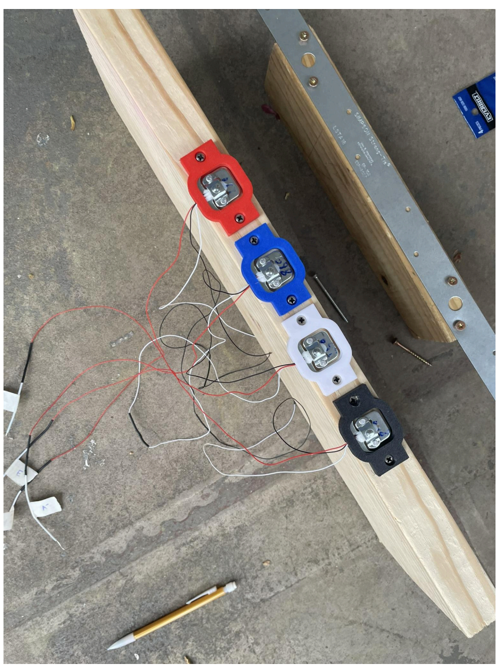
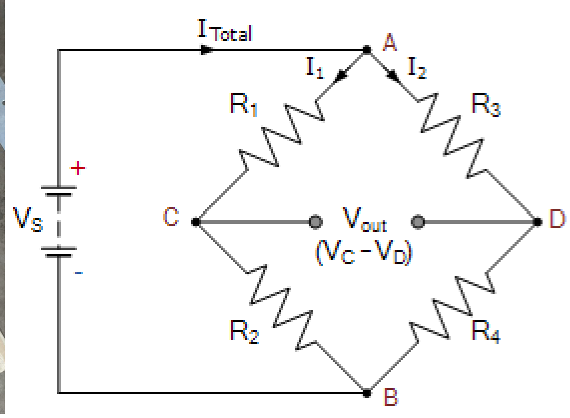
Documentation

Hardware Components

The hardware components of the smart hangboard project include an Arduino Mega as the central microcontroller, which controls the entire system and interfaces with various sensors and displays. The capacitive sensors, made from copper tape, are used to detect the presence of a user's grip on different holds, providing input on the user's interaction with the hangboard. The load cells, four 50 kg sensors, are incorporated into a Wheatstone bridge configuration and amplified using an HX711 amplifier to measure the weight being applied on the hangboard. A push button is included for resetting the timer and display values, allowing the user to start a new workout. The system features 7 single-digit 7-segment hex displays to show the number of sets for individual holds, controlled using shift registers to minimize the number of microcontroller pins needed. Additionally, a 4-digit 7-segment hex display presents the live time of how long a user has been hanging, providing immediate feedback to the climber.



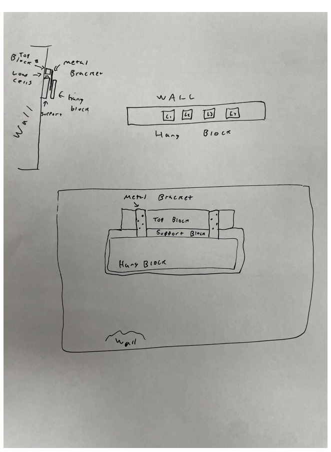


Libraries Used:

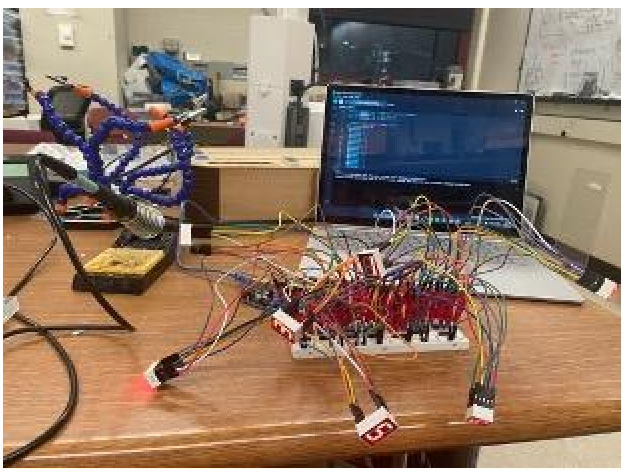
The Capacitive Sensor Library is used easily to read data from the capacitive sensors. The HX711 Library interfaces with the load cells, enabling precise measurements of the weight being applied to the hangboard. The SevSeg Library simplifies the process of controlling the 7-segment displays, allowing the system to easily output training data such as set count and load values in real time. All of these libraries contained lots of documentation and examples making them very easy to incorporate into our code.

Custom Parts and Designs:

- Hangboard CAD and CAM: We utilized a pre-existing CAD file as a template for our changeboard and made some small changes in dimension and hold sizes. To CAM the file for wood CNC milling we worked directly with a CAM Master at the Invention Studio
- Housing Box: Designed and laser printed a custom SVG file to act as the housing for all of our wiring and to cleanly display our push button and displays
- Hangboard framing design: We designed the mounting system in a way that the hangboard rested on top of our load cells. The load cells were attached to a backing piece of wood. When the board is hanged on, the load cells are compressed allowing us to get a reading



Skills Learned: Throughout the process we learned a variety of different skills. One of our first action items was to wood cnc mill the hangboard. This required CAD, CAM and Wood CNC Milling all of which neither of us had any experience with going. For the CAD file, one of our friends had recently designed a hangboard and we asked if we could utilize his design as a starting point for our hangboard. For the CAM and wood CNC milling process, we went to the Invention Studio where a CAM Master both helped us with camming our file along with training us on how to use the actual CNC machine. We also gained experience using the laser cutter in lab. It took several iterations to ensure that the holes for the displays were exactly the right size, so by the end of the process we became very familiar with utilizing the laser cutter. Due to the extensive amount of wiring that was involved (specifically with the hex displays) we became very adept at organization with wires along with soldering skills.



