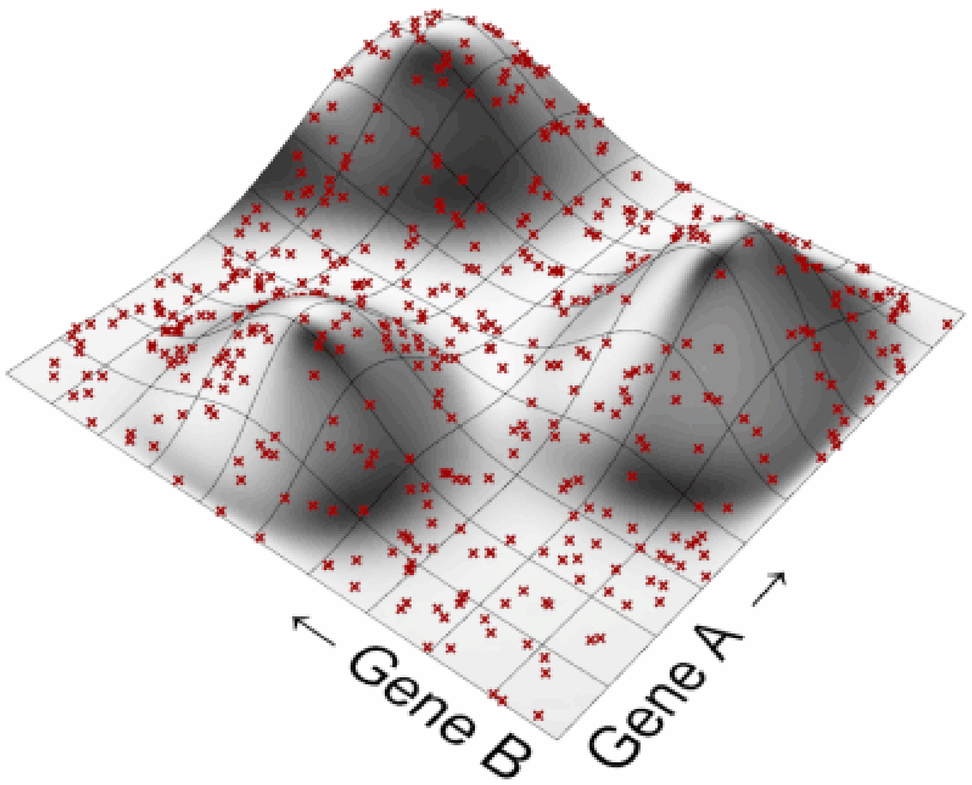
All the possible solutions conform a **FITNESS LANDSCAPE**, which represents the nature of the problem that we are trying to solve.



Fitness Landscape containing 2 genes or variables (A and B)

Unknown at the beginning of the process

https://www.grasshopper3d.com/profiles/blogs/evolutionary-principles



Start

Random population to approximate the nature of the Fitness Landscape

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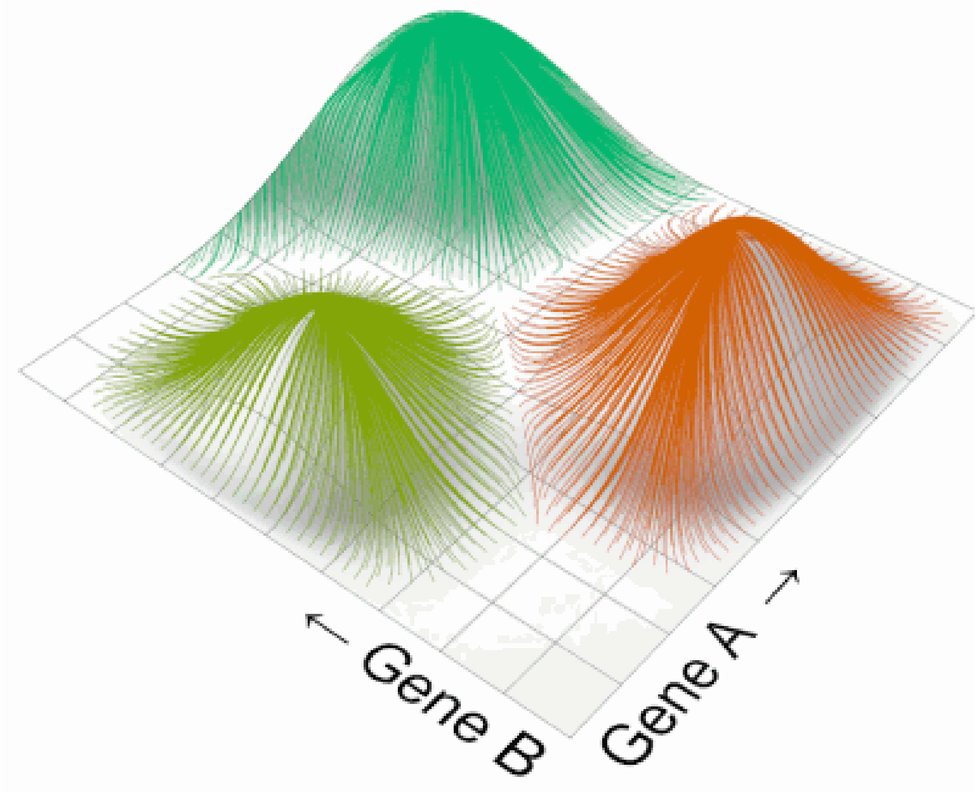
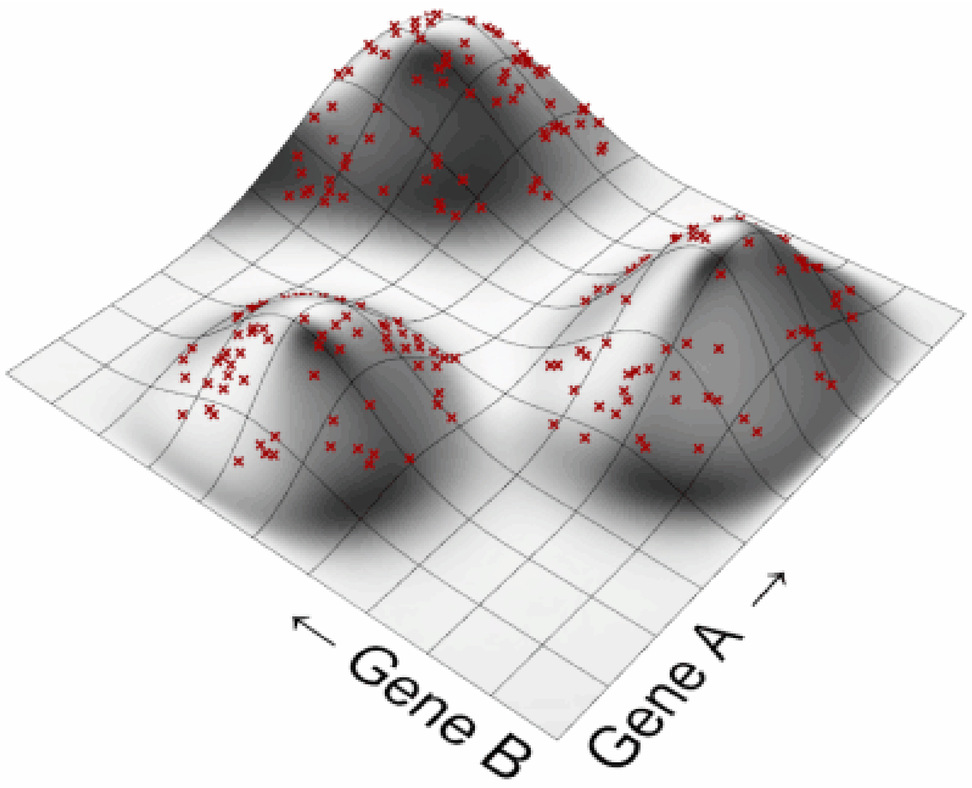


Basin of Attraction

Determine in which direction genomes should travel

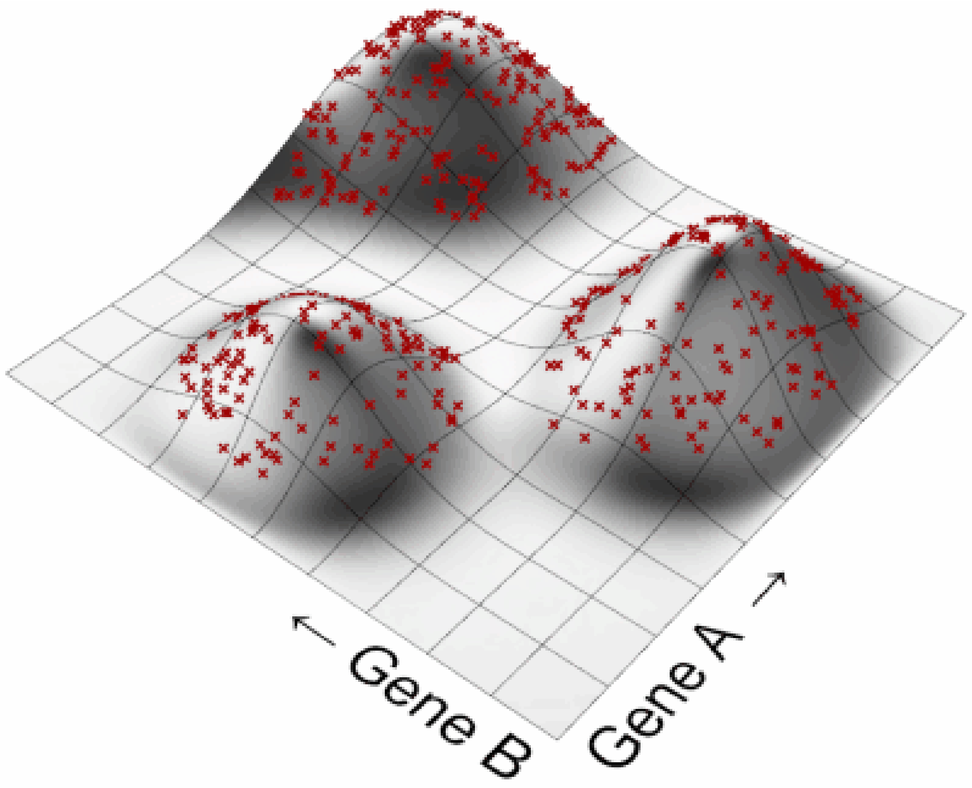
https://www.grasshopper3d.com/profiles/blogs/evolutionary-principles



Selection

Only the fittest genomes survive

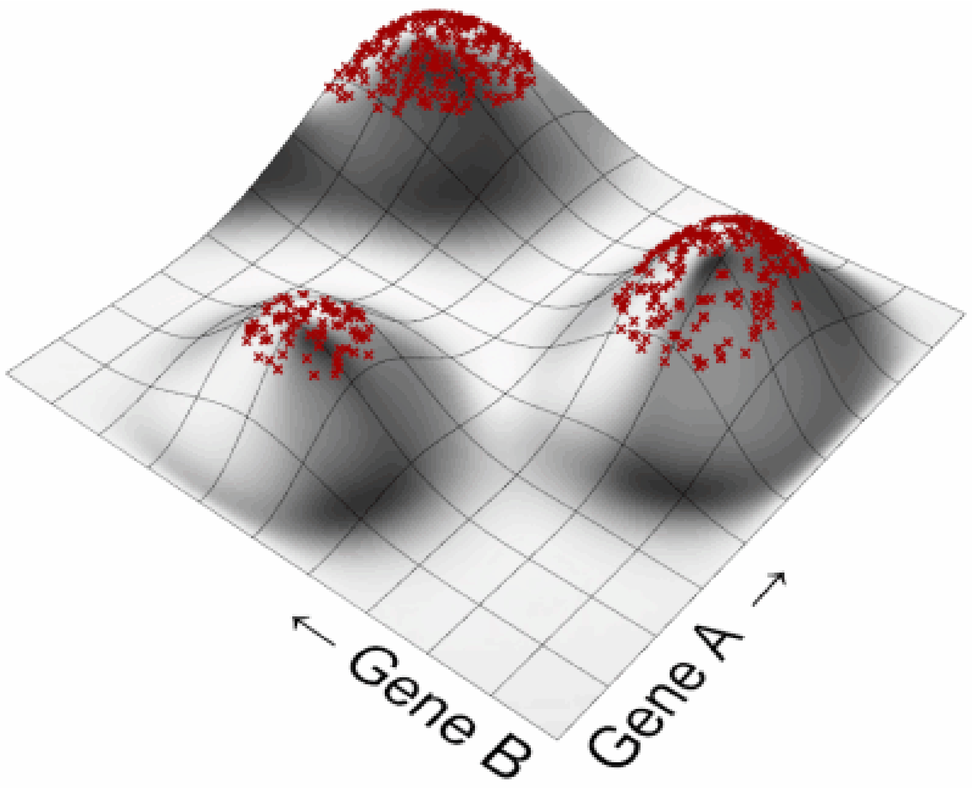
https://www.grasshopper3d.com/profiles/blogs/evolutionary-principles



New Generation

Defined by fittest genomes and basin of attraction

https://www.grasshopper3d.com/profiles/blogs/evolutionary-principles



Subsequent Generations

The process repeats until satisfactory solutions are found (or not)

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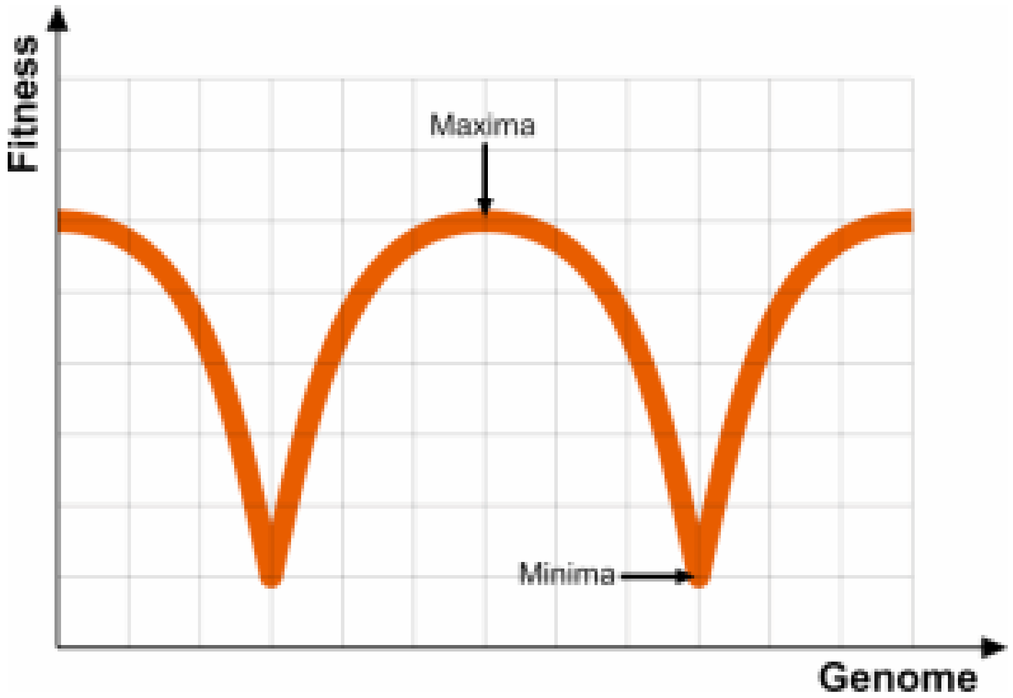
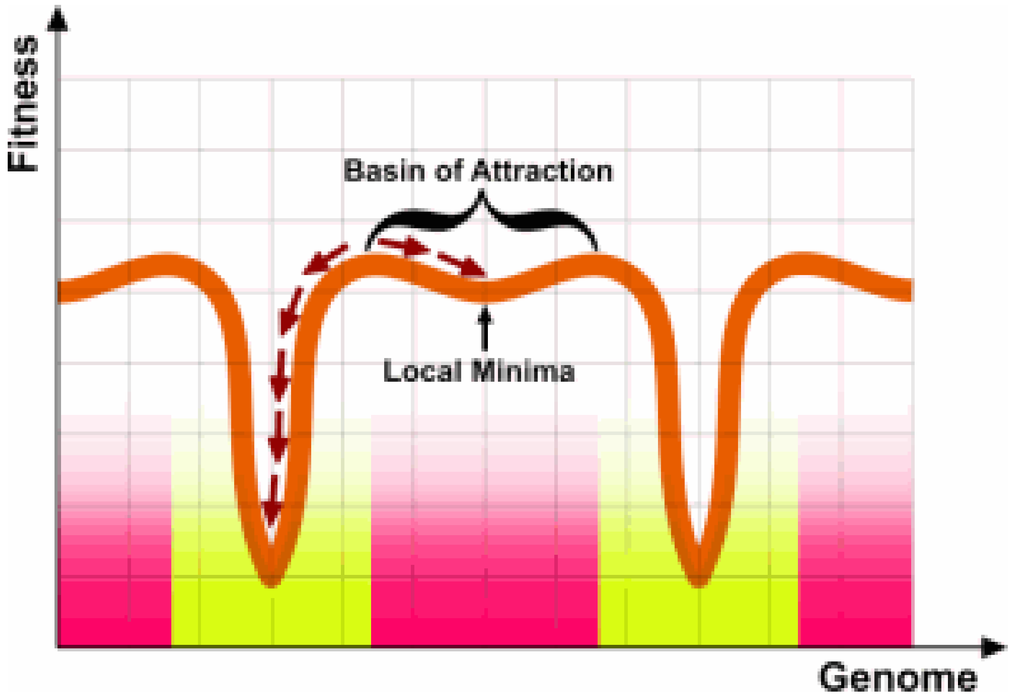
FITNESS LANDSCAPES



Simple

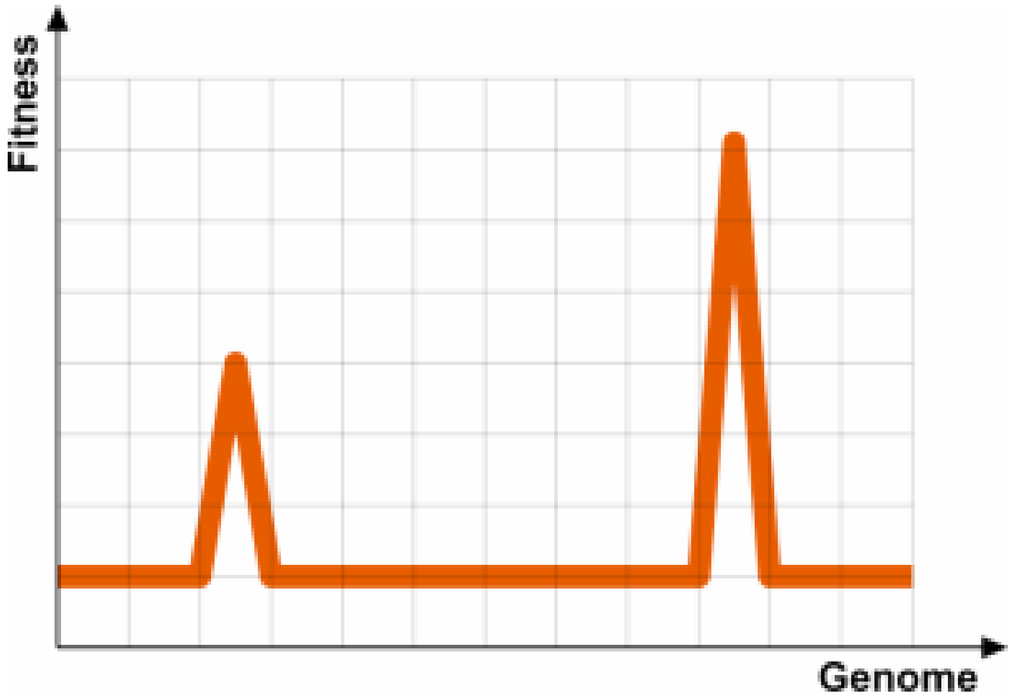
Basins of attraction will always take you to an optimal result

https://www.grasshopper3d.com/profiles/blogs/evolutionary-principles



Complex

Half of the landscape dominated by a basin that attracts to a poor solution



Small Basins

Low chances of finding a (good) peak

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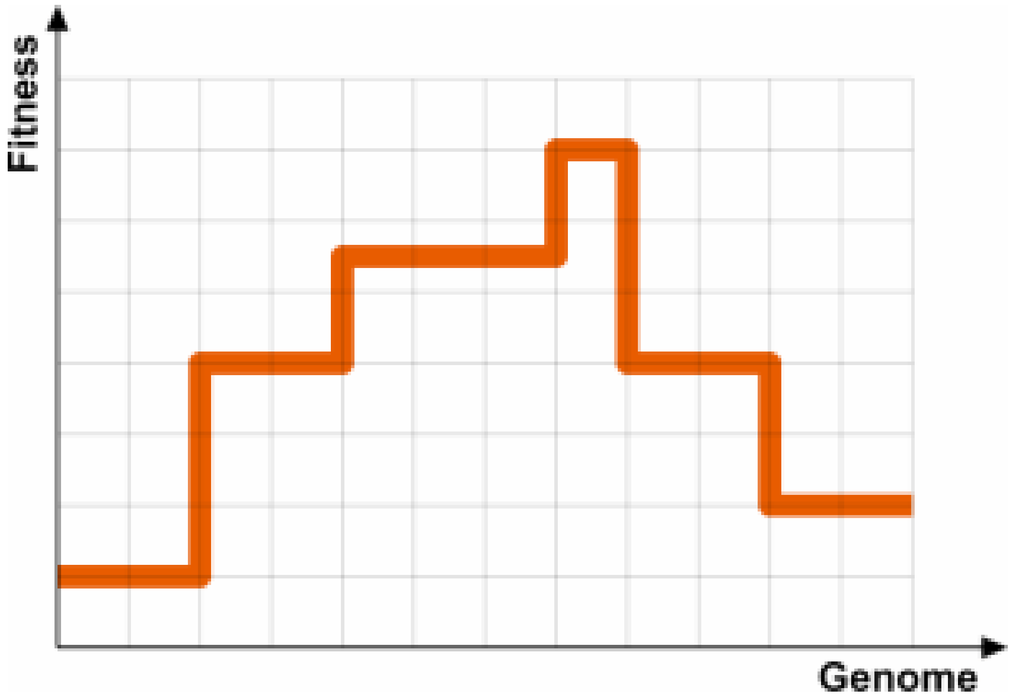

Discontinuous

Plateaus without ‘improvement’. No basin to an optimal solution

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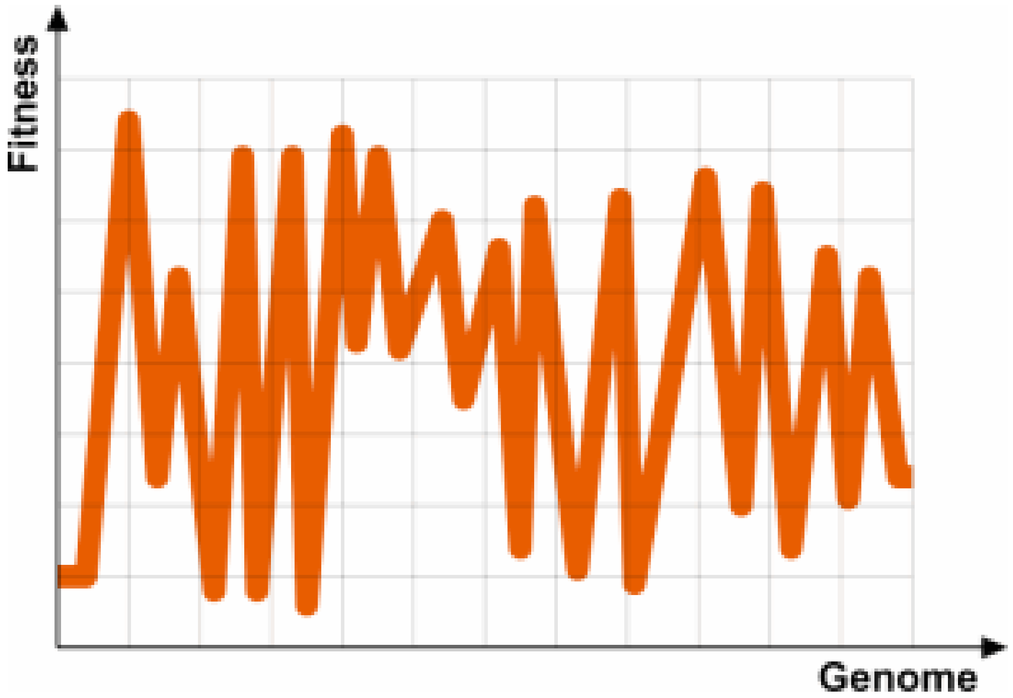


Noisy or Chaotic

Impossible to make any intelligible pronunciations regarding the fitness of a local patch

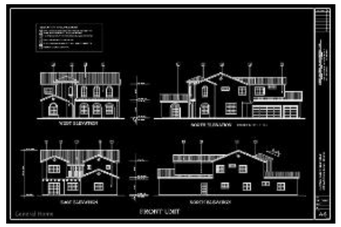
https://www.grasshopper3d.com/profiles/blogs/evolutionary-principles

TRADITIONAL DESIGN
RECORDING DECISIONS

PARAMETRIC DESIGN
ASSOCIATING GEOMETRY

GENERATIVE DESIGN
DESCRIBING GOALS + CONSTRAINTS

COMPUTER AIDED DRAFTING

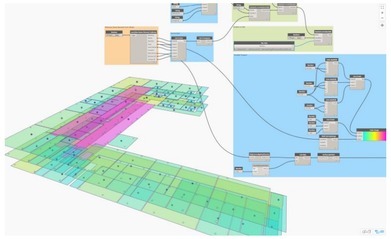


AUTOCAD

PARAMETRIC MODELING

REVIT

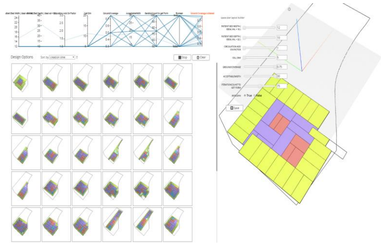
VISUAL PROGRAMMING



DYNAMO

GRASSHOPPER (RHINO INSIDE)

