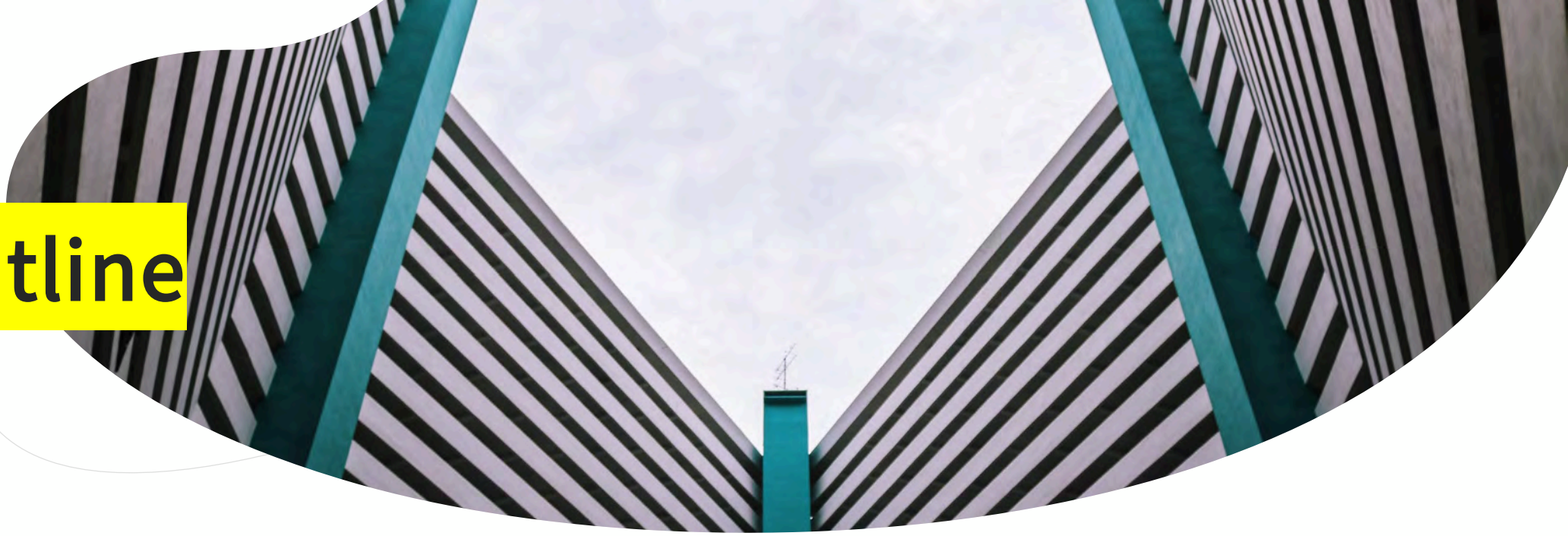
Week 11
GRASSHOPPER PLUG-INS

This we will be gaining knowledge of available Grasshopper plug-ins. It is more of a surface approach on what are available out there, to inform your decisions in your future use of this parametric design software.

Photo by Robin Schreiner on Unsplash



Outline

01

The use of plug-ins

What do we gain from the use of plug-ins of the plug-in (Grasshopper)?

02

Available plug-ins

A list of commonly used Grasshopper's plug-ins.

03

Discussion of 4 specific plug-ins with their unique functions

Ladybug, Kangaroo, Galapagos and Ivy.

Photo by Daniel Lim on Unsplash

Aims and objectives

- To elicit purposes of additional plug-ins
- To contextualise the use of plug-ins in parametric design thinking
- To enumerate available plug-ins and their common use
- To illustrate kinds of analysis and data obtained from selected plug-ins
- To inform how can plug-ins be useful for future use in design

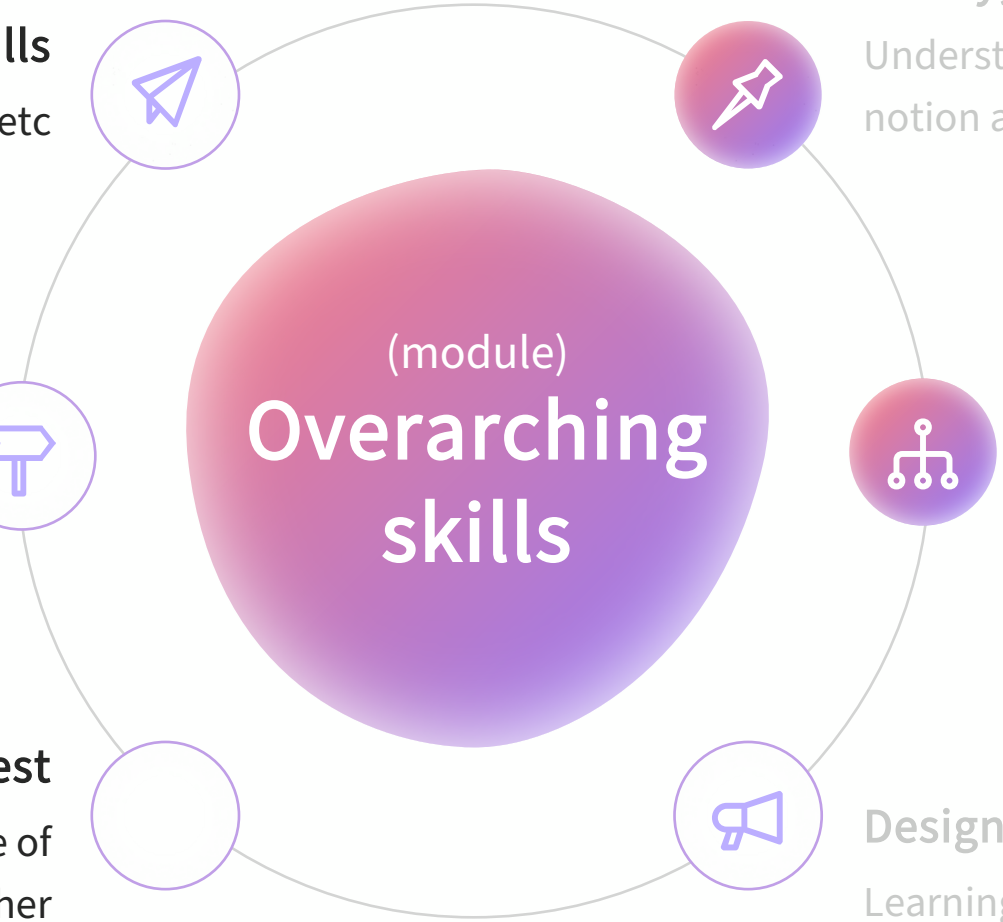
Learning outcomes

Students will be able to..

01 Gain understanding on how to incorporate GH plug-ins for future use.

02 Gain understanding how the GH plug-ins can bring positive impacts on design decisions and processes.

03 Choose which GH plug-ins they will decide to learn first.



Software skills

Rhino, Grasshopper, etc

Theory, history and current debate

Understand historical background of this notion and relevant debates.

Research skills

Designing through extensive research

Important concepts

Digital fabrication and construction
Digital design cognition
Human-computer interaction
Digital craftmanship
etc

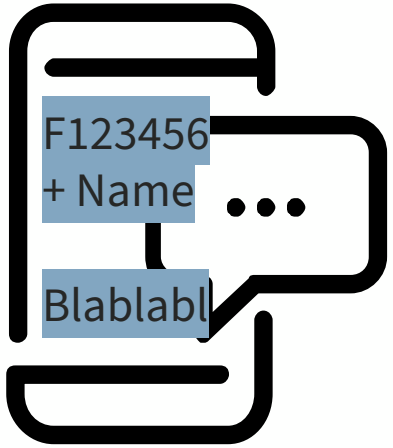
Personal interest

Exploring a preferred scope of design to be developed further

Design precedents

Learning through analysis of completed project

Discussion

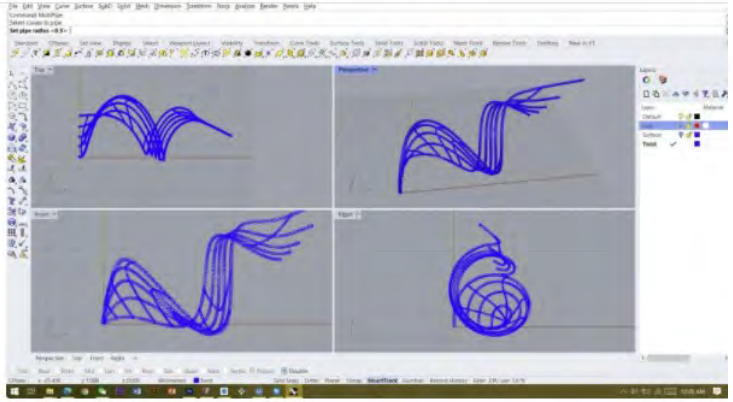


Choose one from listed plug-ins in this lecture material and do an online research on it. How does the plug-in contribute to design phases, in ways that we could not achieve without parametric software system?

Write down 200 words of reflection on this

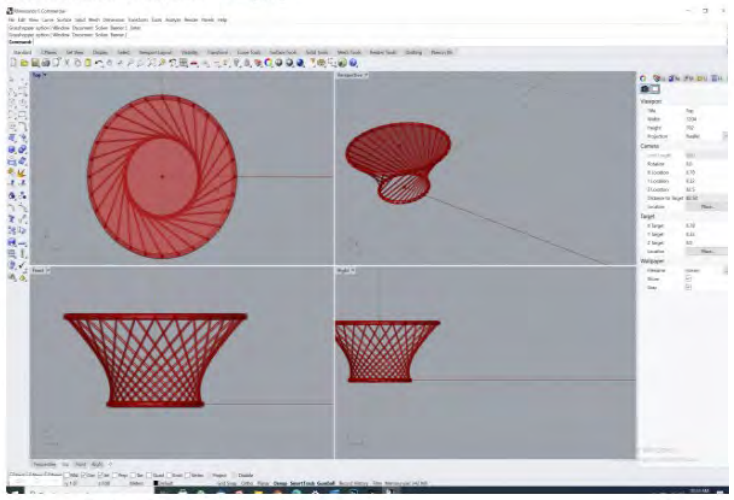
https://miatedjosaputro.com/2022/04/02/dg-week-11-2/

Previously in Week 8 - Rhino Week 9 - GH



Reply · Share ›

Feissal Hassan F17411030 · 12 days ago



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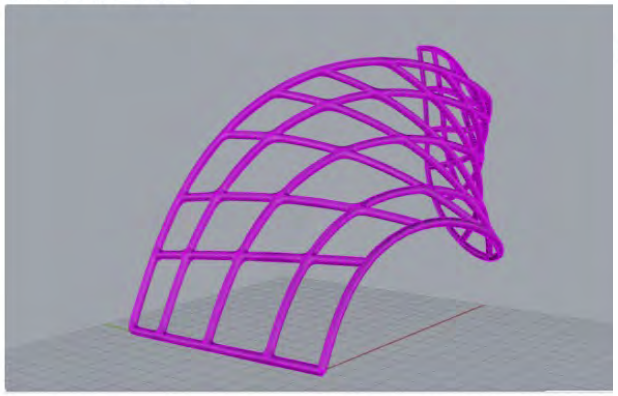
Gelila- F17411022 · 13 days ago

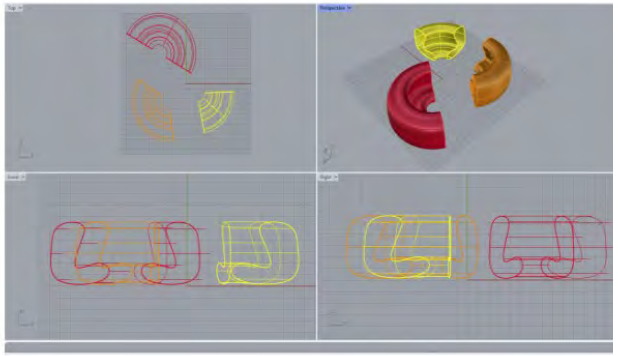


see more

Reply · Share ›

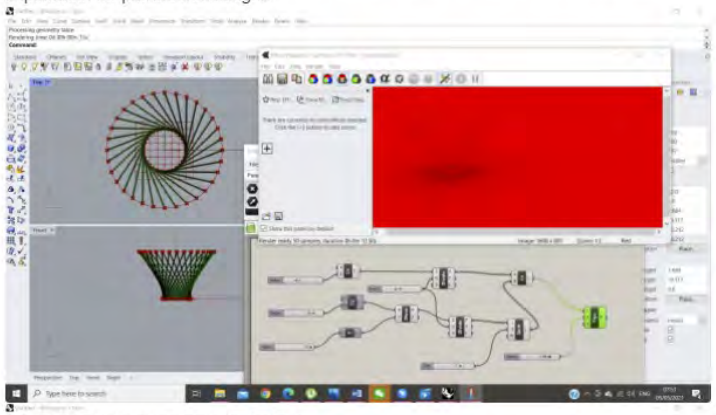
Mia Tedjosaputro Mod · 14 days ago

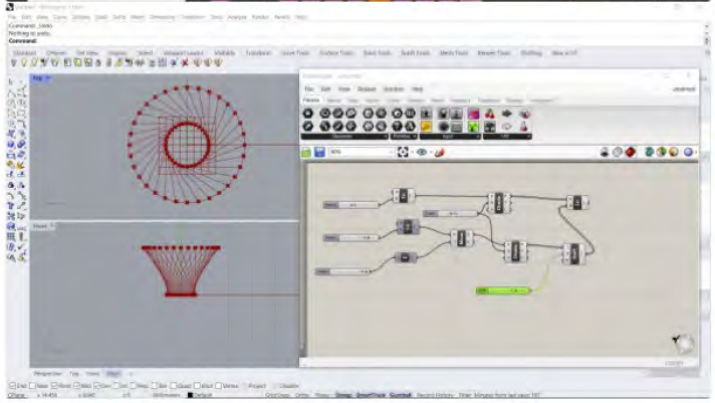
Week8+ F17411036-Patricia



Tusankine F17411024 · 5 days ago · edited

incredible! extremely interesting and quick to work with. Definitely worth doing deeper exploration for parametric designs.





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Previously in Week 9..

