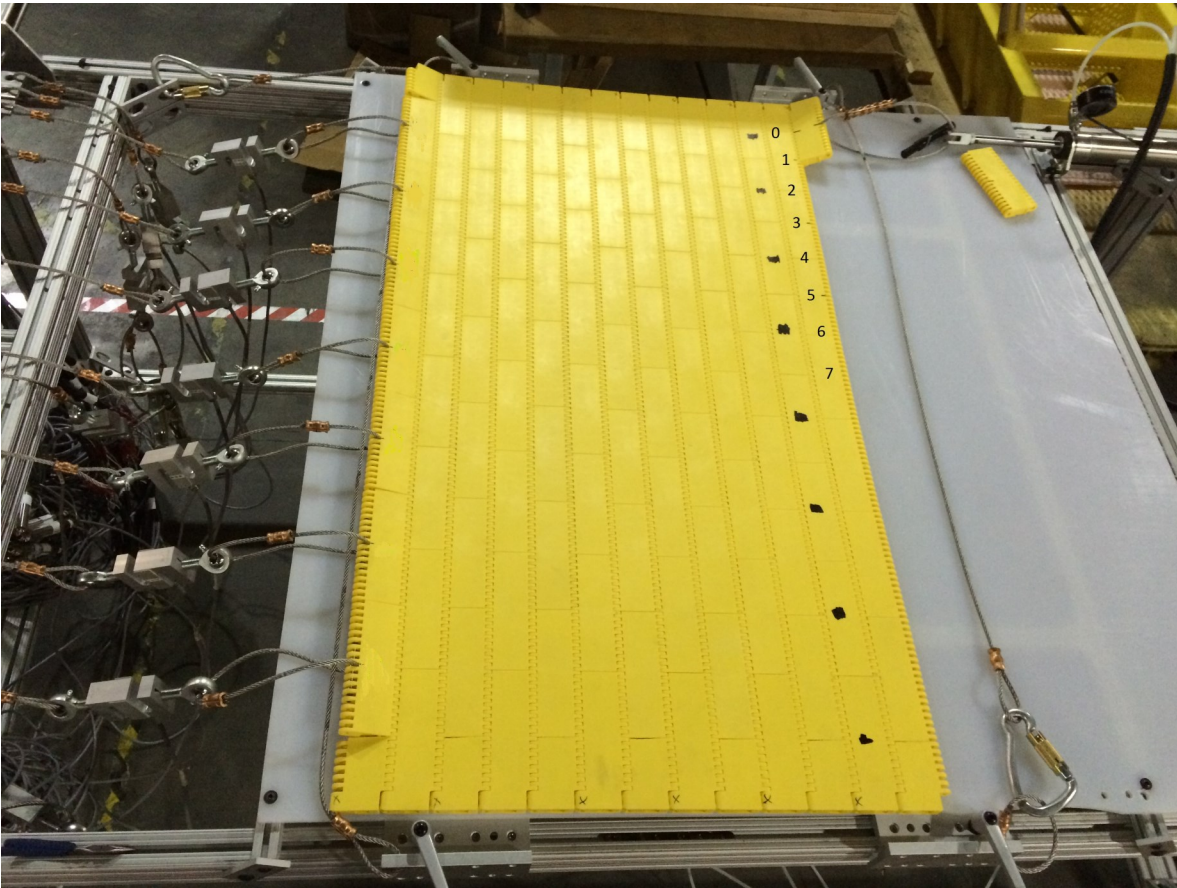

Jack Qiu

Mechanical Engineer

Load Distribution

Overview:

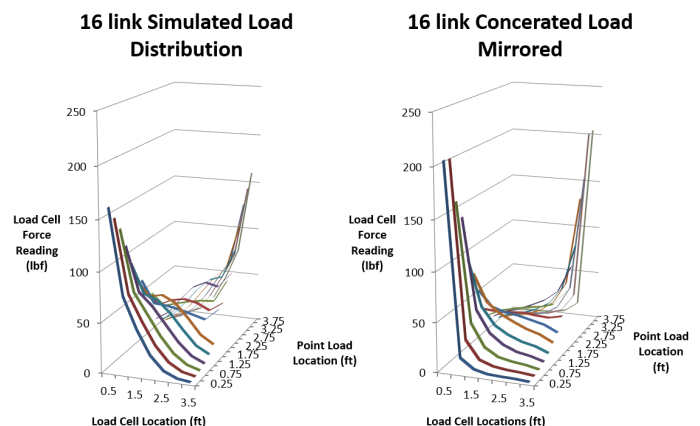
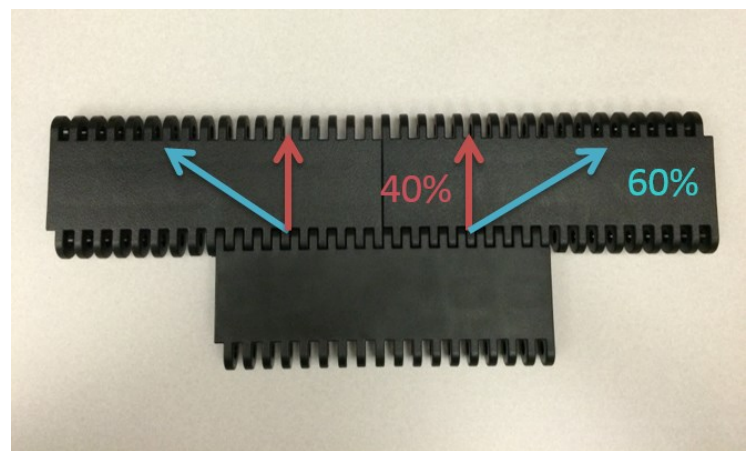
To measure how concentrated loads spread out over modular conveyor belts, I designed a table with a piston and load cells to measure force distribution.