OPTION GENERATION



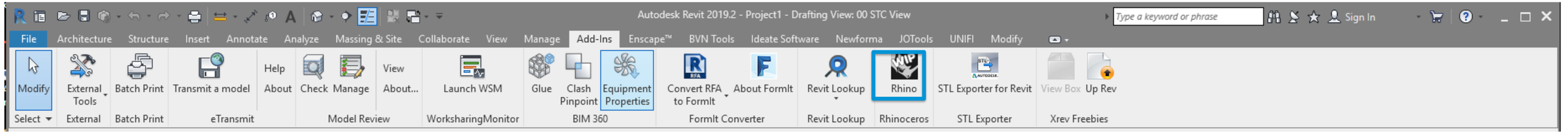
DESIGN OPTIMIZATION

REFINERY

GALAPAGOS

OCTOPUS

WALLACEI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Add-Ins
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Ideate Software
Newforma
JOTools
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Batch Print
Transmit a model
Help
About
Check
Manage
View
About...
Launch WSM
Glue
Clash Pinpoint
Equipment Properties
Convert RFA to FormIt
About FormIt
Revit Lookup
Rhino
STL Exporter for Revit
View Box
Up Rev
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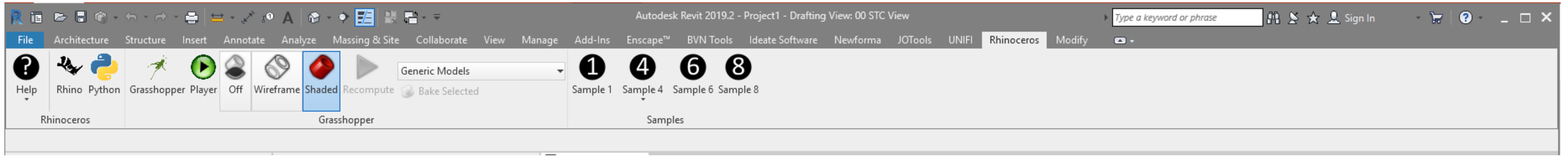
Revit Lookup
Rhinoceros
STL Exporter
Xrev Freebies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Enscape™
BVN Tools
Ideate Software
Newforma
JOTools
UNIFI
Rhinoceros
Modify
Help
Rhino
Python
Grasshopper
Player
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Wireframe
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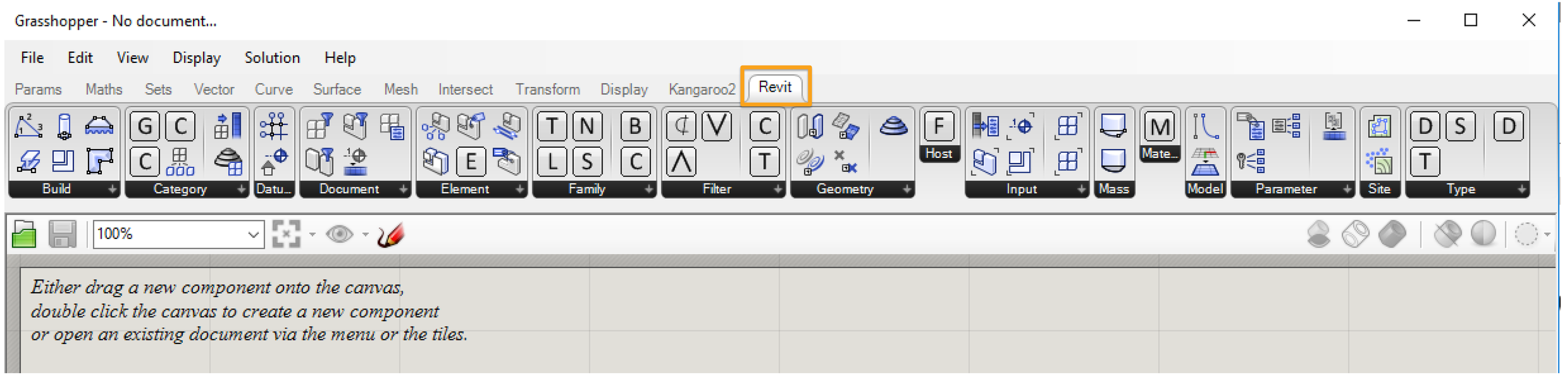
Sample 1
Sample 4
Sample 6
Sample 8
Rhinoceros
Grasshopper
Samples


Grasshopper - No document...
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Kangaroo2
Revit
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Type
100%
Either drag a new component onto the canvas,
double click the canvas to create a new component
or open an existing document via the menu or the tiles.

File | Architecture | Structure | Insert | Annotate | Analyze | Massing & Site | Collaborate | View | Manage | Add-Ins | Enscape™ | BVN Tools | Ideate Software

Help | Rhino | Python | Grasshopper | Player | Off | Wireframe | Shaded | Recompute | Generic Models | Bake Selected | Sample 1 | Sample 4 | Sample 6 | Sample 8

Rhinoceros | Grasshopper | Samples

Modify | Walls

Project Brow...

Views (

CO

10

DC

10

21

30

40

49

50

53

56

57

58

60

62

63

69

MC

ST

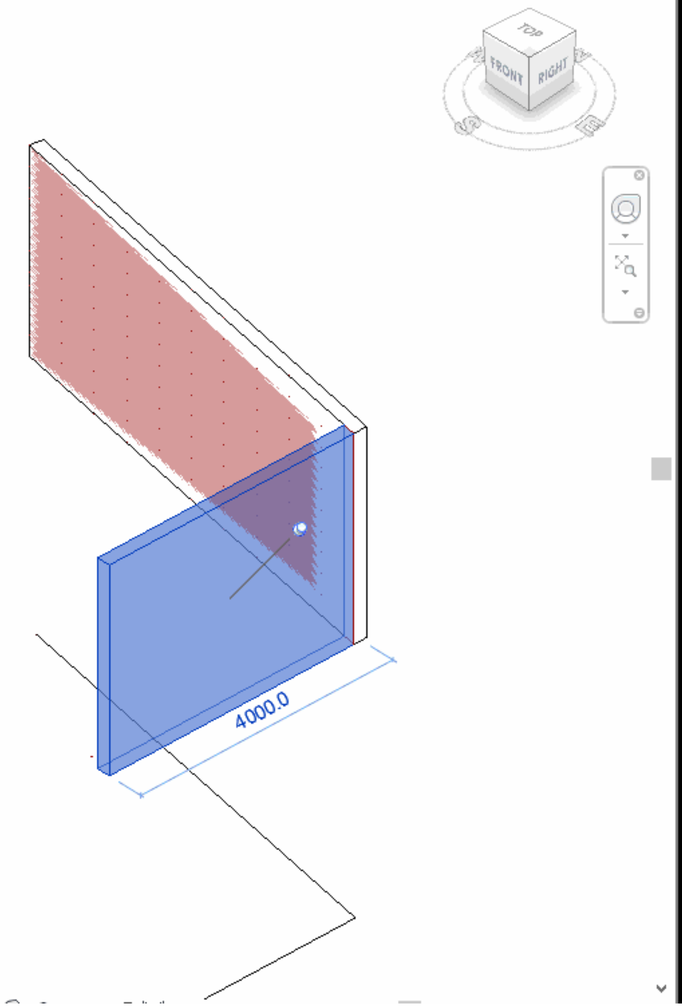
Properties

Basic Wall
Concept_200mm

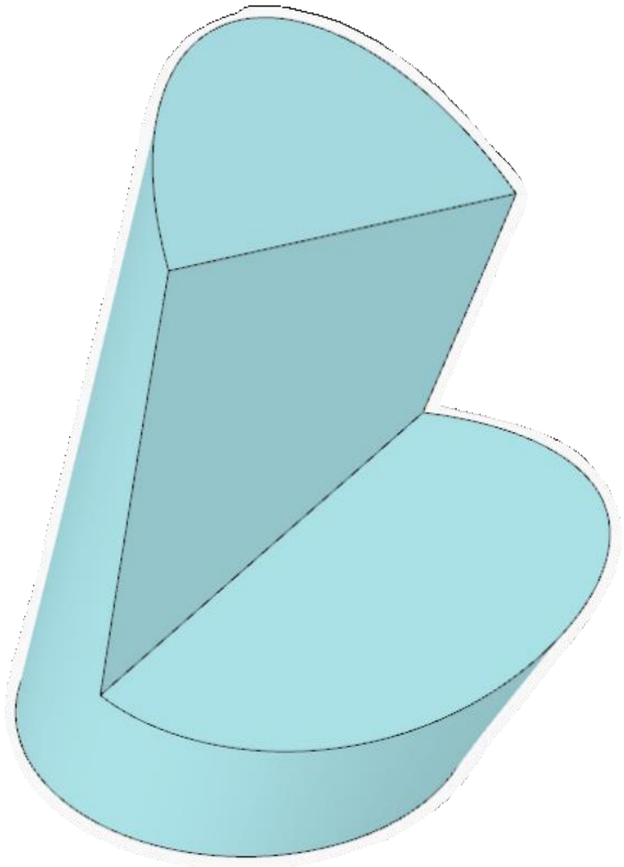
Walls (1) | Edit Type

Constraints	
Location Line	Wall Centerline
Base Constraint	LEVEL 01
Base Offset	0.0
Base is Attached	
Base Extension ...	0.0
Top Constraint	Unconnected
Unconnected H...	3000.0
Top Offset	0.0
Top is Attached	
Top Extension ...	0.0
Room Bounding	☑
Related to Mass	
Text	
Acoustic Rating	
Structural	
Structural	☐
Enable Analytic...	
Structural Usage	Non-bearing
Dimensions	
Length	4000.0
Area	11.748 m²
Volume	2.339 m³
Identity Data	
Image	
Comments	
Mark	
Phasing	
Phase Created	New Construction
Phase Demolish...	None

00 STC View | {3D}

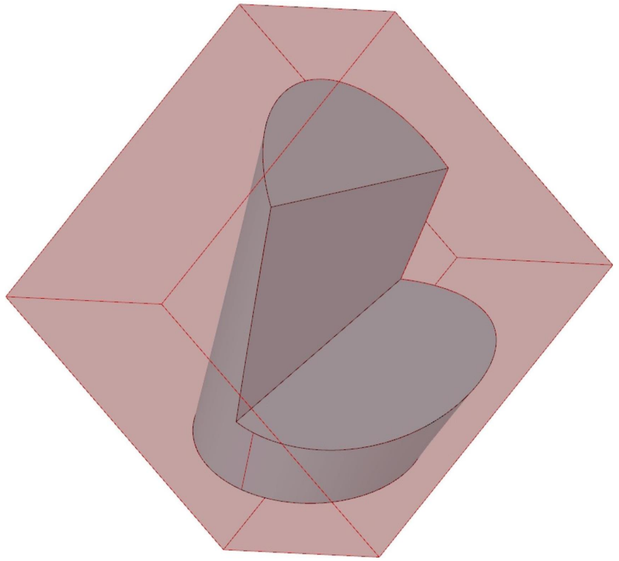


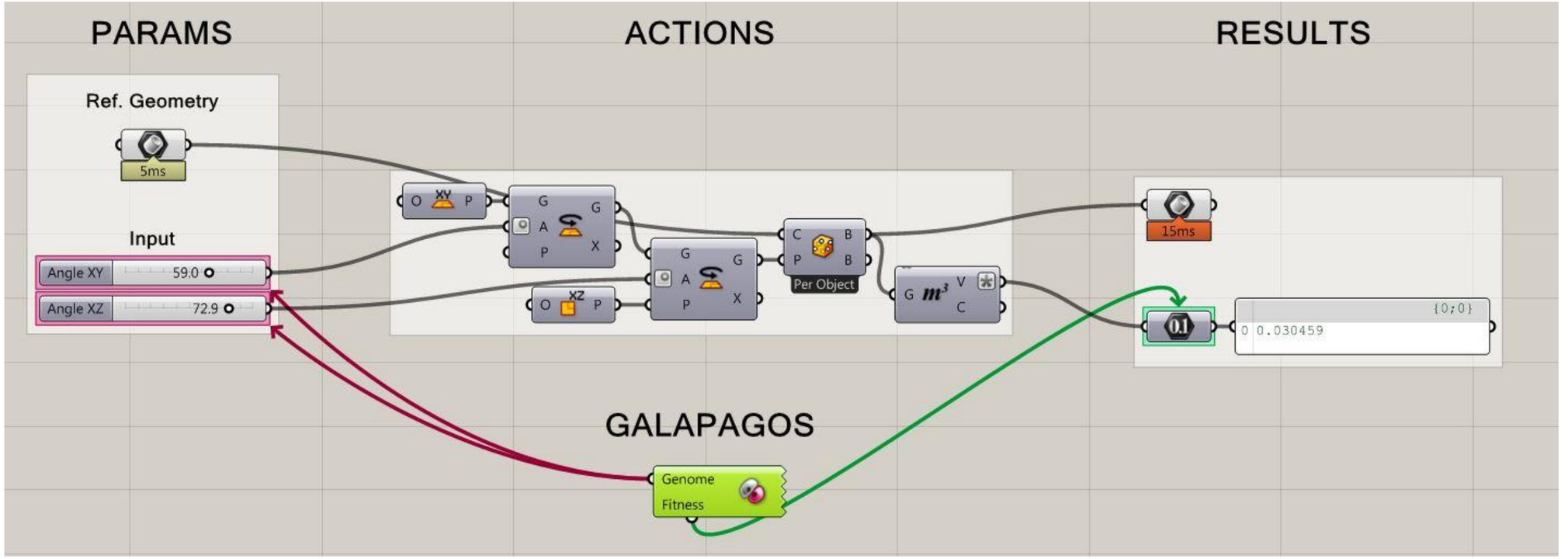
SINGLE OBJECTIVE OPTIMIZATION
GALAPAGOS FOR GRASSHOPPER



CASE 1

Minimum Volume Bounding Box




PARAMS
ACTIONS
RESULTS
Ref. Geometry
5ms
Input
Angle XY
59.0
Angle XZ
72.9
XY
XZ
Per Object
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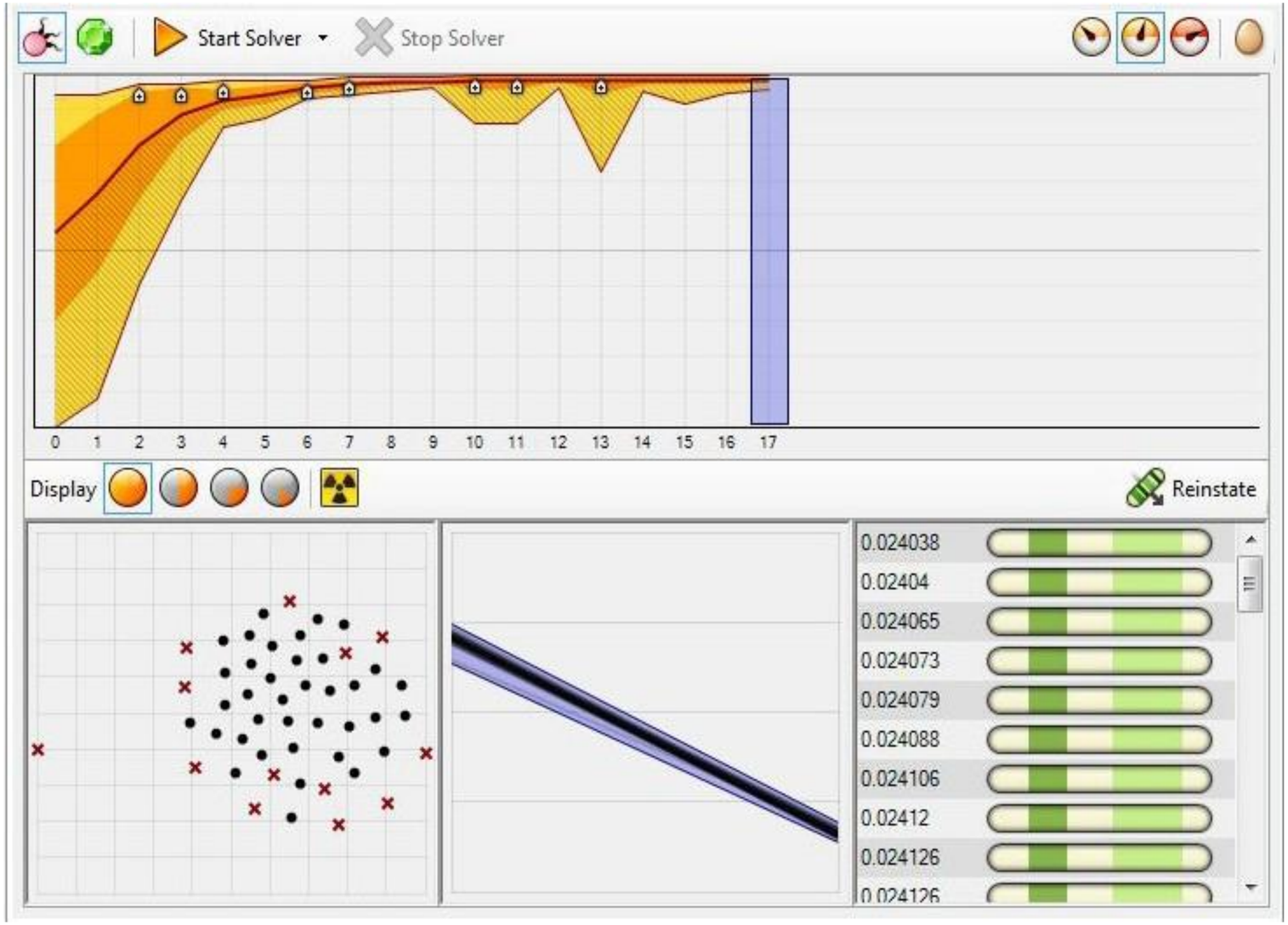
GALAPAGOS
Genome
Fitness

EVOLUTION

GENERATION

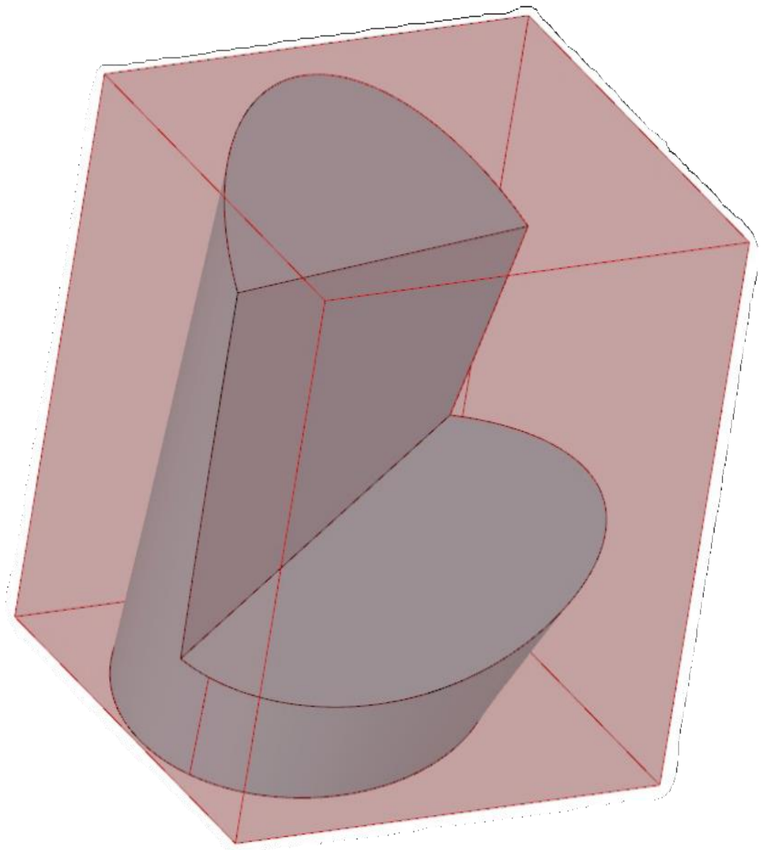


GENOMES INTERACTION

GENE A (Angle XY)

GENE B (Angle XZ)

BEST GENOMES



OPTIMAL SOLUTION

ANGLE XY = 63.3 | ANGLE XZ = 14.2 | VOLUME = 0.24 m^3

File | Architecture | Structure | Insert | Annotate | Analyze | Massing & Site | Collaborate | View | Manage | Add-Ins | Enscape™ | BVN Tools | Ideate Software

Modify | Cope | Cut | Join | Paste | Edit Family

Select | Properties | Clipboard | Geometry | Modify | View | Measure | Create | Mode

Modify | Duct Fittings

Project Brow...

Views (

CO

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STA

Properties

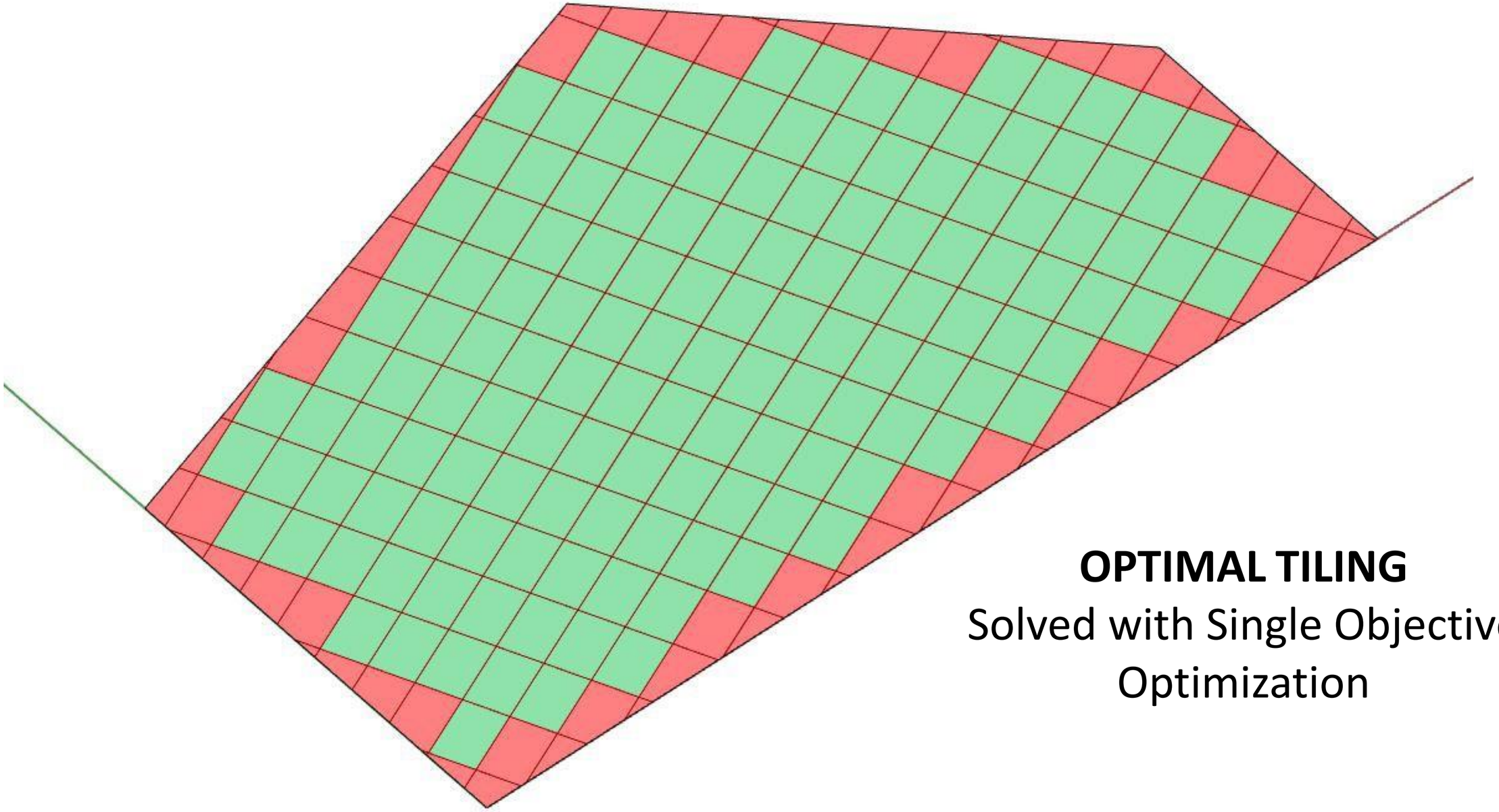
Duct Fitting_Oval_Shoe Branch_Flanged_DUC Standard

Duct Fittings (1) | Edit Type

Constraints	
Level	LEVEL 00
Host	Level : LEVEL 00
Offset	-53.7
Graphics	
Use Annotatio...	
Dimensions	
Takeoff Lengt...	300.0000 mm
Takeoff Length	200.0000 mm
Takeoff Fixed ...	200.0000 mm
Flange Width	400.0 mm
Flange Thickn...	5.0 mm
Flange Height	350.0 mm
Flange Extensi...	50.0 mm
Duct Width 2	300.0 mm
Duct Width 1	500.0 mm
Duct Height	250.0 mm
Angle	45.00°
Size	300 mm/250 m...
Mechanical	
System Classif...	Undefined
System Type	Undefined
System Name	
System Abbre...	
Loss Method	Coefficient fro...
Loss Method ...	Edit...
Mechanical - Flow	
Pressure Drop	
Identity Data	
Image	
Comments	
Mark	
Phasing	
Phase Created	New Construct...
Phase Demoli...	None
Insulation	
Overall Size	300 mm/250 m...
Insulation Thi...	0.0 mm

