Rapid Development of Video Processing Algorithms with RealTimeFrame

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Rapid Development of Video Processing Algorithms with RealTimeFrame

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ABSTRACT

The software framework *RealTimeFrame* is presented. It offers core services for the development of real time video processing algorithms. Five medical image processing algorithms implemented using *RealTimeFrame* module templates are subsequently introduced.

Keywords: Computer aided diagnostics, real time, video processing, algorithm development, software framework

1. INTRODUCTION

Rapid development of image processing algorithms for medical applications and easy testing of their capabilities in a clinical environment is essential for efficient implementation of medical video processing software. This often takes place in a C++ development environment and requirements include real time capabilities, separation of algorithms and GUI, and a modular design. We present a software framework that complies with these needs.

2. REALTIMEFRAME

RealTimeFrame is a platform for the development of real time video processing algorithms.[1] The core framework was designed to generate little CPU overhead and, therefore, to offer maximum performance to the algorithm. It features video acquisition from different sources such as stored video files or framegrabber cards. Various video and image input and output formats are supported. The framework uses Mircosoft DirectX to display the processed video. The customizable process chain is the core feature of *RealTimeFrame*. Image processing algorithms developed in C++ can be implemented into dynamic link library (DLL) files with easy-to-use template modules and inserted into the process chain. *RealTimeFrame* is multithreaded and allows the implementation of parallel algorithms. Furthermore, it permits the use of graphics processor units (GPU) via NVIDIA's Compute Unified Device Architecture.

3. PROJECTS

RealTimeFrame is a platform for algorithm development. Below, we introduce five example implementions based on the framework.

3.1 Highlighting fascia tissue

Fascia is connecting tissue often found between anatomical structures. During many surgical interventions it is good practice to cut along the fascia as there are often no risk structures like blood vessels or nerves located nearby. It may be separated with little risk of bleeding or side effects. One example for such an endoscopic intervention is colon mobilization. Fascia, however, is often difficult to recognize in the endoscopic images. We developed an algorithm that highlights fascia in the real time video streams from an endoscope to enable the surgeon to follow the tissue more easily.[2] The results of the alorithm are shown in Fig. 1.

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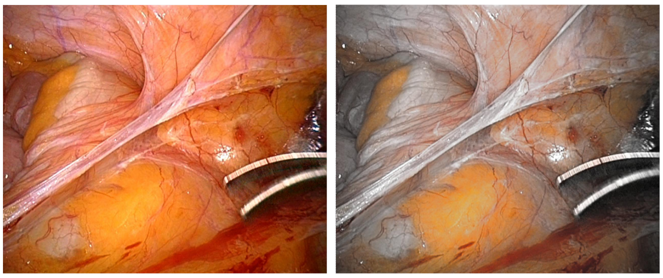

Figure 1. Results of fascia tissue enhancement

3.2 Vessel enhancement filter

Blood vessels are an important factor for medical decisions both during diagnosis and surgical interventions. Based on Frangi's vesselness filter[3] we implemented an algorithm for the interpretation of eigenvalues of second order derivatives (Hessian matrix) on the GPU. Fig. 2 shows the results of the vessel enhancement filter for endoscopic video streams.

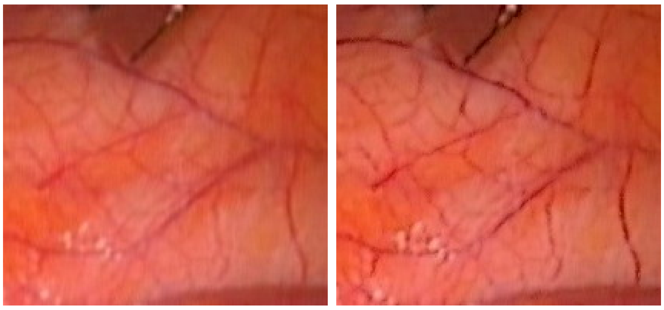

Figure 2. Results of vessel enhancement filtering

3.3 Temporal recursive filtering

Fluorescence endoscopy is used to diagnose cancer of the bladder. A marker substance which is accumulates in cancerous cells is administered to the patient. This substance fluoresces under blue illumination and allows a distinction between healthy and malignant tissue. In fluorescence endoscopy narrow band illumination with blue light (PDD endoscopy) is used. This enforces strong amplification and results in noisy images which can be improved by filtering as illustrated in Fig. 3.

