PORTFOLIO

My name is Marco Pellegrino and my portfolio is a representation of what I have learned as an Engineer and Researcher.

The samples in this document show how my critical thinking skills have evolved over the course of the time and a library of script have been created. The topic range from Structural Engineering, Automation of process, Research and Software Development.

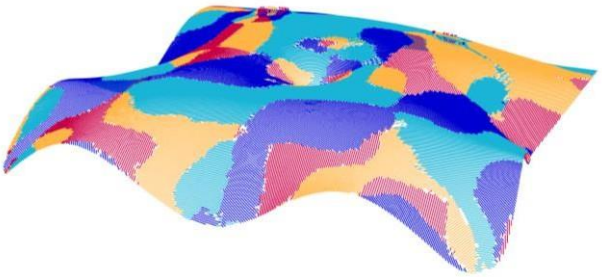
My personality is pointing to the research aspect of the work. Reseaching is an attitude that appears constantly in anything I do. It is about taking path that no one has taken before and explore with the desire to find something unique.

BIG DATA
MACHINE LEARNING

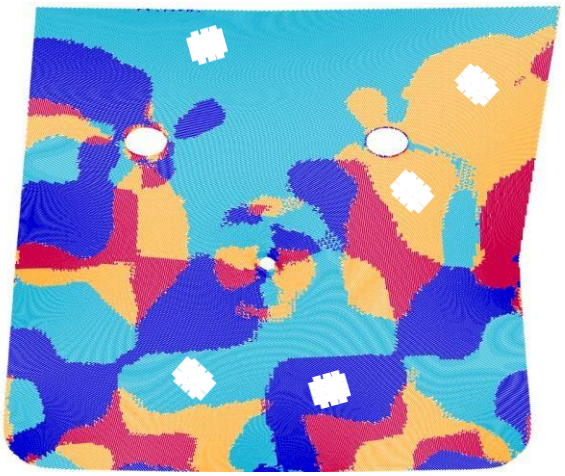
- **Python**
- **Scitik-learn**
- **Pandas**
- **Bokeh**
- **matplotlib**

REINFORCEMENT BAR PLACEMENT

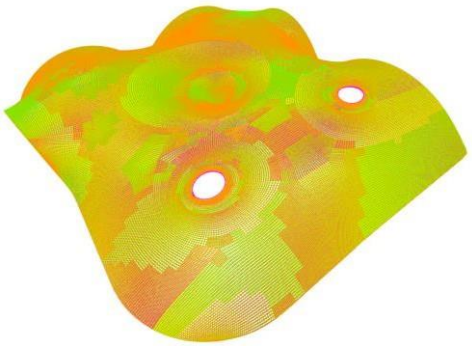
The ML algorithm try to subdivide a vector field in *k* optimal orientation to place an orthogonal mesh of steel rebar. The technique has been used for a Concrete Shell that will be built in Spring 2021 in Bath, UK.



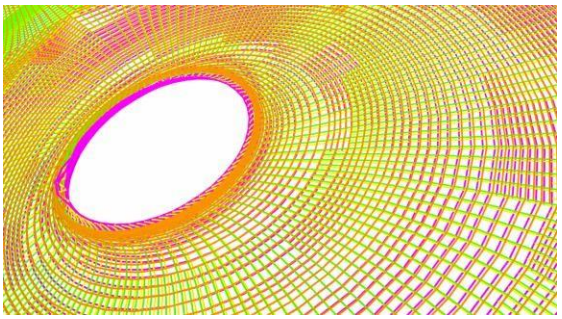
Vector field orientation, *K-means* clustering



k-means clustering applied to the unroll geometry

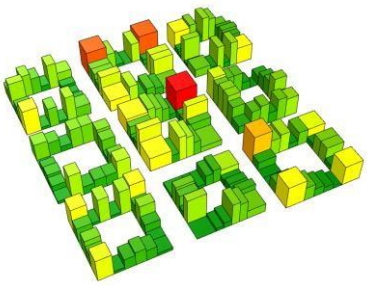


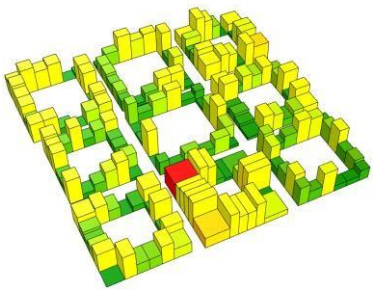
Final reinforcement steel bar layout

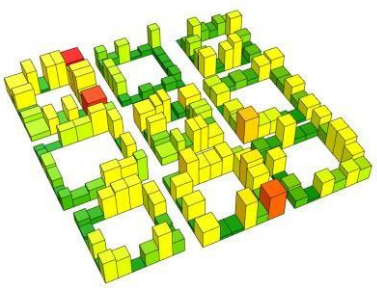


Detail of the final reinforcement steel bar layout

URBANPLAN OPTIMISATION





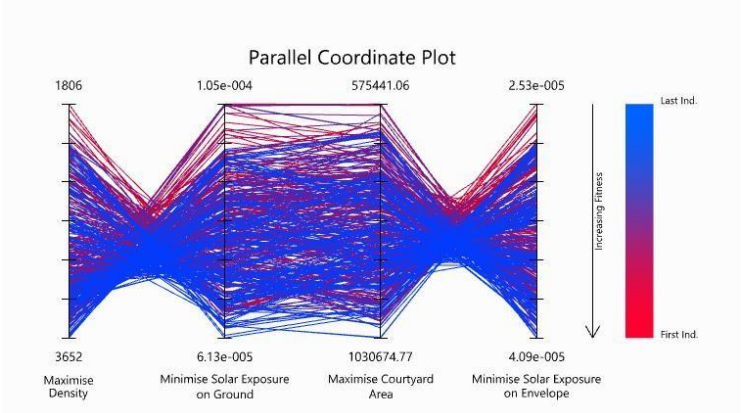


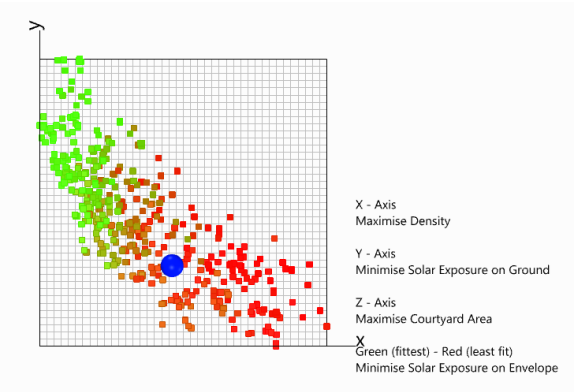
I created a script performing an urbanplan optimisation.

