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Title: Parametric structure with Rhinoceros and Grasshopper

1 – Aims

The objectives of this Rhinoceros and Grasshopper tutorial are as follows:

Learning about a CAD software with great tools for 3D modeling.

Knowing how to call the Rhinoceros plug-in to make parametric designs.

Knowing the Grasshopper interface and the differences between a parameter and a component.

Creating from simple shapes like a hexagon, to more complex geometries like a hyperboloid.

To know an example of Grasshopper in the BIM methodology.

2 – Learning methodology

The teacher will briefly explain what Rhinoceros is and, a little more extended, Grasshopper; making sure the student understands what a parametric design is.

Students should read this tutorial before watching the videos.

Students will follow the steps shown in videos 1, 2 and 3.

Students will watch an application example in Video 4.

To assess the achievement of the practice, each student will write a report.

3 – Tutorial duration

The practice described in this tutorial will be carried out in a computer classroom.

It will last 4 teaching hours.

4 – Necessary teaching recourses

Computer room with PCs with Internet access.

Required software: Rhinoceros, AutoCAD

Hardware required: Pcs

5 – Contents & tutorial

5.1 – Introduction. What is Grasshopper?

Parametric building structures.

The parametric structures design is a tool that allows us to explore solutions that beforehand we do not know. This tool simply establishes input parameters and rules between them. The development of parametric design computer tools, such as Grasshopper and Dynamo, has allowed to create a visual programming more accessible to users with little experience in other areas of programming. It allows to create complex geometries from the association of geometric components and parameters.

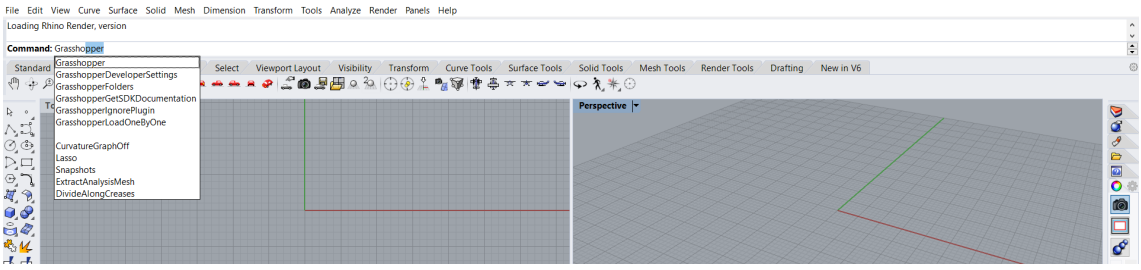
Visual programming.

Visual programming consists of a visual editor and a 3d modeling environment. In the virtual editor, the algorithm that performs a certain task is developed. In the 3d modeling environment, the resulting geometry is obtained.

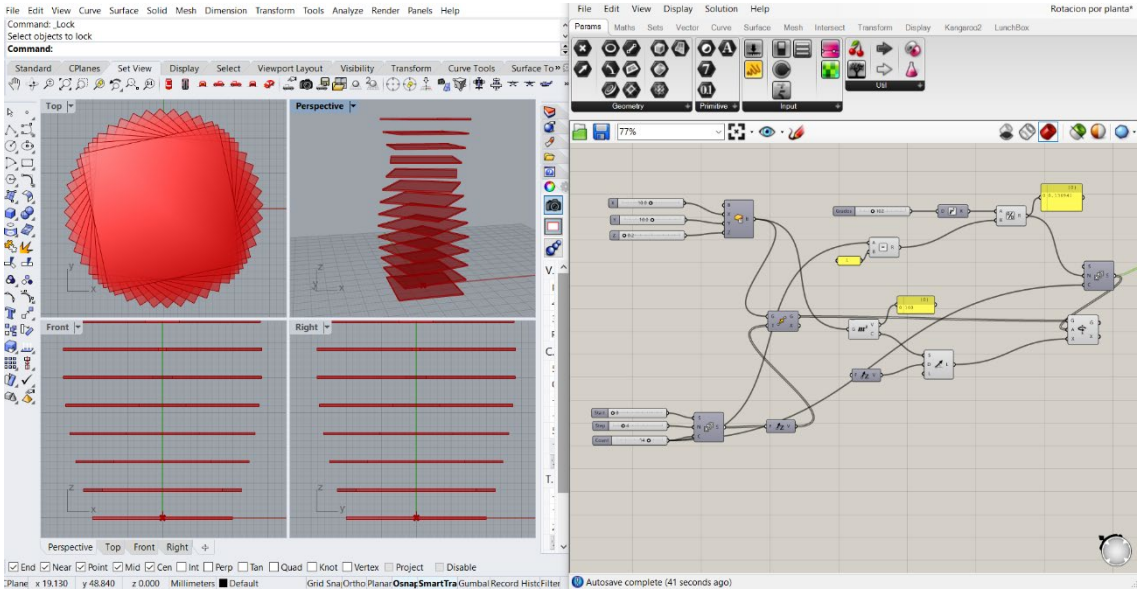
In the visual editor you can find different objects: parameters and components. The main ones are the parameters, which store the data or the starting geometry. The components are the elements that perform actions on the parameters. Both elements are linked with wired connections. In this way, it is very easy to follow the algorithm flow.

