MICROSCOPE LOW-COST MOTORIZED STAGE

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BME Design

Abstract

The biomedical engineering teaching labs at the University of Wisconsin-Madison have two inverted fluorescent microscopes, the Nikon Eclipse Ti-U and the Olympus IX71. Both of these inverted fluorescence microscopes are currently controlled using manual translational control knobs. These manual control knobs do not allow for automated imaging and automated stitching of images. Integrating a motorized stage allows for a range of functions including time-lapse imaging, automated tracking, and image mosaic creation. The current commercially available options for motorized hardware for the stages of microscopes are quite expensive. The goal of this project is to design, program, and fabricate a lower cost motorized stage to be used for inverted fluorescent microscopes to allow for automated imaging and automated stitching that can be integrated with the Nikon Elements imaging software in the teaching labs. The mechanism must cost less than $100 and the resolution of the stage's movement should be around 1 um. The fabricated prototype is comprised of a worm system driven by two bipolar stepper motors. The stepper motors are connected to a rail system which can slide with the stage in the y-direction.

Problem Definition

- Manual control knobs do not allow for automated imaging and stitching
- Motorized stages increase research efficiency and precision of imaging
- Turning the manual knobs in the y-direction shifts the manual knobs.
- Commercial motorized stages can cost up to $70,000 [1]
- An inexpensive stage would allow students to save time, while creating consistent images that are able to be stitched together.
- Dr. John Puccinelli wants a cost-effective device that can motorize the stage of the Nikon Eclipse Ti-U microscope in the BME Teaching Lab on campus

Design Specifications

- Stage movement should be controlled by joystick or computer software.
- Stage movements should be within a resolution of **1-10 microns in x and y direction**.
- The program should be able to perform automated imaging and stitch images together.
- Should be able to be **easily attached and removed.**
- Should not inhibit the movement of the stage in any direction.
- Remain in budget of **$100**

Five Main Components

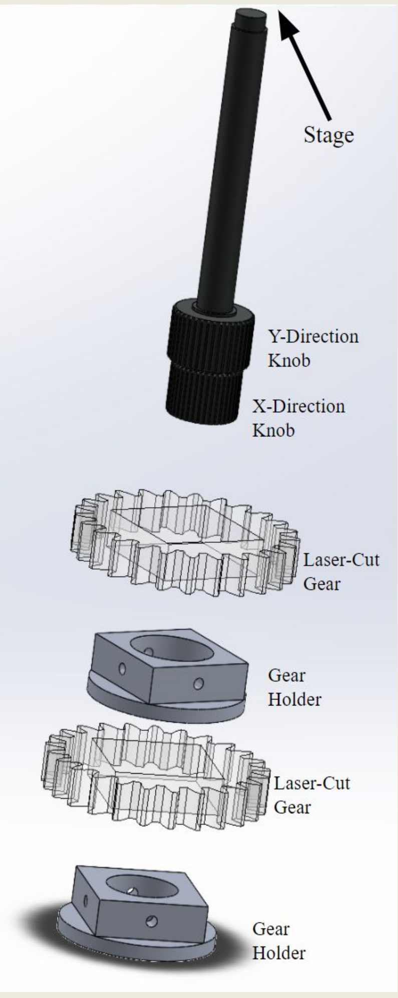


Figure 1. The Gear-knob attachment. Set screws fixed a machine holder to each of the two manual knobs. Each holder held a laser-cut gear with a diameter:teeth ratio of 88 mm/32 teeth.

Figure 2. The worm drive gear. It attaches to an the adapter for the motor shaft. The worm drive gear turns the laser-cut gears on the control knob.

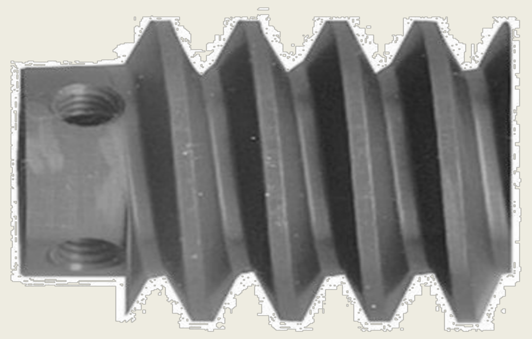


Figure 3. The adapter between the stepper motor shaft and the worm drive gears.

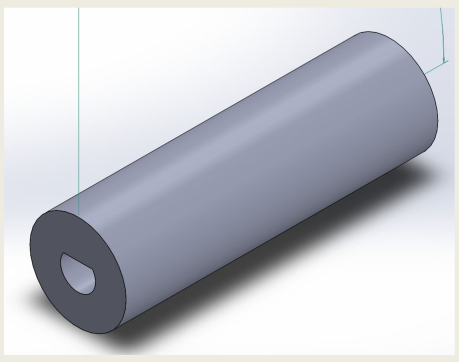


Figure 4. Two linear rails used to hold the stepper motors while allowing freedom in the y-direction.

