L-TREE, AN ORGANIC SHADING DEVICE

FALL 2012

CONTENT >

COURSE	ARCH 678 ADVANCED CONSTRUCTION
SEMESTER	FALL 2012
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GENERAL CONDITIONS >

CONTEXT

Natural sunlight is, for most part, an the element sought after in our Nordic climate. Wheather being in the work environment or in the private domain, the architect's reflex has been to allow as much sunlight into building or spaces as technically possible. Architectural intentions have evolved to a point where people are expected to work and live in an environment that resembles and is experienced as an outside space. This has led to a certain quantity of by-standing problems. Montreal's geographic location makes it one of the most evolutive climates in the world with extremes from -20s to the 30 degrees Celsius. These extremes create a need for both heating and air conditioning of buildings that utilize massive quantities of energy. In the summer months, overheating of interior glazed spaces through a green-house effect and passive heating of solids within the space hampers the comfort of the users. The temperature can rise rapidly within a space and air circulation or man-engineered air conditioning needs to be planned for the space to remain comfortable. The extremes are also true in the differences in angles of incidence throughout the year. In the winter months, problems of glare and excessive sunlight create moments of the day where working in proximity to the windows is uncomfortable or even impossible. The seasonal changes to the path of the sun make it difficult to address the problems in only one simple gesture.

Architects and engineers have been developing different approaches to addressing sun related problems through louvers and shading systems. These systems have grown from fixed to evolutive and parameterized solutions. In Canada, having to address angles of incidence spanning more than 50 degrees of difference between summer and winter, shading patterns are best designed to address a multitude of angles rather than two or three problematic ones. The design of shading has also been oriented at the reduction of heat gain by positioning the system on the outside of the glazing. The control of sun rays on the outside of a space rather than inside ensures that the rays do not get trapped between a shading installation and the glazing and bounces back into the space. This scenario, working in the manner of a greenhouse effect, would not reduce heat gain but rather create a warm buffer zone close to the windows.

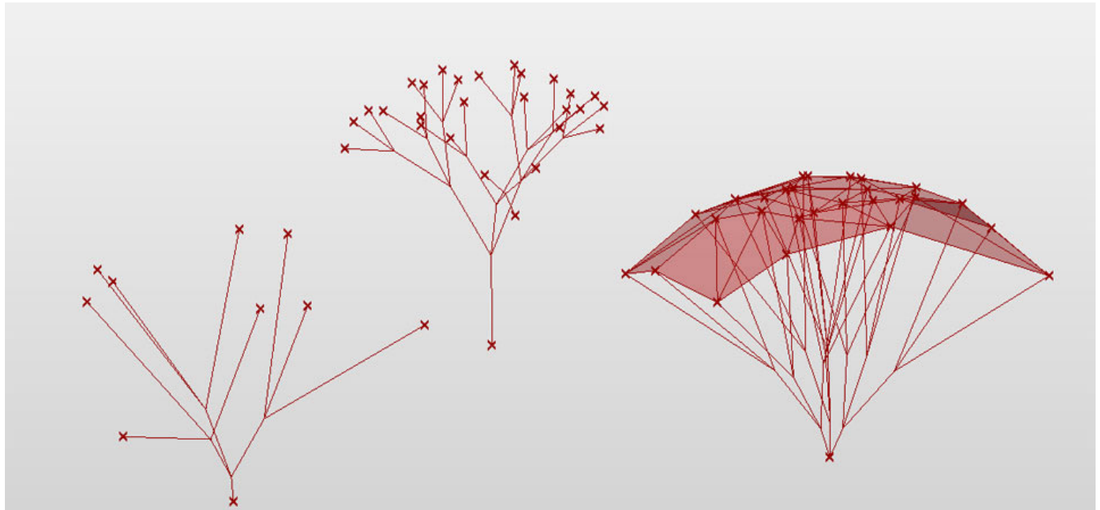
This project intends at addressing overheating and glares problems for a specific space at the school of architecture at McGill. The installation is to address the specificity of sun-related problems for a specific façade and window bay. The space is located on the first floor of the architecture school building (Macdonald Harrington) in the first year studios (in the North-West annexe) and the given façade of intervention is oriented South-West. The windows are more or less 2 meters high with bays spanning 1 meter wide. Students using the space have been addressing sun-related problems, most specifically glare, by installing makeshift blinds in cardboard boxes. The course, advanced construction, through its practical and applied assignment, intends at offering the students shading installations adapted to their needs using tools of parameterization as well as available manufacturing methods available to them at the school.

DESIGN PROCESS >

CONCEPT

Giving the context of the course as well as specific geographical and spatial considerations for the project our first intention was to create a shading system that would be evolutive and adaptable to different types of situations and sun conditions. Our first reflex was to observe and analyze natural patterns and systems of shading. The tree appeared as an optimized system by both its systemic complexity and simplicity. Its branching system allowing for amplitude and its extension of covering foliage over and within this structure created a diversified cover. The idea of evolution of the tree foliage in Quebec between the summer and winter (with and without leafs) led us to believe that the tree would create a foliage that intervened differently for summer and winter conditions. For summer, a greater coverage would be provided to divert rays away from the space while during the winter, the foliage, being sparser, would let rays through while addressing the glare problem experienced by the students.