What is Grasshopper.

Grasshopper is a plug-in that is installed in Rhinoceros. But you just must call it. To do this, type Grasshopper on the command line, and press Enter key. As you type, it shows us the available commands and options.



This software is design-oriented, allowing the modelling of simple or complex shapes through interconnected parameters and components. It is ideal for parametric design.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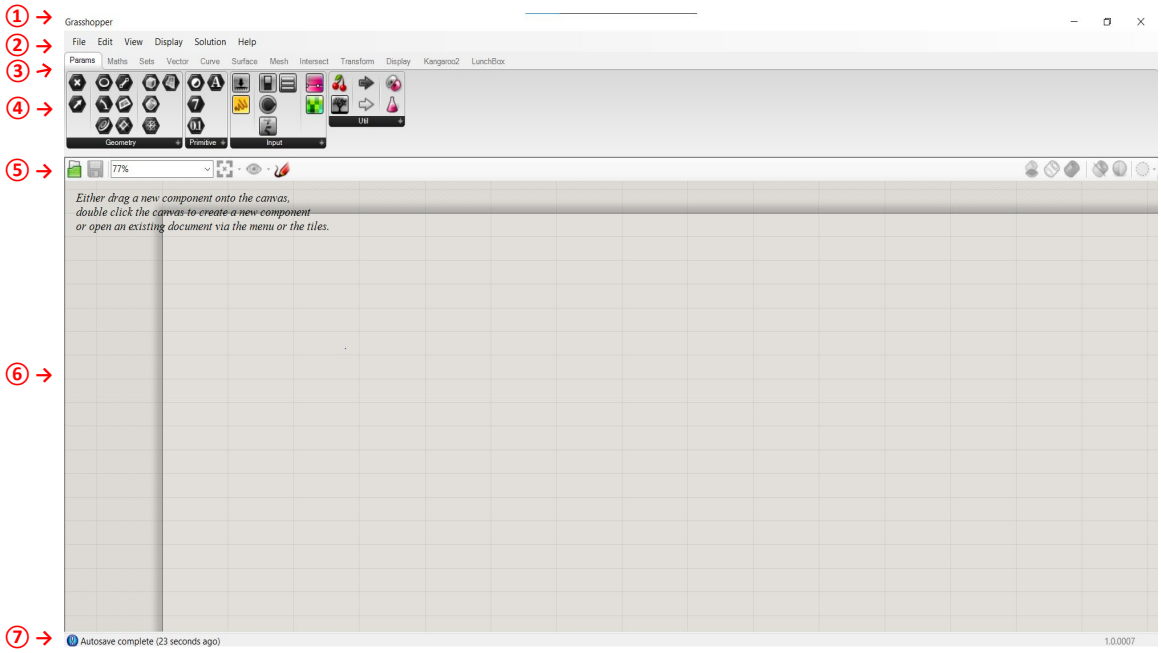
Its interface is the following:



Where:

① → **Title bar:** display the software name and the file name you are working with. There are also the minimise and close window options.

