Sonoco: Interactive Visual Comparison of Filtering Operations on Time-Dependent Medical Imaging Data

Deniz Gezgin*
Sergej Stoppel†
Supervised by: Stefan Bruckner‡

University of Bergen / Norway

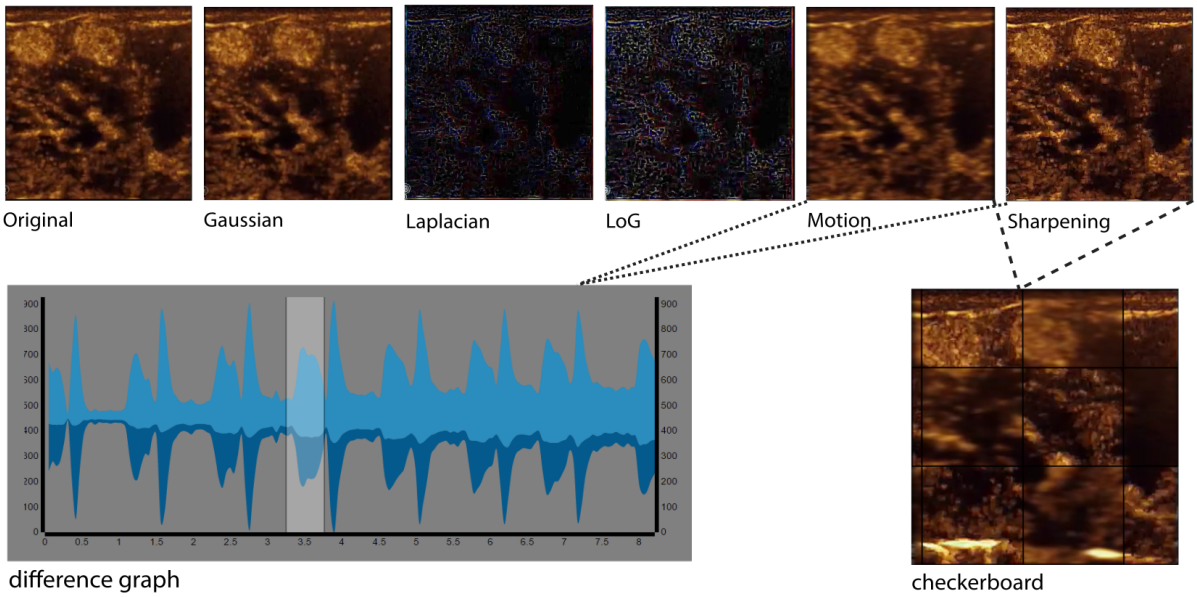

Figure 1: Sonoco Overview of a contrast-enhanced ultrasound video stream. The figure shows the different views. The used data is taken from Youtube. [7]

Abstract

Medical imaging often requires fine-tuned processing pipelines to reduce noise and to remove artifacts. Visual assessment by experts is a critical step in determining the performance of individual techniques or parameters, as goals are often ill-defined and trade-offs need to be considered. In this paper, we address the visual evaluation of filtering and other data enhancement operations on time-dependent medical imaging data. We present *Sonoco*, a web-based comparative visualization system which provides the user with flexible tools for comparing multiple filtering operations on one or several data streams. By providing a visual overview of temporal changes, our approach enables the quick identification of major differences which can then be explored in their spatial context.

*dgezgin90@gmail.com
†sergejsto@googlemail.com
‡stefan.bruckner@gmail.com

Keywords: Comparative Visualization, Visualization of time-dependent data, Web-based tool, Filtering, Image Processing

1 Introduction

Decision support based on visualization is very common in the medical area. In radiology, contrast-enhanced ultrasound has many applications like blood flow rate detection or organ edge delineation. The time-domain often needs to be preserved for different reasons, e.g., tracking the distribution of a contrast-agent. Image filtering is applied to highlight or smooth specific features which need to be inspected further and compared by the domain expert. Furthermore, it is often necessary to view multiple video streams simultaneously. The high spatial and temporal resolution of ultrasound makes detection of differences a

challenging task. A phenomenon called change blindness can occur, where visual changes in space and time are not noticed by the observer [4]. Time is also a very critical parameter. For example, the user has no time restriction to compare multiple images, but in video data, the displayed image is changing rapidly, depending on the frame rate. Gleicher et al. shows a variety of comparative visualization techniques [1]. However, these methods are not suitable for multiple temporal data. There is currently no application for image processing experts to compare filtered time-dependent ultrasound recordings.

