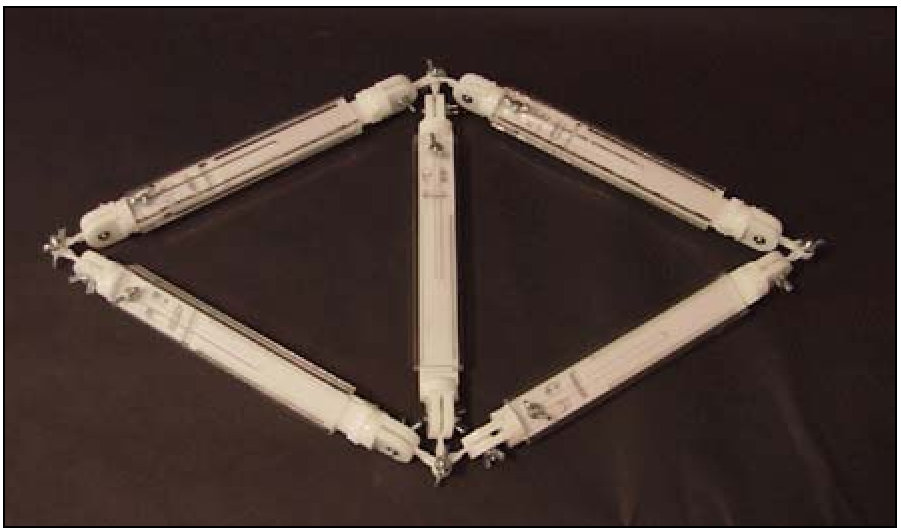
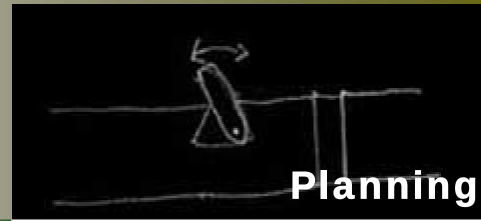
T-C Members

John Mayfield

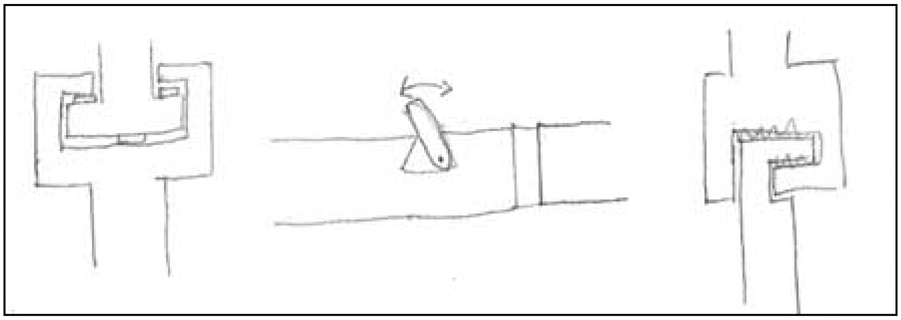
T-C Members are individual truss members which, when loaded, indicate mechanically whether they are in tension or compression. They can be assembled into complex 2D and 3D trusses. They are intended to be used as a learning tool.



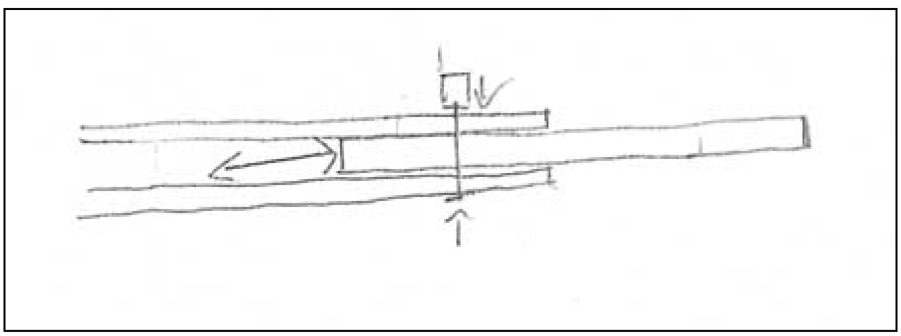
T-C Members



There were several major design problems that had to be tackled in the initial planning phase. I knew what I wanted the members to accomplish, but not how.

