Mapping Cartilage Material Properties

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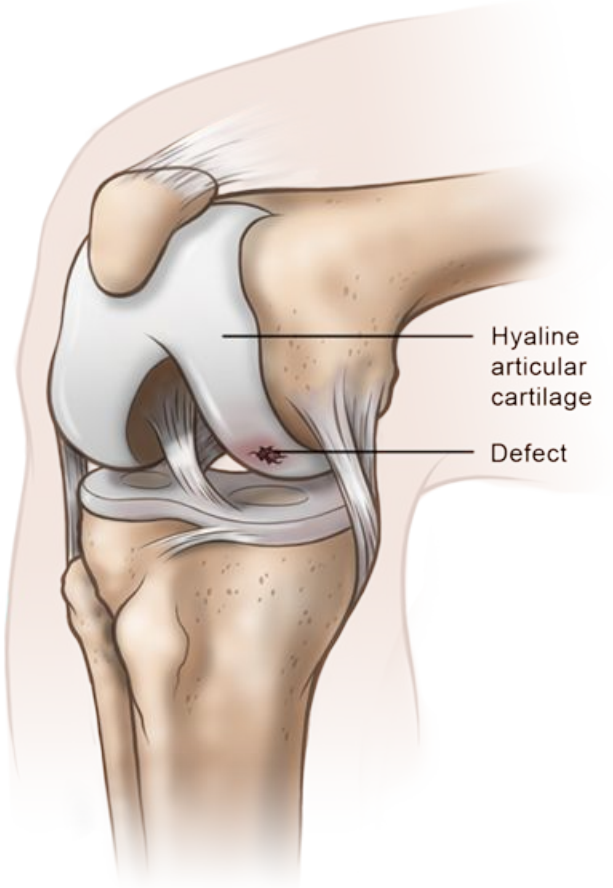
Context

- Cartilage breakdown results in:
  - Arthritis
  - Change in material properties

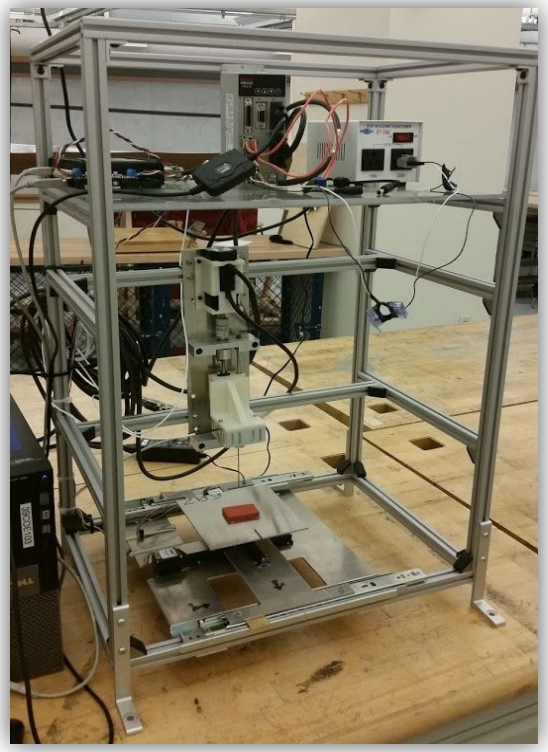
- Symptoms only arrive after cartilage is fully degraded

- No current means to quantify cartilage damage

Problem Statement:
Develop a machine to perform indentation tests on cartilage in order to map material properties across the surface of a dissected (in situ) joint



Issues with Phase I



- Non-existent user interface
- Inability to perform indentation tests
- Components of system did not communicate
- Heavy reliance on operator

