Grasshopper Learning Material

Syracuse Architecture / Apr 10th 2010

by Woojae Sung / woojsung.com

GH Version 0.6.0059

Chapter 01
Grasshopper Introduction

Chapter01 Grasshopper Introduction

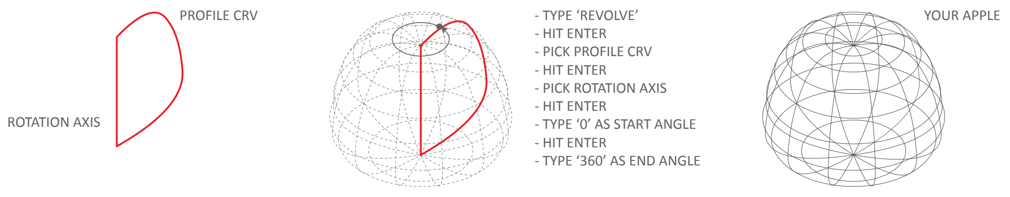
Basic Concept

Grasshopper is a graphical algorithm editor. We work on real 2D/3D geometries with Rhino. With Grasshopper, we work on the algorithm behind those real geometries.

Basic Concept : Apple Making Process

In Rhino

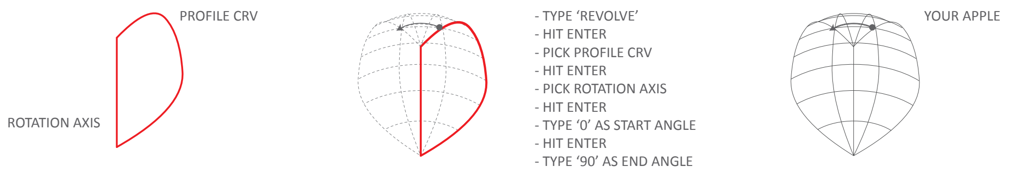
Below is an usual work process to make an apple in Rhino work environment. First we need to draw a profile curve and a rotation axis. Then, type in ‘Revolve’ then pick the profile and rotation curves with starting and ending angles. In this case, we supply 0 as the starting angle and 360 as the ending angle to get a whole apple.



- TYPE ‘REVOLVE’
- HIT ENTER
- PICK PROFILE CRV
- HIT ENTER
- PICK ROTATION AXIS
- HIT ENTER
- TYPE ‘0’ AS START ANGLE
- HIT ENTER
- TYPE ‘360’ AS END ANGLE

$$\begin{tikzcd}
\boxed{\text{TYPE ‘REVOLVE’}} \arrow[r, "\text{ENTER}"] & \boxed{\text{PICK PROFILE CRV}} \arrow[r, "\text{ENTER}"] & \boxed{\text{PICK ROTATION AXIS}} \arrow[r, "\text{ENTER}"] & \boxed{\text{‘0’ AS START ANGLE}} \arrow[r, "\text{ENTER}"] & \boxed{\text{‘360’ AS END ANGLE}} \arrow[r, "\text{ENTER}"] & \boxed{\text{YOUR APPLE}}
\end{tikzcd}$$

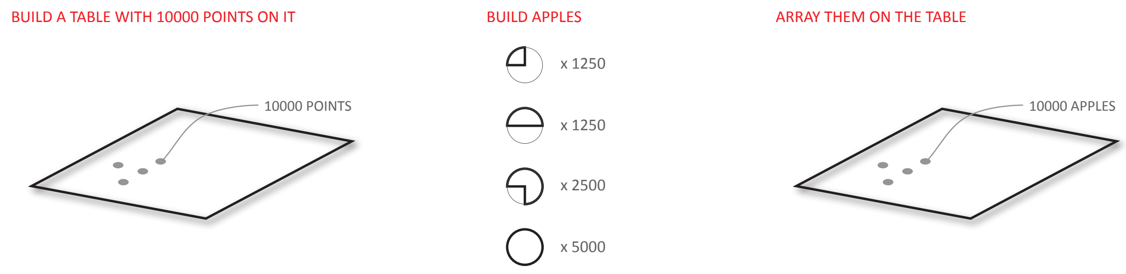
What if we want to have only a quarter of an apple? Basically, we need to do the same thing again, but this time, we supply 0 as the starting angle and 90 as the ending angle.



- TYPE ‘REVOLVE’
- HIT ENTER
- PICK PROFILE CRV
- HIT ENTER
- PICK ROTATION AXIS
- HIT ENTER
- TYPE ‘0’ AS START ANGLE
- HIT ENTER
- TYPE ‘90’ AS END ANGLE

$$\begin{tikzcd}
\boxed{\text{TYPE ‘REVOLVE’}} \arrow[r, "\text{ENTER}"] & \boxed{\text{PICK PROFILE CRV}} \arrow[r, "\text{ENTER}"] & \boxed{\text{PICK ROTATION AXIS}} \arrow[r, "\text{ENTER}"] & \boxed{\text{‘0’ AS START ANGLE}} \arrow[r, "\text{ENTER}"] & \boxed{\text{‘90’ AS END ANGLE}} \arrow[r, "\text{ENTER}"] & \boxed{\text{YOUR APPLE}}
\end{tikzcd}$$

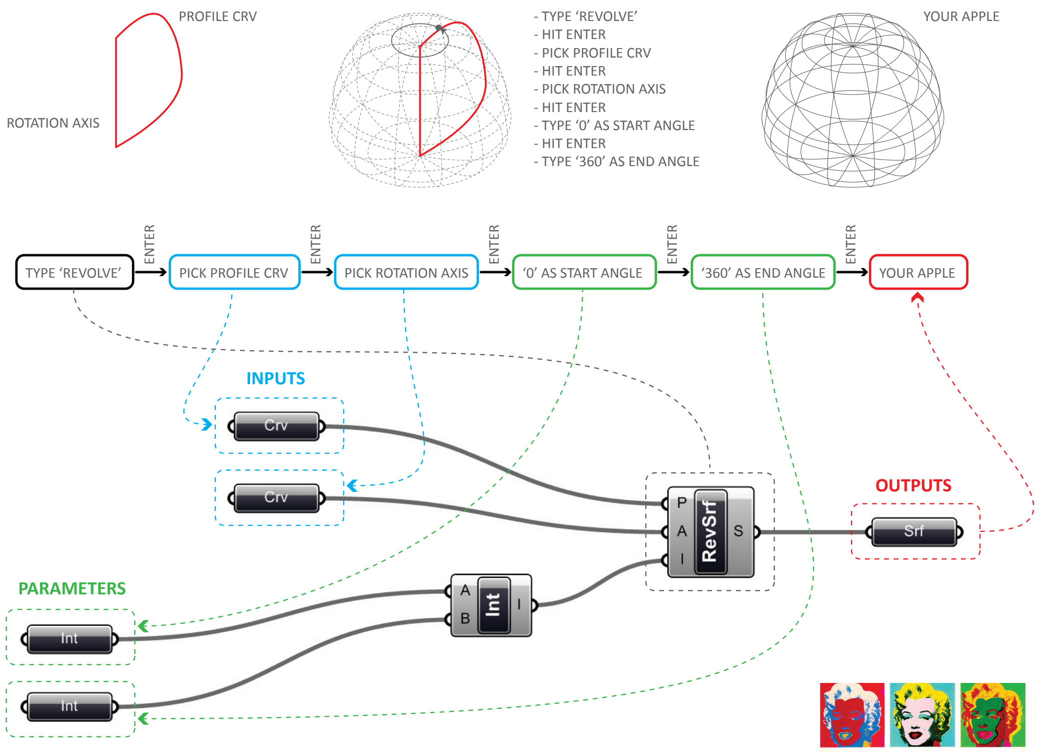
Now, your boss wants to have a table on which 5,000 apples, 2,500 three quarter apples, 1,250 two quarter apples, and 1,250 one quarter apples are distributed randomly. First you should make a table which has 10,000 reference points on it. Then make 4 different types of apple, copy and move one by one to the reference points. Don’t forget to count apples so as to make your boss happy.