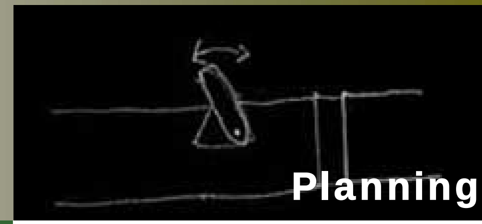


The first problem I set out to accomplish was the problem of the indicator. At this point, the options for what would be indicated, and how, were pretty open. A brainstorm in the DMG provided many options. Some of the more notable ones included using LCDs to create a visible stress pattern on the surface of the truss, using force sensors to measure the precise tension or compression forces in each member, or a simple pair of LEDs that would light to indicate whether the member was in tension or compression. The indicator I eventually chose to pursue was a simple mechanical one—I'm no electrical engineer.

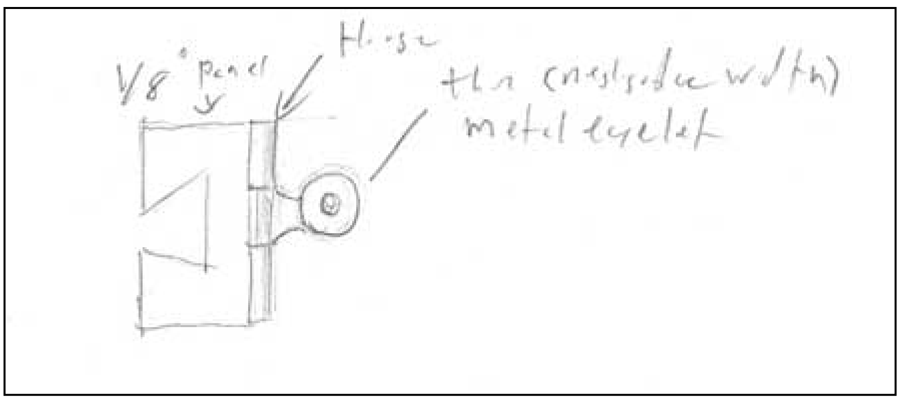


The easiest dilemma to overcome was how to make the length of the members adjustable. I decided to simply make each member out of two pieces, with one nested in the other, and some means to tighten a sliding connection between the two.

T-C Members



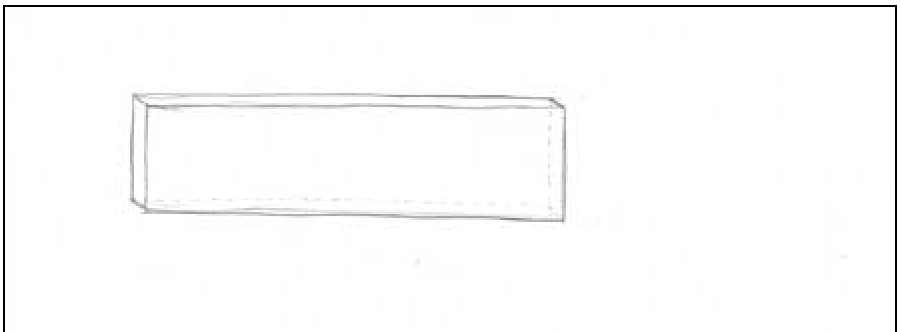
The most difficult issue to overcome is one that is still not solved to my satisfaction. How to connect the truss members to each other. The best way I could think of to join a variable number of truss ends to each other was with a pin connection. There would be some small variations due to material thickness, but nothing I though would cause a problem. The problem was in trying to incorporate the allowed ranges of motion for both 2D and 3D trusses into my joints.
In the initial planning stages, the unique problems associated with connecting 2D truss members had not yet occurred to me. If they haven't yet occurred to you yet either, don't' feel worry; I'll explain later. For now, though, I was focused on the problem of the 3D truss.