Other parametric plug-ins: Bridging architecture with other disciplines

ENVIRONMENTAL ANALYSIS:

Ladybug
Honeybee
Geco
Heliotrope-Solar

STRUCTURAL ANALYSIS:

Kangaroo Physics
Karamba
BullAnt
Hummingbird
Mantis

https://www.arch2o.com/10-parametric-plugins-every-architect-should-know/

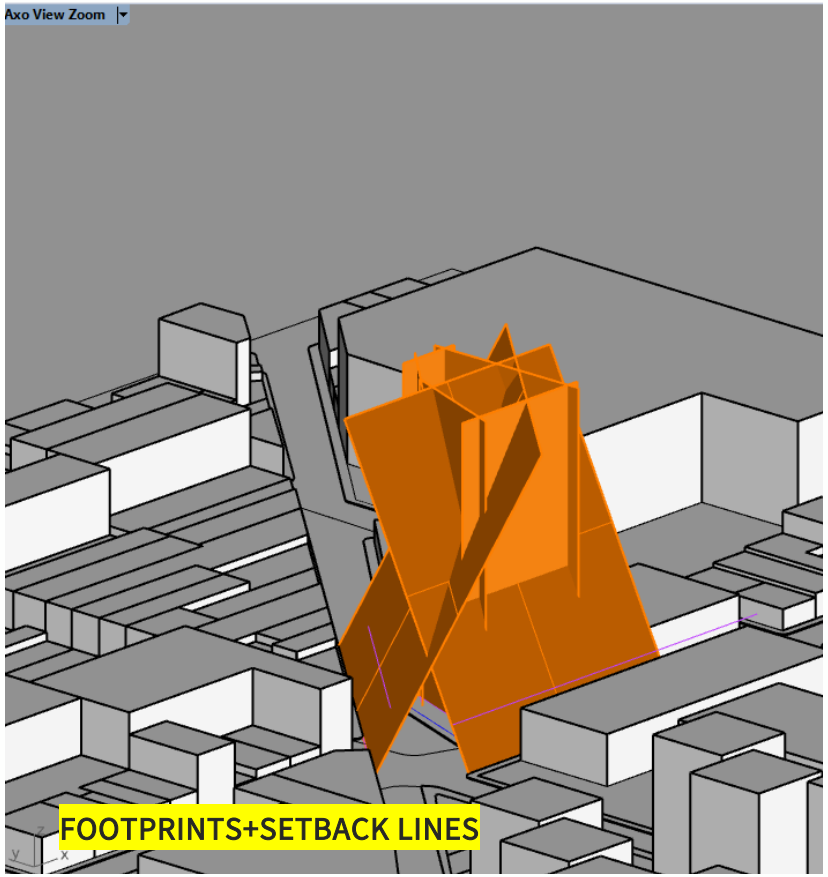
GH Plug-ins

https://www.grasshopper3d.com/forum/topics/gh-s-origin

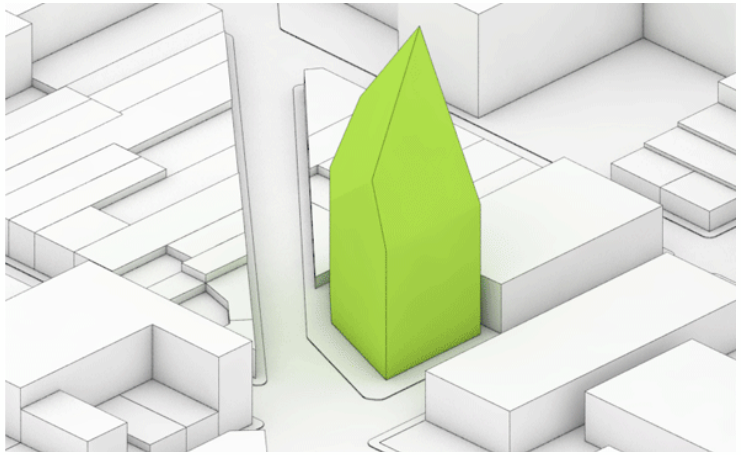
This week I do not expect you to learn individual plug-ins. You have the whole summer for finding out which one works for you. But I would like you to stay informed on what available out there and reflect on how can these tools be useful for your future design projects.

Example use of GH in early design stage:

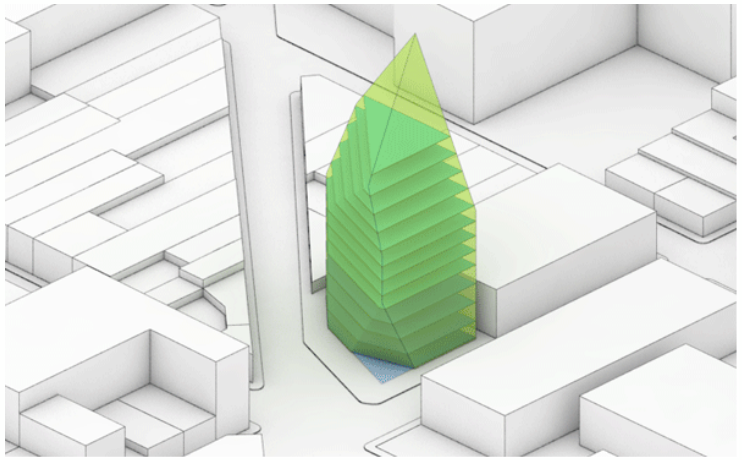
http://designplaygrounds.com/blog/creating-models-for-development-analysis-with-grasshopper/



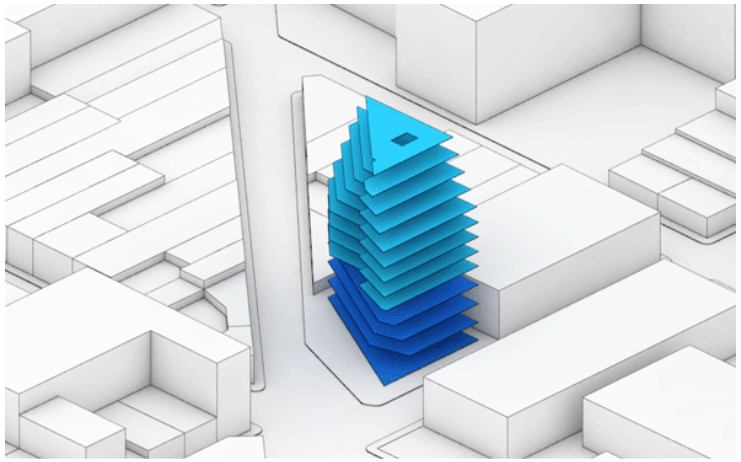
FOOTPRINTS+SETBACK LINES



BOUNDING VOLUME BASED ON RESTRICTIONS

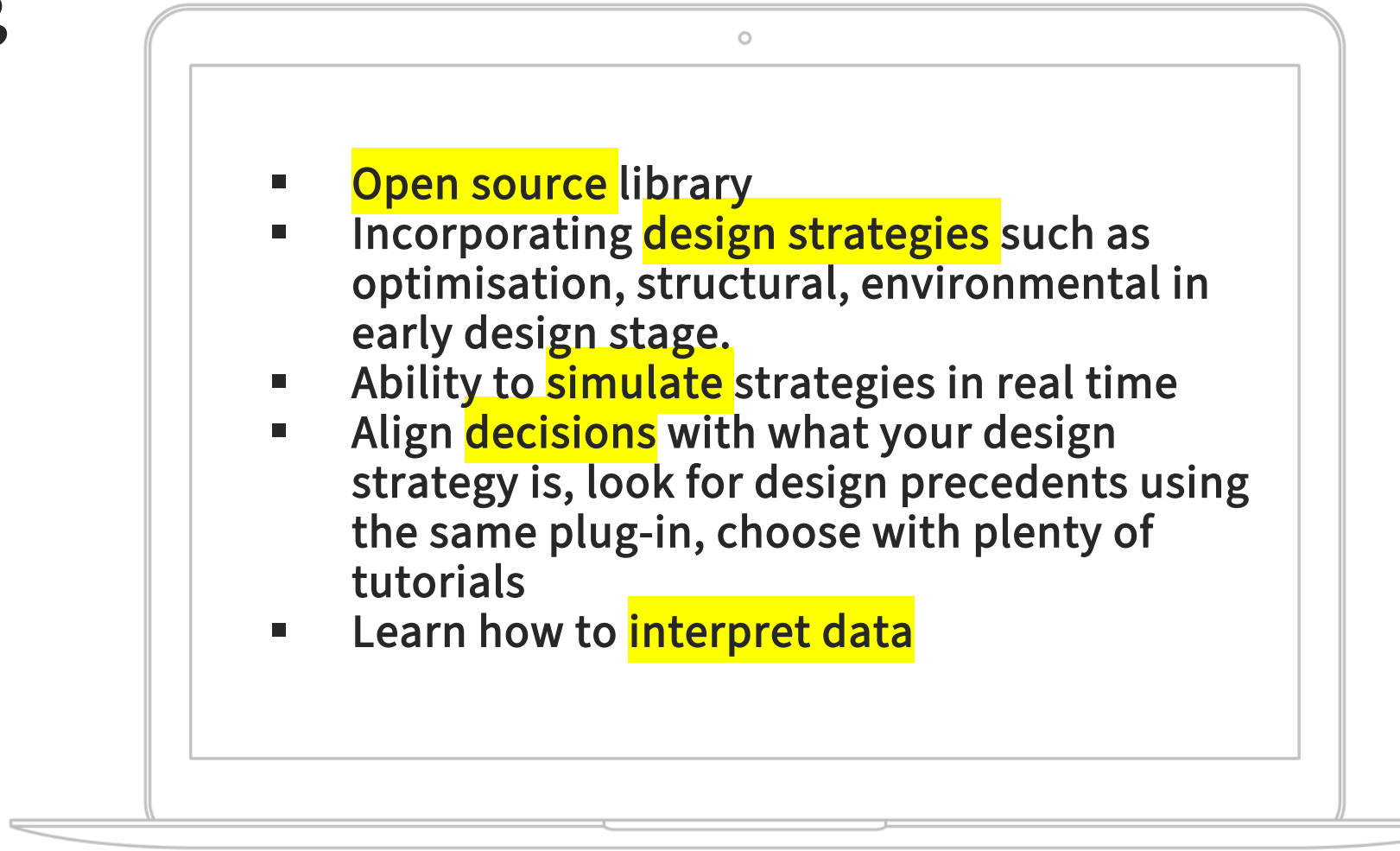


FEASIBILITY STUDY OF GFA



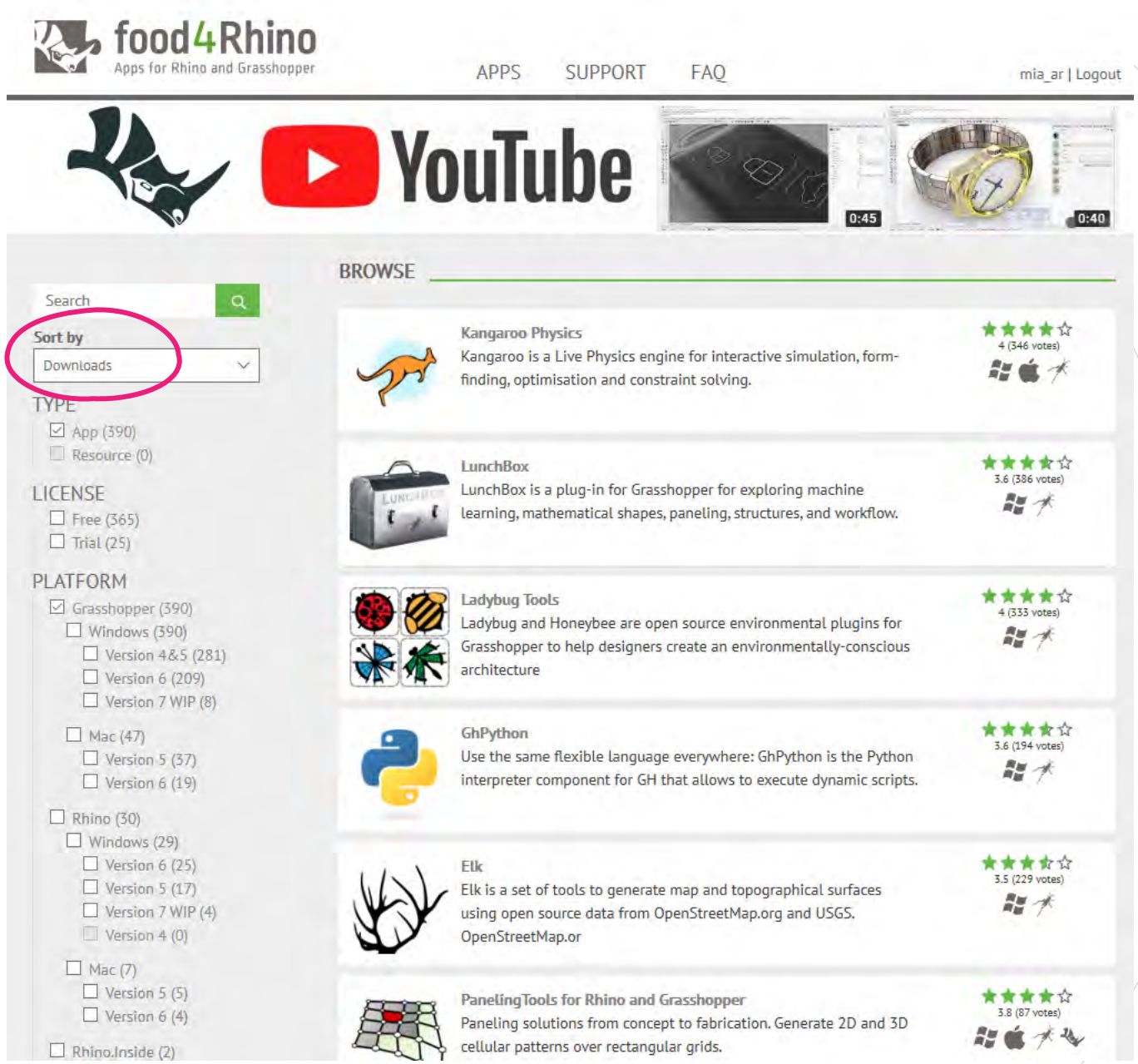
LIVE CHANGES ARE MADE IF ONE OF THE CRITERIA CHANGED (FOR INSTANCE, NARROWER SETBACKS)

What do we gain from using plug-ins? How to choose from hundreds of them?



Popular GH plug-ins

https://www.food4rhino.com/



Review of 35 GH plug-ins

https://architosh.com/2020/03/insider-a-brief-tour-of-select-grasshopper-add-ons/

INSIDER: A Brief Tour of Select Grasshopper Add-Ons

by **Anthony Frausto-Robledo, AIA, NCARB, LEED AP**

We look at 35 Grasshopper plugins that add additional capabilities and superpowers to the number one AAD tool in the market used in AEC. Importantly, there are quite a few GH plugins working for the Mac version of Rhino + Grasshopper—a growing reality that is good for the market.

Grasshopper Plugins

In this brief article, we briefly discuss 35 Grasshopper plugins and what they essentially provide to the Rhino + Grasshopper user community. They are organized by category and we provide information on which plugins say, or we could confirm, work on both the Windows and Mac versions of Rhino + Grasshopper. Importantly, many entries in the Food4Rhino page can be incorrect in which plugins do or do not work on the Mac versions of

Review of GH plug-ins based on category

http://james-ramsden.com/resources/list-of-grasshopper-components/

A mix of favourite and interesting plugins for Grasshopper.

ENERGY AND BUILDING SIMULATION

Ladybug and Honeybee	Import EPW files, solar radiation analysis, daylight calculations, thermal calculations
Diva for Rhino	Daylight calculations
mr comfy	Thermal and daylight calculations

GEOMETRY

Jackalope	Rhino morph operations
Lunchbox	Convert surfaces to panels
MeshEdit	Essential mesh manipulation tools

WORKFLOW

Octopus	Multi-objective optimisation
Lunchbox	Read and write to Excel
GeometryGym	Move geometry between different BIM/analysis file formats
Firefly	Arduino control and internet data control
Mosquito	Facebook, Twitter and Google Maps queries

VISUALISATION

Giulo Piacentino's renderAnimation	Generate frames for animation
Horster	Control Rhino camera

