PathScan: A Digital Pathology Pipeline for Efficient Cancer Diagnostics

Uddip Kashyap

PROBLEM

INEFFICIENT CANCER DETECTION METHODS

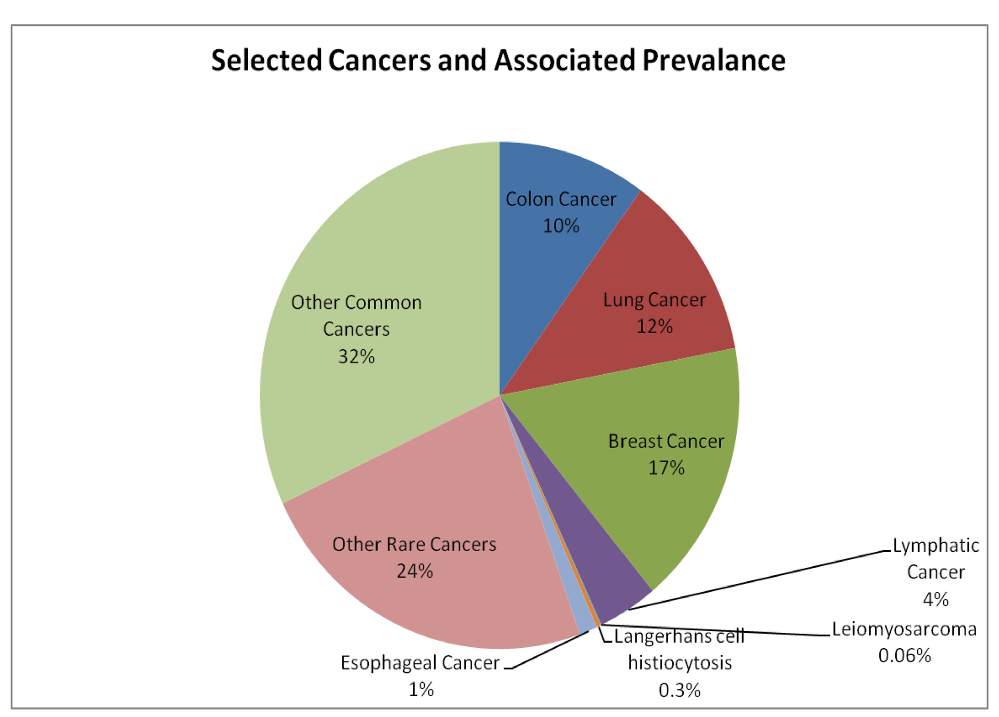
COSTLY DIGITAL PATHOLOGY SCANNERS AND PATHOLOGIST DIAGNOSTICS

CANCER DIAGNOSTIC DISPARITIES

LOW-INCOME AREAS CANNOT AFFORD QUALITY CANCER DIAGNOSIS.

- Rare cancers and cancer adjacent diseases such as leiomyosarcoma, esophageal cancer, and Langerhans-cell histiocytosis make up 25% of all cancers in the U.S. (NIH)
- However, individually, rare cancers are defined as cancers that affect less than 40,000 people per year
- This makes it incredibly difficult for doctors to diagnose such cancers due to the lack of information and data needed to identify signs of a tumor
- This issue is exacerbated further in low-income and rural areas due to being exorbitantly expensive for some individuals, requiring highly trained doctors, and requiring costly equipment
- The gold standard for tumor diagnosis is tissue biopsy and analysis by a pathologist with a histopathology scanner
- However, the equipment and finances needed to fund a single scanner can reach up to $300,000 (Digital Pathology Association), making it incredibly difficult for developing areas to purchase and receive high-quality cancer diagnoses
- Patients may also have to individually pay up to $3000 for a full procedure (Turquoise Health)

A cheaper and more accurate rare cancer detection system must be built



Makeup of all cancers as compared to selected cancers. Image Credit: Uddip Kashyap