00 STC View | {3D}

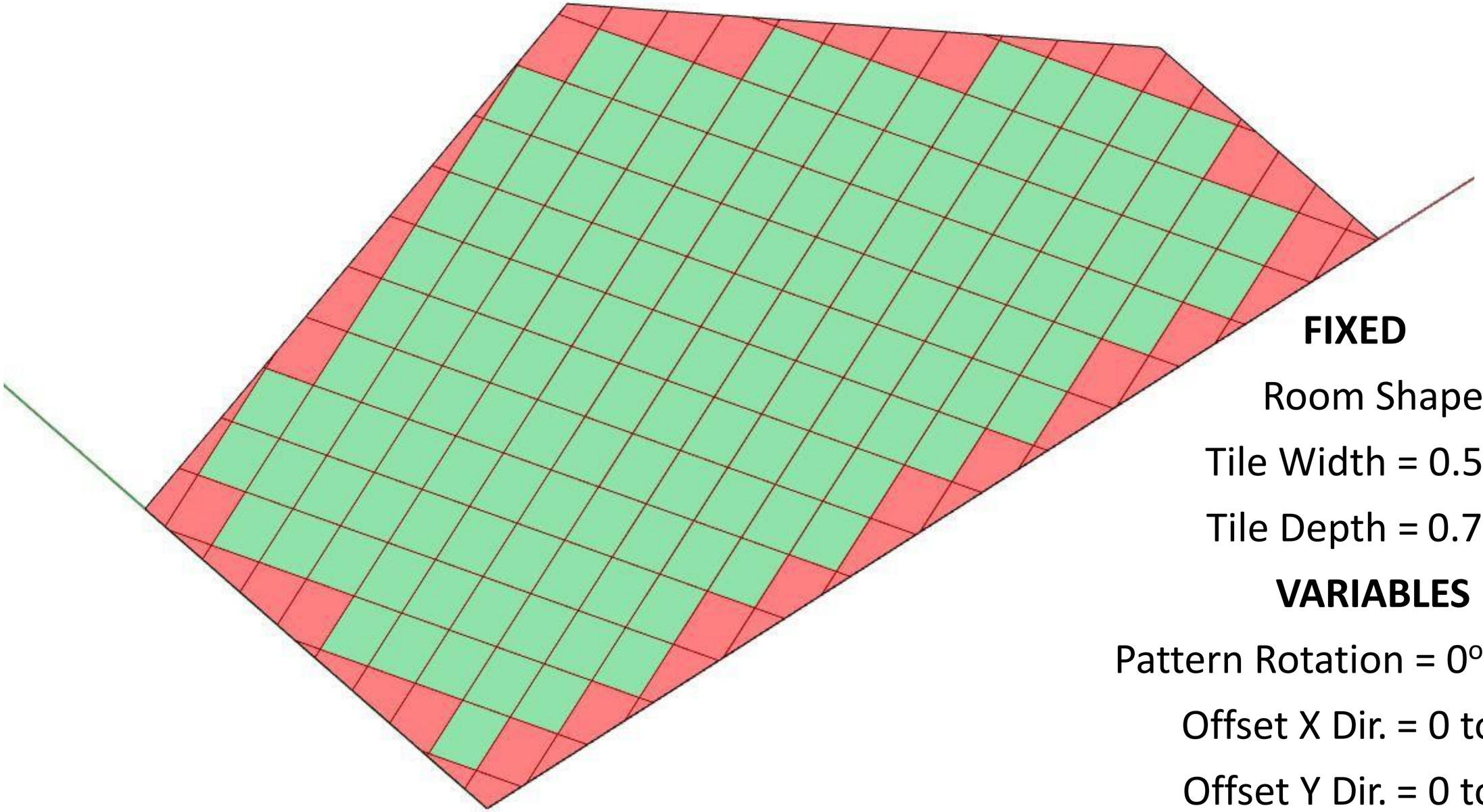
TOP FRONT



OPTIMAL TILING

Solved with Single Objective Optimization

PARAMETERS



FIXED

Room Shape

Tile Width = 0.50m

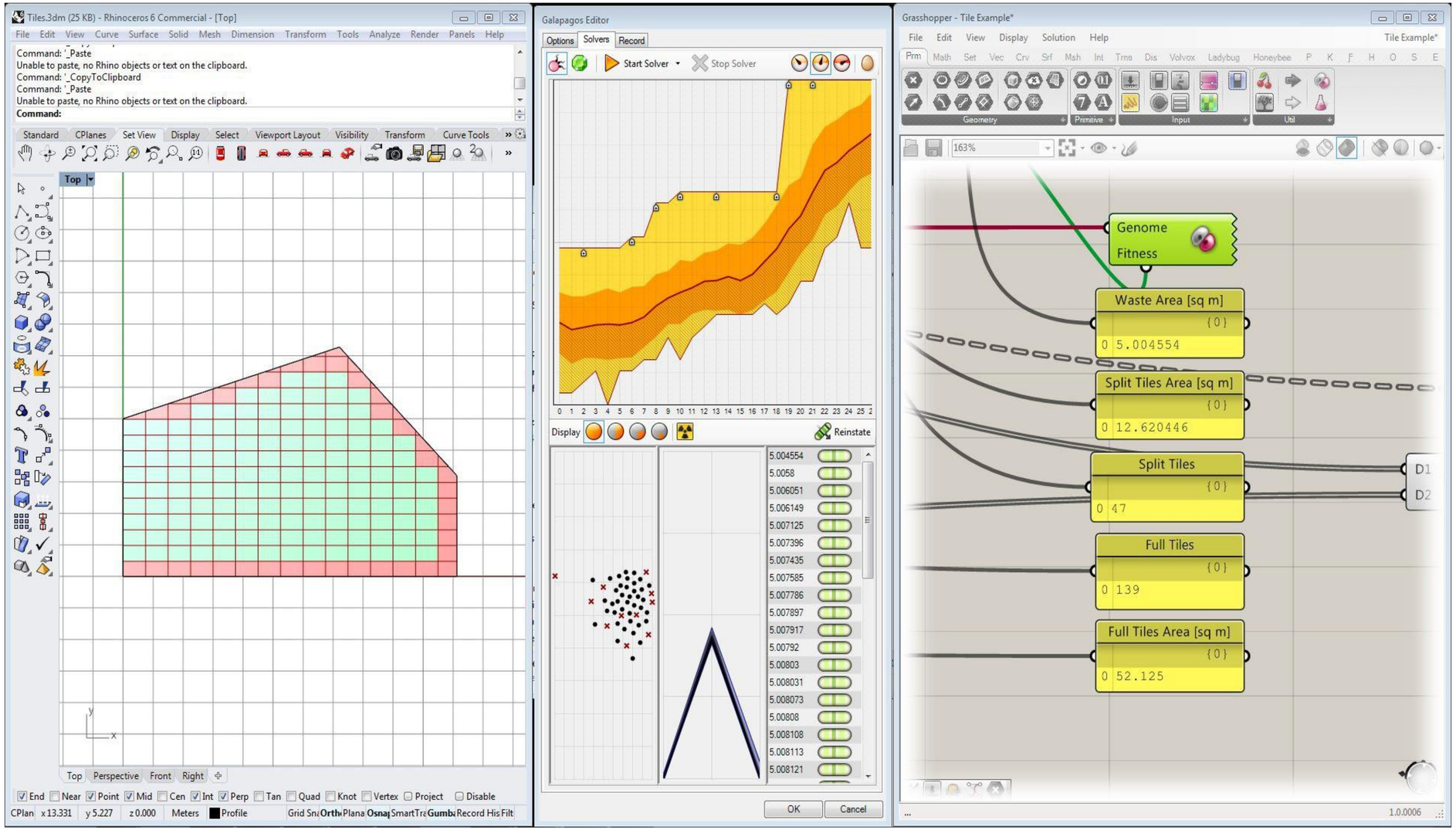
Tile Depth = 0.75m

VARIABLES

Pattern Rotation = 0^{o} to 90^{o}

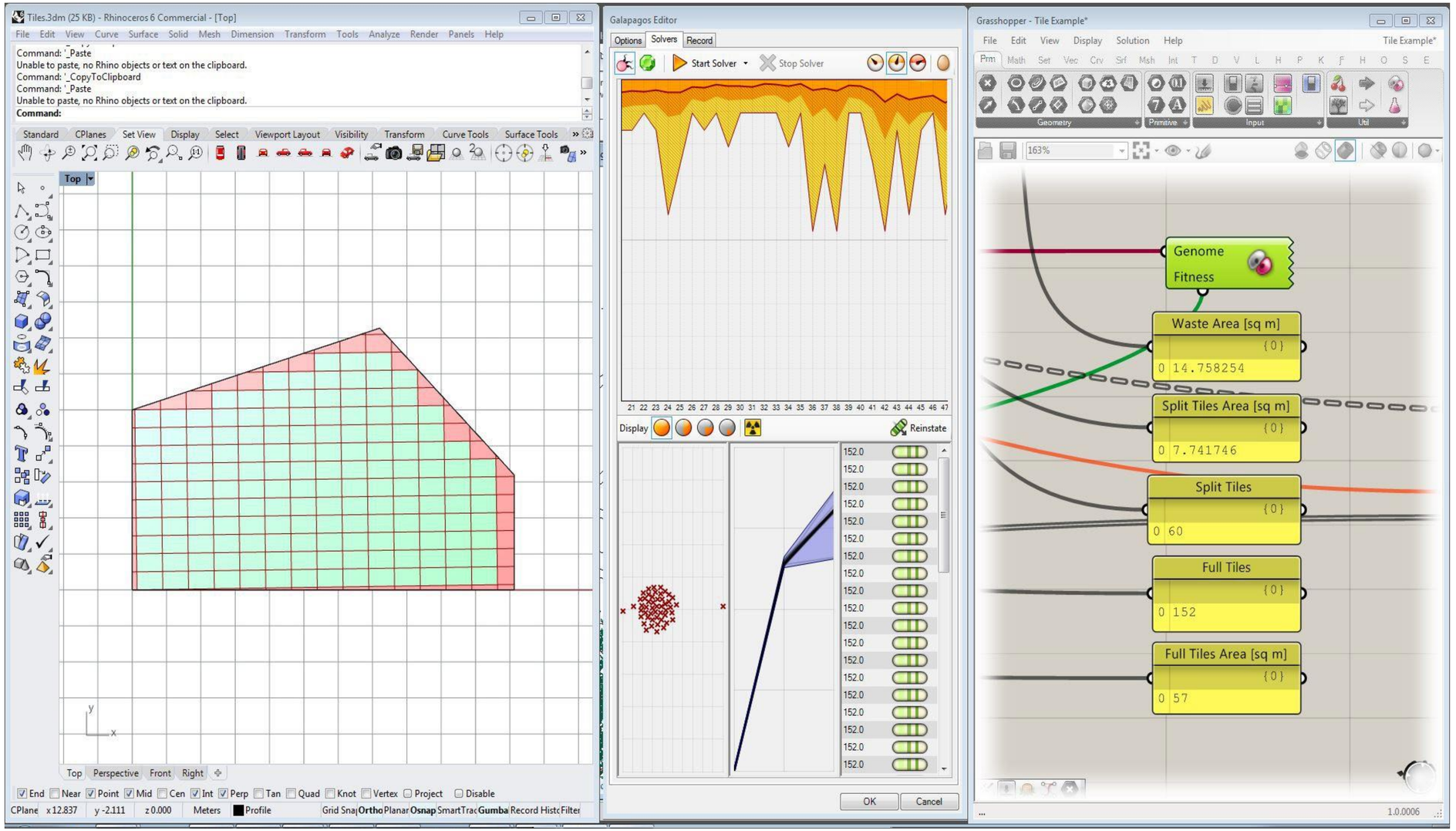
Offset X Dir. = 0 to 1

Offset Y Dir. = 0 to 1



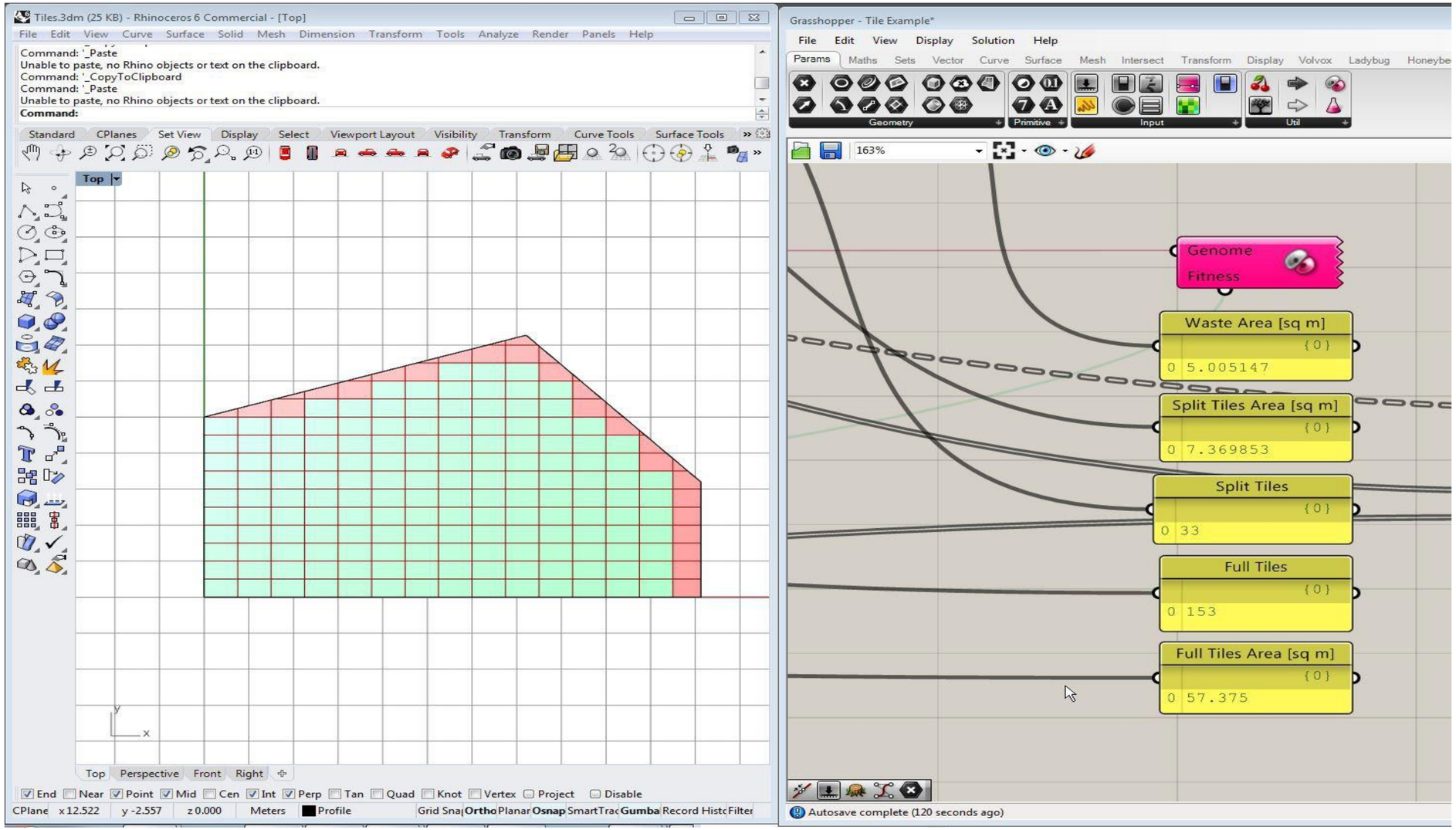
OPTIMIZATION A

Minimum Waste Area [m^2]



OPTIMIZATION B

Maximum Full Tiles [n]



OPTIMAL SOLUTION

After studying both cases, we can manually set the optimal parameters

IS THERE A BETTER WAY TO RESOLVE THIS?

YES

WE CAN COMBINE BOTH RESULTS INTO A SINGLE ONE, LET'S SAY... COST

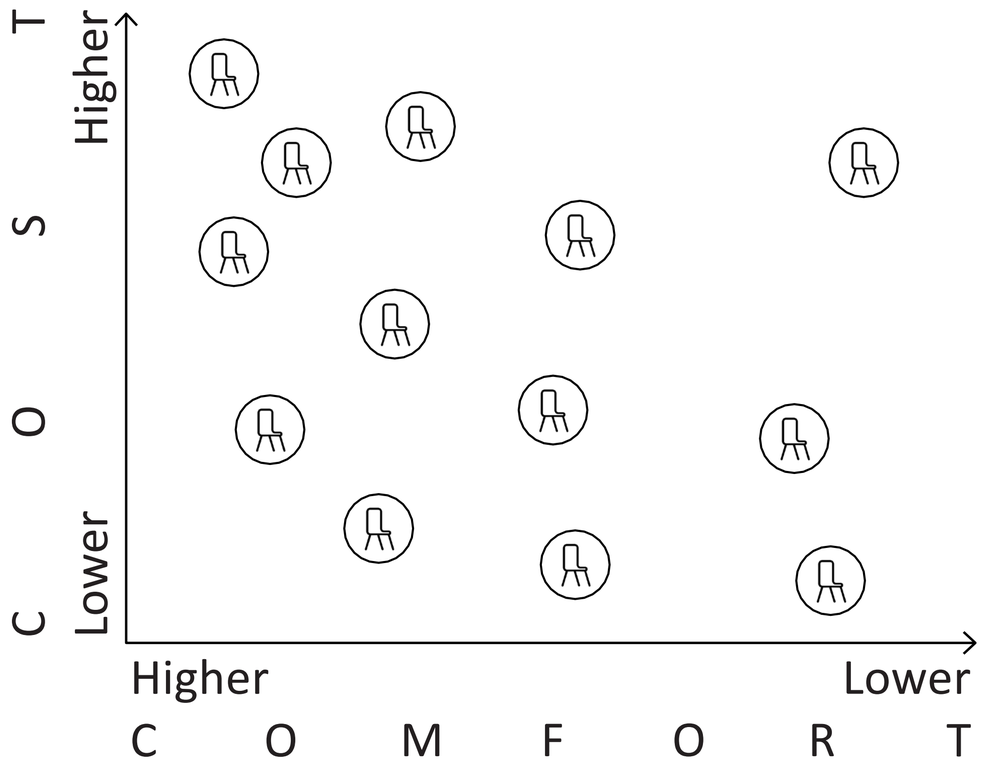
BY QUANTIFYING THE PRICE/M2 OF TILE (MIN. WASTE) + THE COST OF THE LABOUR REQUIRED TO CUT A TILE (MAX. FULL TILES)

OR...

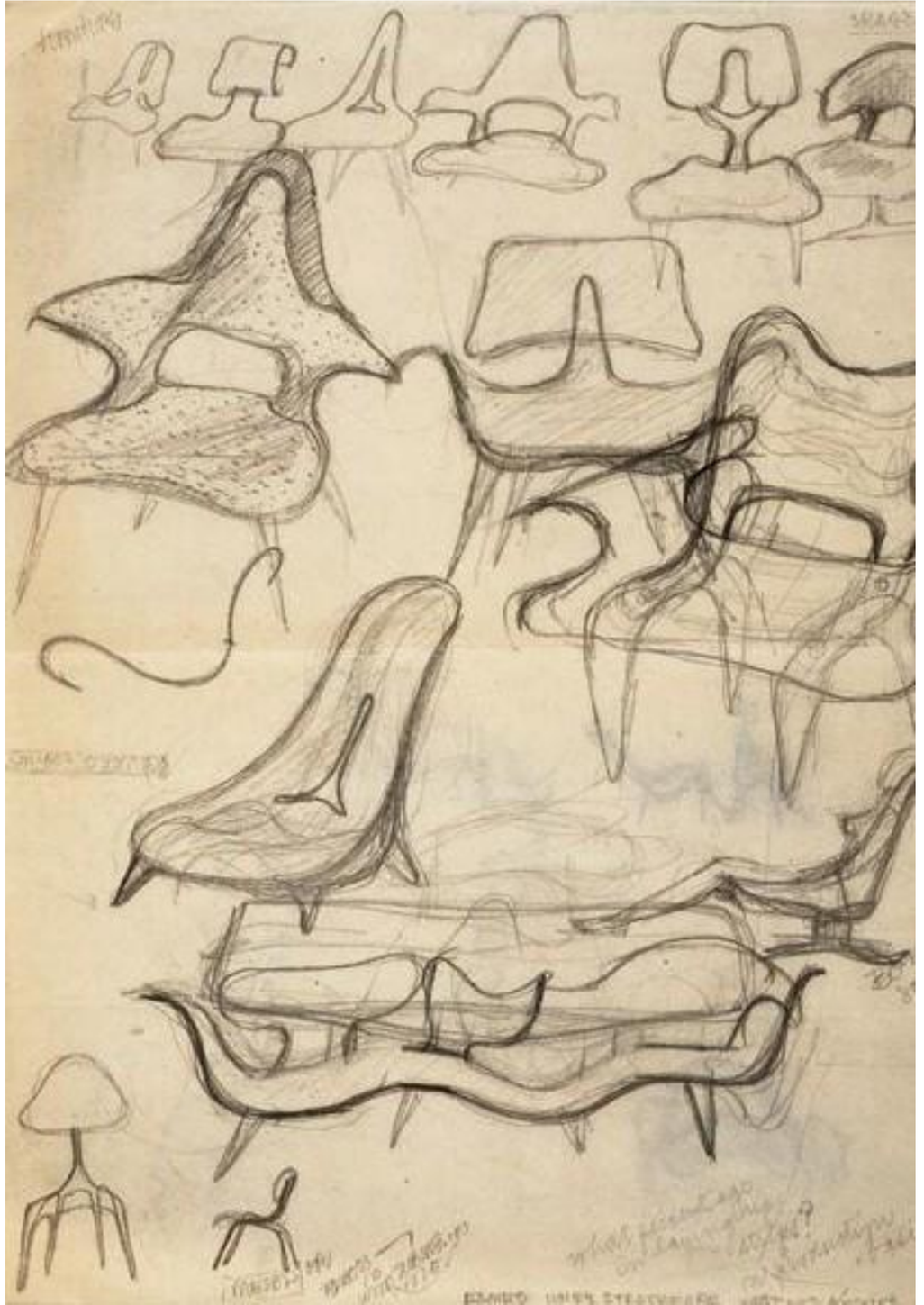
MULTI OBJECTIVE OPTIMIZATION
OCTOPUS FOR GRASSHOPPER

MAXIMIZE COMFORT

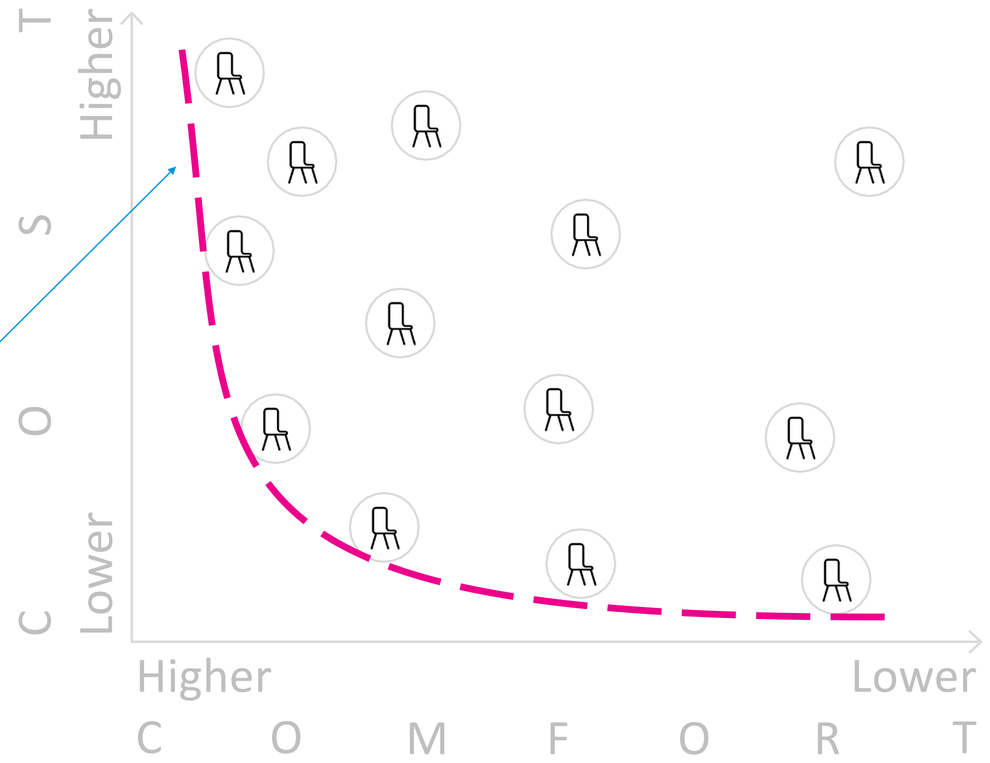
MINIMIZE COST



Each genome (variation) has a representation in the Multi Objective Optimization Graph