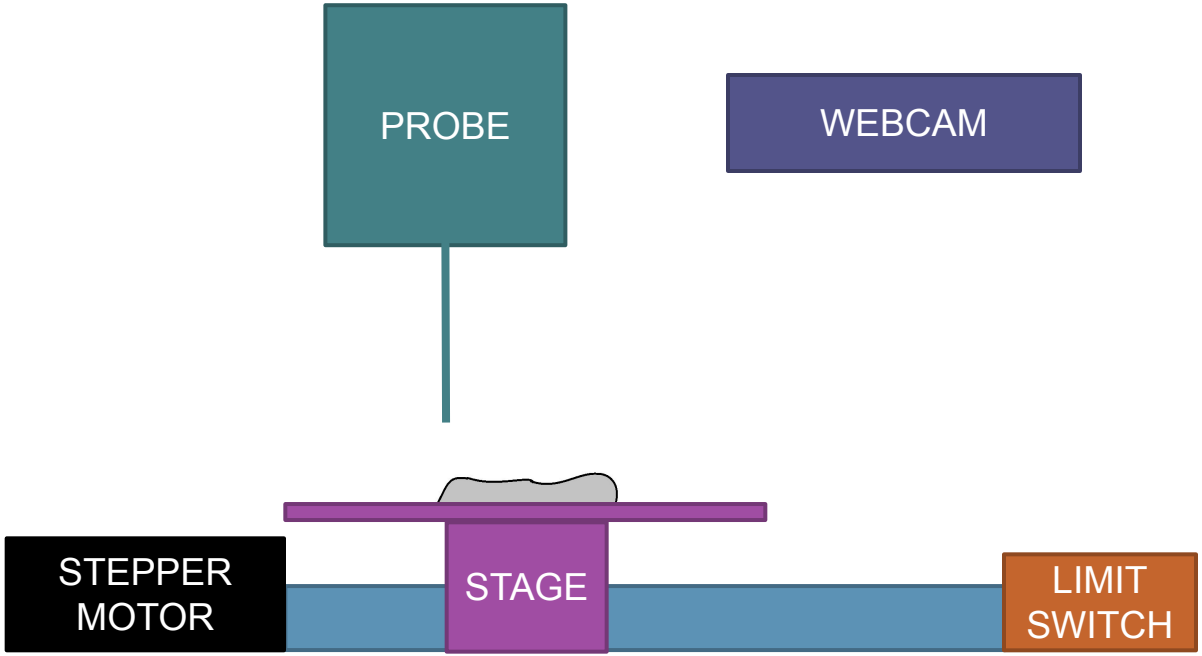
Goals of Phase II

I. Add **imaging and mapping** capability to the system
   - Capture image of sample and plot its surface

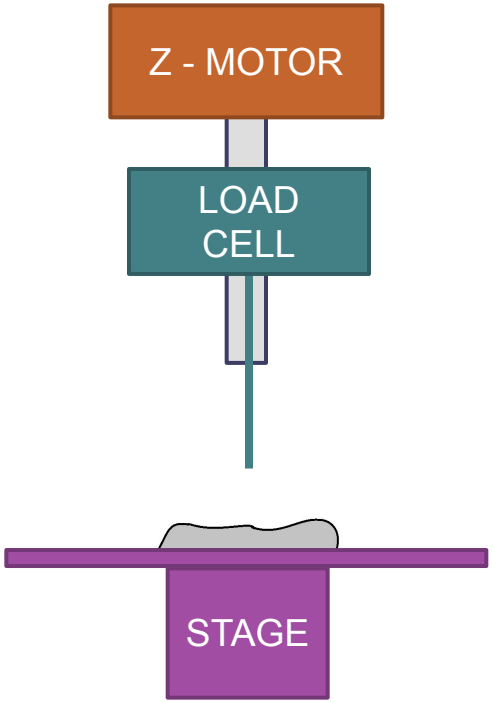
II. Automate **surface detection**
   - Develop a fully automated means of locating submerged surface

III. Create an intuitive **graphical user interface** (GUI) for the system
   - Complete control of system and automate testing procedures