The script try to find the solution with:

- Minimum Volume
- Minimum Courtyard
- Maximise difference in heights

The results are plotted in several chart to highlight the solutions.

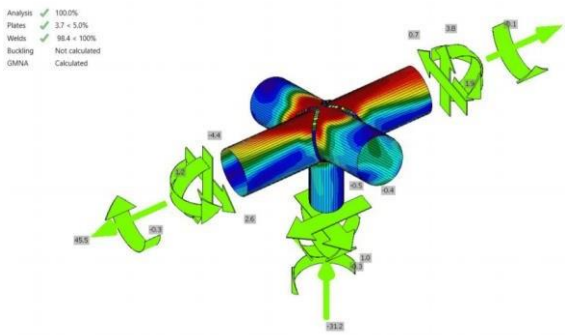




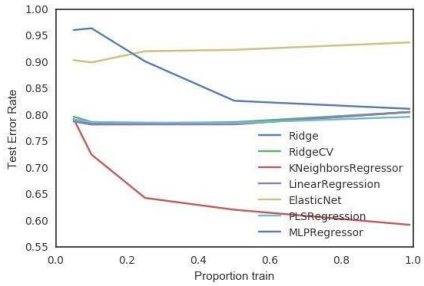
Feasible solutions, Pareto-front

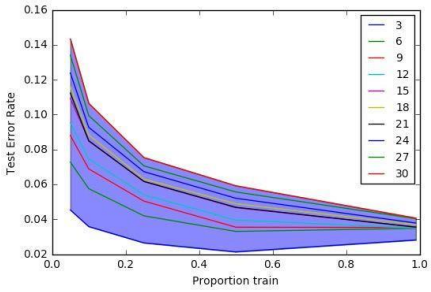
BEST STEEL CONNECTION

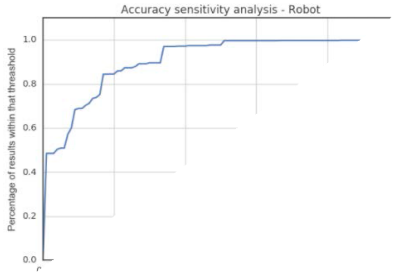
Most part of their time, engineers around the globe are asked to design over and over again the same or very similar structures, without just taking what has already been done or learning from the past. Arguably the same structural elements with given acting forces and constraints have been designed thousands of times.
This research tries to take a step further in the realm of structural optimization by having a fresh look at machine learning strategies to address one of the above-mentioned challenges: the automatic design of 5 node steel connection.



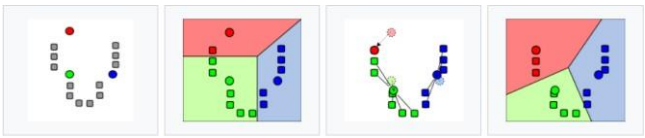
Von Mises stress for 5 valence node





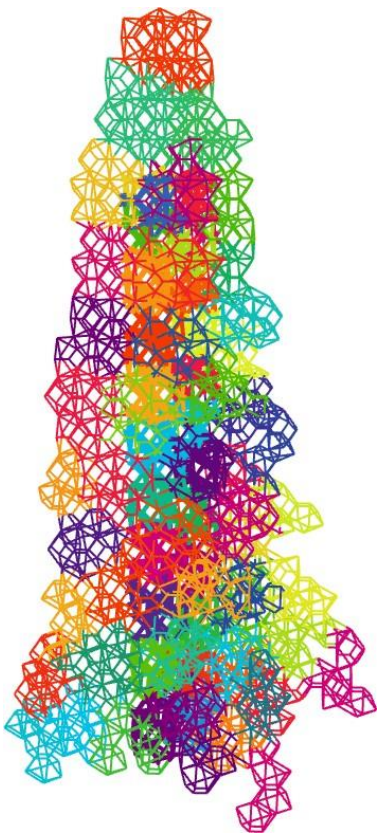


K-MEANS CLUSTERING



k-means clustering aims to partition *n* observations into *k* clusters in which each observation belongs to the cluster with the nearest mean.

The algorithm has been used to generate 75 different cluster to allow the fabrication to become easier. The clustering has taken in account the internal force of each element as driven of the algorithm.