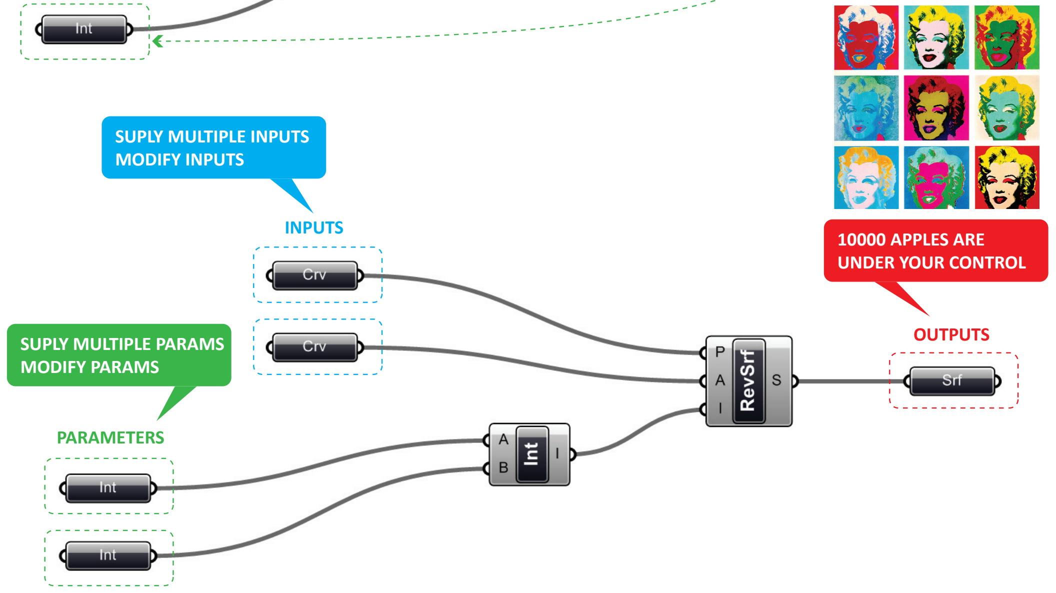


Your boss is not happy with this. He wants to change the mixing ratio of apples. You have two choices; do it again, or find another job.

In Grasshopper

In Grasshopper, you don't work on the real geometries. Rather, you work on the logic behind the geometries. Once the apple making logic has been set up, you can change parameters such as starting and ending angles. Also you can change the shape of apples by supplying different profile curves as well as rotation axis. Or you can make multiple apples out of just one definition by supplying multiple angle values and/or profile/rotation curves to the definition.





Chapter02

Interface / Basic Knowledge

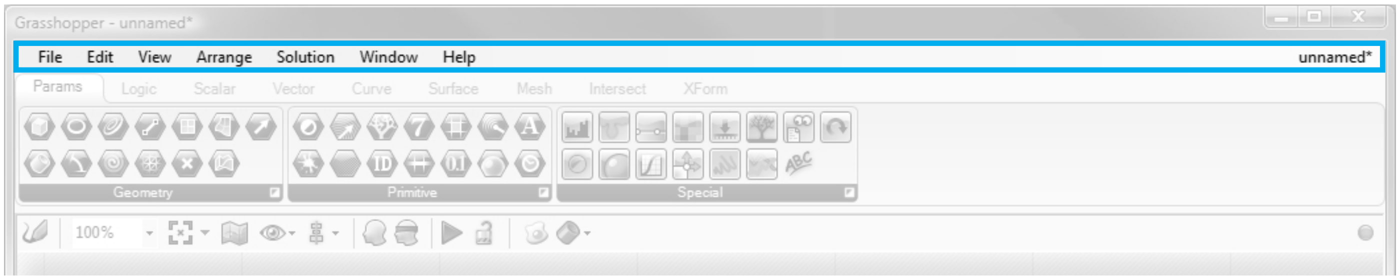
Chapter02 Interface / Basic Knowledge

Interface

Grasshopper’s workspace is pretty similar to other windows applications. However, as a history/algorithm editor, it has some unique features like components/parameters, which eventually will be linked to each other to make a working definition.

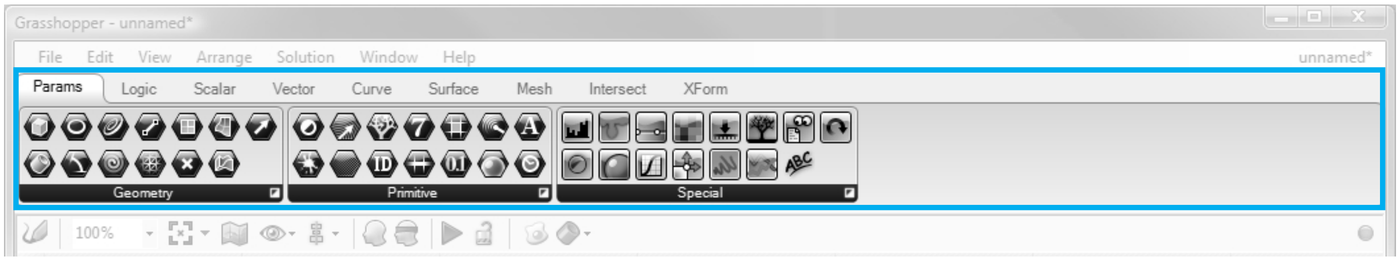
Interface : Workspace

Main Menu



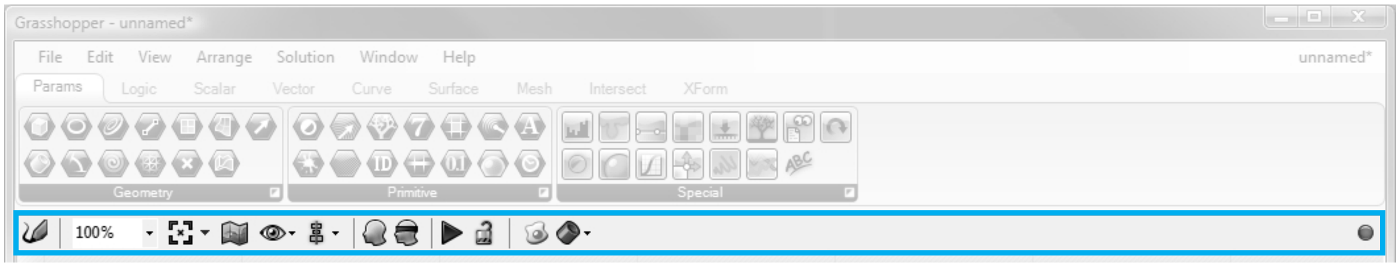
File handling, copy/paste, undo/redo, interface/display setting, realtime solution toggle, etc..

Shelves



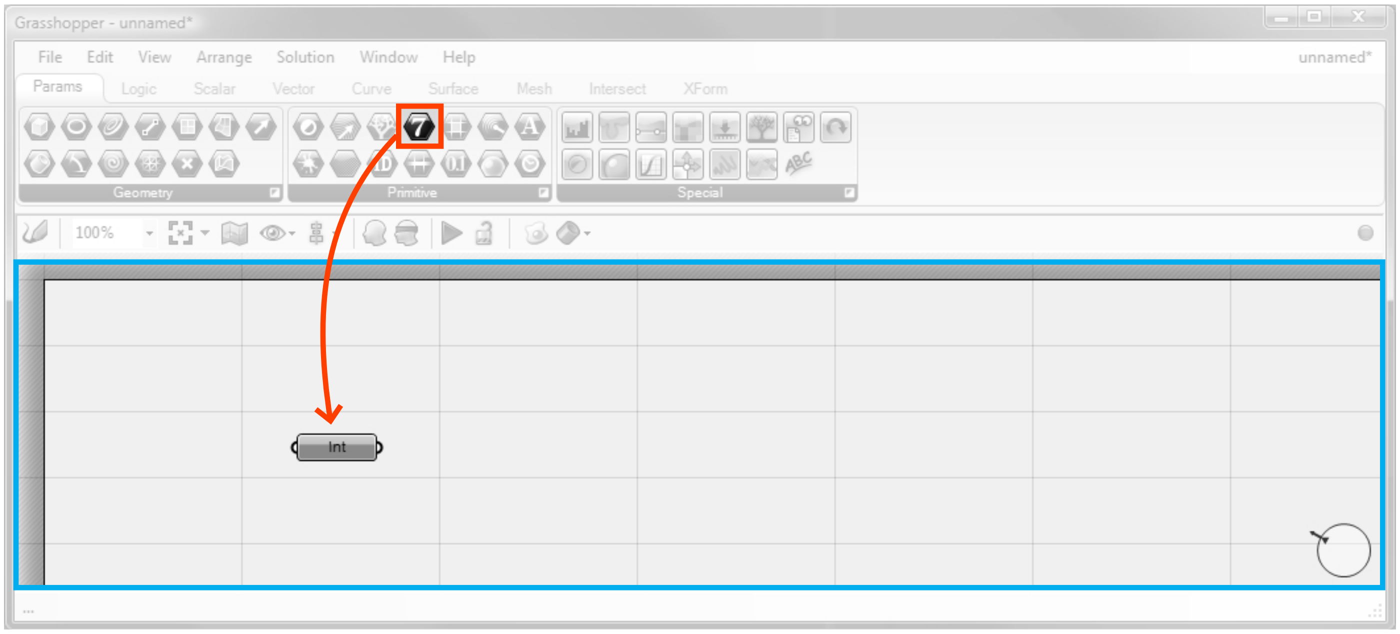
Shelves are where all Grasshopper objects are listed by categories. Each shelve has its sub tabs which show limited numbers of items. To access to all available components/parameters, click on black title bar at the bottom.