Imaging & Mapping Procedure



Indentation Procedure



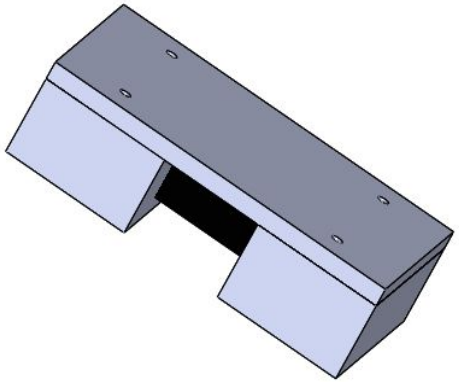
Project Breakdown

Imaging & Mapping

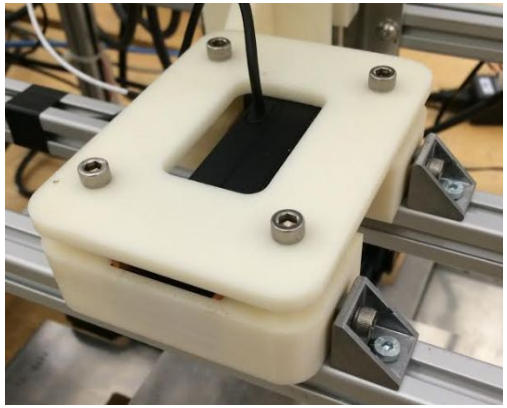
Surface Detection

GUI & System Integration

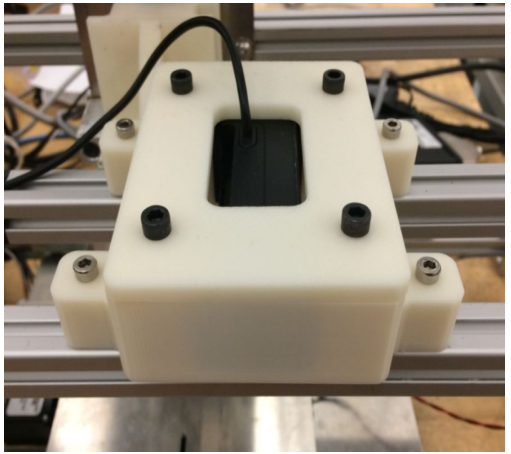
Webcam Mount Assembly



Revision #1



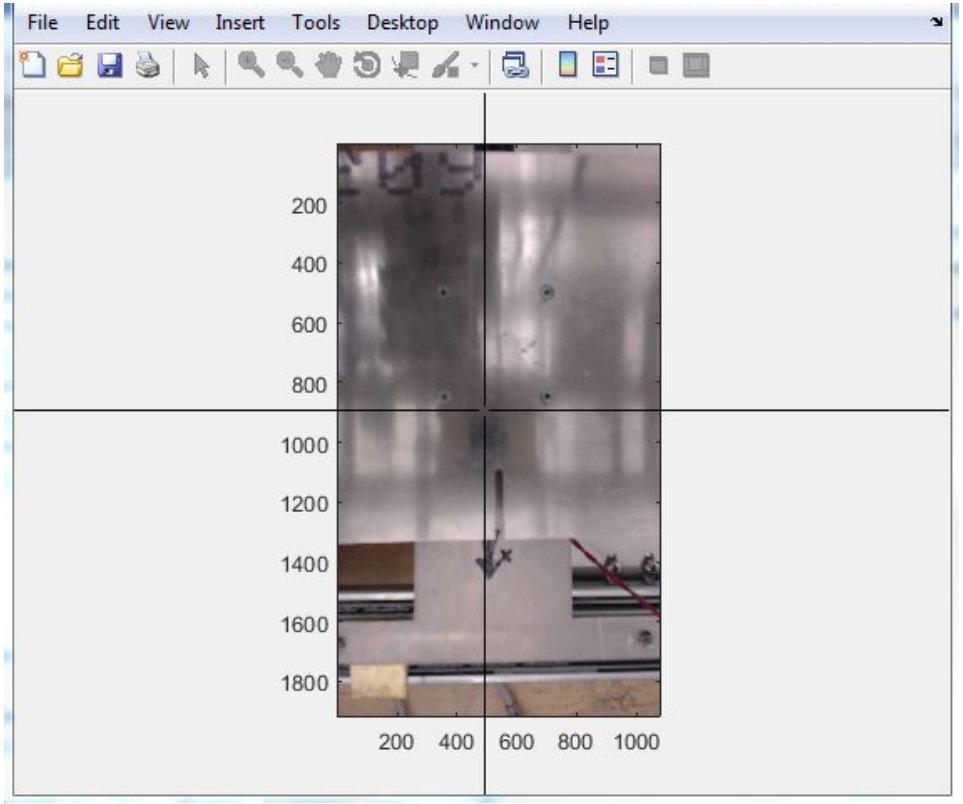
Revision #2



Final Revision

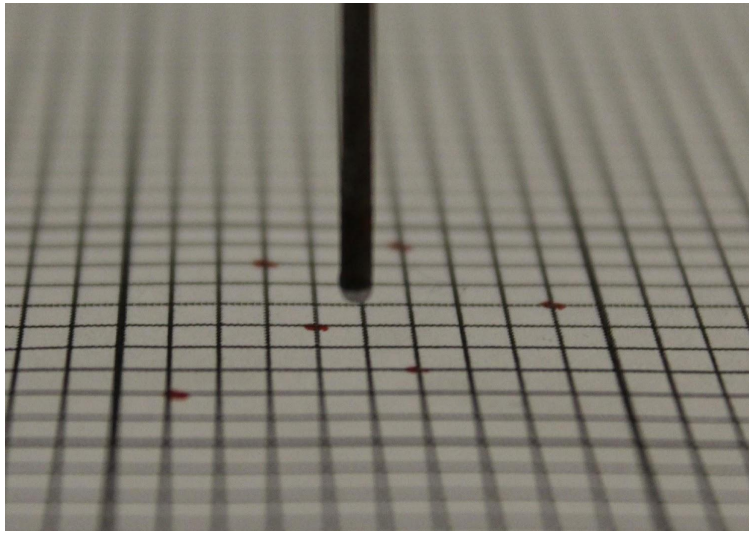
Mapping Program

- Converted coordinated system of image for communication with motors
- Calculate distance between test points
- Distance is translated for Arduino to understand

