COMPUTING COMPLEXITY

UBLLU1-15-M

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PROJECT TITLE

THERMAL COMFORT OPTIMIZATION AT QUEEN SQUARE, BRISTOL

By

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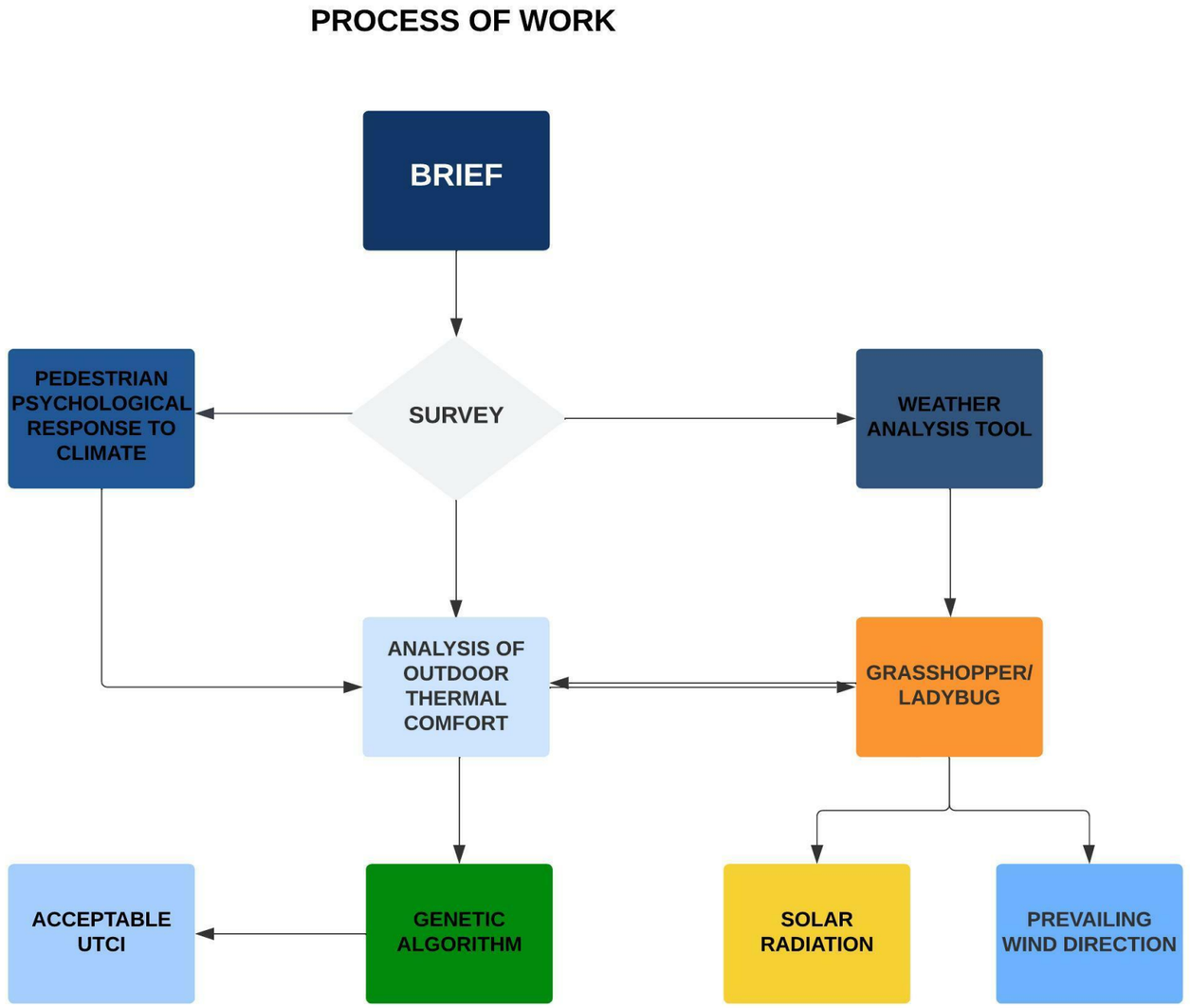
Msc Computational Architecture 2022/23

PROJECT BRIEF

- To investigate the Old City of Bristol within the context of Urban phenomenon focusing on Queen Square.
- Using a computational method to analyse the impact of climate on the use of the Square .
- To generate an algorithm to solve a problem identified.



Abstract

The scope of this project attempts to investigate the correlation between spatial behaviour and outdoor thermal comfort of urban open spaces. A field survey was conducted at Queen Square, Bristol (the area of interest of this project) on a typical sunny day in October to observe the behavioural pattern of the users. Environmental analysis tool – Ladybug plugin in Grasshopper generated the Universal Thermal Climatic Index (UTCI) which helped to investigate this behavioural pattern observed during the field survey. The results indicated a likelihood of users occupying shady spaces during a typical summer day and unshaded spaces during a typical winter day.

Introduction

The concept of outdoor thermal comfort and open spaces has become a critical factor in measuring the viability of an urban open space. The impact of the microclimatic conditions on the human body is what creates a feeling of comfort or not within an urban open space. Khim Bok (January 2021) argued that focus has been on aesthetics of urban open spaces ignoring the microclimatic factors that make such space habitable. Designers have become increasingly aware of the need to make open spaces more comfortable by exploring diverse ways of investigating the climate and making the right design decisions.

The four major factors that have been accepted for calculating the climate for human comfort are the air temperature, relative humidity, wind speed, and solar radiation. Too little or too much of one or more of these factors results in comfort or discomfort.

Background

Queen Square, Bristol

Queen Square is located at the centre of the old Bristol city. The Academy of Urbanism described the square as occupying 2.4 hectares with lawns and wide diagonal, horizontal and vertical gravel paths, and a perimeter of mature deciduous trees. The square serves as a major pedestrian circulation point as well as a park within the city.

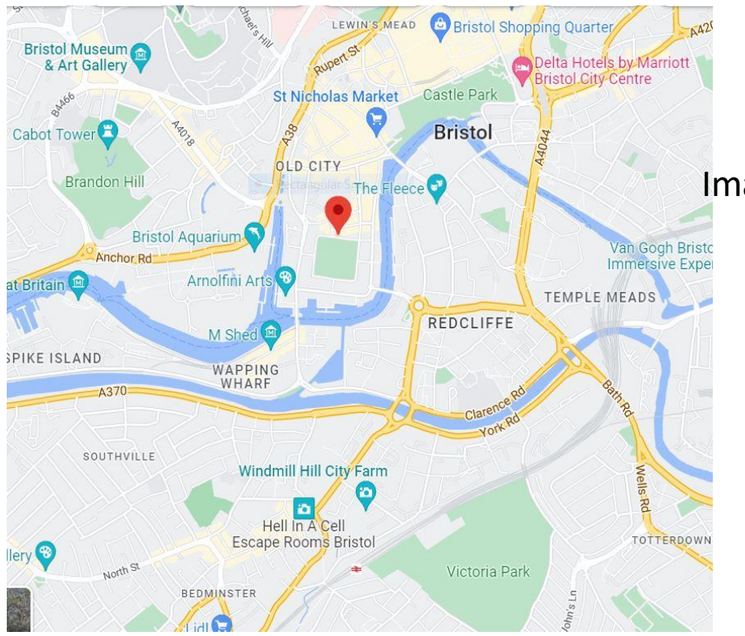


Image 1 Source: Google map

Image 2e

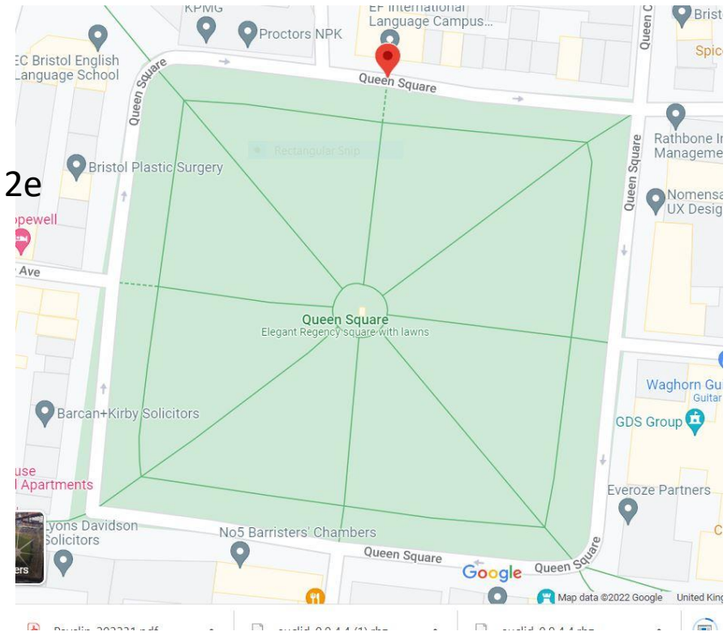


Image 2 Source: Google map

Image 3 Source: Google map

The Study

This project focuses on the climatic analysis of the square to see the level of thermal comfort obtainable at the square during different seasons of the year and to proposes a computational approach to solve it.

Pictorial Analysis

The pictures of the Square showing trees at different seasons of the year. Shade are created around the trees' location.

Photo credit: Google.com

Weather Data for Bristol

Bristol, United Kingdom - Sun path diagram

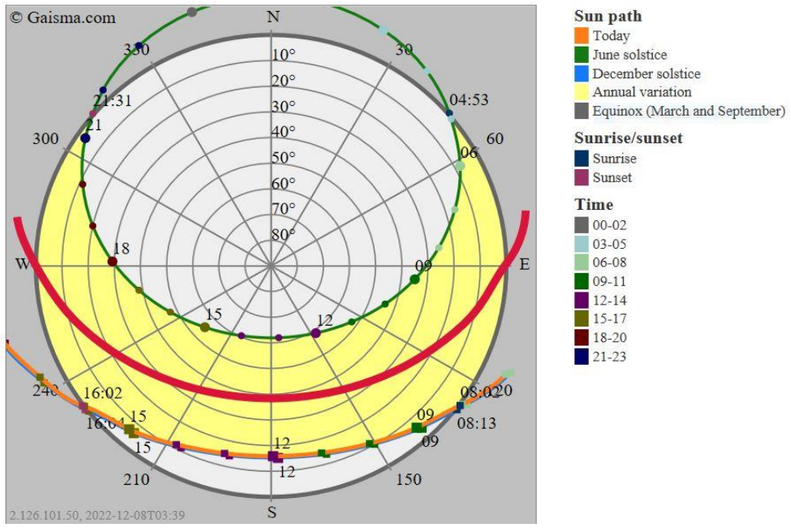


Image 2a (Sun path diagram source: www.gaisma.com)

Bristol, United Kingdom - Sunrise, sunset, dawn and dusk times, table

Future | Past

Date	Sunrise	Sunset	Length	Change	Dawn	Dusk	Length	Change
Today	08:02	16:02	8:00		07:23	16:42	9:19	
-1 day	08:01	16:02	8:01	00:01 longer	07:22	16:42	9:20	00:01 longer
-1 week	07:53	16:05	8:12	00:12 longer	07:14	16:44	9:30	00:11 longer
-2 weeks	07:43	16:11	8:28	00:28 longer	07:05	16:49	9:44	00:25 longer
-1 month	07:16	16:32	9:16	01:16 longer	06:40	17:08	10:28	01:09 longer
-2 months	*07:24*	*18:30*	11:06	03:06 longer	*06:51*	*19:04*	12:13	02:54 longer
-3 months	*06:36*	*19:39*	13:03	05:03 longer	*06:02*	*20:13*	14:11	04:52 longer
-6 months	*04:55*	*21:25*	16:30	08:30 longer	*04:08*	*22:11*	18:03	08:44 longer