Canvas Tool Bar



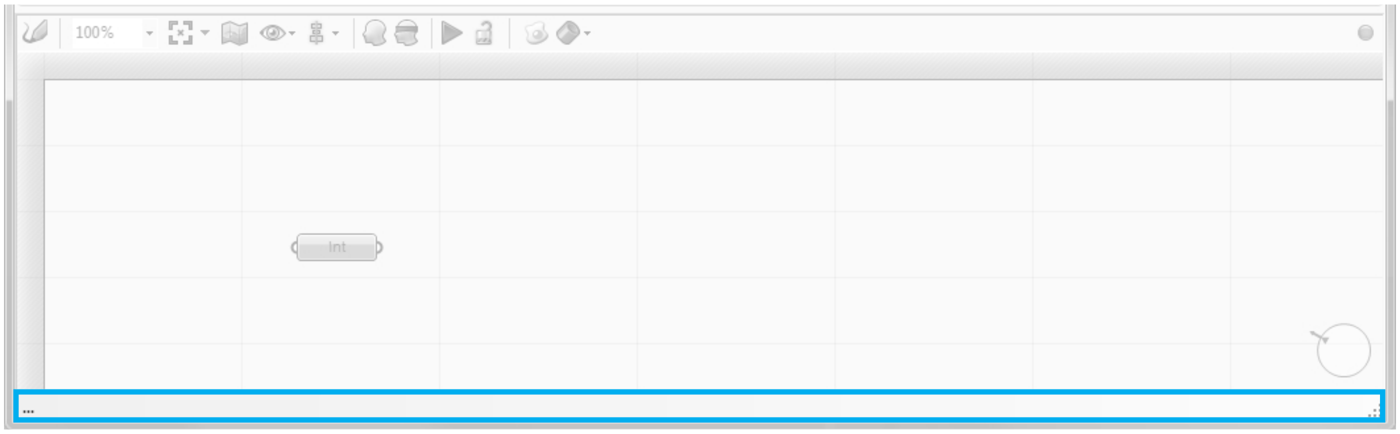
Short cuts for some frequently used commands such as ‘zoom extend’, ‘realtime solution on/off toggle’, ‘show/hide toggle’, ‘component on/off toggle’, and ‘bake command button’.

Canvas



Canvas is the main workspace where you work with lots of component/parameter to make an actual definition. To activate a component/parameter, click the component/parameter icon on a shelve and drop it on canvas by clicking somewhere on canvas. Once you drop it, you can move, delete, copy or paste as you do in other windows applications. You can also pan/zoom your working canvas with mouse button as you do in Rhino.

Status Bar

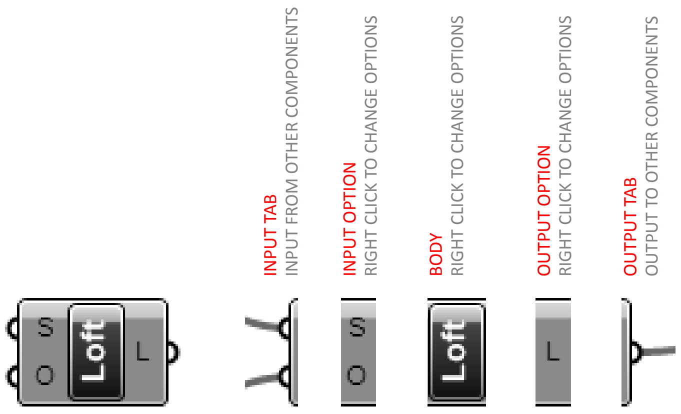


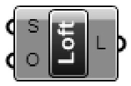
Displays information such as errors, warnings, etc..

Interface : Grasshopper Objects

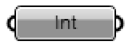
Grasshopper objects fall into two major categories, components and parameters, which will be covered later on this tutorial. However, before we move on, it is important to understand how Grasshopper objects are structured.

Structure & Types of Grasshopper Objects

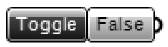

INPUT TAB
INPUT FROM OTHER COMPONENTS
INPUT OPTION
RIGHT CLICK TO CHANGE OPTIONS
BODY
RIGHT CLICK TO CHANGE OPTIONS
OUTPUT OPTION
RIGHT CLICK TO CHANGE OPTIONS
OUTPUT TAB
OUTPUT TO OTHER COMPONENTS
S
O
Loft
L



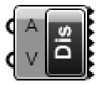
INPUT TAB + INPUT OPTION + BODY + OUTPUT OPTION + OUTPUT TAB



INPUT TAB + BODY + OUTPUT TAB



BODY + OUTPUT OPTION + OUTPUT TAB



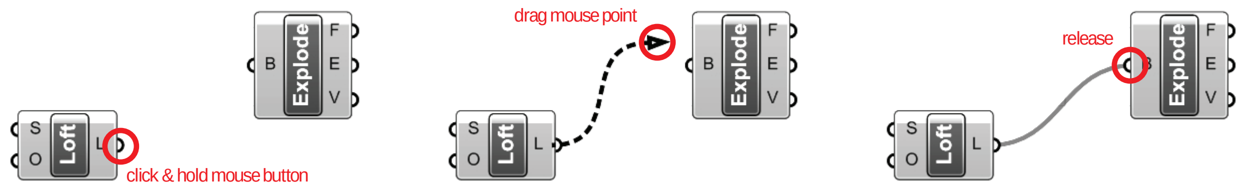
INPUT TAB + INPUT OPTION + BODY

Grasshopper objects usually can be divided into 5 different parts; Input Tab, Input Option, Body, Output Option, Output Tab. However, depends on object types, some of them have only 3 parts as shown in the figure above.

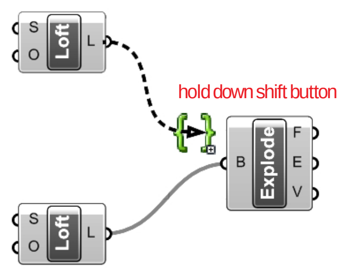
'Input Tab' is where an object get input from the output data of others. If you are not sure what kind of data should be connected to an input tab, you can check the tool tip by hovering your mouse point on top of the 'Input Option' character right next to the input tab. You can also access to an input option setting window by clicking right mouse button on the character. If you want to change data processing setting of an object, right click on the 'Body'. 'Output Option' is pretty same with 'Input Option', where you can change some output data setting. 'Output Tab' is where output data stored so we can pass it to other Grasshopper objects.

Object Connection

To connect your output data to other Grasshopper objects, click on the white little bubble in 'Output Tab' and drag and drop it onto input tab(s) of other Grasshopper objects as shown in the figure below.

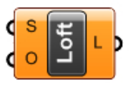


If you want to have multiple connection, hold your shift button while you connecting tabs as shown below.

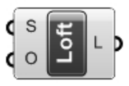


Object Status

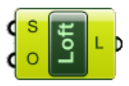
There are couple of different object colors which indicate the status of object.