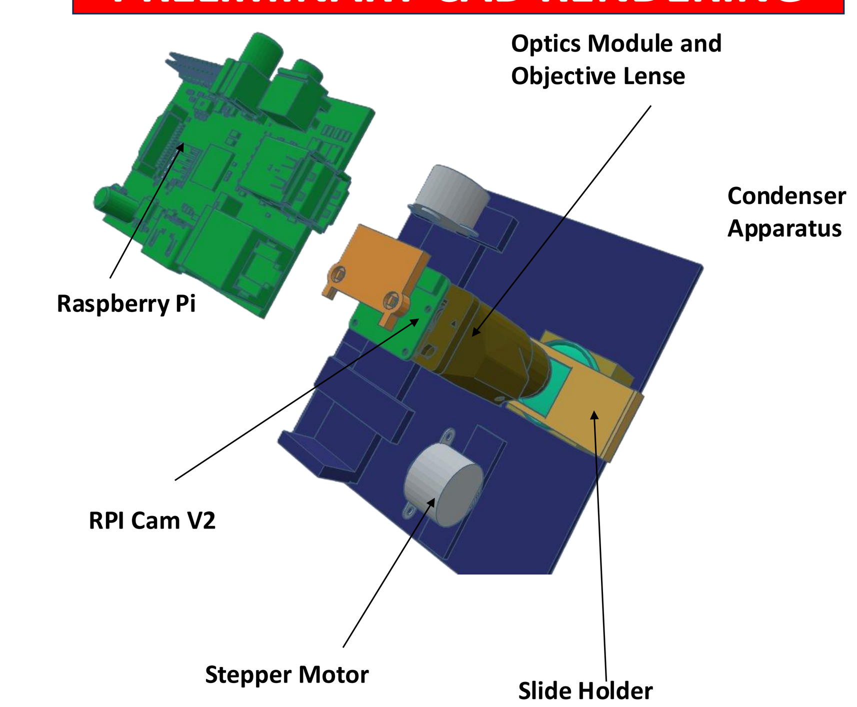
ENGINEERING GOALS

- Cost: The device should be of a cost less than or equal to $500
- Quality: The device should be able to capture high-resolution images at different magnifications
- Viewing: The device should have software that enables images to be stitched together for whole-slide image (WSI) viewing
- Usability: A user-friendly application must be developed, and the software must be compatible with said application

METHODOLOGY: SCANNER

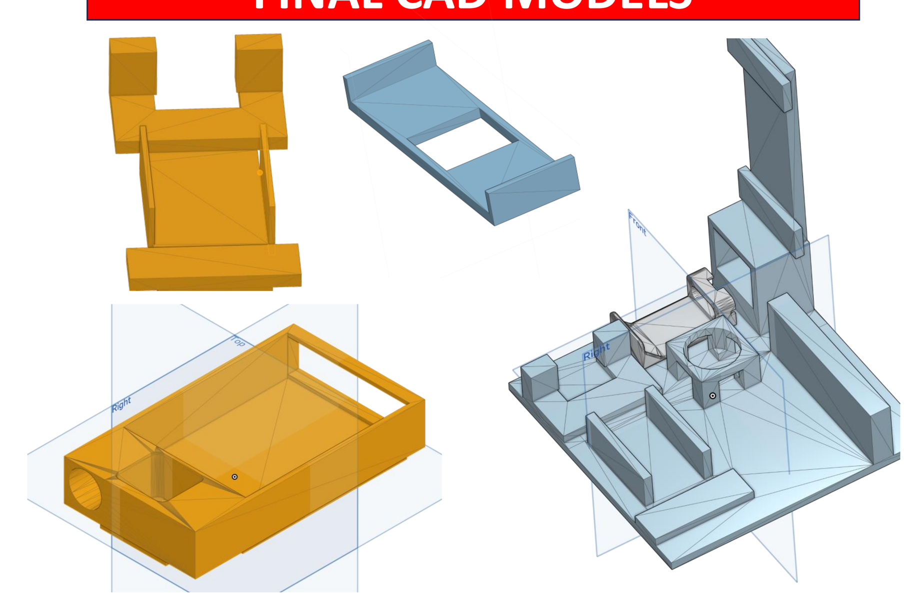
1. **ProGAN Generation**
   - Upscale images from 4x4 pixels to 32x32 pixels
   - Generate synthetic datasets of 100 images using random noise vectors
2. **CNN and Fine-tuning**
   - Tune ProGAN hyperparameters to achieve FID ≤ 250
   - Create CNN for detection of each rare cancer type
3. **Scanner Design**
   - Design and develop scanner with low-cost components
   - Capture and stich images for analysis
4. **Deployment and GUI**
   - Simple GUI with AI integration for cancer detection
   - Data security mechanisms to protect patient information