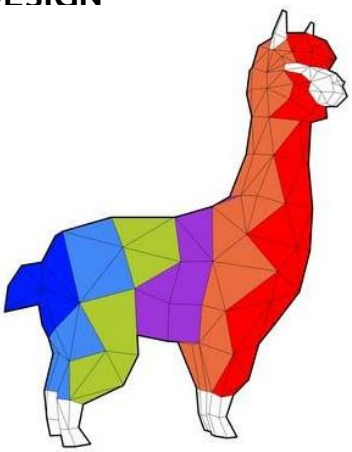


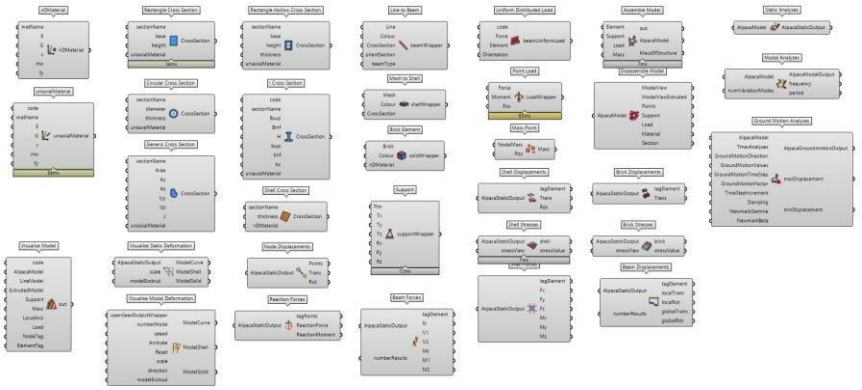
K-means clustering results

OPENSOURCE

- OpenSource tool
- Python, tcl
- Github
- Social Media
- Teaching
- Workshop

ALPACA4D - PARAMETRIC STRUCTURAL DESIGN



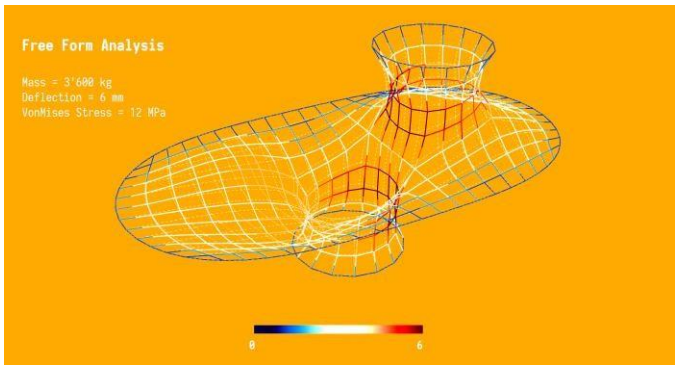


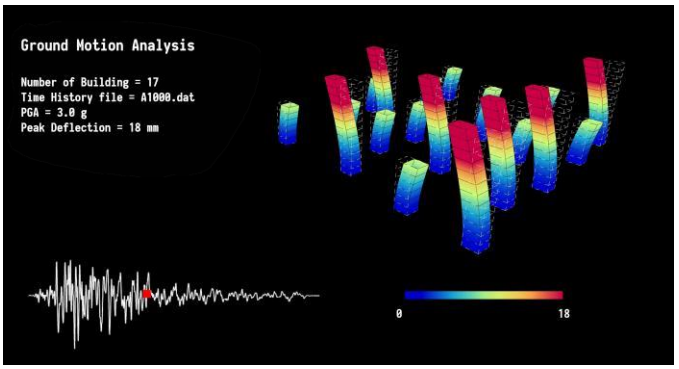
Alpaca4d is a Grasshopper plugin which I wrote from scratch on top of OpenSees Library. The library is mostly used by researchers and academia because of the not user-friendly interface even if the math behind the library is highly sophisticated. The main idea of Alpaca4d is to provide an efficient and easy way to use OpenSees without writing any line of code.

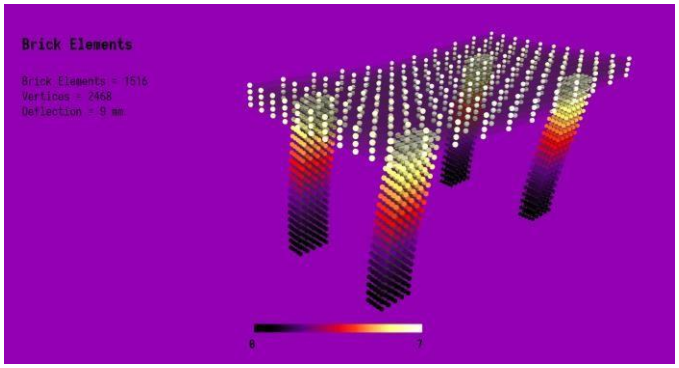
The project involved:

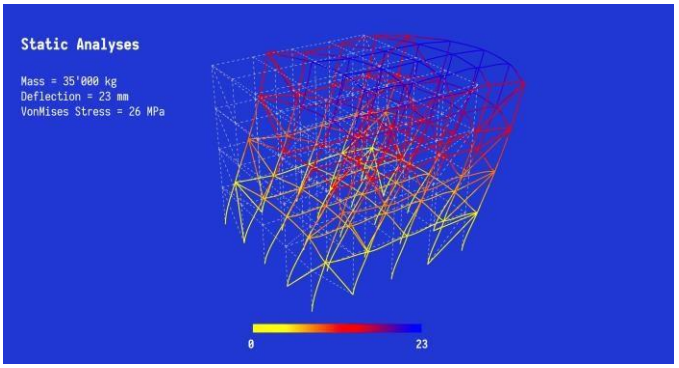
- Python code 2.x/3.x
- tcl code
- subprocess
- JSON
- Object-oriented programming
- Software deployment
- Portable Python
- Drawing icon
- Writing Documentation
- Remote collaboration
- Social Media adverts
- Research
- Mentoring student

The tool has been developed to fill the gap in the Grasshopper community. There were no tool which allow to perform Dynamic and Non-Linear Analysis. The project has started with a friend at the beginning of the Covid-19 and it has been developed with a remote collaboration.





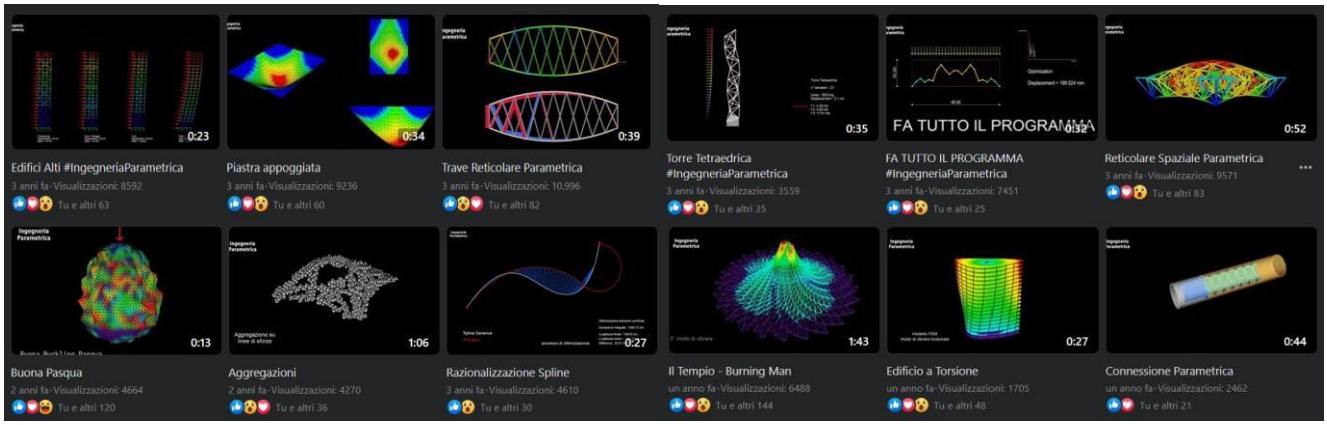




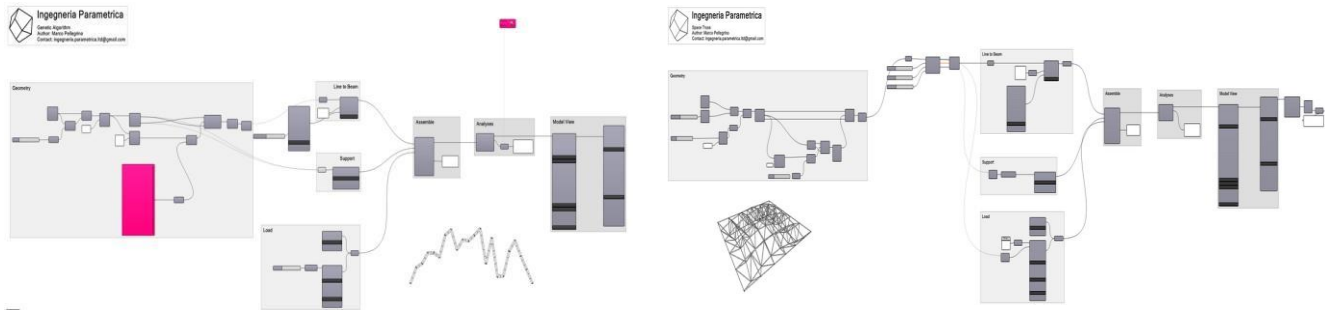
Github: https://github.com/Alpaca4d/
Food4rhino: https://www.food4rhino.com/app/alpaca4d
Instagram: https://www.instagram.com/Alpaca4d/
Facebook: https://www.facebook.com/Alpaca4d/

INGEGNERIA PARAMETRICA - COMMUNITY

Ingegneria Parametrica is a community of 4500 people interesting in computational methods for the resolution of civil engineering structure. The material is completely available for download on Github. The scripts are ready to use with a minimum effort and an edited video is attached for each script in order to have an overview.
The community has been created to share knowledge and help the students/professional to keep up to date.



