Real time display and automated image classification for confocal microendoscopy

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Objective: Diagnostic in-vivo cellular imaging

- Develop a confocal microendoscope that can present real time in-vivo cellular imaging to the physician.[1]
- Develop automated image classification methods to display real time diagnostic information during a procedure.
- Develop an interface to control image display, focus, dye delivery, and data archiving.
- Test system in a small-scale clinical trial on women undergoing oophorectomy to assess its ability to detect ovarian cancer.

Confocal micro-endoscope

System

System consists of a custom slit scan fluorescence confocal microscope coupled to an imaging catheter. (Figure 1)

- Custom slit scan confocal microscope: Anamorphic optical system shapes laser into a line of illumination scanned in one dimension across proximal face of imaging catheter. Line scanning system provides video imaging speeds. Argon-ion and krypton-ion lasers in illumination arm provide potential excitation wavelengths throughout the ultraviolet and visible spectrum. System operates in either greyscale or multispectral mode.
- Imaging catheter: 3mm in diameter containing a 30k element coherent fiber bundle[2-4], miniature achromatic objective lens, miniature mechanical focus mechanism, and dye delivery channel. The catheter can be used as an independent device or as daughter scope through the therapeutic channel of an endoscope.[5-6] (Figure 2)

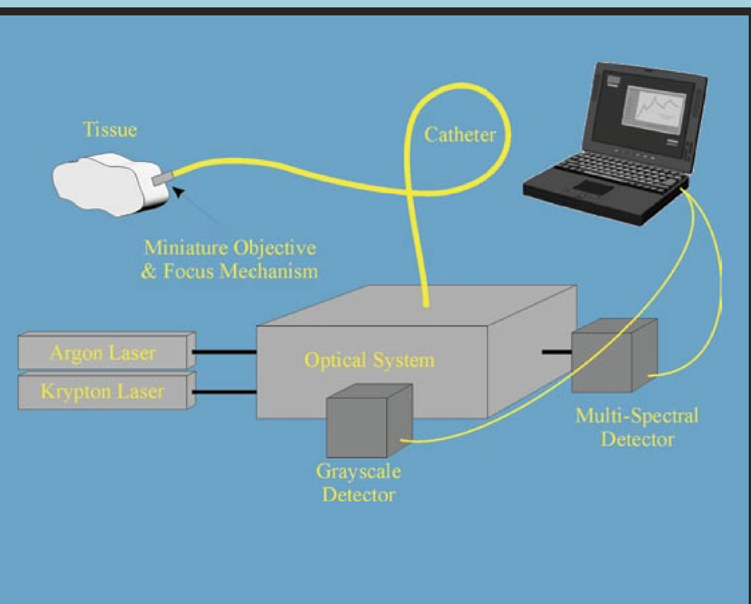


Fig. 1: Functional components of the confocal microendoscope.

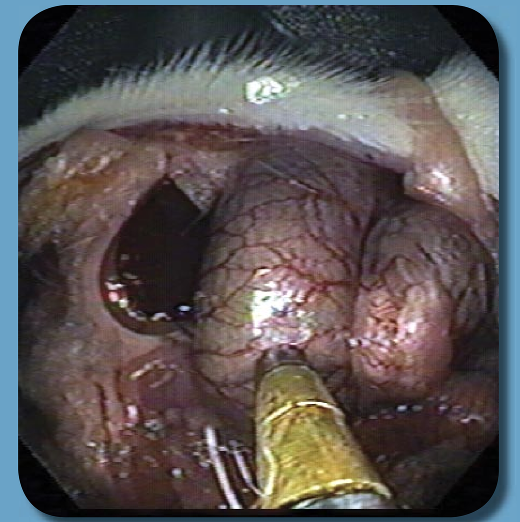


Fig. 2: View of confocal microendoscope as seen by a colonoscope. Microendoscope inserted through the therapeutic port.