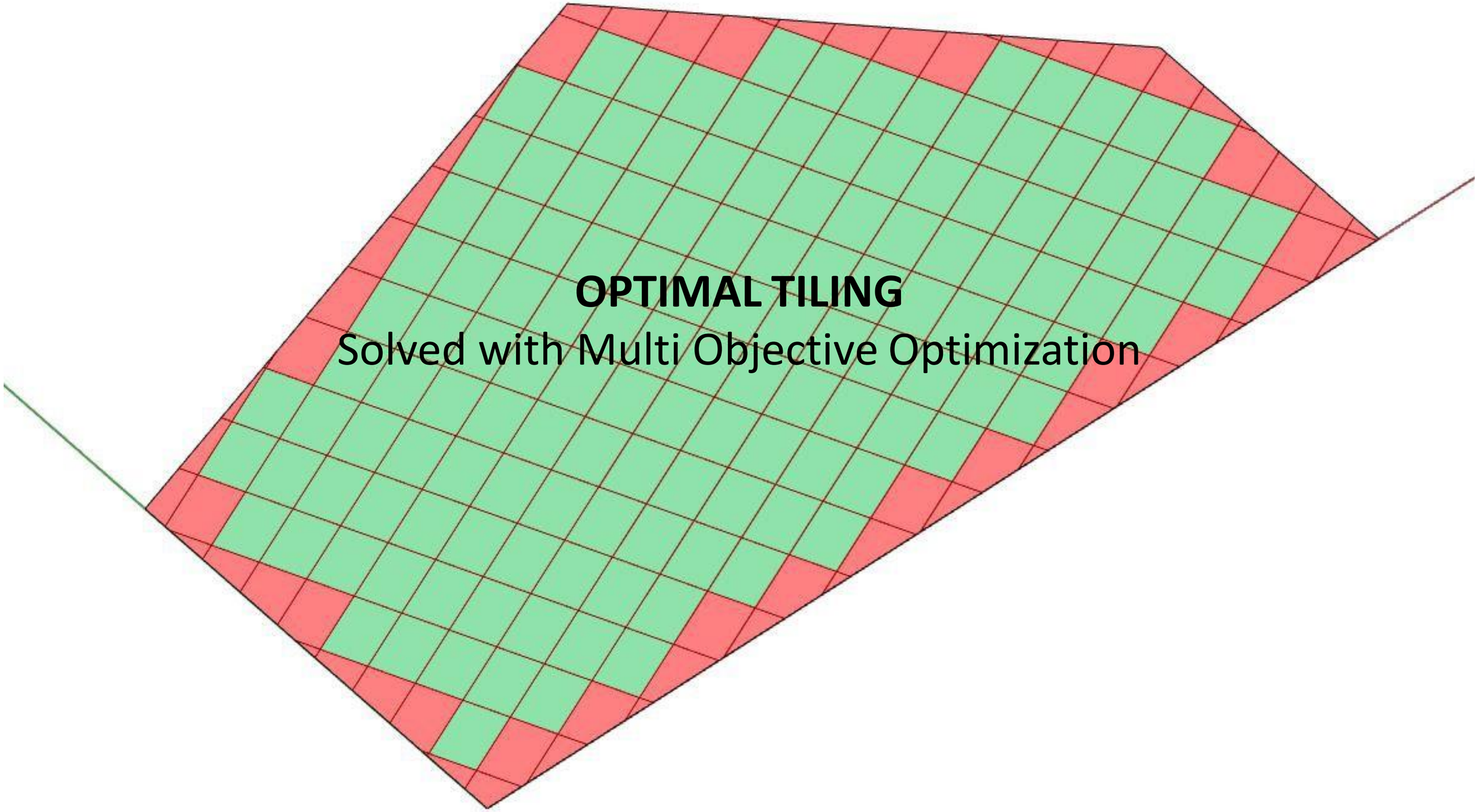


PARETO FRONT



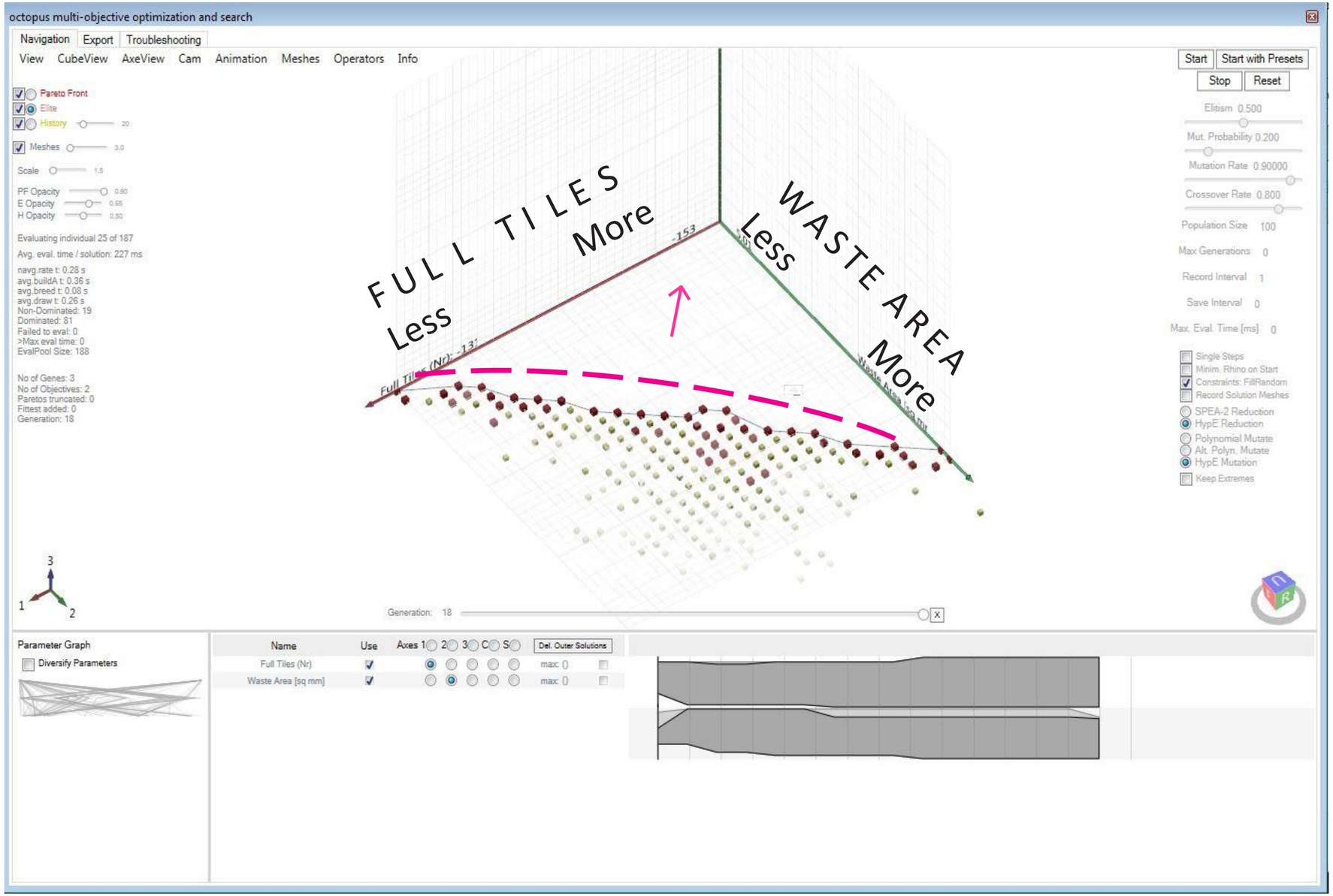
PARETO FRONT

Collection of options that represent optimal solutions

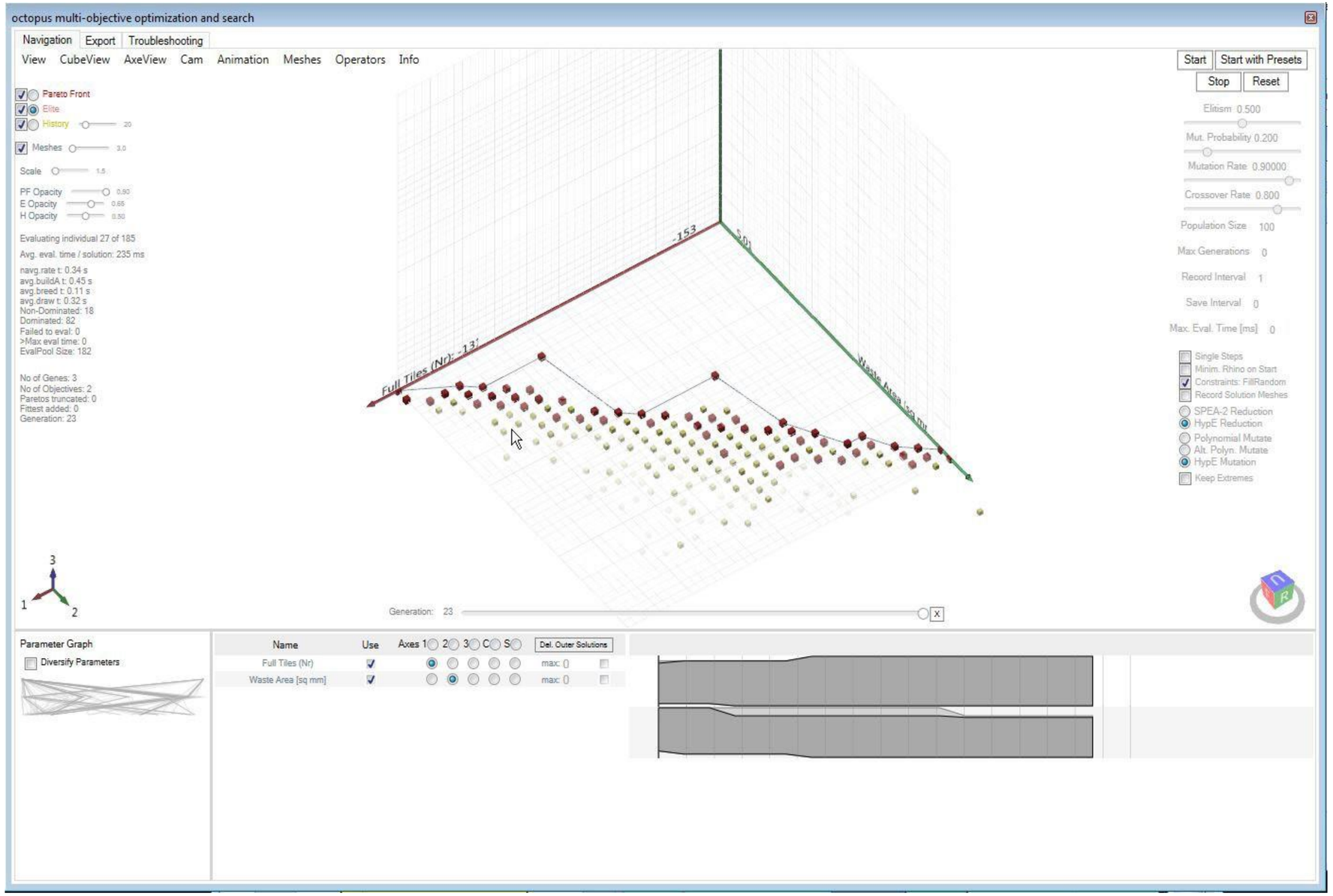


OPTIMAL TILING

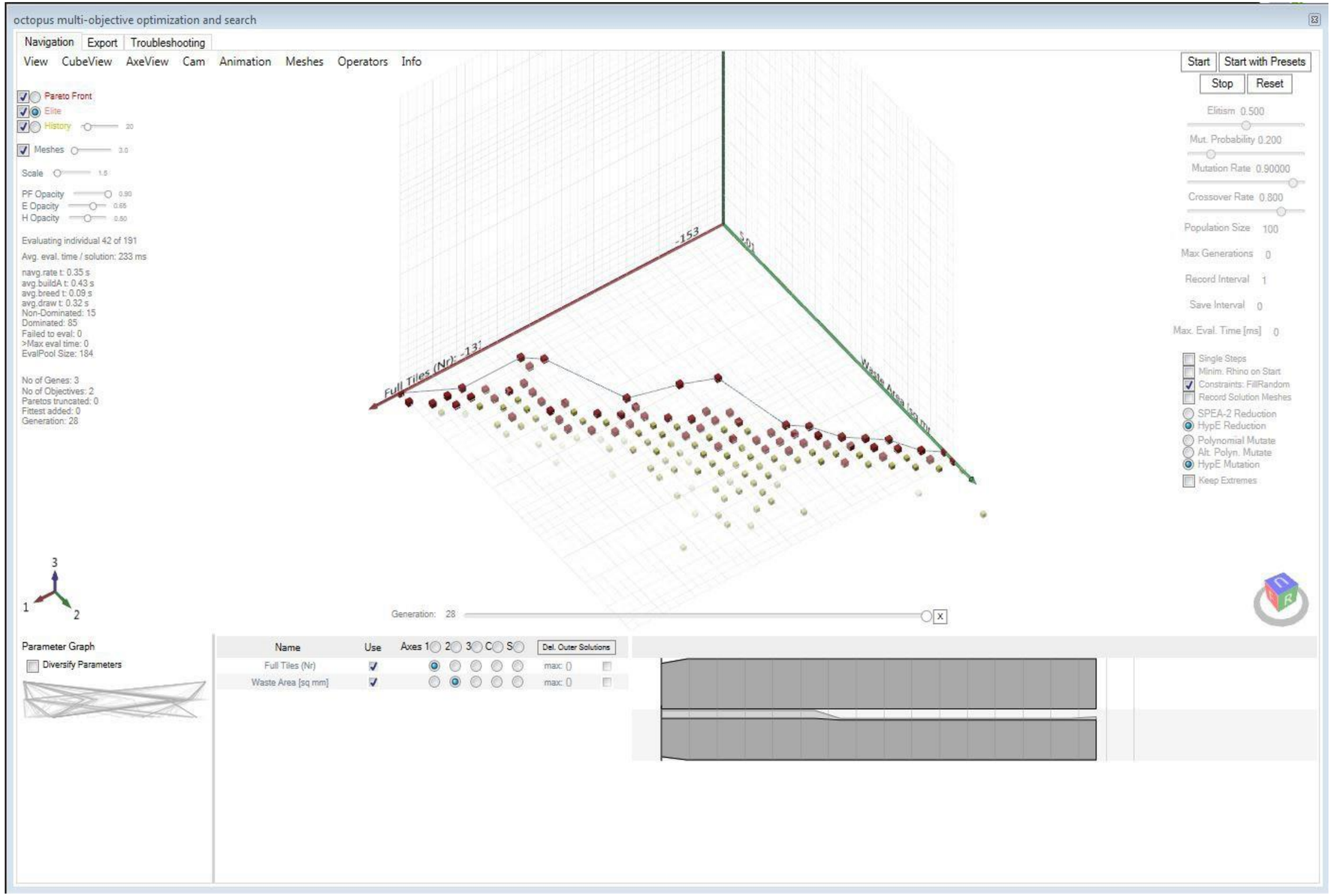
Solved with Multi Objective Optimization