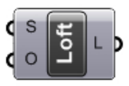
default status without data



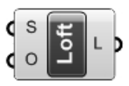
preview on



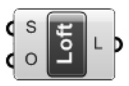
object selected



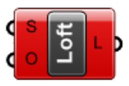
preview off



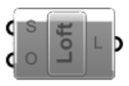
default status with data



object on



error



object off (do not process data)

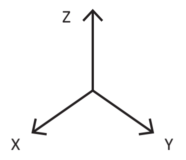
Basic Knowledge

There are some background knowledge you should understand before we move on.

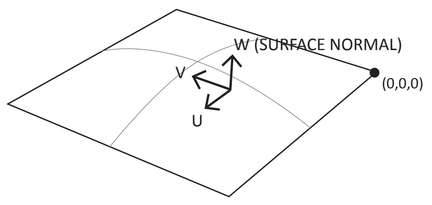
Basic Knowledge : Coordination Systems

Grasshopper provides couple of different coordination systems, some of which are familiar with Rhino users.

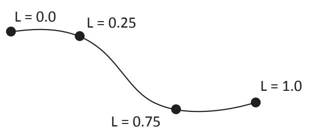
A. XYZ (WORLD)



B. UVW (SURFACE)

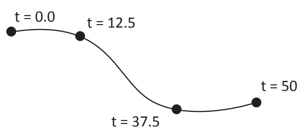


C. L (CURVE/CURVE ON SURFACE)



CURVE LENGTH = 1 (UNITIZED)

D. t (CURVE/CURVE ON SURFACE)

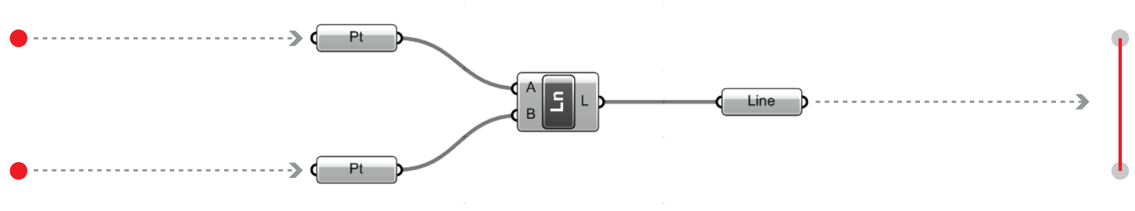


CURVE LENGTH = 50 (REAL SCALE)

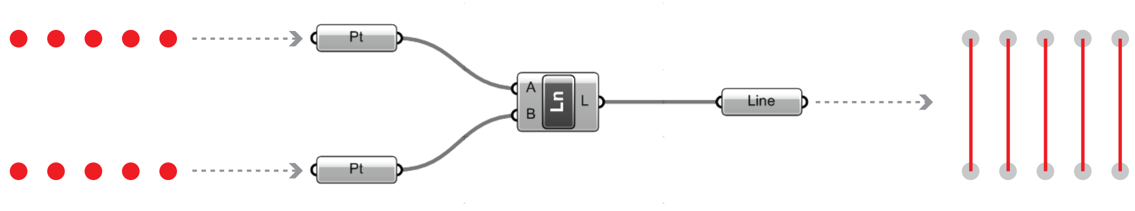
Basic Knowledge : Data Matching

Data matching is one of key concepts of most parametric tools. Since a Grasshopper object deal with multiple data from different input sources, we need to have a clear logic on how to match data.

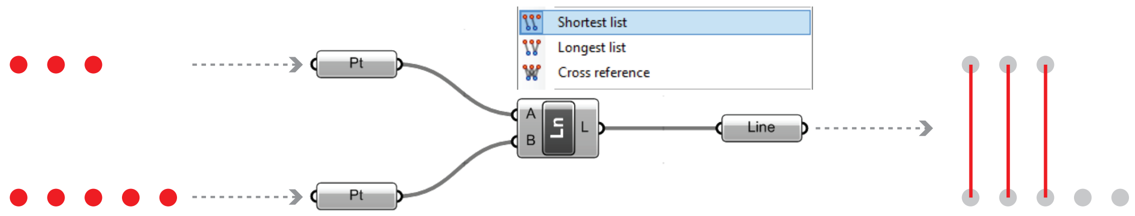
For example, let’s say that we have a Grasshopper object which draws a line out of two input points like below.



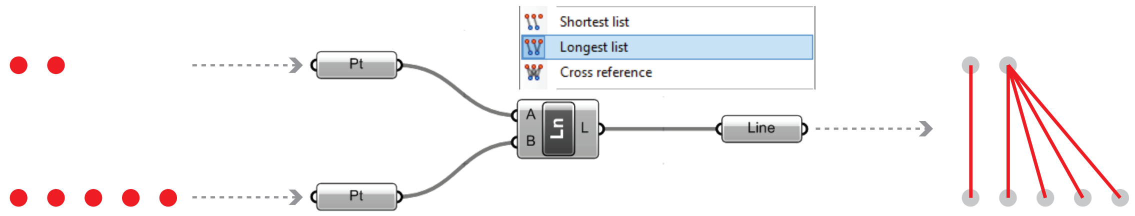
We can also supply multiple points to get multiple lines at the same time as below.



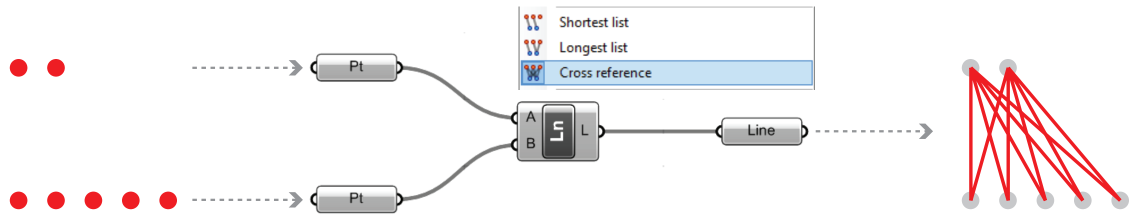
What if we have different numbers of points for each input? This may cause problem in drawing lines because the number of input points are not matching. If we set the data matching option as ‘Shortest list’ in option window, Grasshopper will draw lines based on short input list.



Else if we set the data matching option as ‘Longest list’ in option window, Grasshopper will draw lines based on longest input list.



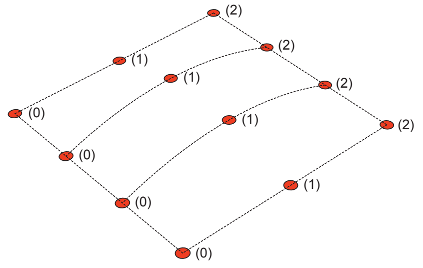
Or we can set the data matching option as ‘Cross reference’ in option window, in case we want to have crazy data matching.

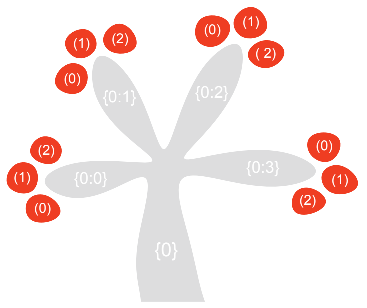


Basic Knowledge : Data Structure (Tree / Branch / List / Item)

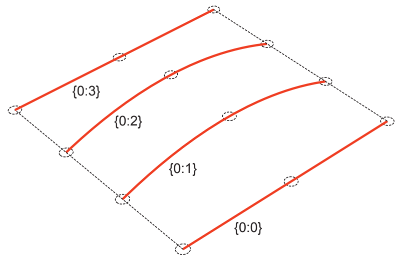
Grasshopper provides multi-dimensional data structure, which we call 'Tree'. 'Tree' is composed of multiple 'Branches'. Branches can have sub branches. Only the branches at the lowest hierarchy can have 'List'. A list is a one-dimensional array containing items with index number.

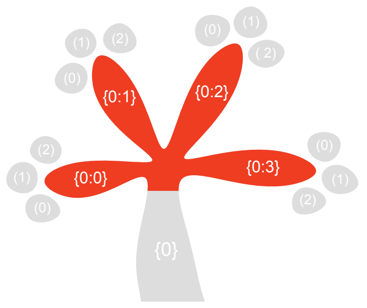
Let's say that we have 4 lists, and each of them has 3 items in it. Numbers in round bracket in the figure below is item index number.