Performance

- Lateral resolution: 2 μm
- Axial resolution: 24 μm
- Full field of view in tissue: 450 μm
- Range of focus in tissue: 0 to 200 μm

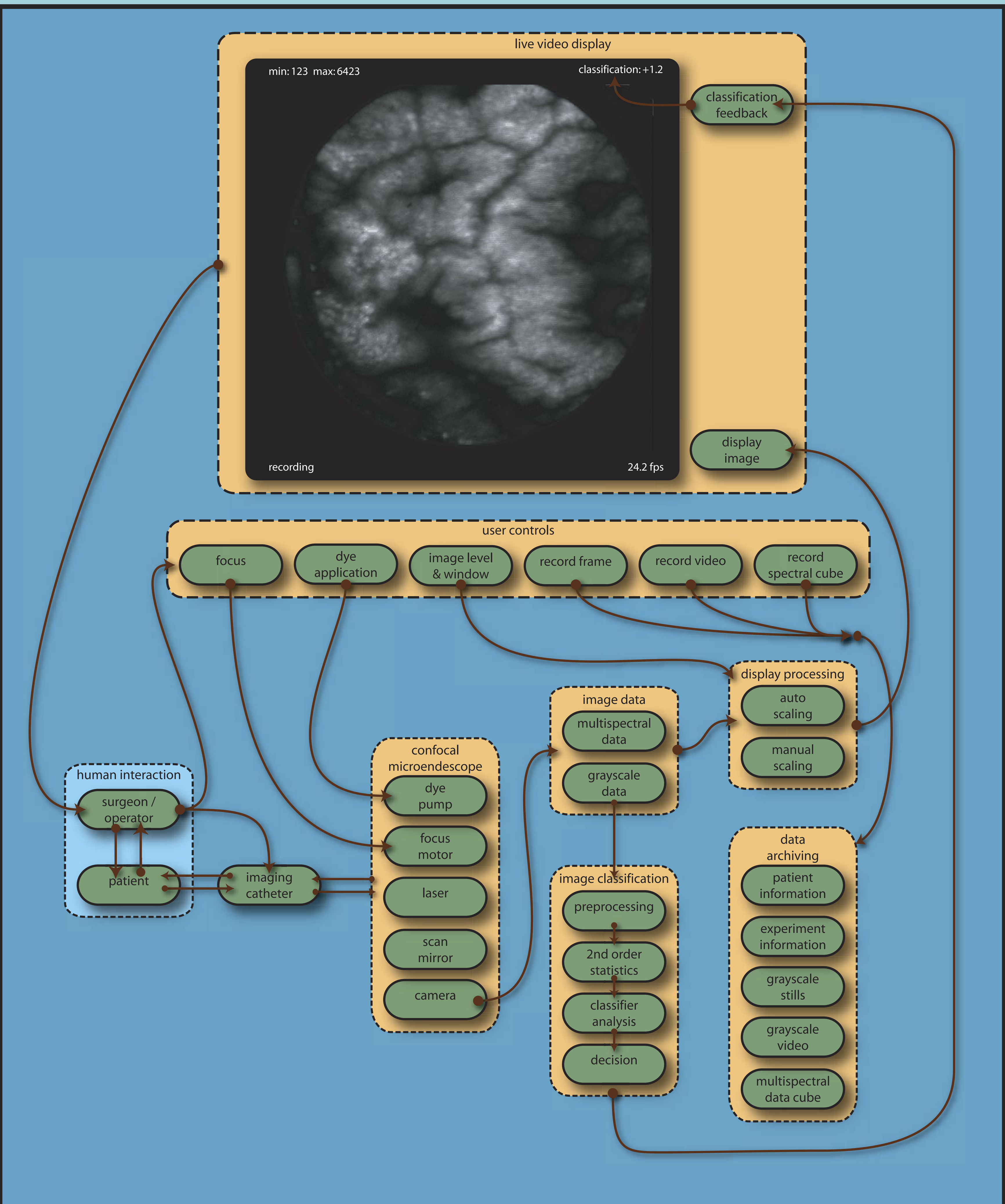
Classification algorithm

Algorithm

- Images are preprocessed before analysis to reduce extraneous data.
- Spatial grey-level dependence matrices are used to extract statistical features from images.[7-8]
- A subset of features was selected based on discriminability.
- A linear discriminant is used to classify tissue as diseased or normal.
- Performance was characterized by ROC analysis.[9]
- Trained and evaluated on ovarian tissue samples from 38 patients.