MAPPING

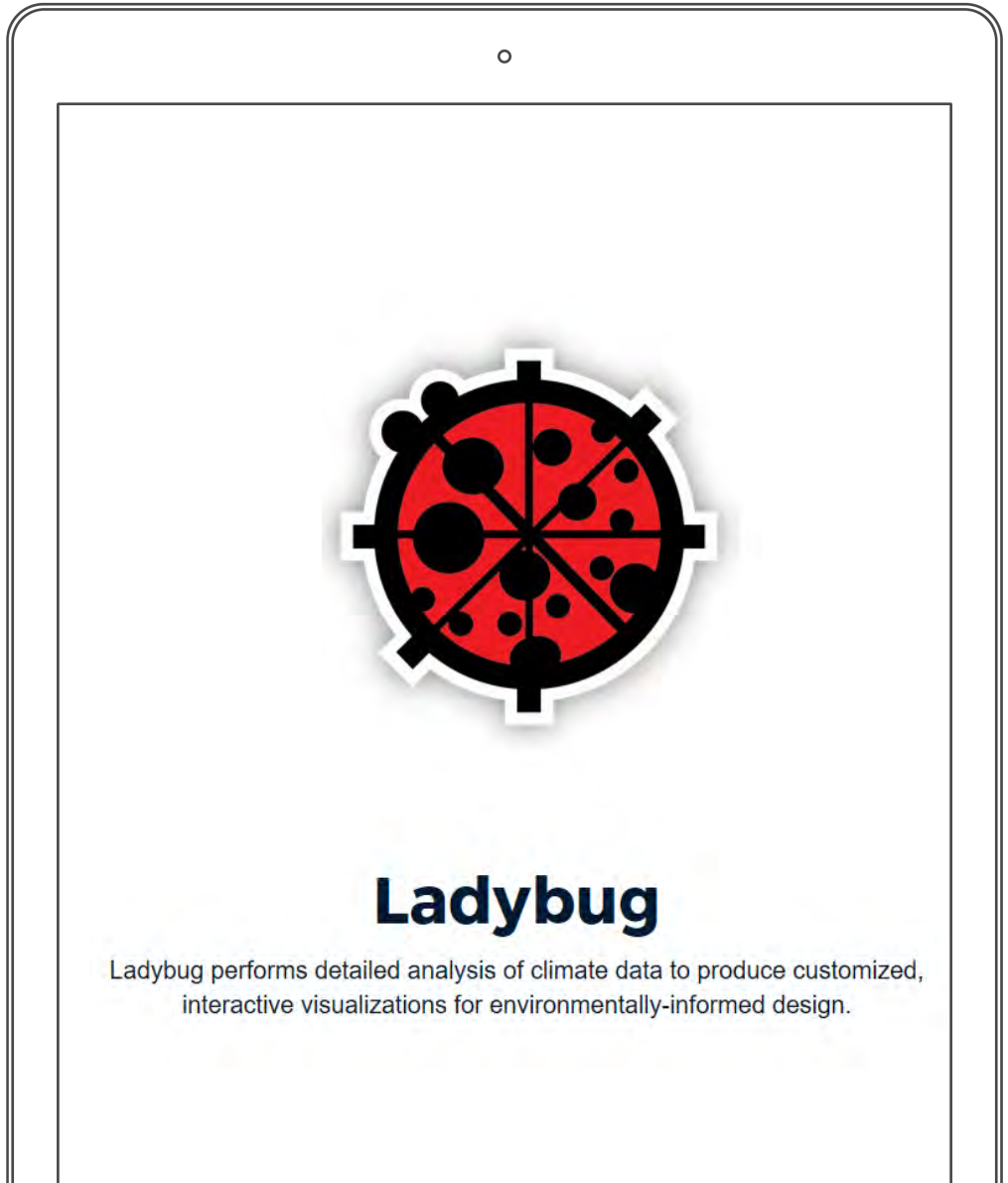
Elk	Process OpenStreetMap OSM data and USGS HGT height data

...and of course there is the Food4Rhino directory for the full list of the most popular component

Plug-in 1: Ladybug

For environmentally conscious design decisions using local weather data

By: Mostapha Sadeghipour Roudsari



Plug-in 1: Ladybug

Download the plug-in here
https://www.food4rhino.com/app/ladybug-tools

Interview with both co-founders (**Mostapha** and **Chris Mackey**) about how it came into existence:
https://architosh.com/2020/03/insider-ladybug-tools-aim-to-take-environmental-analysis-to-wider-audience/

Getting started with Ladybug with **Chris Mackey**, the co-founder
https://www.youtube.com/playlist?list=PLruLh1AdY-Sj_XGz3kzHUoWmpWDXNep1O

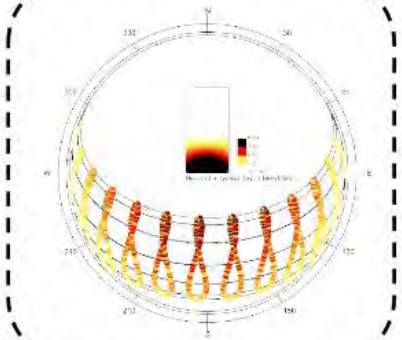
Resources:
FORUM: https://discourse.ladybug.tools/
SHARING PLATFORM: http://hydrashare.github.io/hydra/

Plug-in 1: Ladybug

Ladybug Analysis Tools

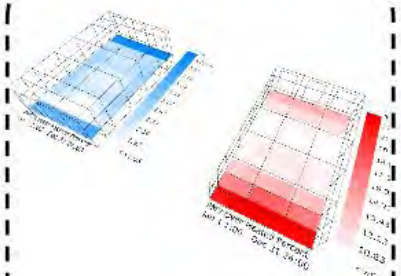
Ladybug

Climate Visualization + Analysis



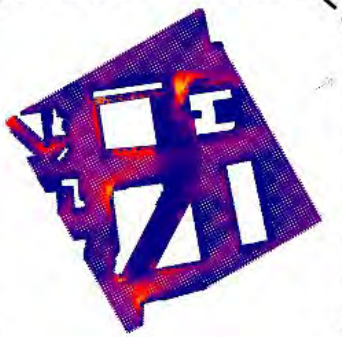
Honeybee

Building Energy, Daylight + Comfort Modelling



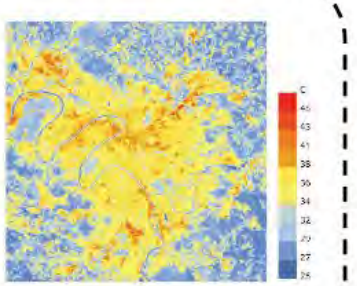
Butterfly

Airflow Modelling (CFD)



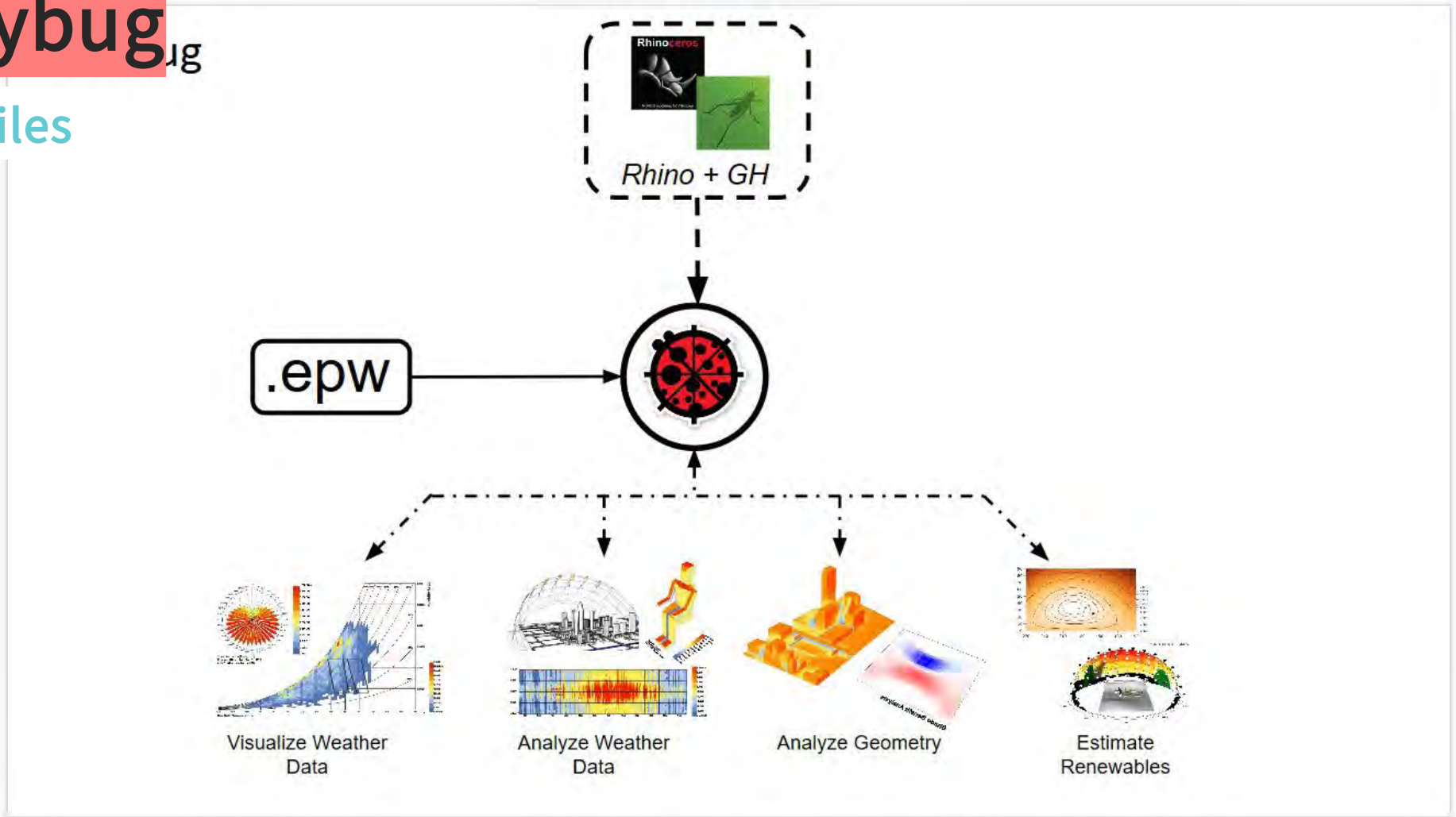
Dragonfly

Climate Modelling (heat island, climate change)



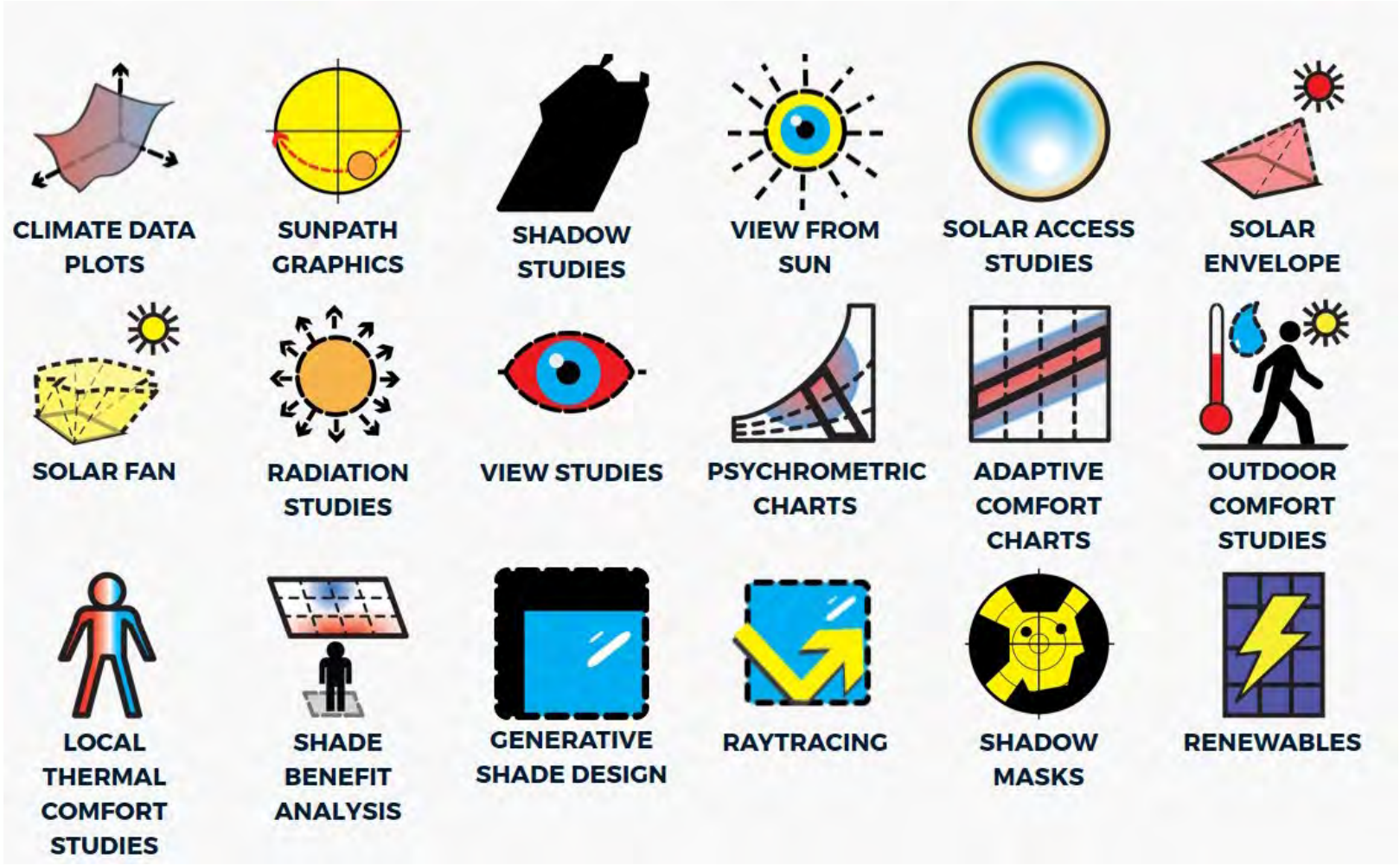
Plug-in 1: Ladybug

.epw files



Plug-in 1: Ladybug

Instantaneous feedback and evaluation



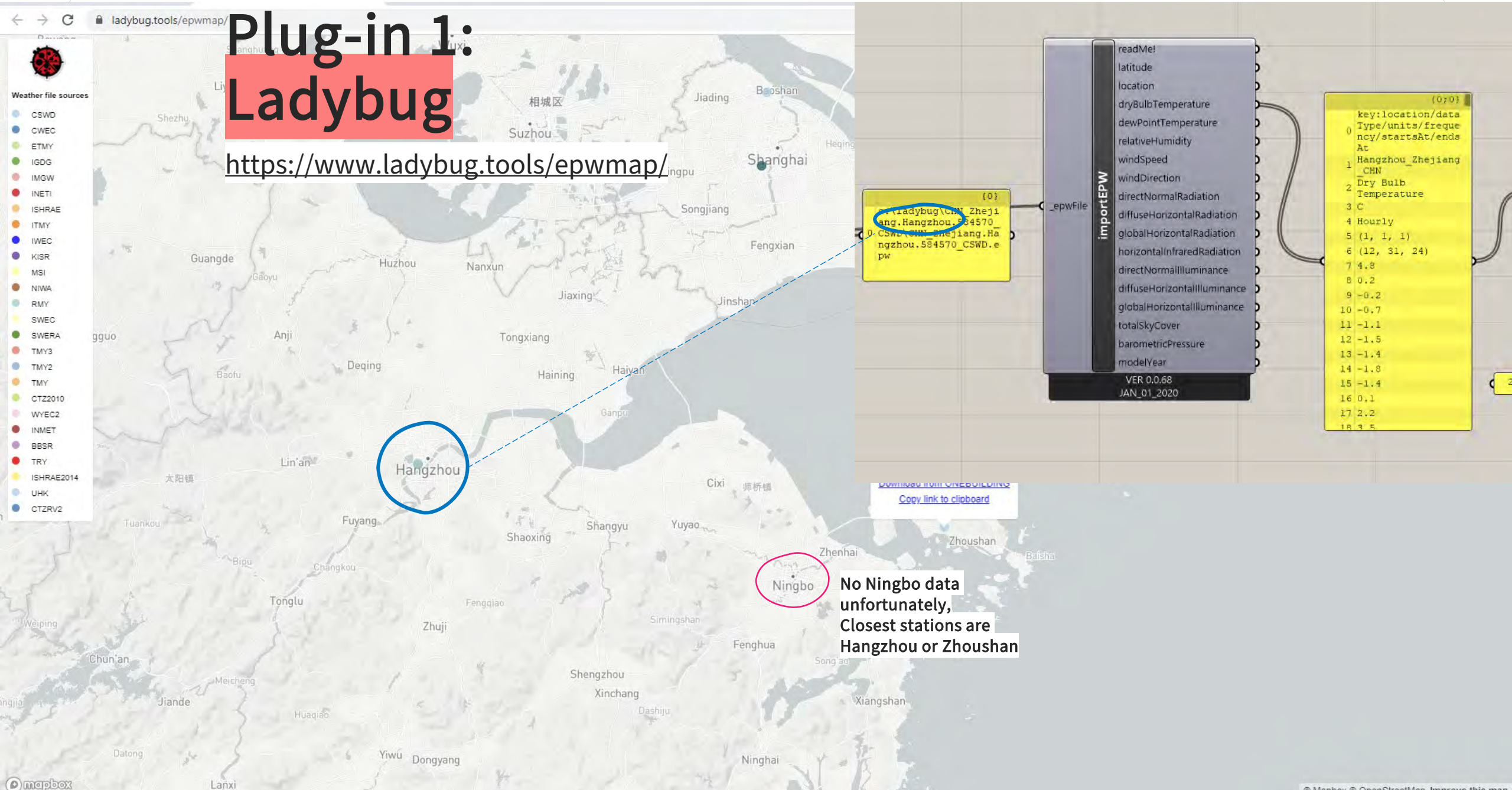
Plug-in 1:
Ladybug

Potential use:

