Digital Microscope for Whole Slide Imaging

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Abstract

A Digital Microscope for whole-slide imaging is an imaging system designed to capture high-resolution images of entire microscope slides. In this work, we present the development of a Digital Microscope for Whole Slide Imaging, which utilises a stepper motor-based approach to achieve rotational-to-linear digital microscopy. The prototype is designed to provide an advanced imaging solution that is suitable for various applications such as biological research, materials science, and quality control. The integrated automated image-capturing system of the microscope enables high-resolution imaging with enhanced precision and speed. The use of a digital reconstruction algorithm, along with a computerized system, allows for the automated stitching of multiple captured images to create a complete digital reconstruction of a whole slide image.

The microscope's motorized stage allows for automatic movement and positioning of the sample, enabling accurate focusing and efficient image acquisition. The automated image-capturing feature further streamlines the imaging processes by eliminating manual intervention, saving time and increasing throughput, which is critical for medical diagnosis where many samples need accurate and efficient processing. Incorporating machine learning and image analysis techniques can enhance the low-cost digital microscope's capabilities for whole-slide imaging and become a valuable tool for research and diagnostic purposes.

Keywords: Whole Slide Imaging, Low-cost, Automated image-capturing,

Introduction

The use of a digital microscope with an automated base that moves in the X-Y direction and captures images offers several benefits in imaging. With the movement of the microscope stage automated, high-resolution imaging with enhanced accuracy and speed is possible, reducing the risk of user error and enabling consistent results. Moreover, the automated image capture feature further streamlines the imaging process, eliminating the need for manual intervention and reducing the risk of data loss or corruption.

The digital microscope also has the advantage of digital storage capabilities, making it easy to store and transport large volumes of image data. This digital storage capability reduces the burden of physical storage and enables collaboration across teams and institutions.

In fields such as medical diagnosis, where a large number of samples need to be processed efficiently and accurately, the use of a digital microscope with an automated base and image capture feature is particularly important. The automated processes allow for faster and more accurate analysis, reducing the time and cost of diagnosis. The digital storage feature also allows for easier sharing of data between institutions, facilitating collaboration and improving the accuracy and speed of diagnoses.

Literature Review

In their 2012 study [3], Bhakti and colleagues developed a system to automate the movement of microscope slides. The system included two stepper motors connected to the rails of the microscope's moving stage. To convert the motor's angular movement to linear movement, a linear actuator was assembled on the shaft of the motor. This allowed the slide to be driven along the X and Y axes on the horizontal plane. However, the study only focused on automating the slide movement and did not investigate other aspects of the system.

In 2015, Soon and colleagues [4] developed a prototype of Autoslide movement for the microscope, which used stepper motors to control the direction of slide movement. The motors were connected directly to the translational stage of the microscope, which converted rotational motion into linear motion. The rotation of the stepper motors was controlled by a joystick arrangement, where the input signal from the joystick provided instructions to the microcontroller. The controller processed the input signal and sent the corresponding information to the motor driver to rotate the motor.

The existing literature indicates limited prior efforts to automate the movement of microscope slides and capture associated images. Some studies have utilized stepper motors to automate slide movement and enable autofocusing. This project seeks to develop an affordable system for automatic slide movement and image capture, utilizing a web camera for imaging purposes.

Motivation

The disadvantages of utilising existing digital microscopes are that medical professionals must move the slide manually along the X- and Y-axes in the horizontal plane and spend a lot of time viewing the area of interest through the eyepiece. Automated systems in this domain are quite expensive and inaccessible to many labs. Consequently, one of the key goals of this project was to create a prototype that could replace the current manual slide movement arrangement with an automatic movement.

Methodology

Our system uses a stepper motor and rack and pinion system to move the microscope slide and capture images of local regions of the slide. The captured images are then digitally reconstructed to create a high-resolution image of the entire slide.

The digital microscope system is designed to be cost-effective by using off-the-shelf components such as a camera module, stepper motor, and rack and pinion system. The system also uses open-source software to create a fully functional imaging system. The simplicity of this system make it accessible to a broader range of users, including smaller labs and medical facilities that may not have the budget for traditional whole-slide imaging systems.

The system is capable of capturing images of local regions of the microscope slide and stitching them together to create a high-resolution image of the entire slide. The stepper motor and rack and pinion system provide precise movement control and ensure that each local region of the slide is captured with high accuracy. The captured images can then be digitally reconstructed to create a complete image of the entire slide, which can be used for research, education, and clinical diagnosis.

Prototype model

Figure-1: Prototype model; To test the mechanism, we built a prototype model as a proof of concept.

