James Dyson Foundation Undergraduate Bursary (2016/2017) - Department of Engineering, University of Cambridge

Outreach Report: Deployable Structures, Algorithmic CAD and Bistability

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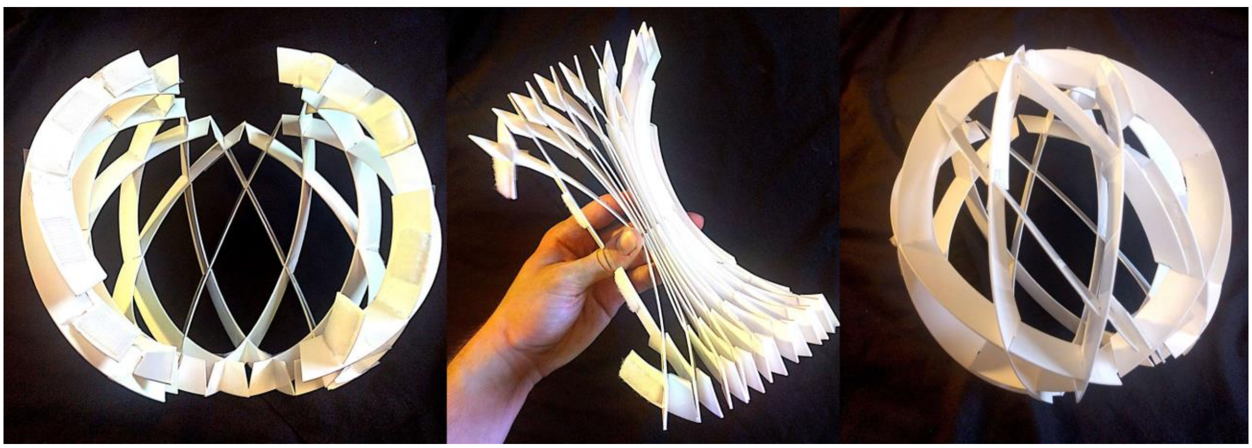
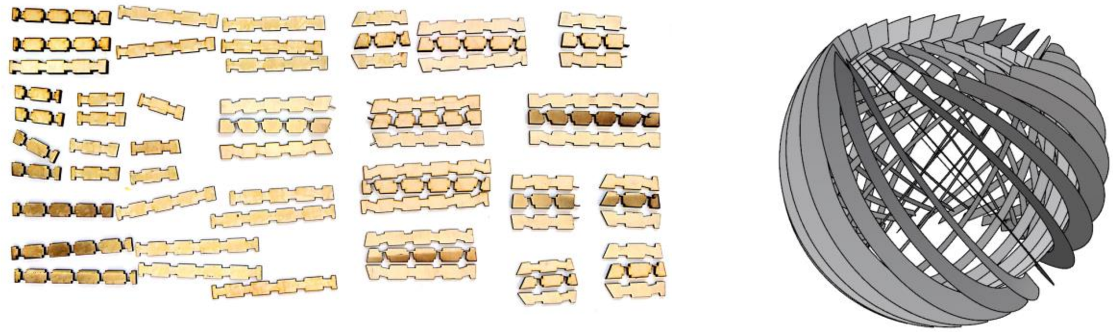
The idea behind this outreach project was to introduce the students to an interesting, often quite beautiful area of engineering, discuss some useful computer tools that enable it, and throw in a little bit of physics to give some inspiration for future applications.

The first section of the outreach project was a short presentation to introduce the students to deployable structures, and specifically collapsible sliceforms, the class of structures my masters project was focused on. In basic terms, we first looked at the way they were manufactured using interlocking sheets of material, discussing why that might be useful in terms of manufacturing considerations and bringing up a number of applications, from emergency shelters to space structures.



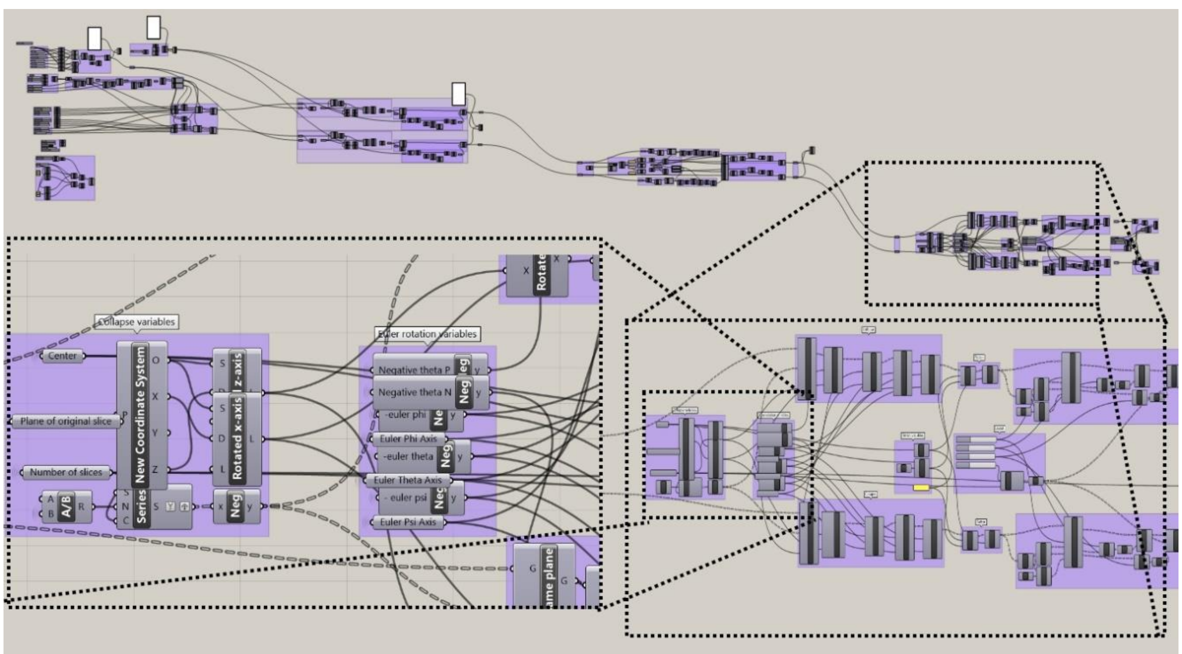
An example of a simple spherical pop-up sliceform