Image 2b (Sunrise, sunset and dusk times, table diagram source: www.gaisma.com)

Bristol, United Kingdom - Seasons graph and Earth's orbit

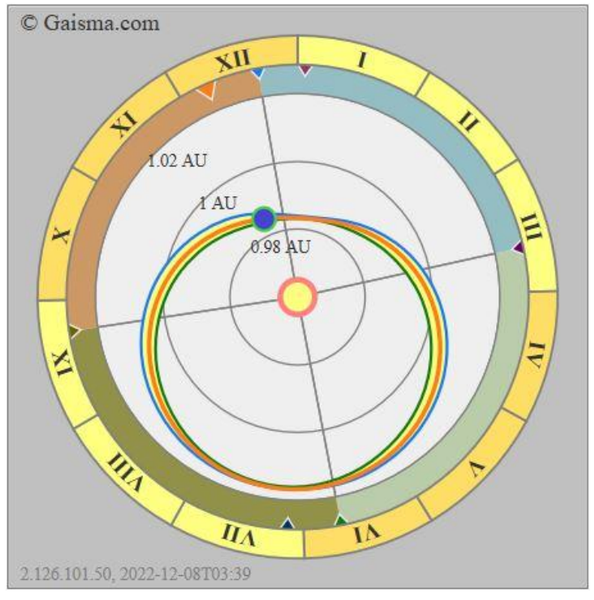


Image 2c (Season's graph and Earth's orbit diagram source: www.gaisma.com)

Bristol, United Kingdom - Sunrise, sunset, dawn and dusk times, graph

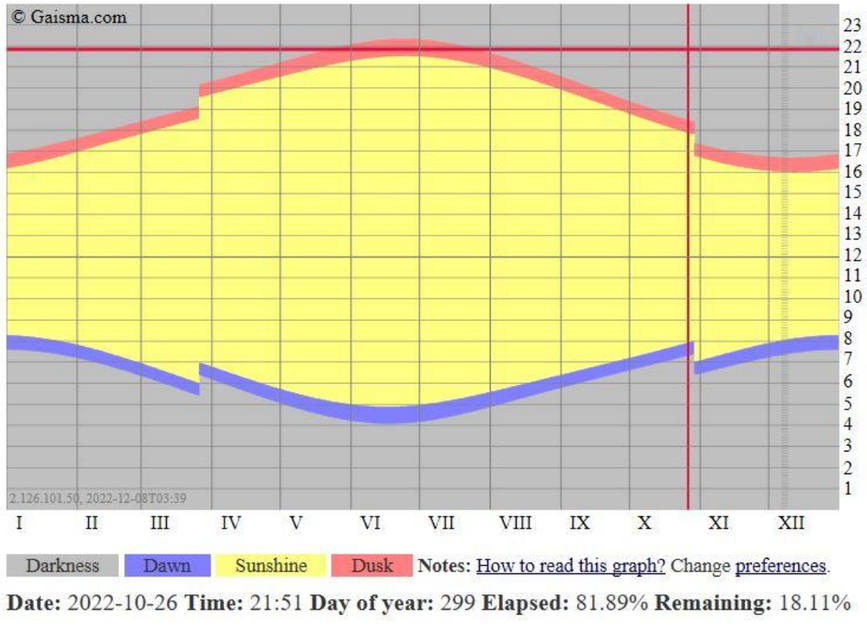


Image 2d (Sunrise, sunset , dawn and dusk times, graph diagram source: www.gaisma.com)

Bristol, United Kingdom - Basic information

Latitude: +51.46 (51°27'36"N)
Longitude: -2.6 (2°36'00"W)
Base time zone: UTC+0 hours [?]
Local time: 03:54:15
Country: United Kingdom
Continent: Europe
Sub-region: Northern Europe
Distance: ~18 km (from your IP)
Altitude: ~60 m
Bristol, nearby locations

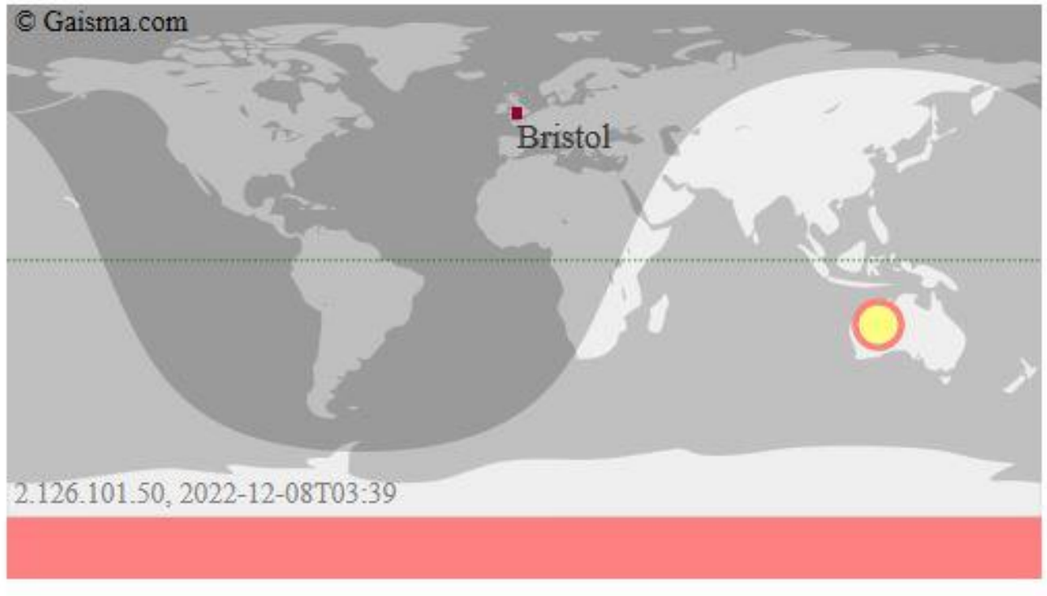


Image 2e (Basic information diagram source: www.gaisma.com)

Bristol, United Kingdom - Solar energy and surface meteorology

Variable	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
Insolation, kWh/m²/day	0.69	1.21	2.18	3.44	4.42	4.70	4.67	3.91	2.75	1.54	0.83	0.52
Clearness, 0 - 1	0.30	0.32	0.36	0.40	0.42	0.41	0.42	0.42	0.39	0.33	0.30	0.27
Temperature, °C	4.45	4.31	6.13	7.93	11.84	15.24	17.57	17.27	14.59	11.05	7.12	5.06
Wind speed, m/s	8.83	8.19	8.25	7.07	6.47	6.07	5.97	6.08	6.89	7.61	8.27	8.63
Precipitation, mm	90	65	72	56	68	66	61	74	82	82	86	97
Wet days, d	18.6	13.7	16.4	14.6	14.9	13.0	11.7	13.5	13.5	16.4	17.0	17.9

These data were obtained from the NASA Langley Research Center Atmospheric Science Data Center; New et al. 2002

Image 2f

Image 2f (Solar energy and surface meteorology diagram source: www.gaisma.com)

Analysis

Image 2a shows the Sun Path diagram for Bristol, United Kingdom indicating the position of the sun at different times of day for the whole year. This is an important parameter in calculating the outdoor thermal comfort. Also, for providing shades on the site, the sun path analysis helps to determine the location of the devices.