Video advertising



Grasshopper Script available on Github

Github: https://github.com/Marco-Pellegrino/IngegneriaParametrica
Facebook: https://www.facebook.com/ingegneriaparametrica/
Instagram: https://www.instagram.com/ingegneriaparametrica/

TEACHING

I am part-time tutor for Computational Design at the Architecture Association in London and the engineering Department in Turin. Teaching helps me to keep my knowledge up to date and learn something new all the time.

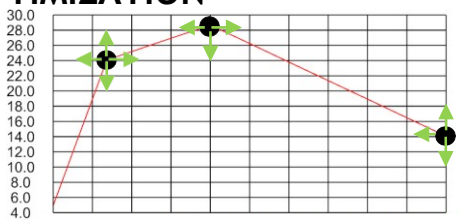
POLITECNICO DI TORINO

GEOMETRY RATIONALIZATION
STRUCTURAL OPTIMIZATION

Custom scripts and Grasshopper

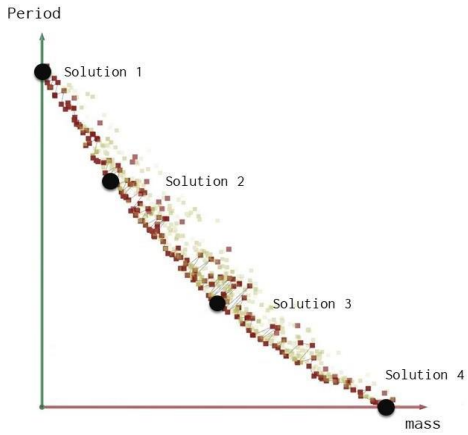
- **Adaptive Form-Finding**
- **Fabricability optimisation**
- **Surface optimisation (top-down, bottom-up)**
- **Advanced geometry modelling and optimization**
- **Panelization**

SINGLE AND MULTI-OBJECTIVE OPTIMIZATION

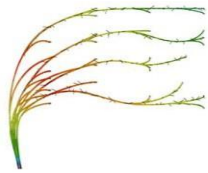


Cross section function

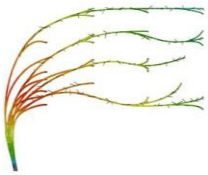
Multi-objective optimization problem is when no single solution exists that simultaneously optimizes each objective. The Pareto-front is the space of all the optimal solutions. I wrote a script that minimise the mass while increasing the stiffness of the structure.



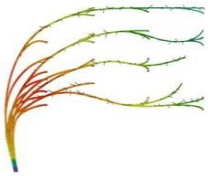
Feasible solutions, Pareto-front



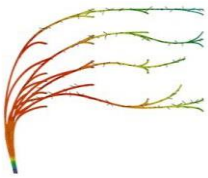
Solution 1



Solution2

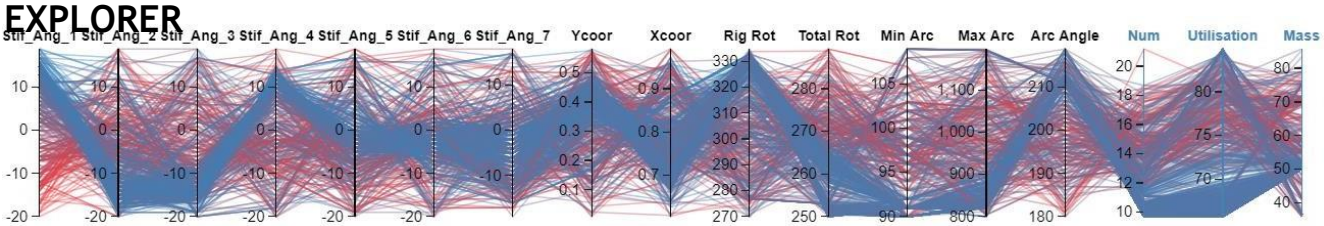


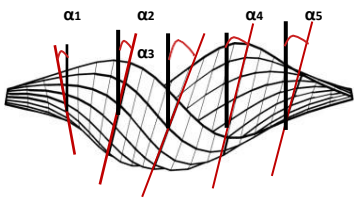
Solution 3

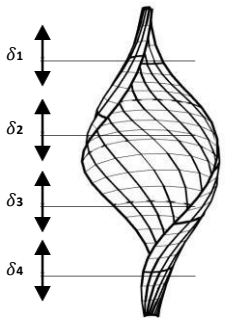


Solution 4

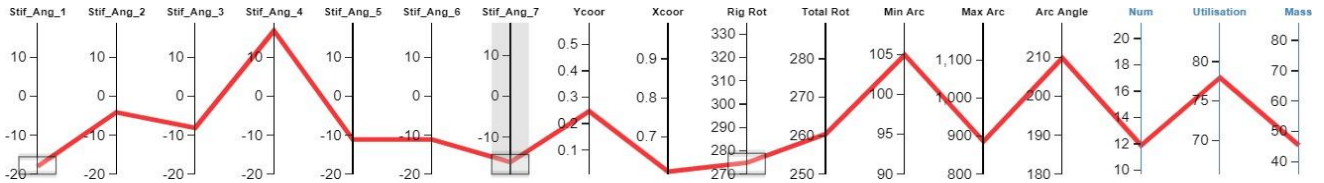
DESIGN EXPLORER

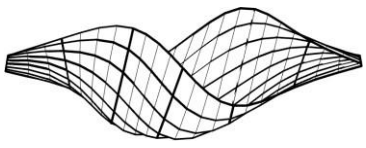






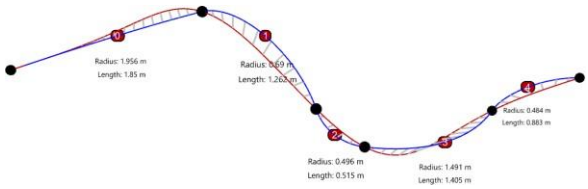
Visual representation of the design space. The user can explore the solution looking at the aesthetic while the structural behaviour update is some automatically. output Jupyter Notebook to explore the design space.