INITIAL SKETCHES

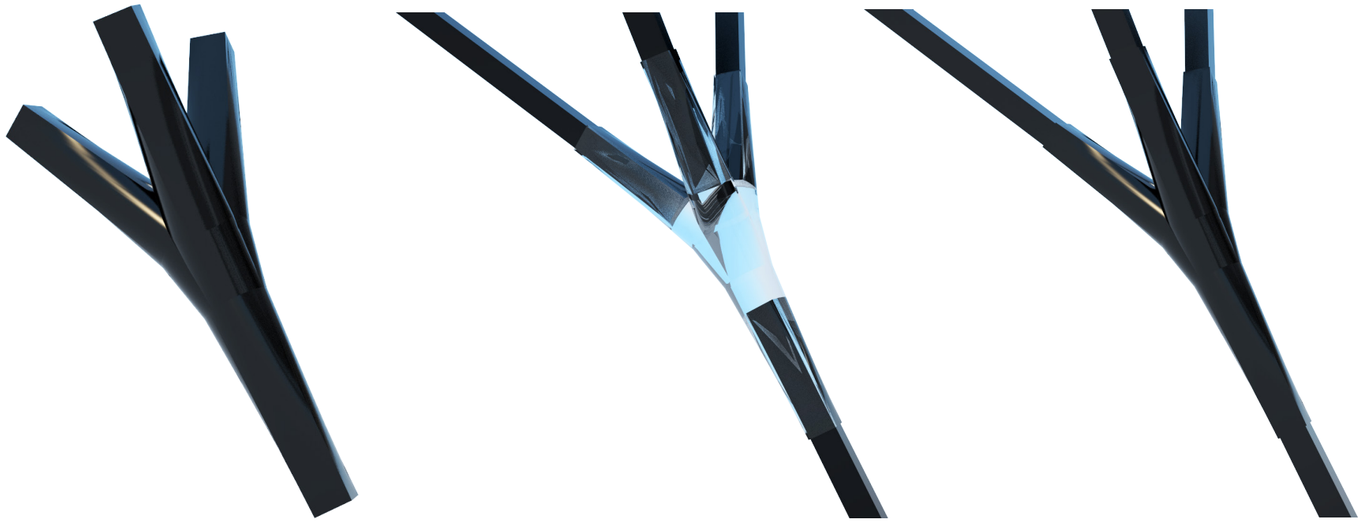


INITIAL SCRIPT GENERATOR

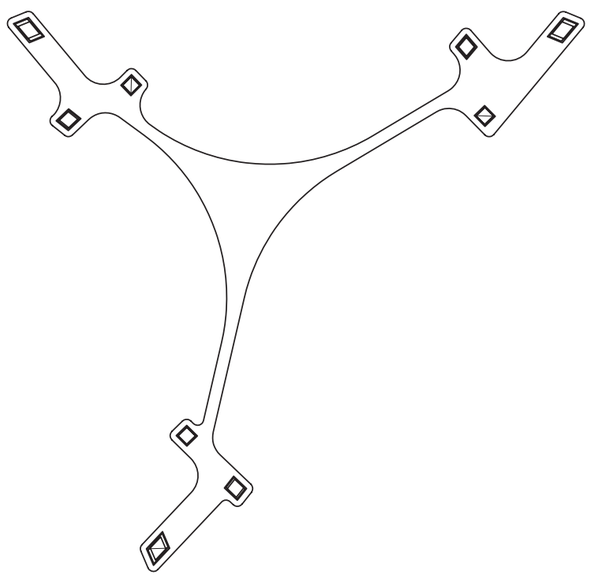
DESIGN PROCESS >

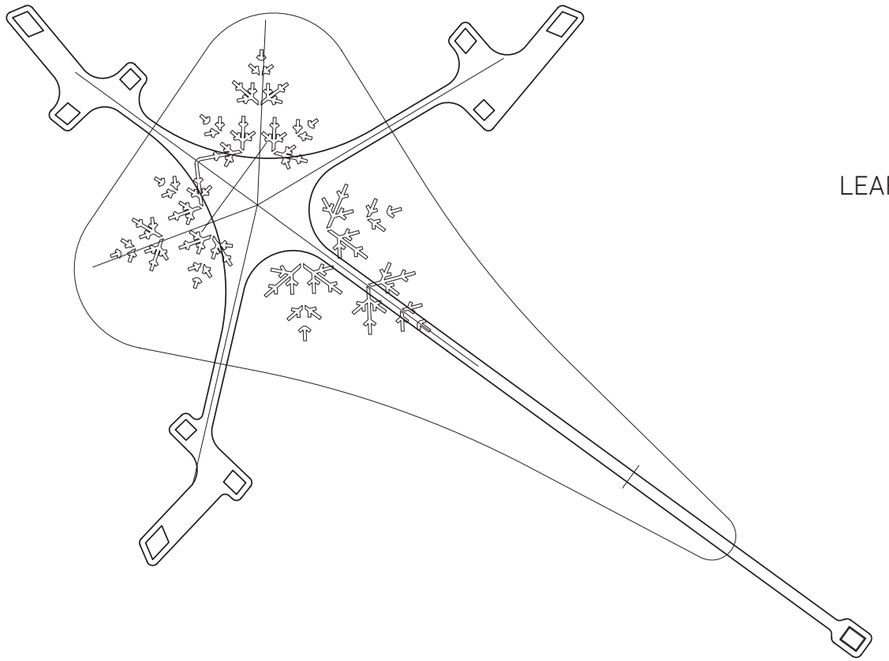
FINAL DESIGN / GENERAL

The designed system was rationalized into two joined systems: the branching and the foliage. The branching system is based on a parameterized fractal system bio mimicking a tree structure. The tree is created from a first branch by the reproduction and rotation of three other branches at its head. Each branch then generates another 3 branches and so on. By scaling the length of the branches the wanted density, amplitude and height can be obtained. By adding or subtracting generations of branches (levels) the tree is inclined outwards to address the lowest sun incidence angle. The branches are square dowels that are scalable to address the efforts generated by the growth and height of the tree. These dowels are square to ensure a proper lock at the connecting point between branches. Round dowels would have allowed for a 360 pivot that would have randomized and destabilized the structure. To allow the branching system to go up, connections were designed to join the four branches together with material. This connection morphs the four dowels together creating a rigid link. The foliage was created by joining the three connectors of a generation with the connector of the generation below. The shape included within the triangulation of the top three connectors was then pulled towards the lower connector as if stretched or tensed. To rigidify both leaf and the connectors of a same generation, a structure was added to the leaf. This allowed the leaf to be installed floating between the connectors and ensured that shear forces were addressed so that the tree would not split apart at its connectors.



CONNECTORS WITH DOWELS

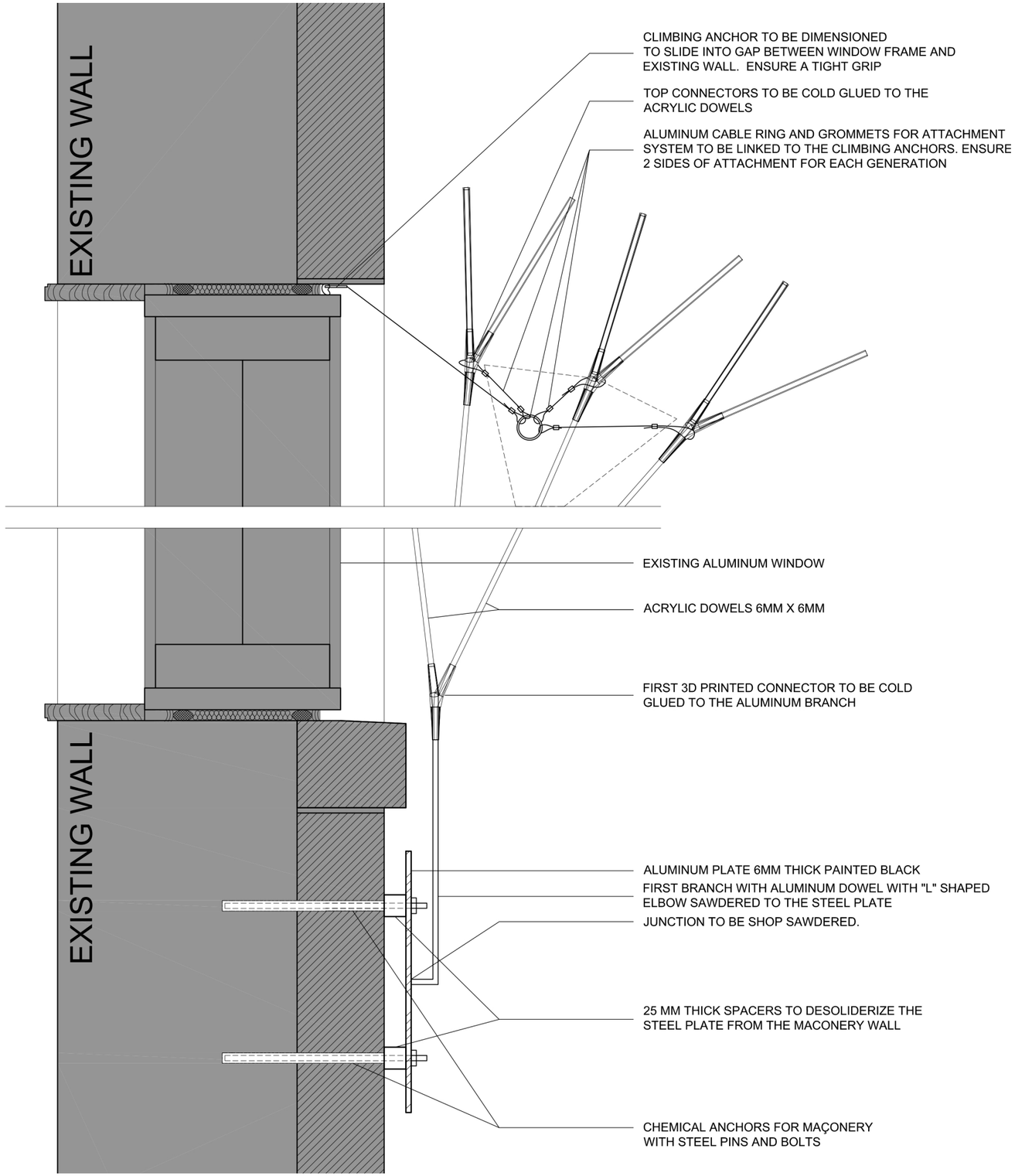




LEAFS WITH SPINE

DESIGN PROCESS >

TECHNICAL DRAWING



WALL SECTION
SCALE 1:5

DESIGN PROCESS >

SCRIPT - BRANCHING

CONTROLERS

The script is based on a self -rowing algorythm that uses the L-Branching system developped by Morphocode. The imput section uses our developped lines of commands for the growing pattern and all the factors and variables that modify the sysem following our constructive criterias and those extracted from our initial sun analysis. The angles of growth of the branches, their lenght, the number of generations, the rotation of the whole tree and also the amplitude at which it opens up.

ORGANIZATION

This part is the most important for the rest of the development of the script. All the datas coming out from the algorythm component are filtered and reorganized here, in order to regroup the datas from each generation of growth, and also, related them in smaller group in order to create the branches and the leaves. This regroupement of datas allows us to control every next steps of the script.

PLANES AND VECTORS

Every nodes where the branches are divided are analysed compare to the branches in order to isolate every vectors of each branches realated to their center of growth. A plane is created on each branches for the next step of extrusion.

BRANCHES

The branches are created with a slider that adjust the base dimension of the square extrusions. Another slider adjust the point of departure of these extrusions to create the sleeves in the connectors.

LEAVES

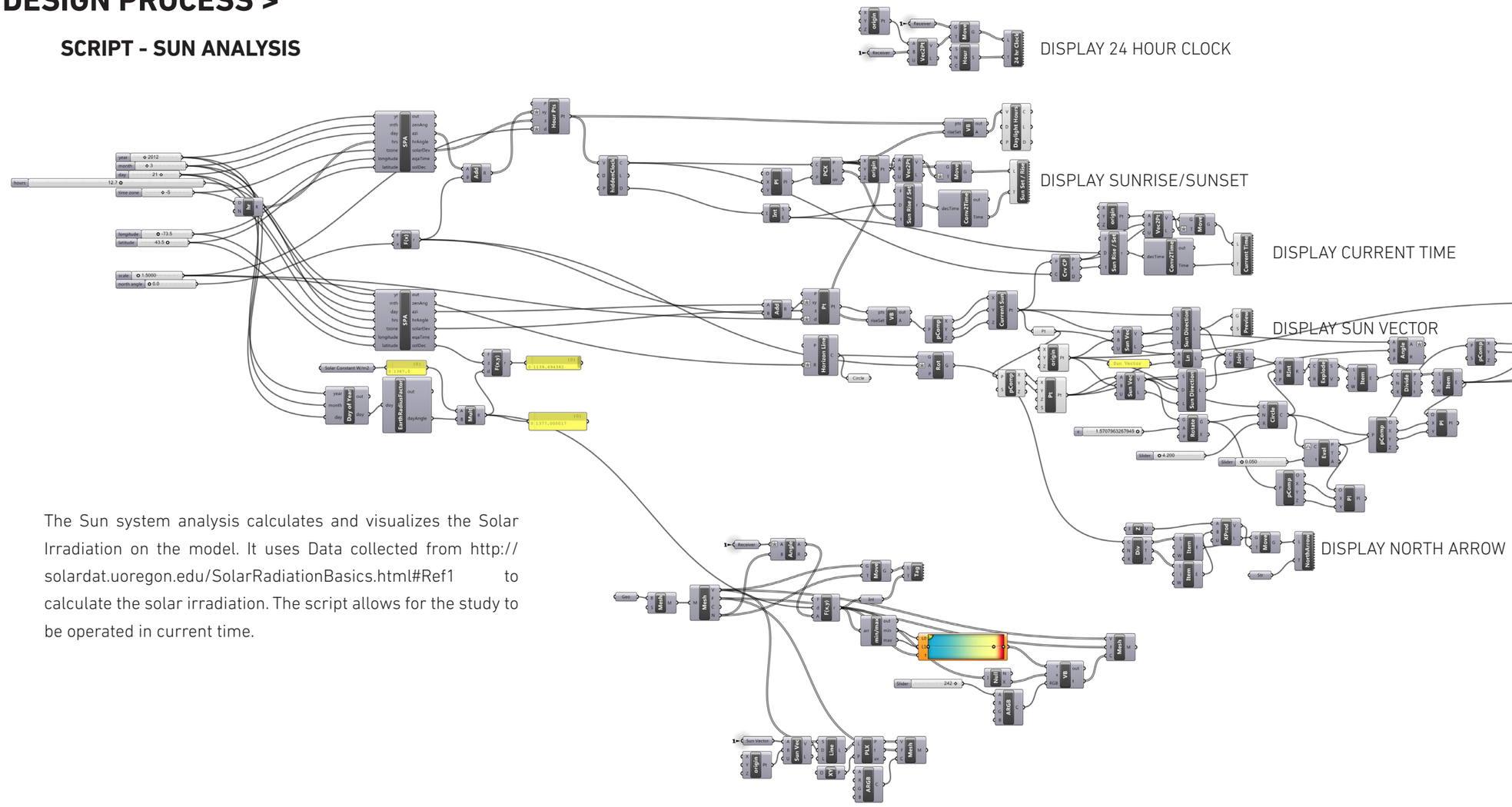
The leaves are created for the sun analysis as planes based on the 3 nodes at the tip of each branches that grows from the nodes.