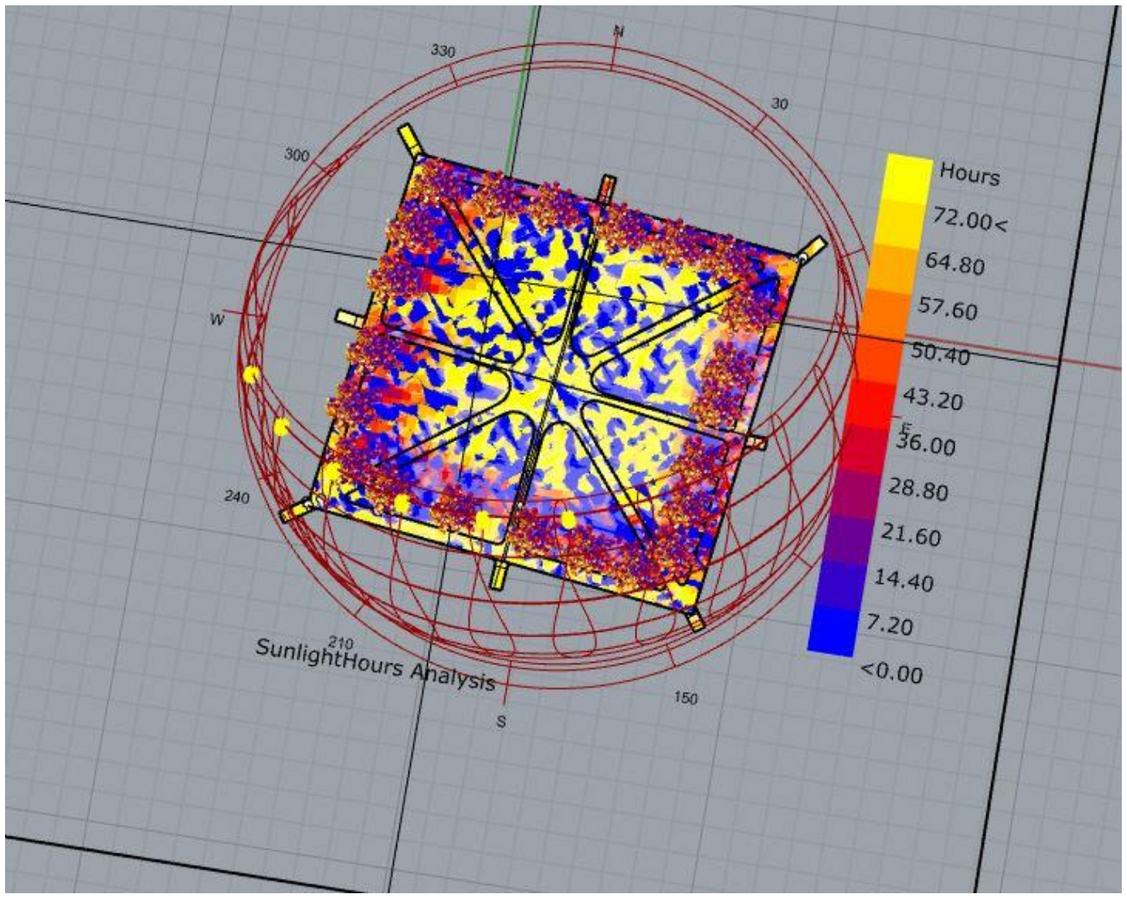


Image 3a Sunlight Hour analysis map for Queen Square

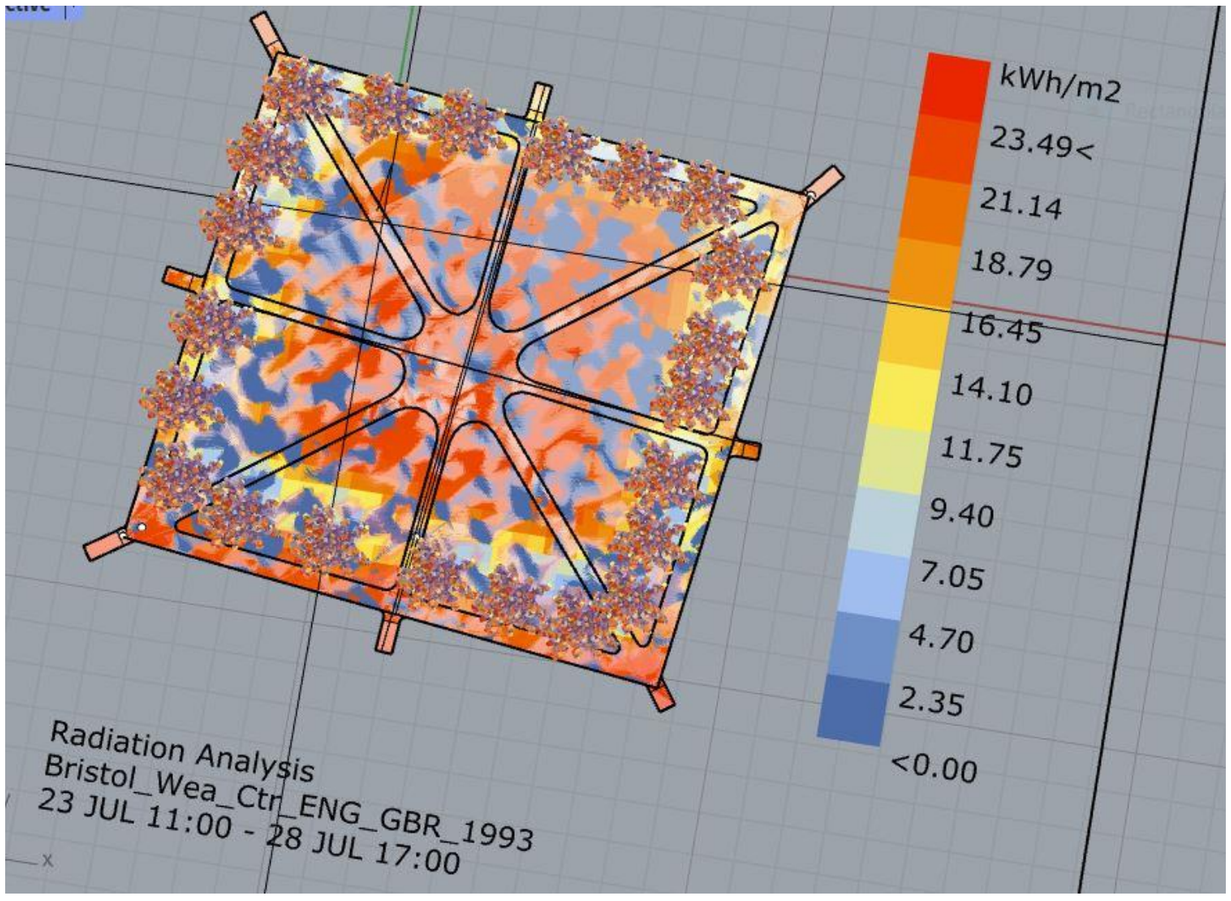


Image 3b Radiation analysis map for Queen Square

Image 3a is the Sunlight hours analysis generated in Rhino – Grasshopper with Ladybug plugin. It shows amount of direct sunlight each portion of the square receives within a specified time of the year. Image 3b illustrates the amount of radiation (heat) received during the specified period.

Methodology

UTCI (Universal Thermal Climate Index)

Rhinoceros 3D with Ladybug and Grasshopper plugins were used to the UTCI of the square based on the available data. Ladybug is a weather analyzing tool that obtains access to any location through Open Street map or any other world's map and downloads the weather data for such location and uses it to analyze, calculate and predict climatic information.

The parameters used were Solar Radiation exposure, Solar Adjusted Mean Radiant Temperature, Wind Speed and Relative Humidity (Image 4b). With effective use of these environmental analysis tools, the Solar Radiation exposure study revealed how exposed the square would be to the sun’s rays at any period of year. This also gave a good preview of the areas that are well shaded or poorly shaded throughout the year.

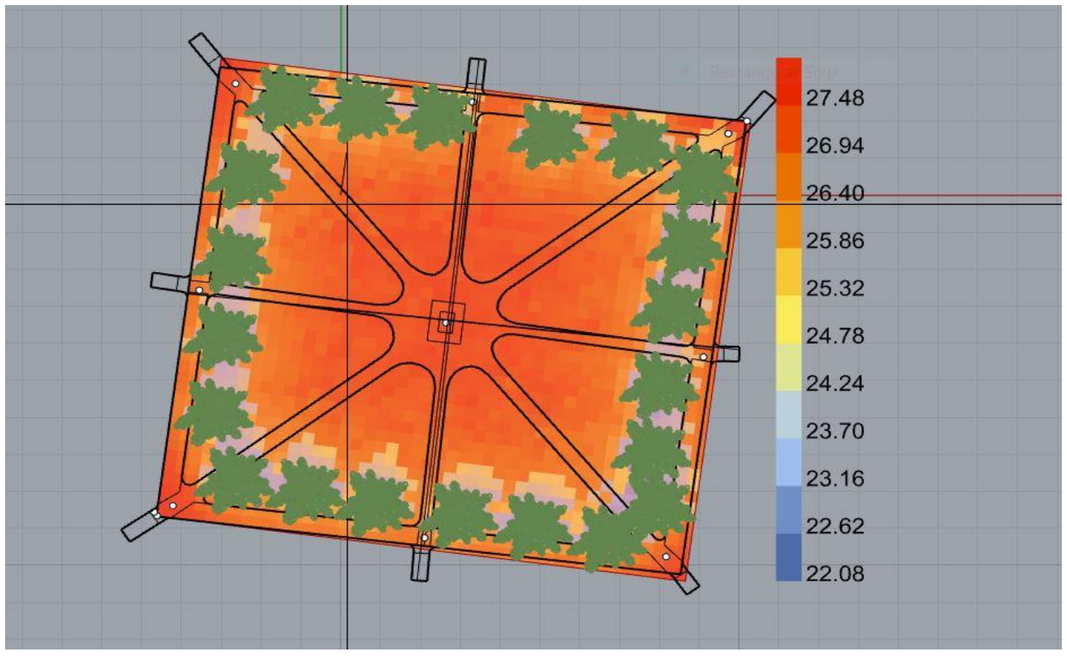


Image 4a UTCI map

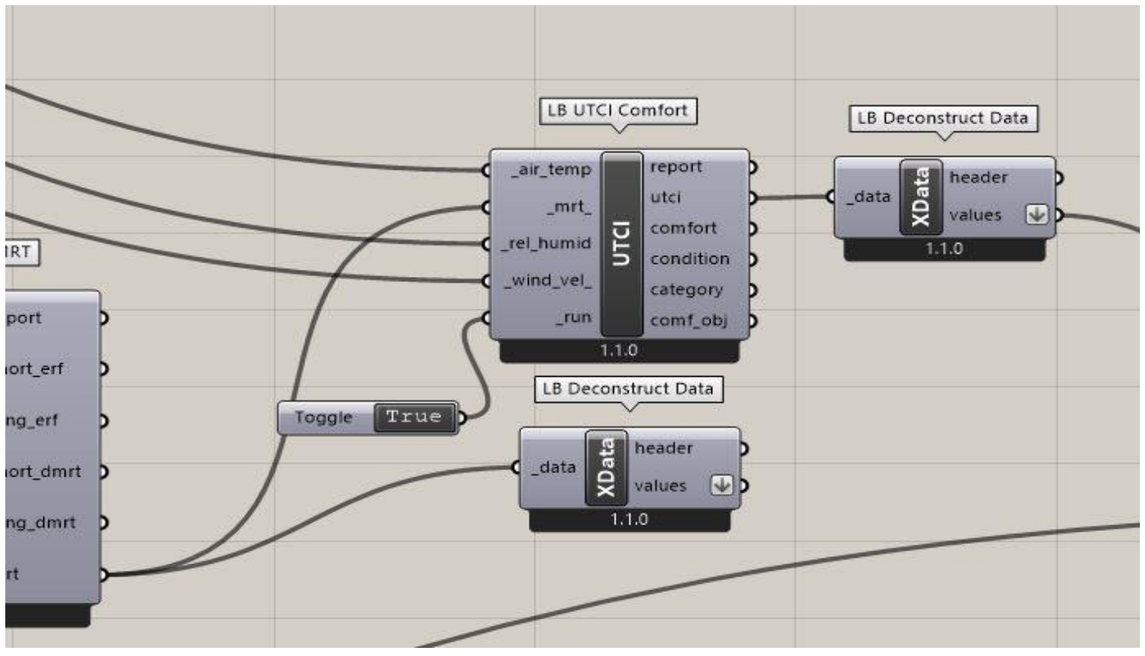


Image 4b UTCI (components set up)

Findings and solution

The analysis showed that the square does not enjoy shade on some points which may be undesirable for the users during a typical summer week. Therefore, it would appropriate to provide additional shade within the square to reduce the direct sun light impact on the users.

Deciduous trees are the best form of shade to be provided. It gives shade during the summer and shed the leaves during winter which opens up the surface to sunlight at this period.

Optimization

To minimize the total surface area exposed to direct sunlight all year round. This is done by using a Genetic Algorithm (GA) to optimize the location of trees within the square that provides maximum shade within the Square. Trees were represented with a canopy like design in grasshopper to give shade over the surface.