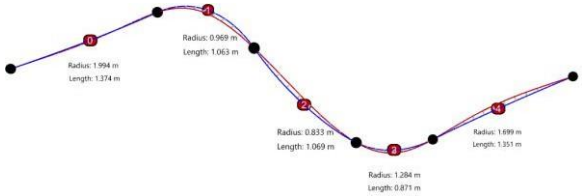


The graph shows the optimal solution chosen from the design space

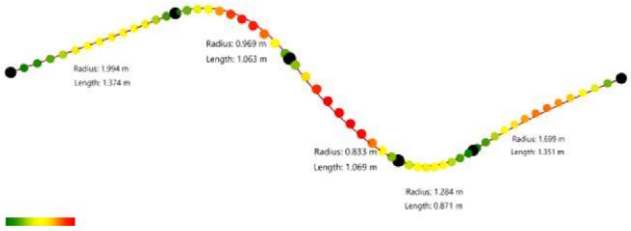
SPLINE RATIONALIZATION



Initial Spline (red), Initial arcs (blue)



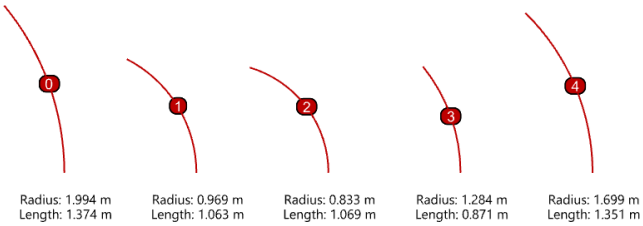
Initial Spline (red), optimise arcs (blue)



0.0

5.0

Deviation graph



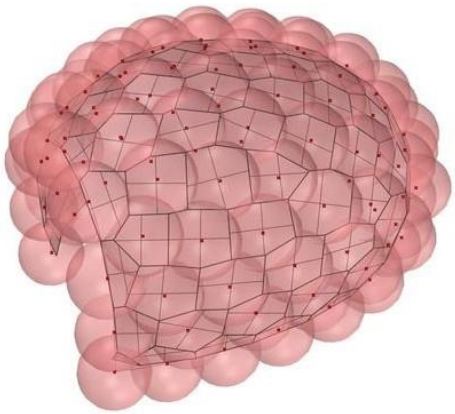
Oriented arcs with geometric information for fabrication

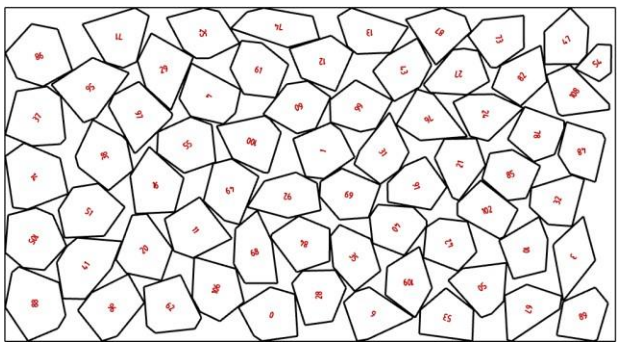
I created a script performing a full Spline rationalization given the number of output arcs.

The algorithm try to find the minimal divergence between the Spline and the arcs with Genetic Algorithm.

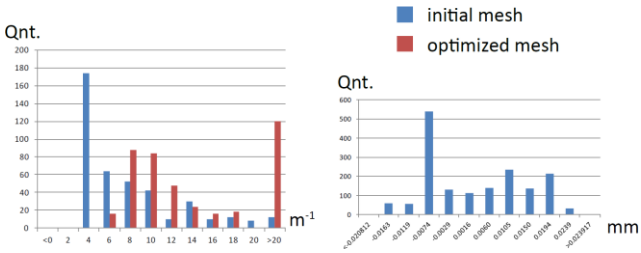
The result is a series of arcs with the same tangent angle

PLANARIZATION



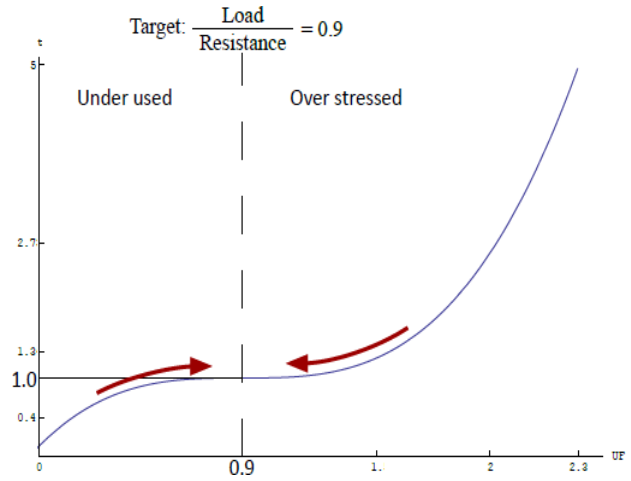


Nesting

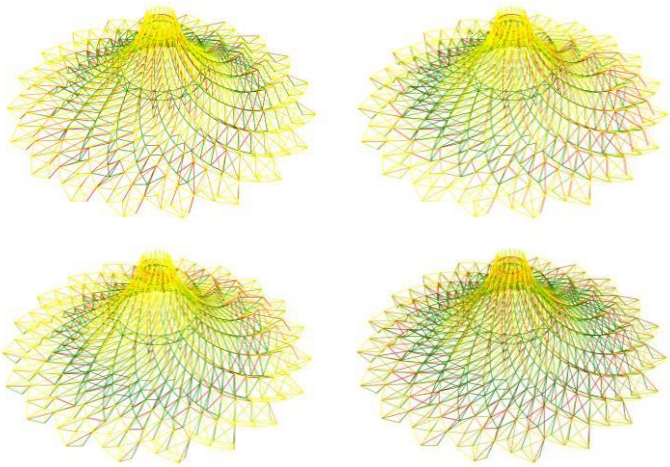


Free-form shape has been tessellate with a n-gon planar surface. The planarization allows to reduce the cost. Nesting is part of the cost reduction because the waste material has reduce to a minimum. After a research and test of the available tool, I have wrapped up the best one in a grasshopper script to be use for the office.