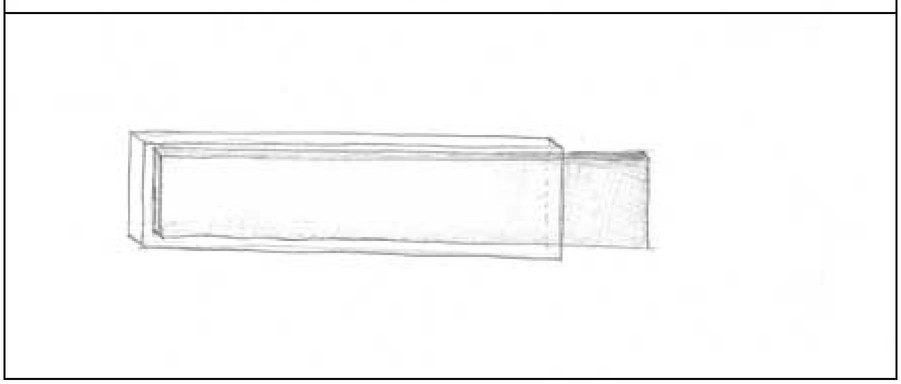


For a 3 dimensional truss, the major problem is simply having enough range of motion to connect at virtually any angle. This could be accomplished with a ball and socket joint, or a joint which could rotate on two perpendicular axes. The pin connection I had envisioned could serve as a hinge of sorts, so all I thought I would need was another hinge.

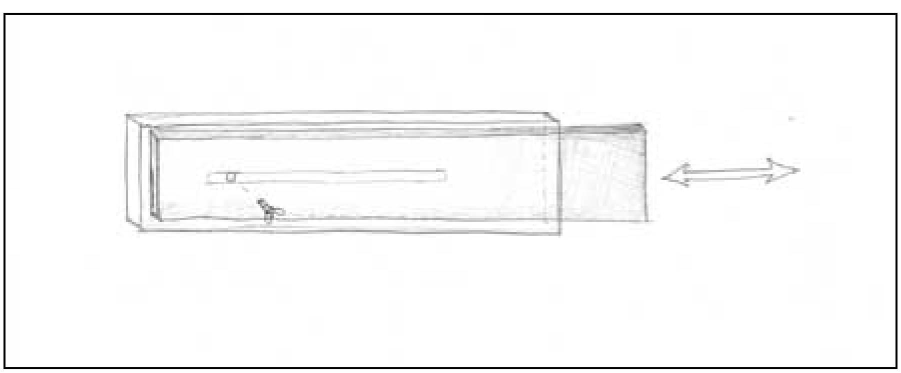
T-C Members

The first version of the kit was designed rather quickly and haphazardly. It was, in reality, a single prototype truss member with which I attempted to address most of the issues I had foreseen in the panning stages.





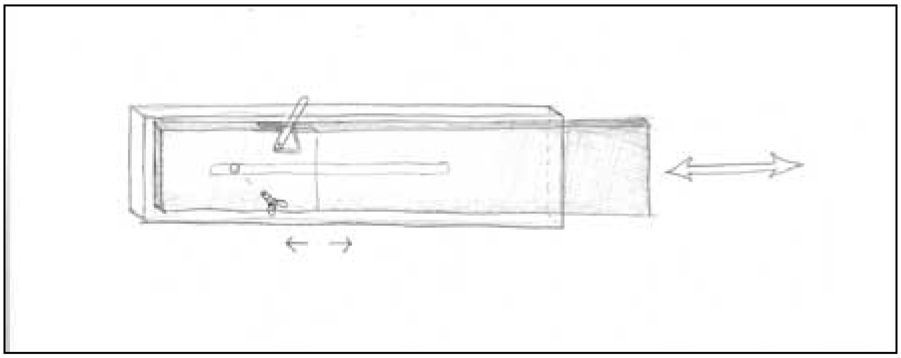
The basic design was made up of roughly 12 pieces of plexiglas which would be glued together to form the three major parts of the member. The first part was essentially a clear plastic sheath—a box with one open end. The other two pieces acted, for the most part, as a single piece contained within the first.



T-C Members

John Mayfield

To allow the length of the member to be adjusted a hole was cut near the inside end of the interior piece, and a channel cut in each side of the outer shell. By inserting a piece of threaded rod through the channels and hole the inner piece could now slide freely within the outer. By adding wing nuts on either side of the threaded rod, the connection could be tightened, holding the member at a specific length.



Remember how I said that the inner piece was actually two pieces? Well that's where the indicator comes in.