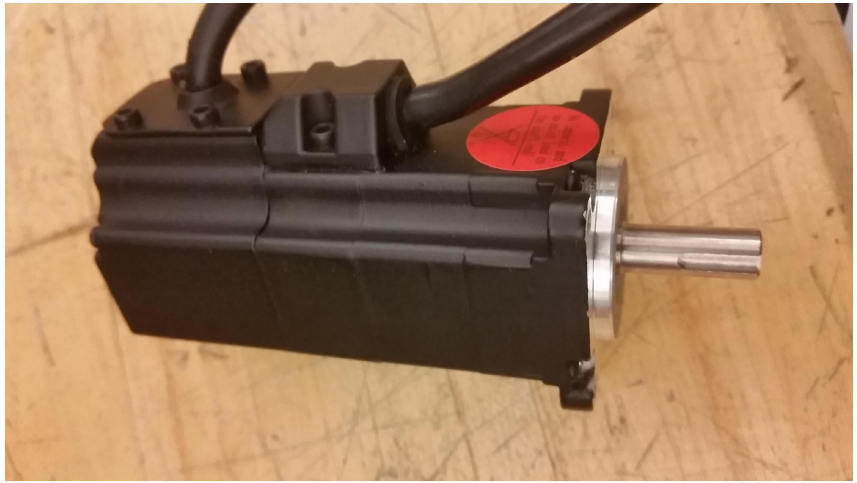


Mapping Test Procedure

- Water soluble blue paint was placed on tip of the probe
- 1 mm x 1 mm graph paper placed on stage
- Test points were marked on the graph paper
- These points were selected through the GUI
- The operator manually moved the probe tip to contact the paper
- Probe location is marked in blue after traveling to each point



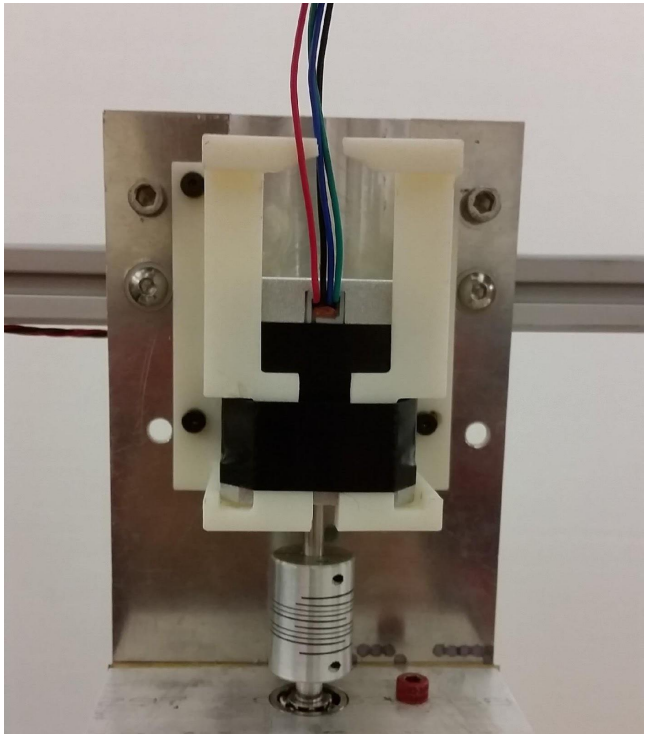
Surface Detection



Servo Attempt

- Wrote commands:
  - Operation Mode
  - Target Velocity
  - Start
- Fabricated custom cable
- Final communication failure

Surface Detection



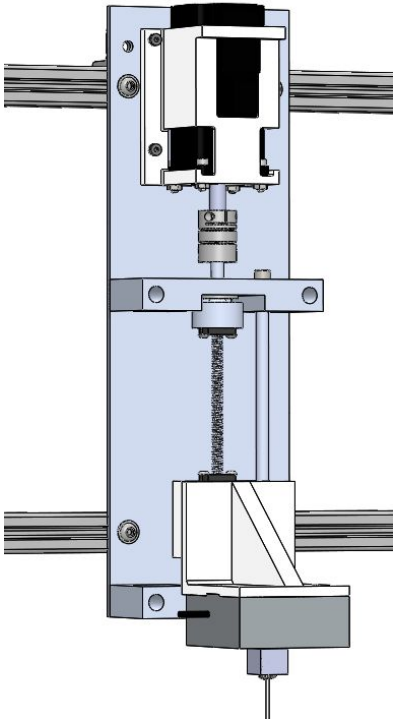
Stepper Motor

- Modified mount and fixture
- Replaced coupling
- Connected to new motor shield
- Used model of X-Y stepper control to integrate function
- Substantial time saving with negligible loss of precision

Surface Detection

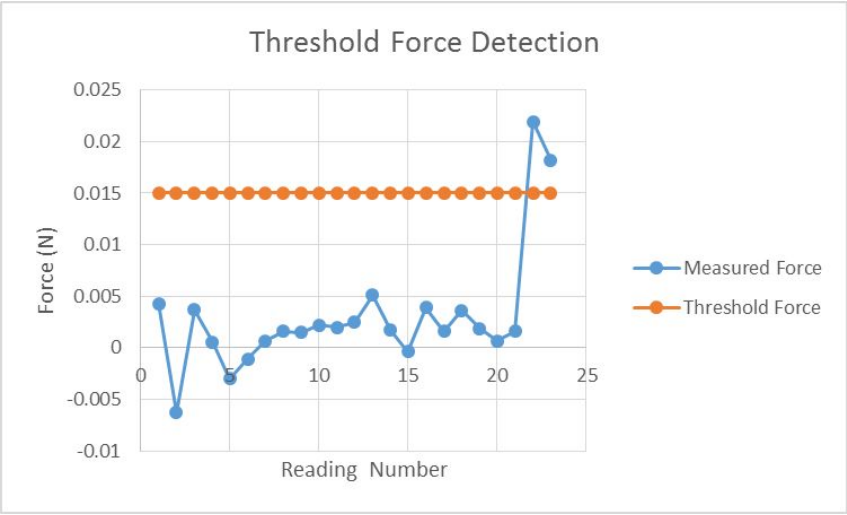
Load Cell

- Communication between MATLAB and Arduino achieved
- Amplifier-to-Arduino circuit built and analyzed
- Load cell/z-axis stepper motor working together in code