Modular conveyor belts have the advantage that they're easily repaired if one module were to fail. Down time can be minimized, which is extremely important at big plants churning out millions of dollars worth of products per hour. The plastic modules can be thick and strong, suited to each application, but because of the modular, bricklay nature of the belt, force distribution from concentrated loads is limited by the module boundaries and connections. If force from a large concentrated load is not spread out before another heavy load is applied, the forces can stack, and putting a few modules under enough force to cause premature fatigue failure.

This problem can occur in industrial applications with heavy loads such as engine blocks with a few small concentrated contact points with the belt. The forces due to acceleration and static/kinetic friction between the conveyor belt and the wear strip beneath it become concentrated forces that affect just a few modules before spreading out. It is in these situations that force distribution needs to be modeled to give, not just a strength rating for a belt, but also a load density rating for belts, to better suit industrial applications.

In reality, modeling and trying to predict force distribution in between plastic parts is extremely difficult. Depending on how much force a module is under, or in this case how close a module is to the concentrated load, the plastic part strains differently, causing its geometry and force distribution across itself to change. Each row of modules is connected to the next by matching up the links and feeding a nylon rod through as a joint. It is unrealistic to model the force transfers across all of the individual contact points, so I divided each module into two halves and guessed at the force distribution across each module (shown top right with a 40/60 spread). I wrote a Python script to cycle through all percentage distributions, the nested loop calculating forces from the first module with the concentrated load to the last row connected to the load cells.



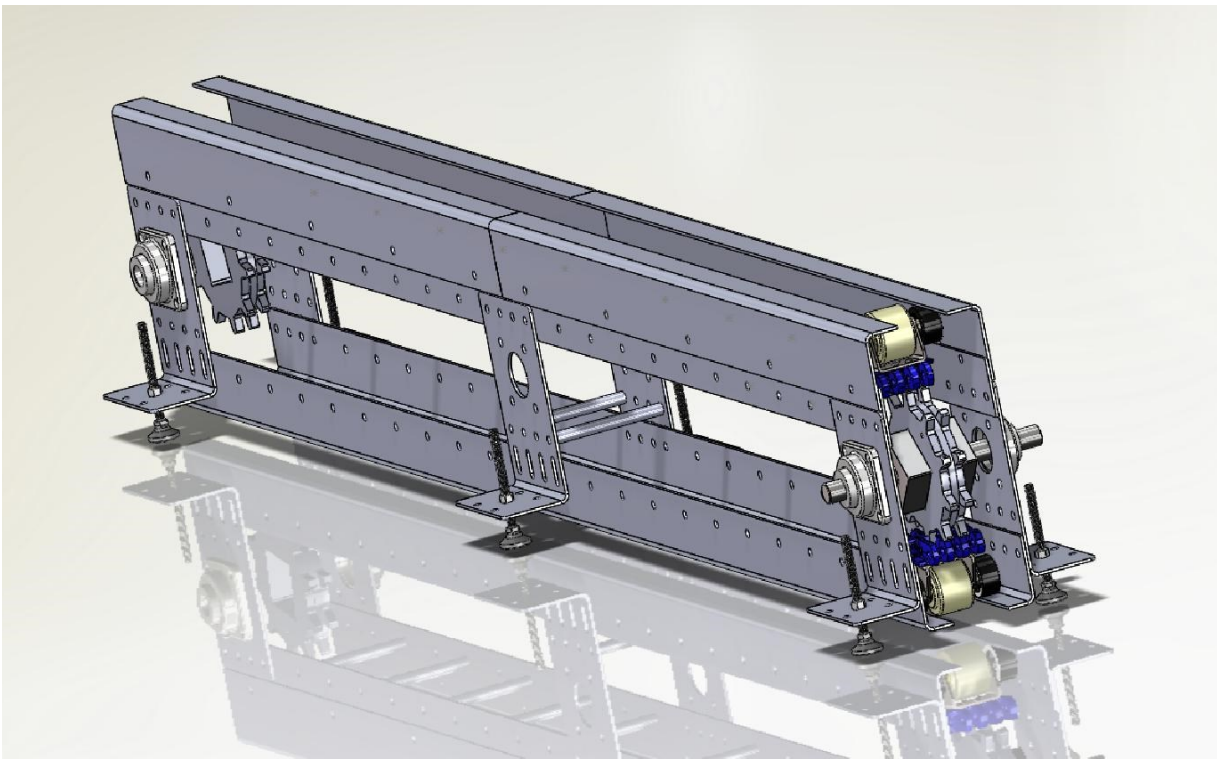
Each iteration of the loop is compared to the measured values, and the iteration with the smallest difference tells the percentage distribution over each module. The two graphs show the force distribution measured, and simulated, for different locations of the concentrated load. The simulation shows the force from the concentrated load being spread out more evenly than in the actual test, but both effectively show that if the concentrated load were to be off center, the force spikes at the edge-most module. To remedy this phenomenon, I proposed that we use patched belts with stiff modules at the center and soft modules at the edges to better distribute forces across belt, and improve belt life.