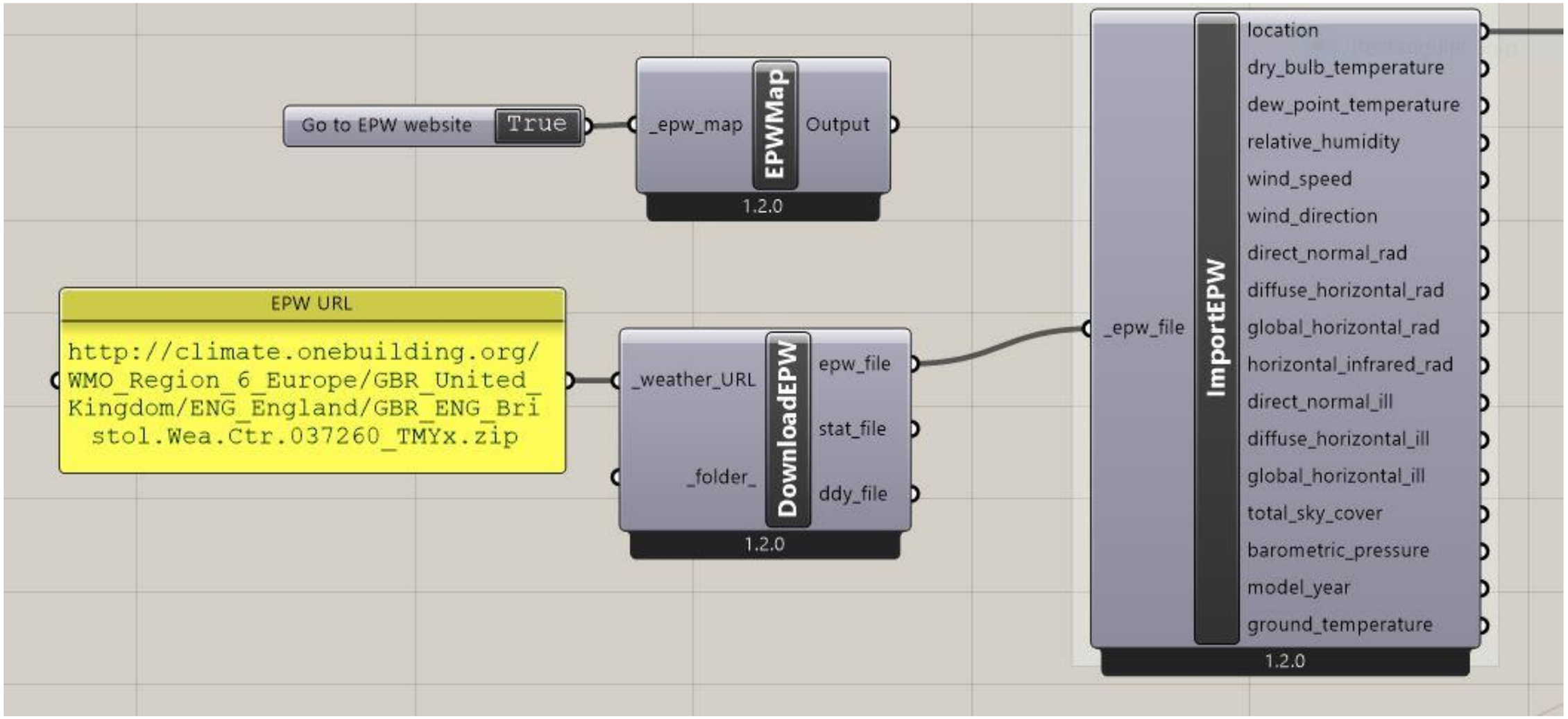


Image 5a Weather Data (Grasshopper script)

Analysis Period - Determining the period of the year to optimize.

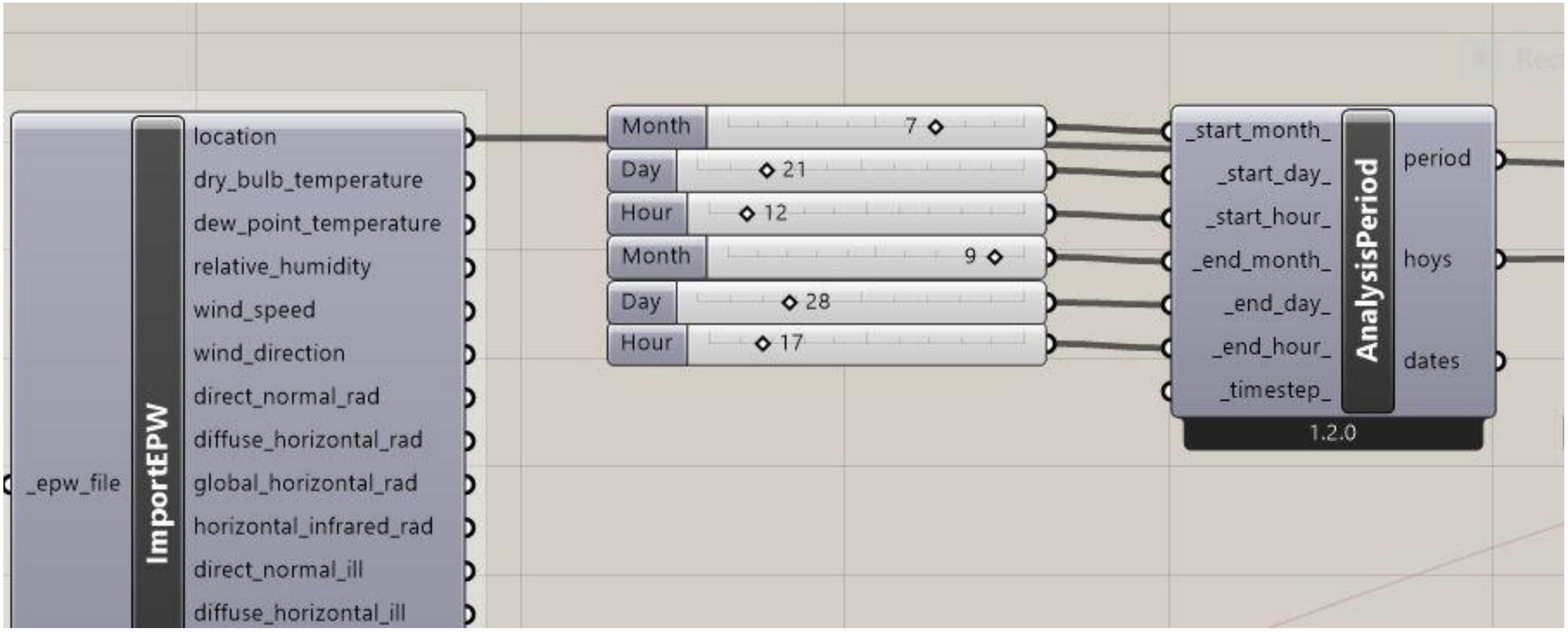


Image 5b Analysis Period (Grasshopper script)

The Sun Path – Location from the EPW and the Hour of the Year (the period being optimized) are the major input here.

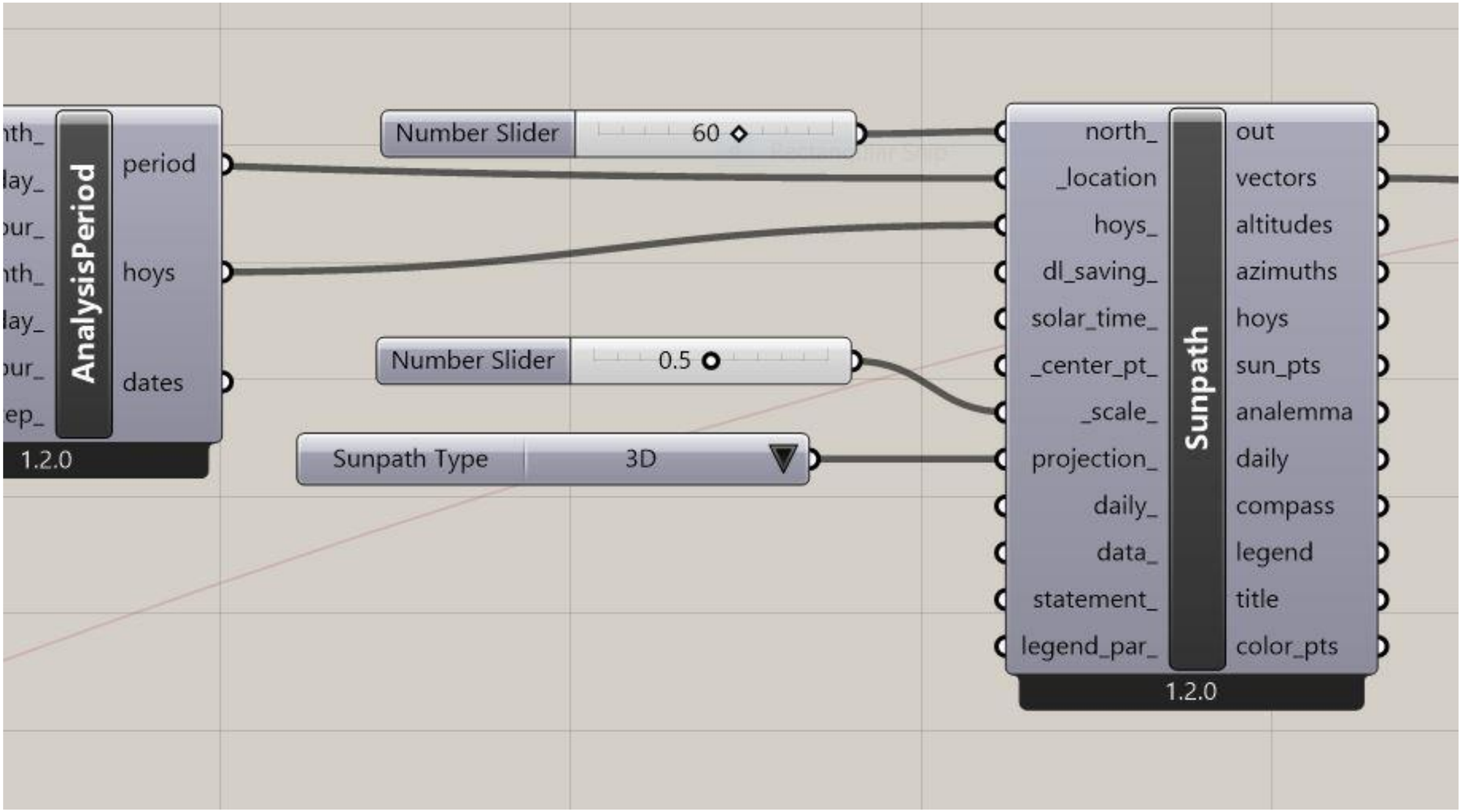


Image 5c Sun Path (Grasshopper script)

Direct Sun Hours – It contains the vectors from the Sun Path component, the surface to be tested with Direct Sun, the context (i.e. the geometry that may block the Sun), run

