Final Project for ProEngineer/Tony Barratt
University Of New South Wales
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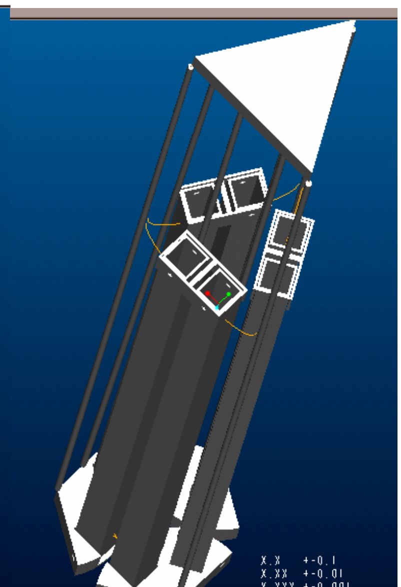
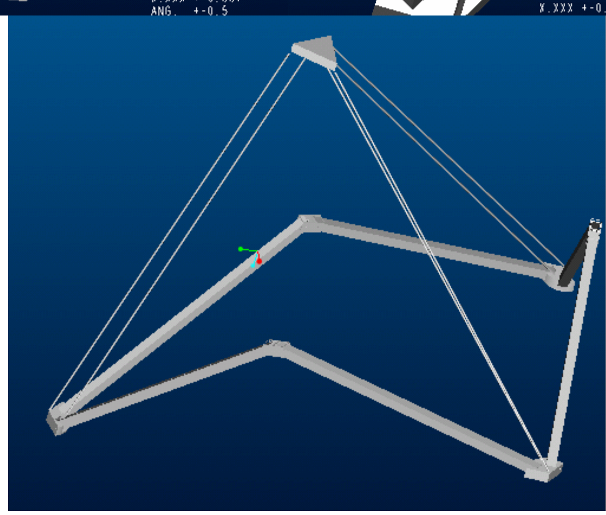
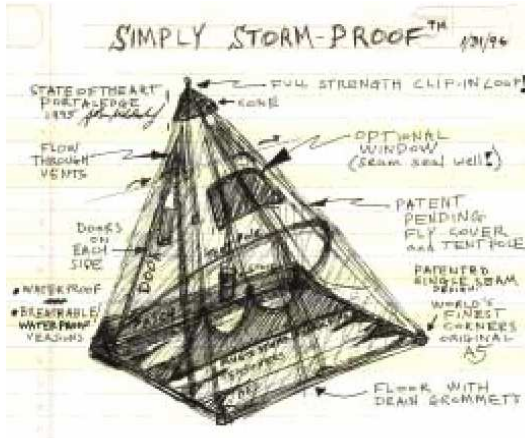




Introduction

For overnight bivouacing on vertical cliffs, rock climbers use a hanging tent system called a portaledge. These were developed in the late 1970's in Yosemite National Park, California, where tall 1000 meter cliffs surround the beautiful Yosemite Valley floor. The original portaledges were homemade versions, often extremely heavy and not very reliable in the vertical environment. Although the original portaledges allowed for more comfort on cliffs, they were not very weatherproof. In the 1980's a company I formed called A5 Adventures advanced the technology of cliff tents to a new realm, and developed strong and lightweight portaledges which enabled climbers to spend the night in fierce conditions. Below are some images of the technology developed then, which is still the current state of the art:



Above: Middendorf's State-of-the-art design, 1996.




Right: the A5 portaledges introduced new levels of ease of use. Setup of the innovative design from packed to fully deployed takes less than a minute.

Above: the two person "Big Wall Condo"1988.

Another innovation was the sheltering system. The sequence shows the deployment of the fly. A5 innovations in weatherproof ledge systems allowed for a rise in international big wall standards.

Fly packed and ready.

Quick and easy deployment.