CONNECTORS

The conenctors are created as morphing elements starting from an adjustable distance on the branches to the middle roud section around the nodes of each growing point.

DESIGN PROCESS >

SCRIPT - SUN ANALYSIS

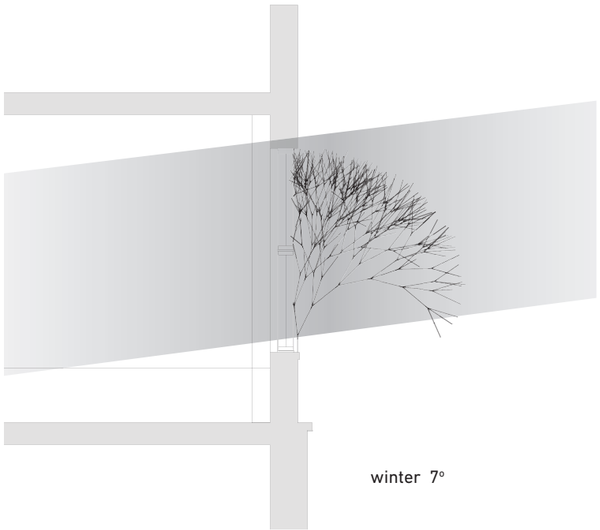


The Sun system analysis calculates and visualizes the Solar Irradiation on the model. It uses Data collected from http://solardat.uoregon.edu/SolarRadiationBasics.html#Ref1 to calculate the solar irradiation. The script allows for the study to be operated in current time.

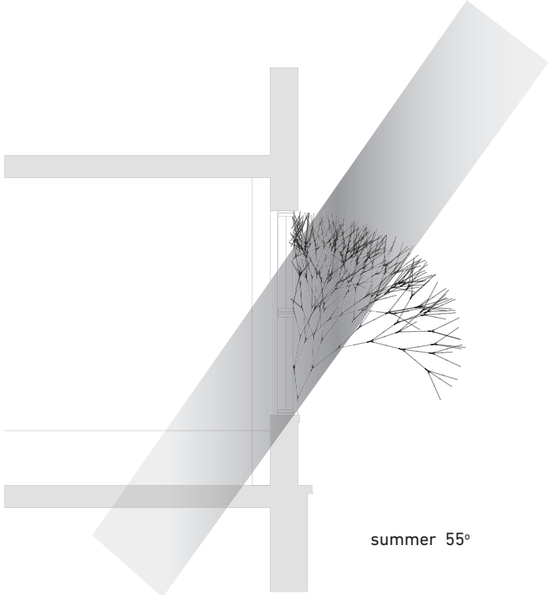
This section converts the solar irradiation into colour variables that are distributed on the model, also using the model to cast vector based shadows for observation.