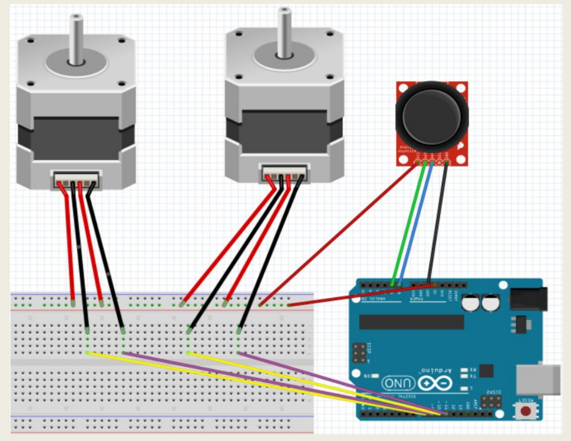


Figure 5. The electrical circuit. Contains an Arduino Uno Rev3 microcontroller, two stepper motors (with drivers not shown), and an Analog 2-axis Thumb Joystick

Final Design

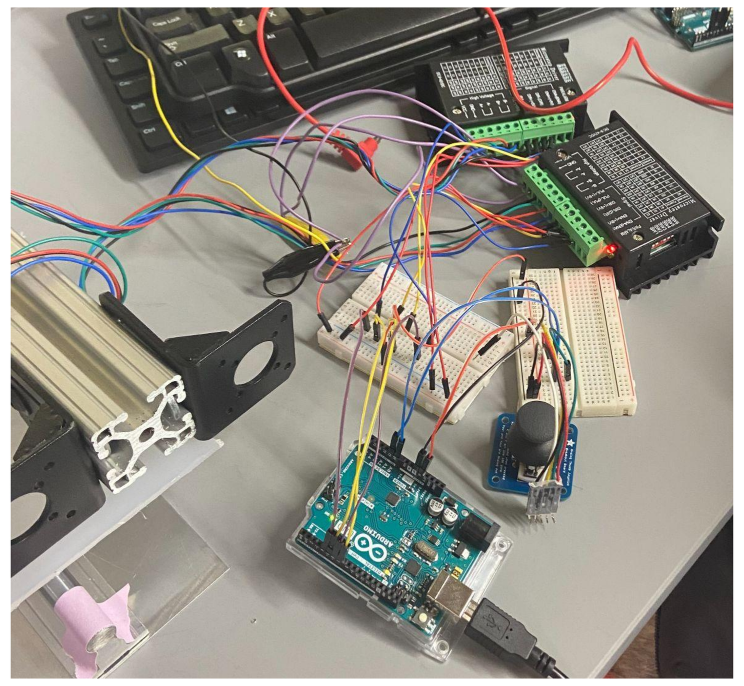


Figure 6. The circuit part of the design. The Arduino connects to the drivers that the stepper motors are hooked up to.

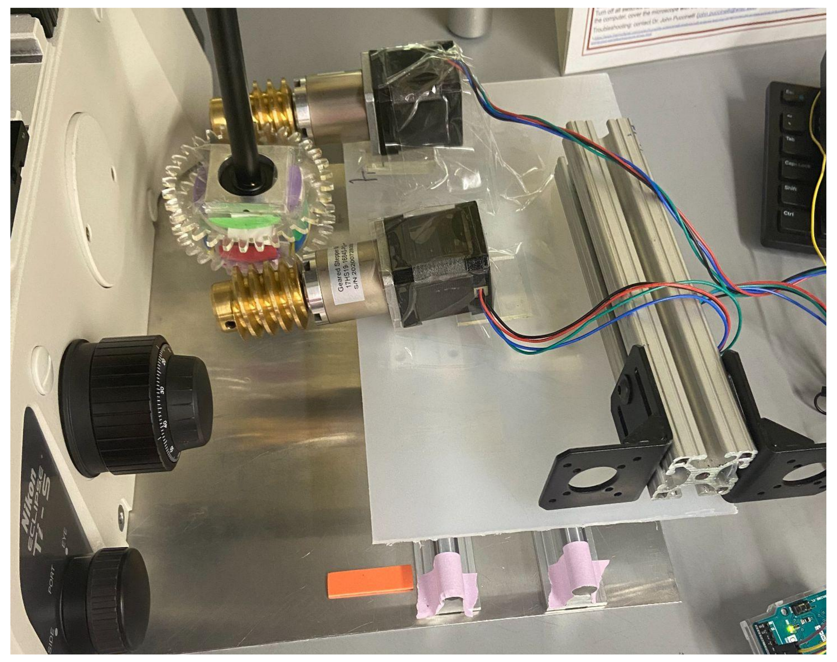


Figure 7. The mechanical part of the design. The stage knob with the gear attachment is shown on the left, with the stepper motors and worm drive gears.