Surface Detection Algorithm

- 500 readings per force measurement @ 10 kHz
  - High resolution
  - Smoothing
- Checks for 2 consecutive threshold values
- Software force limit

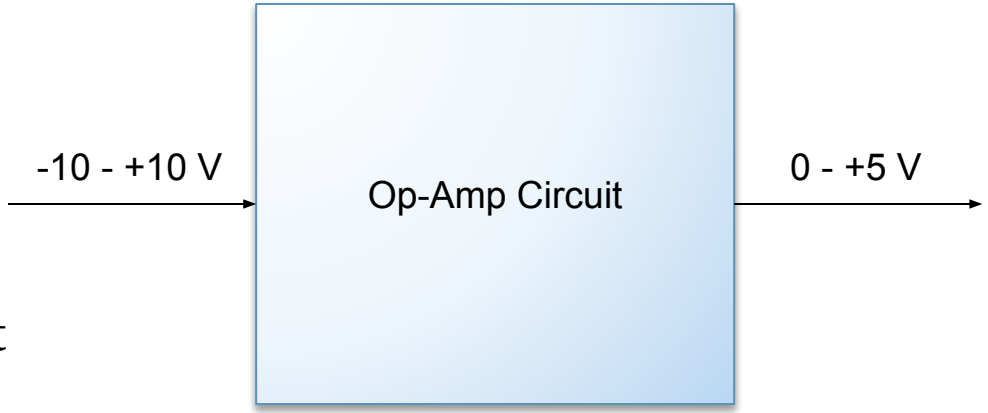


Analog Signal Processing

- Input: -10 to +10 volts
- Output: 0 to +5 volts

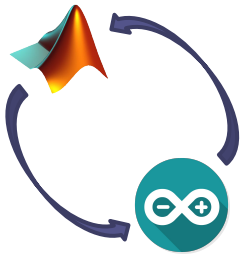
- Fully analog
- One circuit per force component

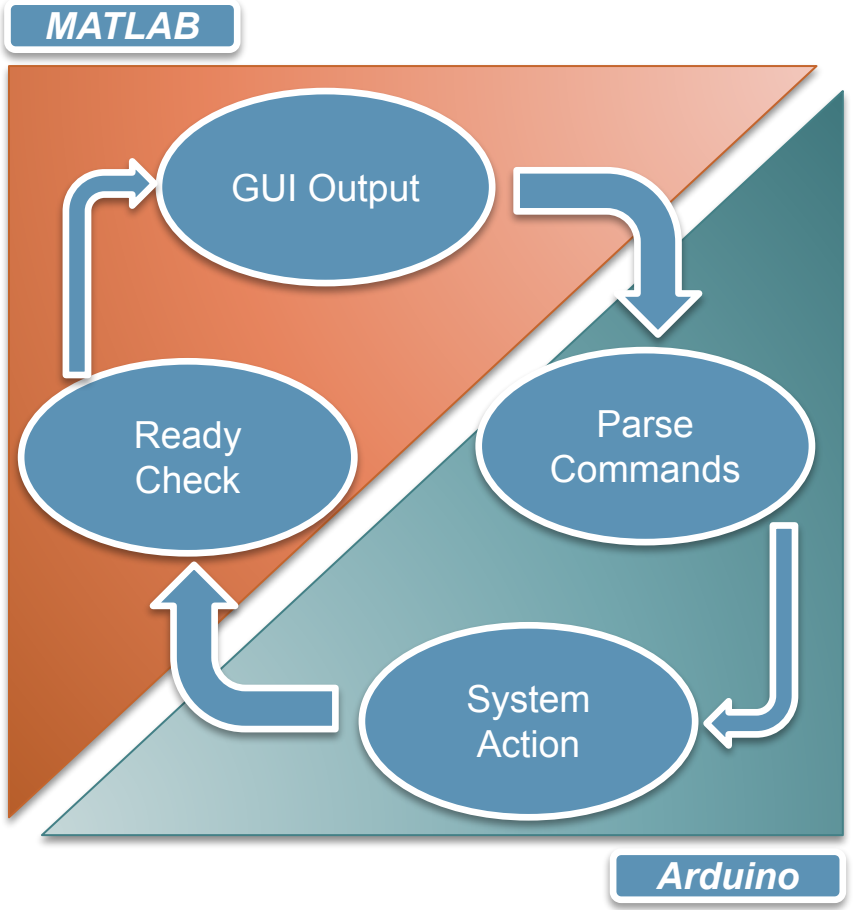
- Paired with differential measurement method
  - Compensates for noise and errors in analog-to-digital conversion