Weather data Visualisation
Basic and advanced sun path study
Sunlight hours study
Outdoor comfort study
Solar radiation study

Plug-in 1: Ladybug

https://www.ladybug.tools/epwmap/

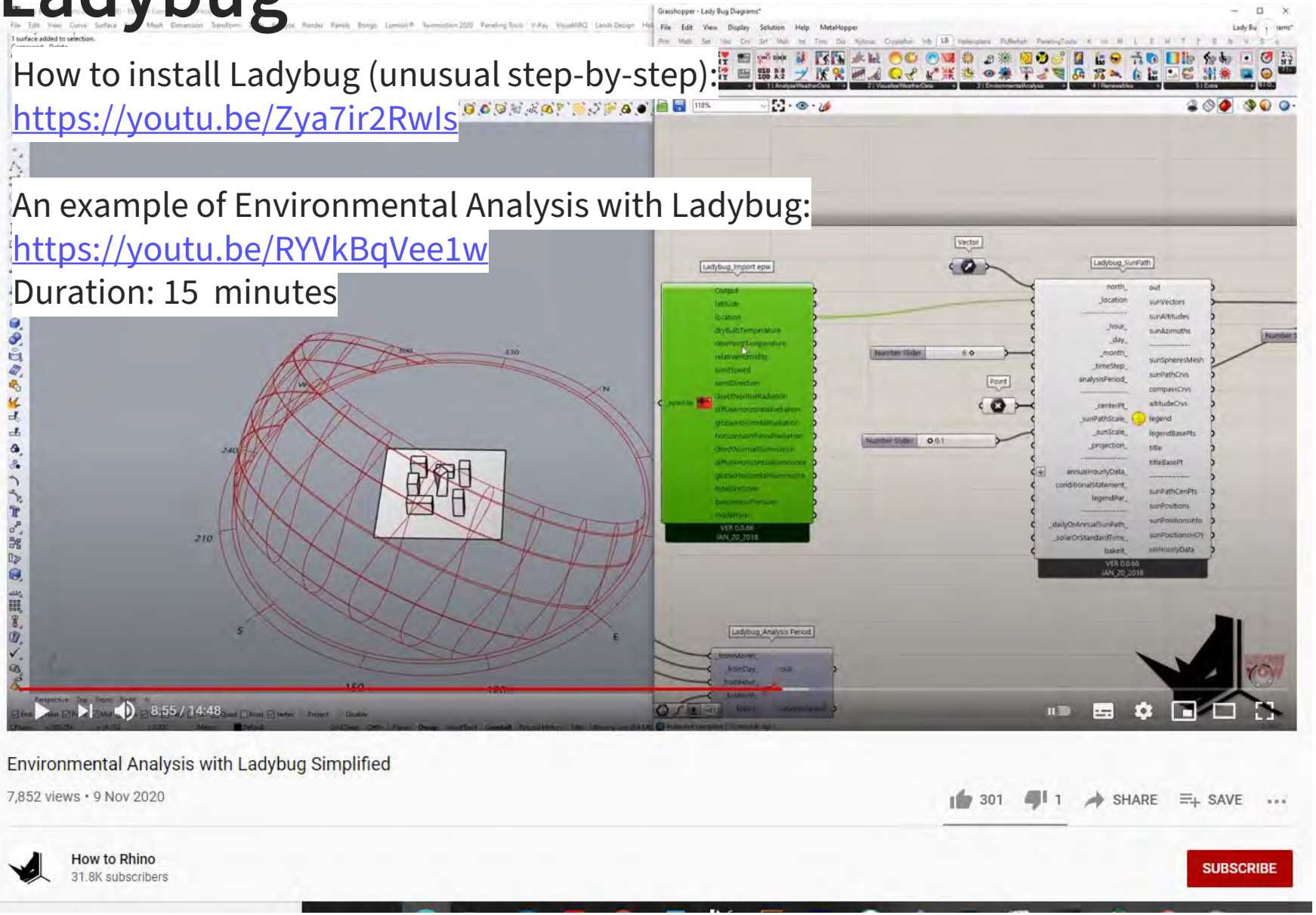


No Ningbo data unfortunately,
Closest stations are Hangzhou or Zhoushan

Ladybug

How to install Ladybug (unusual step-by-step):
https://youtu.be/Zya7ir2RwIs

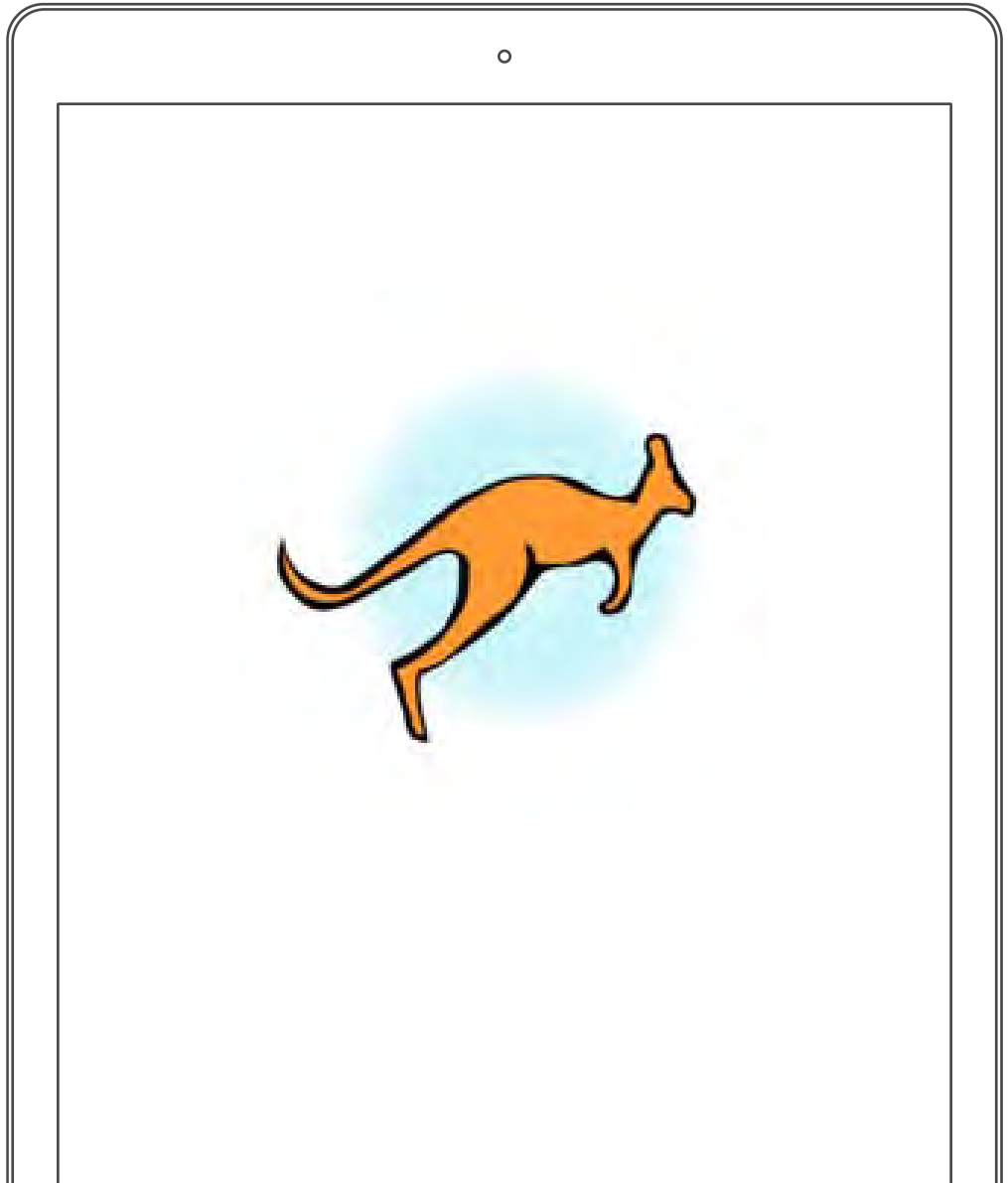
An example of Environmental Analysis with Ladybug:
https://youtu.be/RYVkBqVee1w
Duration: 15 minutes



Plug-in 2: Kangaroo

Physics engine and form finding platform for Grasshopper

By: Daniel Piker



Plug-in 2: Kangaroo

Kangaroo2 comes with Rhino 6 onwards, no need to download or install separately.
http://kangaroo3d.com/

Download link if you need it:
https://www.food4rhino.com/app/kangaroo-physics

RESOURCES:
https://discourse.mcneel.com/c/grasshopper/kangaroo

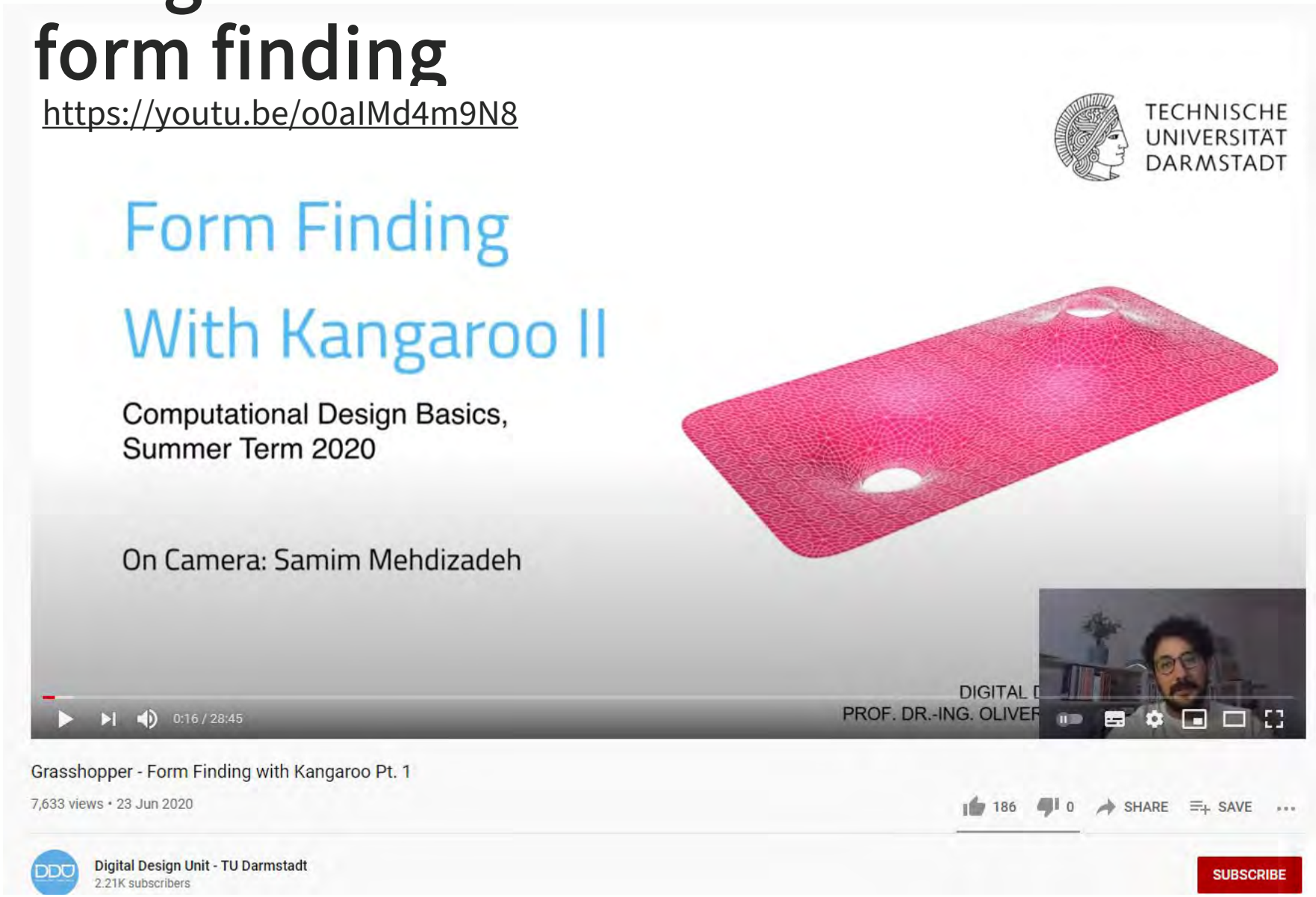
Kangaroo for tensile structure

Useful example:

https://youtu.be/f0DiTj3Gx1A

Kangaroo for form finding

https://youtu.be/o0aIMd4m9N8



Imperial College London

PARAMETRIC DESIGN OF TIMBER GRID SHELL STRUCTURES: STRUCTURAL FORM-FINDING AND OPTIMISATION

S 12

Clara Torres Gómez, Supervisor: Dr C. Málaga-Chuquitaype.
Department of Civil and Environmental Engineering, Imperial College London, UK.

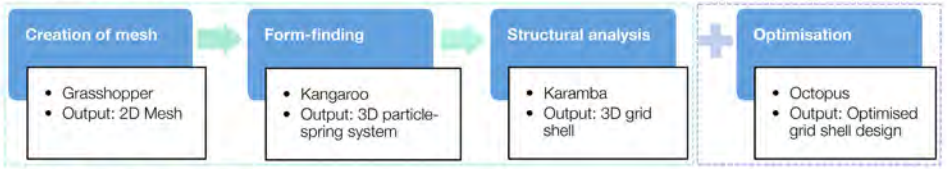
INTRODUCTION

Grid shell structures offer multiple structural and architectural advantages such as optimal use of materials, quick construction process and the possibility to achieve architecturally interesting building forms. Nevertheless, their design is challenging as it involves the use of multiple slender elements. This thesis focuses on the development and testing of a design tool for form-finding and structural verification through optimisation of timber grid shells. The design tool is implemented using the algorithm editor Grasshopper [1].

PROJECT OUTLINE

Part 1: Grid shell design

Part 2: Design optimisation



THE PROJECT

PART 1: GRID SHELL DESIGN

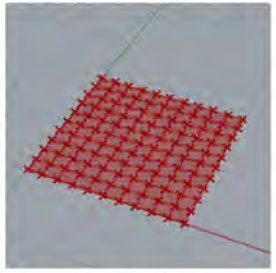


FIGURE 3: 2D MESH

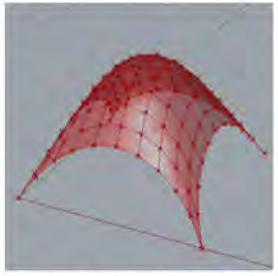


FIGURE 4: 3D PARTICLE-SPRING SYSTEM

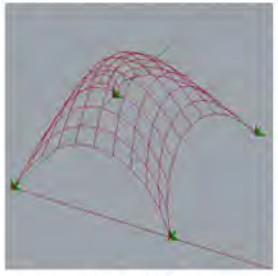


FIGURE 5: 3D GRID SHELL

TABLE 1: 3D GH RESULTS AND % DIFFERENCE WITH OPENSEES RESULTS

	Near supports		Top	
Axial forces (kN/m)	-3.51	**-2.5%**	-0.05	**-8.8%**
Shear forces (kN/m²)	0.05	-	0.05	-
Bending moment (kNm)	0.02	-	0.01	-
Displacement in x,y (mm)	-0.06	-	0.00	-
Displacement in z (mm)	-0.04	**-63.7%**	-0.09	**-3.0%**

Grasshopper (GH) is a graphical algorithm editor integrated with the modelling tools of Rhino3D. A timber grid shell is designed parametrically using GH. The grid shell is initially a 10mx10m flat mesh discretised into quadrilateral elements 1mx1m in size (FIGURE 3).

The form-finding process is carried out using the Kangaroo add-on. The mesh is discretised into a particle-spring system, and subsequently the Dynamic Relaxation method is applied to the system. Kangaroo essentially performs a virtual hanging-chain model of the structure in order to find the most efficient shape to carry the applied vertical loads (FIGURE 4).