DESIGN PROCESS >

SUN ANALYSIS

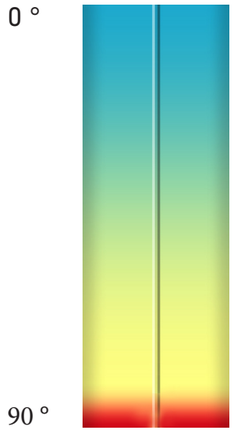


winter 7°

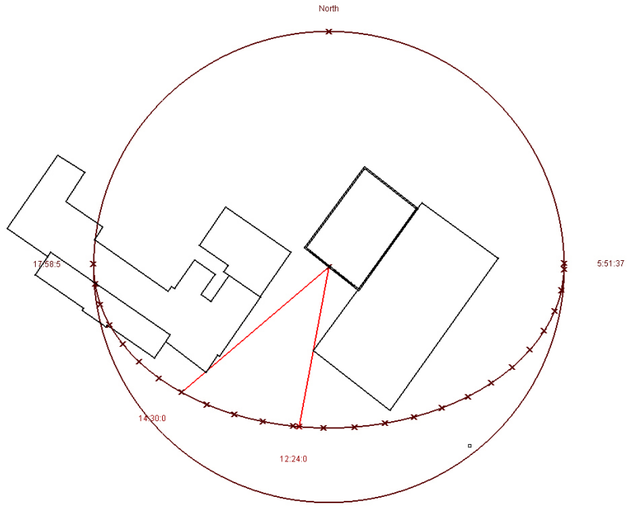


summer 55°

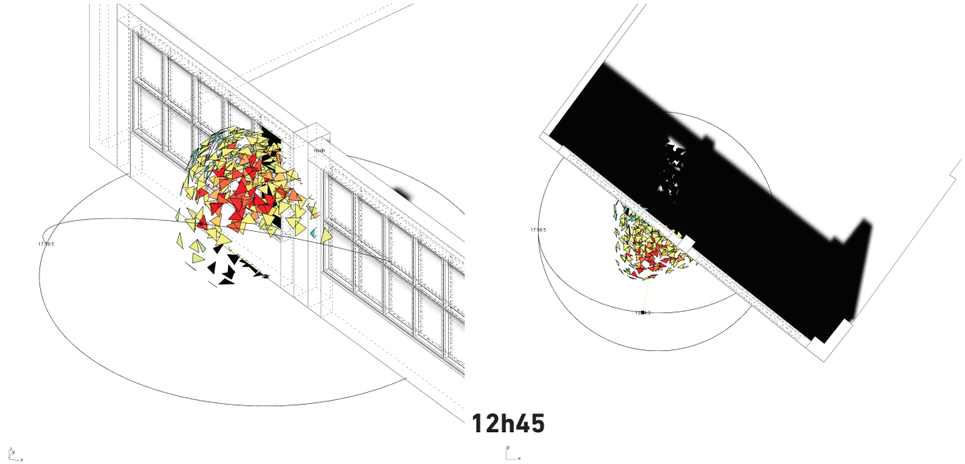
CASE SCENARIO / SEPTEMBER 21st

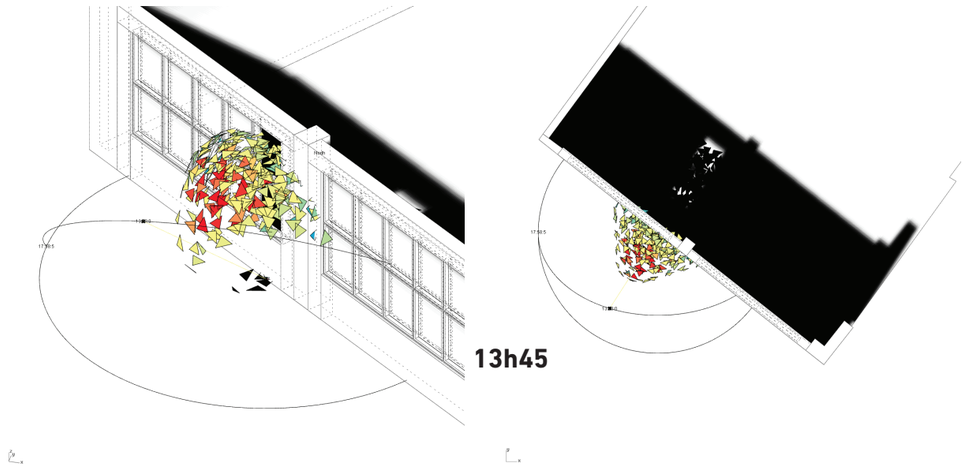


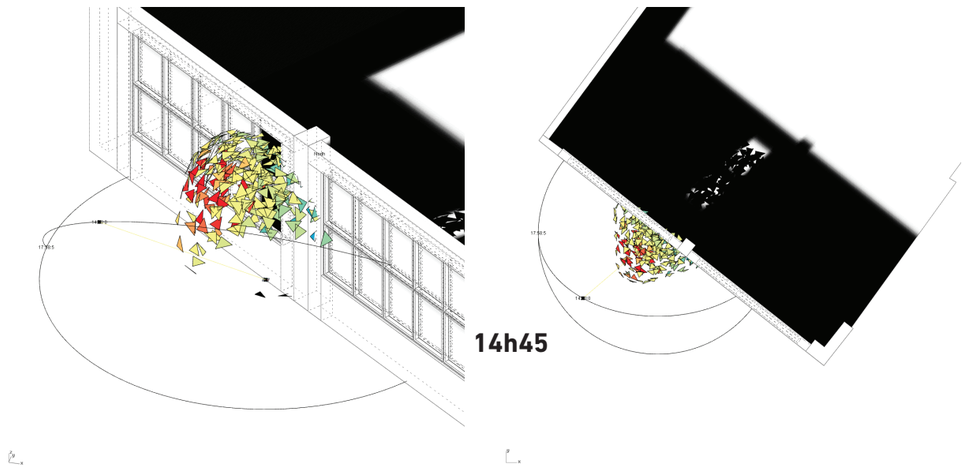
PERPENDICULARITY OF THE
INCIDENCE OF THE SUN WITH
THE LEAF SURFACES



SUN ORIENTATION

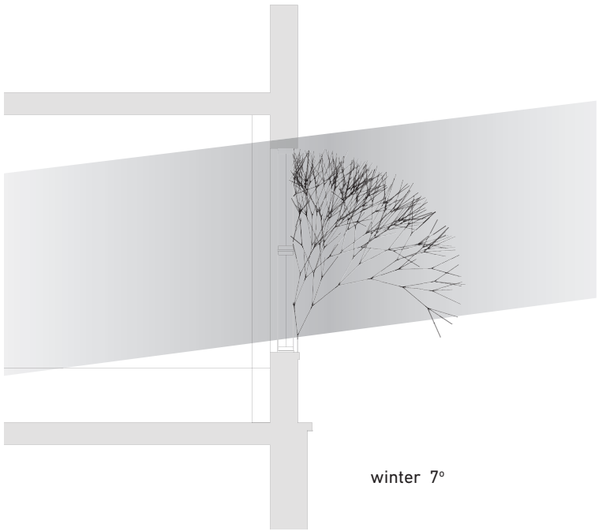




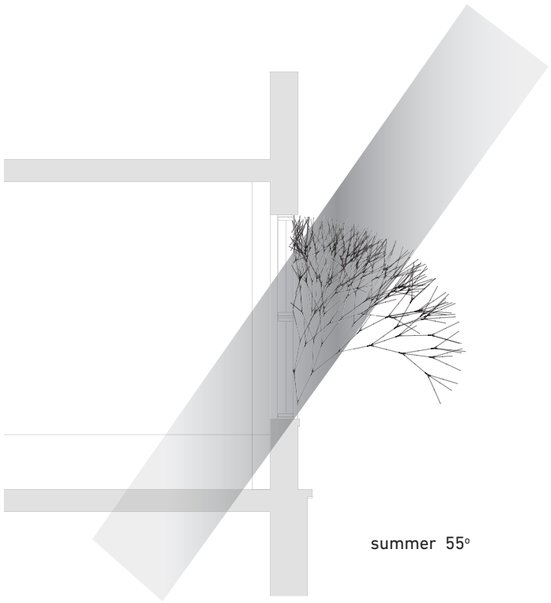


DESIGN PROCESS >

SUN ANALYSIS

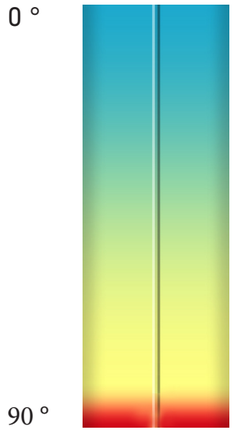


winter 7°



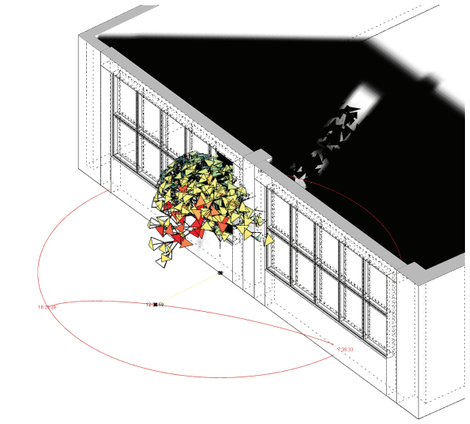
summer 55°

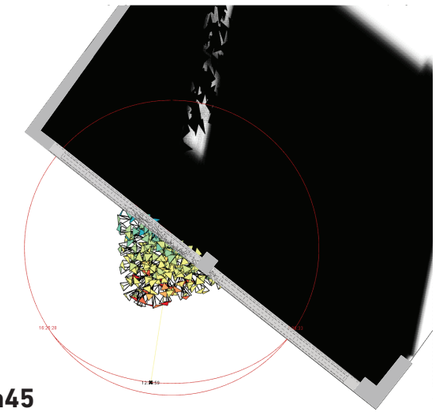
CASE SCENARIO / DECEMBER 21st



PERPENDICULARITY OF THE
INCIDENCE OF THE SUN WITH
THE LEAF SURFACES

SUN ORIENTATION





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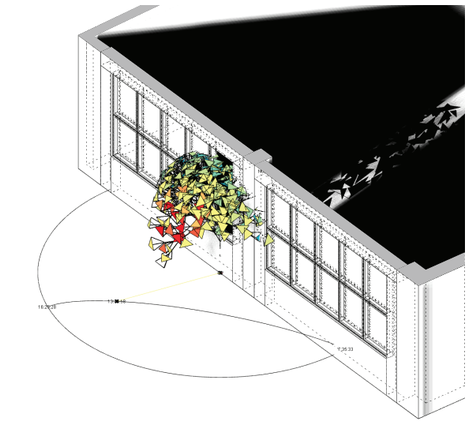

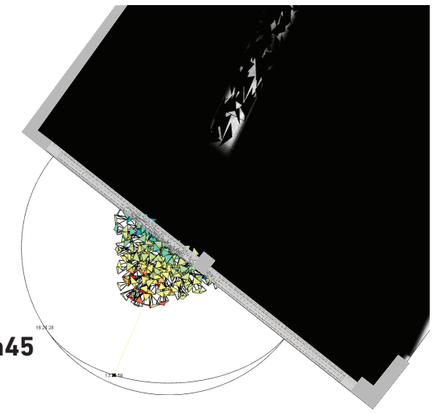

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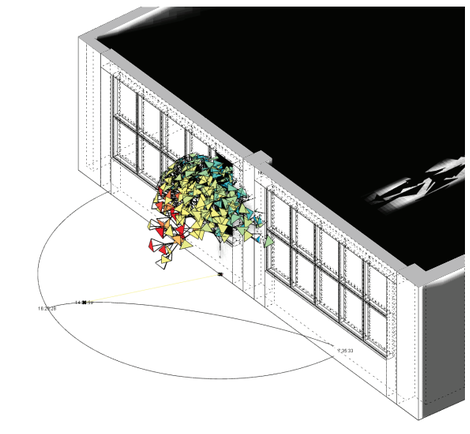
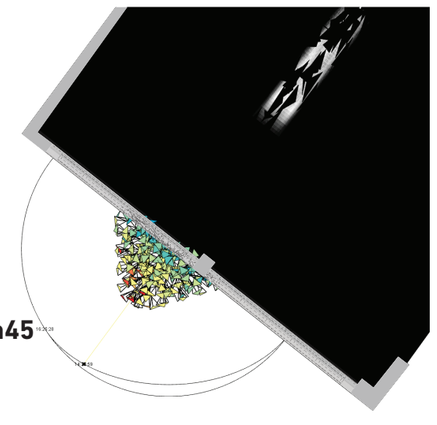
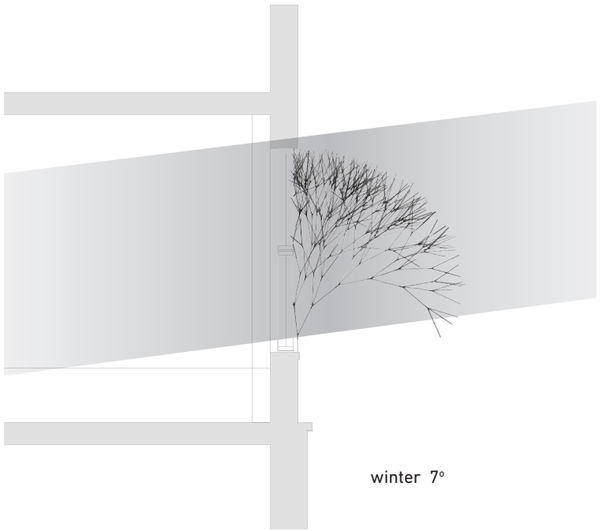