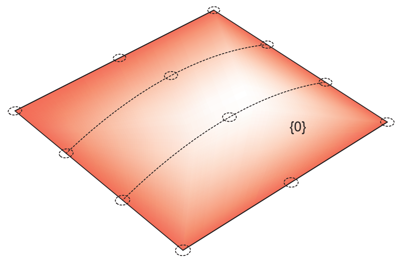


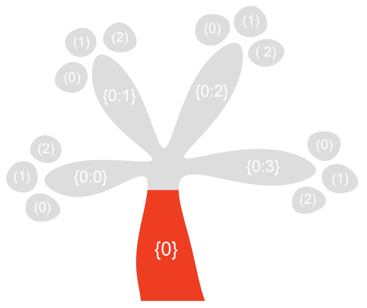


Branch is represented as form of numbers separated by semicolons in braces. Numbers in braces represent hierarchy, which means a branch can have any numbers of sub branches. The 4 lists from the diagram above can be mapped onto 4 branches as shown in the figure below like {0;0}, {0;1}, {0;2}, {0;3}. And these branches can be merged as another branch which is represented as {0}.

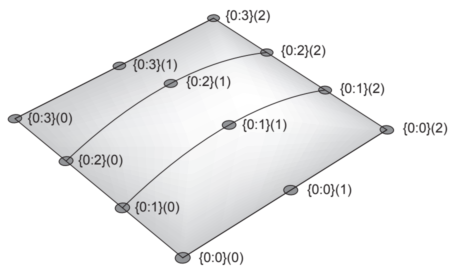


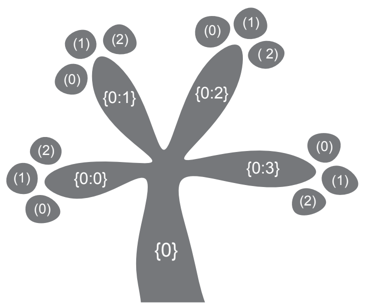






Below is complete map of data tree structure with one main branch, 4 sub branches, 4 lists, and 12 items.





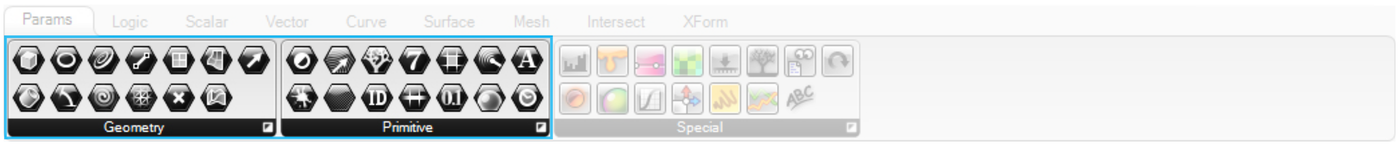
Chapter03
Parameters / Components

Chapter03 Parameters / Components

Parameters

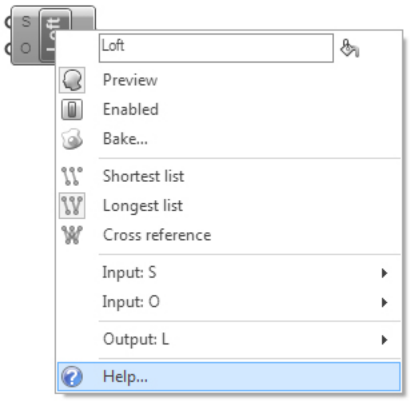
There are two major object types in Grasshopper; parameters and components. Parameters usually store data, while components do some action such as creating curves, surfaces, etc. For example, we need at least two curves to make a loft surface. Those curves are stored as form of parameter in Grasshopper, so we can do loft action out of the curves.

Parameters : Geometry / Primitive

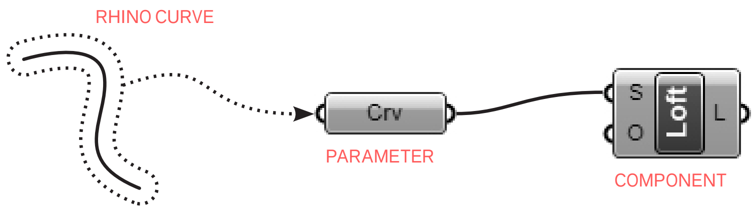


Grasshopper provides three different ways of assigning data to parameters; referencing Rhino data, referencing Grasshopper data, and creating new data from scratch.

Note : For more information about each parameter / component, right click and refer to help file.

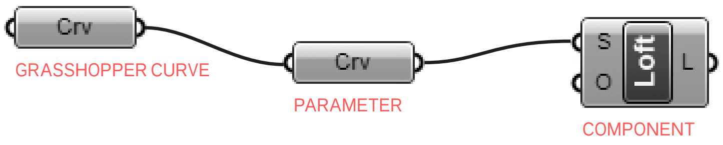


Reference Rhino data



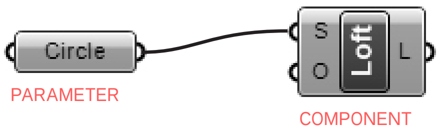
Some parameters can work like bridges between Rhino and Grasshopper data. It is useful in getting inputs from rhino data. For example, to make a loft surface in Grasshopper, the first thing that we should do is to get curves from Rhino. To assign a Rhino curve to Grasshopper's one, right click on curve parameter on Grasshopper canvas, select 'set one curve' from the popup menu, then select a curve from Rhino viewport. Now since they are connected to each other, when we move the curve in Rhino view port, we can see the Grasshopper curve follows it.

Reference Grasshopper data



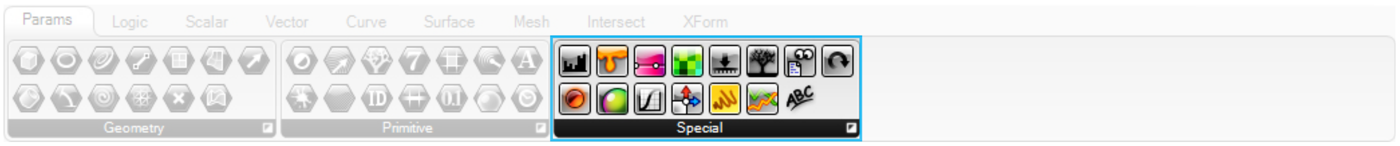
Most of parameter also can reference Grasshopper data itself. It is pretty much like an internal bridge between data in Grasshopper.

Create new data from scratch



Some parameters are not able to get data from Rhino object. For example, circle parameter does not provide connection with Rhino circle. Instead, it has a built-in option to draw a circle directly by providing radius and center point. The circle by the parameter is completely independent from any Rhino object. To make a circle using circle parameter, right click on it, select 'set a circle' from the popup, then draw a circle in Rhino view port.

Parameters : Special



Special parameters are more about controlling, manipulating and representing data, rather than pure parameters. Four major roles; getting new input data, representing data, referencing data, and converting/modifying data.

Get user input

They are useful to get user input such as custom color, numeric number or boolean value.

Represent data

Represent data in graphical fashion. For example, Bar Graph parameter visualizes numeric input data using bar chart. Parameter Viewer parameter shows data tree structure in the form of simple table.

Convert / Modify data

Generate different type of data from user input. For example, Image Sampler parameter produces series of numeric data out of an input image file, by picking up RGB values of corresponding coordinates.

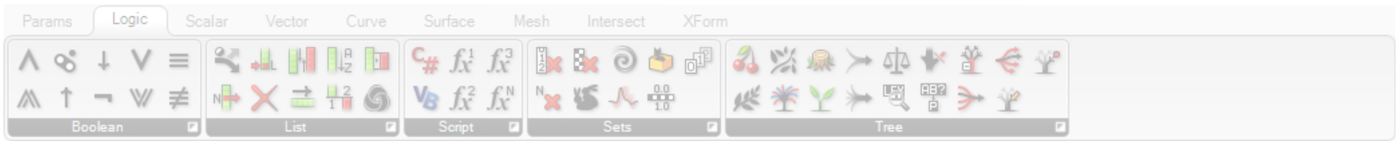
Reference data

Most of special parameters also can reference Grasshopper data.