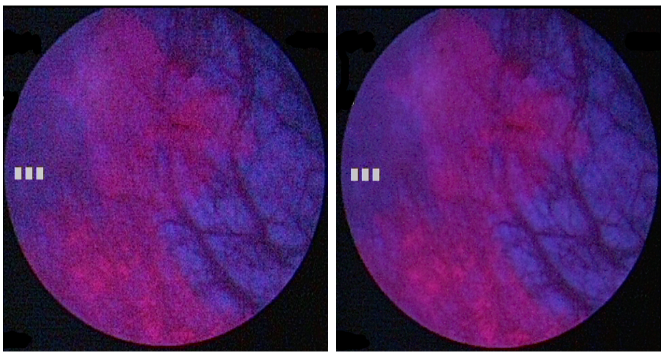

Figure 3. Results of temporal recursive filtering for fluorescence endoscopy denoising

3.4 Contrast enhancement

Fluorescense endoscopy, as mentioned earlier, is applied to distinguish healthy and malignant tissue of the bladder. We developed an algorithm that supports the medical practitioner in his or her decision by applying non-linear contrast transformations.[4] Fig. 4 clearly illustrates that healthy bladder tissue can be better distinguished from malignant tumors.

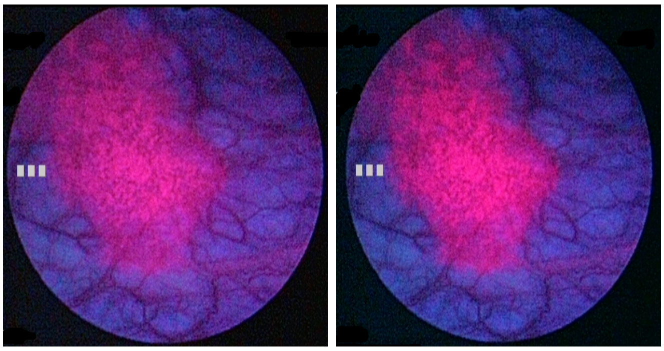

Figure 4. Contrast enhancement in fluorescence endoscopy of the bladder

3.5 Future work: panorama images

For navigation during the therapy of urinary bladder cancer using fluorescence endoscopy as well as for post-interventional documentation, a panoramic image providing a larger field of view of the bladder is often desired. Based on an PDD image mosaicking algorithm,[5] feature points are extracted and matched, as illustrated in Fig. 5. After the registration and blending process a panoramic image is constructed. Fig. 6 shows a panorama composed of 13 endoscopic images. This calculation has been performed offline, but our intention is to compute panoramic images in real time.

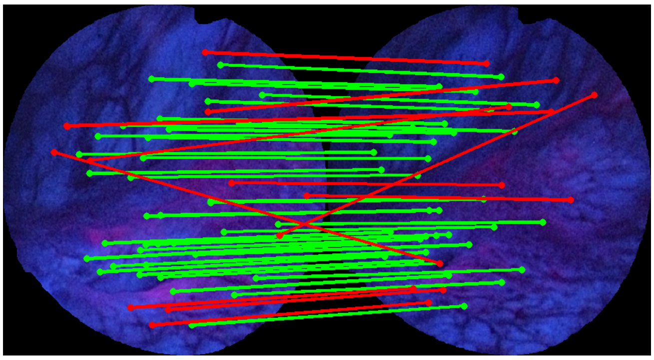

Figure 5. Matching correspondence points

Figure 6. Panorama image (offline calculation)

4. CONCLUSION

We presented our software framework *RealTimeFrame*. Five algorithms for medical image processing implemented on the basis of the framework confirmed that *RealTimeFrame* may serve as perfekt platform for clinical trials.

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Framework requirements

- Fast development of image processing algorithms for medical applications
- Easy testing of real time capabilities
- C++ development environment
- Separation of algorithms and GUI
- Modular design

RealTimeFrame

- Software framework “RealTimeFrame” [1]
  - Multithreading
  - Video acquisition by frame grabber card
  - Support for various video formats (in/output)
  - Customizable process chain
  - GPU processing with NVIDIA CUDA (Compute Unified Device Architecture)

  → Core services offered to run extension modules with medical image processing algorithms
- Maximum performance for image processing algorithms
- Very low CPU overhead (Data acquisition and display < 2% CPU load)
- Two operation modes
  - Strict real time mode with frame dropping
  - Offline (non real time) processing mode taking every frame into account
- Comprehensively documented templates for novel source and processing modules available