Skid Conveyor

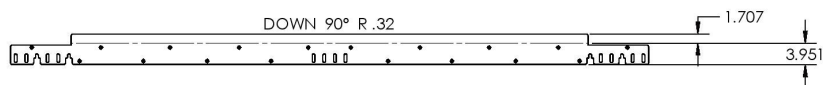
Overview:

To employ a modular belt for an accumulation conveyor we needed a small test section that fit under our customer's size specifications and functioned without stable catenary sag rollers.

In the auto industry, car chasses are carried by skids during painting and other minor processes. The skids ride on an accumulation conveyor on their way back toward the beginning of production lines. Wheels on the conveyor belt allow skids to accumulate if a latch were to forcibly stop skids from advancing while the belt was running continuously. Implementing a modular conveyor belt in this application is difficult because modular conveyor belts do not run under tension. Catenary sag rollers under the conveyor keep the belt engaged with the sprockets by using the weight of the belt to create minimal tension. In this case, however, typical placement of catenary sag rollers would interfere with the trajectory of the belt mounted wheels. I designed a custom solution to use the wheels on the belt as moving catenary sag rollers, with a track underneath the conveyor for the wheels to run on. All this fit within the customer's requirement that the conveyor be 0.5 meters tall.

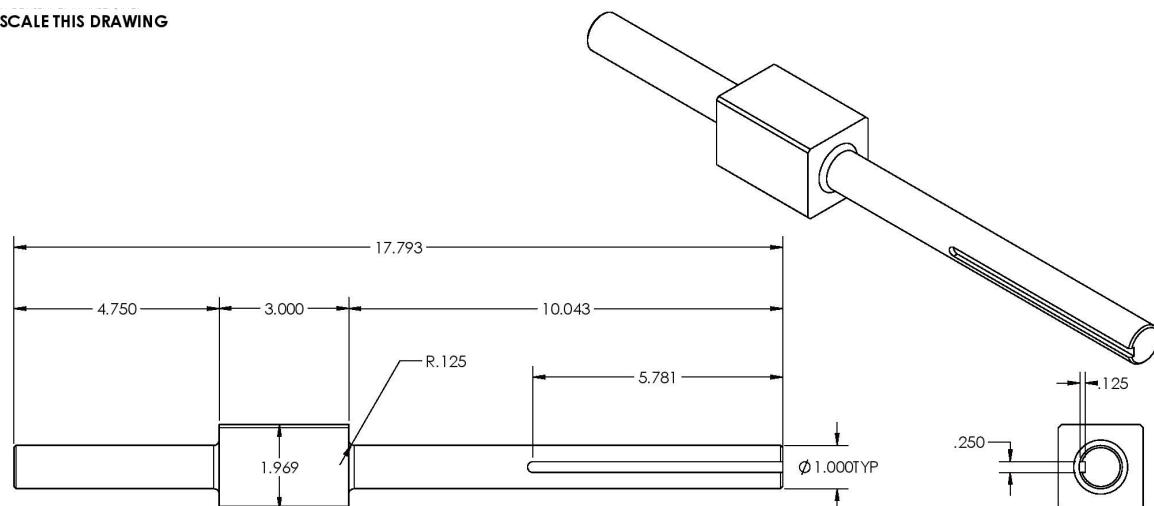


The construction of the conveyor frame is all sheet metal to minimize cost and production time. Hundreds of yards of this conveyor would be implemented so keeping price low is key. All parts are designed symmetrically so that errors are minimized during assembly. Only two sizes of bolts and nuts are used to maximize economies of scale. I designed the parts and assembly in Solidworks 2015 with Solidworks Sheet Metal Tools, and dimensioned drawings and bends according to Laitram Machinery standards. Laitram laser cuts their sheet metal and bends using a press. All holes, cut features, and bends had to be dimensioned and constrained to a reference edge. I prepared pdf drawings like the one below, as well as to scale drawings in .dxf files devoid of dimensions and labels for the laser cutter.



The drive shafts are the only two machined parts of the conveyor. These were designed in Solidworks and dimensioned to standards for Laitram Machine Shop. They were machined from 304 stainless steel square stock, and were compatible with stock conveyor sprockets and bearings. The project was designed based on a report with pictures, memos, and drafts provided by a field engineer who visited the factory of the customer.