The particle-spring system is then converted into a real structure and analysed using Karamba, a Finite Element program, fully embedded in the parametric environment of GH (FIGURE 5). TABLE 1 shows that the results from GH are validated using OpenSees [2]. The percentage difference is missing for the shear forces, bending moments and displacements in x- and y- directions. This is because the values are very small in both cases, this is what is expected in terms of grid shell behaviour.

ACKNOWLEDGEMENT

The author Dr C. Málaga-Chuquitaype for his dedication in making this project an engaging and rewarding experience. The author would also like to thank Arthur Mamou-Mani for his valuable help with Grasshopper.

GRID SHELL STRUCTURES

A grid shell is a **shell** structure discretised by means of a **grid** pattern. It derives its strength from its double curvature.

FIGURE 1: 'GRID SHELL IN THE PARK', SAN ANTONIO, USA

Advantages
- Minimal use of material
- Quick construction process
- Architecturally interesting shapes can be achieved

Disadvantages
- Complex design

FIGURE 2: THE WEALD AND DOWNLAND MUSEUM, SURREY, UK

PART 2: DESIGN OPTIMISATION

The dimensions of the cross-section of the timber laths is optimised to reduce the amount of material used and ensure that bending moments occurring in the grid shell are minimised. This is achieved using the evolutionary solver Octopus, which is an add-on for GH. The results are presented in TABLE 2. The two grid shells are shown on FIGURE 6. The implementation of the optimisation in the grid shell design tool presented in Part 1 is illustrated in FIGURE 7.

TABLE 2: COMPARISON OF INITIAL AND OPTIMISED RESULTS

Section	Initial	Optimised	% Reduction
Volume of material (m³)	4.33	**1.23**	72%
Sum of bending moments (kNm)	2.44	**0.67**	73%
Max. bending moment (kNm)	0.05	**0.02**	60%

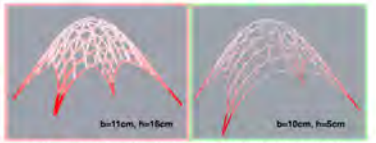


FIGURE 6: INITIAL AND OPTIMISED GRID SHELLS

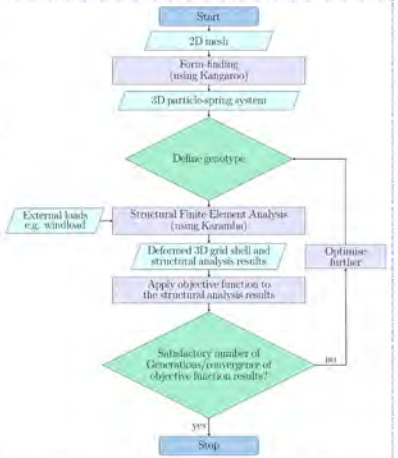


FIGURE 7: TOOL FOR GRID SHELL DESIGN AND OPTIMISATION

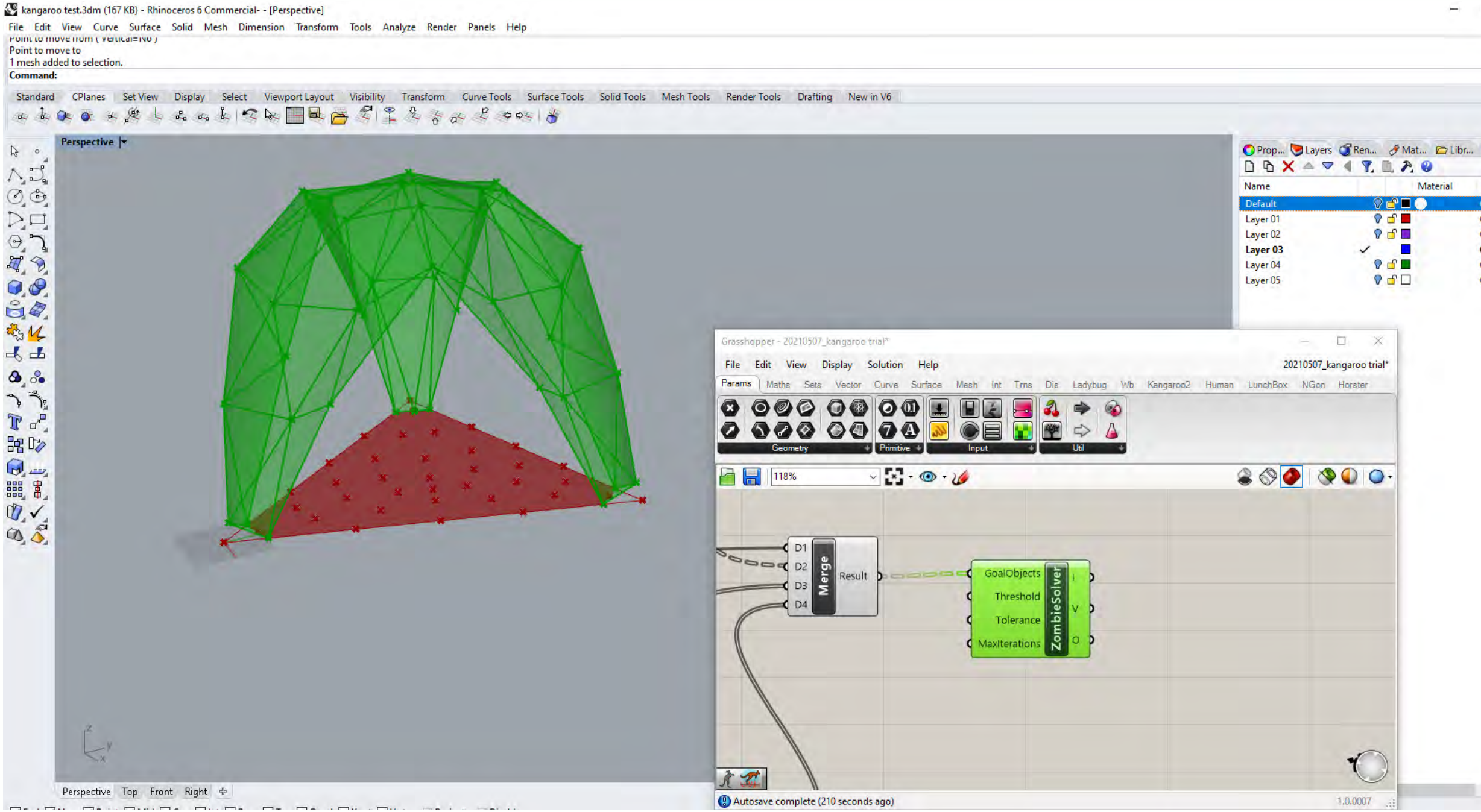
CONCLUSION

Form-finding and structural analysis of a timber grid shell can be successfully combined in a Grasshopper model. The analysis results are verified using the finite element framework OpenSees. It is also shown that the parametric environment of Grasshopper allows for an easy parametrisation of the design problem into objective functions, variables and constraints. The inclusion of an evolutionary solver in the Grasshopper model allows for an optimised structural design.

REFERENCES

[1] Akos, G., & Parsons, R. 2014. Foundations - the grasshopper primer third edition. Available at http://md.uai.cl/workshop/wp-content/uploads/2016_files/Instructors.pdf (Accessed 28 March 2015).
[2] McKenna, F., Fenves, G. L., Scott, M. H., and Jeremic, B., (2000). Open System for Earthquake Engineering Simulation (OpenSees). Pacific Earthquake Engineering Research Center, University of California, Berkeley, CA.

S12---Clara-Torres-Gomez.pdf (imperial.ac.uk)


kangaroo test.3dm (167 KB) - Rhinoceros 6 Commercial- - [Perspective]
File Edit View Curve Surface Solid Mesh Dimension Transform Tools Analyze Render Panels Help
Point to move to
1 mesh added to selection.
Command:
Standard CPlanes Set View Display Select Viewport Layout Visibility Transform Curve Tools Surface Tools Solid Tools Mesh Tools Render Tools Drafting New in V6
Perspective
Prop... Layers Ren... Mat... Libr...
Name Material
Default
Layer 01
Layer 02
Layer 03
Layer 04
Layer 05
Perspective Top Front Right
Grasshopper - 20210507_kangaroo trial*
File Edit View Display Solution Help
20210507_kangaroo trial*
Params Maths Sets Vector Curve Surface Mesh Int Trns Dis Ladybug Wb Kangaroo2 Human LunchBox NGon Horster
Geometry Primitive Input Util
118%
D1 D2 D3 D4 Merge Result
GoalObjects Threshold Tolerance MaxIterations ZombieSolver I V O
Autosave complete (210 seconds ago)
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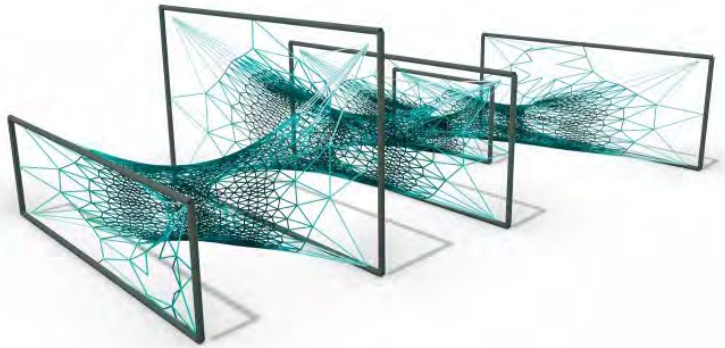
Kangaroo + Weaverbird

[FORCE OF NATURE – IAAC Blog]



Process:

Set Frame (Contour)

Set Hight

Set Opening (Pop20)

Create Basic Mesh (Loft)

Kangaroo Damping Solver

Subdivision Mesh (Weavebird)

Plug-in 2: Kangaroo

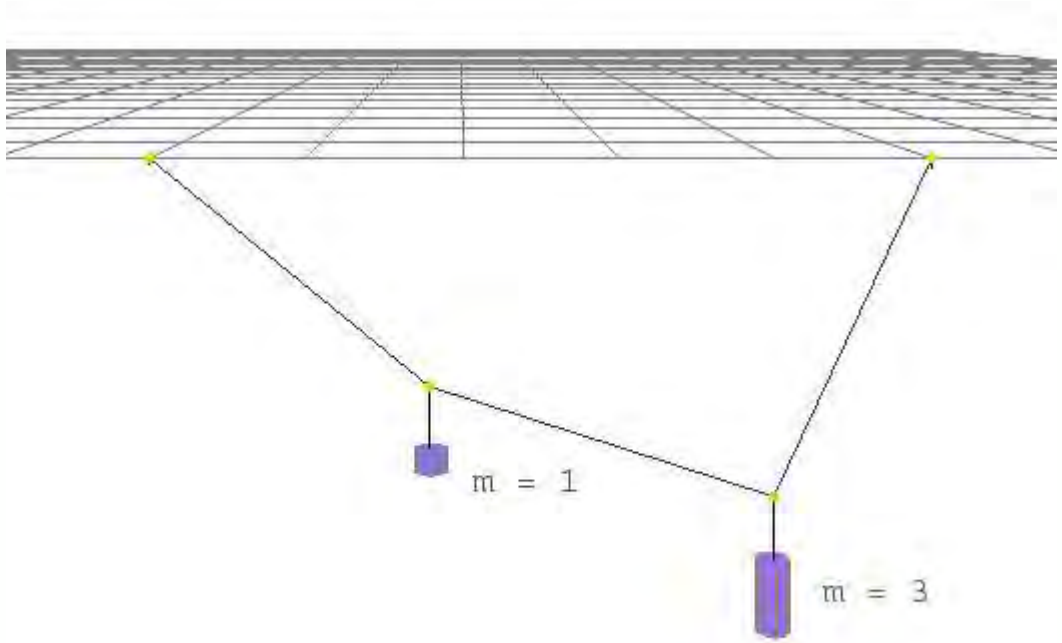
Potential use:

Simulate physical interaction between object
Simulate objects' properties through time
Creating unique shapes *(catenary curves, catenary vault systems, tensile membrane systems, dome and tensile structure)* we could not do using hands by
Modelling different forces

Plug-in 2: Kangaroo

Based on *particle-spring systems*

” Particle-spring systems are based on lumped masses, called particles, which are connected by linear elastic springs”



Equilibrium of simple particle spring system (Kilian and Ochsendorf, 2005)

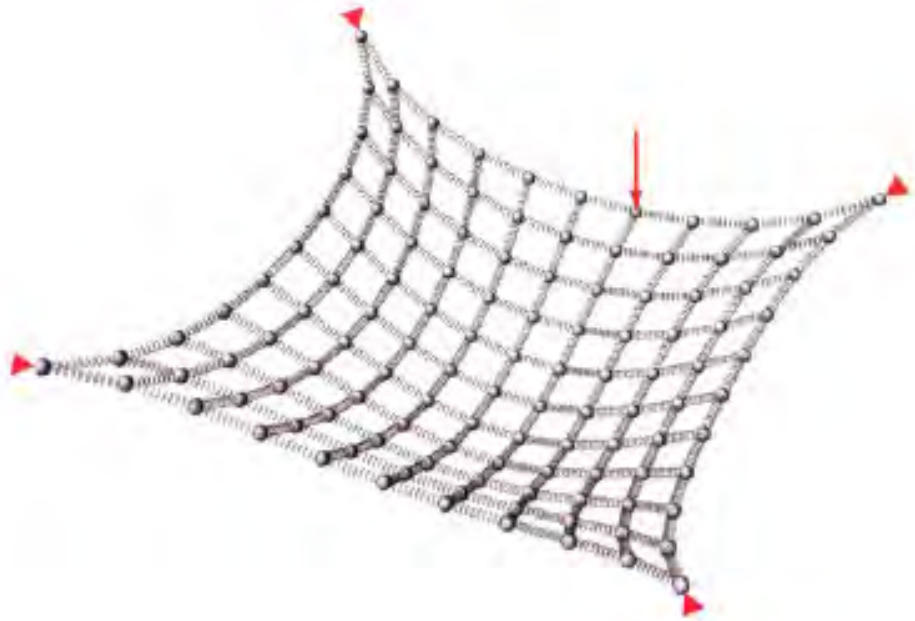
Kilian, A. & Ochsendorf, J. (2005). Particle-spring systems for structural form finding. *Journal of the international association for shell and spatial structures,* 46, 77-84.