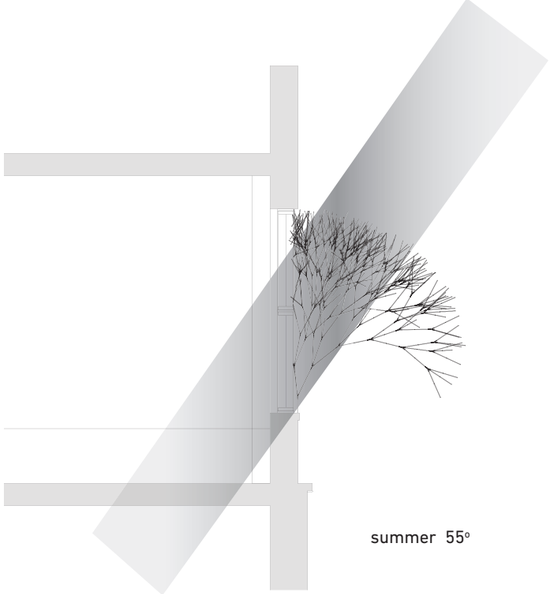
14h45

DESIGN PROCESS >

SUN ANALYSIS



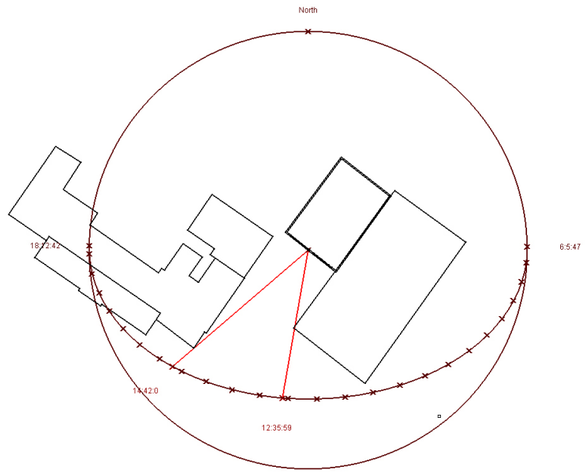
winter 7°



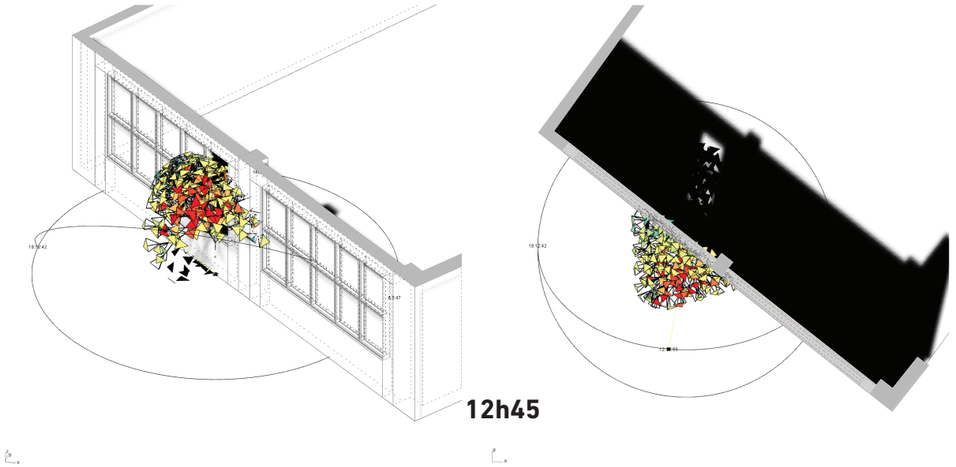
summer 55°

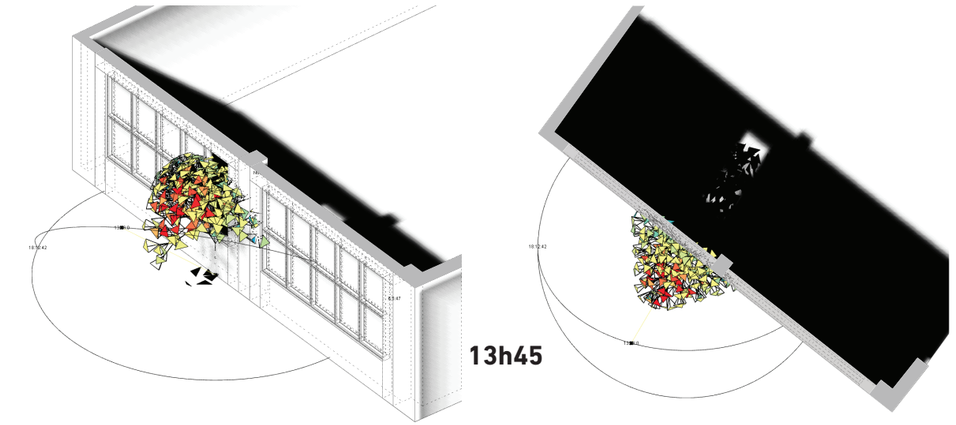
CASE SCENARIO / MARCH 21st

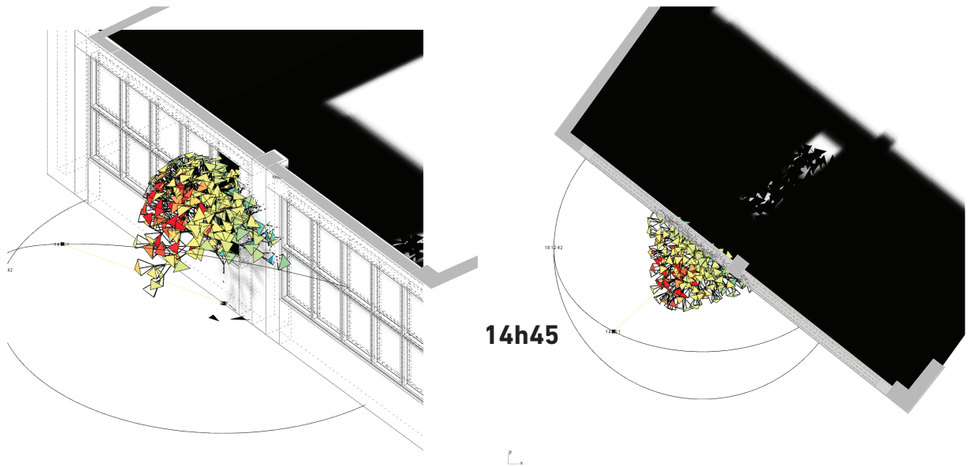
PERPENDICULARITY OF THE
INCIDENCE OF THE SUN WITH
THE LEAF SURFACES



SUN ORIENTATION



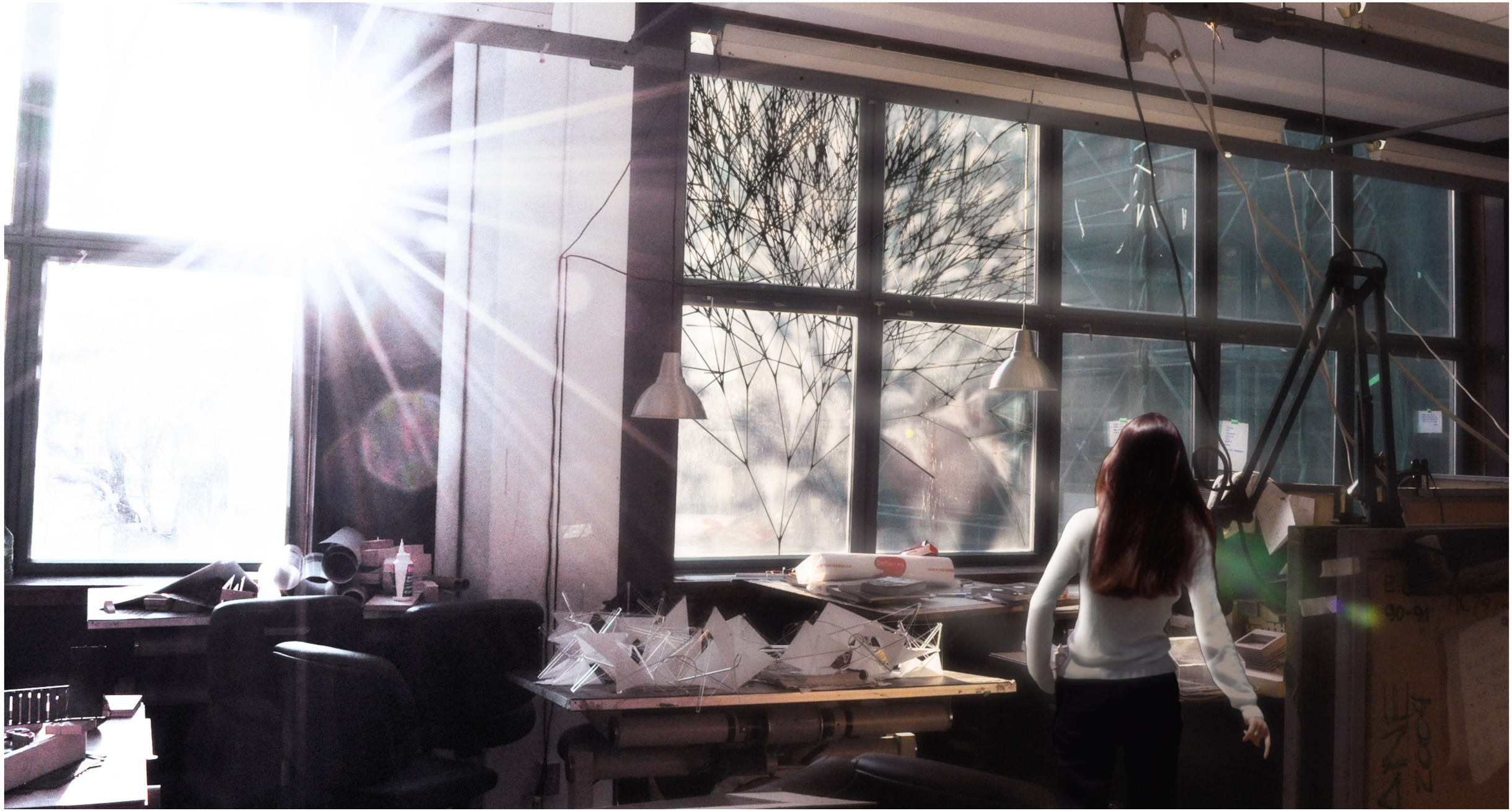




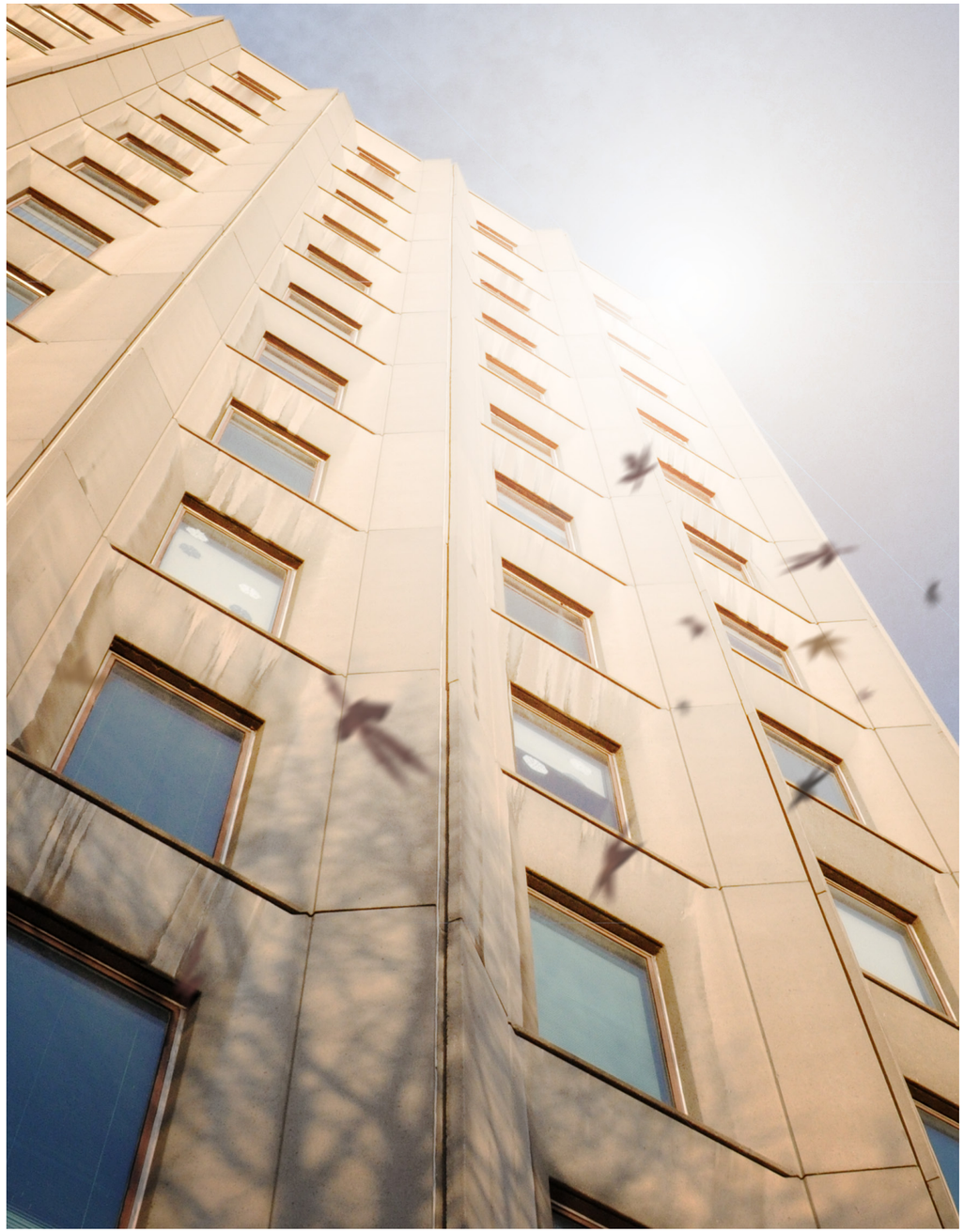
CASE SCENARIO / EXTERIOR OF U1 CLASSROOM (BEFORE)