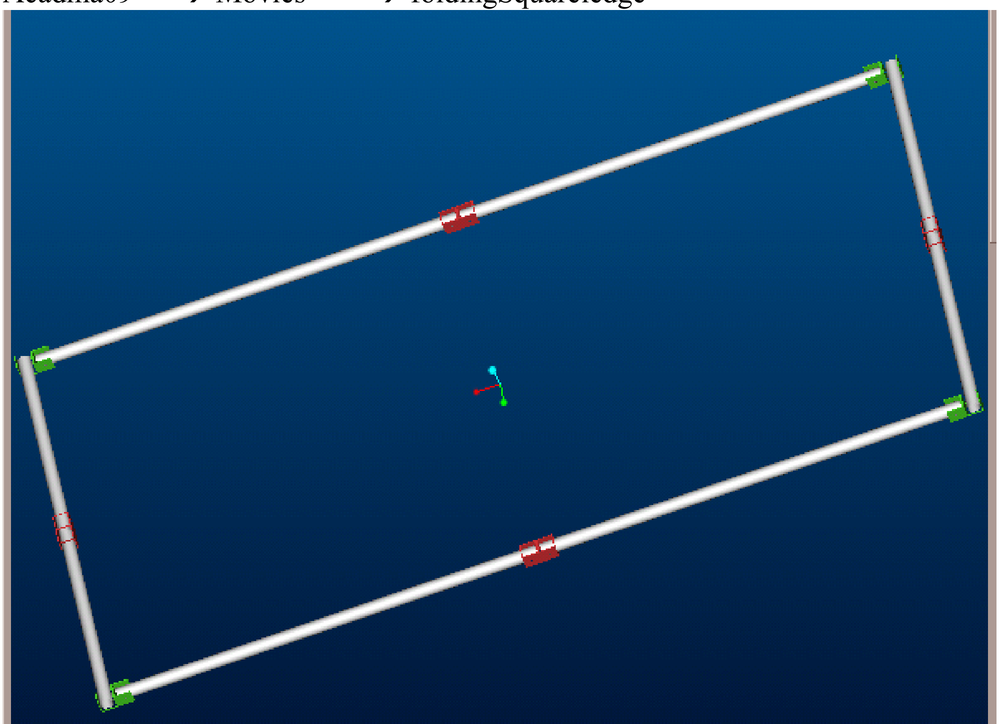
Completely weatherproof hanging shelter.

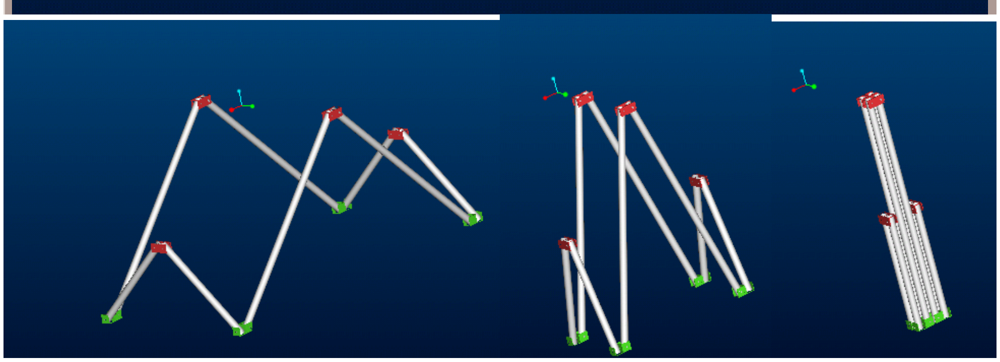
Current hang tent designs employ tubes which are joined by slip fit connections. Although it may only take minutes to set up such a design, it can be difficult if the conditions are windy or dark, as they often are after a long day of climbing. A faster method of deployment, while not sacrificing strength to weight ratio, rigidity, and portability is the next step in portaledge design.

For my final project, I investigated using ProE to analyze folding systems. Ultimately, a folding corner or joint on a portaledge needs to be completely rigid, as winds can lift ledges up in the air. With this in mind, several designs were explored, all of which could be extended and improved by adding a locking mechanism.

