Interactive GPU IP Chain Simulator for Mobile X-Ray Imaging

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I. Objectives

Tuning existing and prototyping new mobile X-ray imaging technologies promise to deliver more imaging information, optimize exposure to radiation, increase usability for image-guided interventions, and look for cost-effective implementation solutions.

GE-OEC 9900 Elite Mobile X-ray C-arm

As a principal system evaluation criterion in medical X-ray fluoroscopy, image quality has been one of the most studied subjects [3]. Its assessment relies on a range of computational and visual metrics. Physical parameters are usually obtained using highly controlled acquisition and computational analysis [4]. At the same time, trustworthy evaluation of clinical imagery is still done based on visual perception by experts and focus groups. Perhaps the most frequent scenario in this category is an assessment of the perceived image fidelity, i.e. comparison of image data acquired, processed, and displayed using various imaging chain settings [3].

In this work we introduce the new tool, GE OEC Interactive GPU IP Chain Simulator, built to streamline tuning of X-ray fluoroscopic IP chain, improve effectiveness of observer studies, and support research efforts. The Simulator has image processing functionality close to one that can be observed on GE Healthcare surgical C-arms. The paper discusses its HW and SW implementation as well as shows early application results.

II. Methods

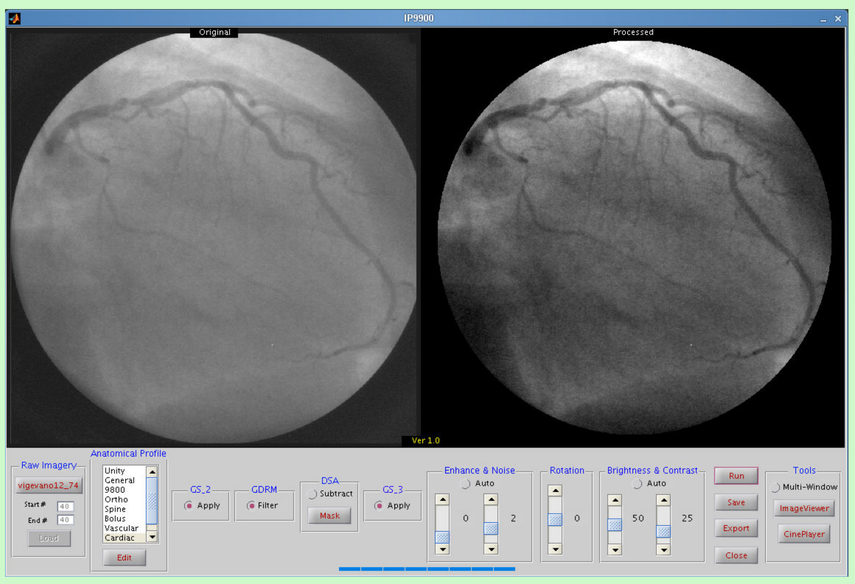
Our methodology is to create a friendly framework utilizing a common workstation, build tools to speed-up trustful image analysis, and improve user interactions. A heterogeneous computing and visualization platform has been tested and deployed to simulate real-time fluoroscopy on a mobile C-arm.

Hardware components include off-the-shelf CPU and GPU.

The software environment comprises a 64-bit Linux, GCC compiler, CUDA compiler, and MATLAB integrated toolkit. All image processing is done using single floating-point operations.

Nvidia Quadro FX5800: 240 thread processors and 4 GB onboard graphics memory

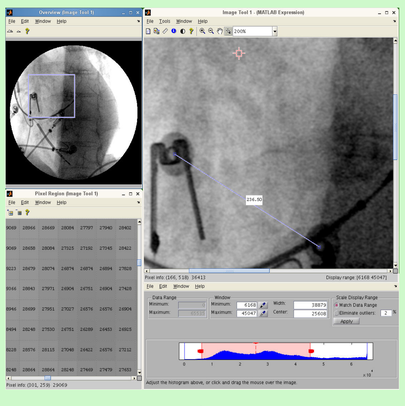
Figure on this slide demonstrates the screenshot of the IP9900 Simulator.



