Comparative Gaze Analysis Framework for Volumetric Medical Images

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Abstract

We present an interactive visual comparison framework (GazeDx) for gaze data from multiple readers, which incorporates important contextual information into the comparative analysis process. A comparative analysis of gaze pattern is essential to understand how radiologists read medical images. However, most prior work on volumetric medical images focused on visualization of gaze patterns, but did not address the need for comparative analyses of multiple readers' gaze patterns. The GazeDx framework supports qualitative comparison based on interactively coordinated multiple views (spatial view with 3D gaze visualization, enhanced navigation charts, and matrix view), and quantitative comparison of gaze patterns in the similarity view with several similarity measures. It also integrates crucial contextual information such as pupil size, distance to a monitor, or windowing (i.e. adjustment of image contrast and brightness which affects visibility of organs and lesions) into the analysis process.

Keywords: Eye tracking, gaze visualization, gaze pattern comparison, volumetric medical images, interactive navigation chart.

Index Terms: H.5.0 [Information Systems]: Information Interfaces and Presentation—General

1 Introduction

In the medical field, comparative gaze analyses with multiple observers have been actively used as principal research methods. For example, researchers investigated impacts of external factors such as expertise on inter-observer difference [6]. Some recent work tried to perform comparative analyses on volumetric images reflecting the growing popularity of CT and MRI [2][7]. However, prior work lacks supports for systematic comparison of multiple gaze data, but rather focused on visualizing gaze data of a single session. Thus, one had to manually juxtapose the resulting visualizations outside the framework for inter-participant comparison. Kurzhals *et. al.* [5] presented ISeeCube to enable systematic comparison of multiple observers' gaze patterns with video stimuli. With a similar design goal in mind, we developed a systematic comparison framework for volumetric medical images, taking into account unique needs in the radiology domain.

There are also many missed opportunities in comparative gaze data analyses as important contextual information for diagnosis has not been properly considered. Such contextual information includes, but is not limited to windowing information, pupil size, and distance to stimuli. For instance, radiologists perform windowing (i.e. adjustment of image contrast and brightness) to highlight different organs or lesions (Fig. 1). Thus we included such crucial contextual information in the comparative gaze analysis for more accurate and holistic analysis results.

2 GazeDx

GazeDx integrates contextual information and the gaze data using multiple synchronized views (Fig. 2) as in ChronoViz [3], and supports interactions based on the taxonomy that summarizes visual designs for gaze pattern comparison [4]. It is designed to aid radiologists in performing both holistic and atomistic analyses of multiple gaze data from medical diagnoses.

2.1 Holistic Analysis

GazeDx presents separate views to show comparative overviews from either spatial or temporal perspective. It also shows quantitative pairwise comparison results.

Spatial view — Gaze data from volumetric medical images have innate 3D spatial information: x-, y-coordinates from the eye tracker and z-coordinate from the index of a gazed slice. Thus we superimposed the gaze data on conventional 2D and 3D representations used in the medical field (i.e. multi-planar reformation (MPR), and volume rendering (VR)). Using the visual representations, users can compare gaze patterns using small multiples (Fig. 2(A)).

Similarity view — GazeDx prepares five similarity measures for 3D gaze volume data: set-based, SSIM, SSD, PSNR, and NCC. Similarity matrix shows an overview of all pairwise similarities using one of the measures. One

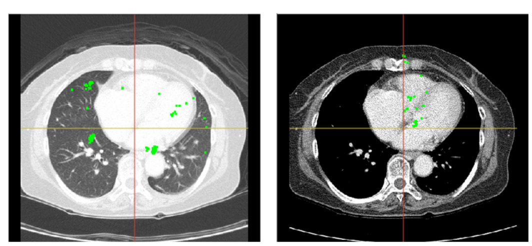

Figure 1: Visibility of organs affected by different window values. (Left) Lung window setting. (Right) Mediastinum window setting.

