Pathology resident experience using a low-cost 3D printed microscope for portable digital pathology

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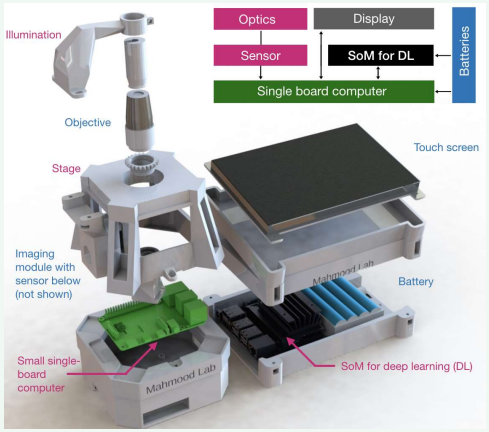
Background

The explosion of interest in digital pathology has not generally made access to slide digitization technologies widely available due to the often-prohibitive requirements for whole slide scanners which can run in the hundreds of thousands of dollars and take up most of a standard desk, not to mention costs associated with training in their use, maintenance, and other indirect costs. Meanwhile, microscopes with attached camera systems can also be extremely expensive, with prices routinely exceeding $10,000 for hardware and software. The high price of admission to the world of digital pathology limits the educational opportunities for trainees to train with digitized images. We have designed and built a low-cost 3D printed digital microscope that allows for cheap and portable digital pathology and holds potential as a unique training tool for residents.

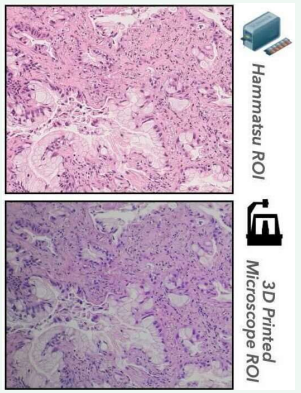
Methods

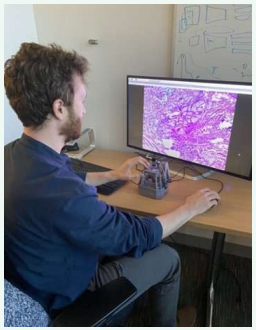
- 3D printed microscope design with a Raspberry Pi and off-the-shelf electronics components, allowing for the transmission and capturing of digital photomicrographs and video, all for a total cost of **$264** at non-bulk prices.
- Easy to assemble and small enough to fit in one hand.
- Two pathology residents took photomicrographs of a total of 398 slides, used for a research project and to test usability
- Design was fine-tuned and prototyped during the testing period based on pathologist feedback



Results

- **Easy & natural to use**: stage and focusing mechanism mimics a standard glass microscope
- **Straightforward image capture**: runs OpenFlexure software on the integrated Raspberry Pi
- **Crisp & clear images:** comparable to traditional microscope-attached cameras; validated on USAF resolution target & NIST color transmission target
- **Ultra-portable**: fits comfortably in one hand, easy to transport (i.e. from office to frozen section room), can run off an electrical outlet or batteries
- **Accessible & efficient digitization**: images were immediately digital allowing for easy sharing within and outside the hospital, minimal computer experience necessary
- **Enhanced education**: easily usable and accessible digital pathology encouraged sharing of educational cases & allowed for residents to build their own collection of cases.
- **Extensible:** with an NVIDIA Jetson Nano, the device can be outfitted with hardware that can run deep learning algorithms in real time, turning it into an augmented reality microscope





A former pathology resident using the microscope to image a region of interest.

Example use cases

Research
- Taking publication-quality photomicrographs cheaply and easily
- Creating a dataset of regions of interest with a morphology of interest

Clinical
- Remote consultation for difficult frozen sections
- Easily sharing images with treating clinicians and patients

Education
- Without onboard AI: creating a gallery of interesting or difficult cases
- With onboard AI: image search for help with new diseases or uncommon morphologies

Conclusions

Digital pathology remains out of reach for many, including pathology trainees due to cost, personnel requirements, speed, and other factors. Our 3D printed microscope is an affordable solution that allows for easy photo capturing, storing, and sharing. The modular 3D printed nature of the microscope allows for the possibility of reprinting missing or broken pieces locally, rather than relying on external manufacturers. This tool could allow residents to have their own digital and "smart" microscope, which can enhance learning and encourage trainees to save and share interesting cases digitally.