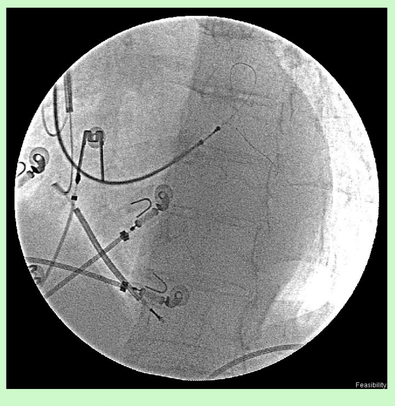
This program essentially emulates image processing implemented on GE Healthcare OEC 9900 Elite C-arm [1]. The graphic user interface of the IP9900 Simulator features Computing Tools and Visualization panes.

Main algorithmic blocks are grayscale conversion, dynamic range management, digital subtraction, noise filtering, edge enhancement, image rotation, and brightness / contrast handling.

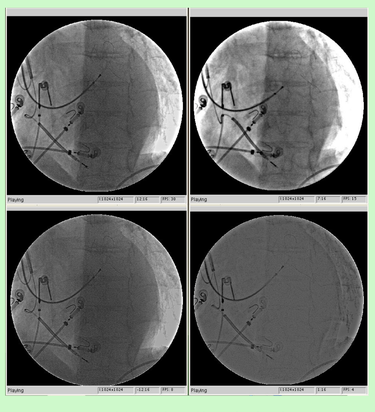
Detailed single frame analysis and dynamic frame playback use external functional calls. The processed imagery can be synchronically played in multiple windows, saved, or exported into common graphics / movie formats for sharing.



Frame Analyzer



Cine Player with Native Pixel



Multi-window Cine Playback

The Simulator is allocated on Linux server and accessible through remote networking.

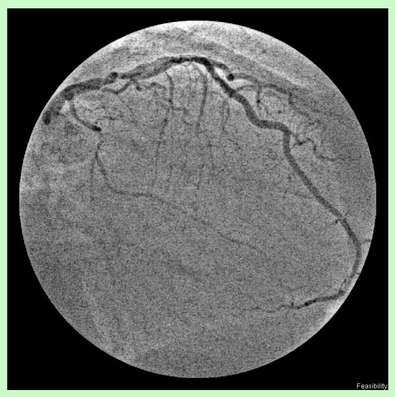
III. Results

We demonstrate the use of the IP9900 Simulator applied to surgical workflow. In cardiovascular imaging and corresponding minimally-invasive applications, it is essential to see a structure of iodinated vessels along with an image of surrounding anatomy or surgical tools. Fluoroscopic C-arm system intends to deliver a clear real-time imagery based on the confirmed user preferences.

Therefore, we customize, tune, and automate the image pipeline. IP chain performance and sustainability become critical to processing capability.

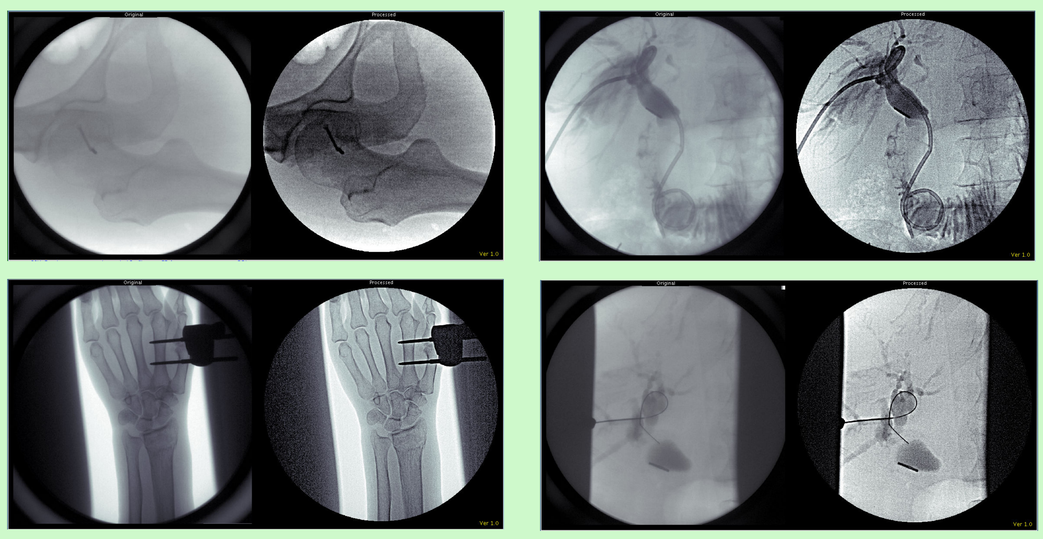
In the tested configuration, we are able to process large datasets comprising hundreds of 1Kx1K images at the rate of 65+ frames per second.