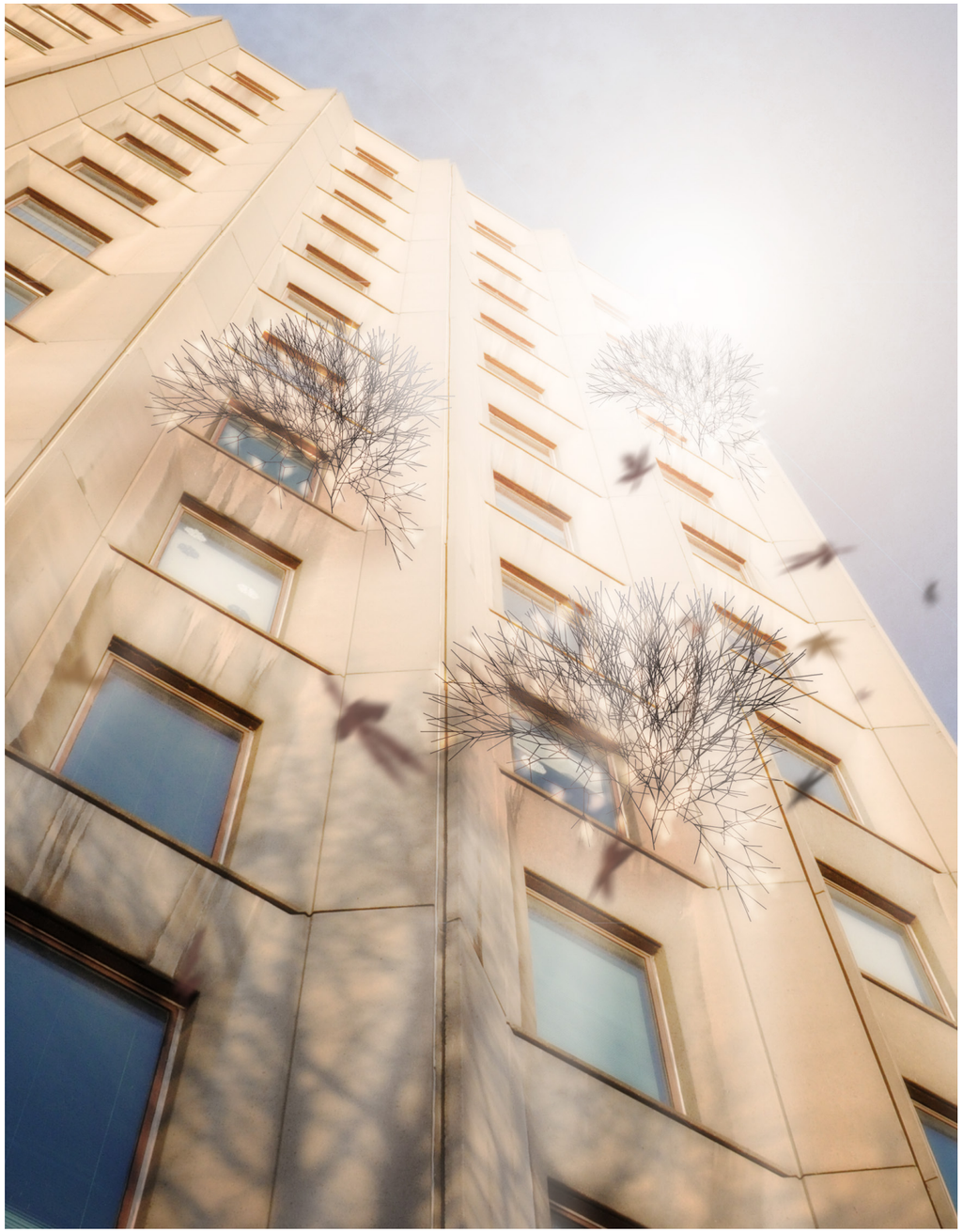
CASE SCENARIO / EXTERIOR OF U1 CLASSROOM (AFTER)

CASE SCENARIO / INTERIOR OF U1 CLASSROOM (BEFORE)

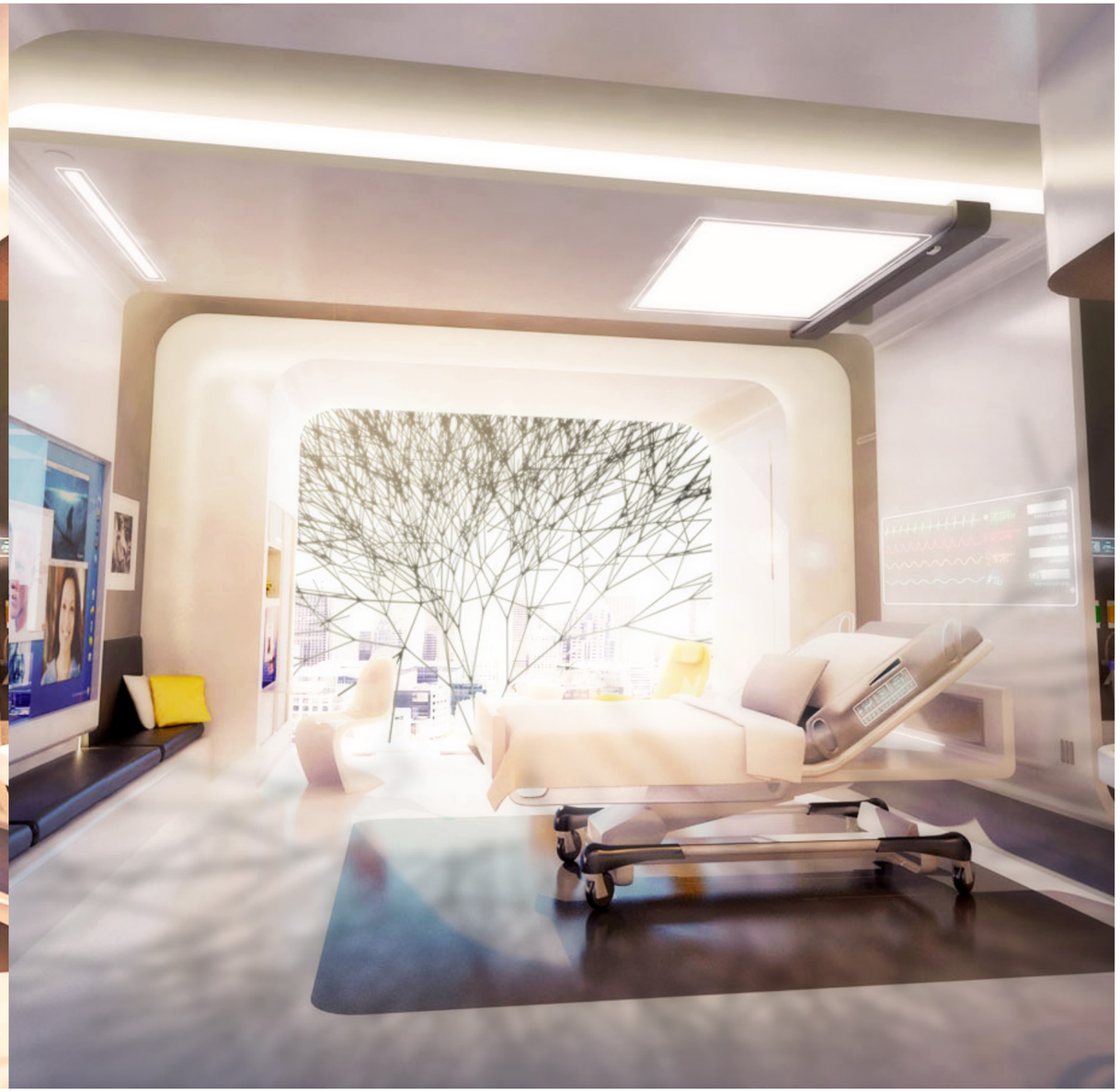


CASE SCENARIO / INTERIOR OF U1 CLASSROOM (AFTER)