The first investigation was in traditional rectangular ledge design. This was modelled in ProE with cylindrical tubes, and two different corner designs: one for the 180 degree joints, and one for the 90 degree joints. This file can be found in the Square Ledge folder, but is exactly the same as presented in the initial assessment of this project. The animation can be found in:

Acadma09 ---→ Movies ------→ foldingSquareledge

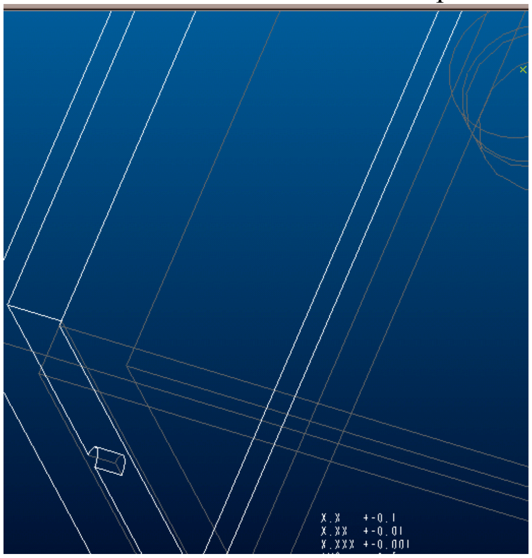


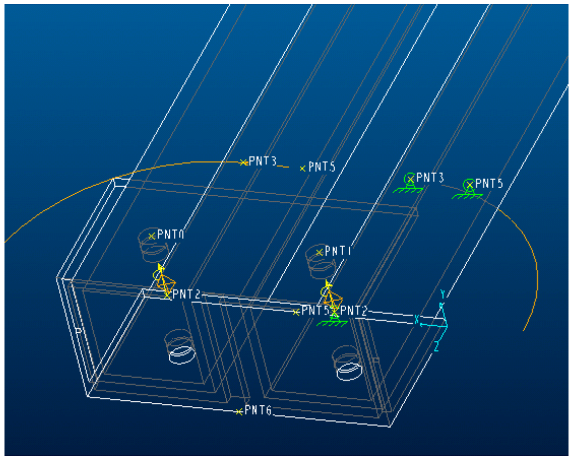


This model used primarily drivers to create the motion and produced predictable results. The main benefit was how it proved the corner and center hinge design was compatible with a closed loop system of tubing.
This project can be found in Acadma09--→SquareLedge--→folding.asm (English units in model.) To run, simply set up a 5 second run in Motion, and the drivers will do the rest.

Stop-motion Hinge

The next challenge was to model the hinged connections more accurately in real world terms. Unfortunately, ProMechanica Motion has no easy way to set up a stop motion system for when two bodies come into contact. Furthermore, since I was using tubing, the contact procedures in ProMechanica were not recommended. Nevertheless, in order to model my folding designs, I tried many possible alternatives. Below are two avenues that did not pan out:





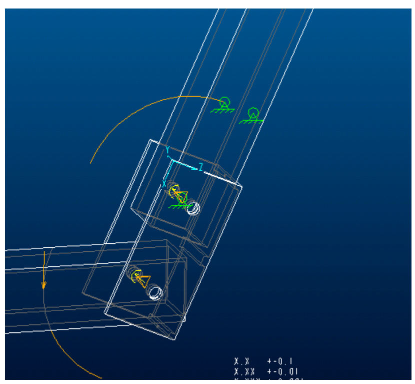
Above Left: using a contact point to measure when the square tubing comes into contact with the hinge. Right: using slots: the idea here was to measure the positions of the points in the slot and have forces applied to stop further travel of the tubing when it came into contact with the hinge. Unfortunately, although I could get these systems to run in simple models, both these methods resulted in major problems when I tried to run them in Mechanica in models that had a total of 18 connections.

TEST.ASM

Going back to the basics, I spent some time working on a single hinge to see what would work most reliably in my complex final model with 18 connections and 4 closed loops.

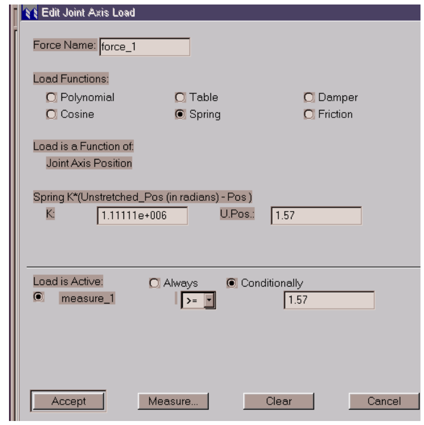
Operation Instructions: Inside the TriangleLedge7 folder is an assembly called "Test.ASM". This assembly was used to look at how a single hinge operates. To use, zoom into the lower hinge mechanism and run in motion.