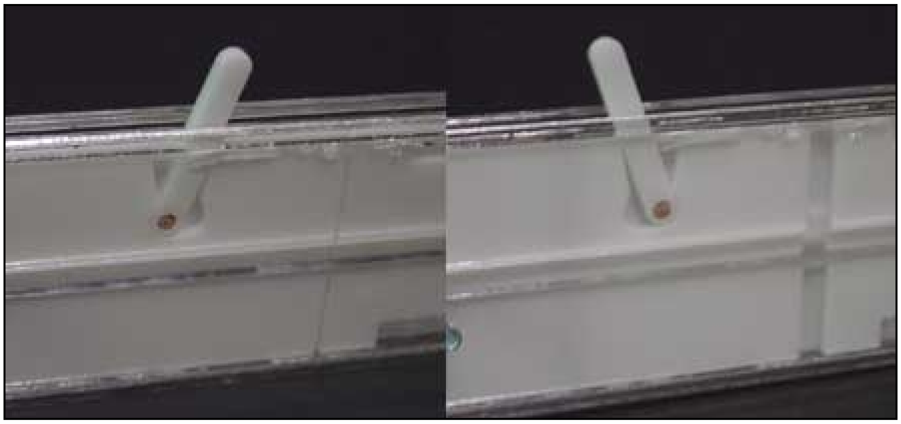
The inner piece was not only two pieces, but two pieces with two layers each. One side incorporated the length adjustor pin, and the other side stuck out the end of the sheath. Where they met, each side continued as only one of their two layers, creating an overlapping indicator zone.

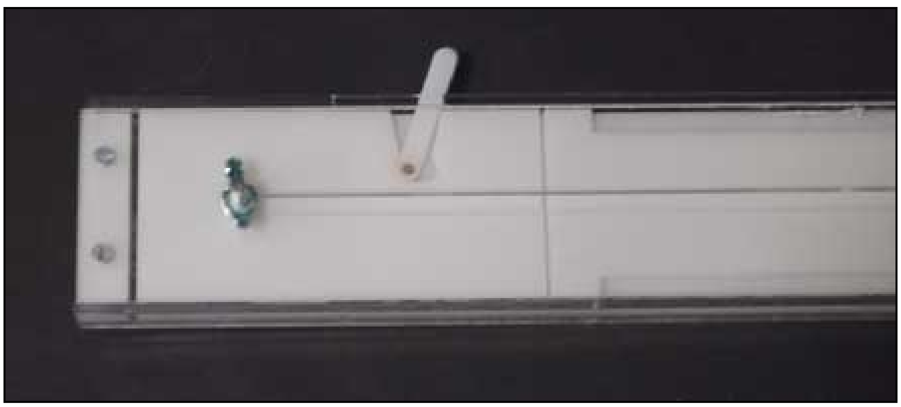
Now, remember that the only thing keeping the length of the truss constant is the tightened wing nuts which are now only affecting one of the two pieces. The other piece, though it overlapped the first, could slide freely to some extent. It's movement was restrained only by a dowel which extended from a small hole in the it's rear layer into a cavity in the front layer of the anchored piece. It could slide around, but only within the range of about a quarter inch.

By adding a small indicator stick, pinning the dowel through it, and contouring the cavity of the front layer correctly, I was able to create a sort of switch. When the non-anchored piece was pulled on, it would begin to be pulled away from the anchored one, but would be restrained by the dowel. As the dowel moved, it would pull the bottom of the indicator stick back and forth. By keeping the top of the cavity small, I insured that the top of the stick, projecting out through a channel in the sheath would move back and forth in the opposite direction.

It worked well, and with a very satisfying click.

T-C Members





The connector on this prototype was a simple hinge made from a picture hanger. It did not work well.

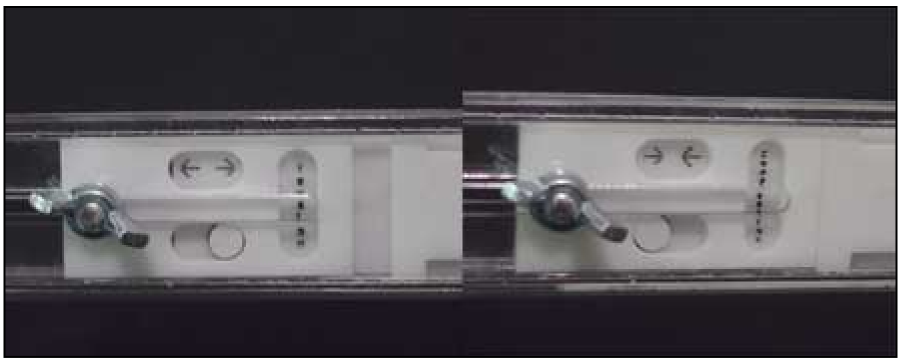
T-C Members

John Mayfield

When comparing the latest version of the kit to the first version there are three major differences that should be noted.

First, and perhaps most readily recognizable, the members are smaller. This doesn't really mean much in terms of how the members function. It was simply a choice I made to make the trusses easier to handle and to conserve materials.

