Challenges of Using Eye Tracking to Evaluate Usability of Mobile Maps in Real Environments

Hua Liao
Beijing Normal University
Beijing, China
liaohua@mail.bnu.edu.cn

Weihua Dong
Beijing Normal University
Beijing, China
dongweihua@bnu.edu.cn

ABSTRACT

Mobile maps are frequently used in real environments rather than in controlled lab environments. However, map usability evaluations are mainly conducted in the lab, which is criticized for lacking real contexts. This paper specifically focusing on using eye tracking for map usability evaluation. We identify the challenges of real-world usability evaluation of mobile maps with eye tracking. We summarize these challenges into two aspects: difficulties in experiment control of real-world user studies and difficulties in eye movement data processing. We also propose potential solutions to these challenges.

Author Keywords

map usability evaluation; visual attention; user behavior; user studies; pedestrian navigation;

INTRODUCTION

Map usability evaluation is a critical step in user-centered map design. By measuring the effectiveness (accuracy), efficiency (response time) and satisfactory of user's completing map reading tasks, designers can identify usability problems and improve map design.

Evaluating map usability using eye tracking

The past decade has witnessed an increasing interest in using eye tracking technology to evaluate map usability (e.g., [1-3]). An advantage of using eye tracking is that it can provide direct and unambiguous evidence into how users allocate their visual attention on the map. By analyzing users' eye movements, researchers can get a better understanding of how visual design of the map affects users' visual attention. Furthermore, eye movement indicators can be easily integrated into two key elements of usability evaluation (i.e., effectiveness and efficiency) [4].

Conducting experiments in the lab and in the real world

To date, most eye tracking-based usability experiments are conducted in the lab [5]. Lab environments can provide higher experiment control than real environments. Desktop- and immersive-based virtual environments are frequently used in the lab. Some studies consider immersive virtual environments (IVE) as a good approximation of the real world [6]. For example, Delikostidis et al. [7] found that IVE was comparable to real environments to detect major usability problems. However, empirical evidence of similarities and differences of visual behavior in IVE and in the real environments is still rare. More importantly, lab environments are criticized by its low ecological validity, especially for usability evaluation of mobile maps. This pushes the need to conduct usability experiments in the real world.

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RESEARCH CHALLENGES

Experiment control in real environments

The experiment control is more difficult in real environments than in the lab. These difficulties include the following four aspects.

- **Dynamic visual stimuli**. The real world is dynamic; people and objects are constantly changing and cannot be controlled. This means that different participants are presented with different visual stimuli. Therefore, eye movement data among different participants is difficult to be compared directly.
- **Participant organization**. In real environments, moving participants from one place to another is inconvenient. Furthermore, participants may get familiar with the environment during moving to the start point.
- **Eye tracker calibration**: Currently, there are technical difficulties to calibrate both near (e.g., a map at hand) and distant (e.g., building) objects in real environments [8]. Many studies conducted eye tracking experiments at a stationary position. Calibrating both near and distant objects requires manual efforts which is time-consuming.
- **Data quality**: Eye movement data quality is easily affected by strong sunlight in real environments [9].

It should be noted that some of the above-mentioned issues cannot be solved; researchers have to make a compromise between maximum experiment control and the ecological validity of mobile maps [10].

Eye movement data processing

The challenge of eye movement data processing is to develop automatic methods to process eye movement data with dynamic stimuli. The goal is to answer *where* the users allocate their visual attention, *what* objects they attend, and *how* they switch their visual attention among objects.

Map detection and spatial fixation adjustment

Analyzing map usage (e.g., *when* and *where* the participants look at the map) is a basic requirement for map usability evaluation. Therefore, the first problem is to detect maps from the video (solve the *when* question) and adjust fixations to a referenced map (solve the *where* question). This also enables us to analyze the attention transition between the map and the environment. A traditional way to address this problem is to manual mapping fixations from the video to a reference map fixation by fixation (Figure 1), which is a labor-intensive task. Therefore, some studies have employed image feature extraction and matching methods to map fixations to reference images automatically (e.g., [11, 12]). Our pilot study also found that such feature matching methods can achieve high accuracy in map detection and spatial fixation adjustment. However, these studies have only tested static maps.

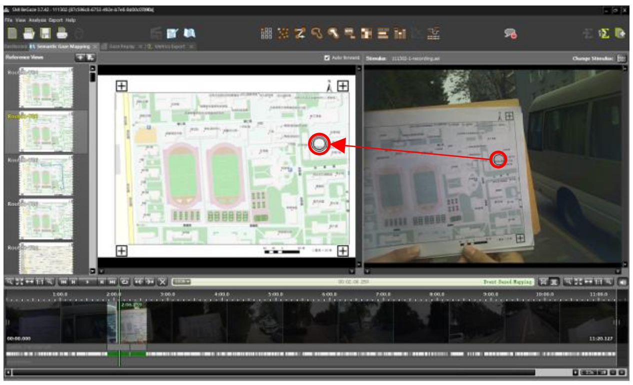

Figure 1. Manual mapping fixations from the video (right) to the referenced map (left) using SMI BeGaze software.

Semantic video segmentation and fixation annotation

The second problem is to identify the semantic meaning of fixations (the *what* question). A simple way to solve this issue is to annotate fixations manually. Researchers have explored using computer vision methods such as object recognition to identify fixation semantics automatically [13]. Besides, recent advances in semantic image segmentation (e.g., Deeplab [14]) may lead to new ways to fully automatic fixation annotation.

Evaluation of the automatic methods

Before applying the automatic methods to processing eye movement data, it is necessary to evaluate its performance (accuracy and /or efficiency).

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