In this paper we present an approach to combine comparative visualization and visualization of time-dependent image data in order to provide users with visual support for observing multiple video streams. *Sonoco*, our interactive system, provides a juxtaposed overview of the filter methods. Selected video streams are used to compute temporal differences. Observing these temporal changes helps to identify the impact of different methods and settings in a quantitative way. A superposition view supports the exploration of the spatial dimension in the same space.

Our system is based on a client/server architecture, which makes it easy to use and save resources on the client. It is directly linked to Matlab, a common environment for prototyping medical image processing filters.

2 Related Work

The subject of visual comparison has been extensively studied. In this paper we focus on the comparison of images or image series, i.e. videos, only. The visual comparison of images can be roughly classified in three categories: image variation measurement via image metrics, emphasis of differences in images and support for image comparison without difference computation methods.
Over the last few decades several **image metrics** have been developed, with different intentions. The image metrics can be classified into perceptual and non-perceptual metrics. We refer to Lin et al. [2] for an overview of the most common and important perceptual image metrics. In this paper we use non-perceptual mean squared metric to compute the differences between consecutive images.
Pixel based image metrics allow to find and **emphasize** local differences in images. A typical example of this approach is the work of Schmidt et al. [6], where the differences in large sets of images were emphasized. Many approaches use color to indicate differences between images, such as presented by Sahasrabudhe et al. [5], where the difference between the image and data-set was emphasized, or by Suomi et al. [8], where changes between MRI images were highlighted. However, these methods are sensitive to global intensity shifts, which occur in video data. We do not utilize direct emphasis of differences in this paper.
In some cases image metrics are not suitable, in these cases no explicit support can be provided to the viewer. The viewer must rely on his or her memory to make the comparison. Several visualizations have been developed to aid the comparison and to reduce the memory effort of the user. Gleicher et al. [1] provides an overview of the most common techniques. In our approach we use a combination of superposition via checkerboard views and a side by side comparison of the video data.

3 Sonoco

Sonoco supports the analysis of time-dependent data. Manual filtering and comparison can take considerable effort and time. Synchronizing multiple video streams is challenging without the right tool. *Sonoco* helps the user to inspect the data by four unique views. The **thumbnail view** gives a first overview of the computed filters. Filter parameters and image properties can be customized. A **juxtaposition view** of selected videos can be set up via simple drag and drop operations. The **temporal difference graph** depicts the pixel changes per time-frame. Users can select regions in this view to loop over the corresponding frames. A **checkerboard view** combines the videos into one single view.
Our combination of the used methods results in a new and integrated visual analytics tool. Interaction between all views is shown in Figure 1. We have chosen this set of methods to fulfill the basic needs of an image processing expert and not overload the interface. Details about the views are described in the next subsections.

3.1 Thumbnail View

Filtered videos are shown on the left side of the interface as a thumbnail view. Filtering image data helps the user to get more information about the data. For example, smoothing helps to reduce noise, sharpening helps to detect edges. There is no right filter, but rather different methods for different problems. The user is very important in a filtering pipeline, since the filter results can not always be quantified. Fully automated calculations does not bring the best result. However, our tool offers basic filter function, implemented in Matlab (*Gaussian Filter, Laplace Filter, Laplace of Gaussian Filter, Motion Filter, Sharpening Filter*). Customization of the default settings is possible, if the parameters are not satisfying. The filtered streaming data is shown as a thumbnail view to compare the different methods right away. Selected filters can be dragged to a 2×1 or 2×2 grid in the center for juxtaposed comparison. Synchronized playback is possible for the dragged videos as well as the thumbnail videos.