Algorithmic CAD (focusing on Rhino with the programmatic Grasshopper plug-in) was then introduced. The students were familiar with traditional CAD, whereby designers can manually define objects and assemblies part by part, but most had not considered problems like "how long would it take to manually design an assembly like one of these sliceforms, with potentially hundreds of intersecting parts?”



Two examples of the complexity of sliceforms with a large number of slices

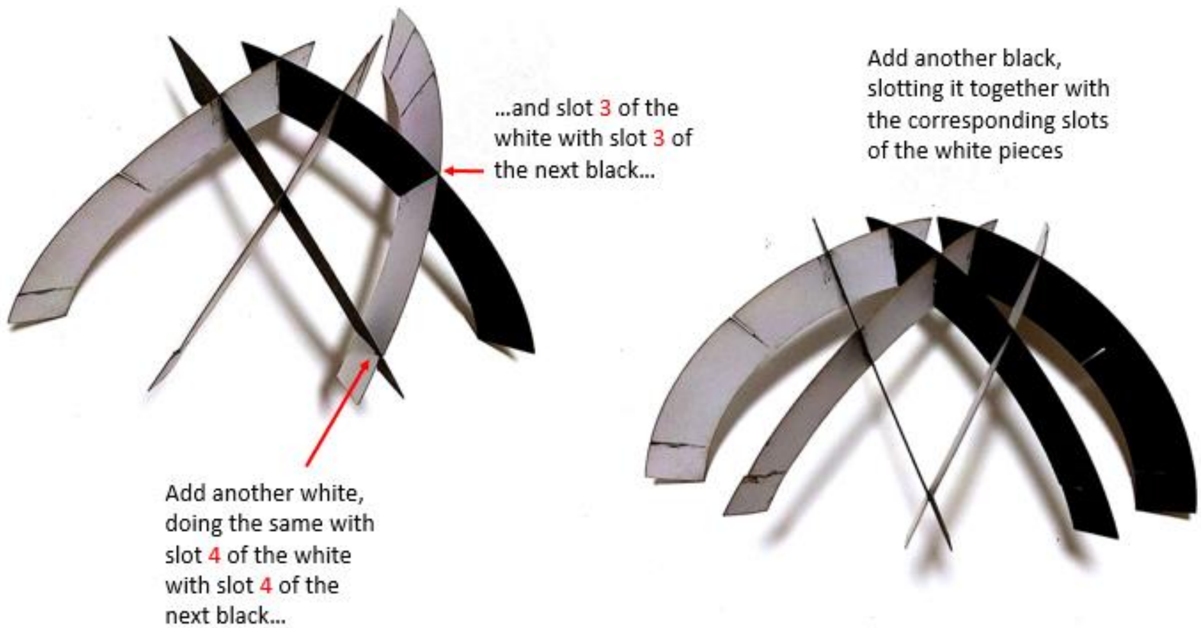
We briefly looked at how many complicated, precise steps were needed for each individual part, before demonstrating the solution: using algorithms to create the complicated geometries for you, based on rules that you define. Initial methods using Grasshoppers flowchart-style interface were demonstrated (and its shortcomings were made clear) before showing how much cleaner and simple a code based approaches (such as the one implemented for this project in Python) are significantly faster and more reliable, adaptable and comprehensible, reinforcing the idea that learning to code is an essential skill applicable to every engineering area. Prototypes of various classes of deployable sliceforms were passed among the class to give the students a chance to interact with and explore their unusual kinematic behavior.



The Grasshopper flowchart used to generate sliceform templates

We then talked about bistability, using the energy hill / energy well analogy drawing on ideas about potential energy and kinetic energy which the students were already familiar with. Demonstrations with a flexible ruler bent by an elastic band were used to make the concept more clear, before moving on to the main focus of the activity: getting each student to assemble their own collapsible, bistable sliceform structure.