ITERATIVE OPTIMIZATION PROCESS



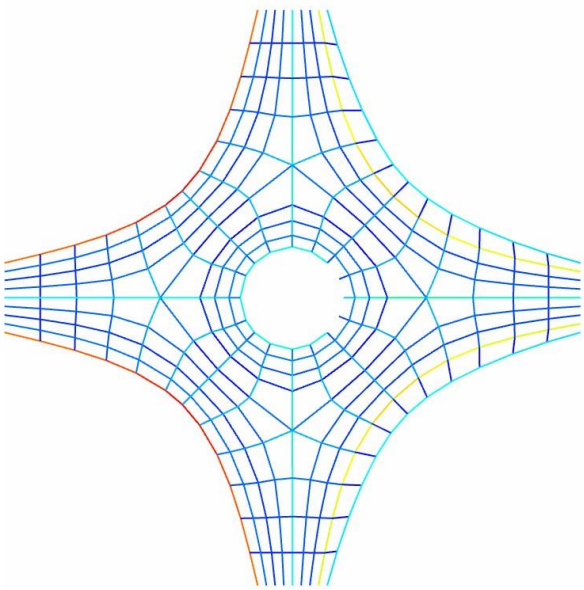
Optimization function used to upgrade members thickness



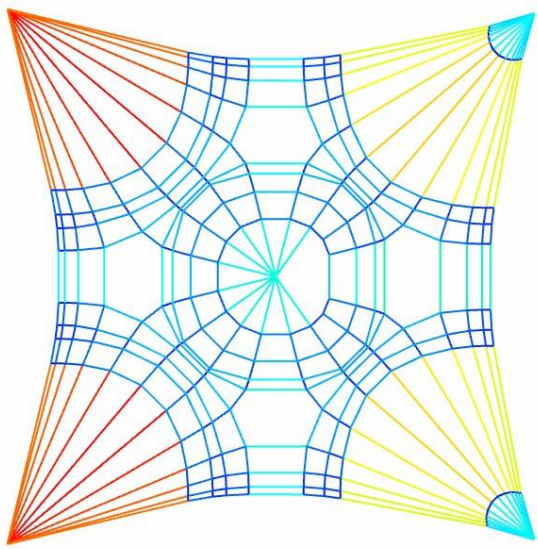
Grasshopper script and output plot for four different load patterns. The algorithm maximizes resistance and stiffness by optimizing the distribution of wood.

FUNICULAR SHELL DESIGN

Algorithms enable an interactive exploration of novel funicular shapes, enriching the known formal vocabulary of shell architecture. The form found has only internal compression force and it the most efficient shape for such a boundary conditions. The technique involve math, engineering and coding. The client demanded an Only Compression force structure and for such demands I have been researching with a tight deadline the best solution.



Form Diagram



Force Diagram

ADVANCED FEA
AUTOMATIZED ANALYSIS

- **Non Linear Plastic/3° order Analysis**
- **Buckling Analysis**
- **Time-history**
- **Automatization through scripting**

ADVANCED FEA WITH CUSTOM SCRIPTS

MECWAY AND PYTHON

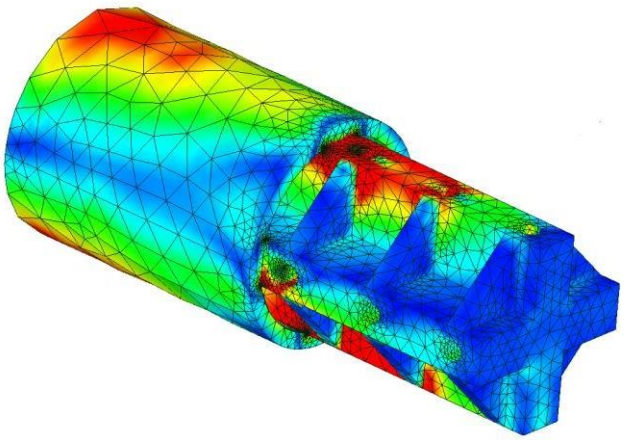
Node data is automatically exported from GH or other software and pulled through Python scripting into MECWAY, performing buckling and non-linear analysis.

```
** Generated by Mecway 11.0
*NODE
1,0,0,0
2,0.7142856121063,0.09090909177114,0.006250000093132
3,0.7857141494751,1.818181873353,0
4,0.2857142388821,0.2727272658309,0.006250000093132
5,0.5714284777641,0.7272727341691,0


*ELEMENT,TYPE=C3D20
1,632,635,608,604,631,634,600,437,774,847,297,859,870,943,391,
959,867,866,293,172
2,635,626,605,608,634,625,440,600,786,654,853,847,882,763,733,
943,866,662,373,293
3,591,580,626,635,588,428,625,634,340,368,786,773,135,666,882,
869,837,975,662,866


*MATERIAL,NAME=Material
*ELASTIC,TYPE=ISOTROPIC
1000000,0.3
*SOLID SECTION,ELSET=Default_Group,MATERIAL=Material

*STEP
*BUCKLE
4
*DSLOAD
pressure_faces,P,80
*NODE FILE,GLOBAL=YES
```

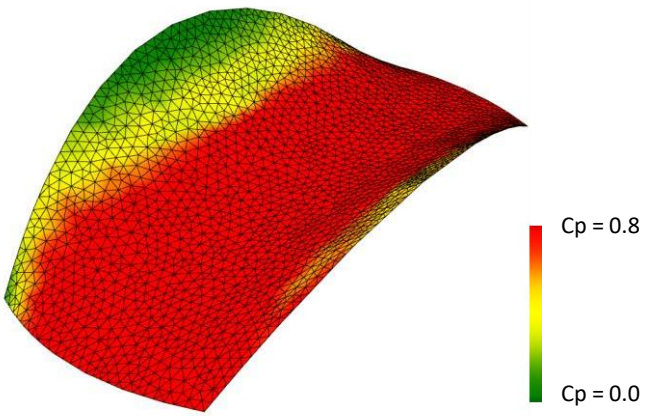


Python scripting: parametric generation of models and iterative analysis

AUTOMATIC GENERATION OF COMPLEX LOAD CASES

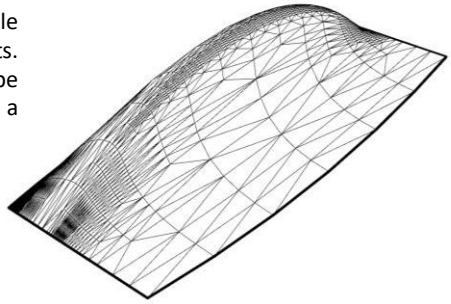
ADVANCED LOAD CASE DESIGN

Free forms require advanced load design for snow, wind, live load. I wrote some particular algorithms accordingly.
On the left, it is shown the Cp snow factor of a free form concrete vault.

