Product Design Specifications: Microscope Low Cost Motorized Stage

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BME 300/200

Clients: Dr. John Puccinelli

Advisor: Dr. Joshua Brockman

Team Members:

Team Leader: Tyler Haupert

Communicator: Nicholas Symons

BWIG: Sawyer Bussey

BPAG: Jerry Zhaoyun

BSAC: Julia Salita

Function:

The inverted fluorescence microscopes of the UW-Madison BME Teaching Lab are manually controlled microscopes that allow users to observe and collect data on cell and tissue culture. While the technology exists to convert these microscopes into motorized and automated devices, it is very expensive and beyond the budget of the school. The client, Dr. John Puccinelli, has requested the fabrication of a device to serve as a solution to this problem. The final working prototype should include mechanical, software, and hardware components to allow for the automation of manual inverted fluorescence microscopes. The physical structures of this device will interface with the manual adjustment knob on the right-hand side of the microscope. It will be capable of moving the stage in a coordinate-based fashion in both the X and Y directions. Software elements will be created to direct the movement of the stage. Finally, the client has also requested the development of software to process and stitch input images to add a scanning feature to the microscopes.

Client Requirements:

1. The device must be a motorized mechanism that controls the stage movement through the manual stage adjustment knobs.
2. The stage should be movable by using a joystick, computer keys, or by inputting values into the user interface.
3. The movements of the stage should be precise down to the micron range, with acceptable deviations within one order of magnitude.
4. The software created must be integrated into the existing NIS-elements software and assist in both taking images of the field of view and stitching them together.
5. The device will be powered by the wall outlets in the lab.
6. The project must remain under a final cost of 100 US dollars.

Design Requirements:

1. Physical and Operational Characteristics:

a. *Performance Requirements:*

i. The device should be able to adjust the microscope stage in both the x-axis and the y-axis using the manual adjustment knobs

ii. The software must be able to participate in image sequencing and be easy to use

iii. The field of view should be movable by using an interfaced joystick or computer keys such as the keypad arrows

b. *Safety*

i. The device should not be hazardous.

ii. The device should not harm the user in any way, including electrical shock[1], physical pinching, or loud sound levels.

iii. The device should not damage the microscope while ensuring smooth operation.

iv. The cords of the device should be safely arranged so that it does not block off the user's workspace. Moreover, the cords should not be placed near or be in contact with any liquid.

v. Labeling

	Signifies that the main plug must be disconnected from the wall outlet prior to maintenance [2].
	Indicates that the equipment labeled is suitable for the use of alternating current only [3].
	Specifies that the operator's manual should be referenced and used during use of device [4].

c. *Accuracy and Reliability*

i. The device should have a movement resolution of 1µm.

ii. The movements should be repeatable without having to recalibrate the device.

d. *Life in Service*

i. The device should be reliable and last at least 10 to 15 years [5].
ii. The stepper motors have a lifetime of 20,000 hours[6], which translates to 2,500 8 hour work days or 500 5 day work weeks. This matches our requirement of a 10-15 year lifetime.
iii. The device should not break easily and withstand daily wear and tear.
iv. The device should be capable of undergoing regular sanitation via autoclaving and/or harsh cleaning chemicals.

e. *Shelf Life*
   i. To ensure the longevity of the device while stored, the device should be kept dry and at regular room temperature and pressure.
   ii. All materials used for the device should be stable at standard lab temperature and humidity conditions.
   iii. The device should be able to be stored either attached or detached from the microscope at normal room conditions.

f. *Operating Environment*
   i. The laboratory will be kept within a temperature range of 20-25 degrees celsius with a relative humidity of 35-50 percent [7].
   ii. The device will be kept in the BME teaching lab and should be able to operate in the above conditions.

g. *Ergonomics*
   i. The device must be small and not disrupt the normal operation of the Nikon TI-U and Olympus IX71 microscopes.
   ii. The software must be operable with the nikon elements software and must have a user-friendly interface.

h. *Size*
   i. The device should take little to no table space next to the microscope.

ii. Ideally, the entire device should be encased to minimize device interference and malfunction due to exposure.

i. *Weight*

i. The device should be lightweight to minimize interference and damage to the function of the microscope.
ii. Weight should not limit usage and accessibility of the microscopes for all users.