System Integration

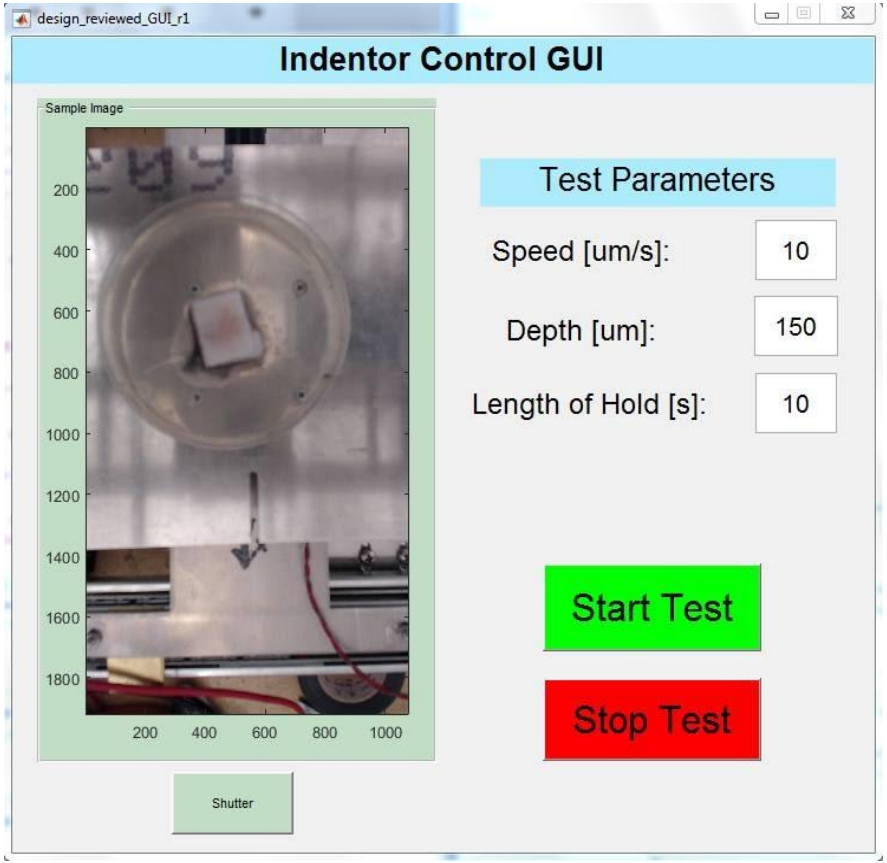
- Initial Design Considerations:
  - Ease of use
  - Feasibility within timeline
  - Post-processing power
  - Compatibility with components
  - Serial communication enabled
- Recent Design Considerations:
  - Working around low-speed serial data transfer (MATLAB)
  - Robust 2-directional data transfer
  - Motor power requirements





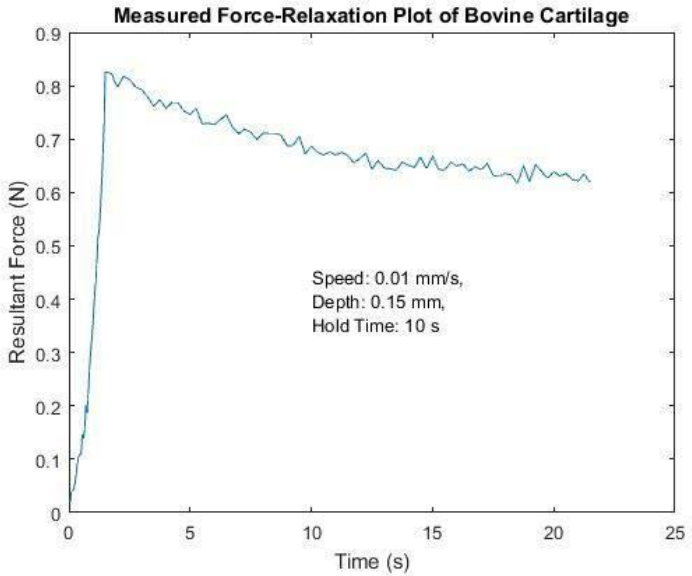
System Functionality

- Initial System
  - User controlled single point testing
- Final System
  - Automated 6-point test capability
  - Entire system controllable from a Graphical User Interface
    - User inputs custom test parameters
    - User can select points visually



Testing and Results

- Initial surface detection verification on rubber
- Indentation plots for banana, cartilage, and bone
  - Bone has clearest linear regime because it was stiffest material
- Six point test
  - Successful indentation tests for six points on bovine cartilage



Conclusions

- Accurate mapping of points on the surface
- System fully controllable through Graphical User Interface
- Reliable and fully automated surface detection
- Collects usable data with much less user input