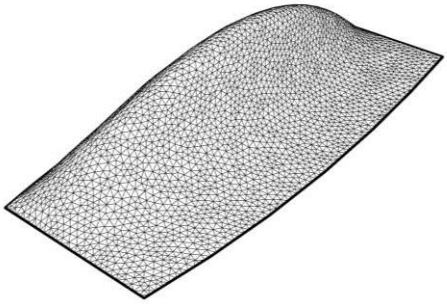


MESH REFINEMENT FOR FEA

Finite element are usually sensible to the shape of the elements. Regular triangulated mesh can be generate automatically in GH via a custom scripts.



Initial mesh



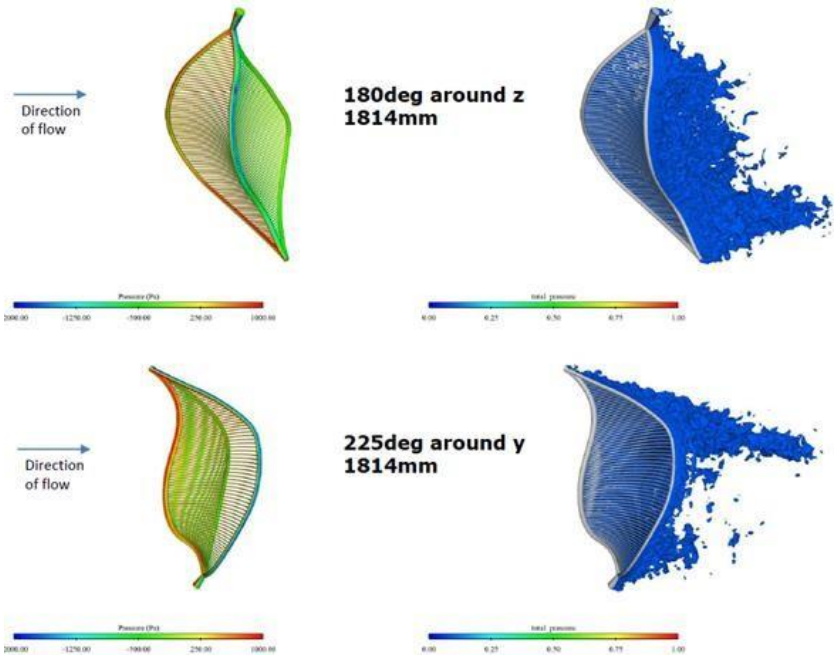
Refine mesh

ADVANCED FEA WITH CUSTOM SCRIPTS

CFD TO FEA

CFD data is automatically exported from a spreadsheet to a FEA software to better understand the behaviour of the structure under wind load. Static analyses can be performed.

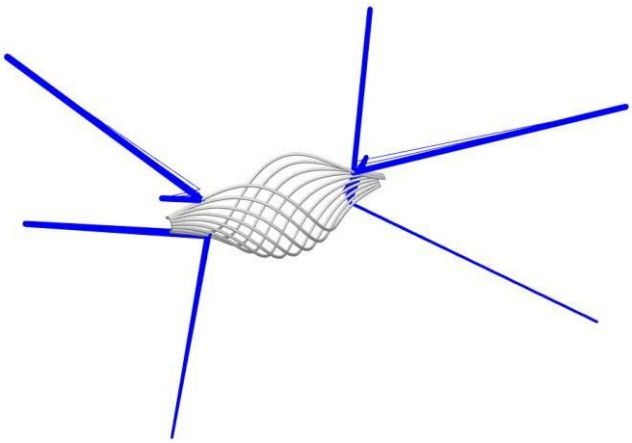
x	y	z	Fx	Fy	Fz
-0.0483	-0.0336	1.6286	-0.0882	0.6336	-0.6343
-0.0194	-0.0424	1.6209	0.2307	-0.1908	0.5069
0.5855	0.2045	-0.0518	0.6096	0.7669	-0.6491
0.581	0.1813	-0.0312	0.8298	-0.298	0.1824
0.5765	0.158	-0.0105	0.7413	-0.3075	0.15
0.5721	0.1347	0.0101	0.6174	-0.2493	0.1338
0.5676	0.1114	0.0307	0.4571	-0.2557	0.0278
0.5632	0.0882	0.0514	0.3335	-0.056	-0.1484
0.5587	0.0781	0.0719	0.1746	-0.2149	-0.0168
0.556	0.0692	0.0933	0.2762	-0.4557	-0.0701
0.5551	0.0616	0.1153	0.1966	-0.3369	-0.0784
0.556	0.0554	0.1377	0.2281	-0.1968	-0.0336
-0.0615	-0.0227	1.6411	-0.0706	0.521	-0.5898
-0.0371	-0.0324	1.6317	0.3203	0.0216	0.4538
-0.0354	-0.0442	1.6152	-0.1197	0.807	-0.7198
-0.0016	-0.0521	1.61	0.0897	-0.3559	0.4242
-0.0229	-0.0543	1.6009	-0.0329	0.9541	-0.6747
-	-	-	-	-	-
-	-	-	-	-	-
-	-	-	-	-	-
0.0693	-0.1003	1.5302	-0.0811	-0.0223	-0.1207
0.1081	-0.101	1.5419	-0.0175	0.1035	-0.0844
0.0395	-0.1035	1.4999	0.5938	0.9316	0.0138
0.083	-0.1074	1.5153	0.0038	0.0078	-0.0143
0.1268	-0.1076	1.5302	0.116	0.1672	0.0928
0.0476	-0.1096	1.481	0.5418	0.9528	-0.0077
0.08	-0.1131	1.4938	0.0384	-0.0334	-0.0037
0.1127	-0.1145	1.5063	-0.1135	0.0096	-0.2439
0.1455	-0.1139	1.5184	0.0624	0.1695	0.0137
0.0549	-0.115	1.4617	0.598	0.897	0.0339
0.0911	-0.1192	1.4771	-0.0011	-0.018	-0.0008
0.1276	-0.1207	1.4921	-0.0297	0.0529	-0.0992
0.1644	-0.1196	1.5065	0.0123	0.1695	-0.059
0.0615	-0.1198	1.442	0.7026	0.7735	0.1011
0.1017	-0.1248	1.4602	-0.002	-0.0199	-0.0002
0.1423	-0.1265	1.4777	0.0157	0.0726	-0.0411
0.1833	-0.125	1.4946	0.0211	0.1661	-0.0419

