DQS Advisor: A Visual Interface to Balance Dose, Quality and Reconstruction Speed in Iterative CT

Ziyi Zheng and Klaus Mueller, *Senior Member, IEEE*

***Abstract*— Low-dose CT has recently shown much progress in its mission to deliver clinically-useful results with reduced radiation imposed on patients. However, for many of the proposed reconstruction algorithms there is still no quantitative link between the settings of the various parameters and the corresponding reconstruction image quality and reconstruction time. As a solution, we propose to combine automatic optimization with human interaction. We developed an interactive visual parameter space navigation interface which assists users in the selection of data acquisition and iterative CT algorithm parameter settings and allows them to intuitively decide among trade-offs. The optimization component is based on our previous parameter optimization framework. We now focus on the visual interface and conduct a study across different data acquisition settings in terms of X-ray tube current and number of projections. The user interface presents the performance data as color-mapped 2D scatter plots and it also provides a gallery feature that allows a qualitative comparison of possible reconstruction results. Our system is embedded into a webpage and can be accessed via a web browser from anywhere and any common computer platform. Further efforts focus on the scalability of our approach, in order to make it applicable to realistic application scenarios.**

I. Introduction

Identifying effective settings of parameters in both data acquisition and image reconstruction can be a daunting task. Trying all combinations suffers from combinatorial explosion even with a modest number of parameters. A knowledge-assisted system coupled with a visual interface has thus great practical value. We propose an integrated solution in this direction, combining automatic optimization with an interactive user interface. For the first component we utilize and extend a parameter optimization framework we recently developed [1]. This framework can match the most effective reconstruction parameter settings given a single CT data acquisition. In our current work we focus on studying the behavior of obtaining optimization results from multiple acquisitions and settings. To appreciate trade-offs that might exist among different imaging objectives, such as dose (D), quality (Q), and GPU reconstruction speed (S), we developed an interactive visualization tool we call *DQS Advisor*. It computes its system expertise from real data or simulations of a fixed CT scanning task, but executed with different X-ray tube current settings and numbers of projections. The optimization algorithm returns for each possible DQS triple the most optimal parameter settings, for both reconstruction algorithm and GPU resource management. DQS-Advisor can then provide the much needed guidance for choosing the best settings of acquisition and reconstruction parameters, given the current objective. Our tool is available as a web service which makes it readily accessible to users who wish to utilize the DQS Advisor's knowledge base to make informed decisions for comparable imaging and reconstruction scenarios.

II. Approach

We begin by using our parameter optimization engine described in [1] to obtain the space of optimization-guided CT reconstructions, taking into consideration quality as well as speed. The optimization generates multi-dimensional data containing many fields (dose, quality, reconstruction time, parameters). Figure 1 illustrates the parameter optimization component during the training stage. The gold-standard is generated by the regular dose scan, and we perform iterative reconstruction with regularization in the low-dose acquisitions. The optimization is done per iteration in the iterative reconstruction.

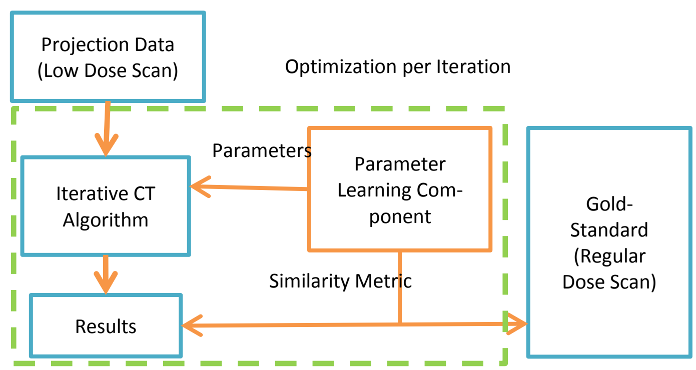

Fig. 1. Parameter optimization for the training dataset.

In the following, we present the interactive multi-dimensional interface by which users can compare images derived from different settings to make informed decisions. The interface is shown in Figure 2. It is composed of the main plot, a control panel with a set of sliders and a four-slot image gallery showing the reconstructed images associated with the four points marked in the main plot. The main plot as shown here is a heat map of dose and quality with time mapped to color.

Manuscript received November 17, 2013. This work was supported by NSF grant 1117132, the Korean Ministry of Science, ICT and Future Planning under the ITCC Program by NIPA. We also thank Medtronic for research funding and data.

Ziyi Zheng and Klaus Mueller are with Visual Analytics and Imaging Lab, Center for Visual Computing Computer Science Department, Stony Brook University, NY and SUNY Korea. (e-mail: {zizhen, mueller}@cs.sunysb.edu).