DO NOT SCALE THIS DRAWING



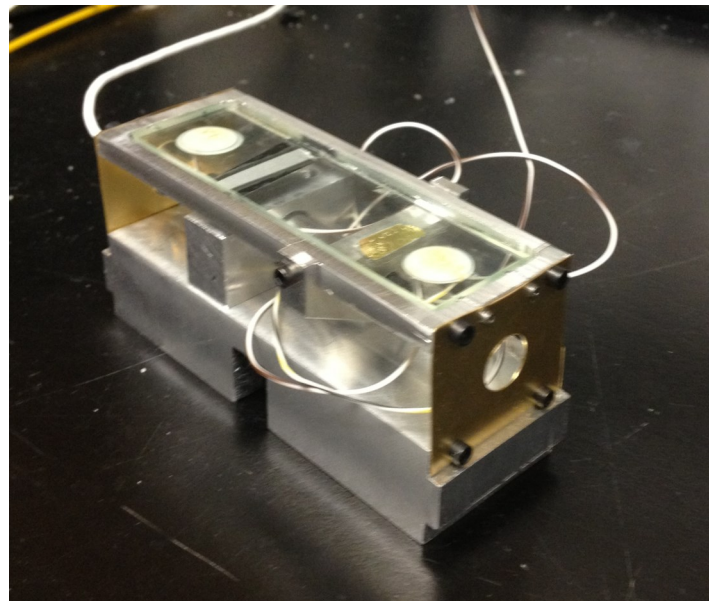
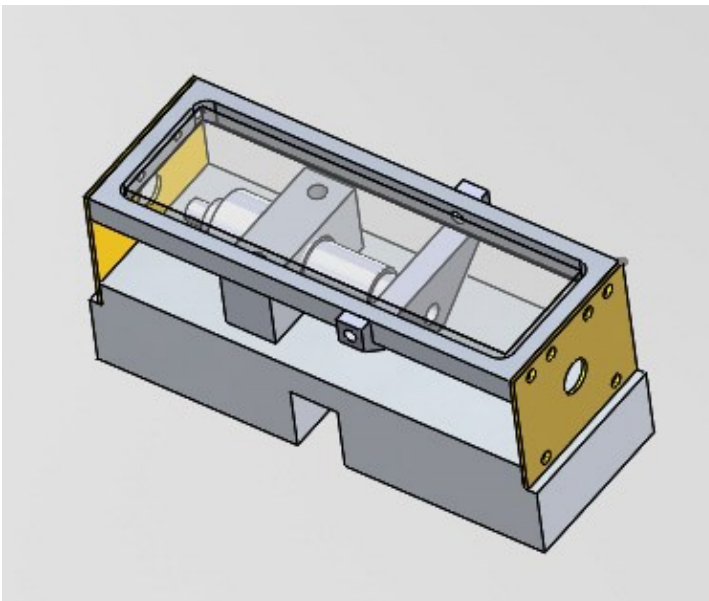
TPad Force Sensor

Overview:

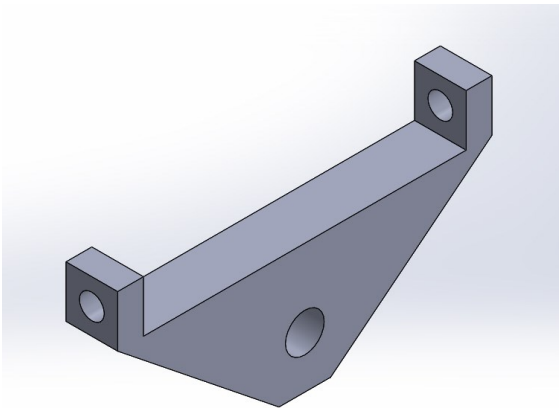
An experiment setup for providing real-time force measurements on finger interactions with a Tactile Pattern Display (TPad) device.

For a research project at Northwestern's NXR lab we had to measure the coefficient of friction generated on a glass surface. Piezoelectric disks attached to the glass are flexed back and forth at over 20 kHz, causing the glass to resonate. If you touch the glass while it is resonating, a squeeze film of air forms between your finger and the glass, causing the friction coefficient to drop. This setup allowed the matching of friction coefficients to specific frequencies fed through the piezoelectrics. This information could then be used to generate textures on the

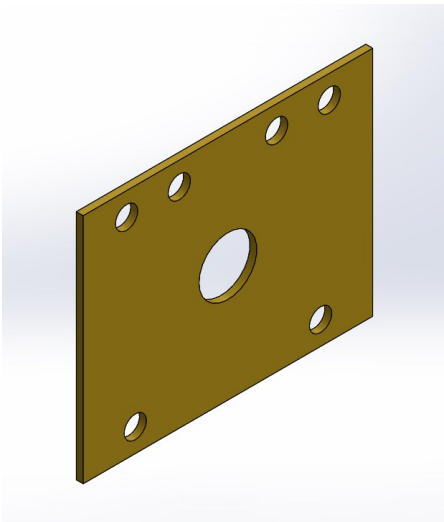
piece of glass. In order to measure frictional forces, the top piece holding the glass had to be able to move back and forth. To accommodate this I used brass sheet metal walls to hold the frame for the glass. The brass pieces would hold against the downward force applied by a finger touching the glass while allowing for tangential displacement resulting from a finger scrubbing along the surface of the glass. Tangential displacement is required to make readings on the force sensor.