PRELIMINARY CAD RENDERING



Simplified exploded view of the PathScan Scanner. Image Credit: Uddip Kashyap

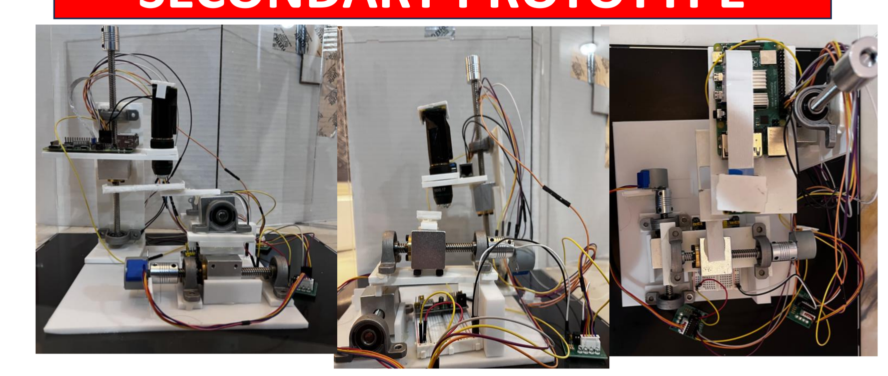
FINAL CAD MODELS



PRIMARY PROTOTYPE

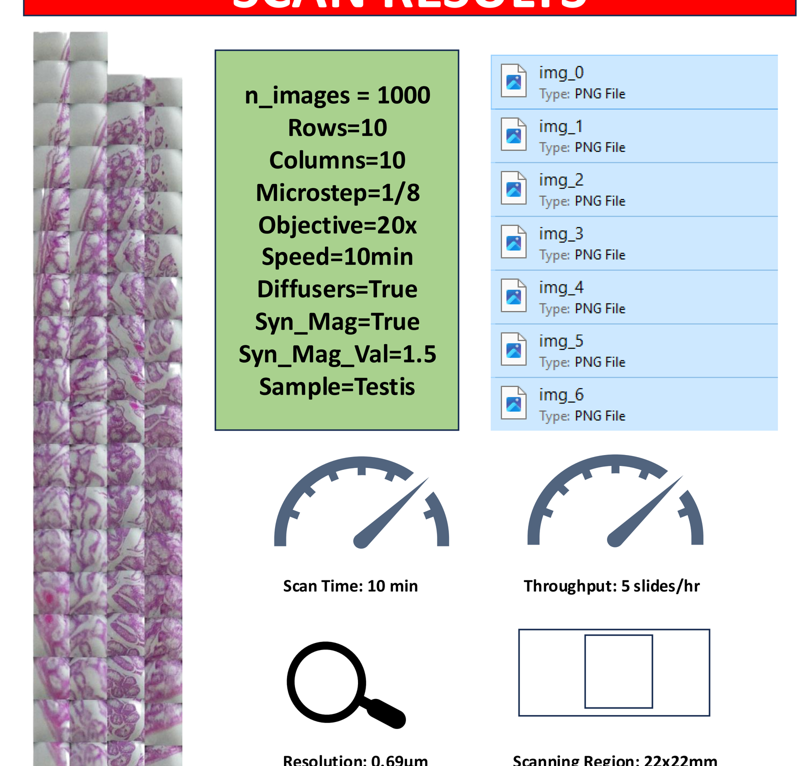
Front, Right Side, and Top views of the initial prototype. Image Credit: Uddip Kashyap

SECONDARY PROTOTYPE



Front, Right Side, and Top views of the reproducible prototype. Image Credit: Uddip Kashyap

SCAN RESULTS



Left-Right: An Example Scan of a Kidney Section. Scan Parameters & Compiled Image Snapshot. Compilation of Evaluative Metrics. Image Credit: Uddip Kashyap

- A Raspberry Pi Camera Module is connected to a modified OpenFlexure optics module and an objective lens to magnify and focus the slide for image capturing
- The slide itself rests on a condenser apparatus which focuses the beams of light onto the tissue. The stepper motors move the slide to capture all aspects of the tissue sample
- Through a ribbon cable, images are transferred to the Raspberry Pi
- Portions of the image can be used by the PathScan Histology Classifier for an independent diagnosis
- Over 20 trials, the scanner averaged 10 minutes per scan, including computation times, showing high efficiency

