Microscope Low Cost Motorized Stage - Excellence - Executive Summary

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The UW Madison Teaching lab is a place for students to learn, develop important skills, and grow into their biomedical engineering major. An important aspect of the teaching lab is access to state of the art, such as the Nikon Eclipse Ti-U microscope, which can be used for imaging samples, and manually stitching images together to get a big picture view of the sample, while maintaining high resolution. This process serves students well for small projects, but manually stitching images together can be a long and tedious process. To address this problem, our client requested a device that can move the existing stage automatically and a program to automatically stitch the resulting images together. An automated stage would save students and faculty valuable time. A commercial automated stage can cost over $30,000. Therefore the goal of this project is to create a low cost motorized microscope stage with a budget of only $100.

Our design consists of two stepper motors, worm drive gears, laser-cut gears, a linear rail system, motor and gear stabilizers, and an Arduino microcontroller. Each stepper motor controls a worm drive gear on its shaft. These worm drive gears are connected to their respective laser-cut gears, which in turn, are attached to the stage knob of the microscope. There are 3D printed motor stabilizers to attach the stepper motors to the linear rail system. Since the manual control knobs move with the stage, a linear rail system is necessary to carry the heavy motors along with the moving control knob. Finally, the stepper motors on the linear rail system connect back to an Arduino Uno which controls the speed of the stepper motors, therefore controlling the movement of the stage.

To test and validate our design, we connected the prototype and integrated it with the Nikon Eclipse Ti-U microscope. For validation, we first did a speed test to calculate the speed of the motors. This test was crucial to help create a program for the accuracy test. We used the Nikon Elements imaging program to do live imaging of our test sample with a 100 µm scale bar. An initial image was taken of the sample and then the motors were turned on, moving the stage in one direction for 2.5 seconds. After the stage was done moving, a final image was taken of the test sample. The initial and final images were overlaid in ImageJ, and the distance between one point from the initial and final image was measured. From there, the speed of the motors was calculated. Three trials of the speed testing were done for each of the four directions of the stage. An accuracy test was performed to determine the percent error between the theoretical distance and the experimental distance of movement of the stage. Using the mean speed from each of the directions in the speed test, we were able to create an Arduino program where a distance could be inputted, and the motors would move that distance. For the accuracy test, we took an initial image, set the motors to move 100 µm, and took a final image. The initial and final images were overlaid in ImageJ, and the distance between one point from the initial and final image was measured to get our experimental distance traveled. The experimental distance with the 100 µm theoretical distance was used to calculate our percent error. The pecent error for moving the stage in the +y, -y, +x, and -x directions were 3.56%, 13.8%, 7.31% and 4.35% respectively, providing how accurate our stage movements were.

The biomedical engineering teaching tabs have two inverted fluorescence microscopes that use stages controlled by translational knobs. Manipulating these manual translational knobs to take and stitch images can be a tedious, and non-uniform process, making it an inefficient system to create sub-par images. Creating a cost-efficient method to automate imaging and stitching can benefit the BME teaching lab with a more efficient way to make accurate images.