Microscope Low-Cost Motorized Stage - BME 200/300 Section 304

Product Design Specifications
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Function:

Contemporary inverted fluorescent microscopes are equipped with manual control knobs that enable a researcher to translate the microscope stage freely in the x and y directions. This manual control system presents a series of challenges to a user in recording and stitching sample images and in relocating or refocusing on specific sample areas. A manual knob is also generally more prone to error and tedious to operate when translating within the sample. A new motorized stage control system is needed that can automate the translation of a sample. The motorized stage with the options of a joystick or computer interface would enable a user to seamlessly and precisely move between areas of the sample. Programmed translations would also allow for the recording and stitching of numerous images. Fundamental specifications for the design include that it be low in cost (<$100) and have a high precision and accuracy in translations(1 µm resolution). As a whole, current inverted fluorescence microscopes necessitate a low cost motorized system for stage translations that would allow for the automated recording and stitching of images and seamless precise translations.

Client Requirements:

- Cost of the product to be within $100.
- Use 3D printing and laser cutting.
- Capable with Nikon Elements imaging software.
- Resolution of the movement is around 1 µm.

Design Requirements:

1. Physical and Operational Characteristics

    a. *Performance requirements:*
    The motorized stage must be compatible with the rest of the microscope. The software that the microscope uses include: Nikon elements, micromanager and the software to automate the locations. The wand of the motorized stage must not inhibit the rest of the microscope functions including the focus or the objectives. The client would like the motorized stage to also be electronic, small and enclosed. The motorized stage will likely be used in a research setting for researchers to image their samples.

    b. *Safety:*
    The motorized stage must be safe to the microscope and the operator of the device. The stage can be properly clean after use by the operator without any difficulty. The material of the motorized stage must be safe and should not cause any harm to the operator.

    c. *Accuracy and Reliability:* The motors must be calibrated to accurately and precisely translate to an inputted location of the sample. Specifically, the stage system should have a 1 um resolution when inputting locations, with a +-0.1 um error. The stage must also maintain the distance between the sample and the lens to ensure that the focus of the microscope remains the same and all effects of gravity are negated. To achieve this accuracy and precision, in addition to effectively calibrating the motors, that design that holds the motors must also be stable and its resistance to movement will prevent the buildup of error throughout its use. The joystick must also be reliable where the stage translations should correspond to its use, and this error should also fall within the +-0.1 um range.

    d. *Life in Service:* The stage must be functional for at least 10,000 cycles of imaging and should only undergo damage due to regular wear and tear. Updates to the software for how the stage translation system interacts with the computer interface may need to be done if a new or updated version of the computer interface is installed.

    e. *Shelf Life:* Power off when not in use and store properly. If using batteries, store in a dry environment to prevent from heat source to secure a higher lifespan.

    f. *Operating Environment:* The microscope will be used in a lab class environment for experiments. Presumably under room temperature and normal conditions. No direct exposure to sunlight and limited shakes and tilts followed by proper microscope use guidelines. Cover the device with a plastic cover to ensure no dust or corrosion gets in contact.

    g. *Ergonomics:* The entire equipment used must be small and not bulky to ensure the comfortable usage of the microscope. The mechanism of the stage must not interfere with the actual functioning of the microscope and must integrate with the software used. The equipment should be easy to carry and fit for storage.

h. *Size:* The product should be as small and compact as possible. It should not get in the way of microscope operation. The components must be enclosed, but still able to access for maintenance.
i. *Weight:* The product must be lightweight and able to easily lift off and reattach back on. Under 10lbs is ideal, in order for any user to move the product throughout the shop floor or between labs.
j. *Materials:* A 3D printer will primarily be used from UW's makerspace to print plastic prototypes. The printing method chosen will most likely be FDM/FFF methods [1]. In addition, a laser cutter from Makerspace will be needed. The model included is the Universal ILS9.150D [2]. An analog 2-axis thumb joystick for operating the device will be purchased. A low cost option is a joystick with select button and breakout board, used by the 2022 Spring BME students. Any materials that cost over a total of $100 should not be used.
k. *Aesthetics, Appearance, and Finish:* The product must look simple and understandable enough for students to use or learn from. While the product should be low cost, it should also appear compatible and designed to complement the microscope. The product's finish should be smooth to the touch for operators.

2. Production Characteristics
   a. *Quantity:* The client would like two universal units for the motorized stage that is functioning satisfactorily for the two microscopes in the teaching lab.
   b. *Target Product Cost:* The ideal cost of the unit should be under $100, including the fabrication and installation. The budget, however, is flexible.

3. Miscellaneous
   a. *Standards and Specifications:* As the device will not be mass produced, there are no manufacturer-required standards that it must abide by. However, there are still useful tools which can be used to test the accuracy and precision of our device. One of these is the Pelcotec™ LMS-20G Magnification Calibration Standard [3]. This is a piece of soda glass with a grid of 10 µm divisions. Using this calibration tool, the ability of the stage to move to a specific position and back can be tested.
   b. *Customer:* The client, Dr. Puccinelli, would like to utilize the fluorescence microscopes in the teaching labs for both the basic and advanced courses that he teaches. As a result, the device should be removable, as to allow Dr. Puccinelli to instruct students on how to use the microscope normally. When teaching the advanced courses, Dr. Puccinelli can reattach the device, and utilize the motorized slide for more complex experiments.

The client would also prefer that the device is small and does not interfere with the normal usage of the microscope. Finally, Dr. Puccinelli would prefer if the motorized slide interfaced with the native software of the microscope, allowing him to utilize the predefined functions to stitch photos together and create timelapses.

c. *Patient-related concerns:* As the device will be used in a teaching lab, there are no patient-related concerns to be addressed.

d. *Competition:* Many other motorized slide solutions are available for purchase for research usage. These designs are often very costly and complex, which limits their usage to large, well funded research groups. Our design serves to fill the gap, and increase access to motorized microscope stages. By creating a low cost alternative, labs with tighter budgets, such as a teaching lab, will be able to perform more advanced experiments.

One of the inverted fluorescence microscopes that the BME design lab operates is the Nikon TI-U. This microscope is also available with a motorized slide, for an additional cost [4]. The motorized version of the microscope, purchased from a third party website, costs $3000 more than the base model [5]. This price difference is monumental, particularly when considering the large startup costs associated with purchasing lab equipment. Our design aims to cost under $100, 30 times cheaper than if purchased through the microscope manufacturer.

References:

[1] “3D Printing at the Makerspace.” *UW Makerspace*, https://making.engr.wisc.edu/3d-printing-the-makerspace/.

[2] “Ils9.150D Platform.” *ULS*, https://www.ulsinc.com/products/platforms/ils9150d.

[3] “Pelcotec™ LMS-20G Magnification Calibration Standard,” Light microscopy calibration standards. [Online]. Available: https://www.tedpella.com/calibration_html/Light-Microscopy-Calibration-Standards.aspx#_688-2. [Accessed: 21-Sep-2022].

[4] “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: 21-Sep-2022].

[5] “Nikon Ti-U Inverted Fluorescence Microscope Pred Ti2,” Boston Industries, Inc. [Online]. Available: https://www.bostonind.com/nikon-ti-u-inverted-fluorescence-microscope-pred-ti2-2. [Accessed: 21-Sep-2022].