② → **Main Menu Bar**: it has six drop-down menus. In this section, you can quickly switch between various uploaded files.

③ → **Options ribbon**: it gives you access to all the commands available in the software. They are classified them by themes.

④ → **Icon bar:** it displays and classifies all the components available in Grasshopper.

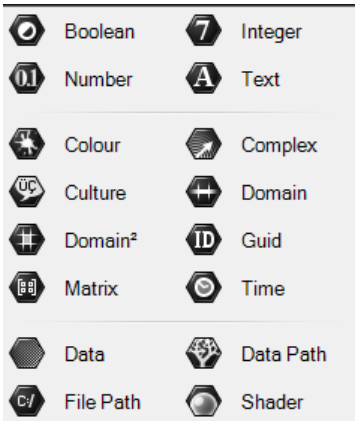
⑤ → **Canvas Toolbar**: it provides quick access to some commonly used functions and others related to the visualization of objects.

⑥ → **Workspace or canvas**: it is the area where parameters and components are inserted and linked to create the project.

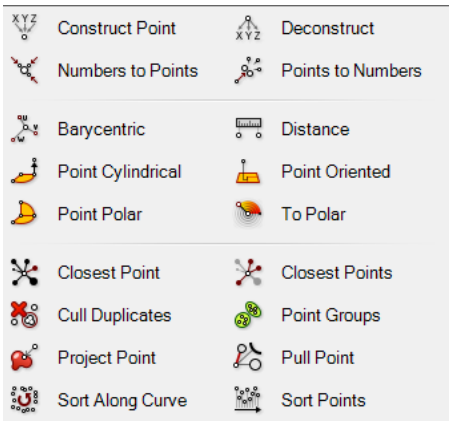
⑦ → **Status bar**: it provides information on the main events that have occurred, and it shows the version of the plug-in.

5.2 – Parameters and components

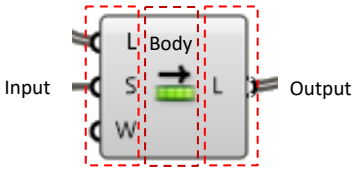
The **parameters** contain data or store information. For example: numbers, graphic panels, colours, etc.



The **components** generate processes, that is, they perform an action. For example: create a circle, sort a list, randomly choose a number, etc.



A component consists of a body and input and output connectors. In the input, necessary data are supplied so that the body carries out the necessary operations to produce the expected results.



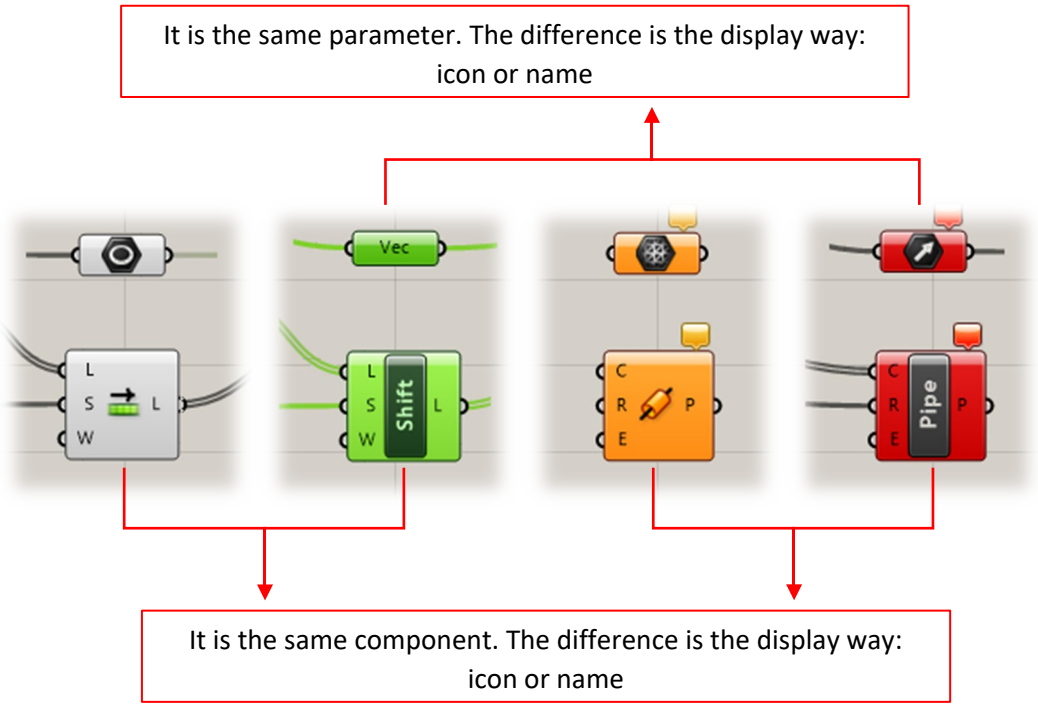
The connection between parameters and components is made with the mouse pointer by dragging. You just make a long click on the semicircle of the corresponding output and drag it to the input of the next parameter or component.