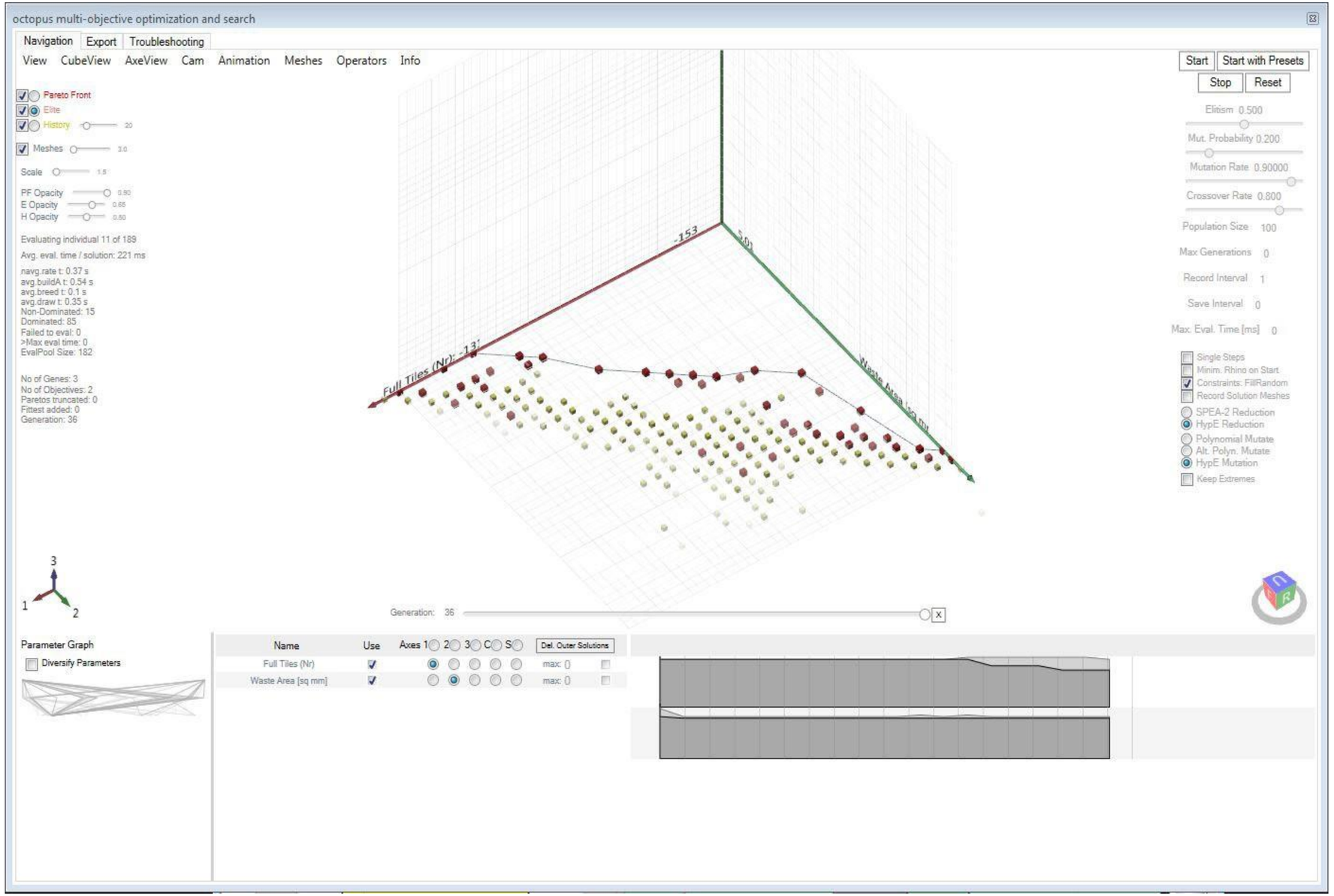
GENERATION 18



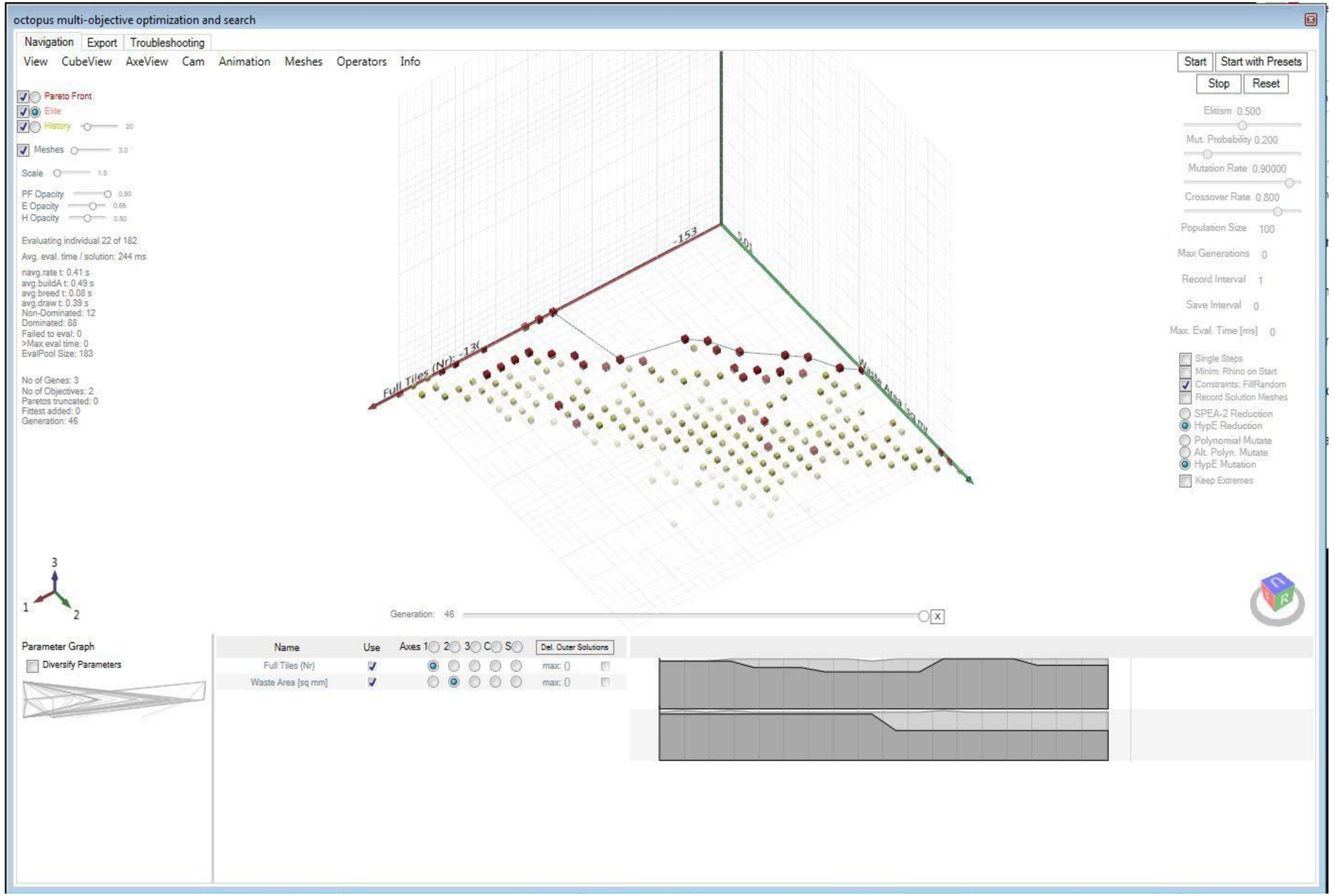
GENERATION 23



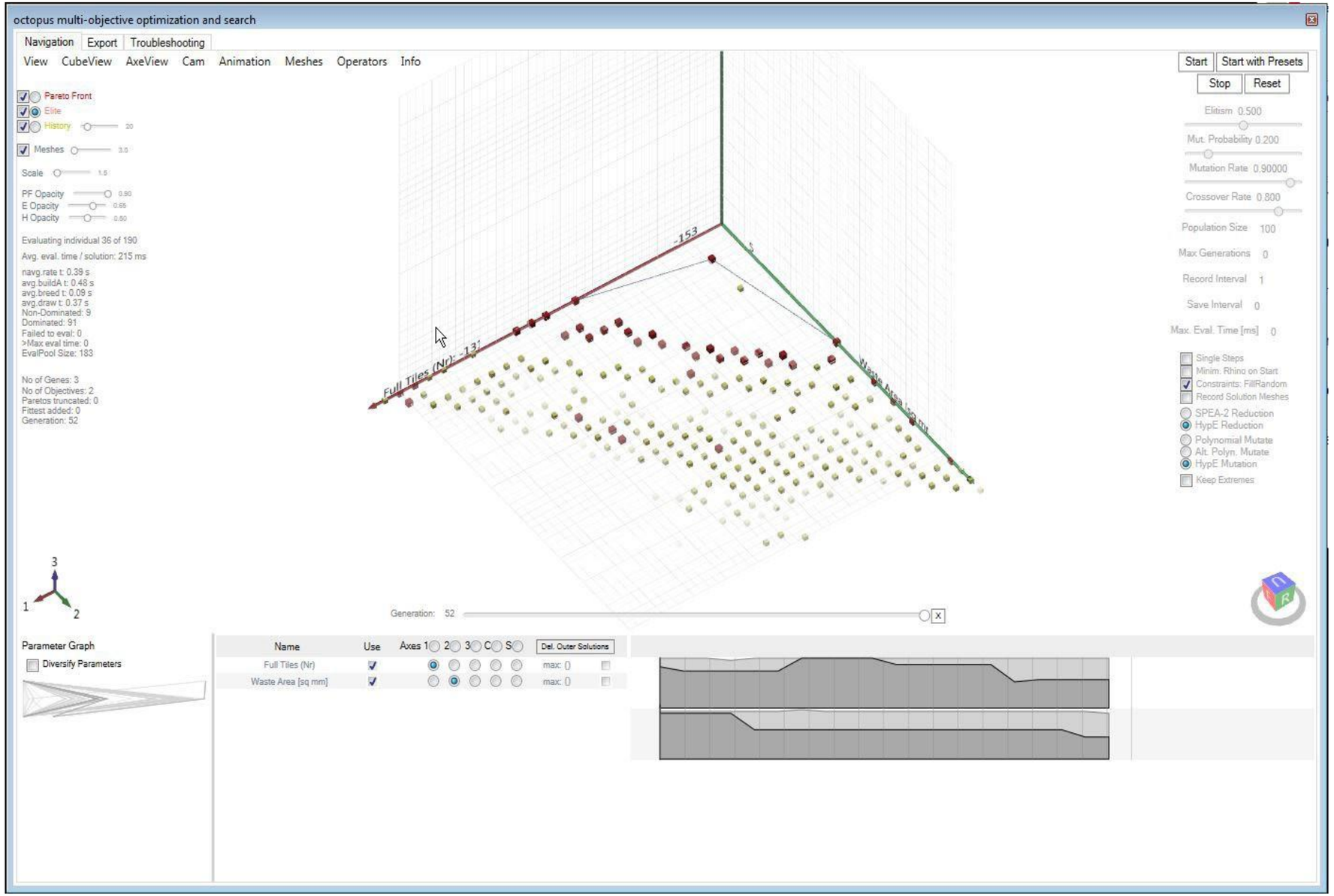
GENERATION 28



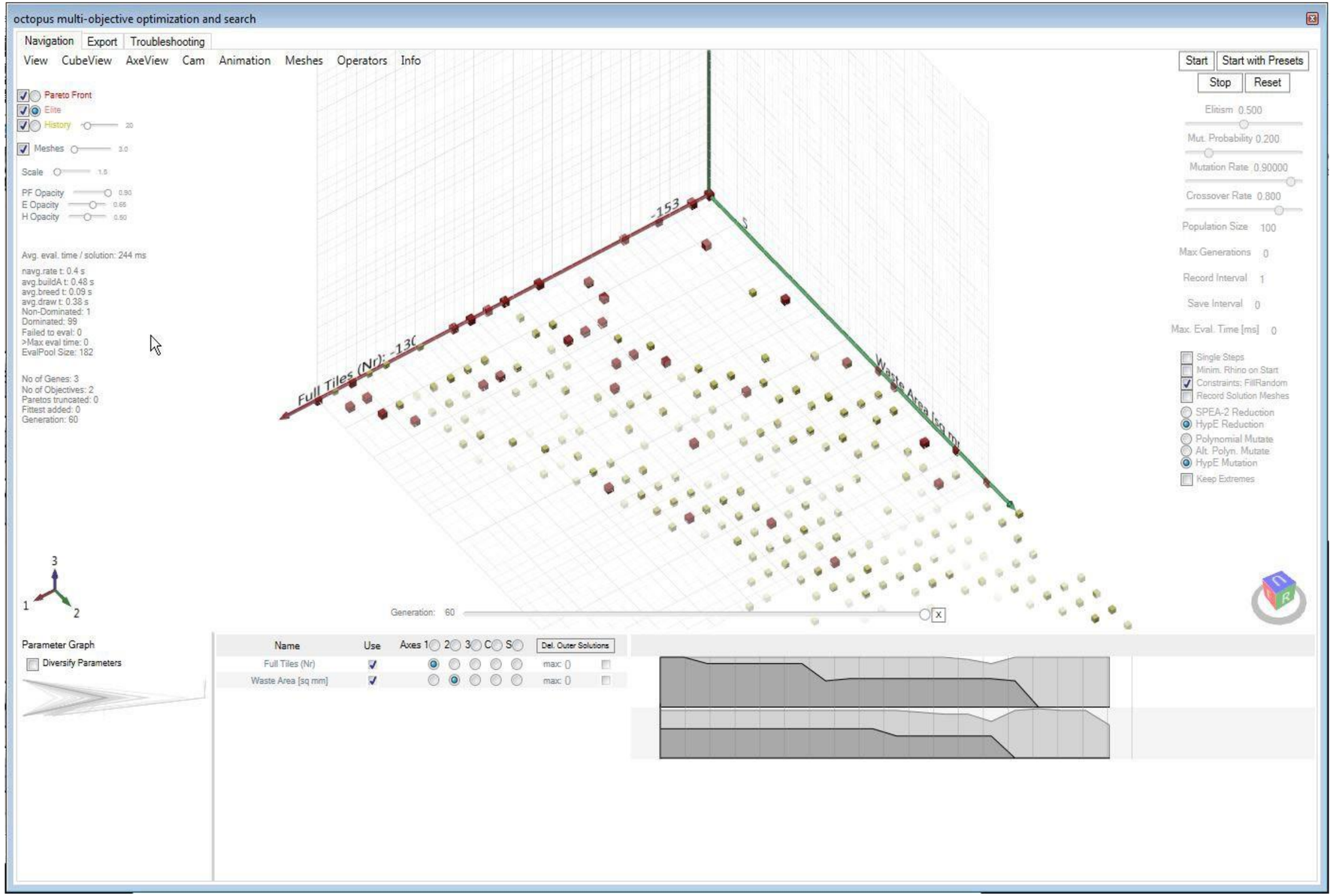
GENERATION 36



GENERATION 46



GENERATION 52



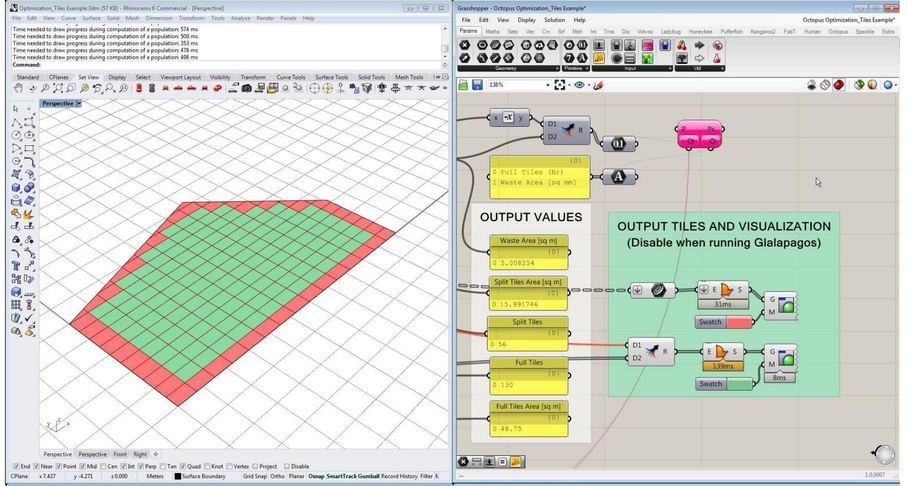
GENERATION 60

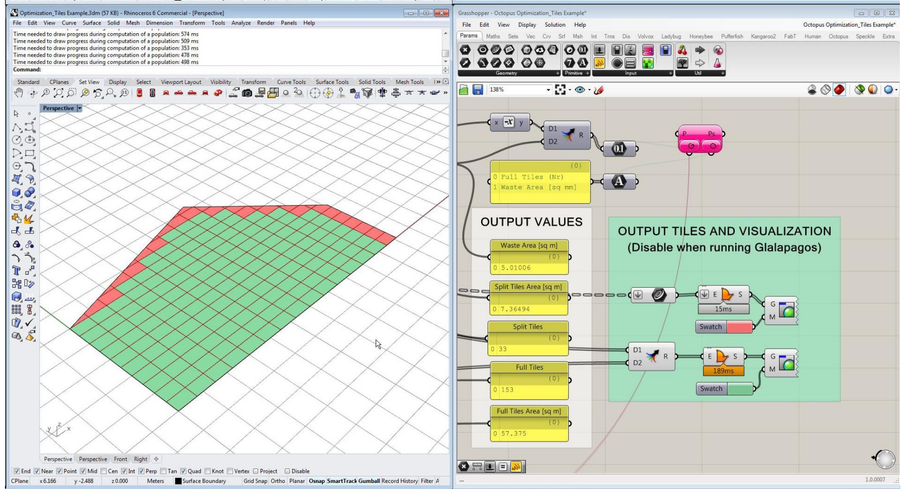
10,800 combinations tested X 244 ms per solution = 43.92 min

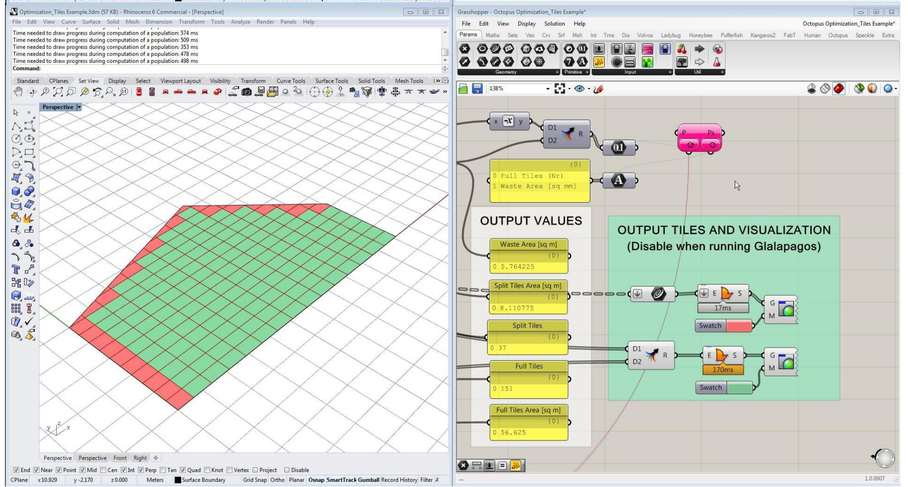
ABSOLUTE MIN. WASTE AREA

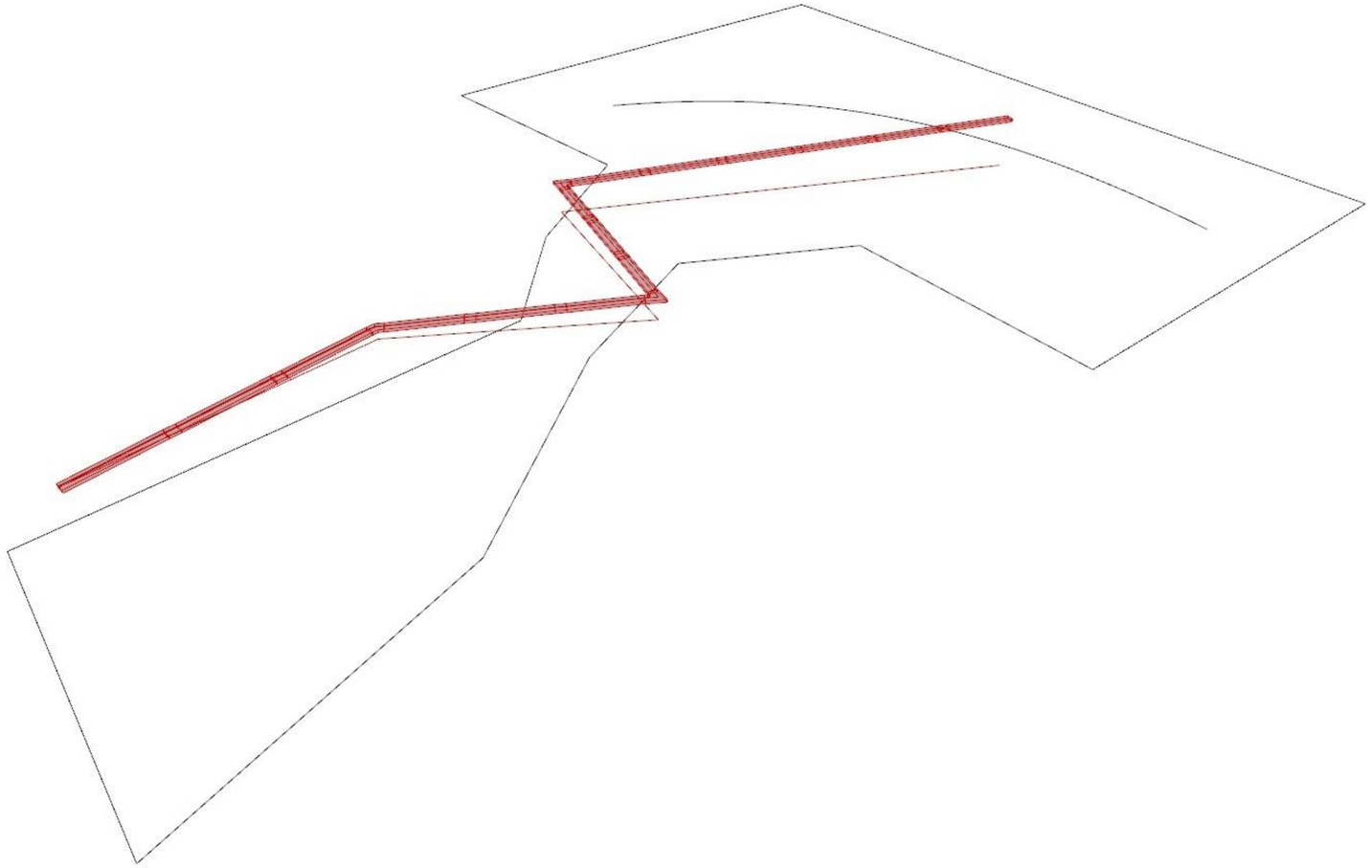
MIN. WASTE AREA
MAX. FULL TILES

POSSIBLE SOLUTION



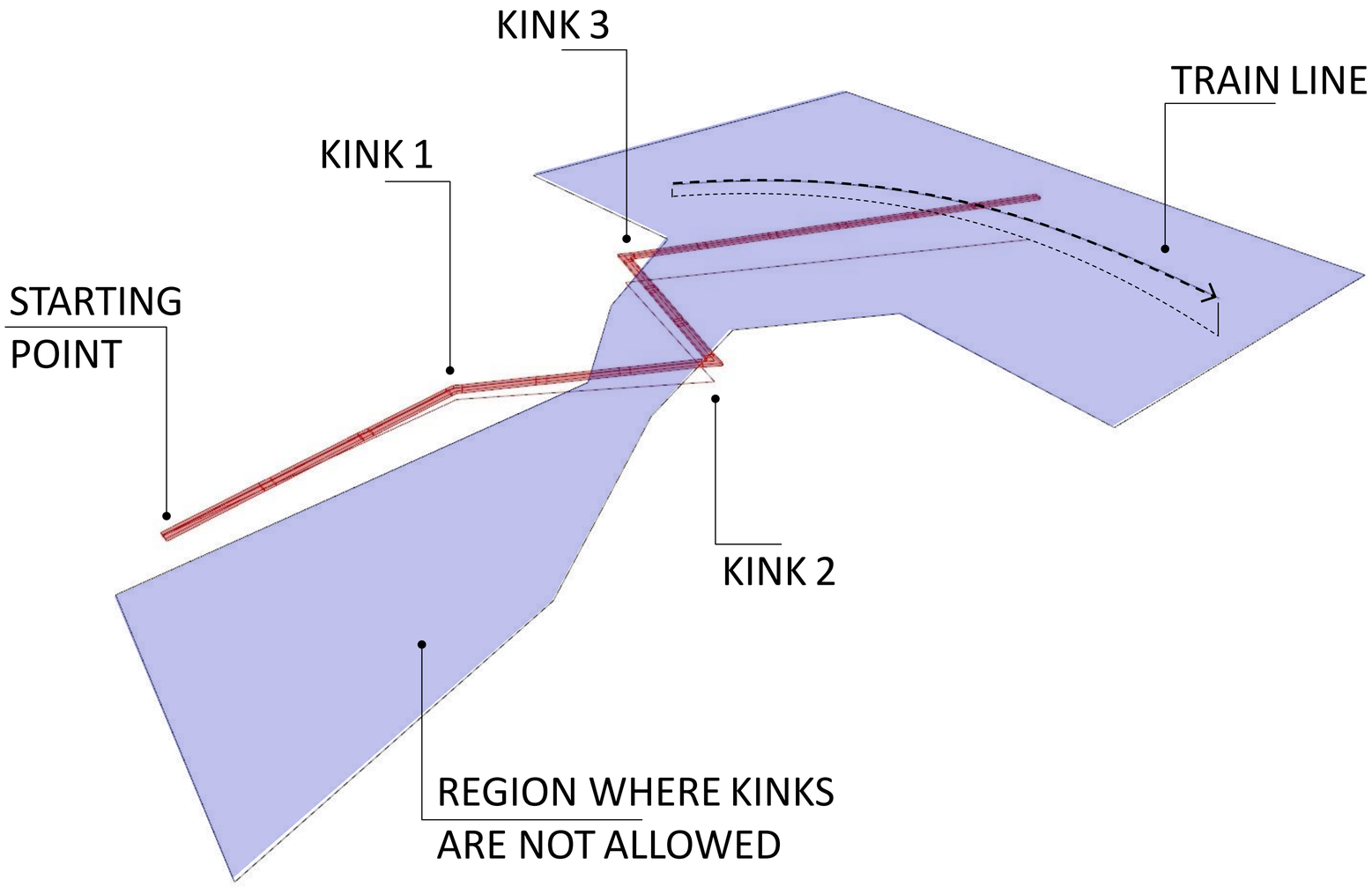






CASE 3

Optimal Ramp to save a clearance over rail line



FIXED PARAMETERS

- Segments Length
- Landings Length
- Ramp Gradient
- Landing Gradient
- Ramp Width
- Train Clearance

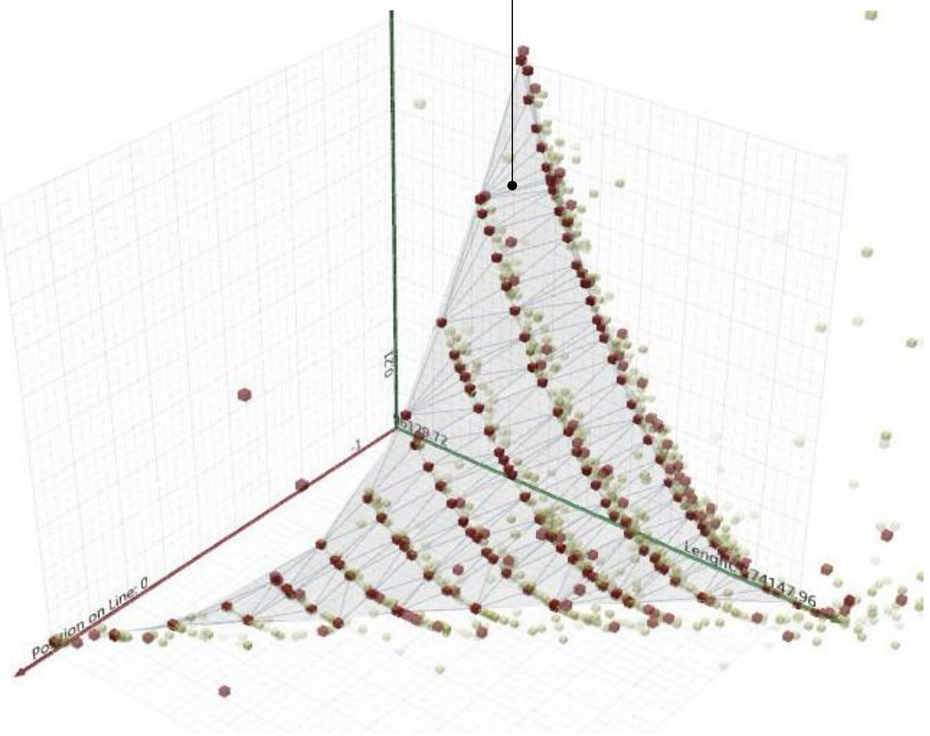
VARIABLES

- Kinks Position
- Arrival Point

OPTIMIZE

- MIN. Length
- MIN. Deviation From Train Clearance
- MAX. Position of End Point Toward Right of Train Line