Software Design

- Workflow arranged in three stages

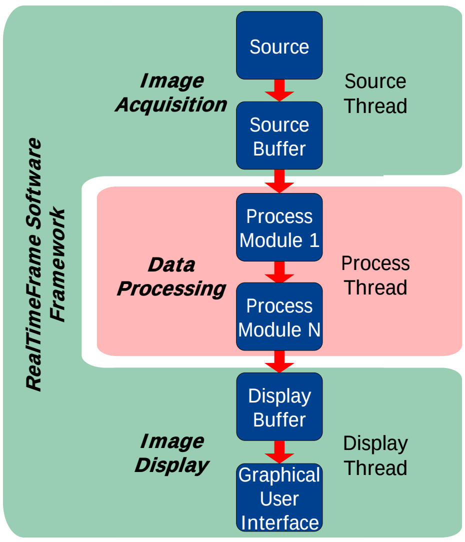

Figure 1: *RealTimeFrame workflow*

Highlighting Fascia Tissue

- Surgery support by optically highlighting important fascia structures [2]
- Colon segment removal
  - Detachment of colon segment from abdominal wall
  - Minimal invasive endoscopic intervention
  - Lowest possible damage to surrounding structures → less complications
  - Follow connecting tissue (fascia)
- Clinical trials → improved visibility of fascia tissue

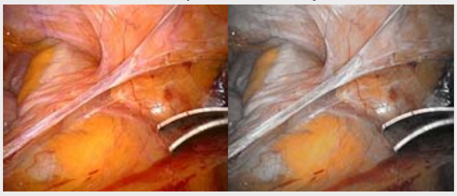

Figure 2: *Results of fascia tissue enhancement*

Vessel Enhancement Filter

- GPU implementation of Frangi’s vessel enhancement filter [3]
- Based on interpretation of eigenvalues of second order derivatives (Hessian matrix)
- Enhancement of tubular structures in videos

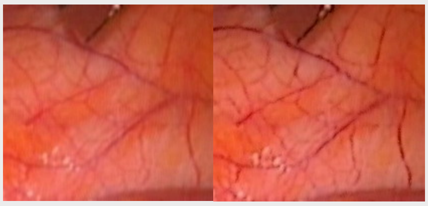

Figure 3: *Results of vessel enhancement filtering*

Temporal Recursive Filtering

- Bladder tumor detection possible with fluorescence endoscopy
  - Fluorescing marker substance
  - Blue narrow band illumination (PDD) (low light dose, high amplification)

  → Noisy images
- Temporal recursive filter with minimum mean square error estimation

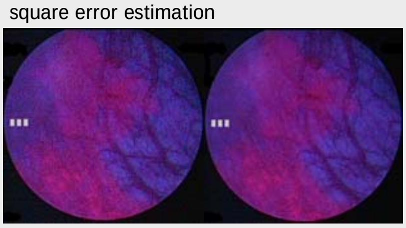

Figure 3: *Results of temporal recursive filtering for fluorescence endoscopy denoising*

Contrast Enhancement

- Better discrimination between fluorescence and background
- New color space designed to optimally separate image components [5]
- Non-linear contrast transformations

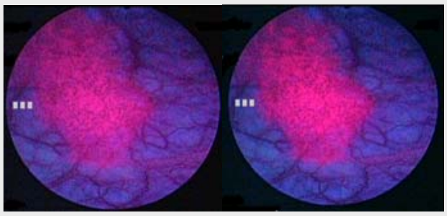

Figure 4: *Contrast enhancement in fluorescence endoscopy of the bladder*

Future Work: Panoramic Images

- Panoramic images provide larger fields of view
- Image mosaicking from PDD endoscope images [6], based on feature extraction, matching, registration, and blending

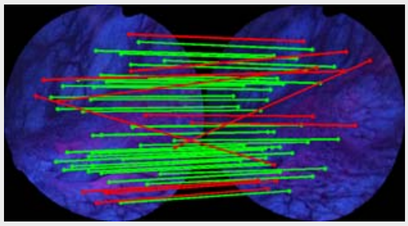

Figure 5: *Matching correspondence points*

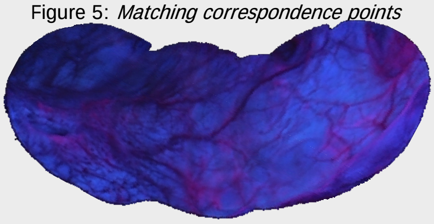

Figure 6: *Panorama image (offline calculation)*

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