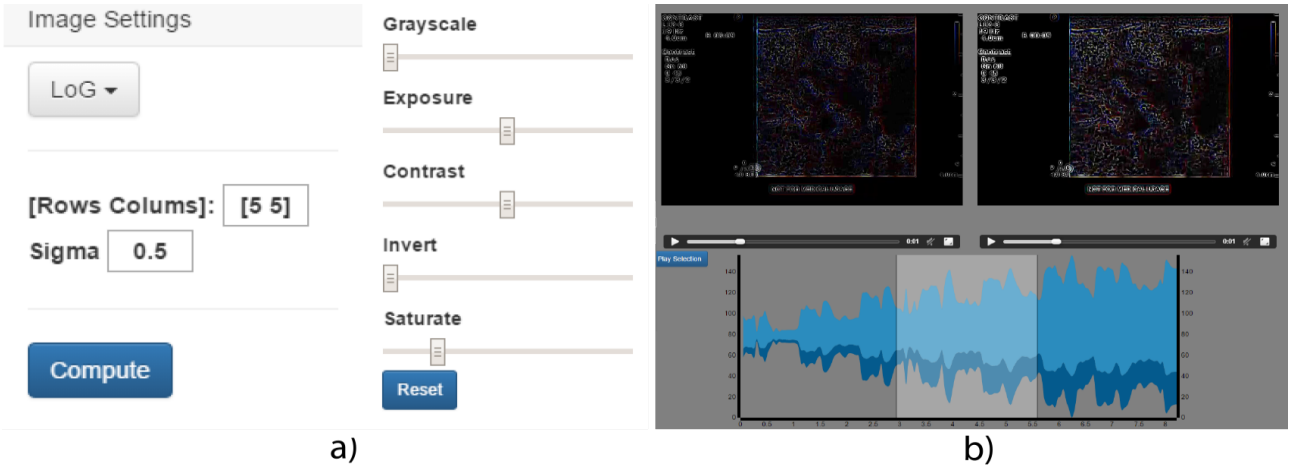

Figure 2: This figure shows the most important steps from section 5 Scenario. a) Original data from the user. b) Thumbnail view of filtered videos after upload. c) Mask for customizing filter parameters and change image settings. d) Juxtaposing two videos & difference graph

3.2 Temporal Difference Graph

Visual analytics supports the comparison process by showing differences over the time domain. The mean squared error (MSE) is a good non-perceptual metric to detect temporal changes. The difference of the greyscale value per pixel between two frames indicates a minor or major change. All these values are summarized per frame and displayed to the user. If two videos are selected with 10 frames each, the graph shows two line charts with 9 values per line. Our graph visualization technique is based on a streamgraph to compare the MSE between different filter methods. For example, a higher MSE of the same frame in another video indicates to a higher level of noise. The impact of different parameter settings can be measured by the MSE.

The shown graph allows the user to mark any region for further analysis. Selected regions are looped during playback to allow a detailed inspection of subtle temporal differences. Unimportant aspects of the data are skipped, which speeds up the analysis.

3.3 Checkerboard View

The checkerboard view superpositions multiple videos and automatically helps the human eye to detect differences. The same filter methods and just different parameter settings can lead to non-detectable differences for the observer. Furthermore, users can interactively change the size of the tiles and also move the checkerboard. This animated view shows the selected graph region mentioned above. The user can move the checkerboard and change size while the videos are still looped.

4 Architecture and Implementation

Figure 1 describes the architecture we used for the realization. The client can access our tool through the web and get all features. A web server provides the front-end. All image processing methods are implemented in Matlab. A Matlab function called *fspecial* creates predefined filter kernels which are used in our tool. *Matlab Jar Compiler* creates a Jar-File for the integration in Java Code. Every Matlab function is mapped to a Java method. Important user interactions trigger an *Ajax* request to the corresponding Java servlet. These servlets are provided by a *JBoss application server* and builds an interface between the browser and the Matlab computations.

Our tool does not require any client installation. Users can upload any known video format and all filtering processes are done on-the-fly. Even people with no MATLAB knowledge can filter their data and compare them.

5 Scenario

Sonoco offers many possibilities to modify and compare video streams. This sections describes a typical use-case, which helps to understand the interaction from the user's perspective.