Components

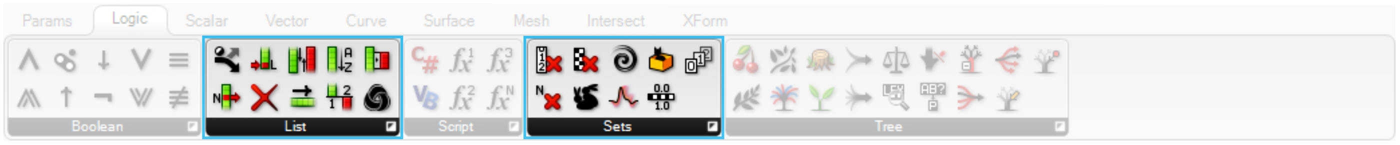
Unlike parameters, components usually do something with input data from parameters or from other components. There are two major actions that components do; data manipulation and geometry creation. For example, some components calculate numeric data operations such as addition, subtraction, multiplication, or division. While some other components do some physical works like creating points, curves or surfaces.

Components : Logic

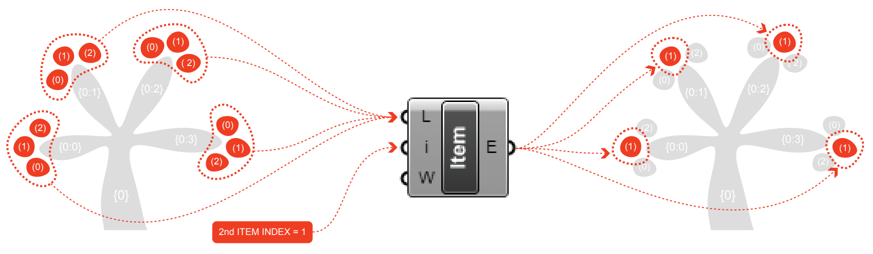


Logic components are pretty much about data manipulation rather than physical works. They fall into four different categories; List/ Sets, Tree, Script, and Boolean. List and Sets components manipulate list data. List data exist in the form of one dimensional array with item index numbers (refer to data tree section). Tree components control data tree itself rather than individual data item in the list (also refer to data tree section). Script components let users to make customized functions as well as components with VB.net / C# language. Boolean components provide stream control like gate and filters.

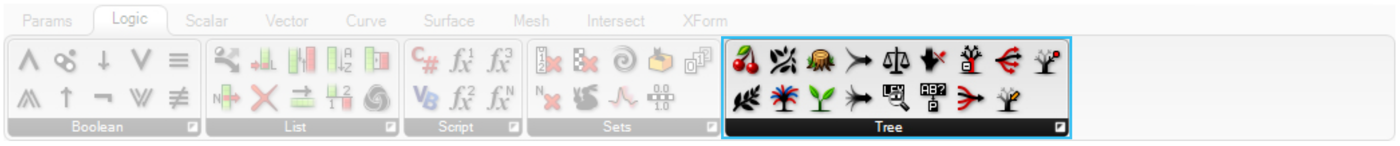
List data handling (List / Sets)



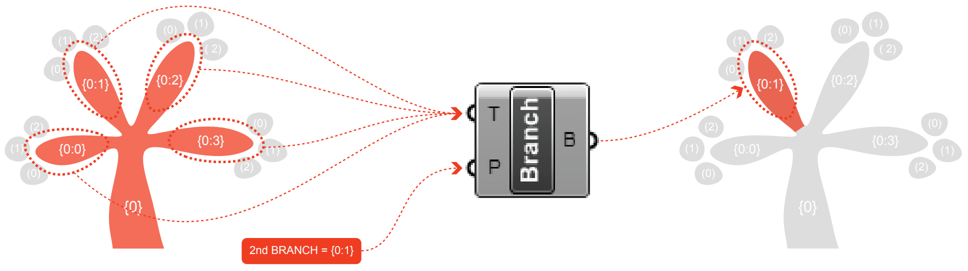
List / Sets components deal with list data, one dimensional array of individual items. Every item in the list data has its own item index number starting from 0. For example, let say that we have 4 lists consisting of 3 items. We can retrieve every 2nd items from those lists by ‘List Item’ component. We can also cull every 3rd items from those lists by ‘Cull Nth’ component.



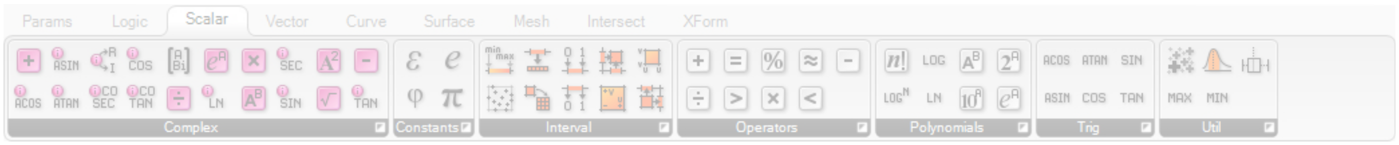
Tree structure handling (Tree)



Most of tree components deal with tree structure itself. In the previous example, if we want to retrieve 2nd branch, we can do that with ‘Tree Branch’ component.

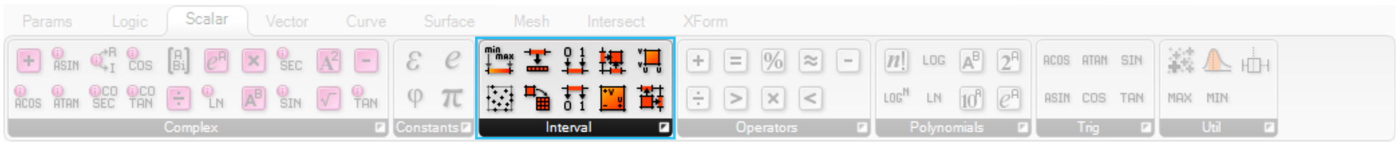


Components : Scalar



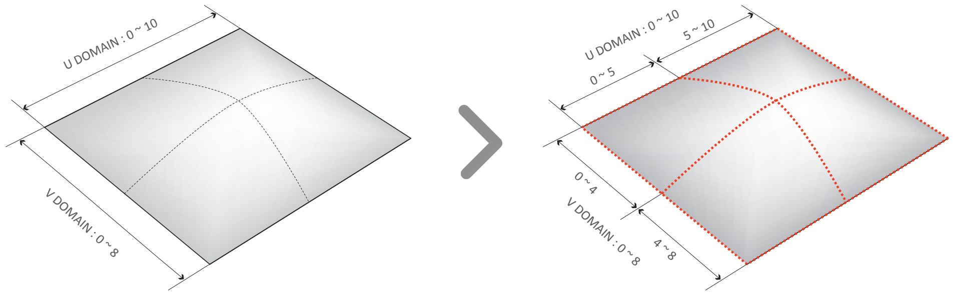
Scalar components calculate scalar operations such as addition, subtraction, multiplication, and division. Also some of them provide built-in functions like Log, Sine, Max, etc. We can also find some useful constants such as Pi in this shelf. However, the most important ones here is Interval (Domain in the later version of GH).

Interval (Domain)

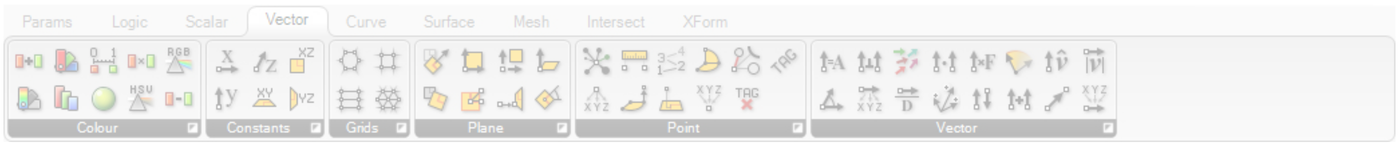


Interval or domain is usually numeric data which has a starting and ending value. In Grasshopper, all objects with coordinate systems can be seen as domain or interval. For now, Grasshopper provides up to two dimensional domain. Curves could be treated as one dimensional objects which have t or L parameters (refer to the coordinate system section). Also, surfaces could be though of as two dimensional domain with U and V value (also refer to the coordinate system section).