While manufacturing the force sensor setup I encountered a number of challenges. For small aluminum parts, the order of in which I milled material off mattered greatly. The small parts of the setup had limitations to how they could be clamped. Aluminum parts in particular are soft and clamping can deform the parts during final milling procedures.



For the aluminum piece pictured on the left, my first operation was to drill the bigger centered hole. It's easy to clamp and drill when the part is still in block form. Also the location and orientation of the hole protects it from deformation during the following machining procedures. I drilled the two smaller holes next for the same reason. Then I used an angle block to mill the two slants. This comes before milling the top slot because if the slot is done first the two small tabs with holes are easy to deform. The slants slowed down manufacturing, but were necessary to reduce weight. The less inertia in the top pieces (glass, glass holder, piece with slants), the more accurate the friction force measurement. Finally the part is completed with one last milling operation for the slot at the top.



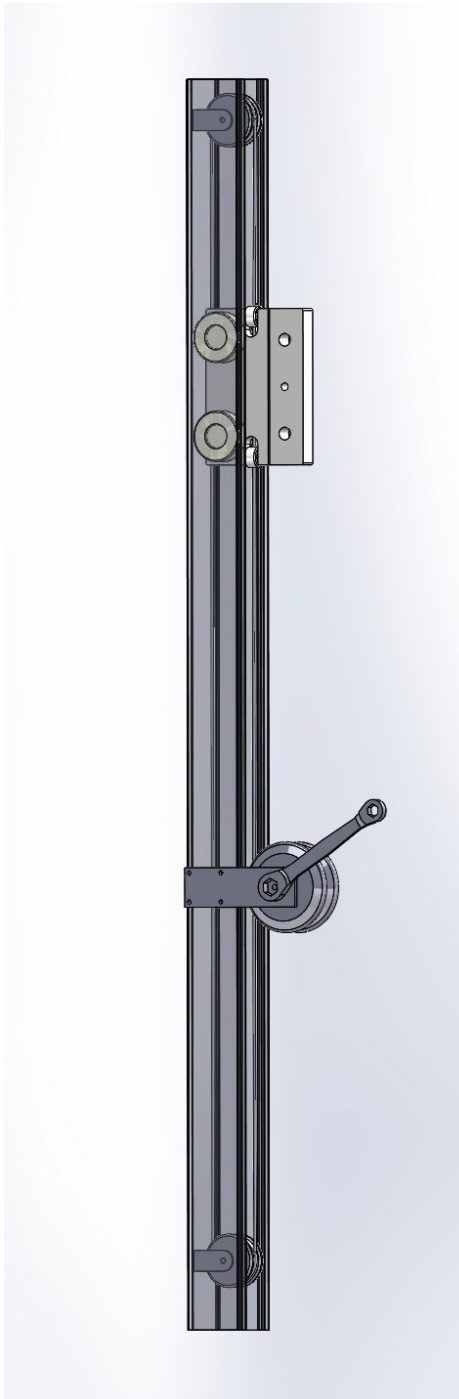
As for the brass sheet metal piece, I made a jig to clamp the brass piece down while I machined the holes.

This force sensor was used in experiments that led to the publication, *Dynamics of Ultrasonic and Electrostatic Friction Modulation*.

The Cranken

Overview:

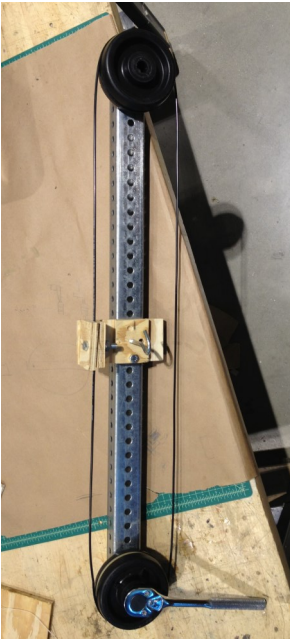
An exercise apparatus that would allow a wheelchair user with limited gripping ability to independently perform resistance training.



For Northwestern's Design, Thinking, and Communications Course (DTC), we had to design an exercise apparatus for a client. Our client was recovering from a car accident in which she received a spinal injury in her C6 vertebrae. She used a wheelchair and could grip some objects through tenodesis, a closing of the hand controlled from the wrist, but not the fingers. Our client expressed a strong desire to exercise independently, so we designed The Cranken to be completely operated by levers she could easily grip.