CASE SCENARIO / EXTERIOR USE ON OTHER BUILDINGS



CASE SCENARIO / EXTERIOR USE ON OTHER BUILDINGS

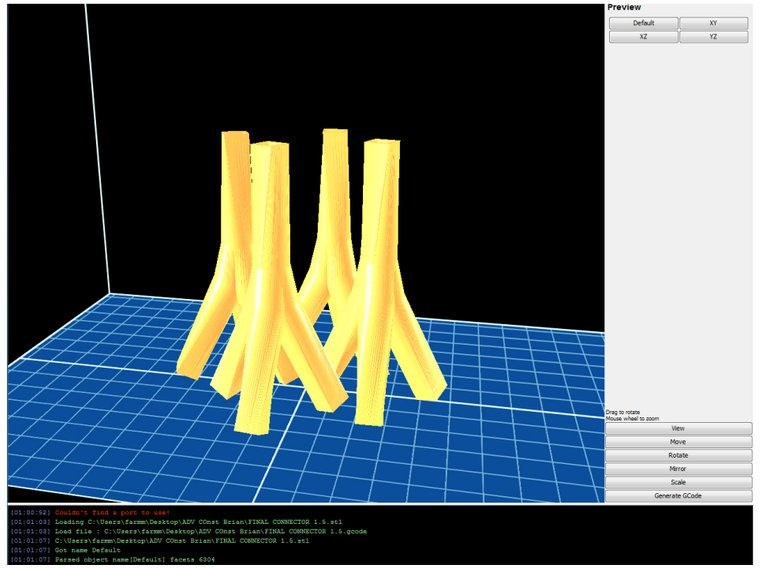
FABRICATION >

BUILDING PROCESS and MATERIALS

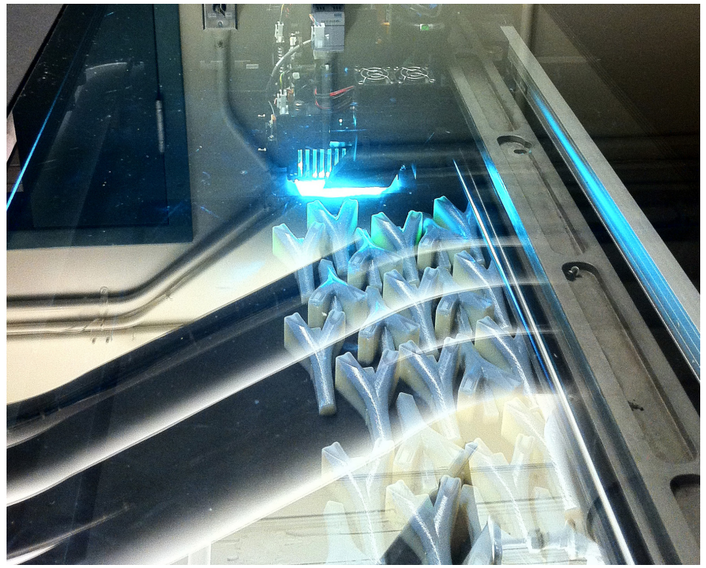
Elements of the prototype were fabricated using both FDM (Fused deposition modeling) and SLS (Selective laser sintering) 3D printing technologies. The connectors have been designed and programed first through Grasshopper and then Rhino. For fabrication, a 3D model was generated using tolerances of 1.5mm following recommendations for the used material thickness. Some experiments were made to produce them on a smaller 3D printer using FDM with ABS materials. This solution was successful for pieces as tests but not for a mass production of the installation. After several manipulations, the material tends to delaminate which reduce life spend of the element, especially considering its use in exterior conditions. Also, the fragility and the imprecision of the machine did not provide satisfying results both at esthetic and structural levels. Instead, SLS 3 D printing technology was used for mass production for the final prototype. The printing material, based on a polypropylene mix, ensure that the object would perform both at in rigidity and durability. The connectors are joined together with acrylic square dowels of 6mm gage (sides.)

The components of the leaf that was created for shading purposes were 2D laser-cut. The rigid support structuring the leaf and linking the three connectors together is cut out of a 1.5mm thick acrylic sheet. The leaf itself was created with a Mylar sheet, a translucent plastic material that diffuses light and UV rays. Mylar generically refers to the polyester films or plastic sheets that are composed of Polyethylene Terephthalate (PET) resin. This polyester Film enhances the properties of glass. A variety of industries laminate and use Polyester film as an applied membrane or sheet to a panel of glass. End users can coat Polyester Film with special adhesives, ultraviolet (UV) inhibitors and protective, scratch-resistant coatings depending on the required intrinsic qualities. Some window films are also metallized for specialized color and solar energy rejection properties.

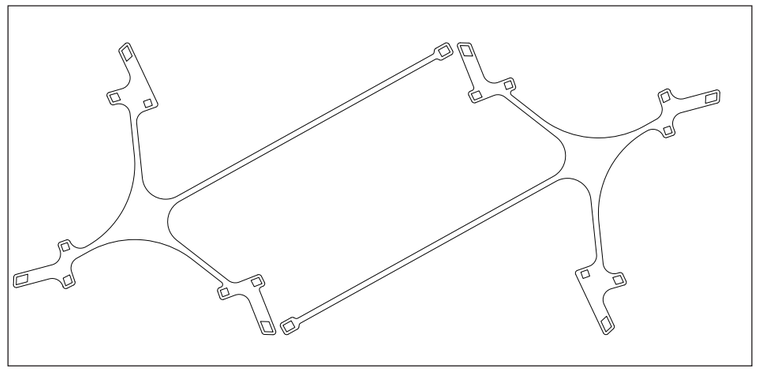
Assembly of the device to the actual window is made possible by the attachment of wires attached on the top and the sides of the window frame. The attachment can be done either with clamps where surfaces are clampable to, with suction cups where windows are fixed and with climbing attachments where reveals exist between the window mullion and the wall. The base of the tree is fixed on a steel plate that is clamped down to the window ledge to provide support to the entire tree.