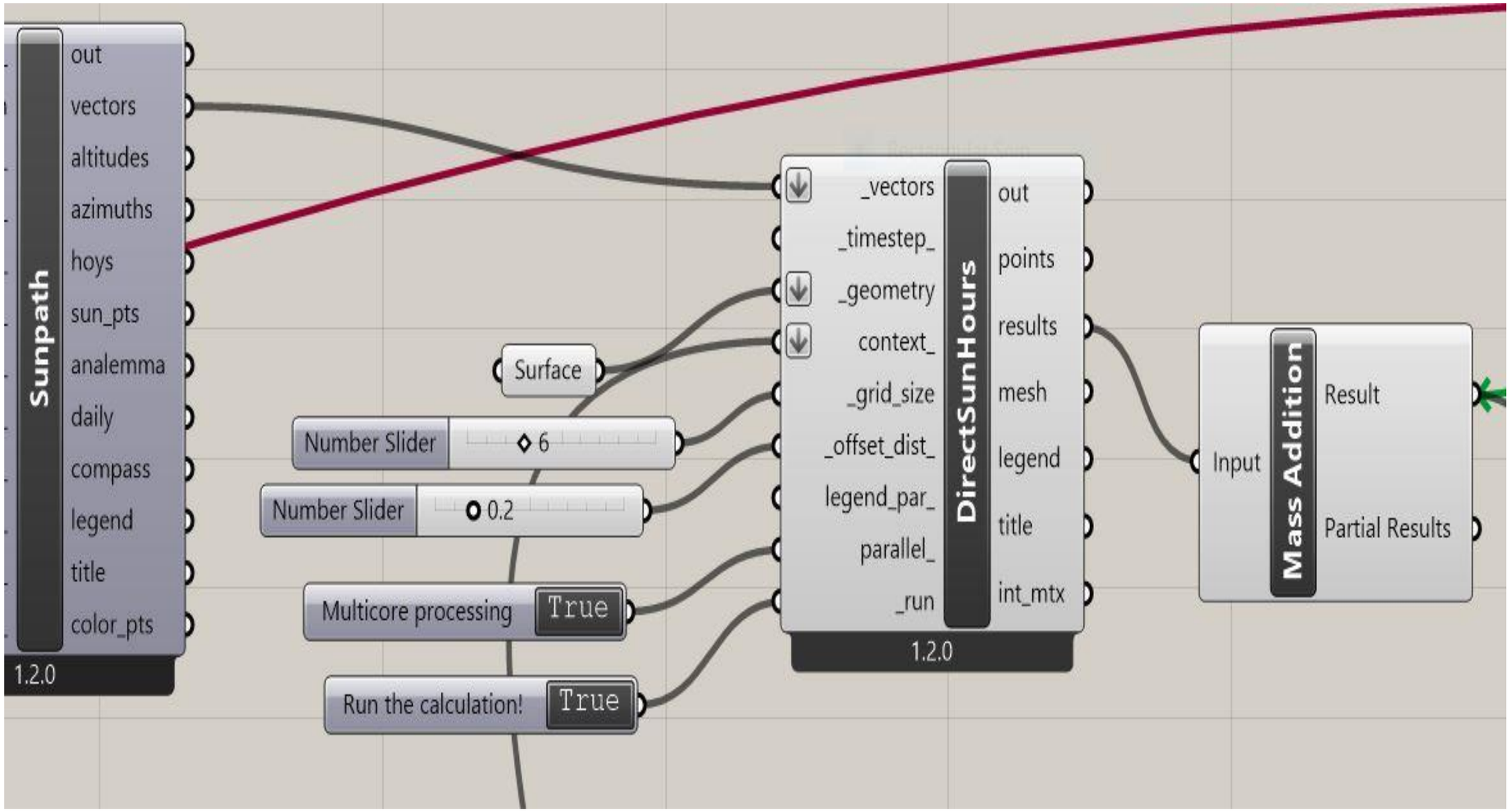


Image 5d Direct Sun Hours (Grasshopper script)

Shade Geometry calculation

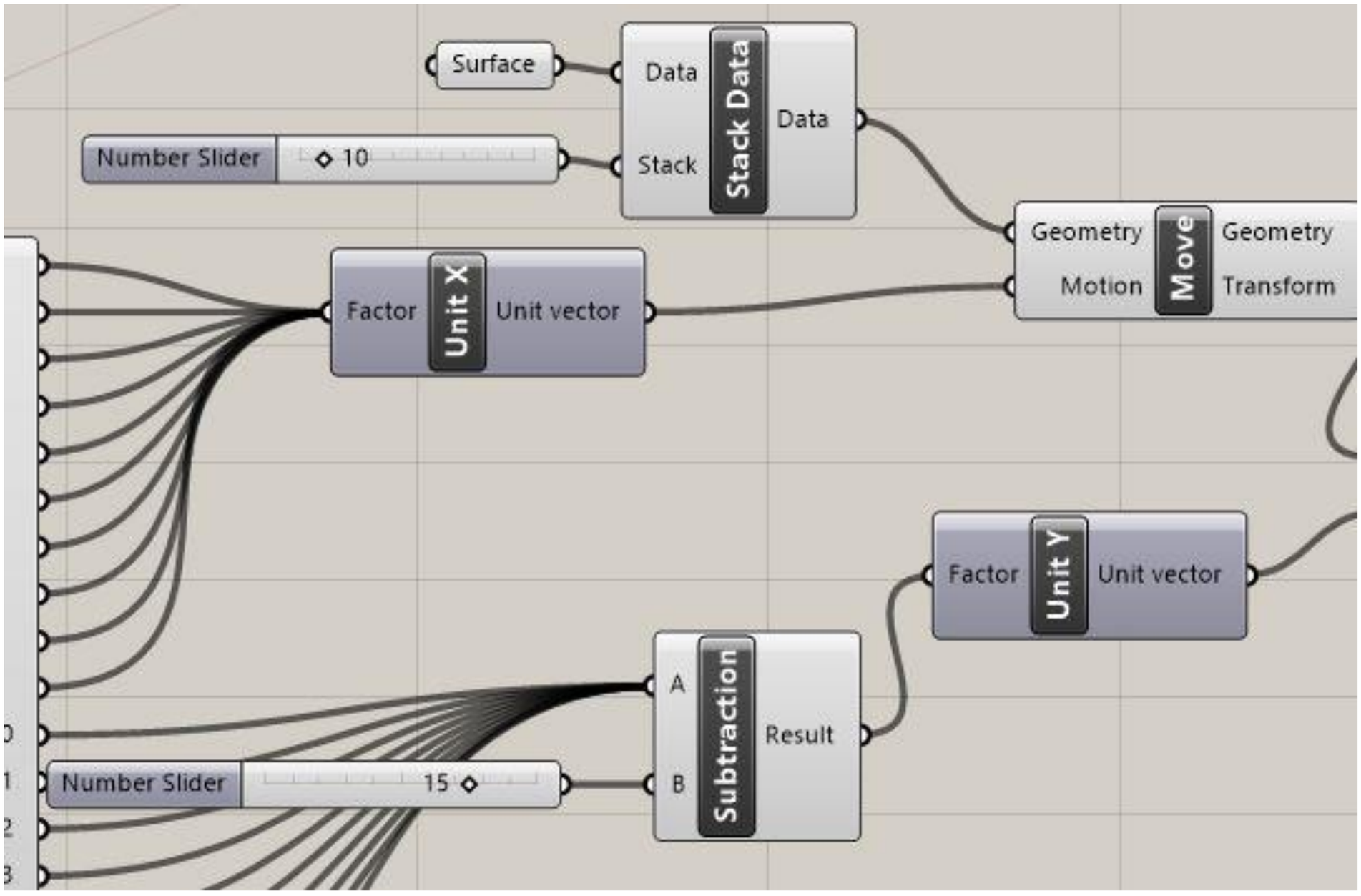


Image 5e (Grasshopper script)

Gene Pool – To collect genes

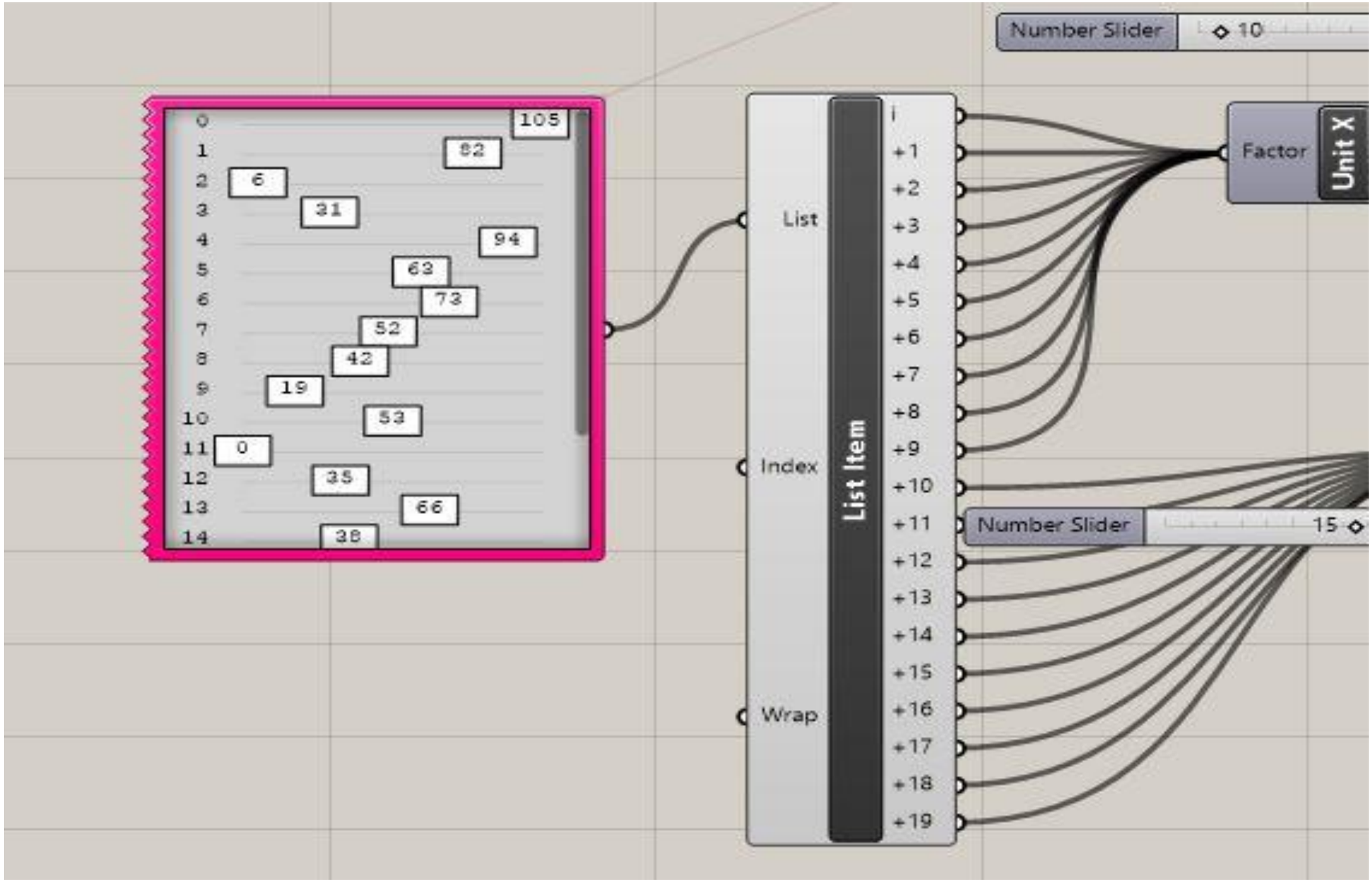


Image 5f (Grasshopper script)