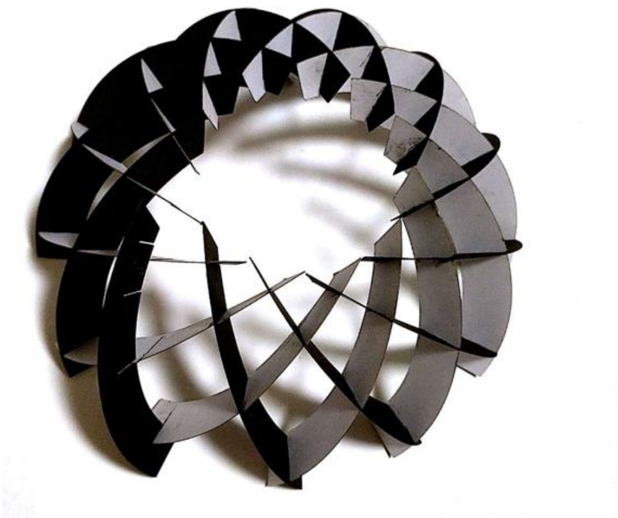
Prefabricated kits composed of two sets of card pieces cut out using a laser cutter were distributed, with the two types of piece (ones leaning to the left and ones leaning to the right) were colour coded to make instructions more clear.

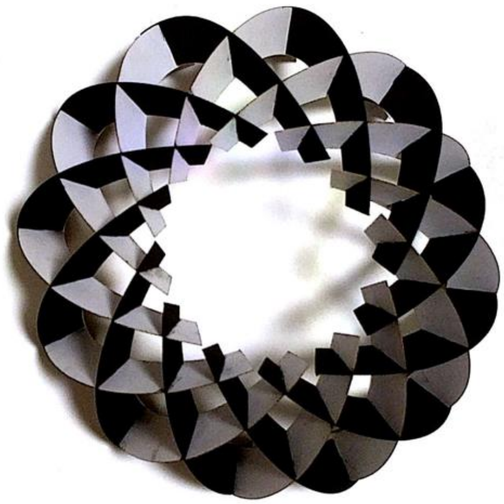


Example slide from the assembly instruction set

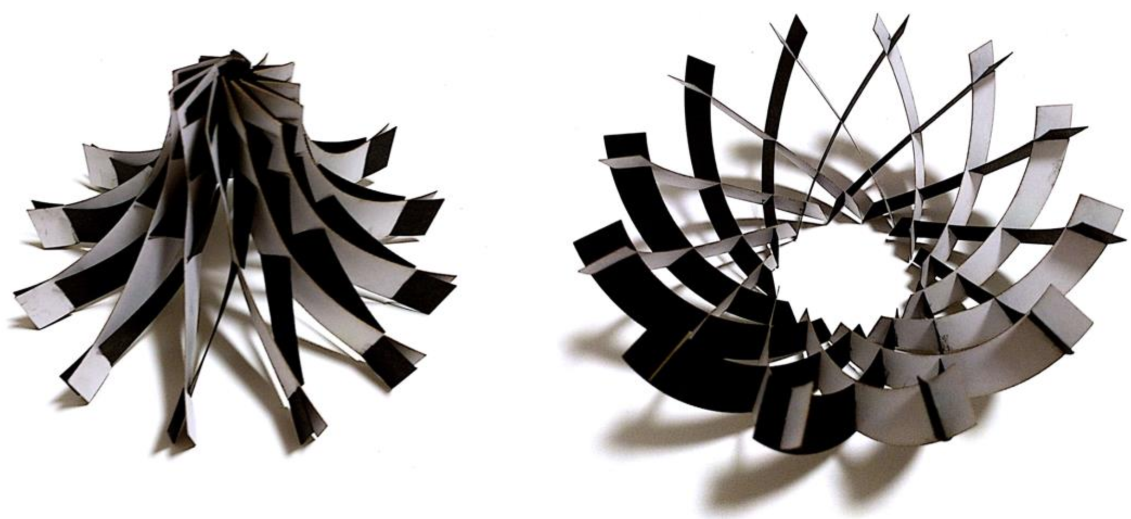
A step by step slideshow showing the assembly method walked the students through the fairly tricky assembly process, challenging them to spot patterns in the process and explore different ways to slide the pieces together.

A significant variation in the speed at which students completed the task was apparent, but thankfully the faster students were in many cases able to help the slower ones, resulting in everyone managing to complete the task in the allotted time.





Having assembled their sliceforms, their ability to invert and ‘pop’ between two stable states was demonstrated, much to the students surprise, and a few minutes were allowed for them to play with the devices and consider how they worked.



The two stable configurations of the sliceform, which the structure pops between when pressed

Finally, we briefly discussed how the bistable mechanism might work (“there are no elastic bands here, so how do you think the potential energy is being stored?”) before concluding with a short brainstorm about where this sort of behavior might be useful (such as pop-up safety helmets, shelters and umbrellas).

All in all, the activity was successful and enjoyable, applying age appropriate physical concepts and leaving the students with a physical reminder of their day at Cambridge.