Performance on training set

- Figure 3 shows the ROC for the algorithm and human observers. Algorithm's performance is markedly better than trained human observers.
- 98% algorithm sensitivity
- 90% algorithm specificity



Flow diagram of confocal microendoscope real time display and automated image classification system.

Real time imaging system

We have developed a real time imaging system to acquire, display, process, and analyze image data. The system is written in Python and C.

Hardware control

- Modular camera support via PVCam library.
- Catheter focus control with automatic hysteresis correction.
- Controlled dye delivery to selected field down to fractions of a micro liter.

Archiving

- Live video
- Video frames
- Multispectral data cubes
- Diagnostic information (Figure 4)

User Controls

- Imaging catheter focus
- Dye (fluorescent contrast agents) delivery
- Image window and level adjustment (manual and automatic)
- Recording of video, frames, and multispectral data.

Performance

Acquired images are 512x512 pixels at 16 bits.

- 24 FPS with live display (automatic window and level) and video recording. [limited by camera hardware].
- 7 FPS with live display, recording, and **automated classification** for each frame. [limited by computer hardware].

Conclusions

- The confocal microendoscope system is capable of displaying, recording, and performing automated classification in real time.
- Classification algorithm has better sensitivity and specificity than trained human observers, indicating that it may be effective in diagnosing pathologies in a real-time clinical setting.

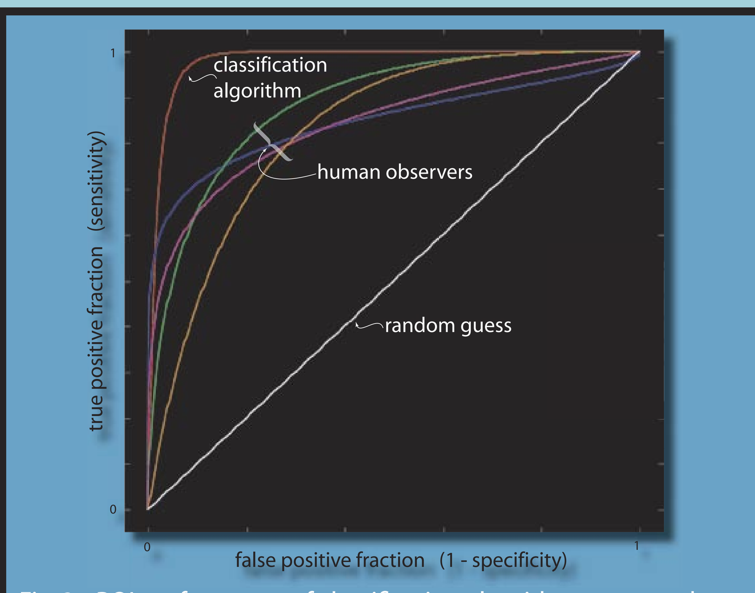


Fig. 3: ROI performance of classification algorithm compared to human observers and random guessing.

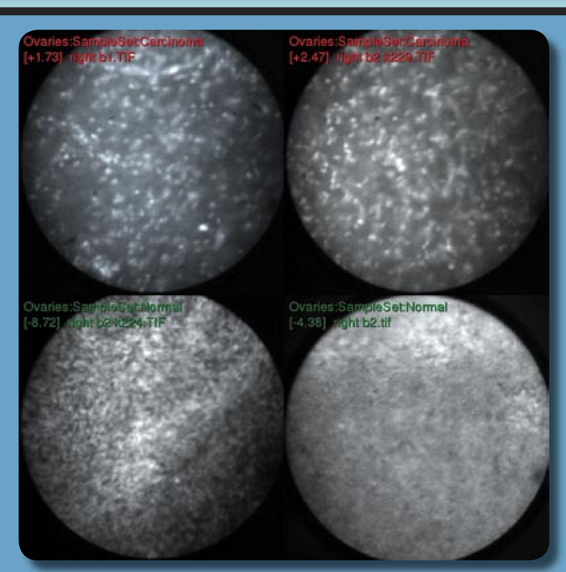


Fig. 4: Archived and classified images from real time system.

Future work

- Training database for classification algorithm needs to be enlarged with more tissue samples.
- Optimize classification algorithm to run at higher frame rates.
- New classification algorithms for other targeted diseases.
- Develop a streamlined clinical interface for the software.

Acknowledgements

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