j. Materials

i. All materials purchased, altered, and used must comply with the guidelines for a biosafety level 1 laboratory listed in the Biosafety in Microbiological and Biomedical Laboratories (BMBL) 6th Edition [8] by the Centers for Disease Control and Prevention (CDC) [9].
ii. 3D printing should be utilized to print most plastic prototypes using the FDM and FFF printing methods [10], [11].
iii. The Universal ILS9.150D [12] laser cutter will be used to accurately cut precise pieces necessary for maintaining accuracy of movement of the microscope stage.
iv. Soldering [13] may be used to stabilize the electronic connections within the necessary circuitry.
v. All included materials must be resistant to the degradative effects of harsh chemicals used for regular sanitization of lab equipment.
vi. Plastic gears should be used rather than metal gears to eliminate the need for lubricant, this would decrease the amount of maintenance needed in order to keep the device operational [14]. Additionally, plastic materials will also help to lower cost.
vii. Plastic materials expand and lose structure at increasing temperatures. Thus, material choice should consider the rate at which different plastic materials heat or cool.
viii. Materials used for gears should be made out of a plastic with a low thermal diffusivity, which is defined as the thermal conductivity ratio to the specific heat capacity of the material. Materials of large Thermal Diffusivity will respond quickly to changes in heat and Materials of low Thermal Diffusivity will respond slowly [15]. Thermal Diffusivity

of PVC (7.8E-6 m^2/s) [16], this is a low Thermal Diffusivity meaning the material heats up slowly. The equation for this value is: α=k/pCp

1. a= thermal diffusivity
2. k= material conductivity
3. p=density of material
4. Cp=specific heat of material

k. *Aesthetics, Appearance, and Finish*
   i. The device should not be distracting to the user.
   ii. The final product should be neat and blend in with surrounding equipment.
   iii. All edges should be smooth and not pose a threat to users operating the device.

2. Product Characteristics

a. *Quantity:*
   i. Only one device will be manufactured for the client
   ii. The device should be replicable in order to produce additional products if necessary or to potentially be mass produced.

b. *Target Product Cost:*
   i. The target budget is to remain under a total of $100 for the final cost of the device.
   ii. The allocated budget for development is $300.
   iii. The team should use previously purchased materials to keep costs low and reduce waste, however, the team should present the final total price to reflect the total cost if the device is to be replicated.

3. Miscellaneous

a. *Standards and Specifications*
   i. All aspects of the device's design must comply with the many guidelines provided by the CDC for biosafety level 1 laboratories [8].

ii. The device should follow all guidance outlined in the FDA's "Chemical, Metals, Natural Toxins & Pesticides Guidance Documents & Regulations" to ensure safety and producibility should the device be reproduced [17].

iii. The following standards are to be referenced and used as guidelines throughout the development and implementation electrical systems designs [18].

1. ISO 9001 Standard: Quality Management System.
2. ISO 14001 Standard: Environmental Management System.
3. ISO SOC Standard: System and Organisation Controls
4. ISO 27001 Standard: Information Security Management.
5. ISO 45001 Standard: Occupational Health and Safety Management System.
6. ISO 10002 Standard: Complaint Management Systems
7. ISO GDPR Standard: General Data Protection Regulation

b. *Customer*

i. While the team's client has a sole interest in the design, there is a potential for a more broad potential application of our design. If fabrication methods can be simplified and streamlined, it is likely that many universities and budget-aware labs would be keen to utilize our low-cost solution to the problem of motorizing and automating manual microscopes.

c. *Patient-Related Concerns*

i. The device should not inflict any danger to the surrounding users and equipment

ii. This device should be capable of undergoing regular maintenance and cleaning with harsh chemicals [8].

iii. No paper, cardboard, or other organic materials should be utilized in the final design.

d. *Competition*

i. The OpenFlexture project is an open-sourced, 3-D printable microscope that can be created and constructed for approximately $200, with multiple stages available to add motorized and automated functionality [19].

ii. One example of market-available motorized stages is Zaber's ASR series motorized XY microscope stages [20].

 1. While these are functional, accurate to within 12 μm, and available, they do not meet client criteria due to cost and the way they interact with the microscope.

iii. Detailed in a 2017 article, a group of German-based scientists created an automated, motorized, 3-D printed inverted fluorescence microscope. The article includes all necessary CAD and software files for construction, as well as a step-by-step instruction manual to aid users in building their device [21].

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