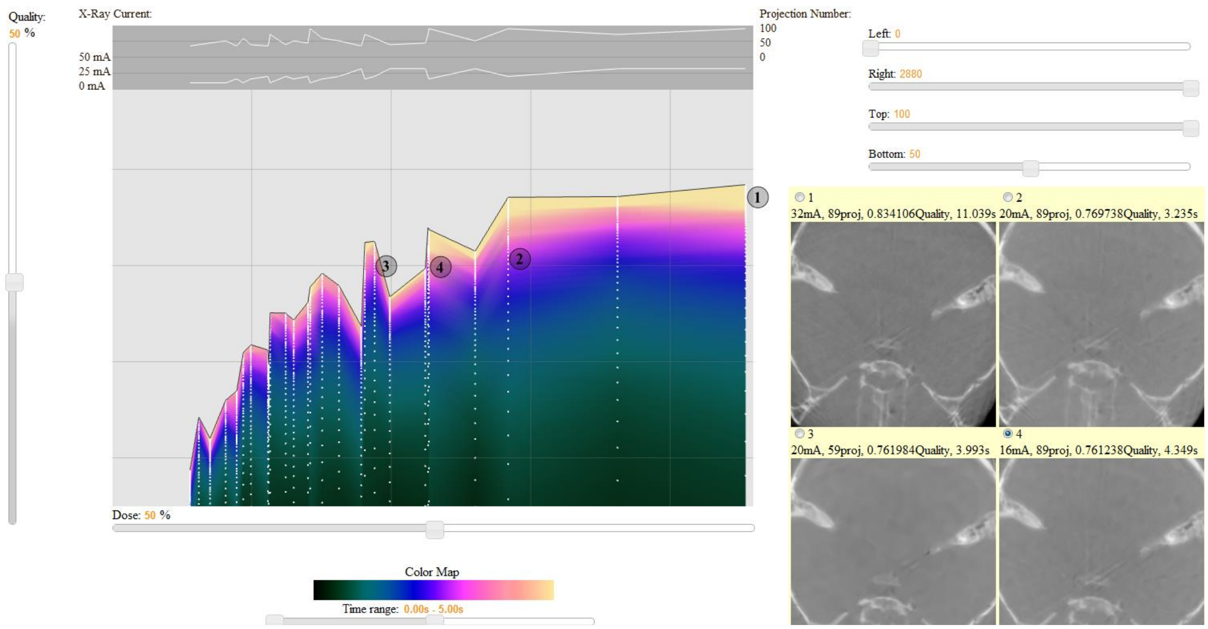

Fig. 2. Visual user interface.

Main plot: The x-axis shows the dose as the product of mA and number of projections. The y-axis shows the measured quality on an exponential scale. In the plots shown here, all data points are displayed as white points. These can be turned off easily using a button on the interface.

Adjustable colormap: The color spectrum is a spiral through HSV color space, starting with black on one side to bright yellow on the other. The range slider on the bottom of the interface can be used to adjust the value range that is mapped to the color spectrum. By dragging the lower/upper handles users can map black and yellow to the set value limits. Values that lie below (above) these limits are saturated to black (yellow). This allows one to emphasize certain value ranges by increasing their contrast. In the configuration shown here the lower value range is more accentuated while the upper range is mapped to a uniform bright yellow.

Dose representation: Since the dose is represented as mA multiplied by the number of projections, we require an additional plot that explains these relationships to the user. Therefore, to visualize the mA and number of projection settings individually, we added an additional profile display above the main plot, parallel to the dose axis.

Region of interest: Users can focus on portions of the display by modifying the left/right/top/bottom boundary of the main plot. This enables them to pan or zoom in/out to inspect the plot more closely in these selected areas and help them to explore sparse regions. This zoom operation is a linear function which preserves the neighborhood without extortion.

Image gallery: Users can mark up to four points in the main plot and the corresponding images will be displayed in the panels of the gallery for side-by-side comparisons, along with the data information. This function is enacted by left-clicking the mouse. Upon a left-click, the system will find the nearest data point (and corresponding reconstructed image) around the cursor, display it in a free panel and mark the location with the panel's ID, integrated into a circle. By ways of showing image, users can understand the image quality much better than with a plain quality metric which only covers certain properties.

By observing the dose composition and image quality in Figure 2, we can easily identify the positive correlation between number of projection and maximum quality. We find that the projection number affects the image quality more than mA. With similar overall dose, higher projection numbers can usually reach better quality than higher mA case.

Our interface is hosted on a webserver and can be accessed by visiting http://vail.cewit.stonybrook.edu/Projects/CTPlot/. The webpage is based on WebGL and JavaScript, and therefore a browser with WebGL support (Chrome, Firefox) is required. Choosing a web browser platform enables worldwide access and cross-platform support. We carefully designed the system to be capable of interactively displaying relatively large data.

III. Conclusions

Our interactive system allows users to actively explore the best-possible CT reconstruction outcomes in terms of reconstruction quality and also computation speed as a function of X-ray dose. Each such outcome then maps to the appropriate settings of internal algorithmic and computing hardware parameters. The exploration occurs in a 2D plot that intuitively visualizes any possible trade-offs. In future work we aim to enable user interaction also in the optimization stage to work as an online monitoring tool in conjunction with a dynamic optimization. The current web service interface is well adapted to the SAAS (Software as a Service) model. More detail on our system is available in a recent journal paper [3].

References

[1] Z. Zheng, E. Papenhausen, K. Mueller, "Searching effective parameters for low-dose CT reconstruction by ant colony optimization," *Int. Conf. Image Formation in X-Ray Computed Tomography*, pp. 182-185, 2012.

[2] H. Yan, L. Cervino, X. Jia and S. Jiang "A comprehensive study on the relationship between image quality and imaging dose in low-dose cone beam CT," *Phys. Med. Biol.* **57** 2063-80, 2012.

[3] Z. Zheng, E. Papenhausen, K. Mueller, "DQS Advisor: A visual interface and knowledge-based system to balance dose, quality, and reconstruction speed in iterative CT reconstruction with application to NLM-regularization," *Phys. Med. Biol*, **21**:7857-73, 2013.