Plug-in 2: Kangaroo

Based on *particle-spring systems*

Main components of a particle-spring system are:

1. **Particles**
2. **Springs**
3. **Forces**
4. **Anchor point**

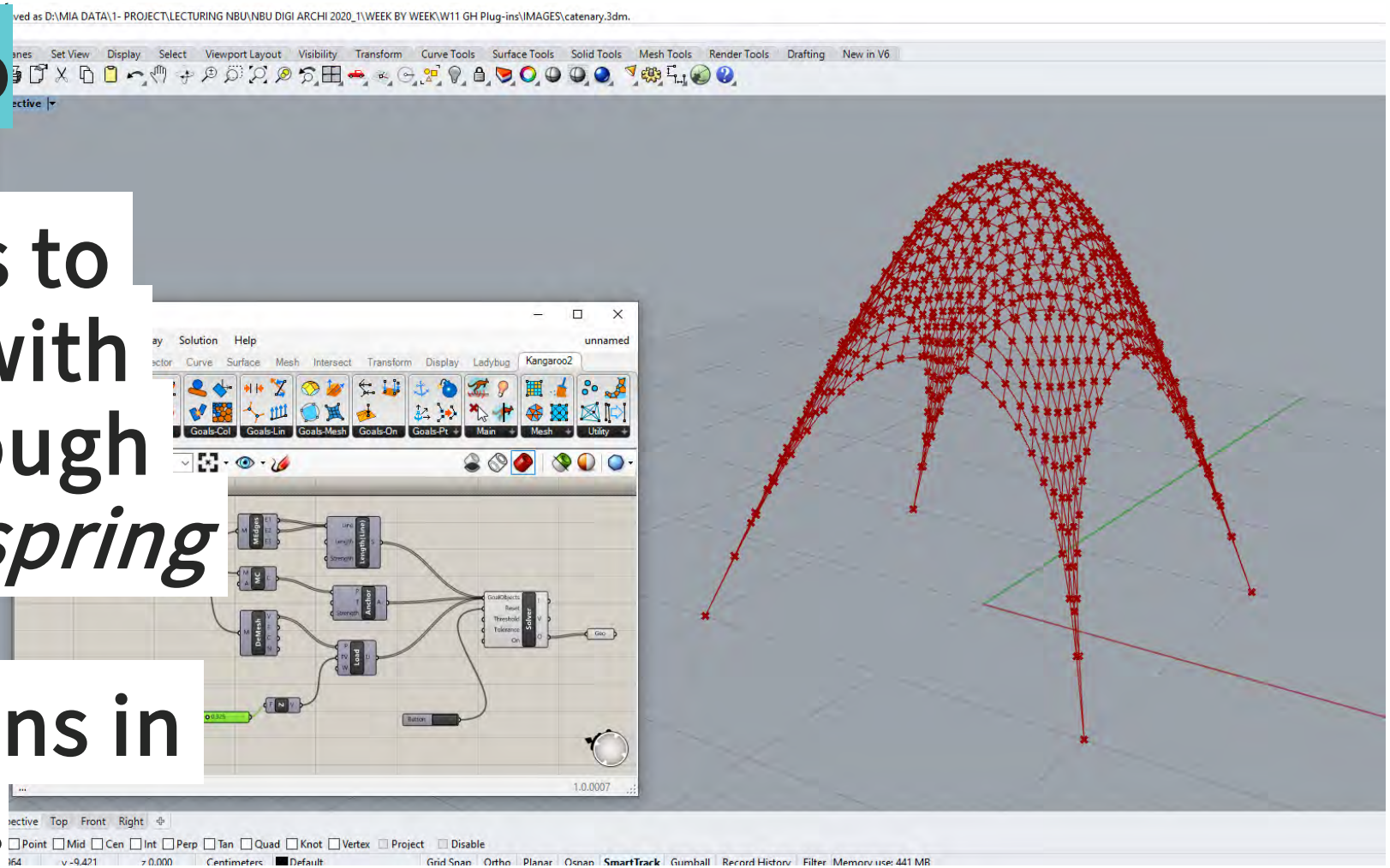


A particle-spring system that simulates a square membrane anchored at its corner. Force vectors are applied to the particles.

Tedeschi, A. (2014). *AAD, Algorithms-aided design: parametric strategies using Grasshopper*, Le penseur publisher.

Plug-in 2: Kangaroo

enables designers to interact with form through *particle-spring system* simulations in real time.



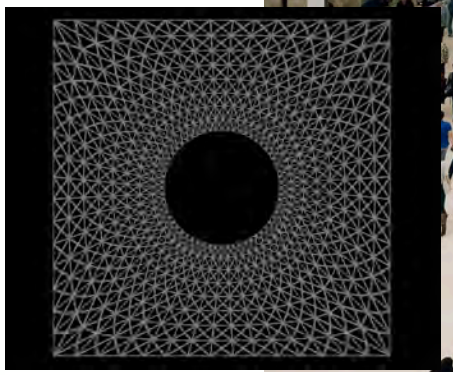
Plug-in 2: Kangaroo

Potential form: Catalan vault

https://inspiration.detail.de/technology-the-catalan-vault-a-historical-structural-principle-with-a-bright-future-106565.html

Plug-in 2: Kangaroo

Other applications: The British Museum

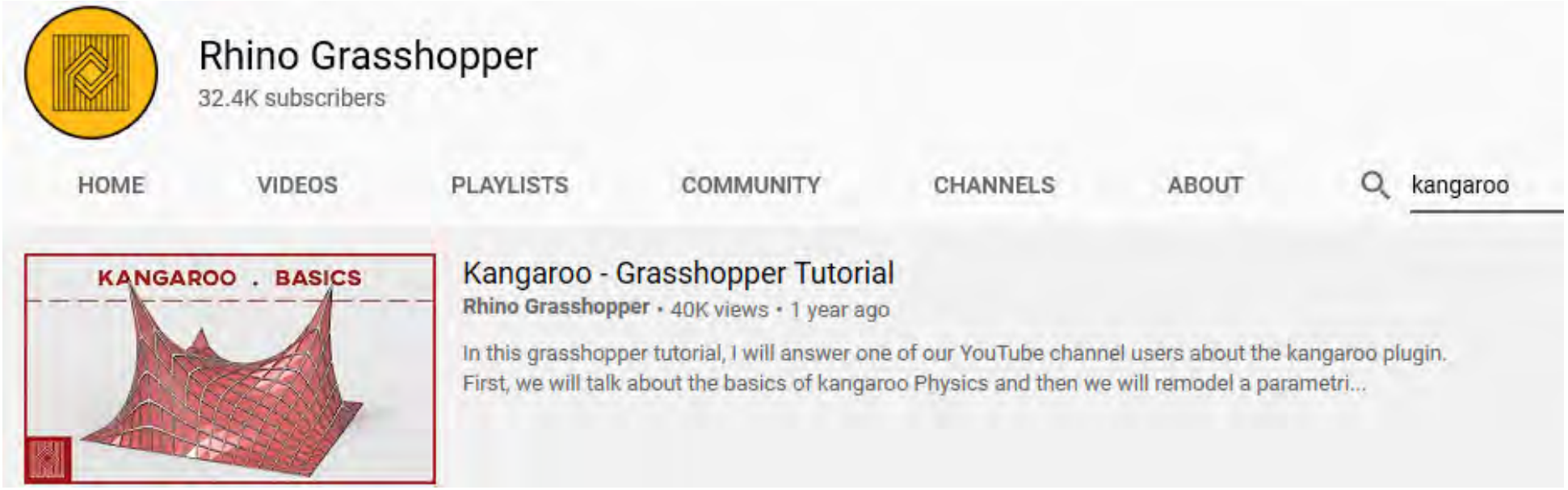


https://explodebreps.wordpress.com/grasshopper-definitions/kangaroo-british-museum-roof-2/

https://www.tripsavvy.com/treasures-of-the-british-museum-1661292

Plug-in 2: Kangaroo Physics and Kangaroo 2 introduction

https://youtu.be/ToHLlEGvhqA

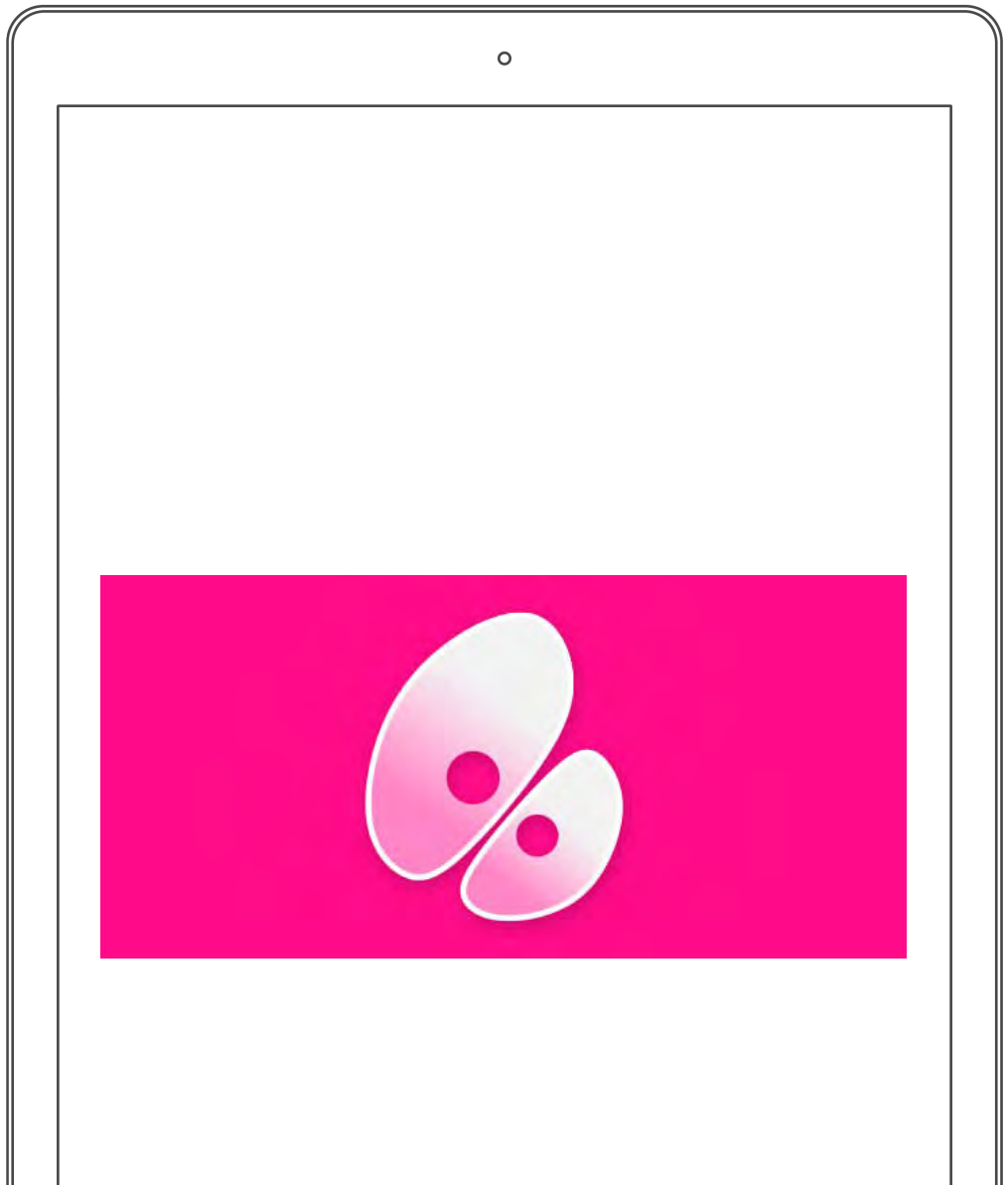


Plug-in 3: Galapagos

Evolutionary Solving, Genetic Algorithm (GA)

By: David Rutten

It is named after the Galapagos Island



Plug-in 3: Galapagos

Galapagos comes with Grasshopper, under Params tab.

Blog post by David Rutten:
https://www.grasshopper3d.com/profiles/blogs/evolutionary-principles

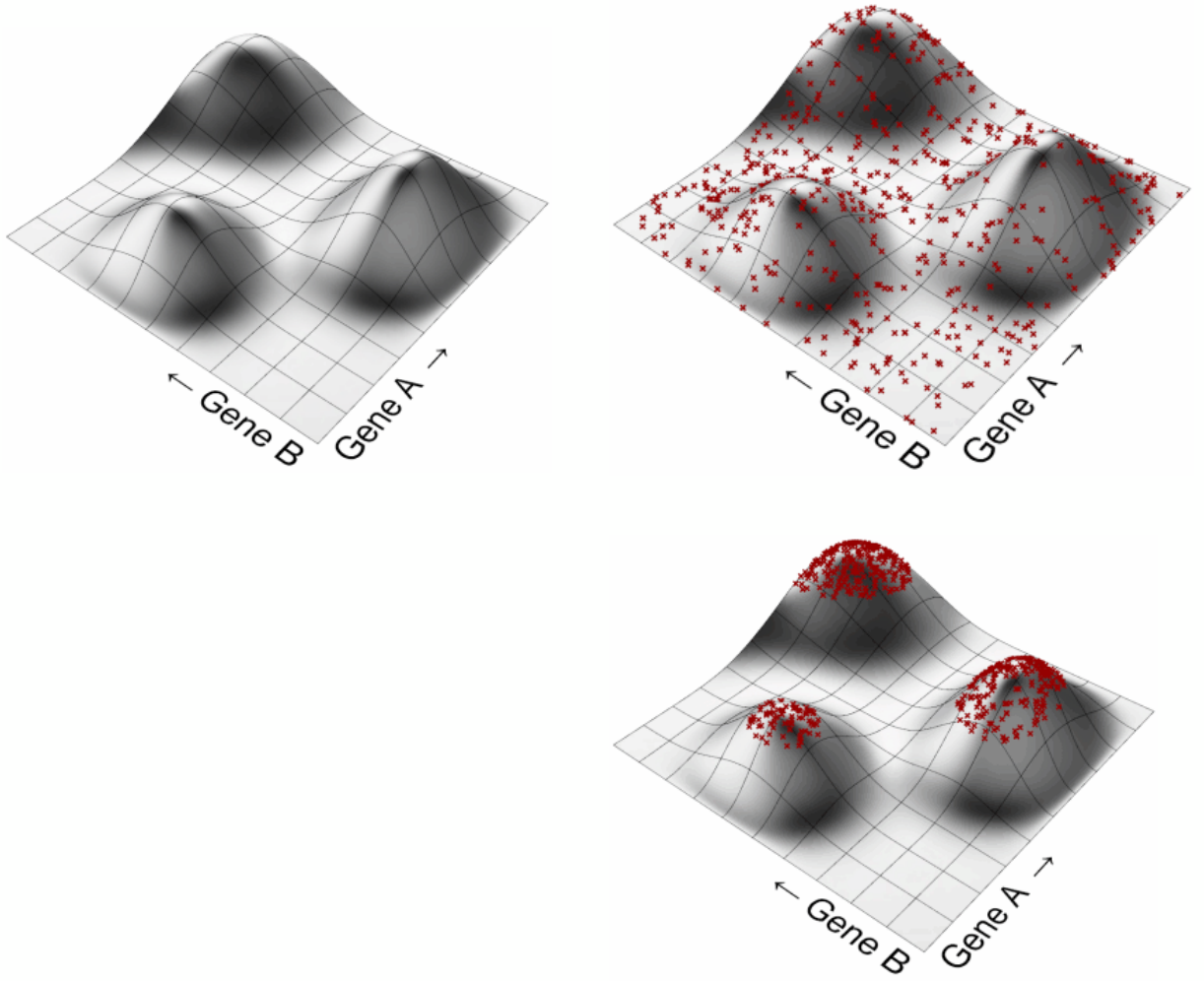
Plug-in 3: Galapagos

Evolutionary computing goes back as early as 1948. Alan Turing proposed the term, “genetical or evolutionary search”.

Plug-in 3: Galapagos

Evolutionary Solver in Galapagos.

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

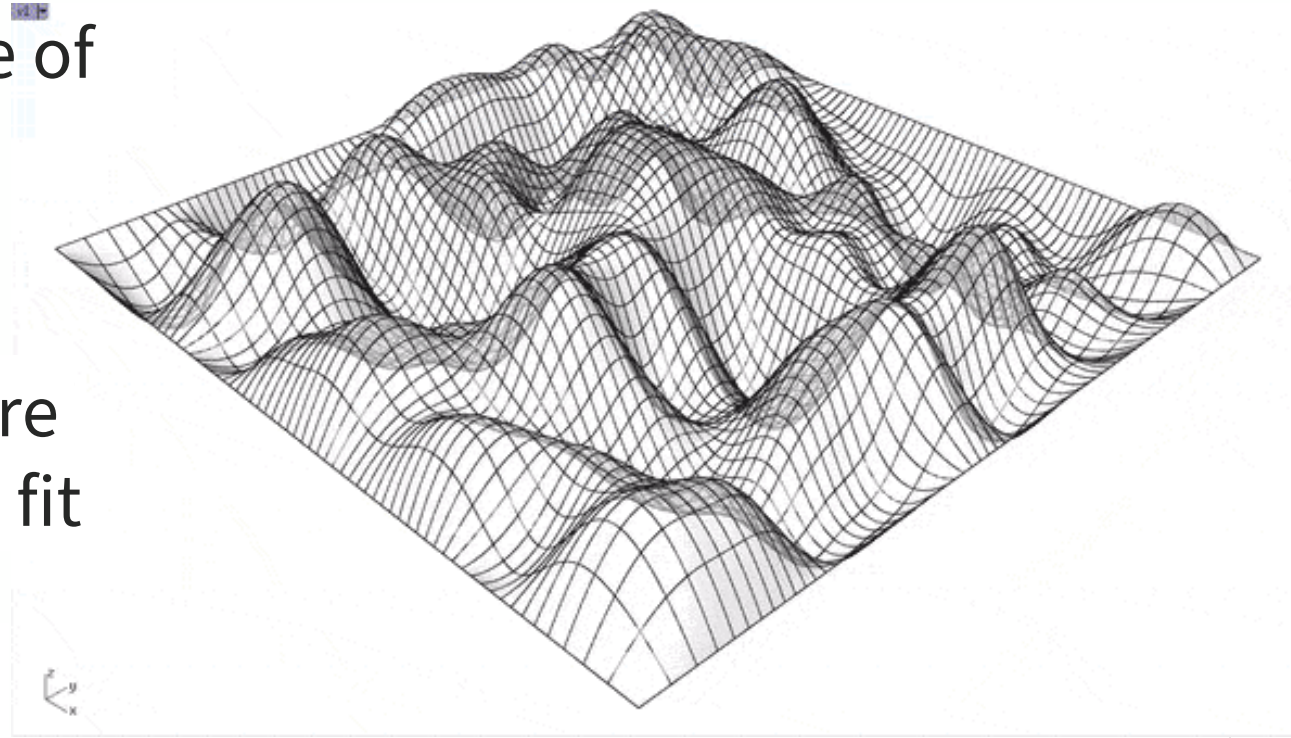


A *Fitness Landscape* of a particular model. The model has two variables (genes), Gene A and B. As Gene A changes, the fitness of entire model also changes. Every combination of A and B results in particular fitness, and it is represented as the **height of *fitness landscape.*** The solver's job is to **find highest peak in this landscape.** The third picture shows a cluster around three fitness peaks, and the process is repeated until we reach the highest peak.