The other two changes were almost total redesigns of the hinge and of the indicator.

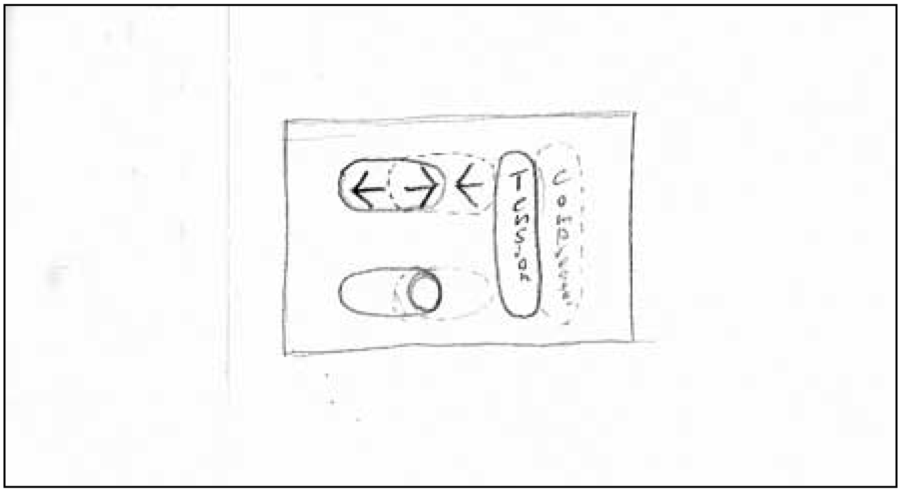


The indicator change was an attempt to make that part of the member more rugged. One of the intermediate steps between the early version and this one was the miniaturization of the early indicator switch. I found that the change in size made certain parts of the assembly too fragile to hold up under stress.

The new indicator was made to be simpler, as well as completely internal.

T-C Members

Latest Version



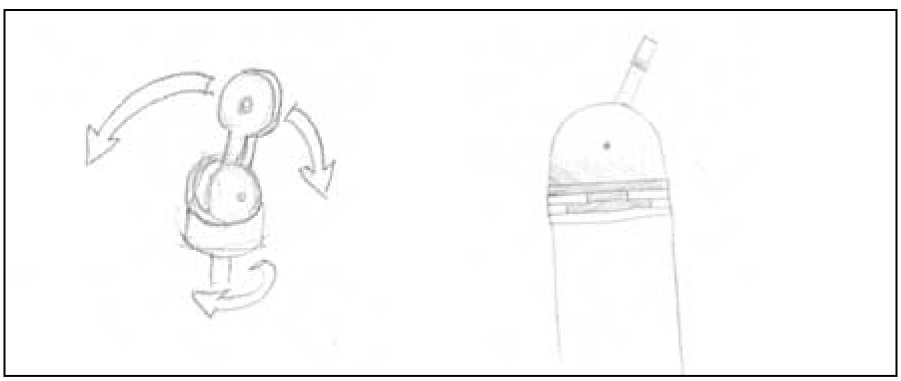
Similar to the first version, the most recent connector is made up of two overlapping layers. One is connected to the anchored interior piece and the other to the unanchored interior piece. The rear layer has a pattern of text and arrows which is revealed in certain combinations as the front layer slides back and forth against it. When the two ends of the member are pulled apart, two arrows pointing away from each other are revealed along with the word “Tension.” When they are pushed together you will see two arrows pointing in towards one another, along with the word “Compression.”

The arrows and text are laser-cut depressions which were wiped with India ink to make them more visible.

The hinges were a more complex problem. I needed to achieve greater range of motion and actually, I had to restrict motion to some extent.