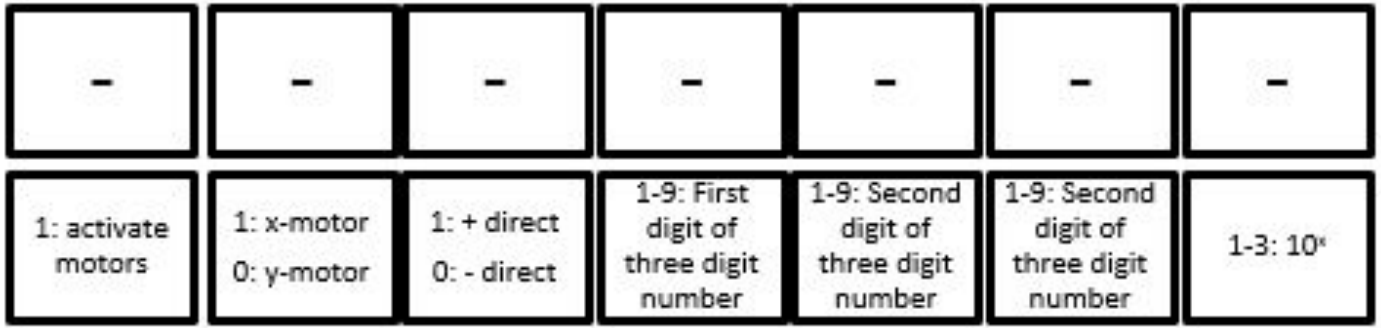
Overall Schedule

Task	July	August	September	October	November
Research					
Basic Functionality					
Refine Controls					
System Integration					
Troubleshooting					
Final Testing & Analysis					

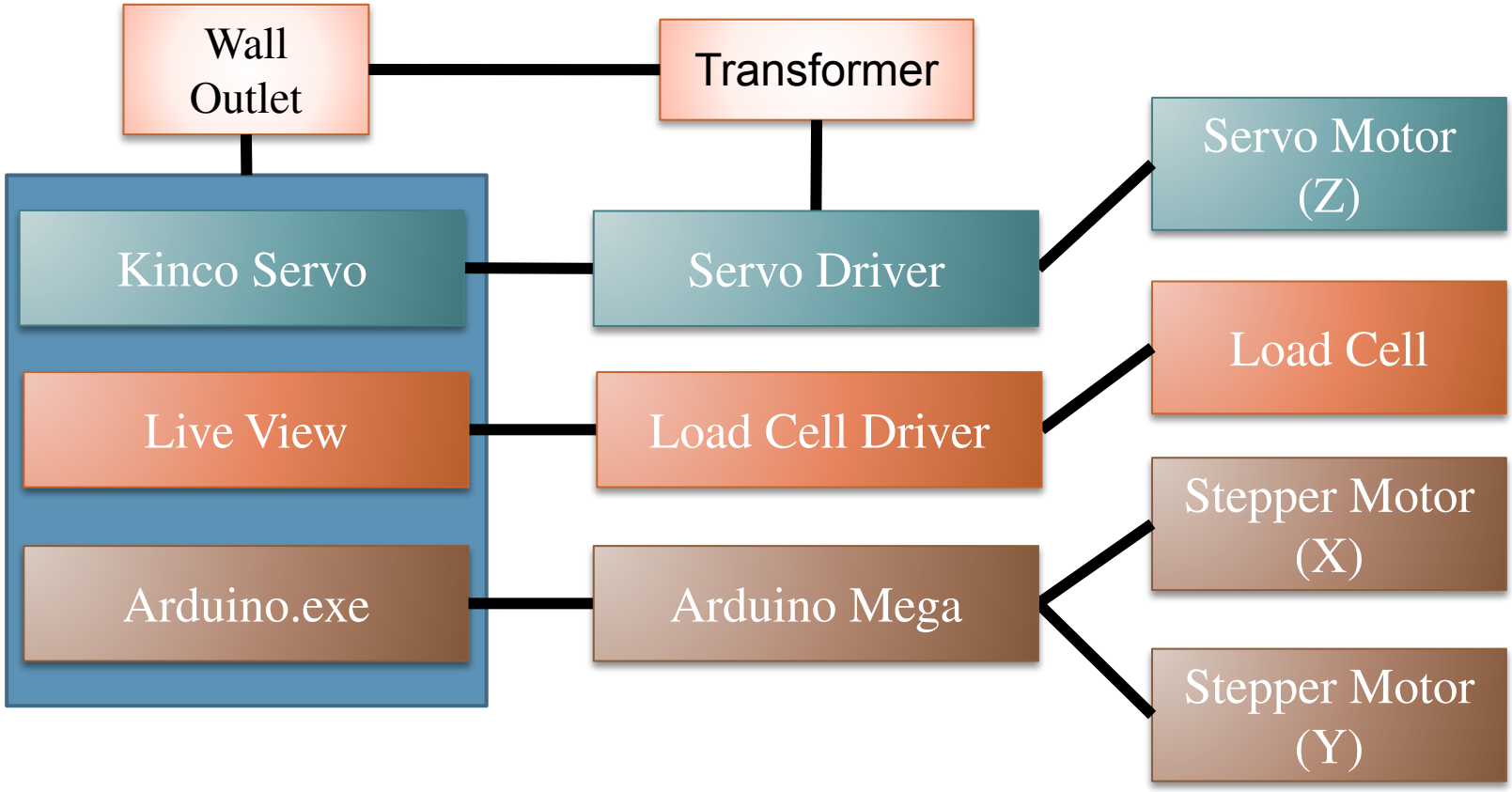
Questions?