To add multiple entries, perform the previous step by holding down the *Shift* key.

The parameters and components show a colour depending on their state:

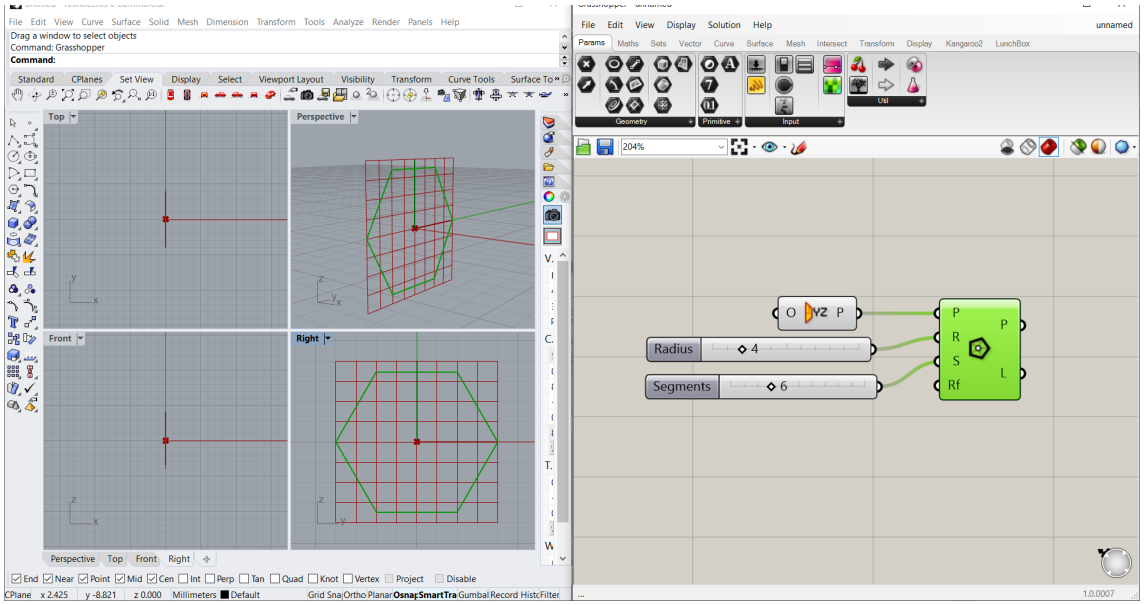
- Gray → normal component.
- Green → selected or active component.
- Orange → a warning of missing data.

- Red → there is at least one error. Check input or output data.



5.3 – Example

An n-sided polygon will be represented on a specific plane. The result is shown below.