T-C Members

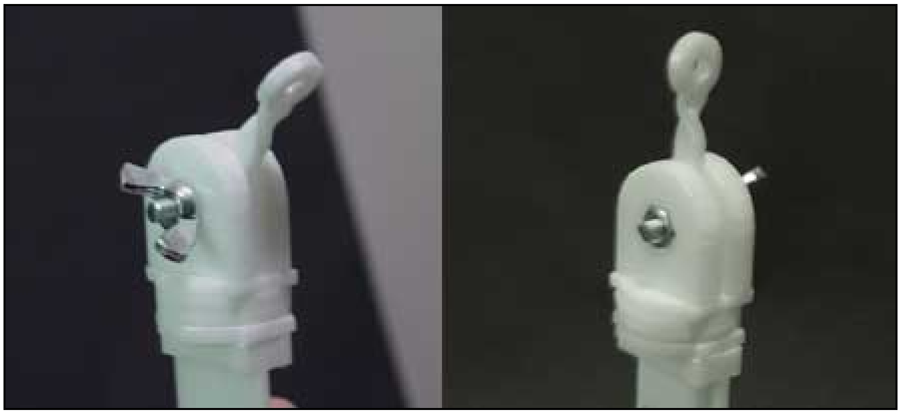
It may not be immediately obvious why you would need to restrict range of motion of the joints in a truss system. The point of a truss is to have all those inherently stable triangles keep the stresses in the members. Unfortunately, what I learned while experimenting with magnetic connections (which besides this difficulty, also proved to be too weak) was that when 2D trusses, which are normally flat pin connections, are given full 3D range of motion, they will often buckle sideways when the truss is loaded.



So I had to find some way to create a joint with a full, yet controllable range of motion. One of the new joints I had envisioned was surprisingly easy to adapt. Based loosely on the furniture caster, this joint would consist of a twistable, swiveling base, and a simple pinned hinge.

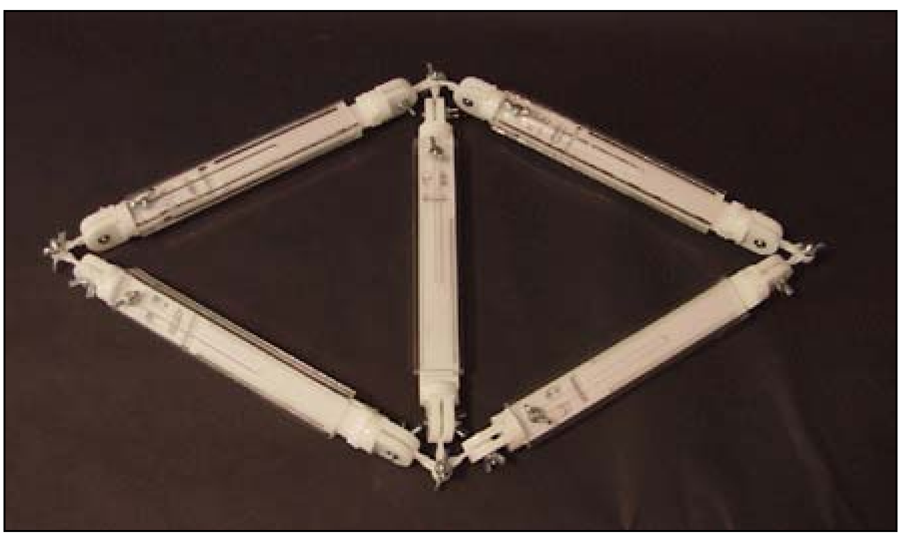
The swiveling base was created using six pieces of plexiglas, in four layers, glued together into two pieces. All the pieces are either discs or rings, and are situated such that a large disc is held, via a small disc, below a tighter ring. This allows the two ends to twist independently without allowing them to separate.

T-C Members



The upper hinge is simply a bit of threaded rod through four layers of plexi. By adding a wing nut, to one end, and embedding a bolt in the outermost layer of plexiglass on the other, this hinge can be tightened to restrict movement. The answer to that range of motion problem.

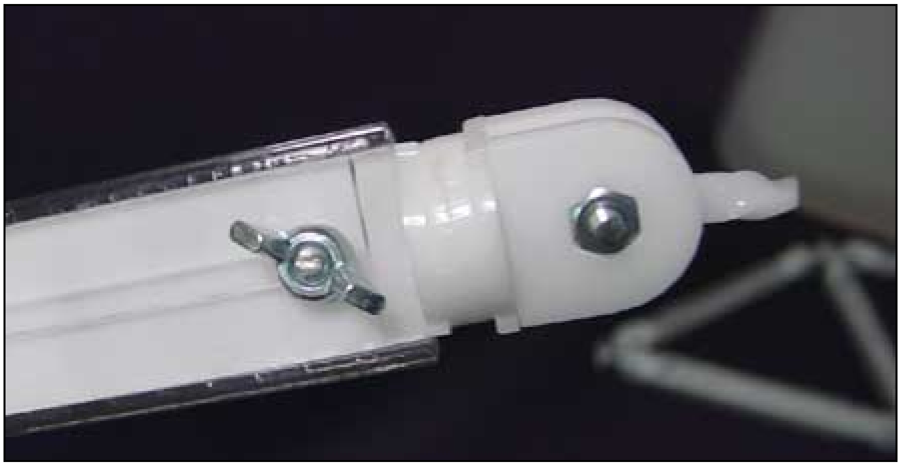
In case you're wondering about that twist, it is necessary to be able to alter the plane on which the ring sits. Without it 3D trusses would not be possible. It was achieved by hitting that piece with a heat gun, then bending it with tweezers.