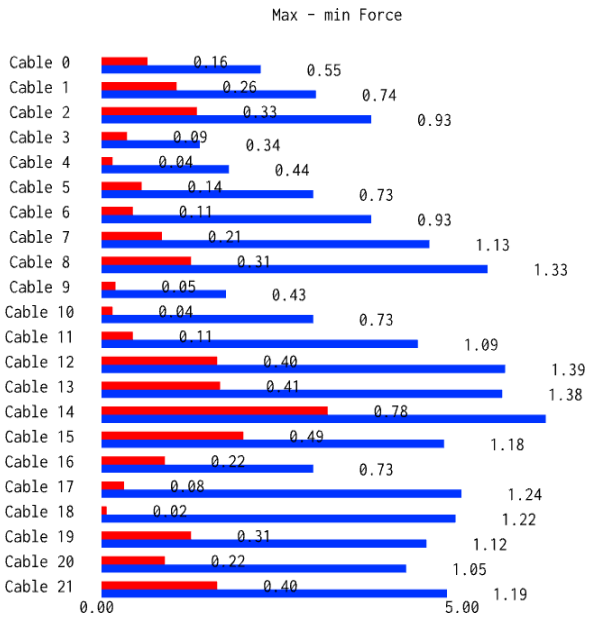


DATA VISUALISATION

PRESTRESS TOOL

Cables are non linear elements that can only work under tension force. Tuning the prestress in order to avoid compression is a complicated and iterative task. I develop a bar chart that update instantaneously and help the engineer to tweak the prestress on each cable.





STRUCTURAL ANALYSIS BUILDING PROJECTS

- Form-finding
- Dynamic NL-analysis
- NL-Buckling analysis
- CFD
- Design to Fabrication
- Export in BIM

THE TEMPLE, BURNING MAN 2018

The Temple 2018 by Mamou-Mani. Very tight deadlines, design to production, complex geometry, 1k unique connections, 18k+ bolts, automatized structural checks and optimization of cross section arrangement.

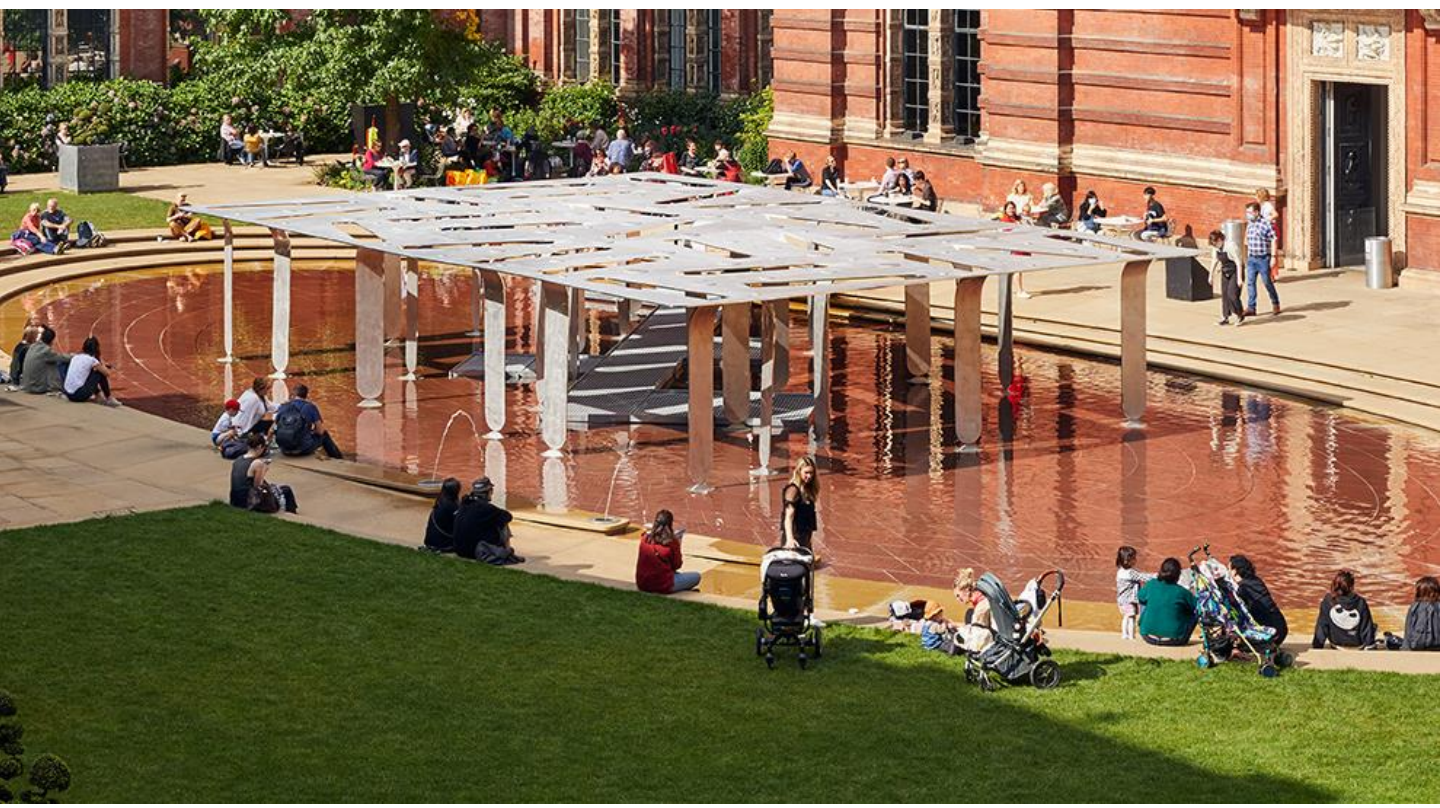
LUZENS

Luzens is a snow machine by architect Walter Klasz. The project involved form finding of bending active beam, geometrical and structural optimization and finally fabrication drawing. All was managed through an automatized workflow.

STEAM PUNK, TALLING PAVILLON 2019

Steampunk is the winning installation for Tallinn Architecture Biennial 2019 by Fologram, Soomeen Hahm Design and Igor Pantic . It's aims echo that of the Biennale, that 'Beauty Matters' and that the pavilion should embody big ideas in a small structure. The twisting and knotted installation was a hugely complex structure of interwoven steam-bent hardwood and stainless steel connecting brackets. The Designers utilised primitive hand tools augmented with the precision of intelligent holographic guides (a Microsoft Hololens).

EN PLUS PAVILLON



The pavilion is formed from 27 sheets of 20mm thick aluminium plate from which the legs are formed by waterjet cutting then bending. The aluminium used for the project is from the first batch of "Inert Anode" aluminium from EN+ Group member Rusal.
EN+ state that the carbon produced during the smelting process is only 0.01 tonnes of CO_2 equivalent per ton of metal. This reduction results in a cradle-to-gate value of only 2.5 tonnes of CO_2 equivalent per ton of metal.

THE WHALE TALE

GOODWOOD FESTIVAL OF SPEED