3D CAD model

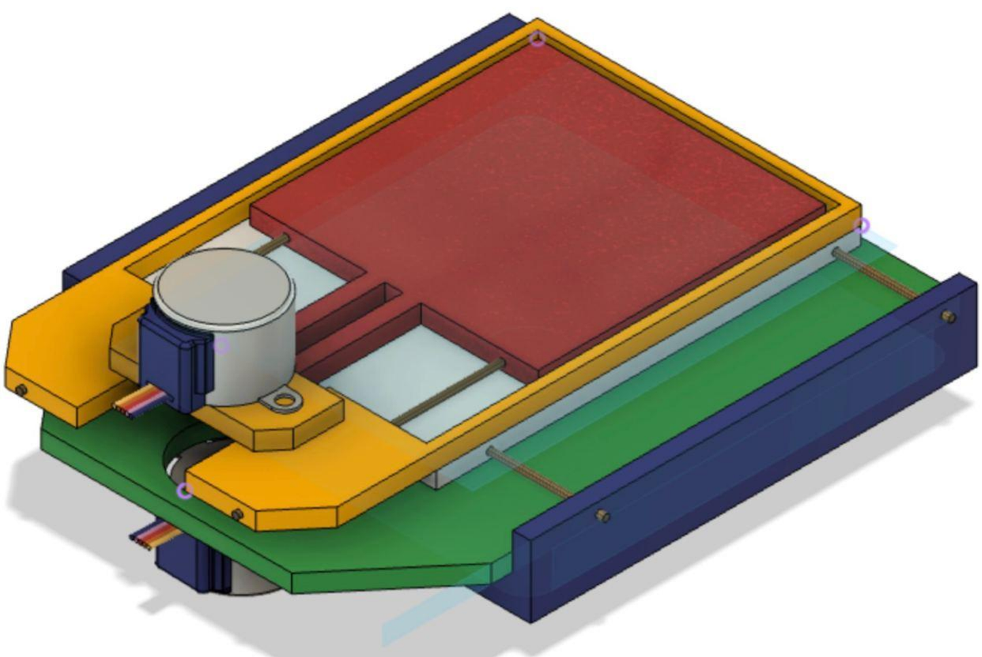

Figure-2: 3D CAD Model. Shown in Blue is the wall of the microscope, Green is the base of the module, which is placed on the microscope's base, Yellow is the X-frame, and Red is the Y-Frame. The stepper motors are placed so as to allow for unhindered movement along both X- and Y-axes.

The description provided in Figure-2 outlines the intricate details of a microscope setup that utilises stepper motors and a joystick for automated and manual slide movement. The blue frame serves as the foundation for the entire system and is inserted into the microscope base, which provides support for the green base. The green base houses the stepper motor that controls the X-axis movement, which is critical for capturing precise and accurate images of the slide.

The X-axis is supported by two rods, which provide stability and prevent any unnecessary movement or vibrations. Above the rods, the yellow base is positioned, which houses the stepper motor responsible for y-axis movement, as indicated by the red base. The combination of the X- and Y-axis movement ensures that the microscope can easily and accurately capture images of specific regions of a slide.

To control the X- and Y-movement, an Arduino is placed under the setup, which serves as the central control unit. The Arduino allows for precise and accurate control of the stepper motors and ensures that the slide movement is smooth and seamless. Additionally, a joystick is also provided, allowing users to navigate the slides manually and providing them with greater flexibility and control over the image capture process.

The use of stepper motors and a joystick in a microscope setup offers several benefits, including increased accuracy and precision, reduced risk of human error, and improved efficiency. The ability to capture images of specific regions of a slide allows researchers and clinicians to analyze and diagnose tissue samples with greater accuracy and precision, ultimately leading to improved patient outcomes.

Discussions and Conclusion

In conclusion, The digital microscopes for whole-slide imaging offer several advantages over traditional whole-slide imaging systems. These systems are designed to capture high-resolution images of entire microscope slides at a lower cost than traditional systems, making them accessible to a broader range of users. Furthermore, low-cost digital microscopes often use off-the-shelf components, such as consumer-grade cameras and microscope optics, along with open-source software to create a fully functional imaging system. This approach offers greater flexibility and the ability to customize the system to meet specific imaging needs.

By using stepper motors and rack and pinion systems to automate the slide movement helps in reducing human error and saving time. These microscopes can capture local regions of a slide image and digitally reconstruct them, making analysis and diagnosis of tissue samples easier for researchers and clinicians, leading to improved patient outcomes. This makes it easier to analyse and diagnose tissue samples, which can ultimately lead to improved patient outcomes.

Future Scope

To enhance our system's performance and provide a more seamless user experience, we have several plans for future improvements. We plan to utilise machine learning and deep learning techniques over the cloud to analyse and process digital images. By leveraging these advanced techniques, we can improve the accuracy and efficiency of our system, particularly in automating repetitive tasks. This will allow users to spend less time on tedious tasks and more on critical analysis and decision-making.

Additionally, we plan to develop an application that will simplify the setup and usage of the system even further. This application will provide an intuitive interface for users to interact with the system and will streamline the process of configuring and running experiments. The application will also allow users to easily visualise and analyze data generated by the system, making it a valuable tool for data analysis and decision-making.

Moreover, we plan to explore the integration of other cutting-edge technologies, such as computer vision and robotics, to further enhance to the capabilities and functionality of our system. This could potentially open up new avenues for research and development and could lead to innovative applications and discoveries in a variety of fields.

Overall, these planned improvements will enable our system to be more efficient, accurate, and user-friendly and be accessible to various labs due to the low cost.

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