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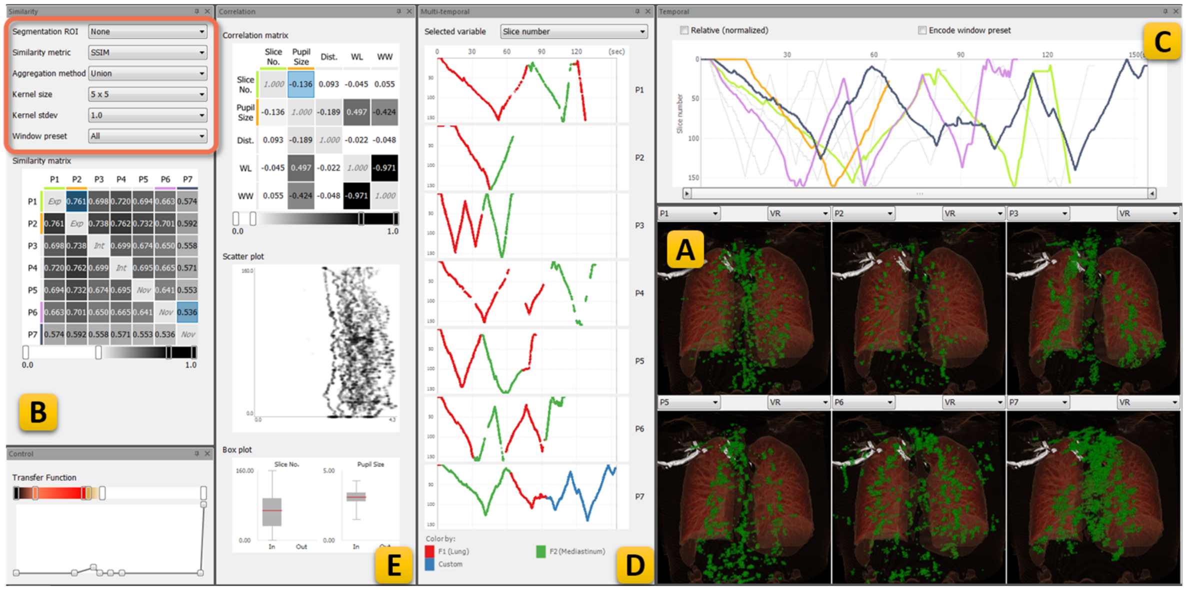

Figure 2: GazeDx interface. (A) Spatial view. (B) Similarity view. (C) Temporal view. (D) Multi-temporal view. (E) Correlation view. In the orange rectangle, there are control widgets for selecting the segmentation ROI (ROI filtering), similarity metric, aggregation method, kernel size, standard deviation (for Gaussian filter used in scalar gaze data generation [7]), and window preset (for window filtering). Bright green dots in the spatial view represents gaze points. An analyst selected readers 1, 2, 6, and 7 for detailed comparison in the similarity view and the corresponding four temporal plots were highlighted in the temporal view.

can check the overview of pairwise similarity among all participants in the similarity (matrix) view where each cell is density-coded by the corresponding similarity.

Temporal view — GazeDx adopts and enhances the navigation chart representation [1] that plots the index of gazed slice (mapped to y-axis) over time (mapped to x-axis). Each gaze data is plotted with uniquely assigned color, which matches the color in the similarity matrix (Fig. 2(C)). The representation supports a relative time scale for varying diagnosis length and an additional visual encoding that maps window preset values at each gaze point to a certain shape.

2.2 Atomistic Analysis

As the number of readers and duration of diagnosis grows, the navigation chart in the temporal view gets crowded with multiple polylines. GazeDx provides a small multiple view for temporal comparisons of individual gaze patterns to remedy this issue (Fig. 2(D)). In addition, one can change the y-axis variable using a combo box (e.g. pupil size and distance to monitor). In the correlation view (Fig. 2(E)), one can further scrutinize the contextual information with correlation analysis. One can perform quantitative analysis between each pair of contextual factors and select a cell in the matrix to explore the data further in a scatter plot.

GazeDx also supports interactive filtering of gaze data by window value, region of interest (ROI), and temporal range. As the visibility of stimuli is affected by window value, filtering with it could reveal the actually visible regions. Also, filtering with ROI could help narrowing the gaze data down to specific organs or lesions.

3 Discussion and Future Work

We designed GazeDx to aid radiologists in comparative analyses of their gaze patterns during diagnoses. We conducted case studies with medical professionals from two departments (chest and abdomen) to evaluate it. We collected gaze data from 14 radiologists, and received positive feedback and meaningful analysis results from two expert radiologists who analyzed the gaze data. We plan to improve our tool in our follow-up design process to aid finding clinical implications, and improving the quality of diagnoses as well as trainings of novice radiologists.

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