METHODOLOGY: AI

Generator

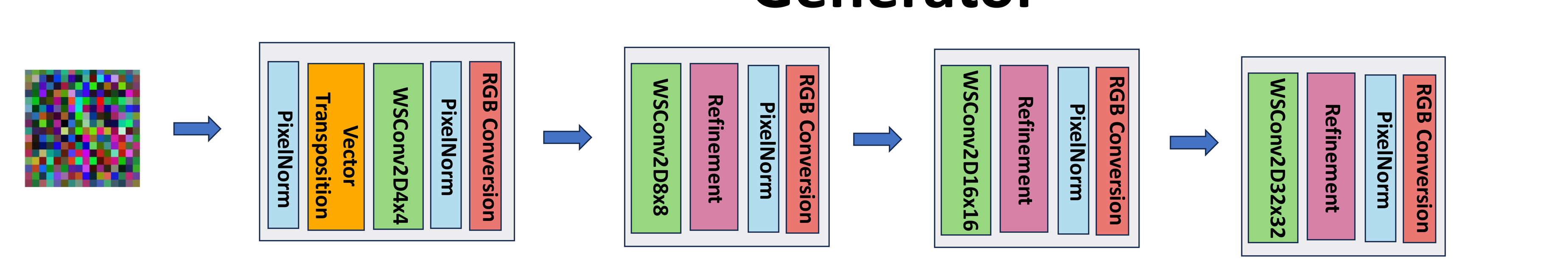
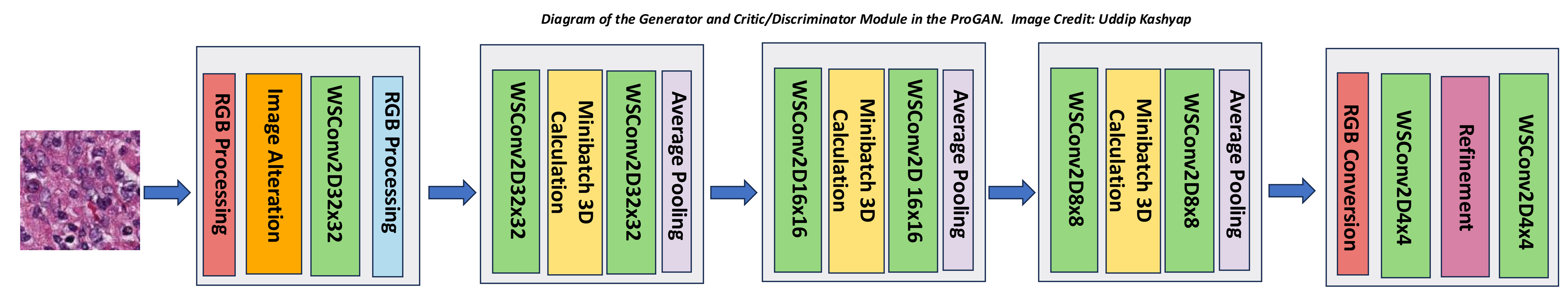
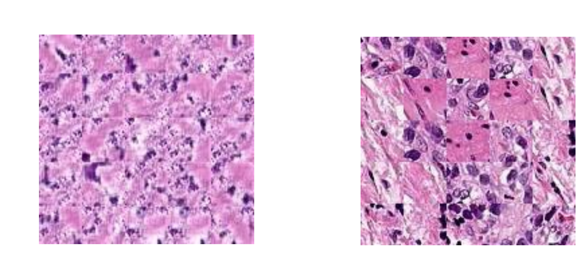


Diagram of the Generator and Critic/Discriminator Module in the ProGAN. Image Credit: Uddip Kashyap