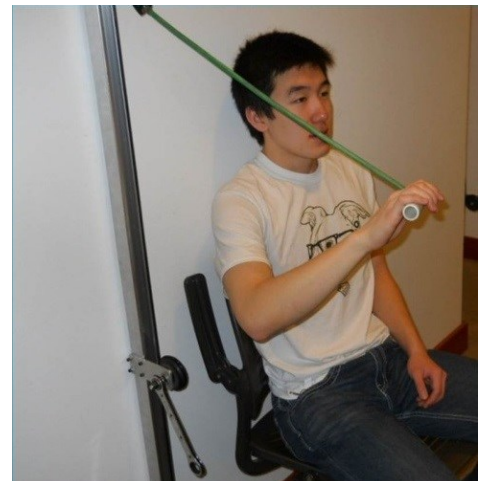
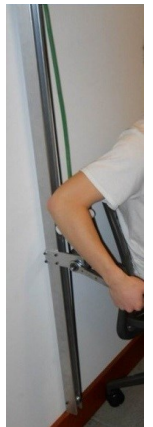
We encased a pulley system inside a strut. Struts are standard parts and easy to find in lengths that we needed. Also a variety of parts with desirable functions have already been built for the strut, such as the strut trolley. The trolley is attached to the pulley cable. The cable is then wrapped around two pulley wheels at the ends of the strut, and a rubber wheel that turns with the ratcheting wrench. The trolley moves when the ratchet is cranked.

Two of the contraptions pictured on the left are wall-mounted just past wheelchair width apart. The entire installation is mounted in an open area so the client could back her wheelchair up to the wall in between the two contraptions. She could then crank the ratcheting levers to move the trolleys. A stretch cord with a handle she could hold is tied on each of the trolleys (not pictured), so she could do a variety of exercises depending on the location of the trolley.



In the design process for The Cranken, we made several mockups along the way to test concepts and to better identify what our client wanted/needed. Pictured to the left was a mock-up for the crank pulley concept. We were able to conduct user testing with it and find out whether our client could operate the lever. Other mockups we made helped us find the optimal way to hold up this contraption. Many of our initial designs were freestanding, and through our mockups we found that wall-mounted setups are safer and more material efficient.

The final product allowed our client to do bicep curls (when trolley is at its lowest point), abduction and adduction (when trolley is at elbow level and wheelchair is parallel to the wall), chest presses (when trolley is at chest level), and lat pulls (when trolley is at its highest point). Our client was very satisfied with our product and installed the apparatus in her home. We received the award for Best Design in the Exercise Apparatus Category at Segal Design Institute's 2013 Design Expo.



Straight

Overview:

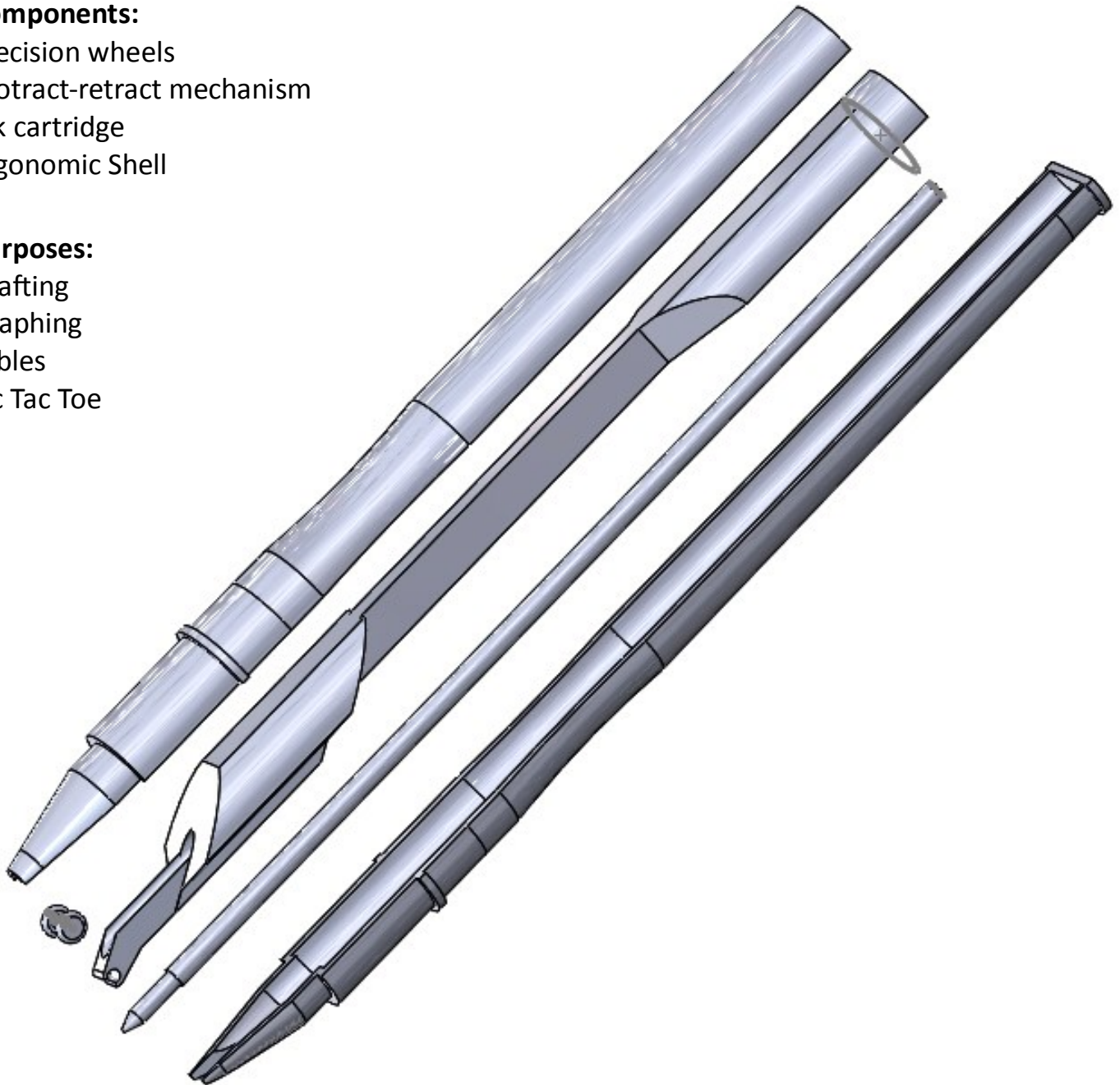
A concept design for a drafting pen or whiteboard marker that can draw straight lines without the aid of a ruler or a second hand, increasing convenience and versatility.