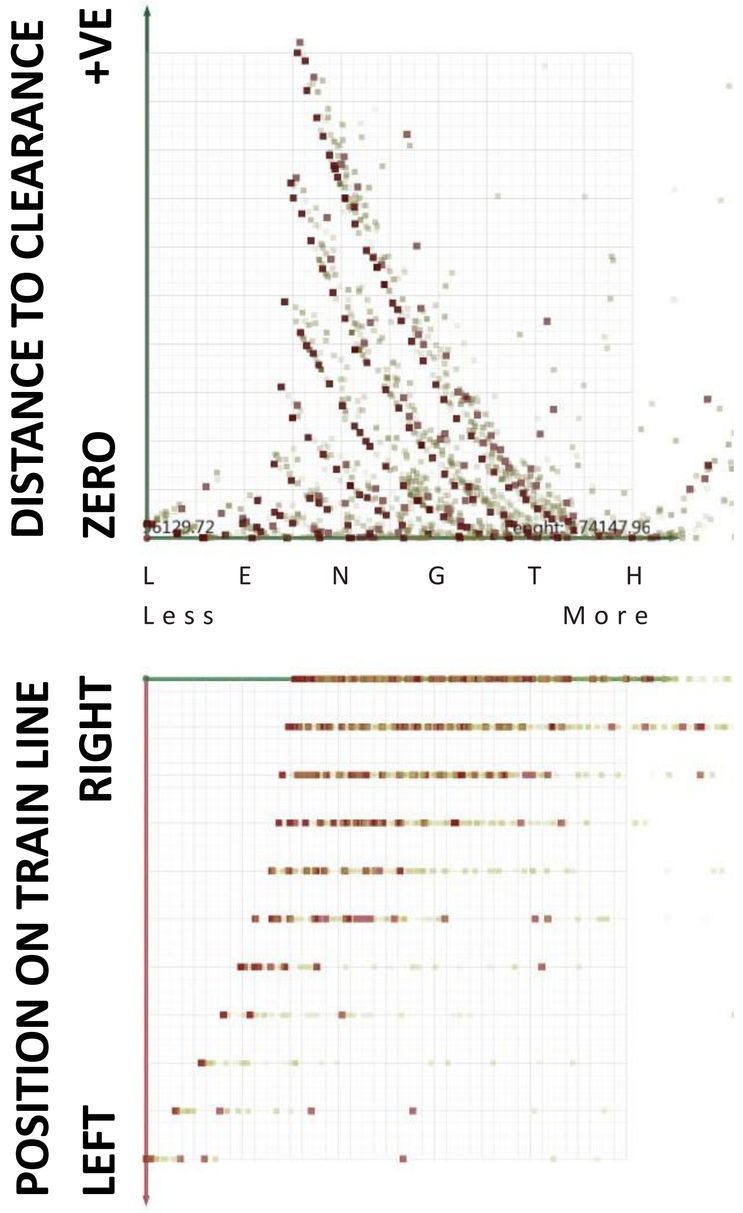
PARETO FRONT MESH

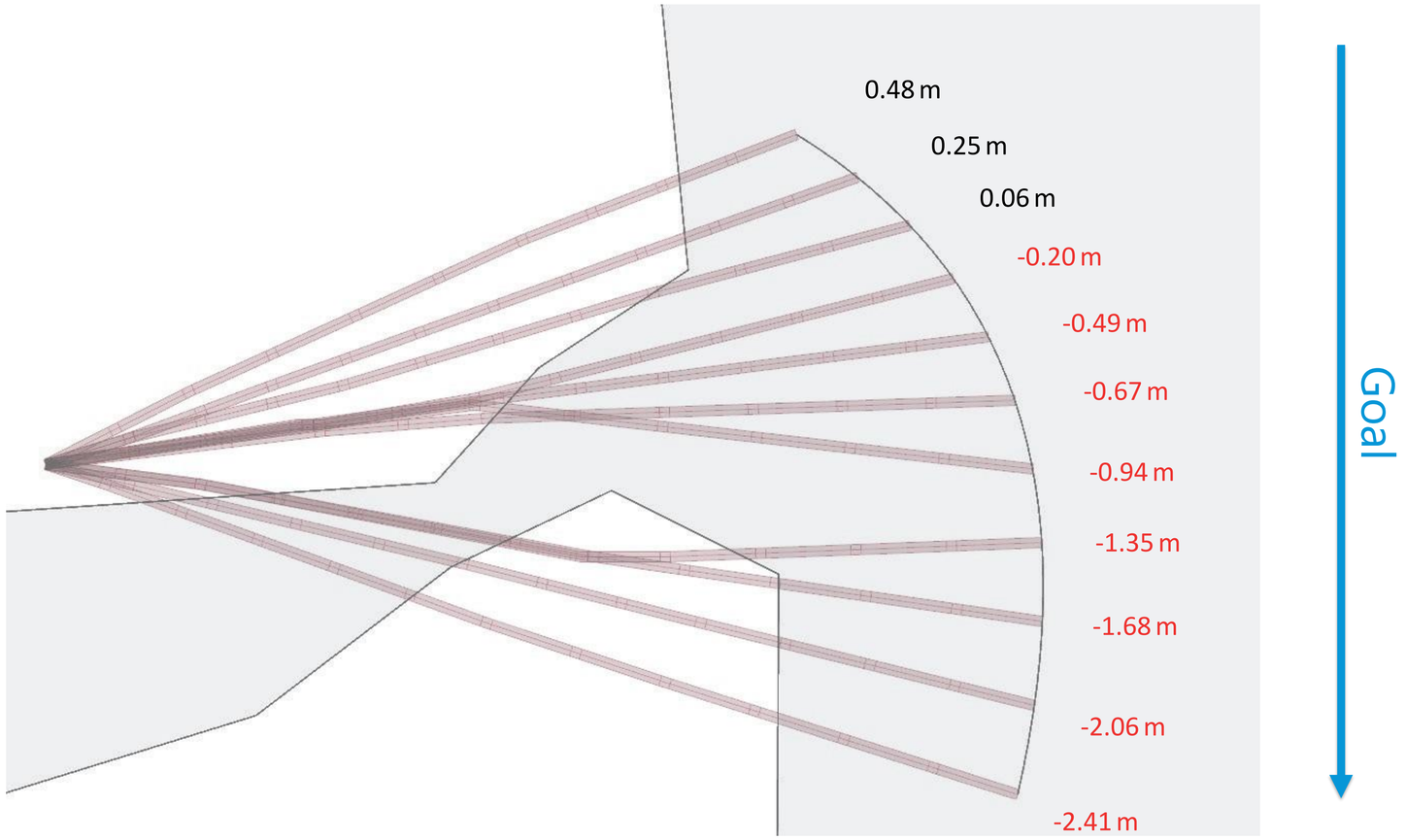


GENERATION 273

54,273 combinations tested X 198 ms

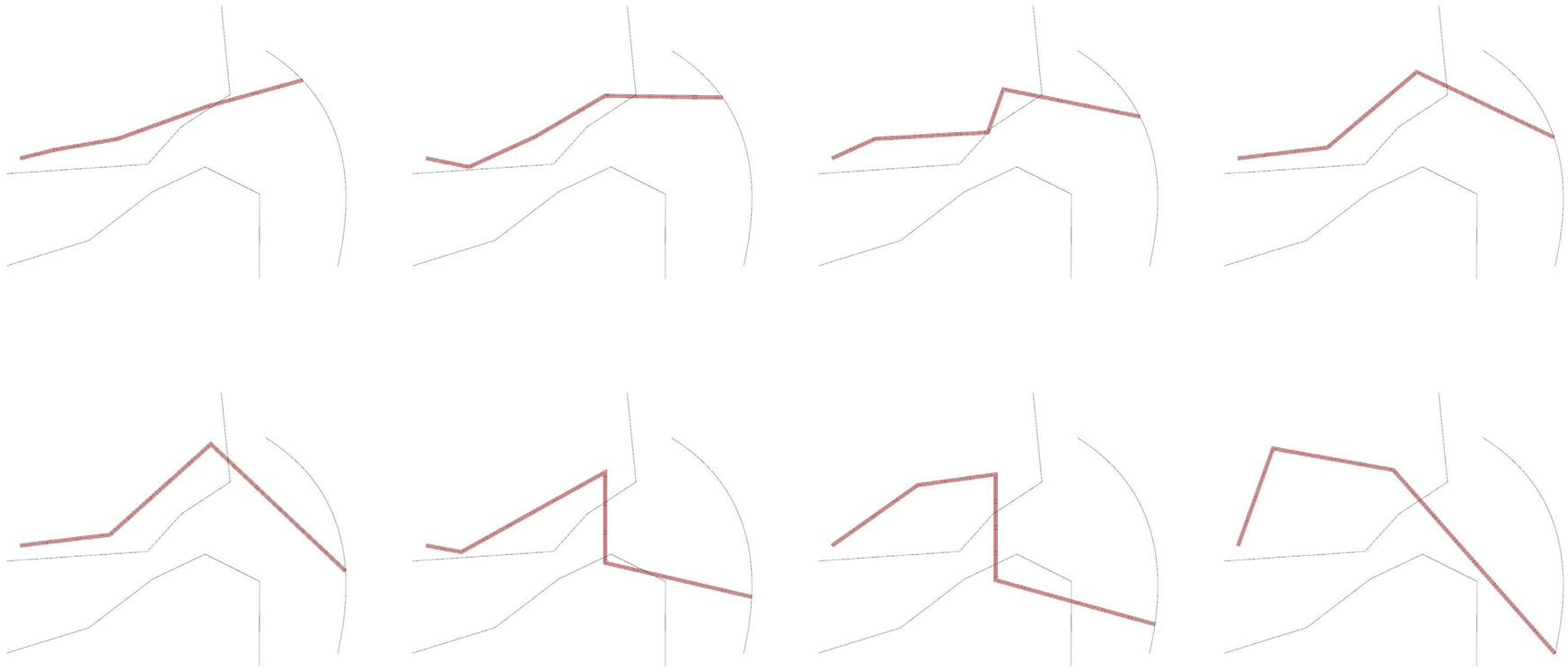
per solution = 179.10 min





SHORTEST LENGTH SOLUTIONS

Distance to min. clearance



SHORTEST ALTERNATIVES

Within the min. clearance

MULTI OBJECTIVE OPTIMIZATION WALLACEI X FOR GRASSHOPPER

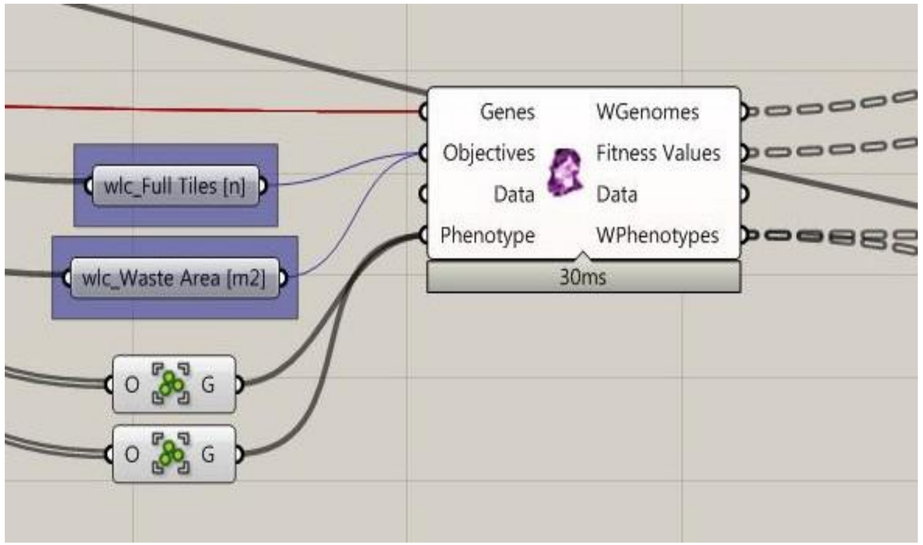
PROBLEM

SOLUTIONS

INPUT

OUTPUT

RUN SIMULATION



IMPROVE

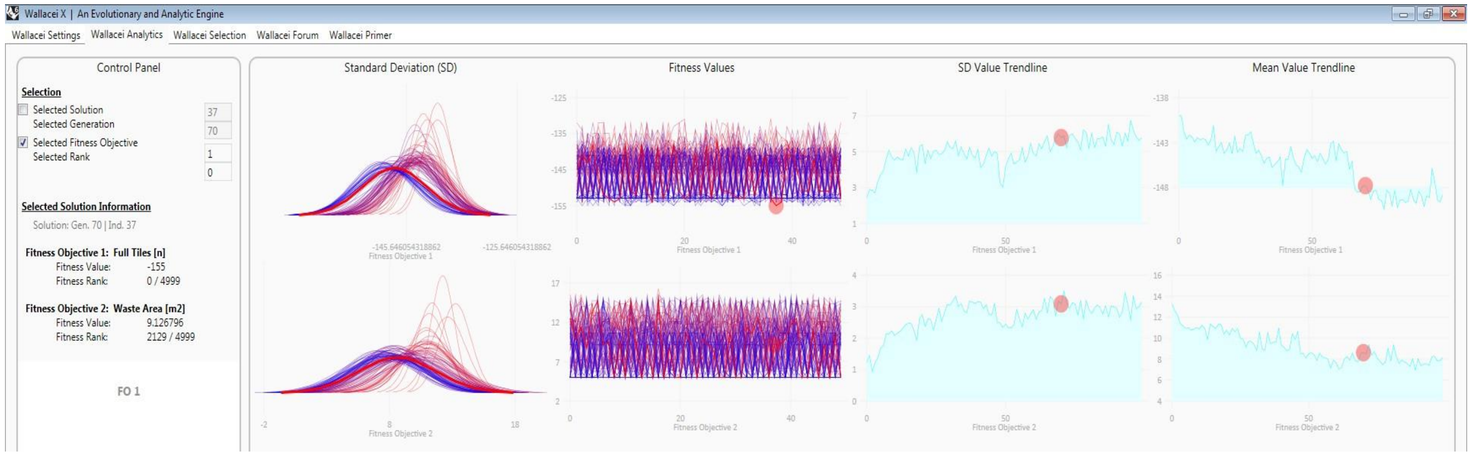
ANALYSE

LEARN

SELECT

WALLACEI SETTINGS

MAX. FULL TILES



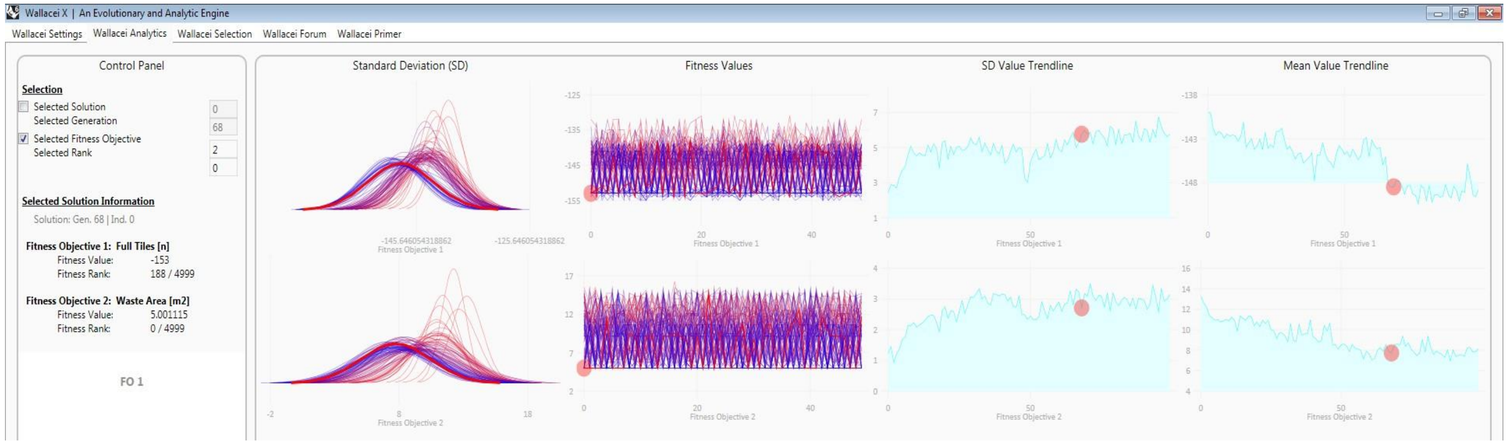
Gen. 70 ~ Indv. 37

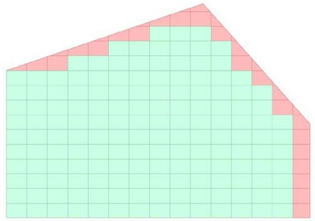
Genes: -89.997 | 0.456 | 0.55 ~ Fitness Obj.: -155 | 9.126796

155 full tiles

9.11 sqm waste area

MIN. WASTE AREA





Gen. 68 ~ Indv. 0

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

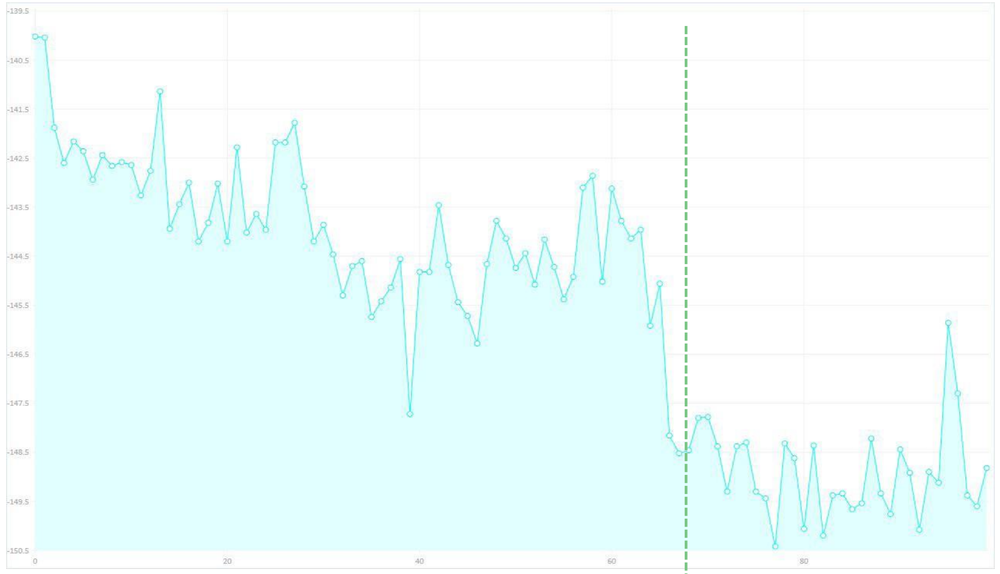
153 full tiles

5.00 sqm waste area

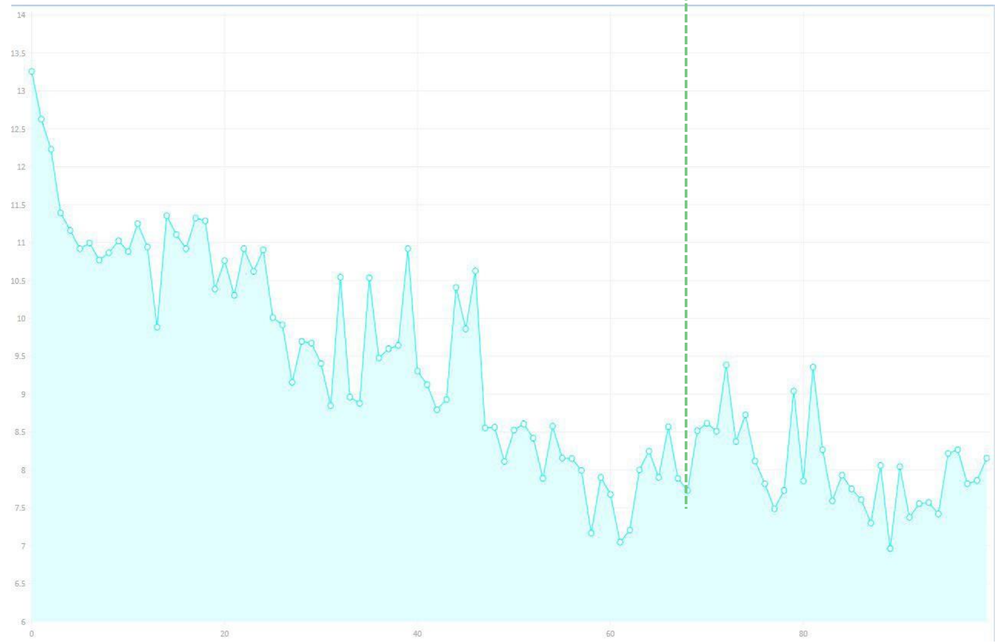
WALLACEI ANALYTICS

5,000 combinations tested = 19.19 min (13 min to find optimal solutions)

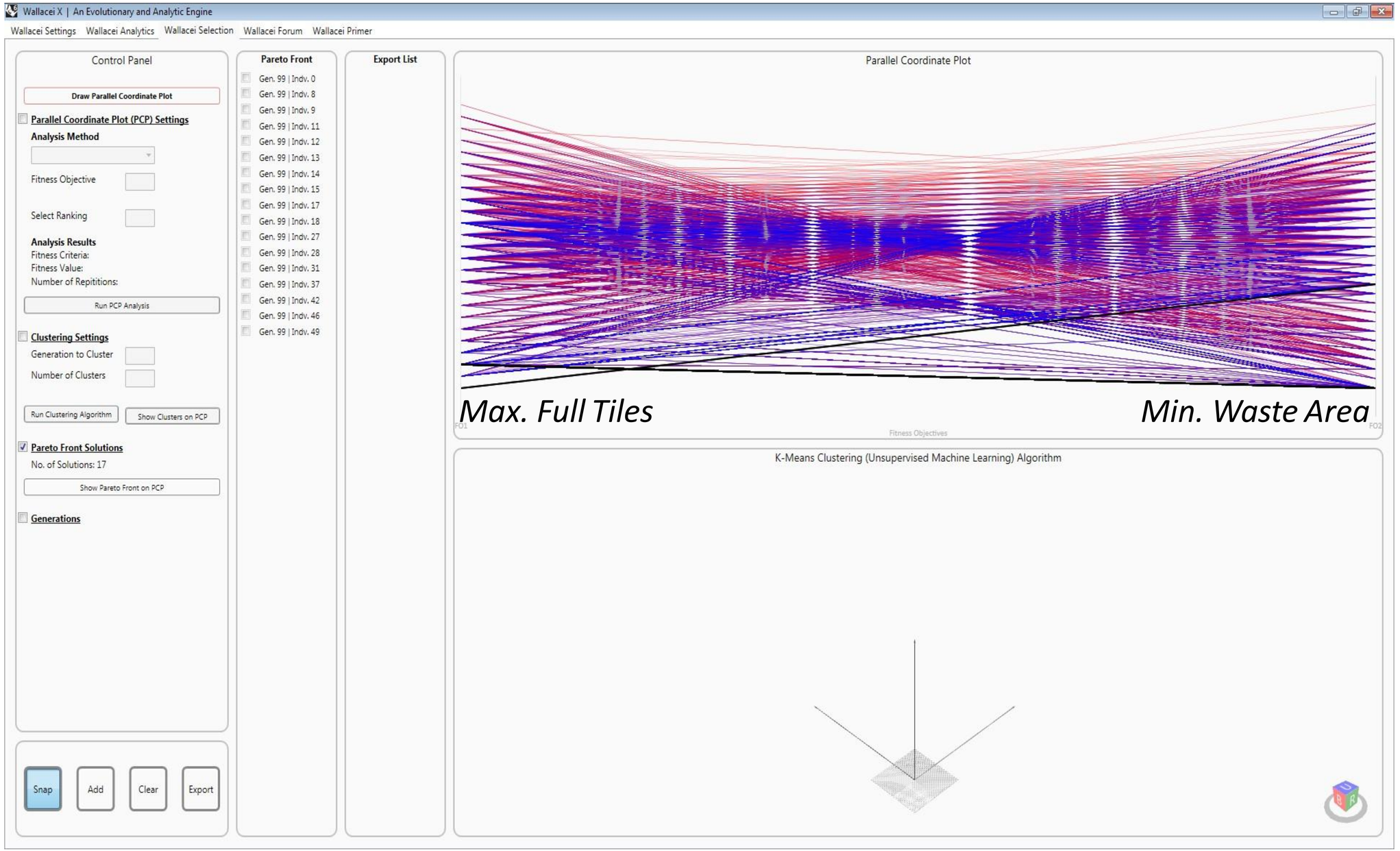
Max. Full Tiles



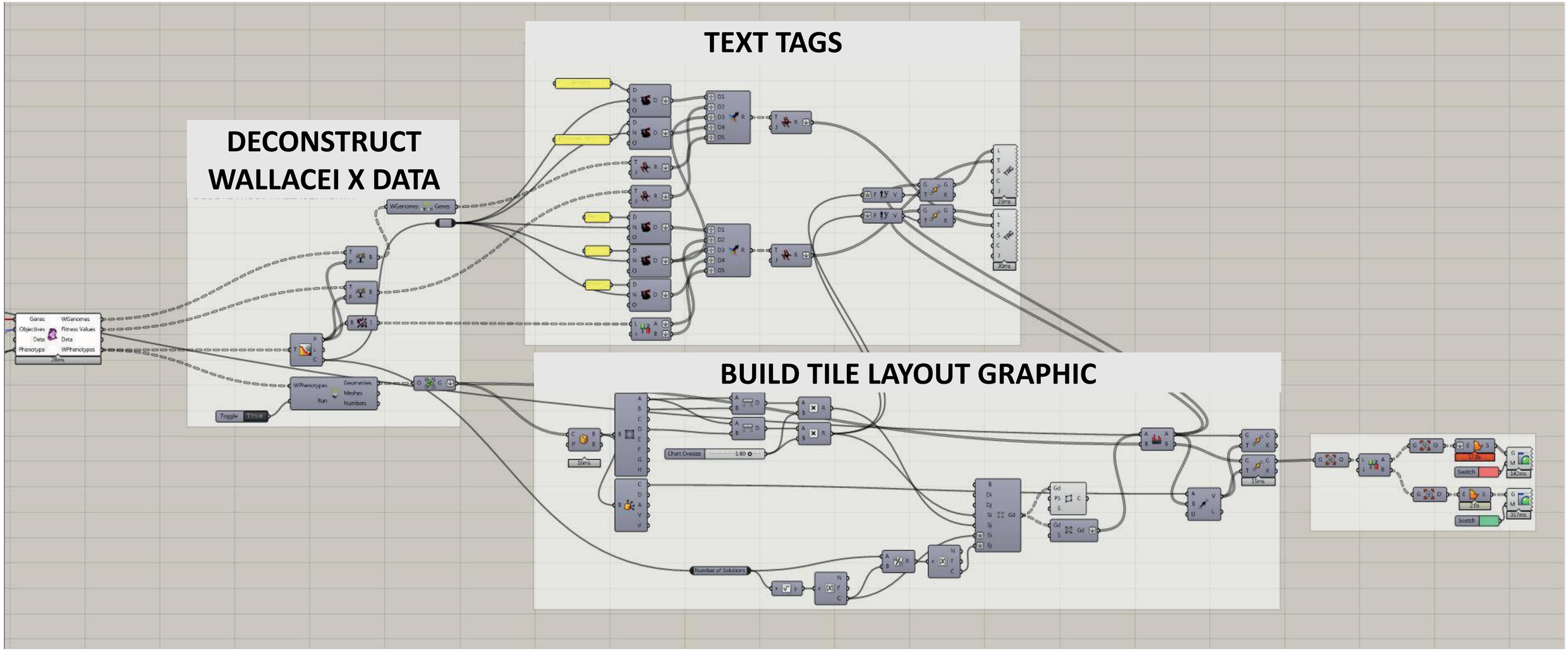
Min. Waste Area



MEAN VALUE TRENDLINE



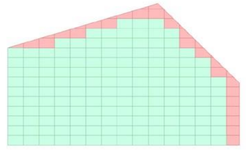
WALLACEI SELECTION



ANALYSING WALLACEI DATA

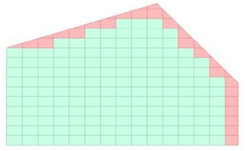
Gen. 99 ~ Indv. 49

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115



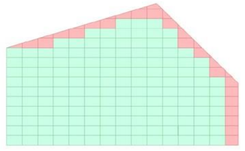
Gen. 99 ~ Indv. 31

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115



Gen. 99 ~ Indv. 37

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115



Gen. 99 ~ Indv. 42

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 46

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 17

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 18

Genes: -89.997 | 0.456 | 0.548 ~ Fitness Obj.: -155 | 9.126795

Gen. 99 ~ Indv. 27

Genes: -89.997 | 0.456 | 0.548 ~ Fitness Obj.: -155 | 9.126795

Gen. 99 ~ Indv. 28

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 12

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 13

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 14

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 15

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 0

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 8

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 9

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 11

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

PARETO FRONT SOLUTIONS

Gen. 99 ~ Indv. 49

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 42

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 43

Genes: -81.523 | 0.456 | 1 ~ Fitness Obj.: -144 | 11.758254

Gen. 99 ~ Indv. 44

Genes: -88.27 | 0.456 | 0.895 ~ Fitness Obj.: -141 | 10.633254

Gen. 99 ~ Indv. 45

Genes: -89.997 | 0.408 | 0.548 ~ Fitness Obj.: -141 | 9.883254

Gen. 99 ~ Indv. 46

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 47

Genes: -89.997 | 0.466 | 1 ~ Fitness Obj.: -152 | 10.632632

Gen. 99 ~ Indv. 48

Genes: -89.997 | 0.419 | 1 ~ Fitness Obj.: -139 | 5.007585

Gen. 99 ~ Indv. 35

Genes: -89.997 | 0.515 | 0.968 ~ Fitness Obj.: -152 | 14.758254

Gen. 99 ~ Indv. 36

Genes: -85.196 | 0.456 | 1 ~ Fitness Obj.: -142 | 10.633376

Gen. 99 ~ Indv. 37

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 38

Genes: -89.997 | 0.456 | 0.529 ~ Fitness Obj.: -154 | 9.501821

Gen. 99 ~ Indv. 39

Genes: -89.997 | 0.456 | 0.999 ~ Fitness Obj.: -153 | 5.005237

Gen. 99 ~ Indv. 40

Genes: -89.997 | 0.456 | 0.997 ~ Fitness Obj.: -153 | 9.126769

Gen. 99 ~ Indv. 41

Genes: -79.354 | 0.456 | 0.539 ~ Fitness Obj.: -143 | 12.133254

Gen. 99 ~ Indv. 28

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 29

Genes: -89.998 | 0.456 | 0.54 ~ Fitness Obj.: -154 | 9.127132

Gen. 99 ~ Indv. 30

Genes: -89.997 | 0.635 | 1 ~ Fitness Obj.: -152 | 10.632621

Gen. 99 ~ Indv. 31

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 32

Genes: -90 | 0.335 | 0.985 ~ Fitness Obj.: -142 | 10.258254

Gen. 99 ~ Indv. 33

Genes: -88.061 | 0.456 | 0.556 ~ Fitness Obj.: -146 | 12.133254

Gen. 99 ~ Indv. 34

Genes: -79.698 | 0.456 | 1 ~ Fitness Obj.: -142 | 11.758254

Gen. 99 ~ Indv. 21

Genes: -79.845 | 0.456 | 1 ~ Fitness Obj.: -142 | 11.383254

Gen. 99 ~ Indv. 22

Genes: -84.57 | 0.456 | 1 ~ Fitness Obj.: -142 | 10.633239

Gen. 99 ~ Indv. 23

Genes: -89.997 | 0.482 | 1 ~ Fitness Obj.: -152 | 10.632631

Gen. 99 ~ Indv. 24

Genes: -89.998 | 0.567 | 1 ~ Fitness Obj.: -152 | 10.632835

Gen. 99 ~ Indv. 25

Genes: -89.999 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.002213

Gen. 99 ~ Indv. 26

Genes: -89.999 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.002213

Gen. 99 ~ Indv. 27

Genes: -89.997 | 0.456 | 0.548 ~ Fitness Obj.: -155 | 9.126795

Gen. 99 ~ Indv. 14

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 15

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 16

Genes: -89.791 | 0.456 | 1 ~ Fitness Obj.: -135 | 6.883534

Gen. 99 ~ Indv. 17

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 18

Genes: -89.997 | 0.456 | 0.548 ~ Fitness Obj.: -155 | 9.126795

Gen. 99 ~ Indv. 19

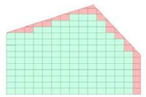
Genes: -90 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.002761