Plug-in 3: Galapagos

designplaygrounds.com/blog/galapagos-101-fundamentals-course/

So a **peak** represents a range of ‘successful’ genomes and a **valley** belong to less fit combinations. With every iteration the genomes that are less fit get discarded and the fit enough one will generate offspring and carry on to the next iteration.



Plug-in 3: Galapagos

Evolutionary Solver in Galapagos.

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

The anatomy of solver requires these 5 interlocking parts:

- Fitness Function
- Selection Mechanism
- Coupling Algorithm
- Coalescence Algorithm
- Mutation Factory

Plug-in 3: Galapagos

Potential use:

Multiple-objective optimisation

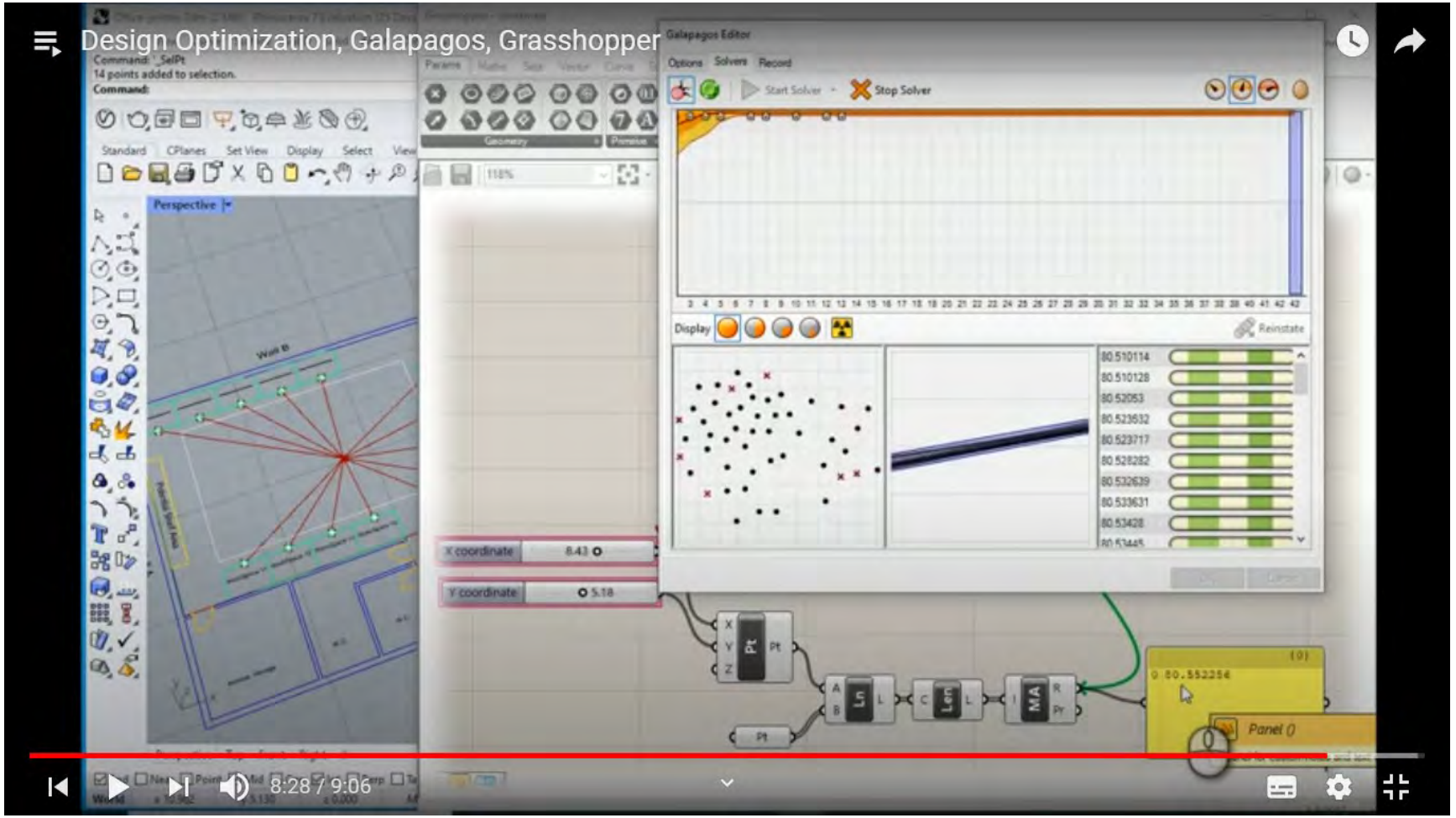
Drawbacks according to David Rutten:

Slow and do not guarantee a solution (tend to run on indefinitely unless good-enough value is specified)

Advantages: flexible (wide variety of problems), forgiving (happily work on problem that have been under or over constrained) and high degree of interaction.

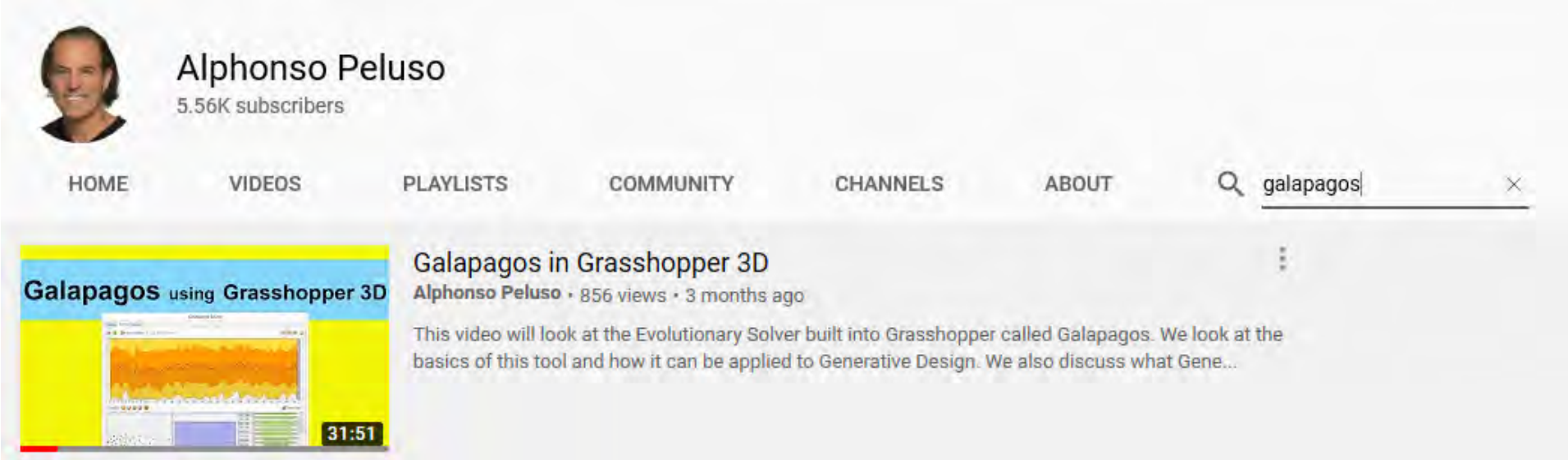
An illustration of Galapagos

https://youtu.be/0F4UY-Ff2t4

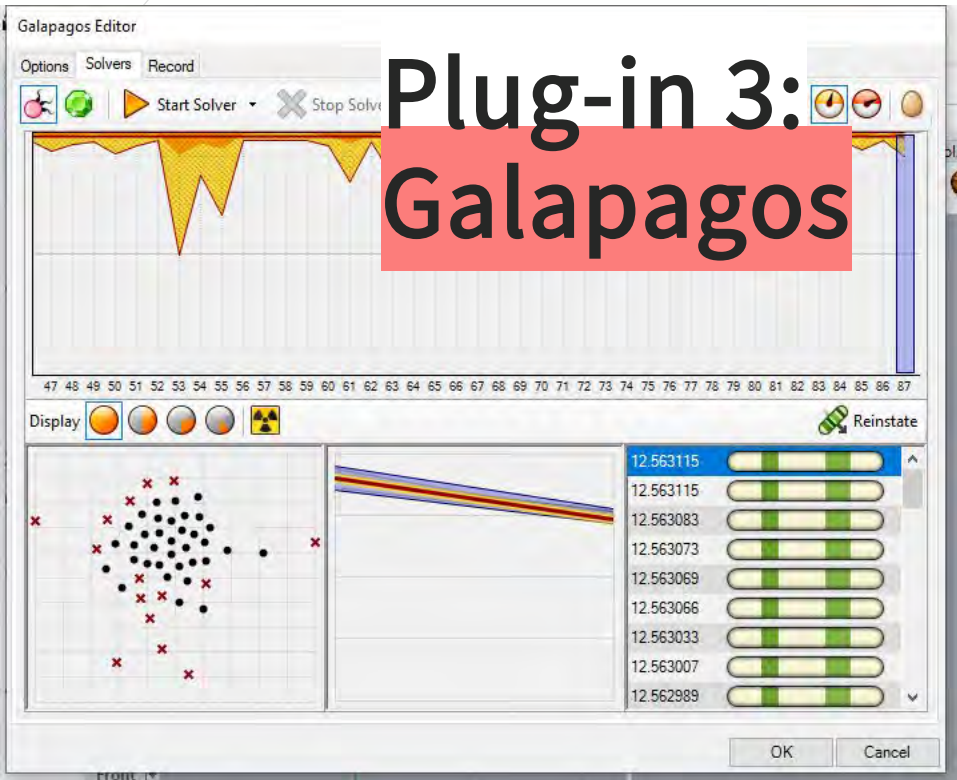


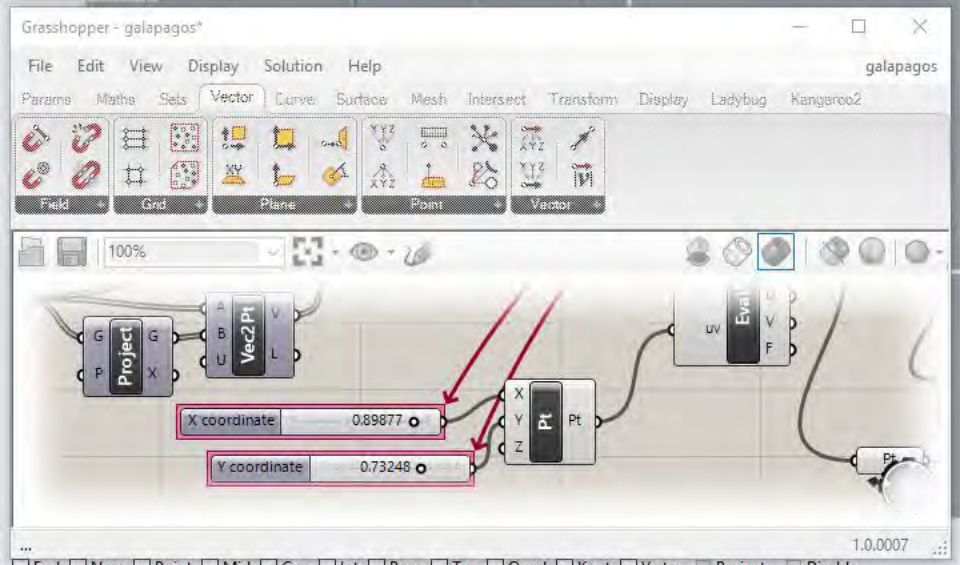
Plug-in 3: Galapagos Introduction

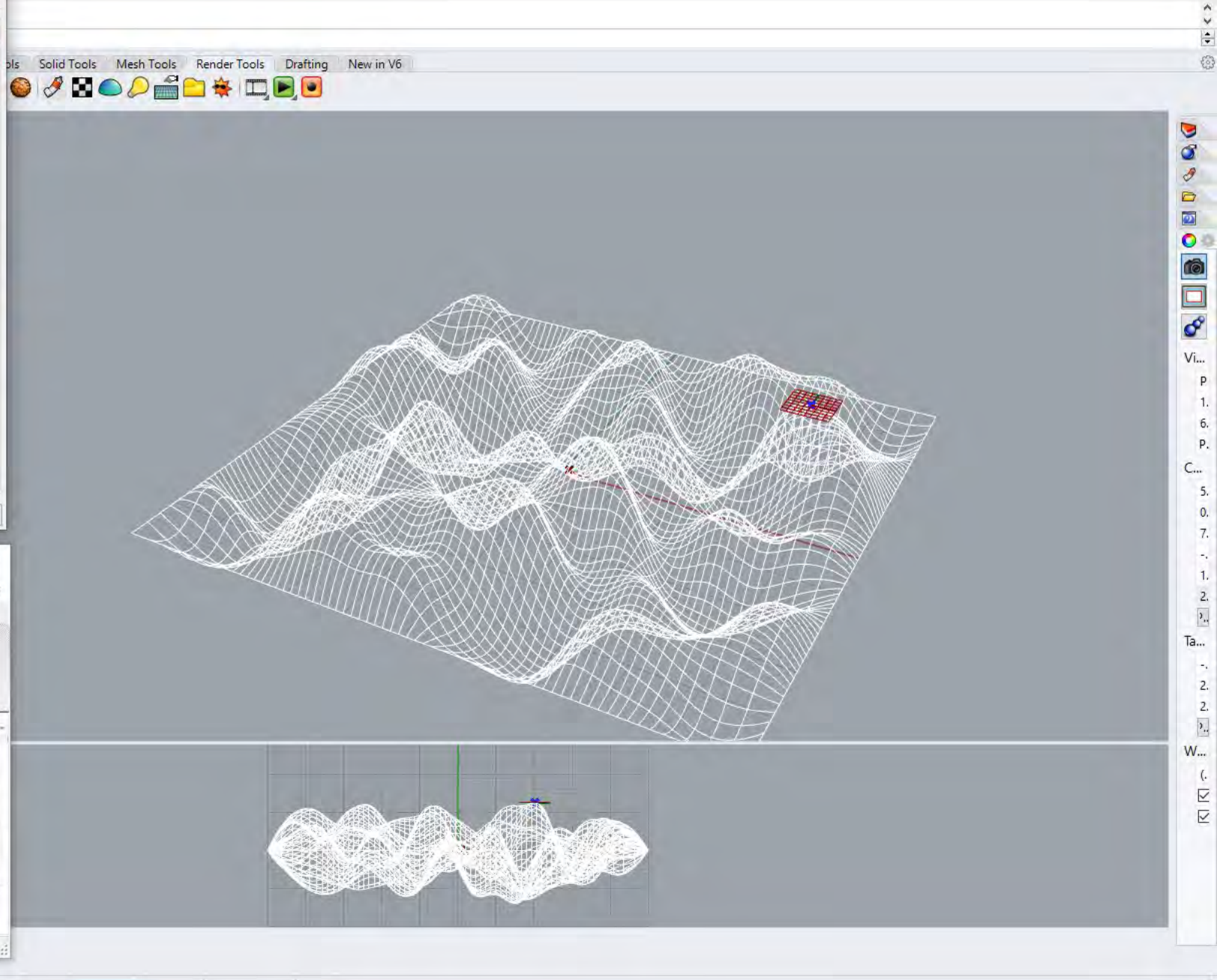
https://youtu.be/PjGcF7STf7c



Plug-in 3: Galapagos







Plug-in 4:
Ivy

Mesh analysis, Segmentation and unrolling

By: Andrei Nejur

Plug-in 4:
Ivy

Download the plug-in:
https://www.food4rhino.com/app/ivy

Andrei Nejur on Ivy:
https://vimeo.com/nejur

Plug-in 4: Ivy

Papers on development

Nejur, A. & Steinfeld, K. (2017). Ivy: Progress in Developing Practical Applications for a Weighted-Mesh Representation for Use in Generative Architectural Design.
Steinfeld, K. (2017). Ivy: Bringing a Weighted-Mesh Representation to Bear on Generative Architectural Design Applications.