The method I found that most accurately modelled a real hinge was to use springs that became active when the tube reached the end of its designed travel. In addition to two springs for each pin connection (modelling an axle), there were two spring loads for each end of its intended travel.



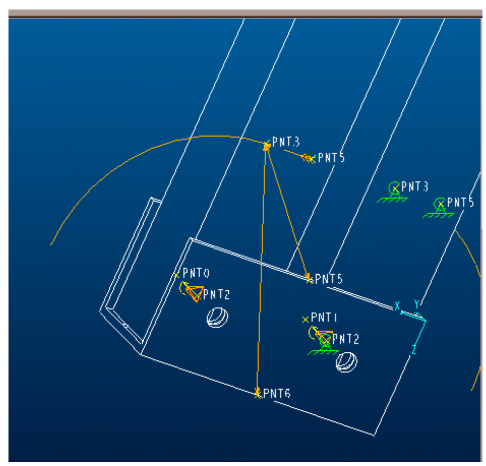
A movie file can be found at Acadma09→movies→hingeonly

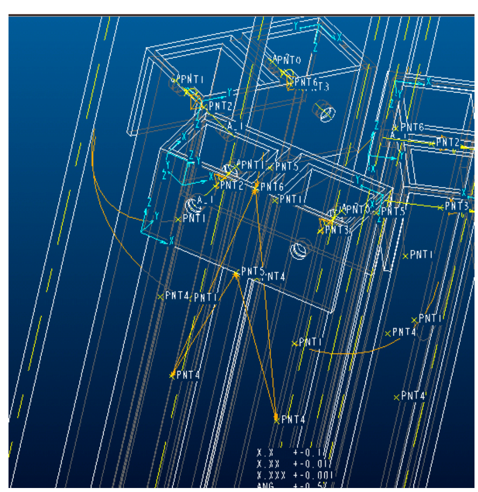
Test.Asm (continued)
The spring loads were based on the measure of the joint axis of the hinge. I was able to identify two types of hinge joints, which I called Type A and Type B, depending on which way the axis was defined and which way the hinge operated. Three loads were applied to each joint axis: A damper with 1111N (Note: I tried friction, but again, because of the complexity of the final model, I was required to use an explicit solver which disabled the use of friction in the model.).



For all hinges, K was set at 1111111N when activated. For type A hinges (Hinge axis pointing inward to the screen, rotation of tube from top to left), a joint spring load with an unstretched position of 0 became active when the joint measure was LESS than 0. The second joint spring load became activated when the joint axis measure exceeded 1.57 (pi/2), and had an unstretched spring position of 1.57. For type B hinges (hinge axis pointing into screen, rotation of tube from top to right), the first joint axis load became active when the measure was GREATER than 0 (unstretched position=0), and a second joint axis load when the joint measure was less than -1.57 (Upos=-1.57).

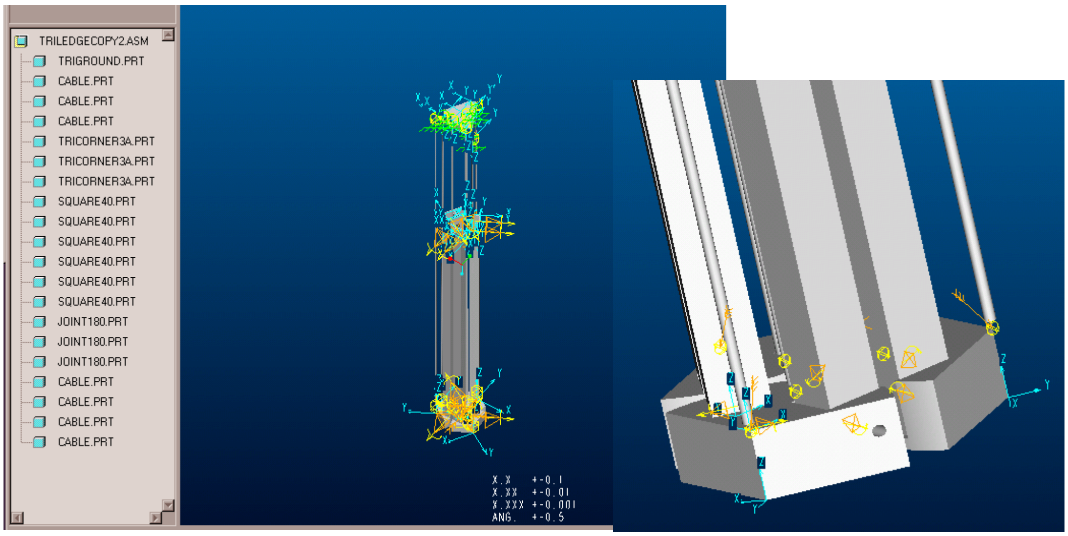
I was also able to successfully model a locking mechanism by adding point to point loads from the hinge to the tubes which became activated when the joint axis was equal to 1.57. I experimented with the range in which these point to point loads became active to enable the most realistic stopping of the hinged tube when it met with the solid parts of the hinge, but many workarounds seemed to result in erratic behaviour. In the end, the three joint load model (damper, and a spring for each end of travel) was chosen to model the hinge. The only problem was the rebound effect that takes place when the tube exceeds its range activating the spring load, and sends the tube out again with more momentum that could be realistically expected. Damper loads and friction were both used to damp out this motion, but in the end, only a damper force was employed as only the explicit solver could process my final model with 4 closed loops and 18+ connections.