One of our image processing experts received a contrast-enhanced ultrasound video from a radiologist. The original data doesn't give enough insight into the data, thus he needs image processing for further analysis. The top row of Figure 1 shows the thumbnail view of the filtered videos after uploading his data to our tool. Filter methods should improve the contrast of vessel boundaries. Therefore, edge preserving filters are chosen. Two selected filters, *Laplacian* and *Laplacian of Gaussian*, are

Input	Length (sec)	FPS	Resolution	Upload (sec)	Graph (Sec)
V1	15	20	848x648	60	23
V2	3	25	848x648	23	8
V3	34	25	552x420	220	25
V4	145	5	850x480	160	40

Table 1: Computational Time. V1 - V3 are contrast-enhanced ultrasound data, varying in resolution, length and frames per second. V4 refers to a surveillance video with a low framerate.

dragged to the centered view for better comparison. The second filter highlights the vessels much better. Parameters can be finetuned, recomputed and the impact compared. The mask for customizing the parameters is shown in Figure 2(a). However, detecting differences on the same filter just by juxtaposition is a challenge, since the comparison relies on the memory of the user only. To get a measurement of the variation, he creates the difference graph to see which filter settings smooth out more artifacts than the other (Figure 2(b)). One specific second of the video shows high amplitude in the graph. This indicates the position, where the contrast-agent got distributed in almost all visible vessels. Sonoco now allows him to select a region and loop over this particular second. As mentioned above, Juxtaposition is not the best choice for comparison time-dependent data, so he opens the Checkerboard view to get an even better comparison for his selected region.

6 Conclusion and Future Work

Our presented scenario shows an easy way to compare time-dependent data. Reduction of the video duration supports the viewer's analysis and decision making. However, Mean Squared Error (MSE) is very sensitive to global changes, which could lead to inexpressive graphs. Ultrasound often comes with movements of the body part or sensor. The resulting MSE only shows high values, since artifacts appear in a different position for every time frame. Another difference detection method, like perceptual metrics, could be used to avoid the movement problem.

The Matlab computation time scales with the frame rate, duration and resolution. Table 1 shows an overview of the computation time. Our tests were done a machine with 32 Gigabyte of RAM and a 3GHz Intel(R) Core(TM) i7-5960X CPU. Matlab allows you to enable GPU rendering or parallel computing which speeds up the calculations. More efficient Matlab algorithms optimizes the computation time as well.

We are currently working on another way to superposition multiple videos. Malik [3] shows an extended approach of the checkerboard. Instead of quadratic patterns, his method uses hexagonal elements for comparison.

Sonoco was specifically designed for use by medical image processing experts, but many of the employed visualization and interaction techniques may be helpful in other different fields, e.g. surveillance data. Our tool helps image processing experts to modify and compare time-dependent data without writing a line of code.

References

[1] Michael Gleicher, Danielle Albers, Rick Walker, Ilir Jusufi, Charles D. Hansen, and Jonathan C. Roberts. Visual comparison for information visualization. *Information Visualization*, 10(4):289–309, October 2011.

[2] Weisi Lin and C. C. Jay Kuo. Perceptual visual quality metrics: A survey. *J. Vis. Comun. Image Represent.*, 22(4):297–312, May 2011.

[3] Muhammad Muddassir Malik, Christoph Heinzl, and M Eduard Groeller. Comparative visualization for parameter studies of dataset series. *Visualization and Computer Graphics, IEEE Transactions on*, 16(5):829–840, 2010.

[4] Lucy Nowell, Elizabeth Hetzler, and Ted Tanasse. Change blindness in information visualization: A case study. In *infovis*, page 15. IEEE, 2001.

[5] Nivedita Sahasrabudhe, John E. West, Raghu Machiraju, and Mark Janus. Structured spatial domain image and data comparison metrics. In *IEEE Visualization*, pages 97–104, 1999.

[6] Johanna Schmidt, Meister Eduard Groeller, and Stefan Bruckner. Vaico: Visual analysis for image comparison. *IEEE Transactions on Visualization and Computer Graphics*, 19(12):2090–2099, 12 2013. Demo: http://www.cg.tuwien.ac.at/ jschmidt/vaico/.

[7] Trust Bio sonics Inc. Tbs-002 in rabbit liver tumor lesion detection (on philips cx50). *https://www.youtube.com/watch?v=vxI8nBSIjVc*.

[8] K. Suomi and Jarkko Oikarinen. Visualization of changes in magnetic resonance image data. In *The 8-th International Conference in Central Europe on Computer Graphics, Visualization and Computer Vision'2000, WSCG 2000*, 2000.