Mapping Program

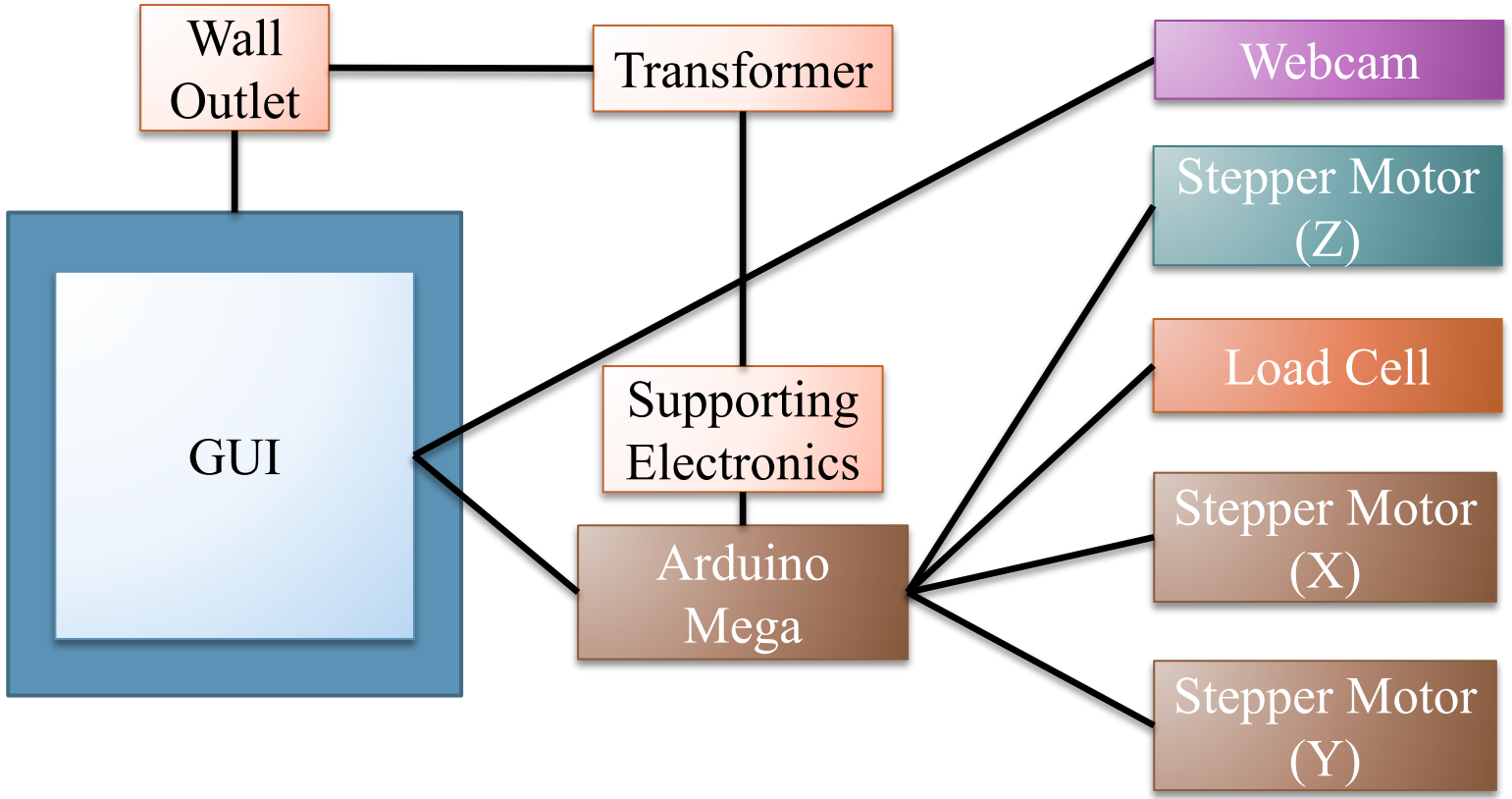
- Converted coordinated system from pixels to steps
- Calculate distance between test points
- Distance is translated into way for Arduino to understand



Initial System, Phase I



Proposed System, Phase II



Op-Amp Circuit

Offset Operation

- Constrains voltage to negative range

Op-Amp Procedure

- Flips voltage sign to positive

Op-Amp Gain

- Scales down the voltage range to be compatible with Arduino