MICROSCOPE LOW COST MOTORIZED STAGE

Mateo Silver, Shreya Godishala, Darshigaa Gurumoorthy, Emily Wadzinski, Nikhil Chandra, Sam Tan

Client: Dr. John Puccinelli

Faculty Advisor: Dr. Kip Ludwig & Dr. James Trevathan

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College of Engineering
UNIVERSITY OF WISCONSIN–MADISON

UW BME Design

Abstract

- Current inverted fluorescent microscopes in teaching labs utilize manual control knobs that makes stage translation tedious and challenging.
- A low cost (<$100) motorized system was developed that automates stage translation that employs a meshed spur gear to spur gear system to rotate two control knobs
- System achieved a sub 4 micron translation accuracy, was ~2 times smaller than previous year's design, and cost less than $100 to fabricate

Motivation

- Manual control knobs on contemporary teaching lab microscopes make it challenging for students to learn advanced microscopy techniques
- An inexpensive, reproducible, attachable, microscope would make microscopy accessible for lesser funded teaching labs, both at and beyond UW Madison
- Inadequacies from previous year prototypes including bulkiness, low stage translation precision, and the lack of a linked software interface. These served as motivations for our project

Problem Statement

The manual translation knobs on current inverted fluorescent microscopes make it challenging to isolate specific areas of samples. Objective is to construct a low cost (<$100) attachable motorized system that could automate the translation of the stage to ~1 micron precision.

Background Research

- Inverted fluorescent microscopes have a light source on top and the stage below where specimen are observed
- The BME teaching lab has two inverted microscopes, the Nikon Ti-U and the Olympus IX71, both controlled by manual control knobs
- The microscope stage can be translated in the x and y directions. During y translation, the control wand also moves
- Competing automated designs like the Nikon TI-U Motorized [1] and Openstage [2] microscopes cost up to $70,000 when new

Figure 1: Inverted Fluorescence Microscope [1]
Similar model to that found in BME teaching lab

Final Design

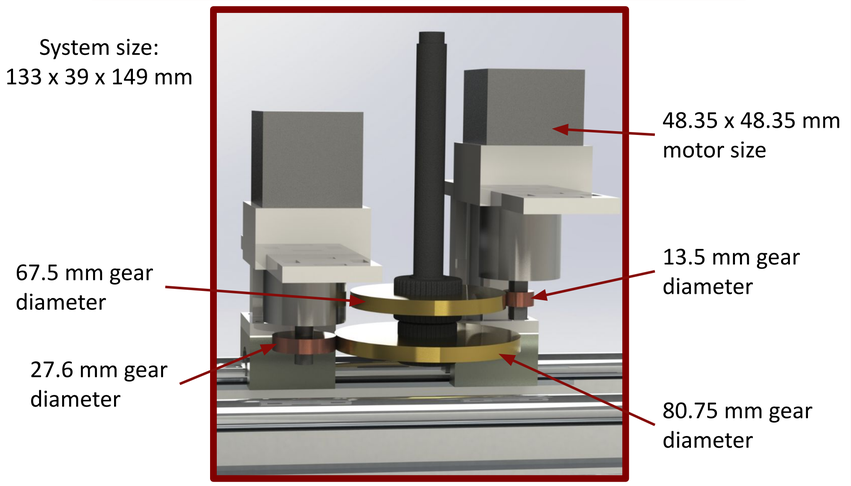


Figure 2. Final CAD Design Viewed Horizontal to Microscope
Design modeled in Solidworks, rendered using PhotoView 360

$$\text{First Gear Diameter} = \frac{\text{Total Gear Diameter}}{[1 - (\text{Motor Step Angle} / 1\ \mu\text{m Knob Angle})]^2}$$

Our Final Design employs a meshed spur gear to spur gear system to rotate the knobs and in turn translate the stage. The formula above was used to calculate gear sizes.