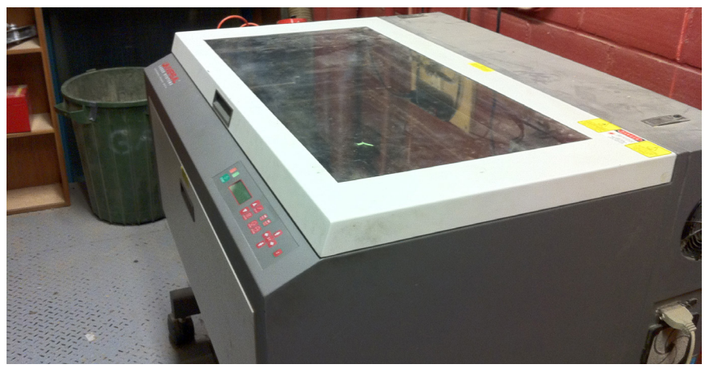
3D MODEL SEND FOR PRINTING



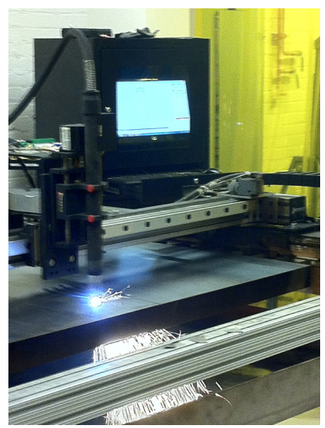
SLS 3D PRINTING



LASER CUTTER LAYOUT SHEET: LEAVES SPINE



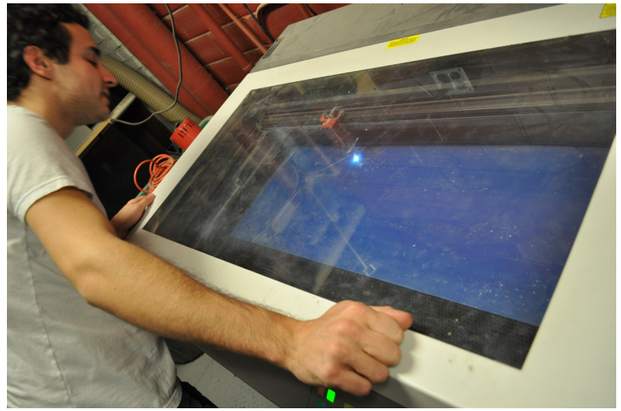
LASER CUTTER

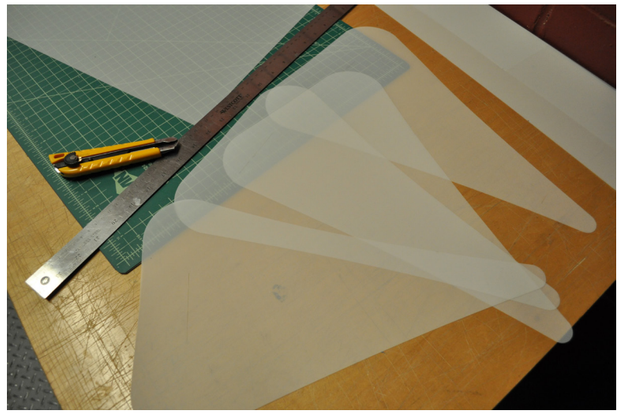


SHEET
METAL WELDING

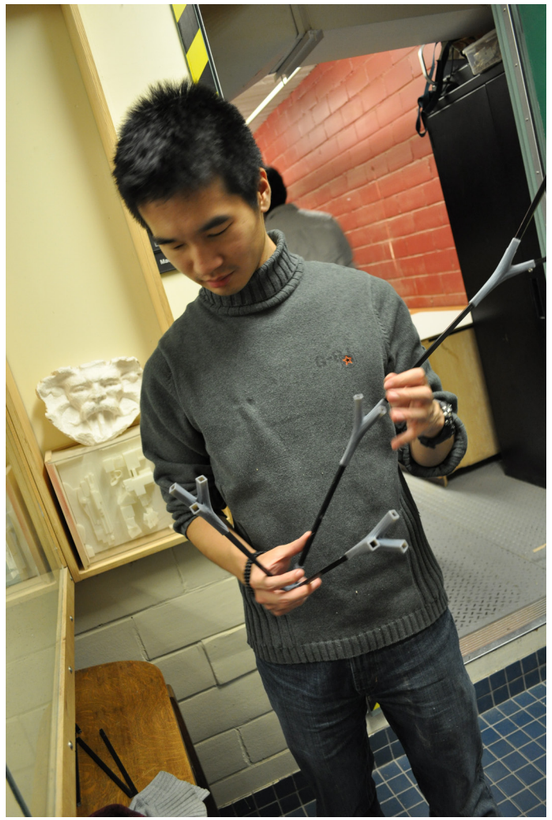
BUILT MODEL >

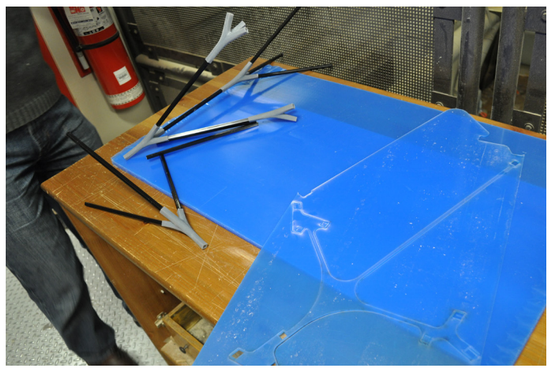
ASSEMBLY AND FINAL RESULT

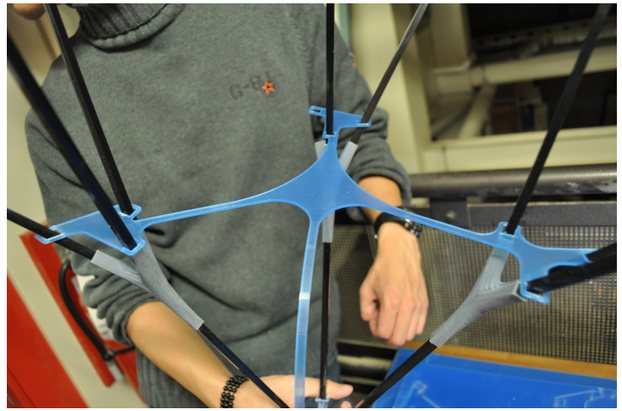


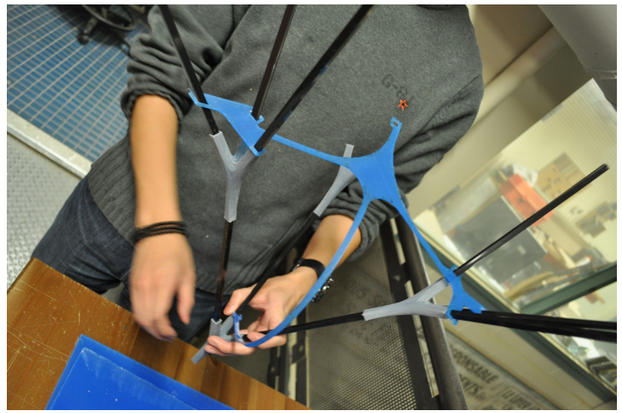


LASER CUTING OF LEAF ELEMENTS SPINE (STRUCTURE) AND LEAF (FOLIAGE)

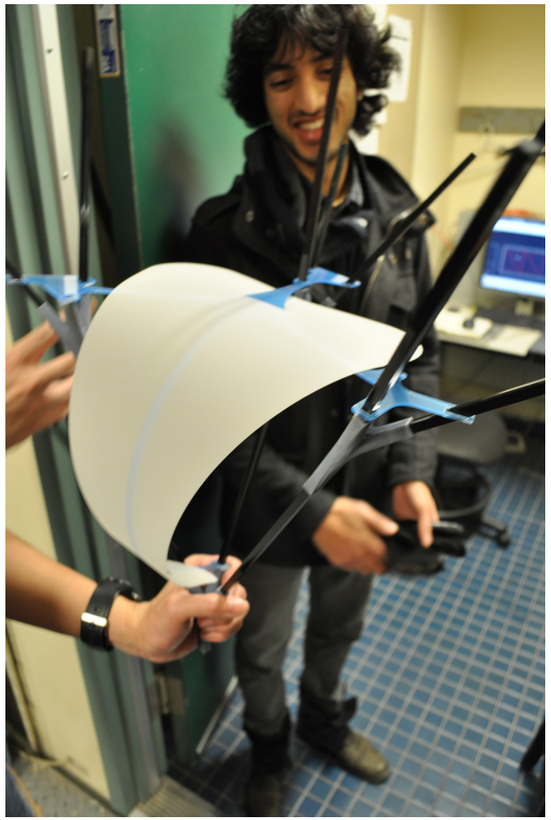


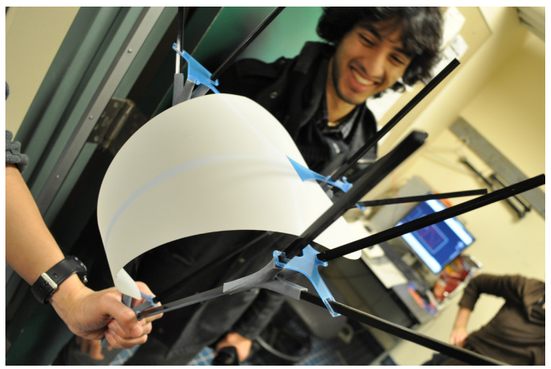






ASSEMBLY OF THE FIRST GENERATION OF THE

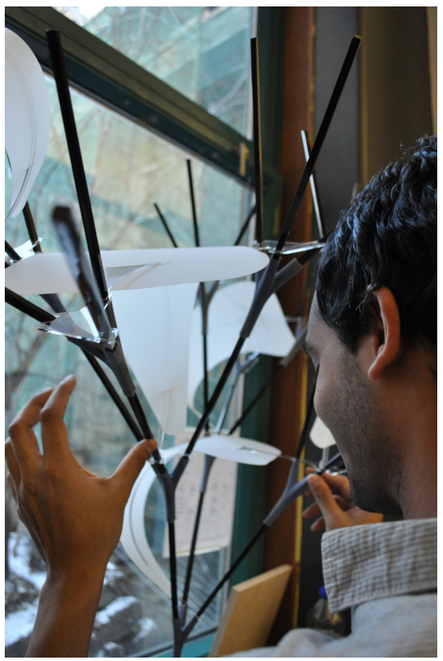




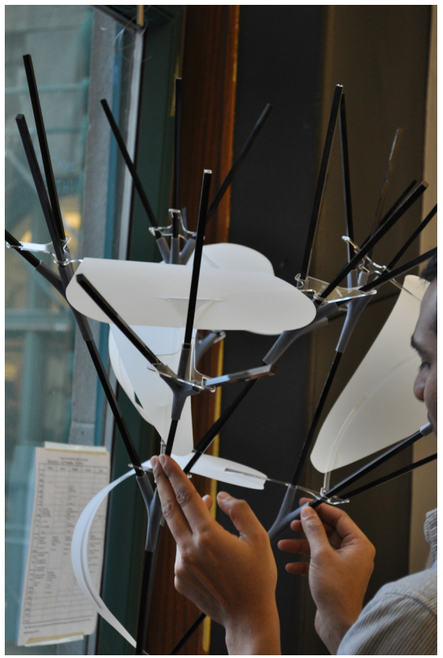
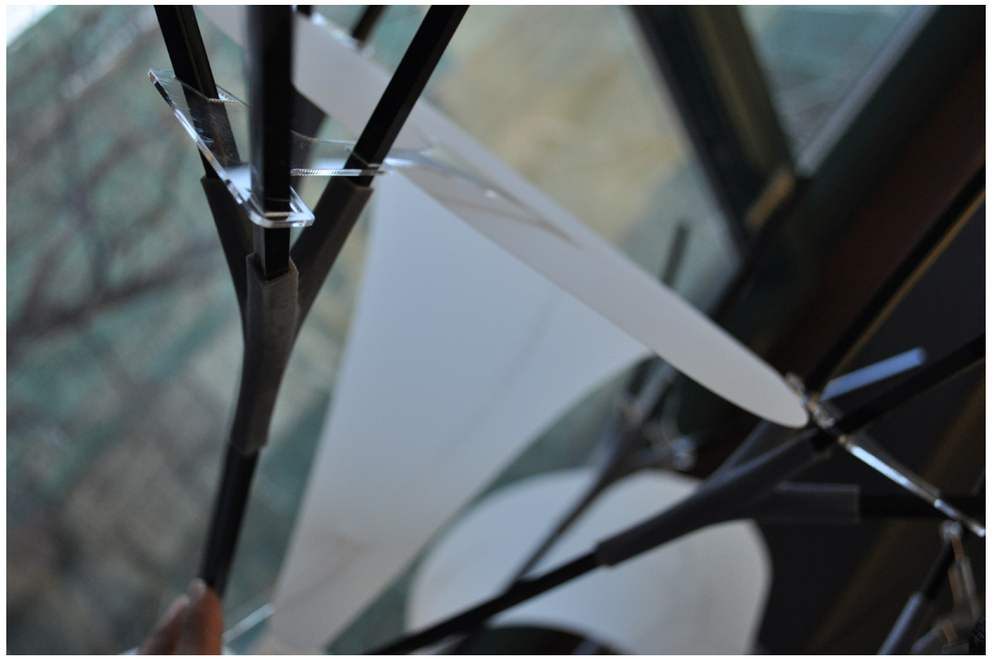
BUILT MODEL >

ASSEMBLY AND FINAL RESULT







BUDGET >

STARTEGY AND COST DETAILS

The cost manufacturing of this section of the prototype was of 940,50$ plus the taxes. Considering that the highest manufacturing cost in the production is the price of the 3D printed connectors, other solutions could by put forward to reduce the overall cost.

This section of the prototype covers an area of about 1 square meter. The full scale prototype is projected to cover twice this amount. The growing pattern of our installation is programmed to achieve a denser foliage in the upper part of the covered window in order to reduce the heat gain in the summer. Follow the growing rules, the number of connectors is multiplied per each generation of growth. This means that the price of 940,$ per sq. meter cannot be applied directly when this is doubled. The estimation for the total covered area would than be of an approximate cost of 2612,15$, meaning an overall price of 1306$ per sq. meter.

	Partial Model			Full height Model		
Description	Qt.	Unit cost	Global cost	Qt.	Unit cost	Global cost
Steel Base plate 75 mm x 200 mm	1	0,63 $	0,63 $			
Steel Rods 4 mm section	1	1,00 $	1,00 $			
Steel primer and paint	1	15,98 $	15,98 $			
Clamps 125 mm	2	13,49 $	26,98 $			
Sub total			**44,59 $**			
Connectors: 3d Printed units	24	32,50 $	780,00 $	72	32,50 $	2 340,00 $
Acrylic rods: 6mm x 6mm x 230 mm	36	0,64 $	23,04 $	96	0,64 $	61,44 $
Splines: 1.5 mm clear Plexi	8	2,08 $	16,64 $	24	2,08 $	49,92 $
Leaves : Mylard sheet	8	2,50 $	20,00 $	24	2,50 $	60,00 $
Sub total			**839,68 $**			**2 511,36 $**
Steel cable and nuts	1	24,20 $	24,20 $			
Top anchors : Climbing TriCam	2	16,00 $	32,00 $			
Sub total			**56,20 $**			
Total Partial Model			**940,47 $**			
Total Full height Model						**2 612,15 $**