So now, by properly aligning the hinges, and pinning through the holes, it is possible to create 2D and 3D trusses. The hinges are flexible. The members can vary in length. And if you load them the indicators will tell you whether each individual member is in tension or compression.

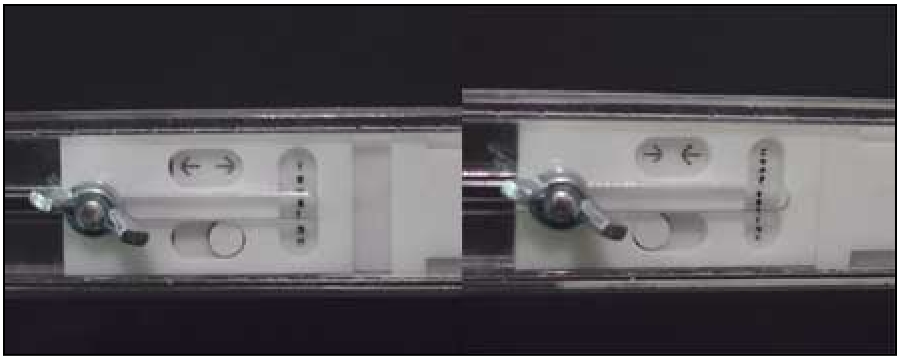
T-C Members

There are, however, a few very prominent problems with the kit as it currently exists.



Perhaps most seriously, and most noticeably, the eyelets of the connectors tend to break off. I am, at this point, unsure if this is simply because of how thin these pieces are, or if it might have something to do with their being melted and twisted. I don't know whether this heating process might have weakened the plastic.

Besides this, the connection process is rather tedious. Putting a bit of threaded rod through several holes and then screwing down wing nuts on either end is something a person can only do a few times before it becomes irritating.



I also feel as though the indicator could be more informative. While it is occasionally unclear which truss members are under tension and which are under compression, figuring it out is not too difficult in most cases. If it were possible for the indicator to show *how much* force was traveling through each member, that might be more useful.

Basically, I feel that the next steps in improving this kit should make the members easier to use, more rugged, and more informative.

T-C Members

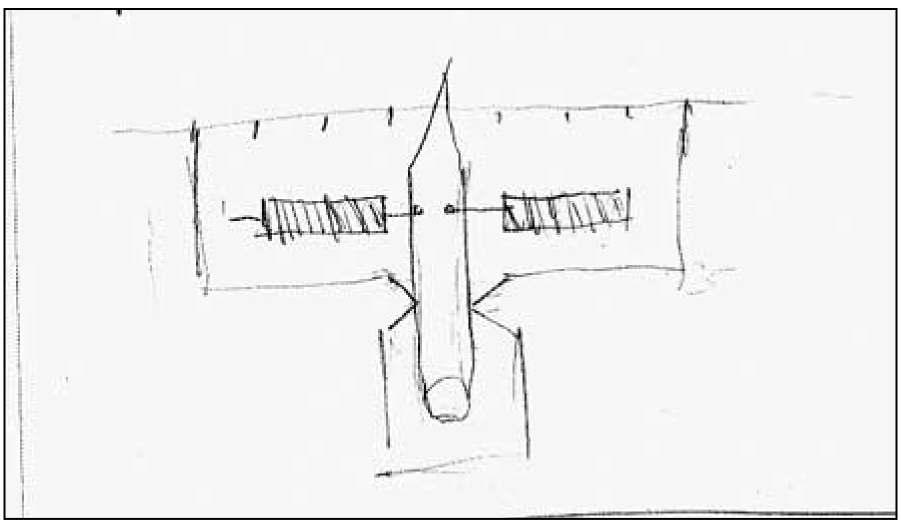
I think that the biggest problem, the fragility of the joints could be solved by simply making them out of a more rugged material, such as metal. Considering the change in material, it might also be possible to change the form of the joints to make them easier to use.

One of the better joint-making websites I have come across is http://www.montereymotiongraphics.com/armatures/index.html. It is intended to teach people to easily create ball and socket joints of adjustable tightness for puppet armatures. Similar joints could likely be employed for our purposes as well.

