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Project Report: The Design and Manufacture of Deployable Sliceform Structures

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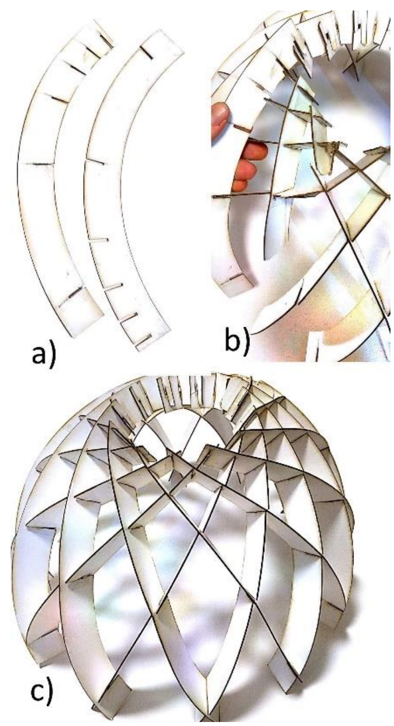
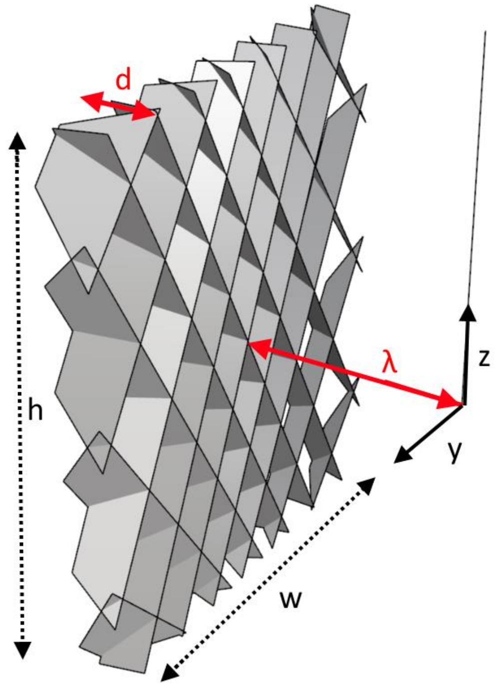
Deployable sliceform structures – structures made with an interlocking array of thin, sheet-like members - have a wealth of potential applications wherever complex curved volumetric designs need to be discretised and efficiently manufactured, in areas as diverse as emergency shelters (for example, pop-up shell structures that are capable of withstanding significant forces from falling debris), personal protective equipment (such as collapsible rigid helmets), and complex architectural form construction. The fundamental concept - replacing a desired volumetric shape with a set of intersecting planar 'slices' that fill its volume with a lattice-style solid array - has the potential to give rise to a structurally sound design form of virtually arbitrary surface geometry that can be manufactured straightforwardly from sheet materials, assembled from pre-cut constituent parts, then collapsed and rapidly deployed when necessary. Such a design would present significant advantages in terms of robustness, deployability and manufacturability over more conventional structures, such as gridshells, reinforced geodesic domes or even accordion-like plate structures.



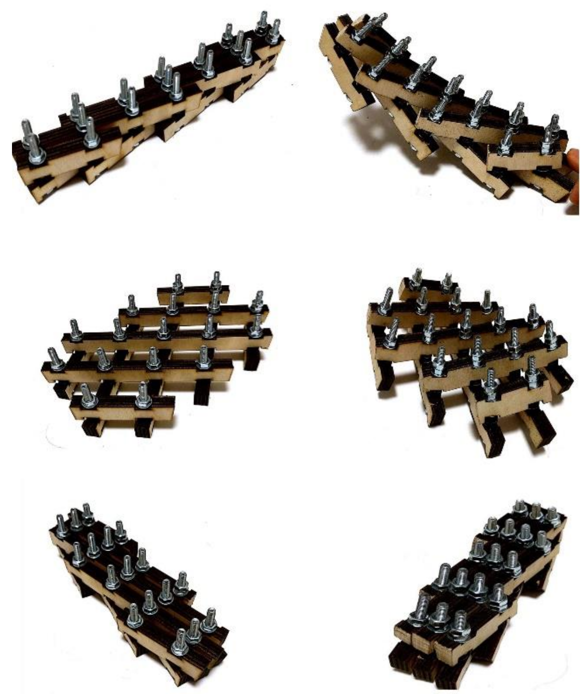


CAD model of the framework designed for planar deployable sliceforms for experimental testing, and an assembled prototype wooden sliceform using offset members

In the past, the geometries and kinematics of these structures had been modelled for thin-member cases, but their structural properties were not well understood, and no successful attempts had been made towards the production of thick-membered versions using engineering materials. The main drives of this project were twofold: first, to attempt to solve some of the major obstacles that hinder the transition from making deployable sliceforms with card to making models with wood, metal or thick plastics, developing design guidelines accordingly, and secondly, to produce prototype physical models suitable for the testing and validation of theoretical deformation models which are still in development.

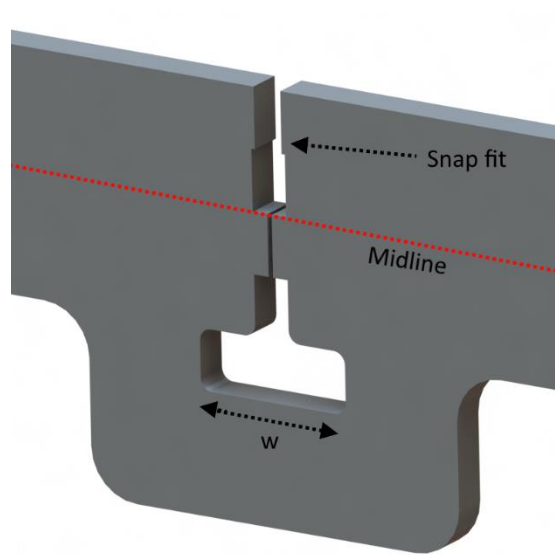
With the help of computer aided design and a significant amount of trigonometry, computer models were developed using a programmable software package (Rhino) which allowed the user to specify a desired shape - such as a sphere - and have the computer calculate the shapes of all the individual slices that would need to be cut out and assembled to make a real, collapsible version of that shape.

The main problem with moving from thin, cardboard structures to thicker, stronger wooden ones was that simply cutting slots to fit the pieces together didn't work. It generated high stresses in the slots that caused the thick wooden designs to fracture when the structure was collapsed.



To overcome this, the way the structures are designed was reimagined; instead of having the pieces slot together and overlap, it was shown that offsetting the pieces (as visible in the photographs of wooden structures here) produced a mechanically equivalent structure, and that by adhering layers of laser cut wood together, acceptably high tolerance hinge joints between the pieces could be easily manufactured, allowing the production of smoothly collapsible, structurally strong designs.

Alternative strategies were developed and demonstrated with thick acrylic structures. These used a 'bridge' structure (see grey slot schematic) to distribute the twist imposed by a structures collapse over a larger length, reducing the stress concentrations and allowing slots to collapse and spring back without damage.



Future work will focus on more sophisticated analytical modelling of the stress concentrations around collapsing slots, and furthering understanding of the deformation behaviors of sliceform structures when deployed.