Chapter 16
Gaze Data Analysis:
Methods, Tools, Visualisations

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ABSTRACT
Analysis of gaze data collected during experiments is an essential part of any study that deals with eye tracking. In turn, analysis of gaze data is not a trivial procedure, on account of the nature of eye movement, peculiarities of human vision, and the imperfection of the measurement tools. In this chapter, we first draw out the most common issues that researchers are trying to resolve for analysis of gaze data, then present in detail the well-known methods and procedures of gaze data analysis, and finally point to the latest achievements in this field. The chapter contains a specification of the most promising directions in this field of research. We finish with a brief description of the most well-known academic and commercial tools that have been developed for gaze data visualisation and analysis. This chapter is based on an updated version of work originally published by Špakov in 2008.

INTRODUCTION
It has been suggested that visualisation tools are necessary for facilitating understanding of large volumes of data because the visual cortex dominates perception. Moreover, the key parts of the perception process occur rapidly without conscious thought (Zeki, 1992). The quantity of data collected during experiments makes researchers who study gaze behaviour eager to embrace data visualisation tools. There has been a steady stream of improvements to analyse and visualise eye movement data while one is observing static 2D stimuli (Lankford, 2000b; Wills, 1996; Wooding, 2002).

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Some researchers also have been outspoken about the tools they wish to have to help them in their gaze data analysis. Many of them have developed prototype systems to illustrate their individual approaches (Halverson & Hornof, 2002; Reeder, Pirolli, & Card, 2001). Some academic prototypes, such as GazeTracker and NYAN, have evolved into commercial systems that are becoming very popular.

While 2D observations already have strong support in analysis tools, improvements regarding gaze data processing and visualisation for dynamic stimuli are still in the early stages. Most techniques are based on frame-by-frame analyses of video data, although some recent findings in this field, such as ‘bee swarm’ and dynamic heat-map visualisations, are implemented in most of the modern commercial tools. However, it would not be too inaccurate to say that nobody has come up with a simple and intuitive way to visualise gaze data for dynamic stimuli so far.

The meaning of eye movement is impossible to interpret according to set rules, as there is very little evidence of gaze behaviour that could aid in distinguishing between a meaningless fixation such as an unintentional one and a deliberate or purposeful one (Posner, 1980). Evaluation of the efficiency and usefulness of existing visualisation methods remains a difficult problem. However, some researchers have illustrated that the application of work-load assessment methodologies (Hart & Wicken, 1990) to data comprehension tasks can provide a highly useful method for distinguishing among the effectiveness levels of various visualisations (Ramloll, Brewster, Yu, & Riedel, 2001). Eye tracking systems are often effective tools only in the hands of specialists who have had significant practice in the use of the technology. An experimenter new to this technology will frequently face several issues: 1) eye tracking devices are not plug-and-play; 2) the data gathered are not always reliable, because of the lack of data validity; and 3) making of meaningful inferences from the high volume of gaze data is difficult.

Another issue with eye tracking systems is that – while tools for processing, visualising, and analysing gaze data are being developed and improved continuously – these tools usually are highly dependent on the tracker system because of the raw data format and the data-gathering method. Therefore, it is often the case that gaze data visualisation software needs to be developed from the ground up for the eye trackers used in many laboratories utilising eye tracking devices. This state of affairs usually leads to duplication of effort in software development for each specific eye tracker. Typically, eye tracker manufacturers sell both hardware and associated software. Thus, the commercially available gaze data visualisation and analysis tools each are, as might be expected, designed for a specific tracker. The industry is showing great progress in developing electronic devices; accordingly, there is an increasing tendency for analysis and visualisation tool development efforts to be dissociated from eye tracker hardware implementation processes. This trend actually can be beneficial for both researchers and manufacturers.

The division of labour leads to a new software/hardware equilibrium, as has happened with other modern standard devices (mouse, keyboard, joystick, etc.). This will pressure visualisation tool developers to give high priority to development of interoperability features necessary to enable their software to access as many raw data formats of eye tracker devices as possible. On the other hand, there is still hope that manufacturers will standardise on a universal raw data format and its means of access.

The COGAIN Network of Excellence has involved preparation of recommendations concerning raw gaze data format for manufacturers as one of its milestones. Deliverable 2.3 (Bates & Spakov, 2006) describes these recommendations, so it is expected that in the very near future the marketing objectives most probably will match the gaze data visualisation tool objectives – in
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