Another benefit to joints like this, besides their sturdiness, and ease of use, would be that they would be able to keep all the truss forces on axis. Because of the way the current joints work, any time they are built into a 3D construction, they must be bent such that the connection happens off the line of the truss member. The above ball and socket joint could, instead of simply bending in one direction, fold back on itself, keeping the forces aligned.

T-C Members

The problem of how to fasten the truss members together is still a problem. The current eyelet and pin method works, but it would be nice if it were less tedious. This might just be a matter of redesigning the pin. Perhaps, rather than a threaded rod and wing nuts, one could use a pin with a head on one end and a rubber cap on the other. This, while still not totally ideal, would allow the connection process to be completed in a fraction of the time.



As to how to make the indicator more informative, I am at a loss, I'm afraid. The two best methods I can think of both have major issues. The first idea, the spring scale indicator, would likely cause too much variation in the length of the members, and would be extremely difficult to calibrate. The second method, using pressure sensors, would require some method to power them and a display would have to be provided. Either method—or a totally different one—might be possible to implement if one were to give it enough thought.

Reflections

John Mayfield

I was asked as the last phase of my employment to write some about my experience building construction kits. I'm not totally sure what things I could write that readers would find useful or entertaining, but I'll do my best.

My first experience building construction kits was for my final architectural studio at the University of Washington. It began as a study of systems in architecture, recognizing how virtually every great design could be broken down into a collection of pieces and rules. One of our first assignments was to develop a set of parts that would make up our own building systems. The pieces I developed would eventually become the Diagram Panels kit.

While most of the class worked from their systems of pieces to create complete designs of individual buildings, I was fascinated with the design of the kit itself. Instead of conceptualizing a building, I spent the rest of the quarter refining my 'construction toy.' I made it more flexible, functional, durable, and even more fun to use.

I was essentially working on a totally different project than the rest of the class. At times, this made me feel like something of an outsider, but the class seemed to like what I was doing, and my instructors were very supportive. I was encouraged to do something outside the norm because that was what interested me, and because there was value in it.

Though I maintained my excitement for the kit up through the end of the quarter, I was somewhat burned out on it afterwards. That might have had something to do with the final push. I stayed up three days straight, working with a finicky laser cutter and gluing almost a thousand tiny magnets into place. By the end of it I couldn't focus my eyes, and my hands were numb and covered with crazy glue and tiny cuts. So when it was all over, I didn't bother to put too much effort into documenting the kit.

Later, my instructors approached me with a somewhat vague job offer: do more, similar work and get paid. After a week or two, I had regained my enthusiasm for the kit and similar things, and after discussing the job in not much more detail, I accepted.

My first project was to document the kit I had already built. I built models, took photographs and built a website detailing the kit and it's construction.

T-C Members

After that I brainstormed ideas for other “computationally enhanced construction kits.” There were many kits proposed, but we could only chose one to implement. We chose the kit idea that would become TC-Members.

I began working on the kit immediately, sketching ideas for how it would work, over the next few days. Over the course of about a week or so, I had built the first prototype. It didn’t work terribly well, but it was a good start. The indicator had a nice visceral click that gave me the same satisfying feeling as the magnets in the Diagram Panels kit.

I spent the next couple months investigating ways to improve the design of the member. I enjoyed the individual tasks well enough, but my enthusiasm for the concept was beginning to wane. It was difficult to make myself believe that the truss design kit would have value in the end. My work hours waned with my enthusiasm.

In retrospect this was probably the time to reexamine what it was I wanted to accomplish, and either change the design enough that I could see the value in it again, or simply start a new project. Unfortunately by the time I had realized this, I didn’t think I would have enough time to make a radical change in the project and still finish within the allotted time.

As it turns out, I had a full month longer than I had thought. This month was spent making minor design changes, mass producing members, and starting the documentation. Documenting a kit I saw as a failure was (is) agonizing work.

I learned many things working on these two projects and watching my classmates work on theirs. The most prominent lesson, though, is this: In order to create something great, the creator must believe that the project has value.

I watched my classmates falter when forced to use a system they didn’t understand the value of, and I saw myself falter when I lost sight of the value of my own project. The end result is that my trusses are an embarrassment, but the Diagram Panels kit, which I believed in enough to sidetrack an entire studio for, is something I hope to be able to show my grandkids.

Never lose sight of the value of the work you do.
Or, if you do...change it.