Chapter 5
Evaluating Visualisations and Automatic Warning Cues for Visual Search in Vascular Images

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ABSTRACT
Visual search is a task that is performed in various application domains. The authors examine it in the domain of radiological analysis of 3D vascular images. They compare several major visualisations used in this domain, and study the possible benefits of automatic warning systems that highlight the sections that may contain visual targets and hence require the user’s attention. With help of a literature study, the authors present some theory about what result can be expected given the accuracy of a particular visual cue. They present the results of two experiments, in which they find that the Curved Planar Reformation visualisation, which presents a cross-section based on knowledge about the position of the blood vessel, is significantly more efficient than regular 3D visualisations, and that automatic warning systems that produce false alarms could work if they do not miss targets.

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INTRODUCTION

The main goal of this chapter is to study visual search tasks in the medical (vascular radiology) domain from a cognitive perspective. In the medical domain, cognitive studies are generally rare. Cognitive aspects of clinical processes are generally not the main focus, and most studies are clinical studies, only studying general clinical outcome of a process as a whole. We also found that knowledge from other domains and generic experiments does not transfer well because of difference in assumptions between the different domains of study. We study the visualisations by introducing the concept of target detection cues. These are visual cues that represent visual targets with a certain probability. This concept is used to examine both regular visualisations (where target detection cues are implicit in the nature of the visualisation) and warning cues generated by automatic target detection systems (where the cues are explicitly added). This enables us to compare research on target detection cues in different domains, and identify some important experimental variables.

One important aspect of target detection cues is their accuracy. Erroneous cues may be either false positives (a cue is visible but there is no target) and false negatives (no cue is visible when there is a target). We find that the error rate and the type of error is important for the effectiveness of a visualisation. Besides a study of the literature, we discuss two of our experiments, which we conducted for visual search tasks in the 3D vascular radiology domain. We conclude with some recommendations for vascular radiology visualisation and visual search tasks in general.

The visualisations in our domain are based on 3D imaging data. 3D images are significantly more complex to navigate than 2D images. In our domain, we were able to simplify navigation by restricting it to movement along a blood vessel. This is a choice that proved to work well in previous research. Other, more minor, choices in 3D navigation are also examined. We also conclude with some recommendations for 3D navigation.

BACKGROUND

In the following sections, we examine visual search in the area of medical imaging, more specifically, 3D vascular imaging. Vascular disease diagnosis can be done effectively by means of 3D imaging techniques such as Magnetic Resonance Angiography (MRA) and Computed Tomography Angiography (CTA). The most common vascular diseases that these imaging techniques help diagnose are stenoses (abnormal narrowings in blood vessels) and aneurysms (abnormal widening or ballooning of blood vessels). We focus on Contrast Enhanced MRA as this is the area of our current research (Suinesiaputra, et al., 2009). CE-MRA involves injection of a contrast agent in the blood stream, making the relevant blood vessels show up as high-density areas on the MRA scan. The output of CE-MRA is a 3D density field (typically around 128x128x128 pixels), with higher densities representing blood flow.

With help of 3D imaging techniques, the thickness of the inside of the vessel (the vessel lumen) can be determined precisely, and assessed quantitatively. This is a very attractive tool in diagnosis. Determination of the vessel lumen is called segmentation. It results in a 3D (usually tubular) surface representing the vessel lumen circumference. Since manual segmentation is time-consuming, automatic segmentation is proposed (Boskamp, et al., 2004; Suinesiaputra, et al., 2009). Automatic segmentation typically first constructs a pathline, which is a line that goes through the lumen of the vessel to be segmented (Boskamp, et al., 2004). From the pathline, a triangle mesh is constructed indicating the lumen. The pathline is also useful as a basis for “intelligent” visualisations.

In automatic segmentation, occasional errors are currently inevitable. Therefore, clinicians have
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