Generate Point – To collect the shade geometry and connect to Direct Sun Hour

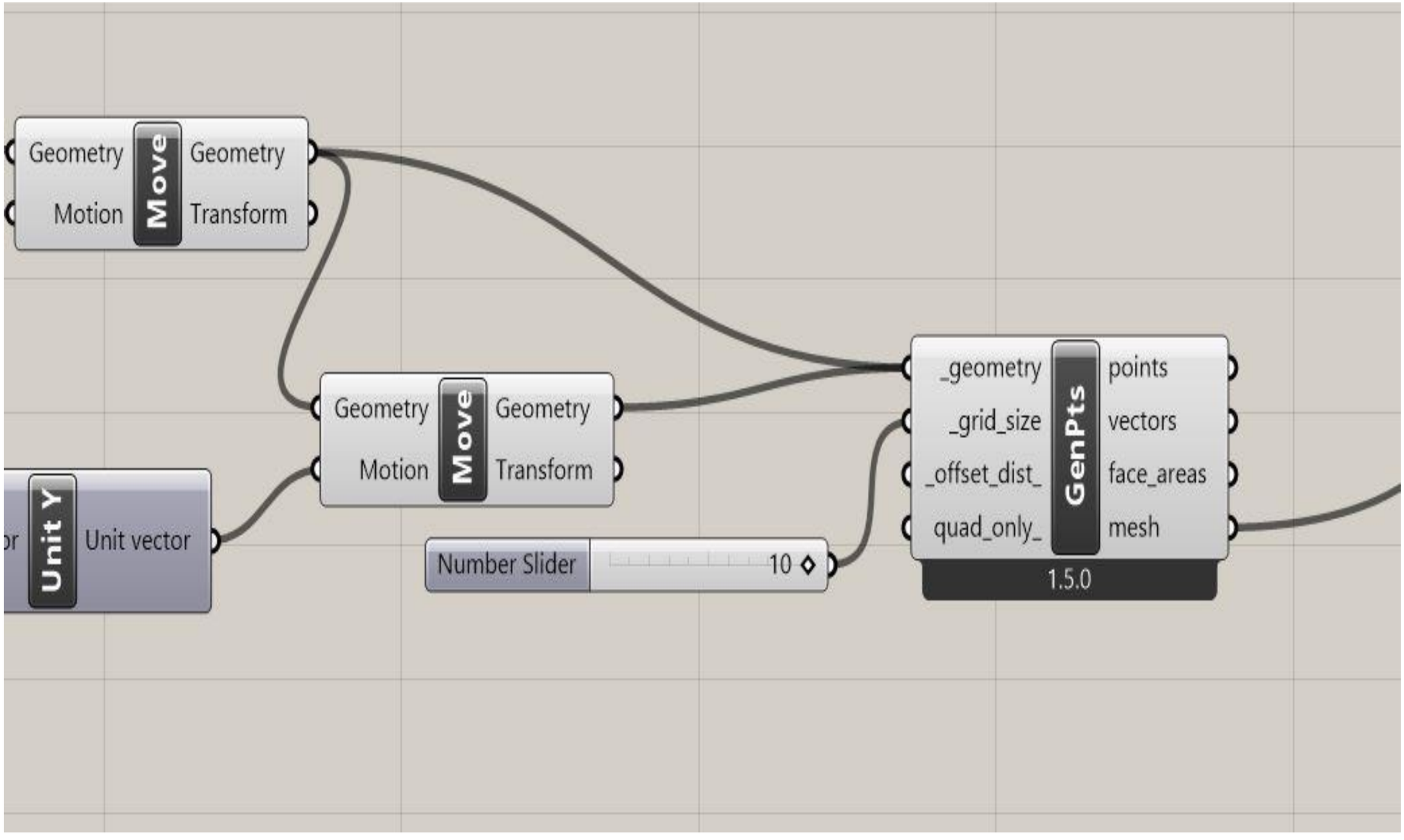


Image 5g (Grasshopper script)

Galapagos!

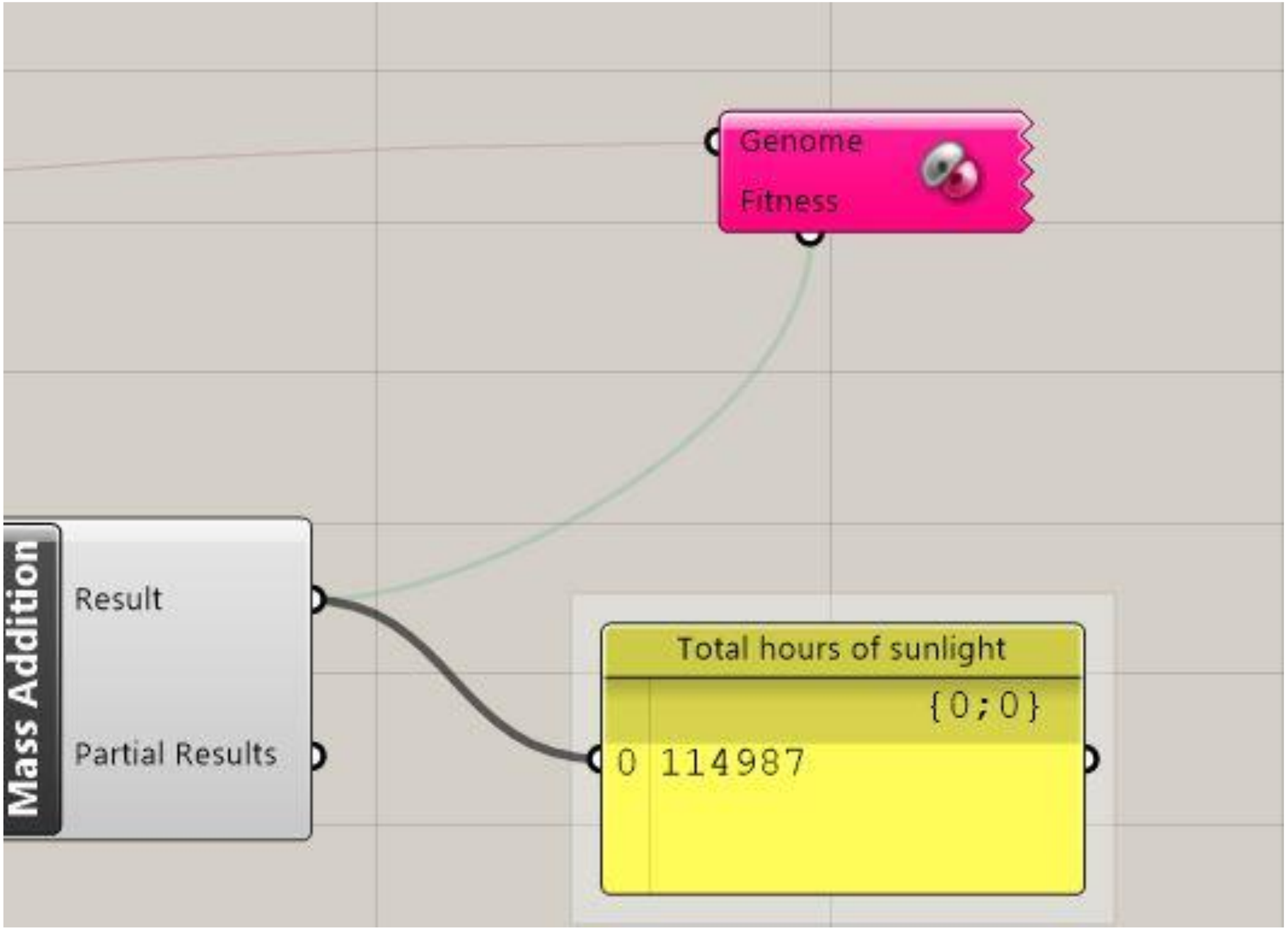
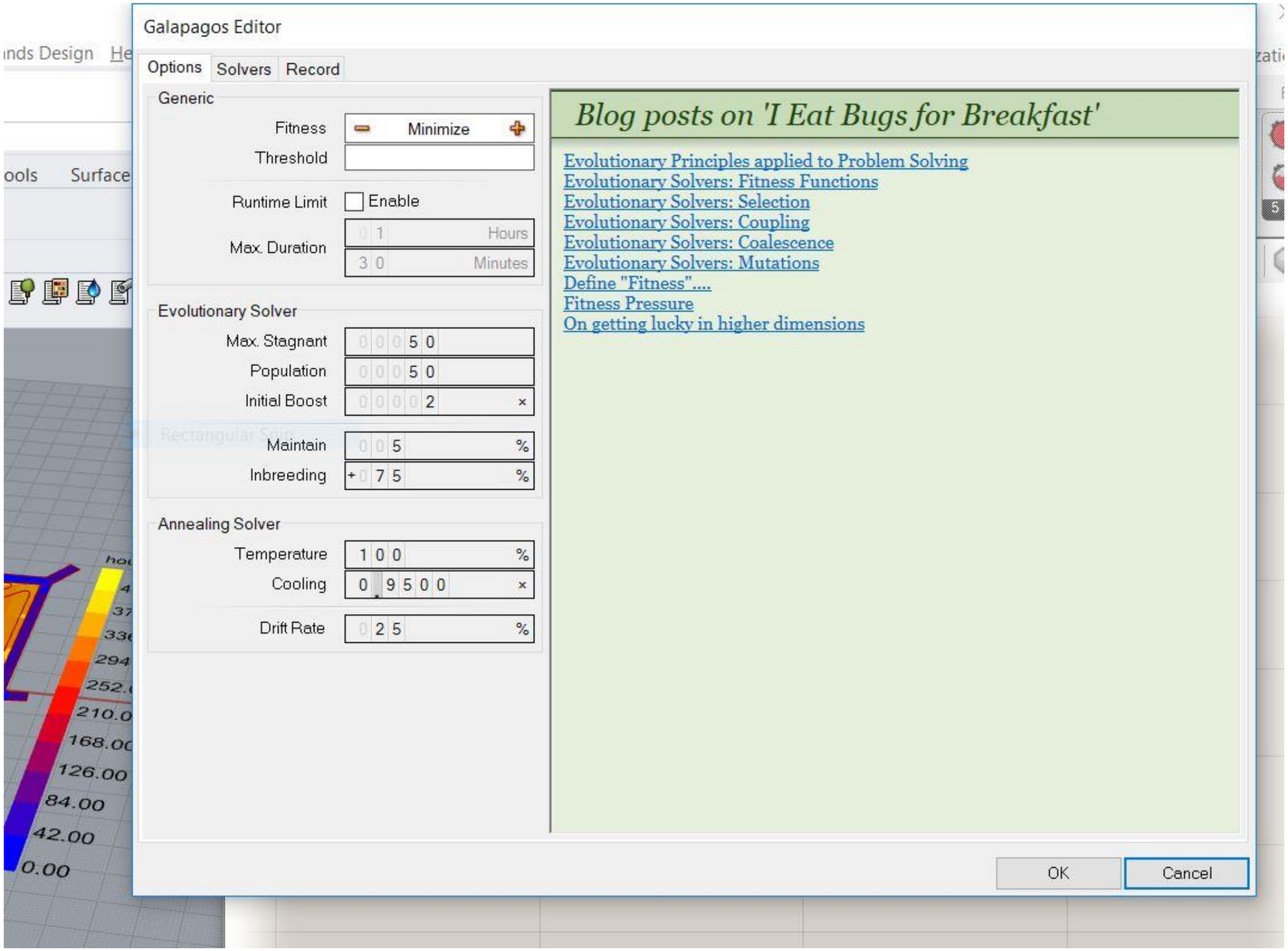