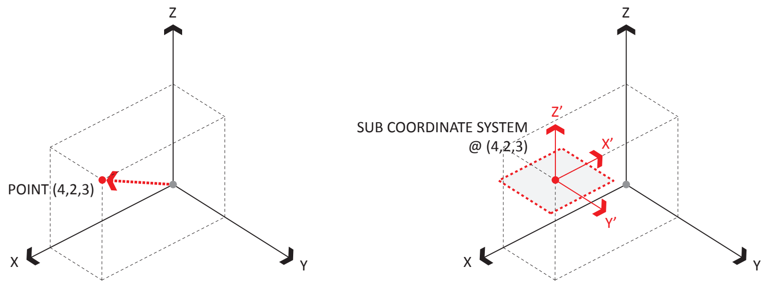
For example, a surface can be subdivided into several pieces by domains. Assume that the dimension of a surface is 10 in U direction and 8 in V direction. Grasshopper recognizes the surface as two dimensional domain; U:0~10 / V:0~8. If we split each domain into two sub domains like U:0~5,5~10 and V:0~4,4~8, we can subdivide the surface into 4 patches.



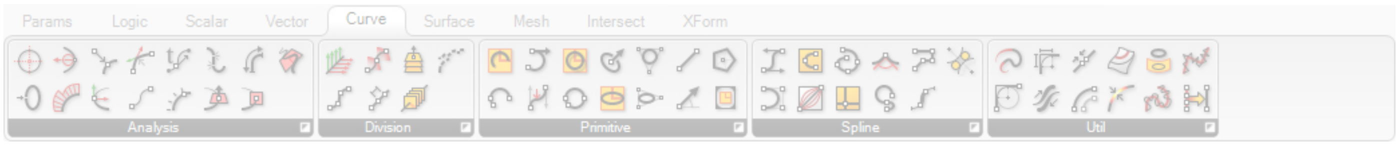
Components : Vector



Vector components create and control vectors, points and planes. This might sound weird because a point does not have direction or magnitude which vectors have in common. However, Grasshopper recognize a point as a vector, precisely as an ending point of a vector. A plane is a vector because it defines origine and three unit vectors (x,y,z) enabling us to use a plane as a sub coordinate system.

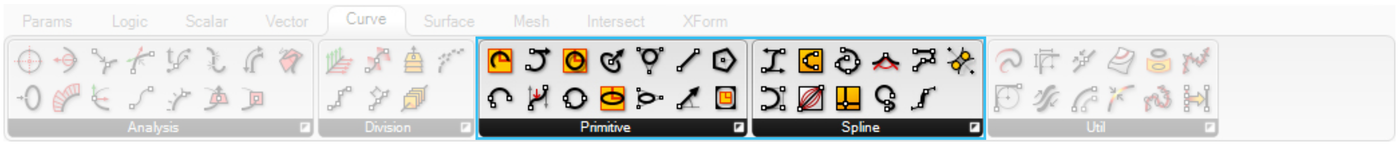


Components : Curve



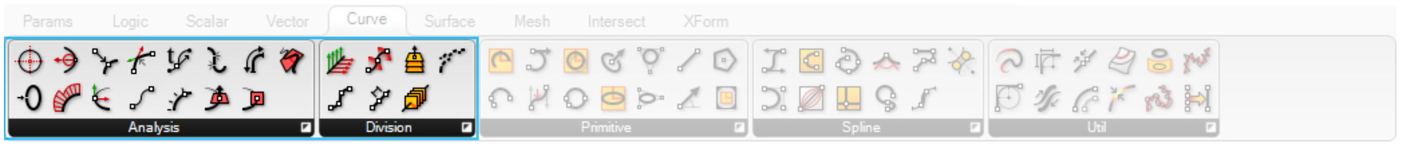
Curve components fall into three categories; Primitive/Spline, Analysis/Division, and Util. Primitive/Spline components create different types of curve out of input data. Analysis/Division components get points or planes out of curves. Util components modify the property of curves.

Primitive / Spline



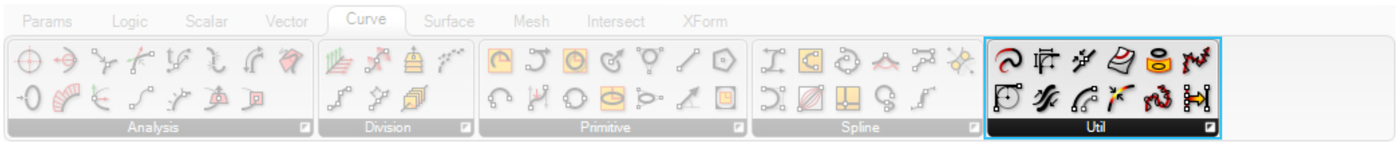
Primitive/spline components create curves based on user input. For example, with 'Curve' component, we can define a curve out of 4 input points from Rhino.

Analysis / Division



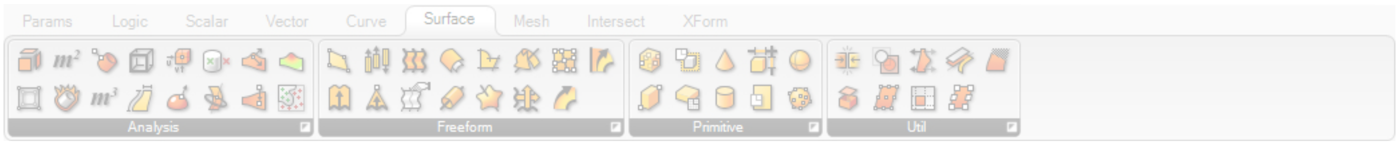
Analysis/Division components produce points or planes as the product of curve analysis/division processes. For example, by supplying a number and an input curve, we can get equidistant points along with the curve.

Util



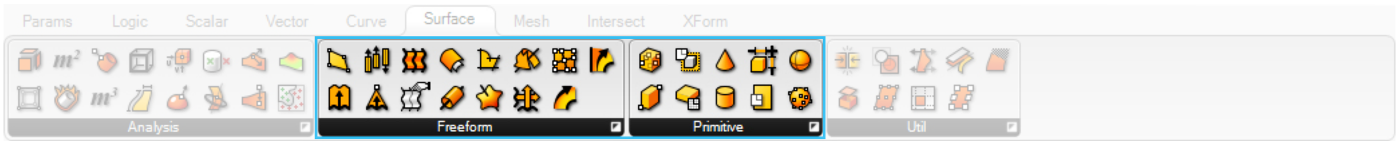
Utility components do some special operations on curves. For example, we can invert the direction of a curve by ‘Flip Curve’ component.

Components : Surface



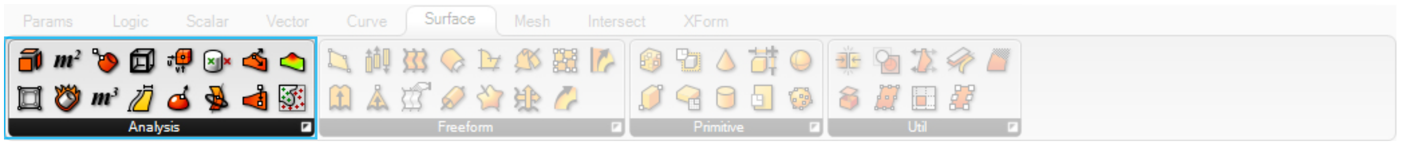
Surface components also fall into three categories; Freeform/Primitive, Analysis, and Util. Freeform/Primitive components create different types of surfaces out of input data such as points, curves, etc.. Analysis components get points or curves out of surfaces. Util components modify the property of surfaces.