Components:

- Precision wheels
- Protract-retract mechanism
- Ink cartridge
- Ergonomic Shell

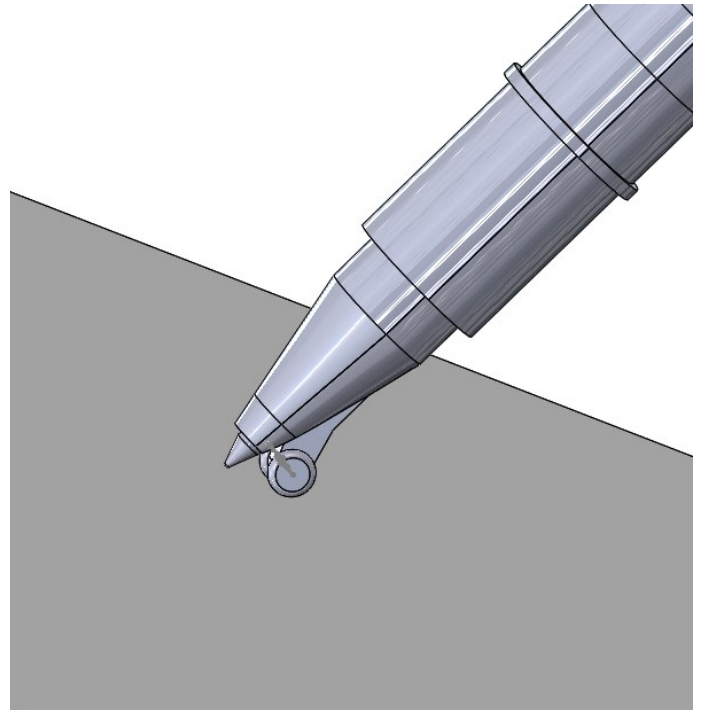
Purposes:

- Drafting
- Graphing
- Tables
- Tic Tac Toe



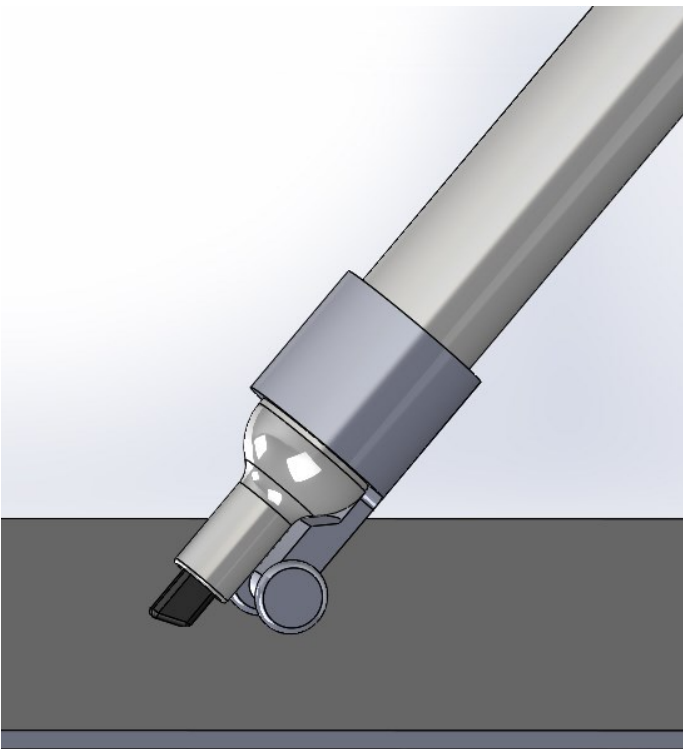
The wheels next to the pen tip are locked on the same axel so they turn together. When the pen is dragged along the wheels and pen tip, the 3 contact points force the pen to travel in a straight line.

The pen tip is stationary while wheels are retractable so as to allow for comfortable free drawing when not drawing straight lines. The moving click piece that holds the wheels is spring loaded and can retract slightly with pressure. This allows for a more natural drawing motion when dragging the pen along a straight line. People generally don't maintain constant angles between pen and paper while drawing.