Ivy

Bringing a Weighted-Mesh Representation to Bear on Generative Architectural Design Applications

Andrei Nejur
Technical University of Cluj-Napoca

Kyle Steinfeld
University of California, Berkeley

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ABSTRACT

Mesh segmentation has become an important and well-researched topic in computational geometry in recent years (Agathos et al. 2008). As a result, a number of new approaches have been devel-

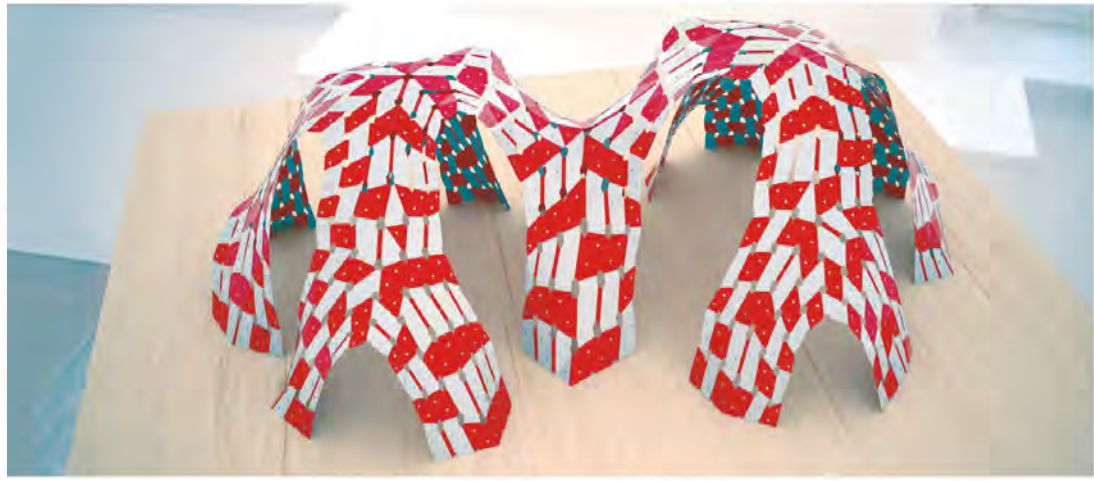
1 The Elephetus project by Anders Holden Deleuran (CITA/KADK) and

Ivy

Progress in Developing Practical Applications for a Weighted-Mesh Representation for Use in Generative Architectural Design

Andrei Nejur
Technical University of Cluj-Napoca

Kyle Steinfeld
University of California, Berkeley



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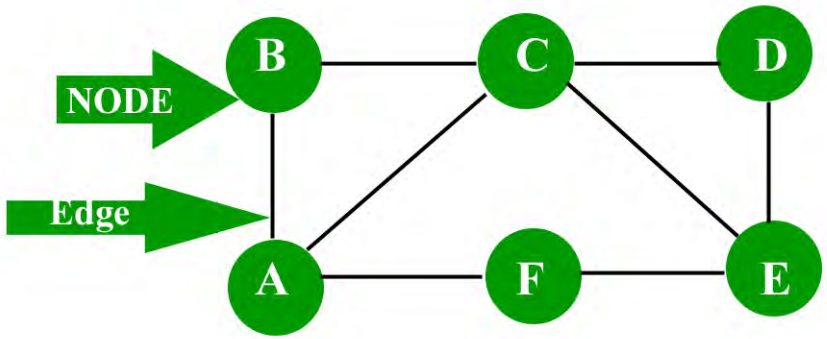
ABSTRACT

This paper presents progress in the development of practical applications for graph representations of meshes for a variety of problems relevant to generative architectural design (GAD). In previous

1 A papercraft model fabricated using Ivy.

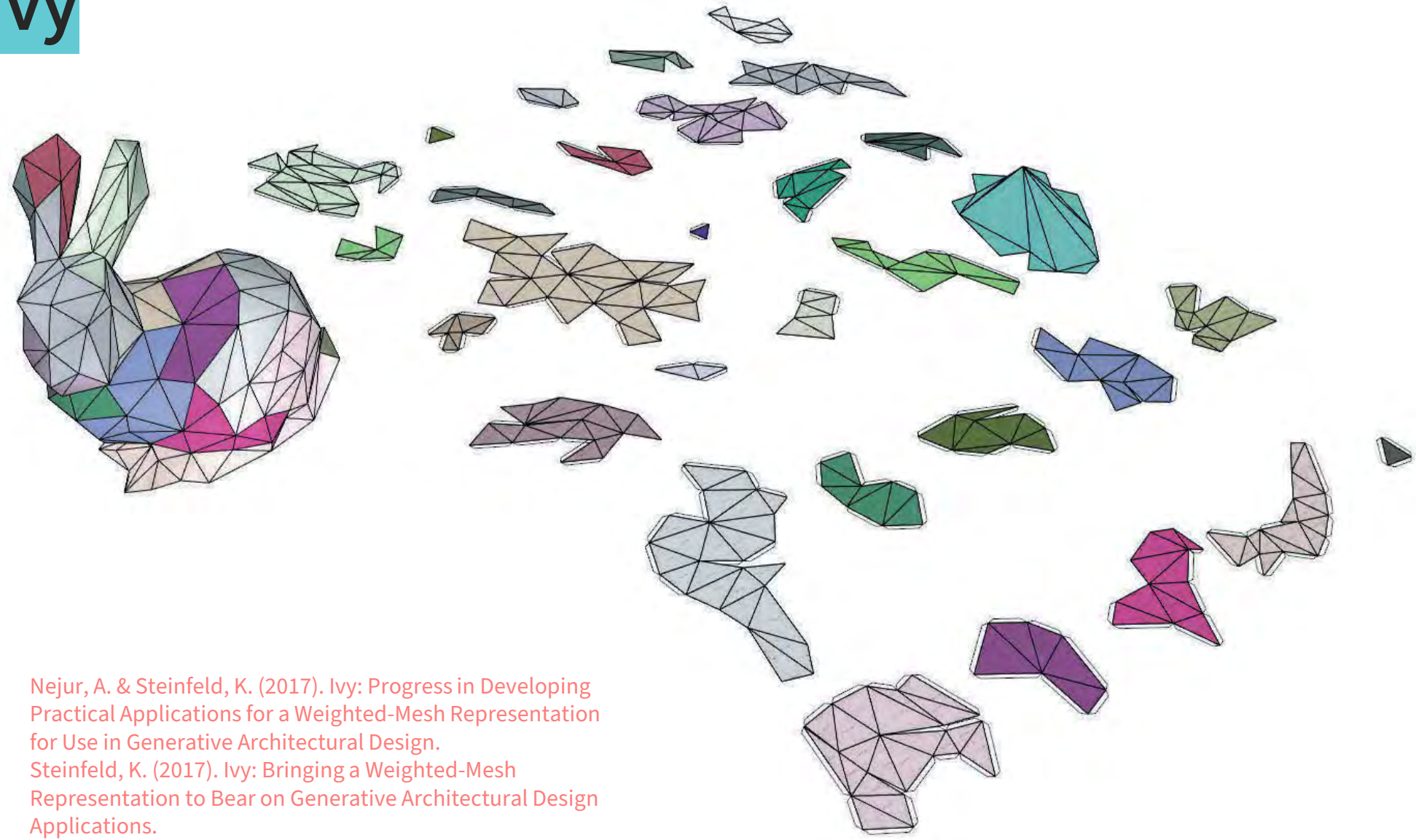
Plug-in 4:
Ivy

Based on
Graph Theory,



Creating
segmentations and
unroll them, then
send them to
digital fabrication
process

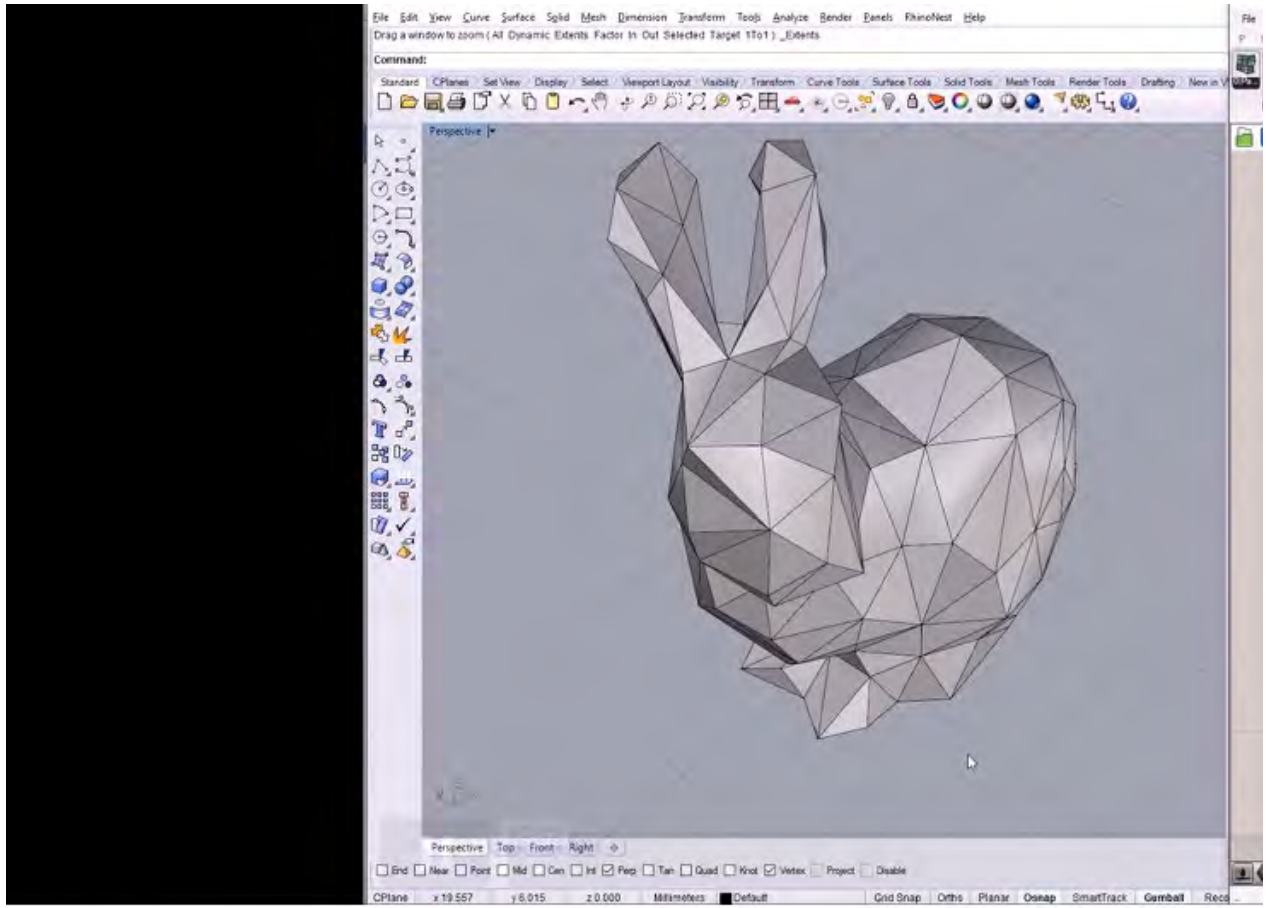
Plug-in 4:
Ivy



Nejur, A. & Steinfeld, K. (2017). Ivy: Progress in Developing Practical Applications for a Weighted-Mesh Representation for Use in Generative Architectural Design.
Steinfeld, K. (2017). Ivy: Bringing a Weighted-Mesh Representation to Bear on Generative Architectural Design Applications.

Plug-in 4: Ivy Introduction

https://vimeo.com/nejur/ivy-01



Six common techniques:
3- Tiling/ Tessellating

It involves development of objects that when assembled together, forming a coherent plane without gaps or overlaps.

Advantages tiling/tessellating in digital fabrication approach:

- Effective time investment
- Provide ways which patterns are generated and optimised (visually and materially sound)
- Optimised for reduction of waste.

Six common techniques:
3- Tiling/ Tessellating

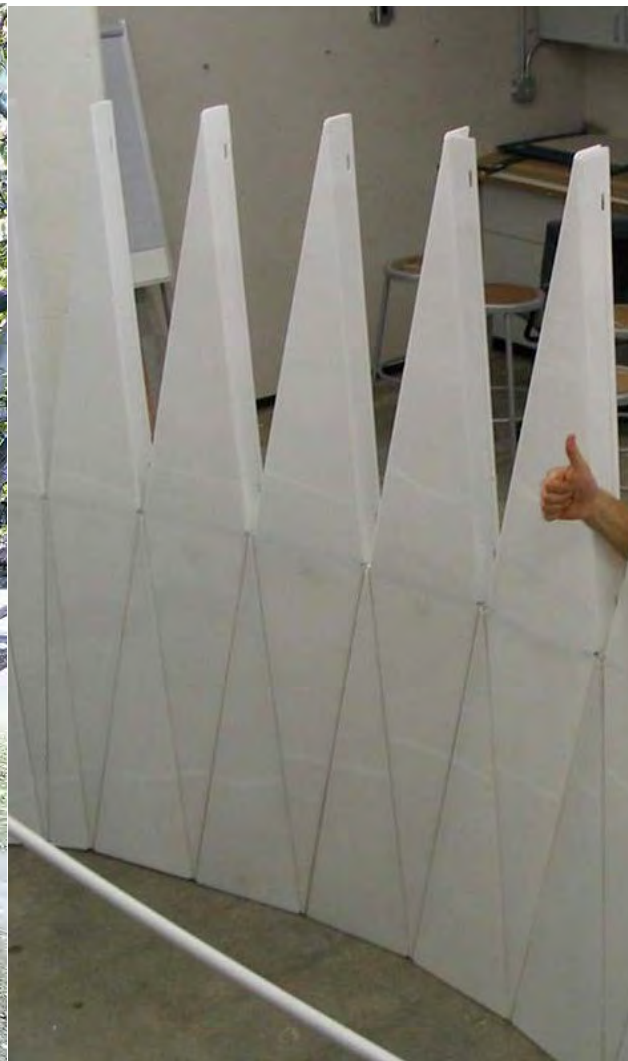
Translating digital information from mesh to complex 3D form, using sheet materials through tiling, has made digital fabrication technique became more apparent from early design stage.

Tiling/tessellating also affords greater variation and modulation, as they provide an inherent economy of means.

Six common techniques:
3- Tiling/ Tessellating

Huyghe + Le Corbusier Puppet Theater, MOS 2004

https://www.mos.nyc/project/puppet-theater



Re-iterated aims and objectives

- To elicit purposes of additional plug-ins
- To contextualise the use of plug-ins in parametric design thinking
- To enumerate available plug-ins and their common use
- To illustrate kinds of analysis and data obtained from selected plug-ins
- To inform how can plug-ins be useful for future use in design