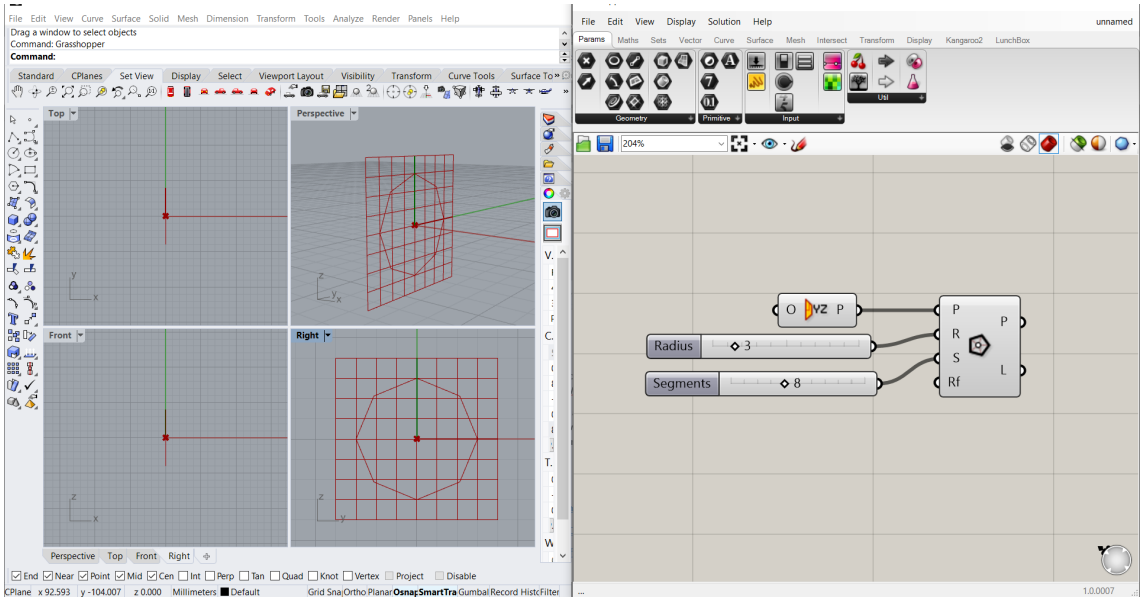


The component used is called *Polygon*. This is found in: *Curve* > *Primitive* > *Polygon*. Its inputs are: a Plane (*P*), Radius of polygon (*R*), Number of segments (*S*) and Fillet radius (*Rf*).

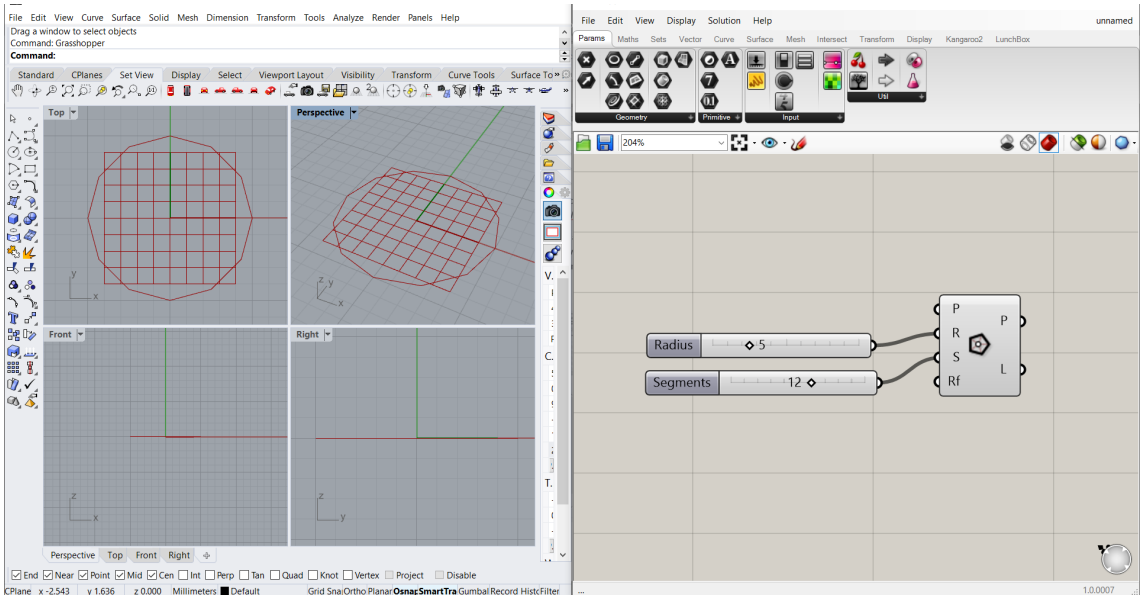
The plane has been specified to be the YZ plane. Otherwise, it would take the XY plane as a reference. To insert it: *Vector* > *Plane* > *YZ Plane*.