Drafting on small coffee shop tables becomes a real possibility with Straight. Making neater tables for organization in planners will be easier too, while a variation of this design with whiteboard markers could help schoolteachers teaching geometry, algebra, and calculus. Drawing graphs and plotting in Cartesian coordinates will only require lining up the marker.

Challenges to manufacturing this design will include the precision of the wheels. Small imperfections that cause the circumference of the wheels to be off from one another will result in the line gradually shifting towards one side.

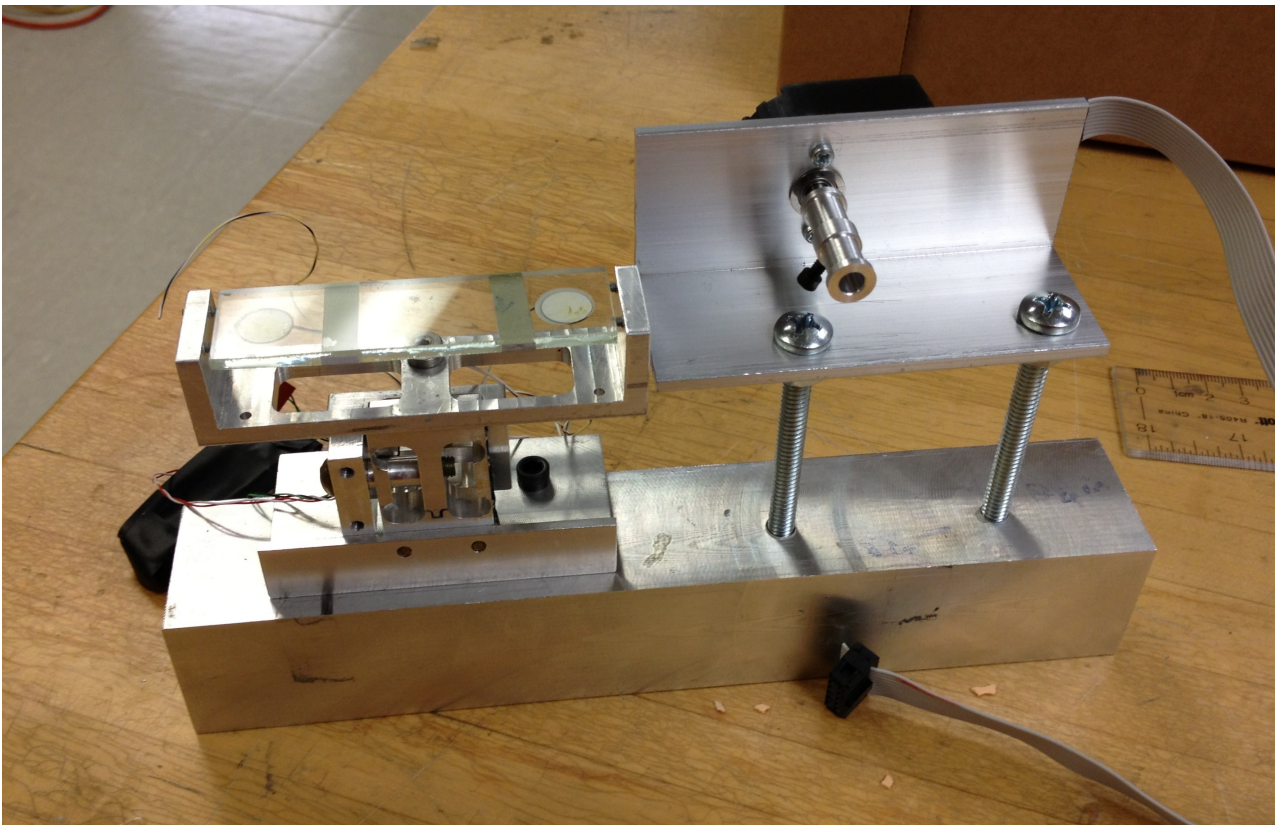


Finger Locator

Overview: A finger locating device that can track a finger's position along a line at 2 kHz or higher.

Another component needed for my research at the NXR lab was a finger tracking mechanism. In order to produce a convincing virtual texture on the TPad I had to know the position of the finger to a high resolution. Given a finger doesn't move faster than 10cm/s across the glass, this finger location mechanism would have to refresh at 2kHz. Most touch screens only refresh at about 90-120Hz, so a custom system had to

be made. I used an encoder with a data acquisition device to reach the desired resolution and refresh rate. A strand of fishing line wound around the axel of the encoder and tied to the finger tracked the location. A spring loaded coil also wrapped around the axel kept the fishing line tight. The setup worked, but the coil and the fishing line would stretch. That skewed the data and blurred the textures produced.



A new design I created used laser cut acrylic, 3-D printed finger sleeve, pulleys, and a steel cable. An encoder still logged the locations. This setup was easy to mount over larger TPads and eliminated the inaccuracy resulting from stretch.

This was part of a TPad project featured on the cover of Northwestern's mechanical engineering flyer, and was featured in on the McCormick Website in 2014. I received a \$5000 grant from McCormick to work on this project.

