

Automated Digital Pathology Slide Scanner



Figure 1: Example pathology slide (left) and segmented tumor area on a breast pathology image (right)

Digital pathology transforms glass pathology slides into high-resolution digital images that can be viewed, archived, shared, and analyzed computationally. However, commercial whole-slide scanners are expensive. The aim of this project is to design and implement a low-cost automated pathology-slide scanner that combines optical imaging, mechanical scanning, image registration and stitching, and image analysis for tissue-level classification and tumor-region localization.

Due to the trade-off between spatial resolution and field of view (FOV), the system will acquire multiple image tiles by automatically moving either the slide or the imaging unit. Since low-cost linear-motion components may have limited accuracy and exhibit backlash, vibration, and mechanical play, micrometer-level positioning accuracy is not expected; instead, sufficient tile overlap and image-based registration will be used to compensate for positioning errors. The scanned tissue region will then be reconstructed from the acquired image tiles. The reconstructed images shall be analyzed using image-processing methods. The complete acquisition and analysis workflow shall operate with both histopathology slides and high-resolution printed pathology images mounted on slide-size substrates.

The system must have the following features:

Scanning Platform

- The platform shall accommodate standard pathology slides of approximately 75×25 mm and provide controlled motion along two orthogonal axes.
- Low-cost linear-motion components such as stepper motors, lead screws, belt-driven mechanisms, modified 3D-printer components, or similar hardware may be used.
- Stage positioning repeatability shall be **250 μ m or better**, and adjacent images shall have at least **20% overlap**.
- The system shall be able to identify a known reference position for the scanning stage and use mechanical or electronic limits to prevent motion beyond the allowed travel range and avoid damage to the slide or imaging unit.
- Stage movement and image acquisition shall be synchronized so that each image is acquired only after the commanded position is reached and mechanical vibration has sufficiently settled, and positioning performance, including repeatability, backlash, vibration, and settling time, shall be experimentally characterized.

- The scanning strategy shall reduce the effects of backlash through approaches such as approaching each position from the same direction, appropriate motion planning, mechanical preload, or software compensation.

Imaging System

- The imaging system may use a custom or commercial camera-and-optics assembly.
- The students shall design and integrate an illumination system suitable for both histopathology slides and high-resolution printed pathology image targets, supporting transmitted and/or reflected illumination as appropriate for the sample. Illumination intensity shall be electronically adjustable and sufficiently uniform across the FOV.
- The system shall provide manual focus adjustment. Motorized focusing or autofocus may be implemented as an extra feature.
- At the selected scanning configuration, the imaging system shall provide a field of view of approximately **1 × 1 mm to 5 × 5 mm**, an object-plane sampling interval of **10 µm/pixel or better**, and a spatial resolution of **20 µm or better** (i.e. to resolve features separated by **20 µm or less**).
- FOV, spatial sampling, effective resolution, and illumination uniformity shall be experimentally characterized.

Image Reconstruction, Analysis and User Interface

- The user shall be able to define or select the region to be scanned, and the system shall automatically scan the entire selected region without manual slide repositioning.
- The software shall coordinate stage motion, illumination, settling time, and image acquisition.
- Acquired image tiles shall be registered and stitched using both nominal stage coordinates and overlapping image content to compensate for mechanical positioning errors. The reconstructed image shall not contain major missing regions, duplicated structures, or clearly visible discontinuities between neighboring tiles.
- The software shall classify a scanned tissue image as **tumor-containing or non-tumor**, and localize and segment suspected tumor-containing regions.
- Classification performance shall be evaluated using metrics such as accuracy, sensitivity, and specificity, and segmentation performance using the Dice coefficient and intersection over union (IoU).
- The user interface shall display scanning progress, the reconstructed image, and analysis results overlaid on the reconstructed image, and support export of these outputs together with image tiles, acquisition metadata, and scanning parameters.
- Acquisition and reconstruction of a **15 × 15 mm** region shall be completed within **5 minutes**.
- Scan coverage, image-registration accuracy, acquisition time, and reconstruction time shall be measured and reported.

Extra Features:

- Automatic detection of the tissue-containing region and scanning only that region
- Higher-resolution imaging mode for detection and counting of individual nuclei
- Motorized focusing, autofocus, automatic exposure or illumination adjustment
- Automatic detection and reacquisition of blurred or missing tiles

- Multiresolution viewing similar to commercial whole-slide imaging software
- Comparison of alternative scanning trajectories and backlash-compensation methods