Two Numbers Sliders have been configured, one for the radius and the other for the number of sides. To insert it: *Params* > *Input* > *Number Slider*. This allows you to slide between values instead of inserting a panel and entering each number manually.

Let's see the result with R = 3 and S = 8:



Now with R = 5, S = 12 and without any plane:



Now the drawing is displayed in the top view and not on the right.

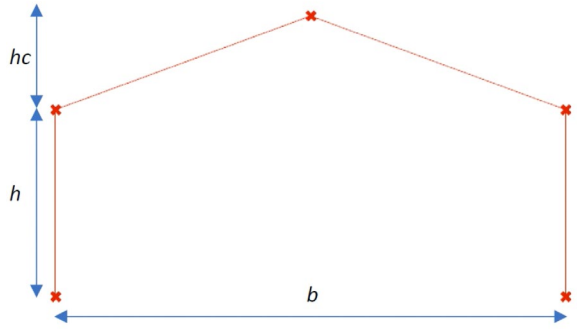
5.4 – Audiovisuals

Four step-by-step examples will be shown in short videos, in order to guide the student in creating the model.

Video 1

In this example, a portico will be parameterized. We are going to see how to configure the *Number Sliders*, how the *Construct Point* components and the *Line type* work, and how to create groups.

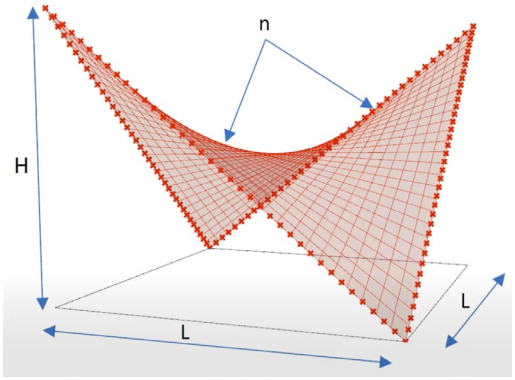
This is the model:



https://www.youtube.com/watch?v=h2byWCkQqNA

Video 2

The aim here is to model a ruled surface corresponding to a hyperbolic paraboloid.

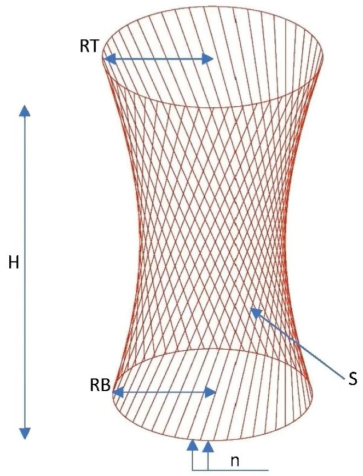


In this video we are going to learn a way to create surfaces, how to hide elements and how the *Divide Curve* component works.

https://www.youtube.com/watch?v=FSvOBJCF-9A

Video 3

Another ruled surface, but now a hyperboloid.



We are going to learn how to export our creations to the available formats. Afterwards, it is going to be opened in AutoCAD for checking.

https://www.youtube.com/watch?v=b5OSnG5s2Ww

Video 4

We are going to see a BIM model of a building, created in the framework of a Master Thesis, where a roof was modelled using Grasshopper.

https://www.youtube.com/watch?v=PWq37CW1qzY

6 – Deliverables

To assess the achievement of the practice, students will write a report of 4 pages maximum.

In this report, the student will explain the steps taken in practice, the difficulties encountered and the decisions taken. The report will be illustrated with photographs, where for each video, there will be a comparison between the original model and another with different dimensions and parameters.

7 – What we have learned?

To create parametric designs in Grasshopper.

To export the design to the available formats (.dwg, .3ds, .pdf, .kmz, etc.).

To visualise the model in AutoCAD.

Implementation of the geometric model in a BIM model.

8 – Files to use in this tutorial

Grasshopper models (.gh format) for each video

Model in .DWG format (AutoCAD) of the hyperboloid