Background

The BME Teaching labs have two inverted fluorescent microscopes, the Nikon Ti-U and Olympus IX71. The inverted fluorescent microscopes are well suited for very small-scale samples and experiments. The microscopes allow for fluorescence tagging of proteins or antibodies within single cells [2]. The Nikon Ti-U is equipped with a TI-SR Rectangular Mechanical Stage [3]. It is controlled by two manual knobs attached to the left side of the stage. The knobs translate along with the stage when the top knob is turned, which caused issues for the previous group's design. Our client, John Puccinelli, Associate Chair of the Undergraduate Program at University of Wisconsin-Madison, wanted a low-cost alternative that was able to operate autonomously. Being able to operate autonomously allows for long term experimentation without the requirement of a person manually moving the stage and recording results, reducing the long and inconvenient hours required for testing.

Figure 8. Nikon Ti-U inverted fluorescence.

References

[1] Discover-echo.com. 2021. *Revolve Fluorescence Microscope by Echo*. [online] Available at: <https://discover-echo.com/revolve> [Accessed 15 October 2021].
[2] K. Thorn, "A quick guide to light microscopy in cell biology," Molecular biology of the cell, 15-Jan-2016. [Online]. Available: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4713126/. [Accessed: 20-Oct-2021].
[3] "Nikon Inverted Microscope ECLIPSE Ti-U Ti-U/B Ti-S Ti-S/L100 Instructions," eliceirilab.org. [Online]. Available: https://eliceirilab.org/sites/default/files/2016-09/Nikon%20Eclipse%20Ti-U%20Manual.pdf. [Accessed: 19-Oct-2021].

Testing Procedure

1. Photograph the sample at position 1
2. Set the motor to a constant speed for 15 seconds
3. Photograph the sample at position 2
4. Import images into ImageJ and calculate the distance traveled of one of the dots, knowing that each dot was 6µm in length

Testing Results

Five trials were run, with the results displayed on a bar graph. In 15 seconds, there was an mean of 171.6 µm of movement with a standard error of 9.53 µm. This translates to a mean speed of 11.44 µm/second

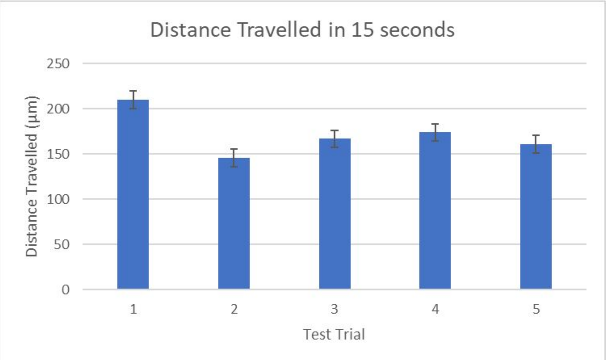
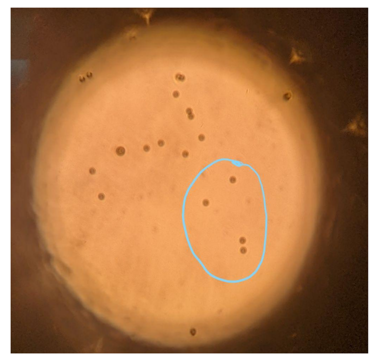


Figure 9. A graph illustrating 5 trials of the distance traveled by the stage in 15 seconds.

Figure 10. A picture of a slide containing dots with a diameter of 6 µm. This is the starting point for the test.



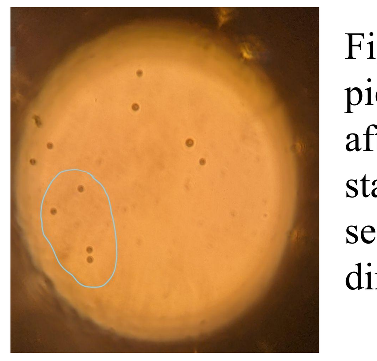


Figure 11. A picture of the slide after moving the stage for 15 seconds in the x direction.

Future Project Development

- Increase Stepper Motor RPM
  - Improve circuits or code
  - Possibly get new motors
- Integrate motorized microscope stage with Nikon Elements Imaging Software
- Optimize stability of motors and gears
- Continue integrating the joystick
- Continue to increase resolution, consistency, and accuracy

Figure 12. Nikon Elements. The imaging software used to process images taken with the microscope.

Figure 13. The thumb joystick used in the circuit.

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