Freeform / Primitive



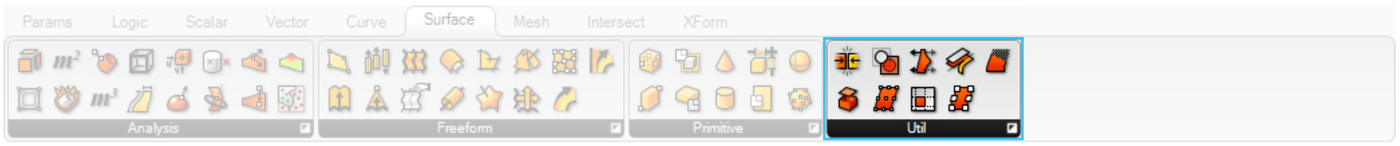
Freeform/Primitive components create surfaces based on user input. For example, with ‘Loft’ component, we can define a surface between multiple curves from Rhino.

Analysis



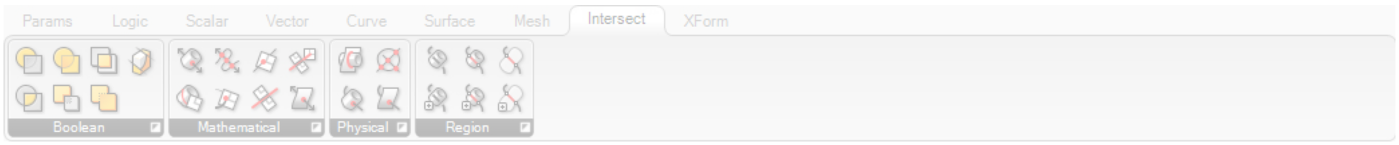
Analysis components produce points or curves as the product of surface analysis processes. For example, by supplying an UV coordination of a point on a surface, we can get the normal vector of the surface on that point.

Util



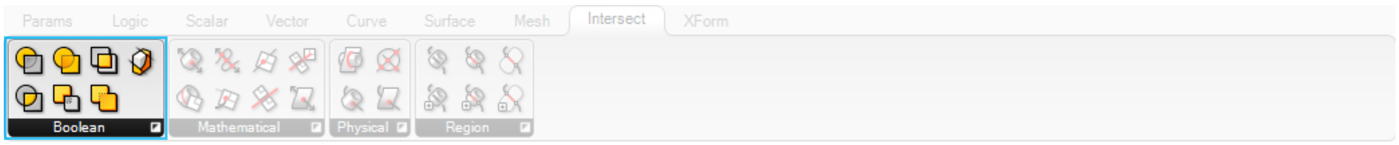
Utility components do some special operations on surfaces. For example, we can invert the direction of a surface by ‘Flip’ component.

Components : Intersect



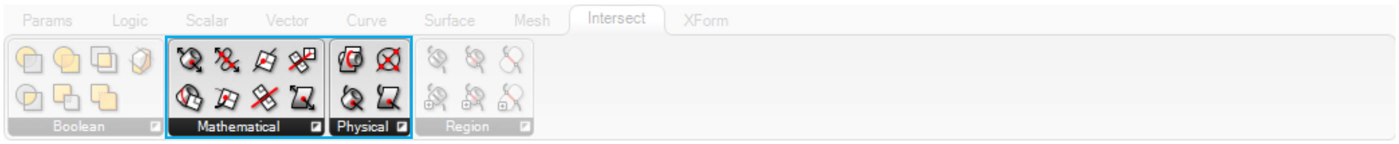
Intersect components fall into three categories; Boolean, Mathematical/Physical, and Region. Boolean components do boolean operations between closed planar curves as well as Breps. Mathematical/Physical components get points or curves between geometries where they intersect with each other. Region components do trim or split curves with any given geometries.

Boolean

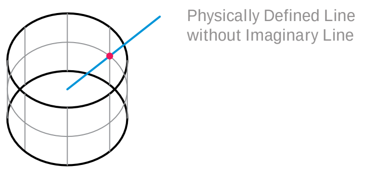


Boolean components are pretty much same as the compound path commands of Adobe Illustrator such as union, intersection and subtraction (difference). They works with only closed planar curves or closed Breps.

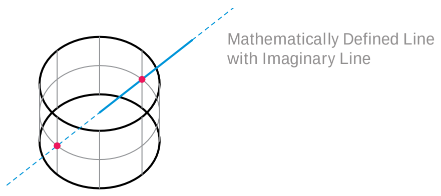
Mathematical / Physical



Mathematical and Physical components are basically same in that they get intersecting geometries such as curves or points. However, Physical calculate the intersection based on purely physical characteristics, while Mathematical do it based on the mathematical definition of the geometries. For example, there are a line and a cylinder, and they meet at a point. Physically speaking, they meet at point A. However, mathematically, they intersect at two points. This is because the line is an infinite with a specific inclination when mathematically defined.

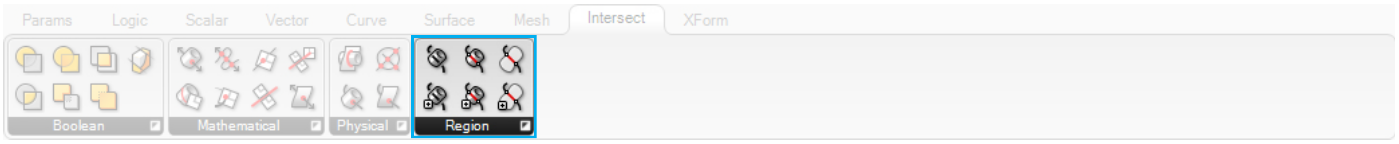


PHYSICAL INTERSECTION



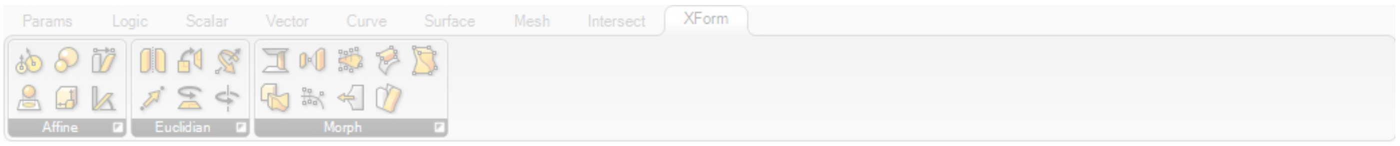
MATHEMATICAL INTERSECTION

Region



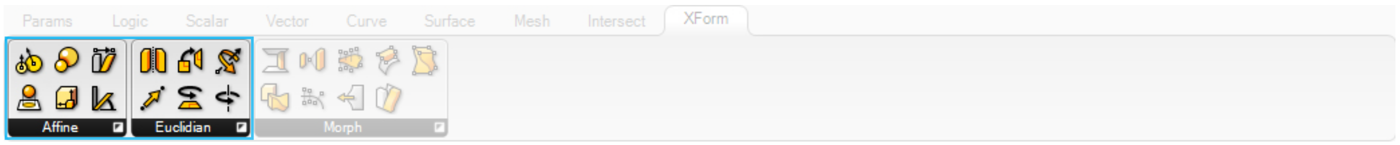
Region components split/trim curves with closed Breps or curves.

Components : Xform



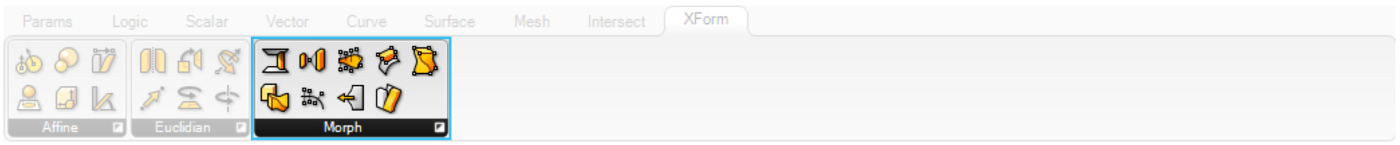
Xform components fall into two categories; Affine/Euclidian and Morph. These components either transform or deform any given geometries. Affine/Euclidian do basic transform/deform actions such as scaling, rotating or moving geometries. Morph literally deform geometries.

Affine / Euclidian



Besides the difference between Affine and Euclidian transform, they are basic transforming tools available in Grasshopper. They usually need reference points or vector for their 3D operations.

Morph



Morph is one of the most powerful transformation/deformation tools in Grasshopper. For example, we can morph a pre-defined component into a twisted box on/in between surface(s). If you are familiar with the concept of Rhino Paneling Tools, you will see most of Morph components are pretty much about it.