Image 5h (Grasshopper script)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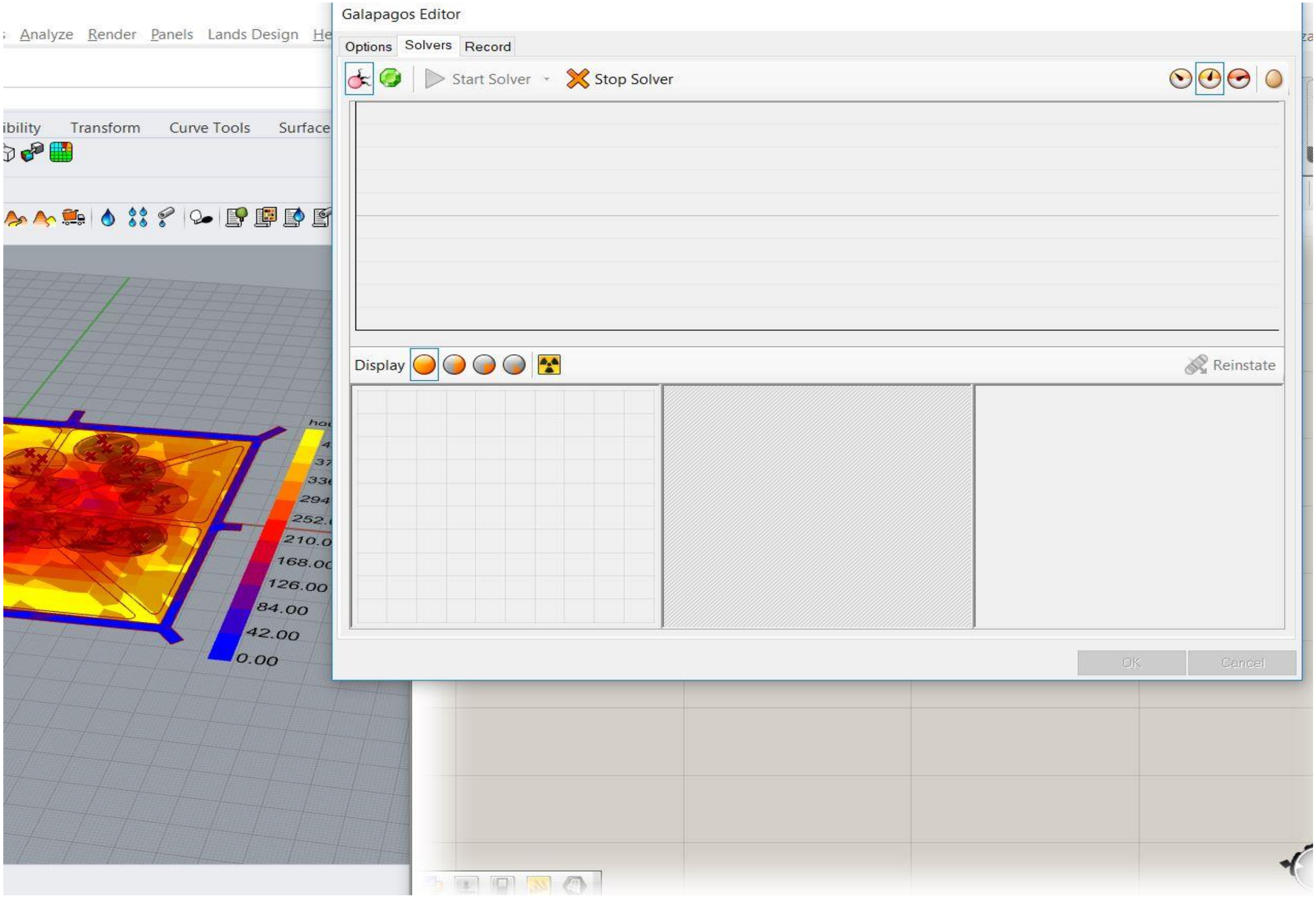
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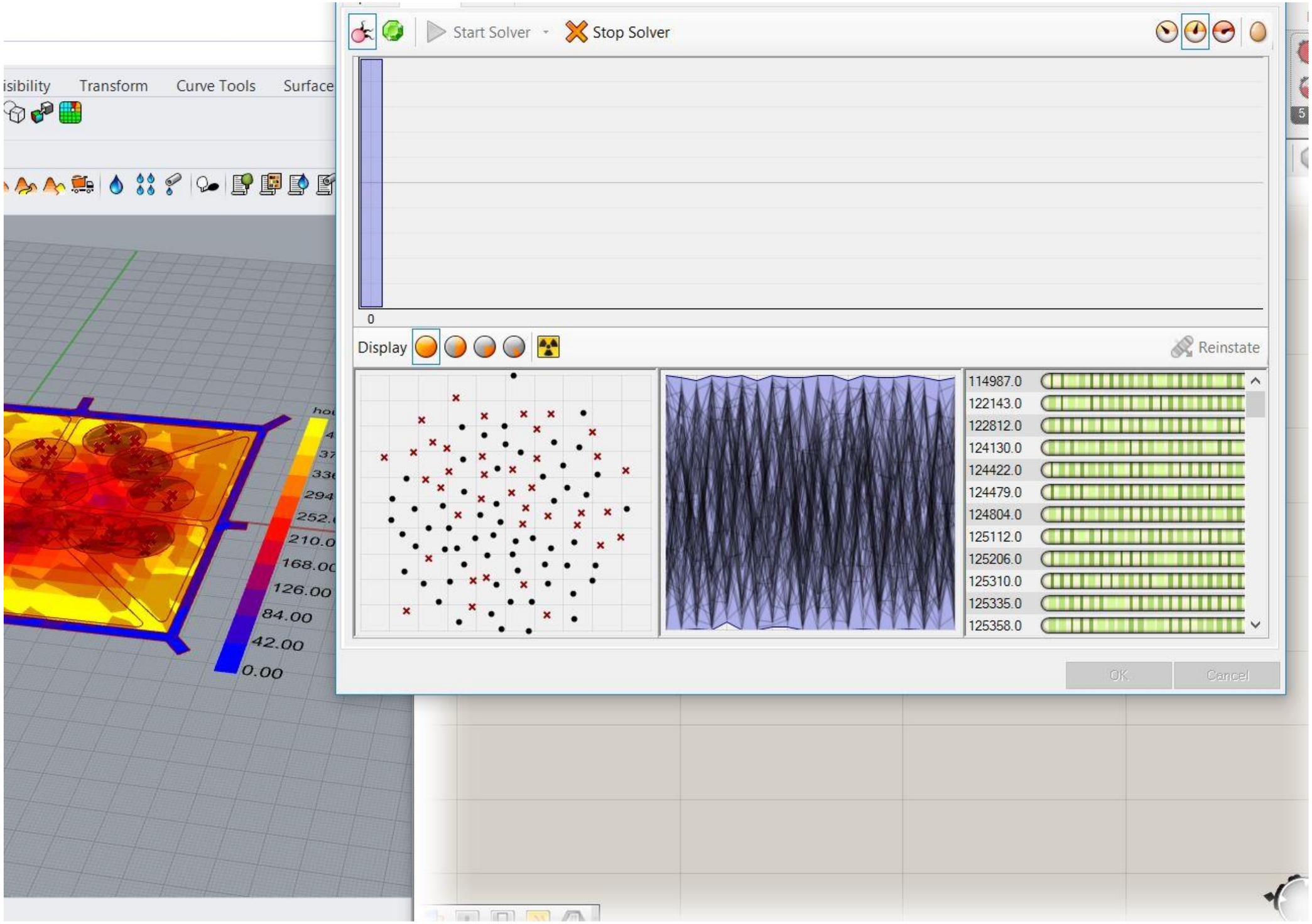
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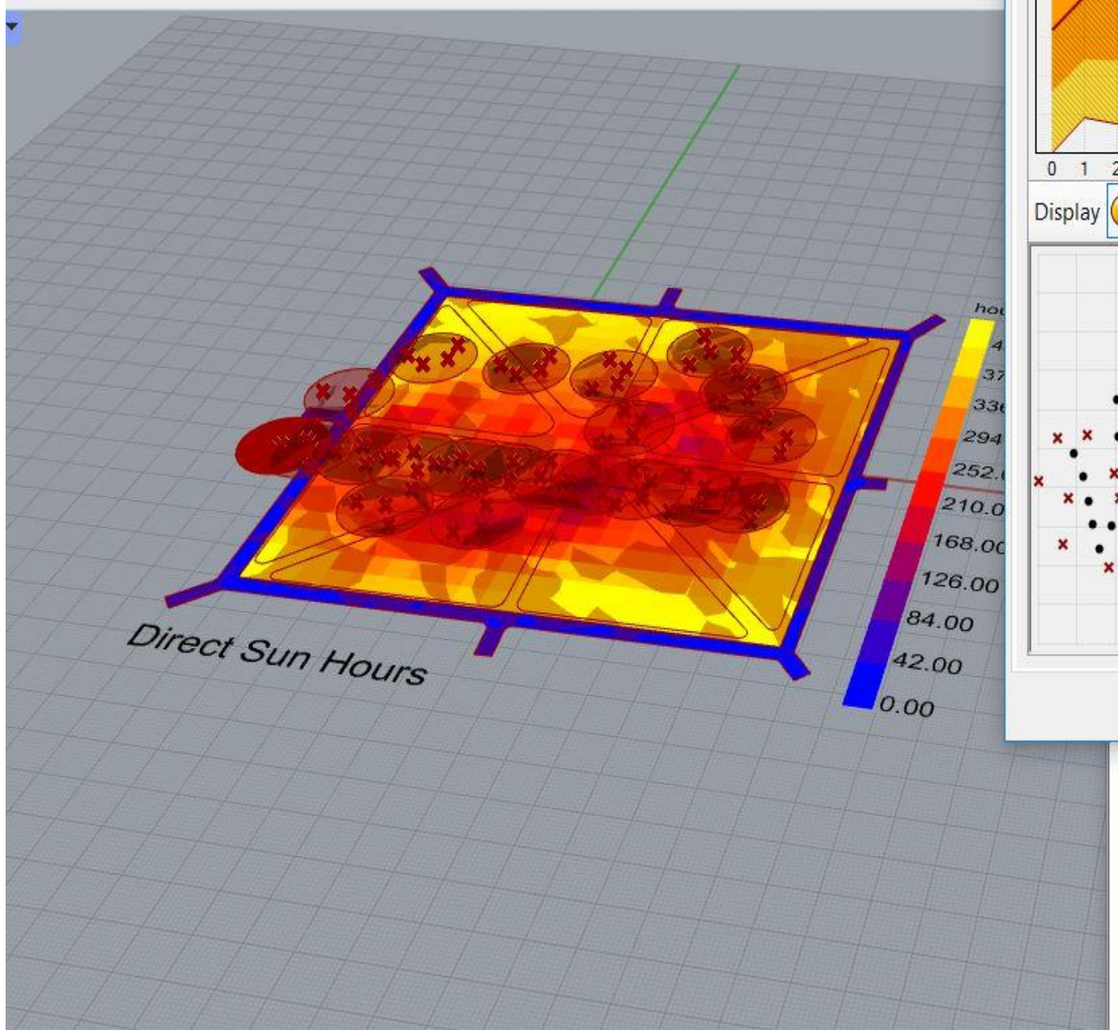