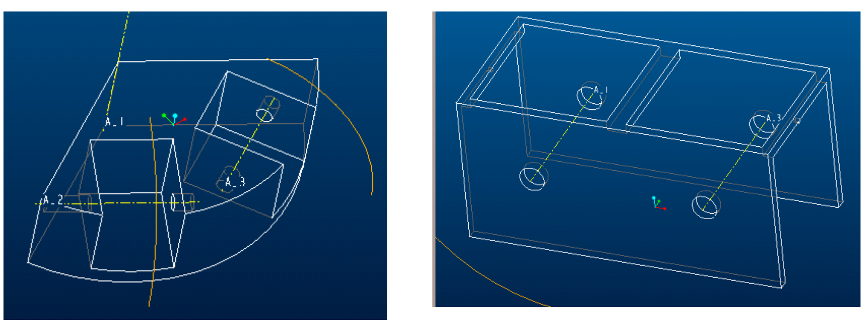


Final Model: Triangle Ledge

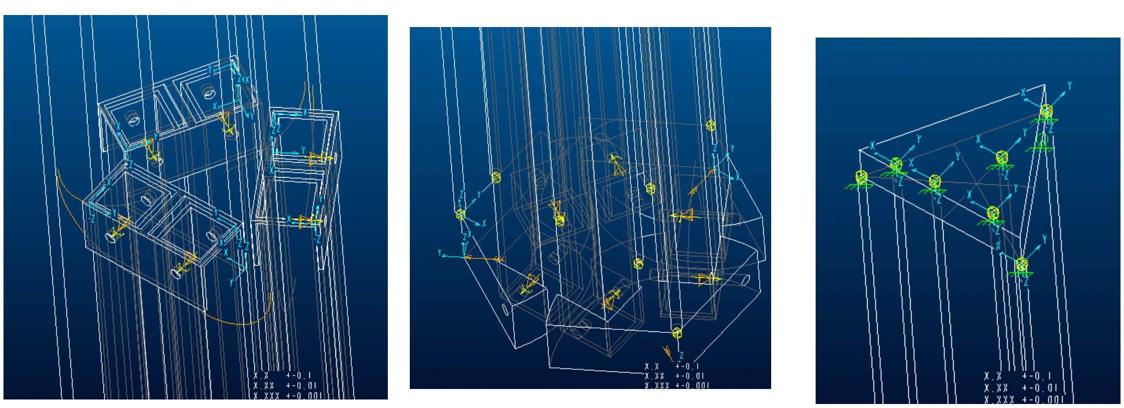
To access, make sure to set the <u>working directory</u> to the folder TriangleLedge7. Then, open TriangleCopy2.asm. Switch to Mechanica. English units are used.



This model uses six 40 inch square tubes, three 180 degree hinge connections, and three 90 degree connectors which angle each tube at 120 degree spacing (the “tri corners”). In addition, the suspension is modelled as cables. Originally, just one cable was used to each tricorner, but I found better results if I added a cable to each tricorner to stabilize the rotation of the tricorners. In the end, I used two for each tricorner, and one had an additional cable to prevent spinning.