Gen. 99 ~ Indv. 20

Genes: -89.997 | 0.471 | 1 ~ Fitness Obj.: -152 | 10.632632

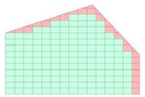
Gen. 99 ~ Indv. 7

Genes: -83.155 | 0.456 | 0.551 ~ Fitness Obj.: -145 | 12.133254



Gen. 99 ~ Indv. 8

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115



Gen. 99 ~ Indv. 9

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 10

Genes: -89.997 | 0.415 | 1 ~ Fitness Obj.: -139 | 5.007586

Gen. 99 ~ Indv. 11

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 12

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 13

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 0

Genes: -89.997 | 0.456 | 1 ~ Fitness Obj.: -153 | 5.001115

Gen. 99 ~ Indv. 1

Genes: -89.997 | 0.481 | 1 ~ Fitness Obj.: -152 | 10.632631

Gen. 99 ~ Indv. 2

Genes: -89.997 | 0.43 | 1 ~ Fitness Obj.: -139 | 5.007585

Gen. 99 ~ Indv. 3

Genes: -89.997 | 0.47 | 0.548 ~ Fitness Obj.: -153 | 15.133254

Gen. 99 ~ Indv. 4

Genes: -89.997 | 0.43 | 1 ~ Fitness Obj.: -139 | 5.007585

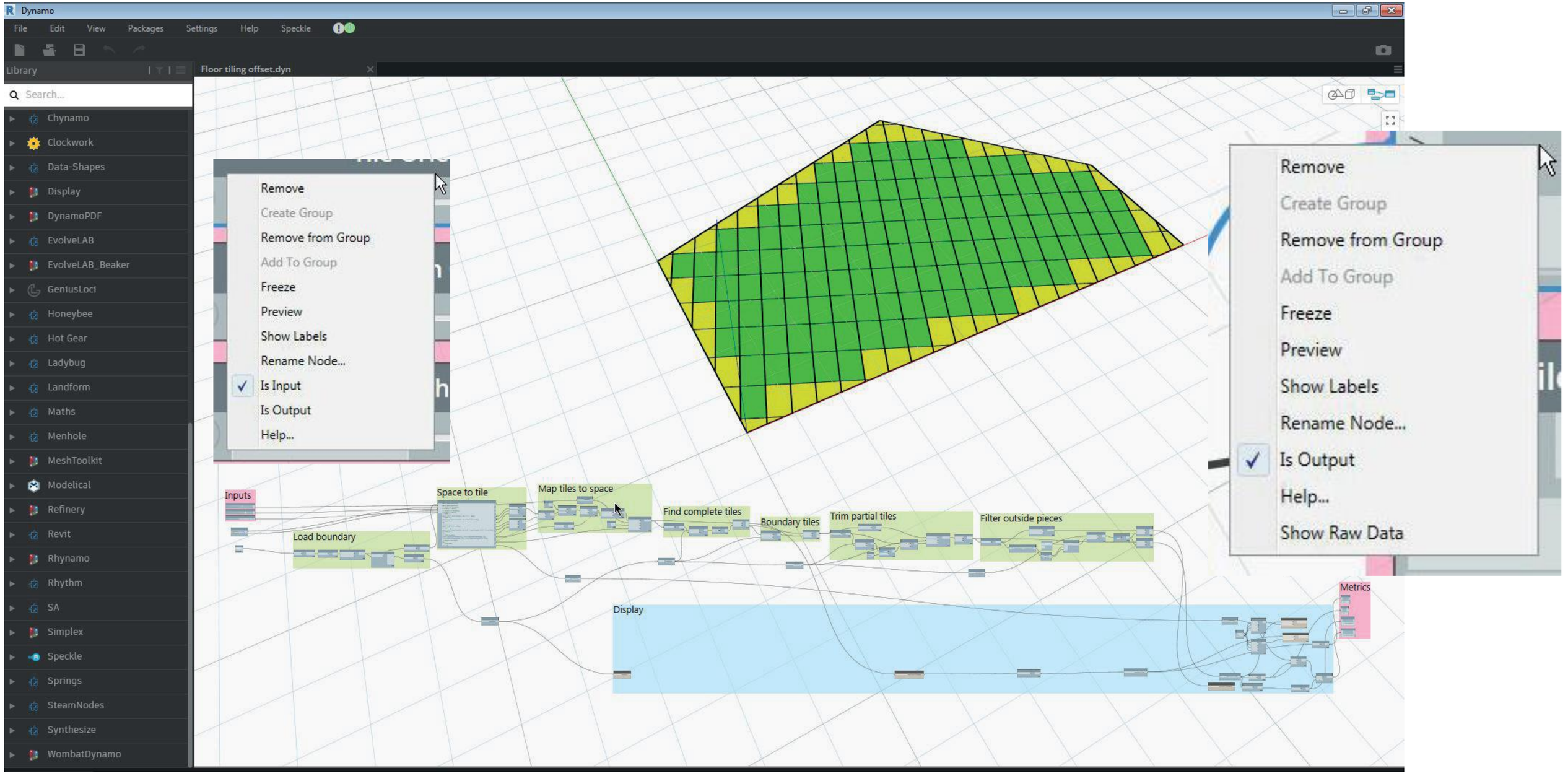
Gen. 99 ~ Indv. 5

Genes: -84.072 | 0.456 | 1 ~ Fitness Obj.: -141 | 10.633254

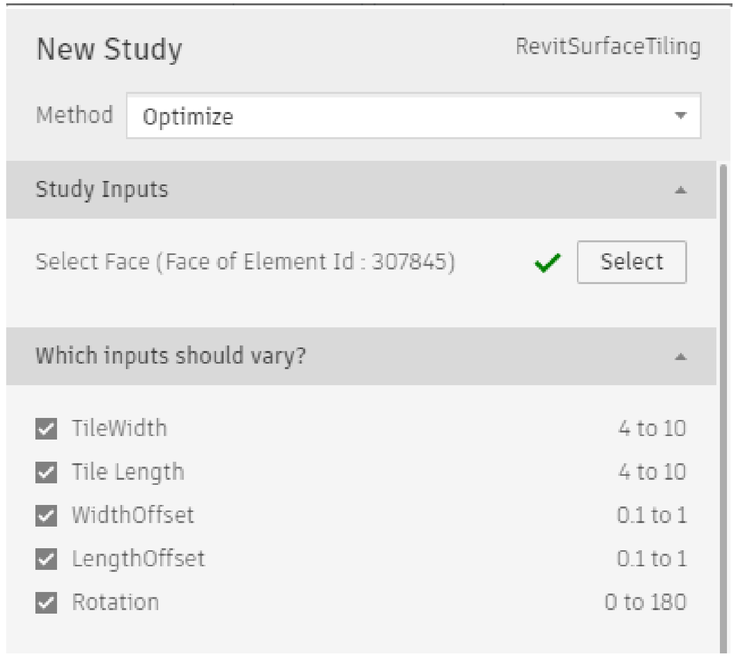
Gen. 99 ~ Indv. 6

Genes: -81.994 | 0.456 | 0.957 ~ Fitness Obj.: -144 | 12.133254

LAST GENERATION SOLUTIONS

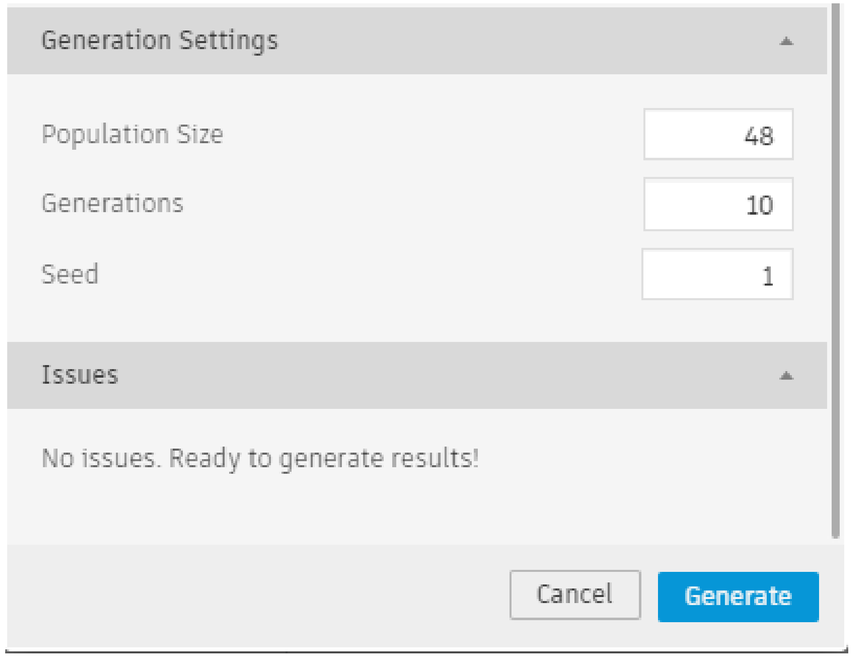

Dynamo
File
Edit
View
Packages
Settings
Help
Speckle
Library
Search...
Chynamo
Clockwork
Data-Shapes
Display
DynamoPDF
EvolveLAB
EvolveLAB_Beaker
GeniusLoci
Honeybee
Hot Gear
Ladybug
Landform
Maths
Menhole
MeshToolkit
Modelical
Refinery
Revit
Rhynamo
Rhythm
SA
Simplex
Speckle
Springs
SteamNodes
Synthesize
WombatDynamo
Floor tiling offset.dyn
Remove
Create Group
Remove from Group
Add To Group
Freeze
Preview
Show Labels
Rename Node...
Is Input
Is Output
Help...
Show Raw Data
Inputs
Load boundary
Space to tile
Map tiles to space
Find complete tiles
Boundary tiles
Trim partial tiles
Filter outside pieces
Display
Metrics

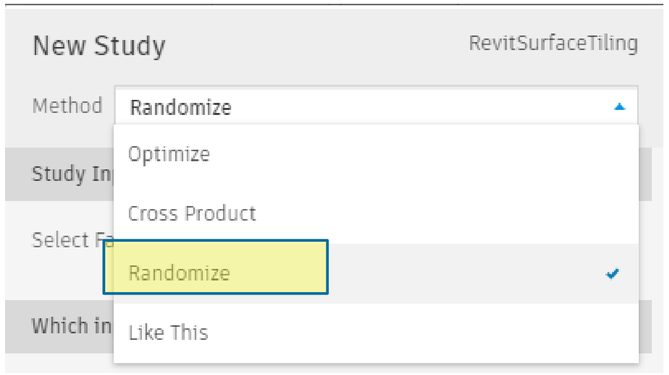
GENES



FITNESS

SETTINGS

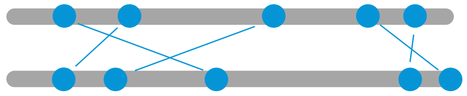




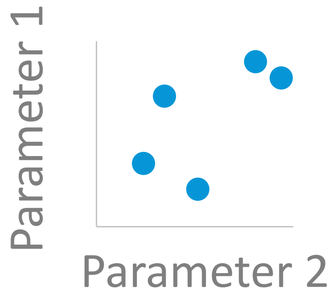
INPUTS

Parameter 1

Parameter 2



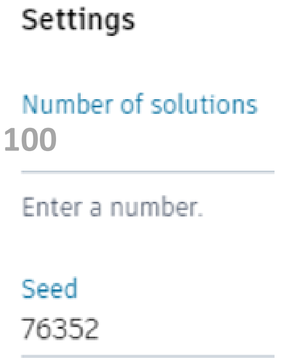
DESIGN SPACE



OUTCOME

5 DESIGNS

defined by user

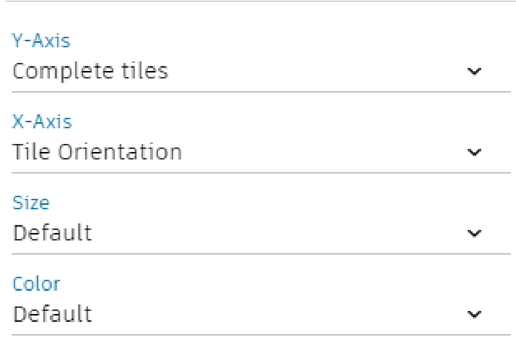


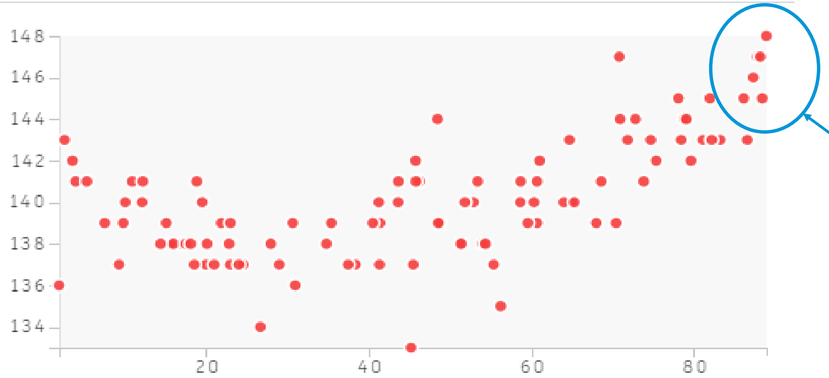
"Optioneering"

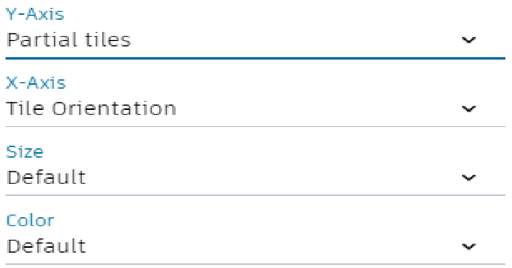
100 possible random solutions

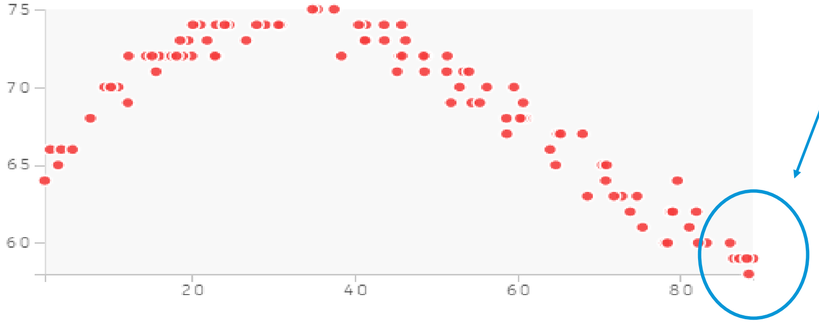
was used as an initial study.

This took approximately 5 minutes to run

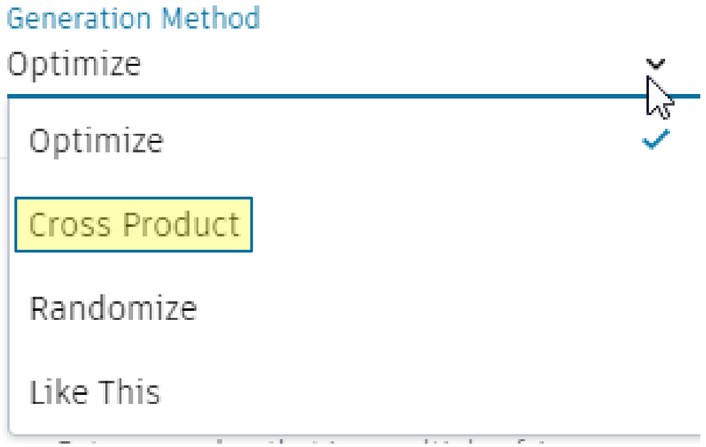


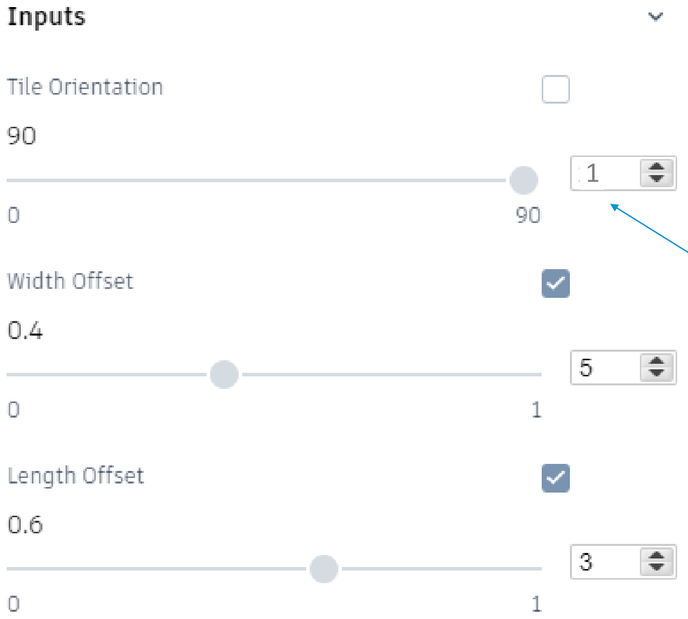


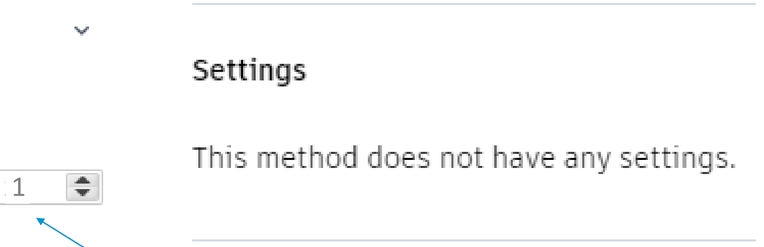




Indicates that maximum number of complete tiles and minimum partial tiles occur when tile rotation is 90 degrees



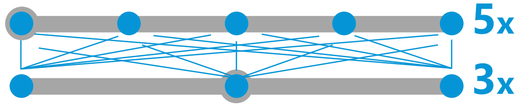




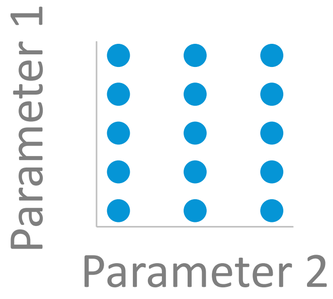
If tile rotation was fixed

INPUTS

Parameter 1
Parameter 2



DESIGN SPACE

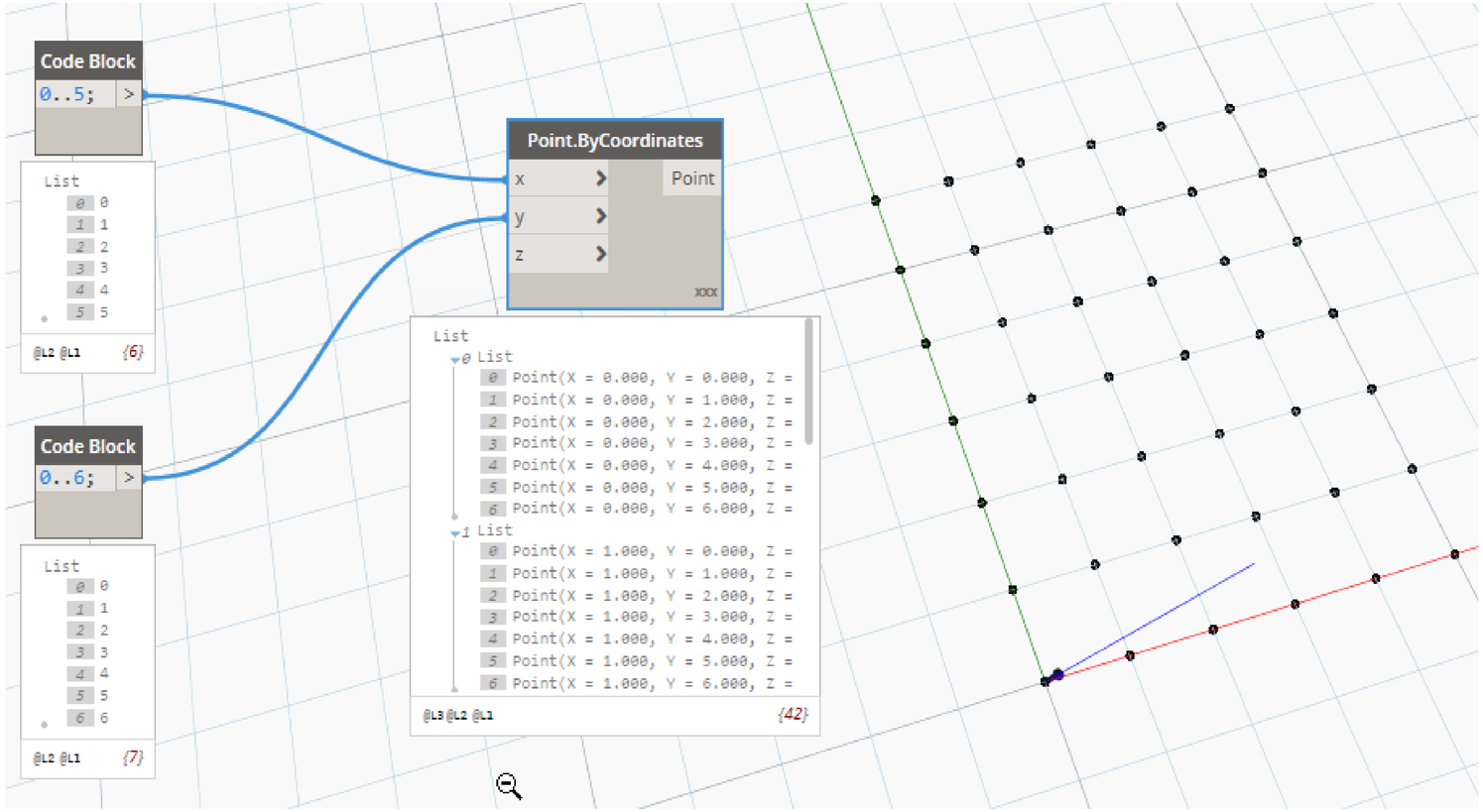


OUTCOME

5 x 3 = 15 DESIGNS

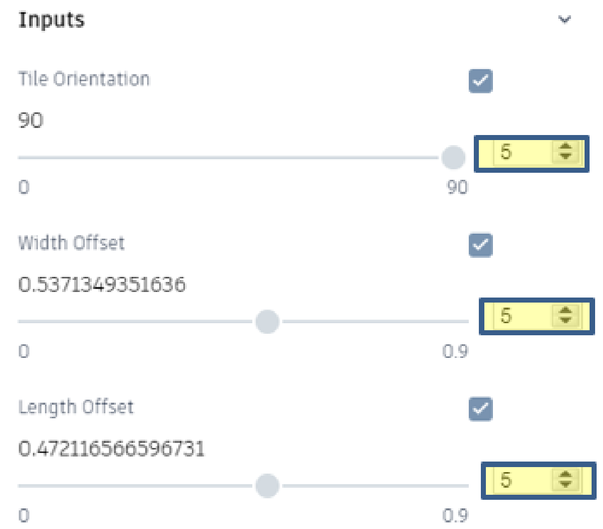
user defines sampling density

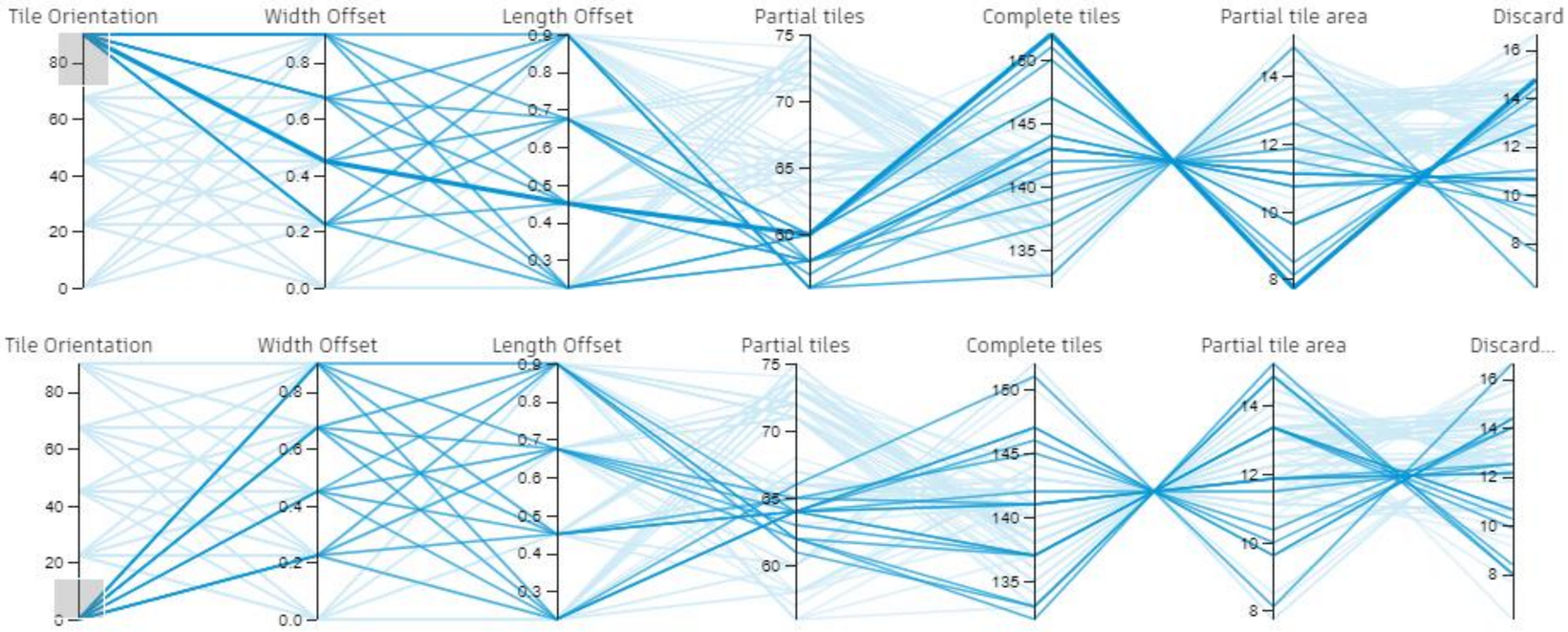
Cross Product Lacing within Dynamo



An input variable with 6 items combined with an input of 7 items = 42 solutions

Cross Product Lacing within Refinery

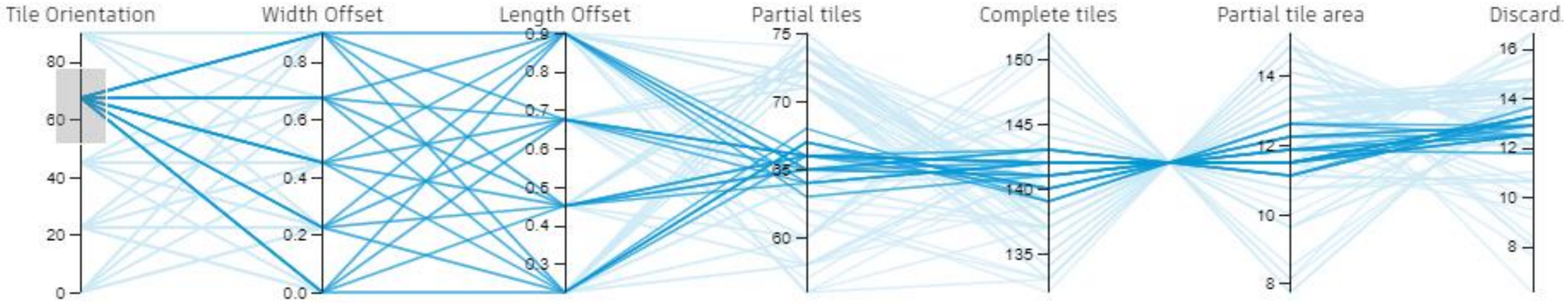




5x5x5=125 solutions

Runtime 5 mins

Filtering for tile orientation for 0 & 90 degrees



Filtering for tile orientation of 67.5 degrees

Generation Method

Optimize

- Optimize
- Cross Product
- Randomize
- Like This

Inputs

Tile Orientation ☑

90

0 — 90

Width Offset ☑

0.4

0 — 1

Length Offset ☑

0.6

0 — 1

Outputs

Partial tiles 60	IGNORE
Complete tiles 150	MAXIMIZE
Partial tile area 8.4917458401...	IGNORE
Discarded area 14.008254159...	MINIMIZE

Settings

Population Size

3

Enter a number that is a multiple of 4.