Critic

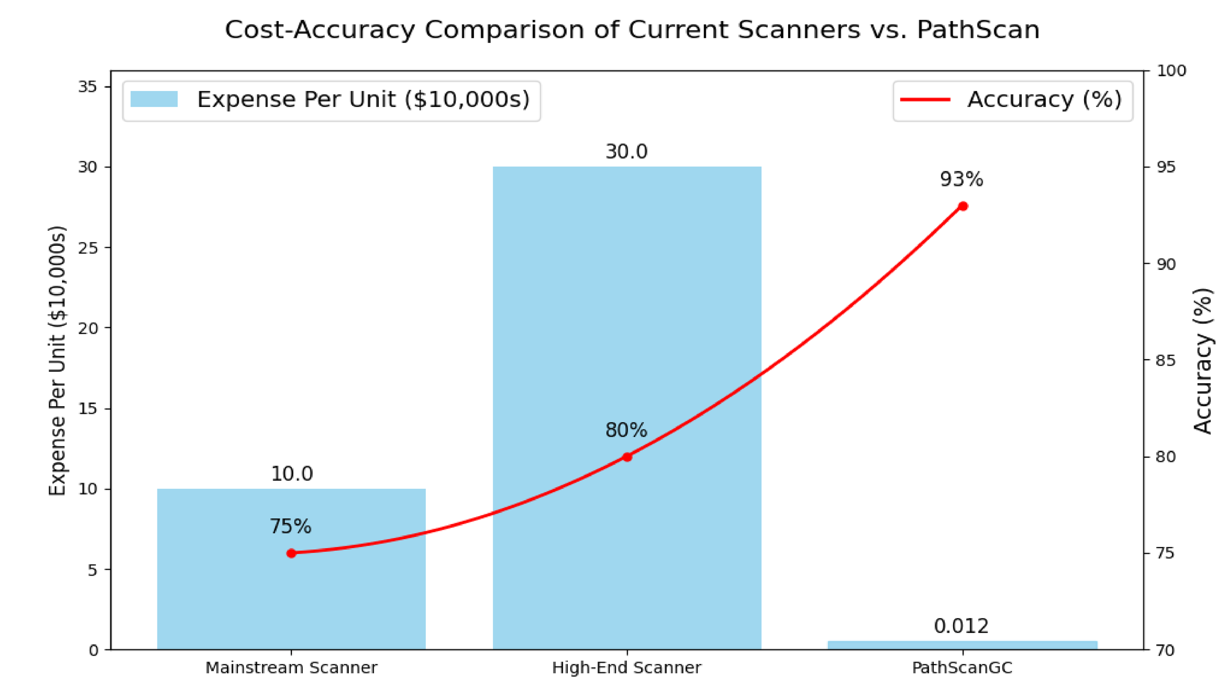




Sample of synthetic images. Image Credit: Uddip Kashyap — *Sample of real tumor images. Image Credit: Uddip Kashyap/ TCGA*

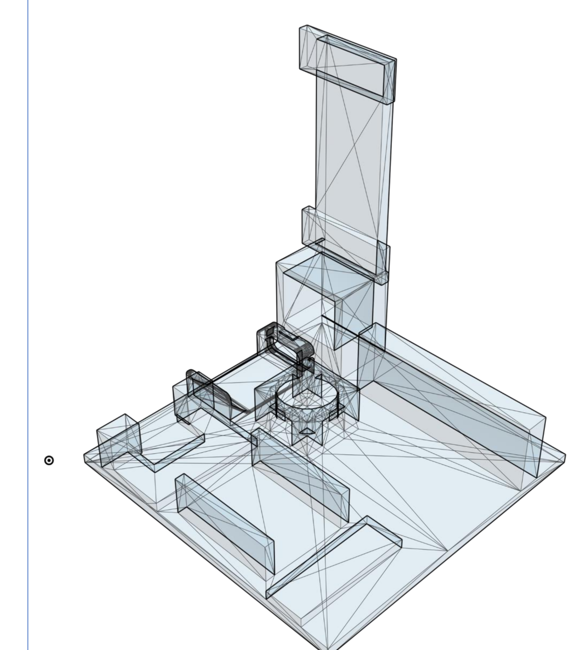
Over time, the synthetic images progressively exhibit greater similarity to real images, capturing finer details and more accurate distributions of features

COST-BENEFIT ANALYSIS



Cost-Accuracy Comparison of Current Scanners vs. PathScan. Image Credit: Uddip Kashyap

MANUFACTURING



- All major aspects of the device can be 3D printed, making assembly easy
- In total, all parts comprise approximately 1 kilogram of biodegradable PLA filament, or about $20 worth.
- The lead-screws, RPI, condenser lens, and battery pack with LED can easily be fitted with little manual labor
- CAD files and adjustable components make personalization simple and cost-effective
- Lens magnifications can also be adjusted based on the requirements of the situation

Cost: $122

Print Time: 30 hr

Assembly Time: 1 hr

MARKETS

- Currently, the digital pathology market is expected to grow immensely to almost $2 billion by 2030
- However, many potential sources for revenue and aid remain untapped, especially in rural regions
- A major cause of this is the cost of the digital pathology scanners themselves, which can cost upwards of $50,000 and have high maintenance costs
- PathScan, by contrast, costs just $122 to manufacture and can easily be sold for upwards of $500 without comprising its low cost
- Additionally, AI-powered diagnostic software is becoming increasing prevalent in the digital pathology space, but almost all systems lack rare cancer diagnostic mechanisms
- PathScan currently stands as the only effective rare-cancer diagnostic method for histopathology, highlighting its potential for growth in the market

REFERENCES

All images were created by the researcher, Uddip Kashyap

About Rare Cancers - NCI. (2019, February 27). Www.cancer.gov. https://www.cancer.gov/pediatric-adult-rare-tumor/rare-tumors/about-rare-cancers

Digital Pathology Market Size & Share Analysis Report, 2030. (n.d.). Www.grandviewresearch.com. https://www.grandviewresearch.com/industry-analysis/digital-pathology-systems-market