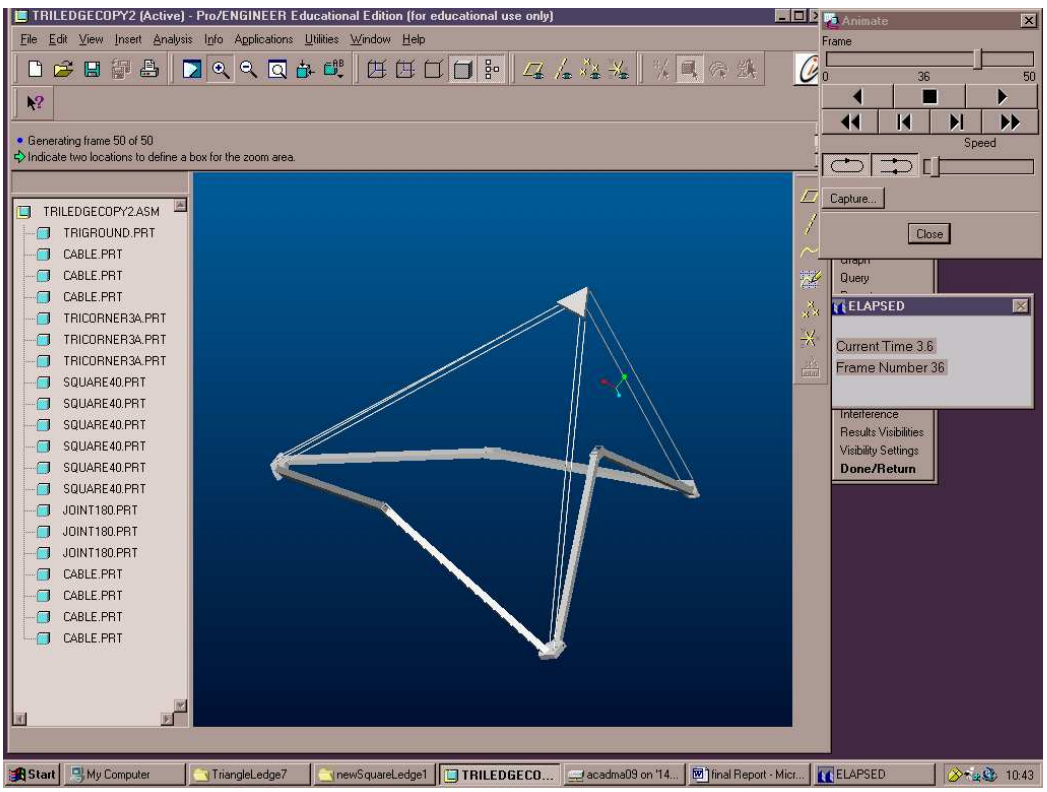


Above: Hinge part designs. Below: Design Details of TriLedge



A great deal was learned from the many Mechanica Motion runs with the model. Without the added cables, the design would often “lock-up” due to the non-rotation of the tricorners (it is necessary for proper unfolding that they essentially remained fixed in their original axis plane for the unfolding process). If no loads were applied, but with gravity, the tubes would simply fall over and hang upside down from the cables. This is what one would expect in real life.

The model enables further experimentation. In the end, I found that applying a initial outward load to the three tricorners would result in the most realistic unfolding behavior. Downward loads on the top 180 degree hinges were applied as well. The model can be manipulated further to investigate how various loads applied while being unfolded affects the outcome of folding. Because of the rebound effect of the springed corner workaround, the model never quite attains stable equilibrium, as one or more tubes will oscillate endlessly. Of course this could be overcome by applying friction, but that necessitates the implicit solver. This model is complex because there are 4 main closed loops for the program to solve. Any force on a particular point affects the rest of the model, and will have a return effect on the point of origin from 4 different closed loops. Further experimentation would involve varying the damper loads as well as the other variables involved, such as the accuracy, time step, material properties, etc. Movie file at: Acadma09→movies→TriangleUnfolding.



SUMMARY:
A great deal was learned from modelling in Mechanica. Modelling without the use of any drivers to perform the motion is challenging in Mechanica, and many workarounds must be employed to account for real world behavior. In the end, it gave valuable insight into the design process for this future hanging tent design.