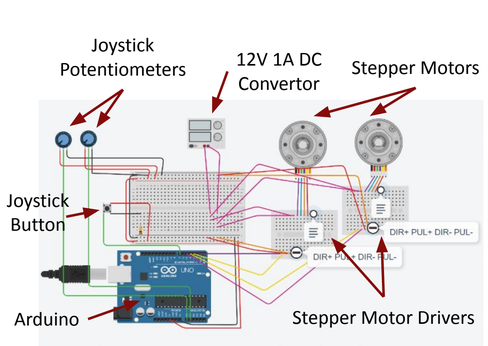


Figure 3. Motor Circuit Diagram
Full circuit design created in Tinkercad. Parts annotated.

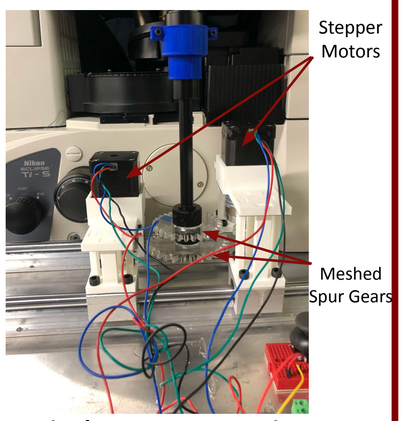


Figure 4. Final Prototype on Microscope
Stepper motors and spur gears annotated.

Design Specifications

- Automated stage translation with joystick for manual control
- <$100 budget
- 2x smaller than 2021 final prototype
- ~1 micron translation precision

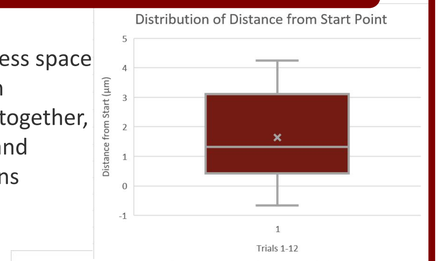
Testing

Qualitative Results

- Current prototype uses ~2x less space compared to previous design
- Mechanical parts mesh well together, are sturdy enough to withstand teaching laboratory conditions

Quantitative Results

- **95% CI** = 1.6442±0.9464µm
- $\mathbf{t_{crit}(.05)}$ = 2.2
- **SE** = 0.4302µm
- **variance** = 2.2213µm
- Initial accuracy of around 0.5µm with an observed exponential increase in error leading to lesser accuracy
  - Possibly due to faulty wire connections



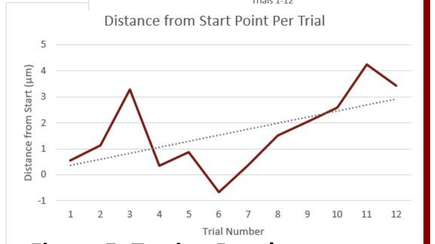


Figure 5. Testing Results
Figures created in Microsoft Excel, statistics calculated using VassarStats

Discussion and Future work

PDS Criteria	Status
2x smaller than 2021 final prototype	The system occupied significantly less space (2 times smaller) than last year's design, by removing the use of worm drive gears
< $100 Budget	Only $51.07 was spent this semester, successfully falling under the allocated $100 budget.
~1 micron translation precision	Achieved a notably small error rate of 0.4302µm -Fine tuning the gear ratios and addressing faulty wiring, motor stability, and gear backlash would be necessary to further decrease the error to achieve a 1 micron accuracy.
Automated stage translation with motor linked to joystick interface	Interfacing the joystick seamlessly with both the x and y stage translation motors is still an area of focus for future work.

While we were mostly successful in our project, further work is still need to improve the consistency of the prototype. Future goals include: integrating the joystick, further incorporating the model with Nikon Elements.

Acknowledgements

We would like to thank our client John Puccinelli and our advisors James Trevathan and Kip Ludwig.

References

[1] "Nikon TI-u inverted fluorescence motorized microscope pred ti2 - AV," Boston Industries, Inc. [Online]. Available: https://www.bostonind.com/nikon-ti-u-inverted-fluorescence-motorized-microscope-pred-ti2-av. [Accessed: 05-Oct-2022].

[2] R. A. A. Campbell, R. W. Eifert, and G. C. Turner, "Openstage: A low-cost motorized microscope stage with sub-micron positioning accuracy," PLOS ONE, 26-Feb-2014. [Online]. Available: https://journals.plos.org/plosone/article?id=10.1371%2Fjournal.pone.0088977. [Accessed: 05-Oct-2022].