Iterative Process:

In our proposal, we outlined pretty similar specifications to our final model, only changing the set display from an LCD screen to seven segment displays to show the number of sets. When drafting this proposal, we had a general idea in mind of wanting to create a smart hangboard, but weren't sure what features we wanted to implement. We did some research on the topic, and found a couple of examples of a timer implementation feature, however a lack of creations that let you track an overall workout, by using sets and differentiating holds. We thought this would be a great gap to target, and we decided to add some additional challenge by creating our own hangboard rather than buying one, giving us more decision making in the design.

After settling on the design, we decided to begin with the load cell sensing and timer output, since this would likely be the most important feature. To do so, we ordered 4 50kg load cells from the internet, and attempted to wire them up in a wheatstone bridge circuit. This gave us a lot of trouble, as the wires that came with it were incredibly thin, and stripping/soldering them turned out to be a big problem. There was a significant lack of documentation for the load cells we ordered, so we struggled to identify which wires corresponded to what signals, but eventually we managed to connect it to the HX711 amplifier and to the Arduino. At this step, we were still getting unchanging values from the load cells, even when seemingly pushing quite hard on the top of them, so we decided to continue searching the internet for solutions. We found a STL file for load cell supports that allowed the push hand more space to be compressed, and after printing and testing these, we finally received the changes in output we were looking for.

With the load cells working, we needed to figure out a strategy for how to activate them by hanging on the board. We went to home depot with a limited idea of the hanging mechanism, and adjusted/drafted our final design based on the available inventory of wood and brackets present there. At the end, we settled for a design consisting of two main components: one backing block which contained the load cells on top, and one forward block of the hangboard which was connected via metal brackets to an upper block which would actually trigger the load cells when used. We had to design extra supports on either side in CAD to help with the flexion on our brackets, but this turned out to be simple. This design ended up working, however I think it would have been better to buy parts to fit a specific design, rather than fit a design to the parts we bought. For future implementation, we are planning on buying linear rails to use for the two block connection, to decrease the amount of torque that is created from hanging and increase the amount of connection points between the two blocks.

We finished these two components by the midterm review, and then began the process of creating the hangboard itself. We had started with an initial CAD file created by a friend of ours, however we had to adjust the dimensions of design to fit the block of wood we bought, and we adjusted some of the holds to better fit our needs and difficulty. From there, since we are not trained on the wood CNC mill and do not have experience in CADing, we scheduled a meeting with a wood master at the invention studio, and he helped us design the CAM file and taught us to operate the machine. Unfortunately, on the very last passthrough the of the mill, when we were adding pilot holes for our screws, we forgot to adjust the tool offset, and it went partially through the board to create a visual defect. Thankfully, this did not actually mess up any of the holds, but it turned into an eyesore and a potential for a splinter with all the messy wood. Additionally, the hold edges were sharp, as we forgot to round the corners before sending it on the CNC mill. In order to account for these two defects, we bought wall filler and patched up the hole in the hangboard, and used sandpaper to smooth all the edges and round out the holds for a more optimal user experience.

With the hangboard made, we moved on to the capacitive sensing. This turned out to be a relatively simple process, and we simply ran copper tape through each hole to the side of the board, where we soldered a wire to the tape on one end and had the send and receive resistor pins on the other. We had to ensure the copper tape ran in a way where it wouldn't be touched while hanging on another hold, and opted to only run tape on one side since holds would be used together. We could have put electrical tape over the holds to prevent the first issue, but thought the copper tape looked cleaner for the final finish. Overall, this turned out to be the least problematic part of the process, however it took many pins on the Arduino since each hold required two pins.

Initially, we had wanted to display these hold counts via an LCD screen, by flashing through what holds were used at the end of the workout. However, we decided that this would not be very user friendly since we had a pretty small screen, so we opted to use single digit 7 segment hex displays. This switch was pretty late in the process, so we did not have time to buy a MAX7219 chip, so we opted to wire the displays in a series using shift registers, decreasing the arduino pin usage to 3 (plus ground and power). This took a really long time to set up, since there were a lot of wires to solder and crimp, and we opted to do it on a breadboard, which allowed for easy power/ground connections and perfectly fit 7 chips onto it.

In order to ensure the wires stayed in the breadboard, we hot glued the plastic bits on, which would make it hard to debug but worked for our purposes, and which we only did after extensive testing of the displays.

We also added an LED push button to help reset the counts when a user ended a workout, but this was a simple addition and only required one digital pin on the arduino.

With all the pieces completed, we just had to figure out the best way to house it. We decided to create a laser cut box rather than 3D printing, since this would allow us to test multiple implementations to get all the sizing right. For our final box, we bought some 5mm plywood at home depot, and adjusted the laser cutter settings to accommodate. We screwed the box into the hangboard on the side, and glued all the pieces except for the top one for debugging/display. We used superglue to attach all the hex displays, and hot glued the Arduino and breadboard to opposite walls to help with cable management. Initially, we had used a battery to power the arduino, but after browning out during our demo video, we swapped to

wall connection to ensure higher and more stable Voltage powering it.

Resources:

- HX711 Library: https://github.com/bogde/HX711/tree/master

- CapacitiveSensor Library: https://github.com/PaulStoffregen/CapacitiveSensor
- SevSeg Library: https://github.com/DeanIsMe/SevSeg/tree/master
- Literature on other smart hangboard implementations: https://www.mdpi.com/2504-3900/2/6/227
- Example Wheatstone Bridge configuration with 50kg Amazon load cells:

  https://www.youtube.com/watch?v=LIuf2egMioA&t=400s
- CAD File for load cell housing (in design file zip)