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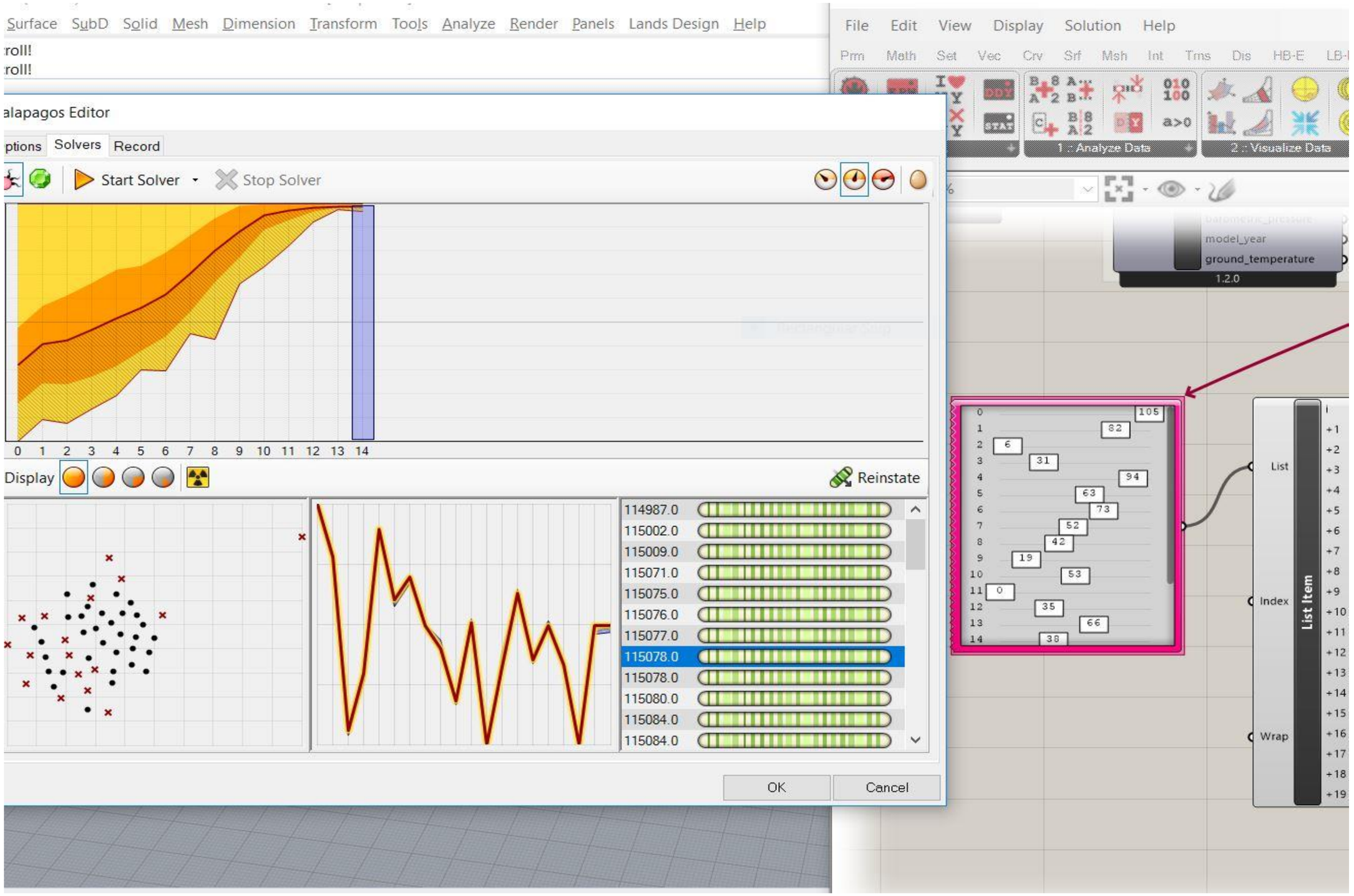
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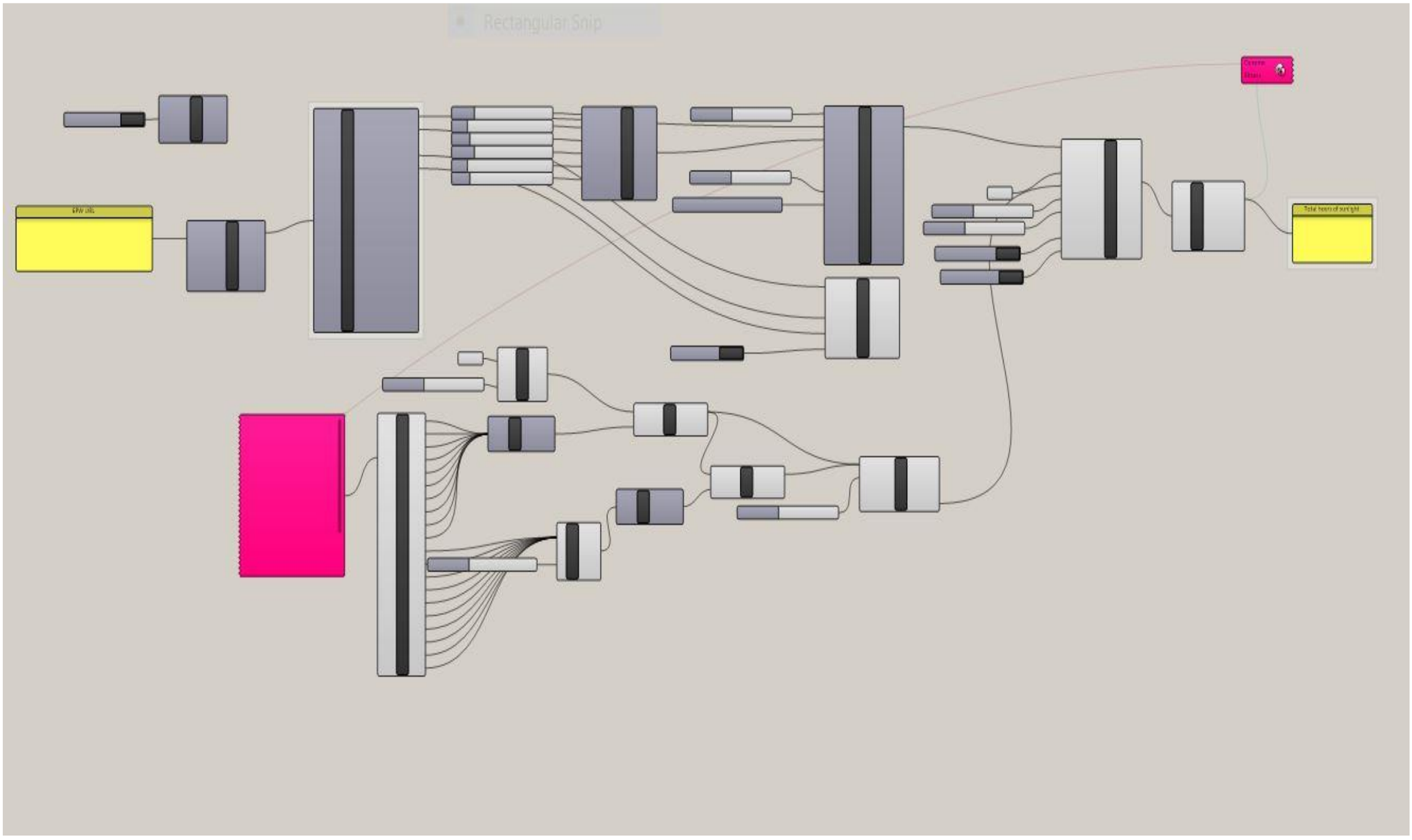
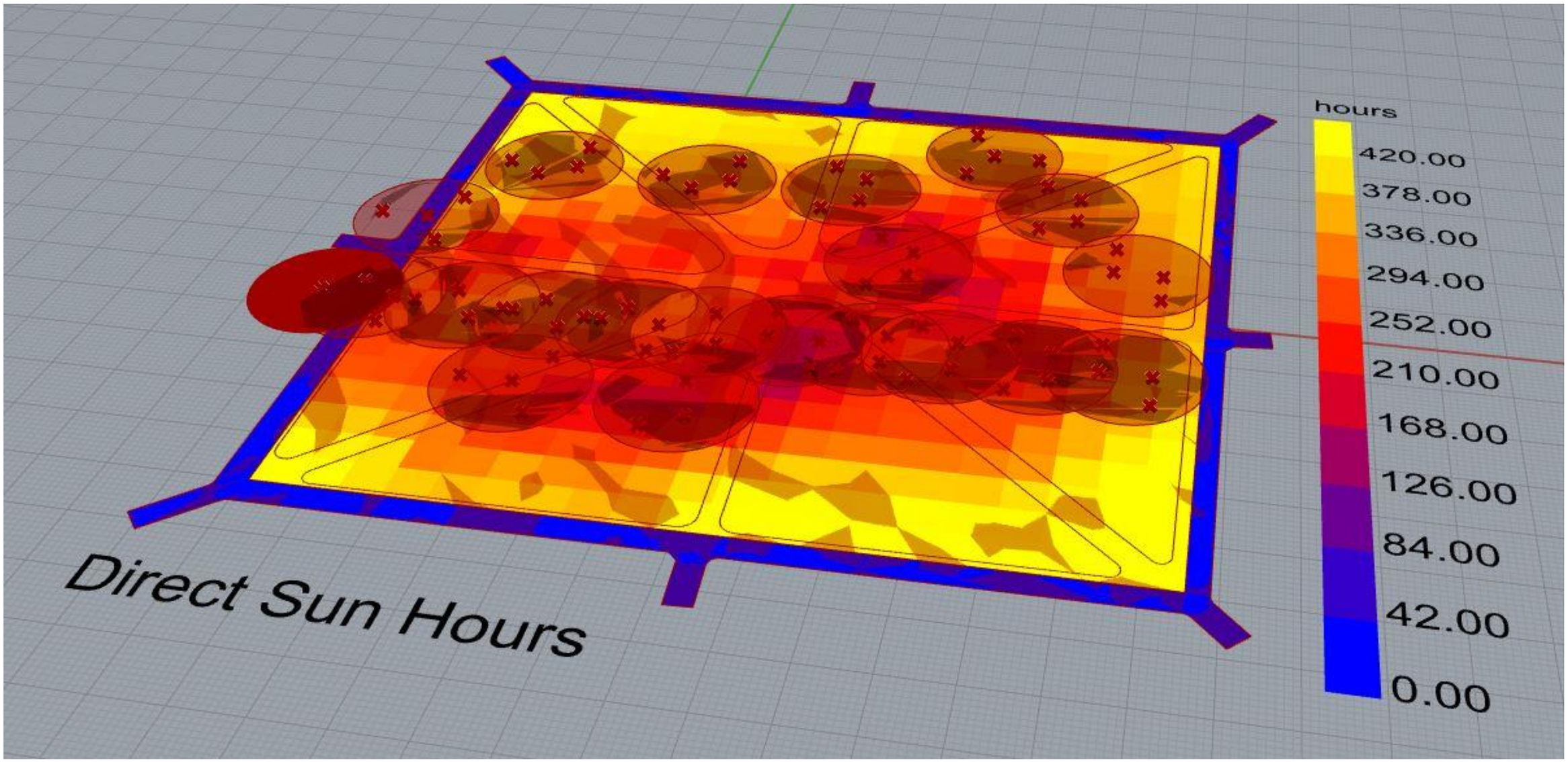


Discussion

The use of trees for shade in an open space has been proven to be one of the most effective way of reducing urban heat. The subject of thermal is a complex one , designers should therefore continue to aim at optimizing it to give the users a most desirable experience within an open space.



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