9900 Elite GE-OEC: Current Cardiac profile



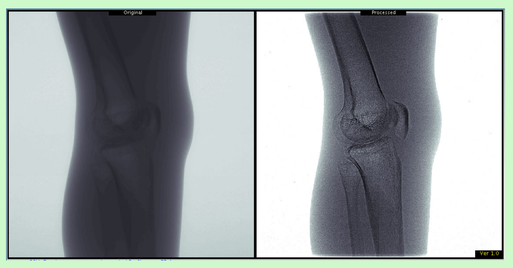
IP9900 Simulator: Enhanced Cardiac profile

These are the results of the processing focused on various subjects of interest. Anatomical profiles, as they are described in [1], are prime tools to manage image processing and display. By using the Simulator we adjust the settings in the anatomical profiles to address clinical requests and challenging cases. Also, a prototyping of new IP techniques using realistic imagery is important to support theoretical proposals and experimental findings. Such feasibility results on HW-accelerated C-arm CT and fluoroscopy were previously published in [2].

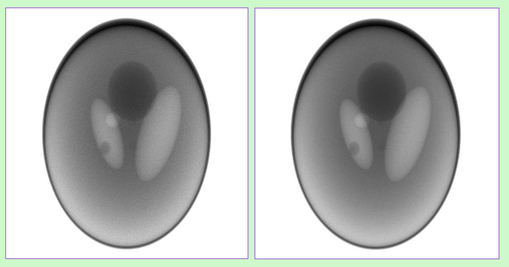


IV. Research

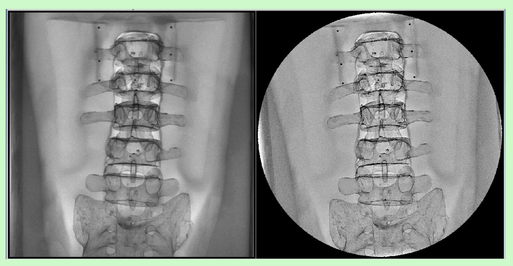
New acquisition hardware



Debluring



New imaging modes



Denoising

V. Conclusions

The Interactive GPU IP Chain Simulator has been found useful in accelerating of image evaluation and prototyping of new imaging solutions. Parallelization of computationally demanding IP algorithms using on-chip HPC solutions could be a key to a practical and cost-effective medical imaging on a mobile C-arm platform.

VI. References

[1] GE Healthcare–Surgery. About the OEC 9900 Elite. http://www.gehealthcare.com/euen/surgery/products/oec-9900-elite/index.html

[2] Riabkov, D., Brown, T, Cheryauka, A., and A. Tokhtuev, 2008, Hardware Accelerated C-arm CT and Fluoroscopy: A pilot Study, SPIE Proceedings, Vol. 6913, paper MI6913-102.

[3] Tapiovaara, M., 2003, STUK-A196. Objective Measurement of Image Quality in Fluoroscopic X-ray Equipment: Fluoroquality. Helsinki, 50 pp.+apps. 13 pp.

[4] Wilson, D. and K. Jabri, 2000, Quantitative Image Quality Studies and the Design of X-ray Fluoroscopy Systems, In Handbook of Medical Imaging, V.1, Physics and Psychophysics, SPIE Press Monograph Vol. PM79.