Generations

6

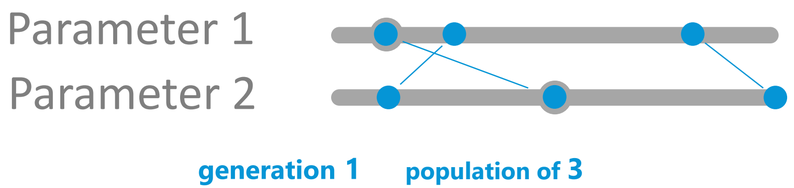
Enter a number.

Seed

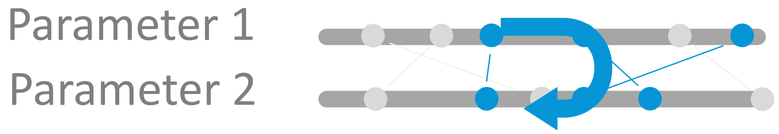
45521

Enter a number to control where randomization starts.

INPUTS

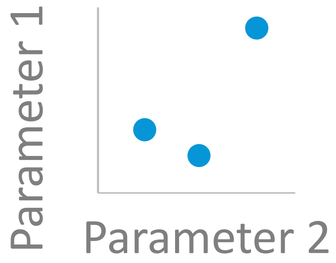


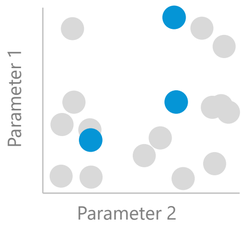
generation 1 population of 3



generation 6 population of 3

DESIGN SPACE

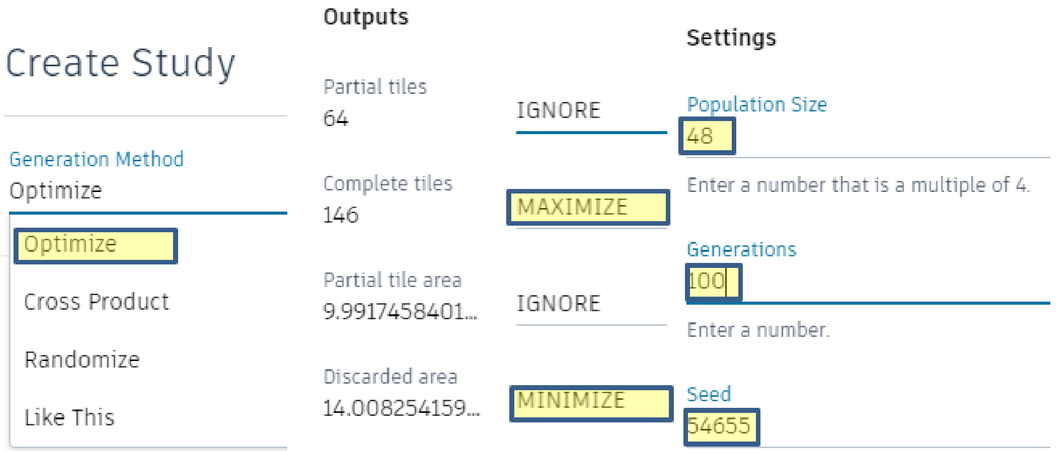




OUTCOME

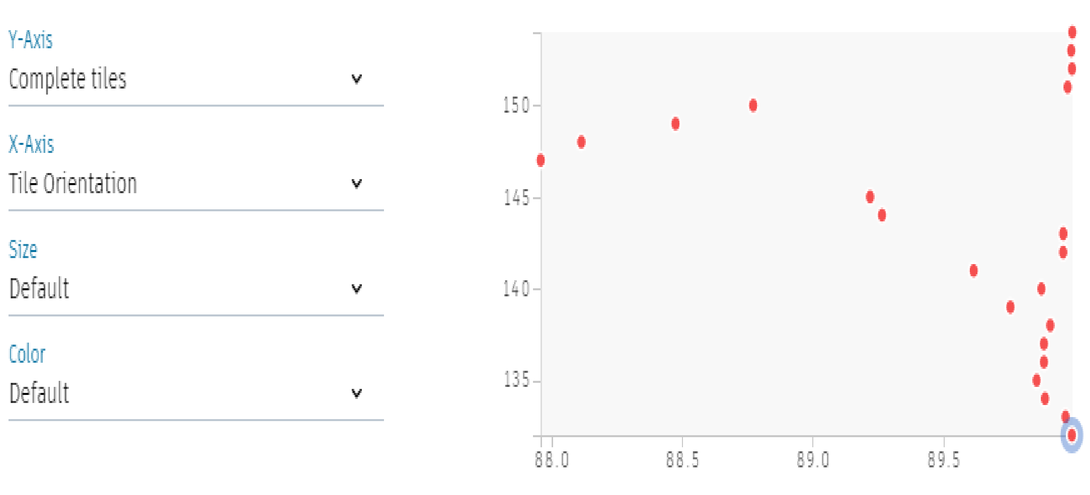
3 x 6 = 18 DESIGNS

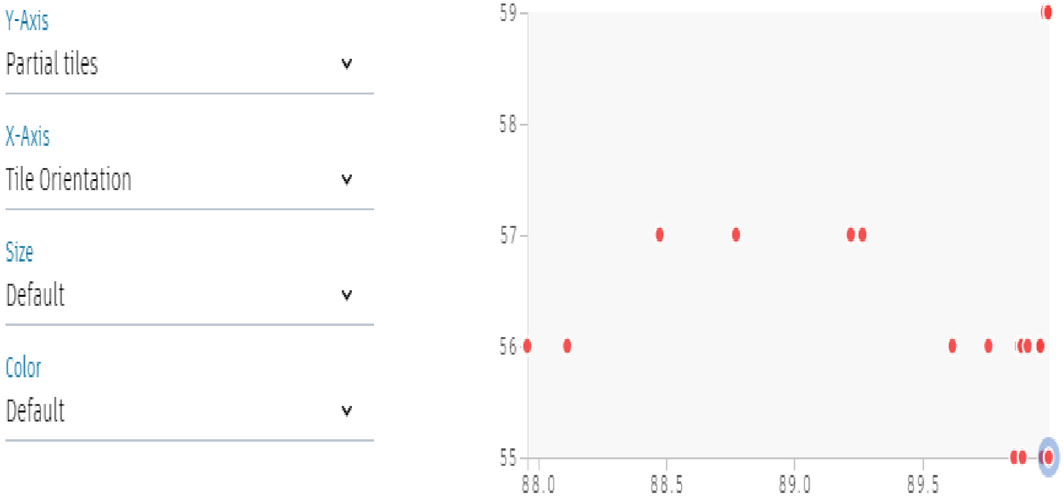
user defines population size
and number of generations



population size of 48, with 100 generations

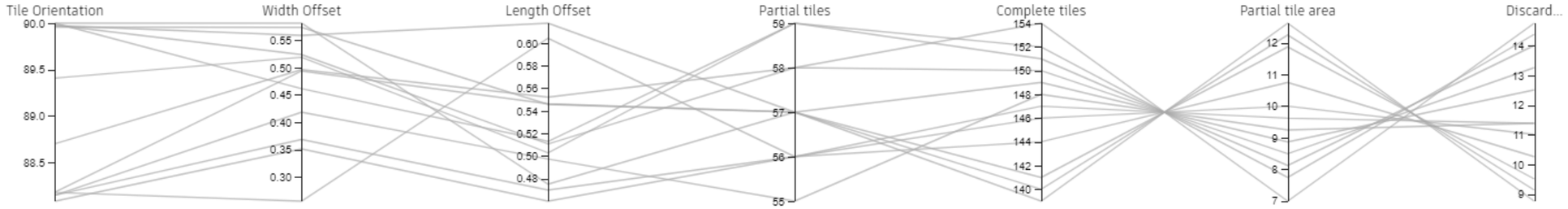
approximately 45 minutes to run.





4,800 options analysed, only one single solution plotted from each generation.

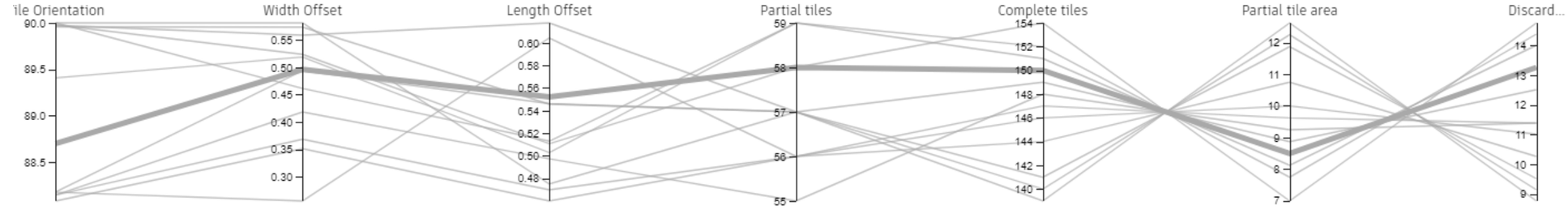
28/28
100/100
14/100
25/25
0/100
7/26
23/100
4/25
100/100



Filter

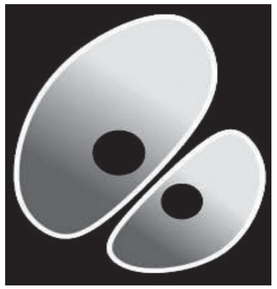
Partial tiles	Complete tiles↓	Partial tile area	Discarded area	Tile Orientation	Width Offset	Length Offset
58.0	154.0	6.992	14.758	89.979	0.523	0.511
59.0	152.0	7.742	14.383	90.0	0.461	0.513
59.0	151.0	8.117	14.008	89.408	0.519	0.503
58.0	150.0	8.492	13.258	88.701	0.496	0.552

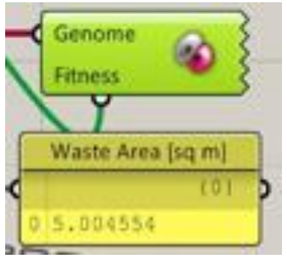
Population 48
Generation 100
Approx. 45min to run



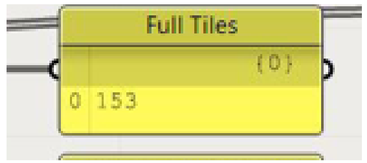
er

Partial tiles	Complete tiles	Partial tile area	Discarded area↑	Tile Orientation	Width Offset	Length Offset
57.0	139.0	12.617	8.758	89.972	0.559	0.618
57.0	140.0	12.242	9.133	89.958	0.573	0.546





10,800 combinations tested X 244 ms per solution = 43.92 min



5,000 combinations tested = 19.19 min (13 min to find optimal solutions)

155 full tiles

9.11 sqm waste area

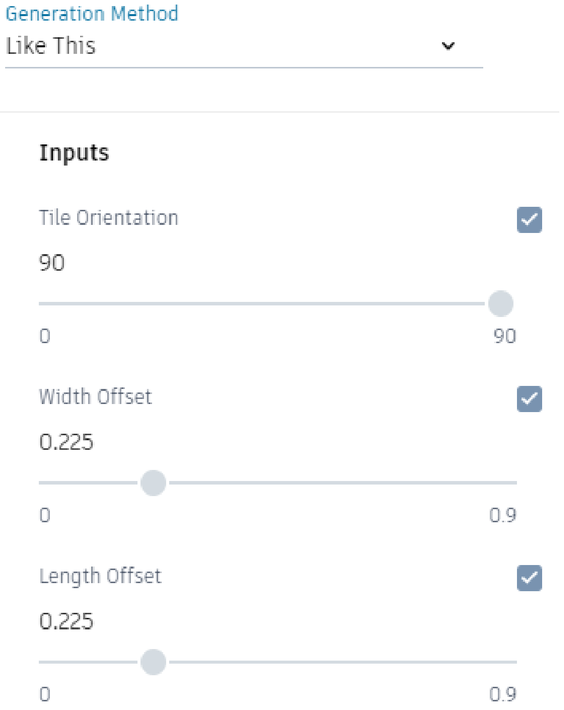
153 full tiles

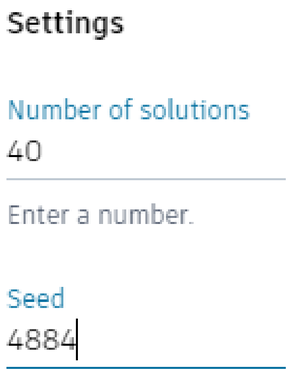
5.00 sqm waste area

4,800 combinations
Population 48
Generation 100
Approx. 45min to run

Complete tiles↓	Partial tile area	Discarded area
154.0	6.992	14.758

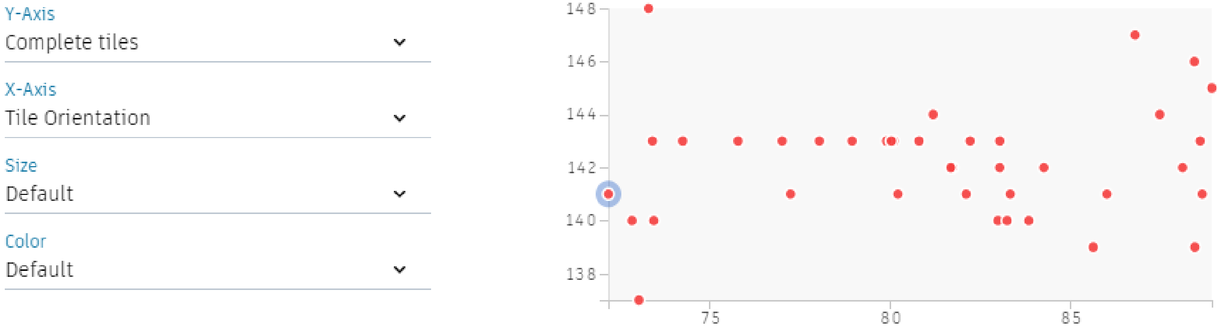
Complete tiles	Partial tile area	Discarded area↑
139.0	12.617	8.758



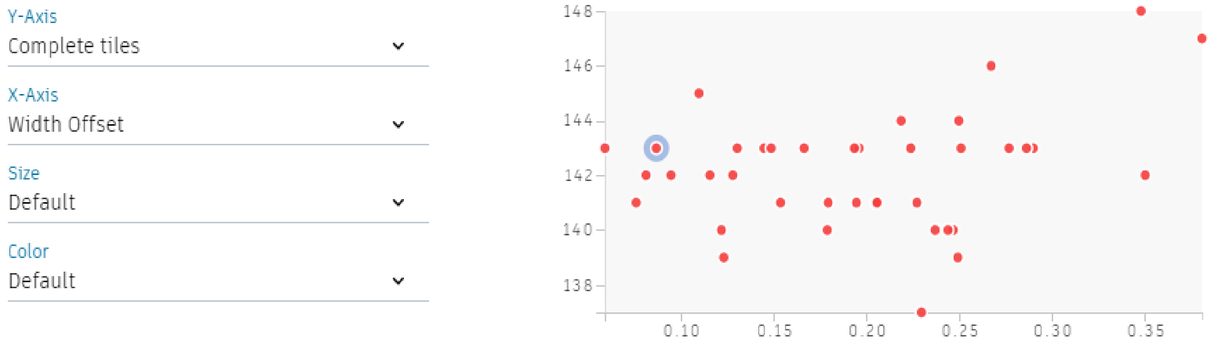


The “Like This” method carries out a minor variation to the noted inputs.

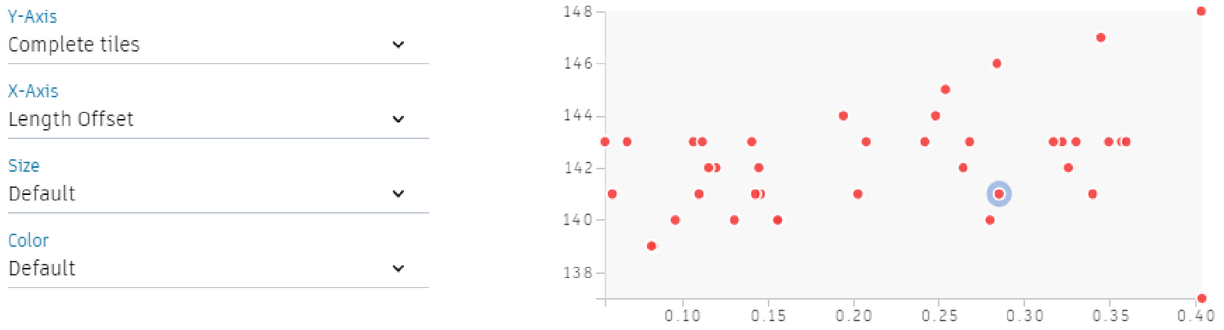
It is not clear how far the “like this” option deviates from the selected inputs



Tile Orientation is limited to 73-90 degrees



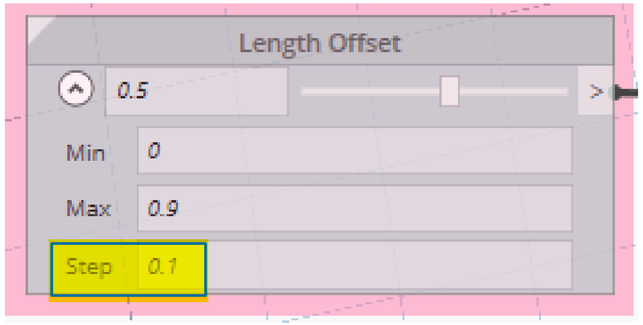
Width offset is limited to 0.05 – 0.40 degrees



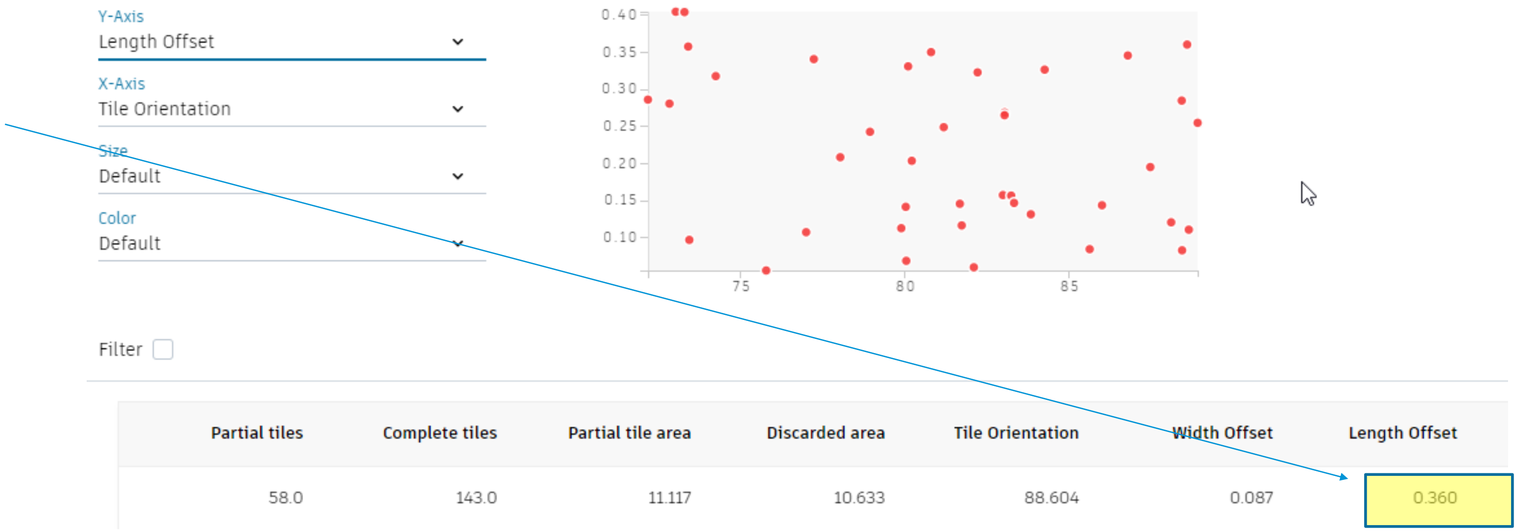
Length offset is limited to 0.05 – 0.40 degrees

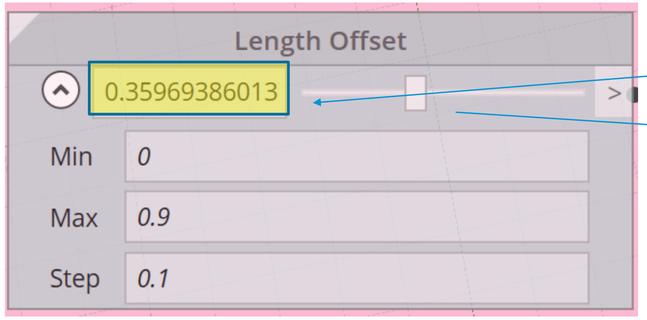
LESSONS LEARNT

Step value appears not to be respected in Refinery



Step Value in Dynamo prior to run in Refinery

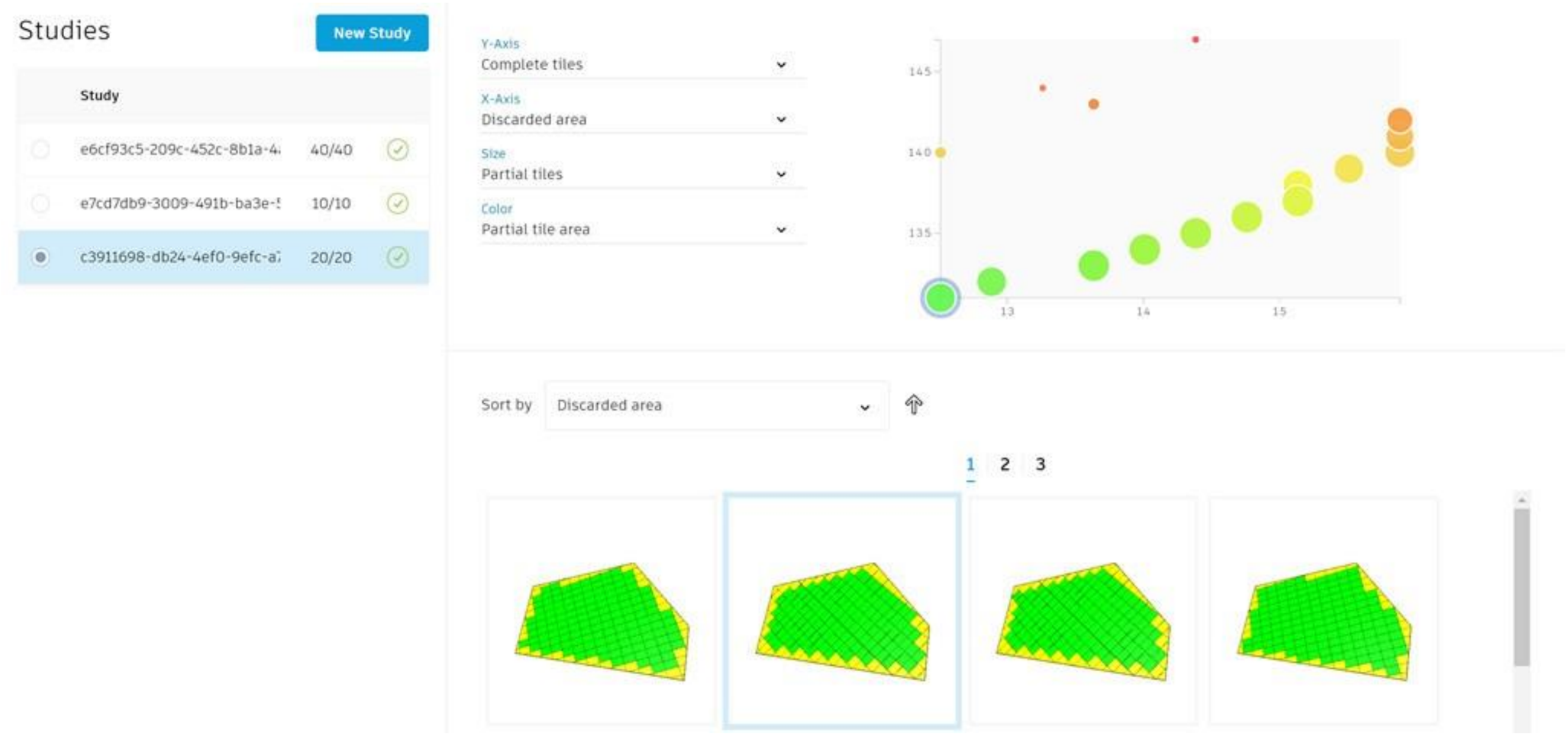




Value in Dynamo post run in Refinery

0.359693860137189

Accurate to 15 Decimal places!



GENERATION 20

960 combinations tested X 394 ms per solution = 6.30 min

7,500 ms per solution on Dynamo alone (x20 SLOWER)

244 ms per solution on Octopus (x1.6 FASTER)

CONCLUSIONS

CONCLUSIONS

- **Evolutionary Solvers** are powerful tools to be used on **specific** or partial **problems**.
- To formulate the right **fitness function** and the set the **key variables** is crucial.
- The process helps to **understand** the nature of the **problem**.
- They are **slow** because of the amount of options to be tested and depending on the complexity of the problem, the efficiency of the script, the platform we are using and the hardware capabilities.
- **Galapagos** is a robust built-in GH tool which is ideal to solve **single objective optimization** problems.
- **Octopus** is a **multi objective optimization** plugin for GH which tackles more complex problems and enables user **interaction** and **solutions exploration**.
- **Refinery** is a **multi objective optimization** beta product by Autodesk that computes **Dynamo** scripts **faster** than within the Revit / Dynamo environment (but still slower than Rhino / GH).
- Unlike its GH competitors, **access to the evolutionary data is harder to access,** behind which is a valuable information to identify good solutions and improve fitness functions.

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