How can augmented reality support spatial knowledge learning in navigation?

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ABSTRACT

Navigation is one of the key topics in location-based services. Research works of navigation services so far have been focused on the promotion of mobility. The development of augmented reality brings new possibilities to navigation devices. In this paper, we present theories to enhance spatial learning in navigation and concerns related to technology, design, and evaluation.

Author Keywords

Spatial cognition; navigation; wayfinding; augmented reality (AR).

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms

Human Factors; Design; Measurement.

INTRODUCTION

Navigation and wayfinding are prominent research topics of location-based service (LBSs). GPS-based navigation systems have been serving drivers and pedestrians since the 1990s. However, their turn-by-turn instructions are not mainly targeted to support spatial orientation and the acquisition of survey knowledge [1]. To support spatial learning in navigation, efforts have been made to enhance spatial knowledge communication between users and devices. Augmented reality (AR) connects the real world and the virtual world by anchoring virtual objects to real-world locations [2, 3]. Existing design paradigms of navigation with AR aim either to enhance the route communication by overlaying navigational aids, such as routes, traffic signs, follow-me symbols on the real world scene, or to enrich the environment communication by adding extra information, including annotating point of interests (POIs), dangerous situations. In this paper, we attempt to explore the potential impacts of AR technology in navigation on spatial knowledge learning.

TECHNICAL DETAILS OF AR DEVICE

To anchor virtual navigational elements to the real world scene, an AR device needs to position itself in 3D and recognize its surrounding environment. The sensor range imposes some limits on the application scenes of an AR device. If the sensor range is up to 10m, the AR device is sufficient to be used indoors, but needs extra effort to work in an outdoor environment. The fusion of the real-time-sensed information and the prior knowledge stored in geo-database is the key to align virtual elements with the real world. The fusion also requires the underlying geo-database to support highly accurate positioning and rich environmental information.

CONTENT AND INTERFACE DESIGN

To investigate the use of AR for spatial learning during navigation, we need to answer two basic questions, under what conditions with what design paradigms, AR is efficient to support spatial knowledge learning in navigation, and how its efficiency can be evaluated.

AR devices have a great impact on users' immersive experience. Virtual elements that are added into a real world scene are also competing for users' cognitive resources. Keeping in mind that safety plays a key role during the navigation, it is especially important to find how this immersion affects the safety in navigation.

Massive visual processing resources are needed during navigation. Purposefully designed virtual elements in AR may influence a driver's attention, for instance, keep him alerted to dangerous situations [7]. Besides this particular

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design, the general influence of virtual elements on drivers' attention in navigation is still unclear.

The lack of depth cues is a common perceptive problem in AR [8], because it weakens the distance estimation in 3D space. Therefore, it is important to know to what extent the virtual navigational elements may act as depth cues and how their effectiveness can be further improved. If the depth cues are misaligned with the real world, we need to know how the users' behavior regarding the safety concern may be influenced.

Inspired by MacEachren's insights on map reading, using VR content can be understood from an information processing perspective, which emphasizes the interaction between perceptive stimuli and prior knowledge [4]. Cognitive load theory (CLT) provides a general framework to describe such interactions [5, 6]. On the one hand, VR provides a powerful tool to examine the hypotheses from CLT on spatial learning and navigation. On the other hand, we can expect the development of CLT to guide the design of VR-based navigation system. However, the priority of VR should not be pre-assumed. Therefore, we give a try to investigate direct experiences of various individuals in order to determine the shared experiences. In this context we raise a general question as "how far can we acquire shared user experiences and use them to guide the development of AR-based navigation system for spatial knowledge learning?"

Pedestrian navigation is different from the navigation for drivers. It is important to know the answers to the same questions for different navigations. Then "whether the conclusions that are drawn from driver's side can be generalized to pedestrians, or vice versa?" and "what is the most important differing factor between pedestrians and drivers we should consider when we generalize the conclusion?".

EXPERIMENTAL STUDY

Experiments that involve human participants are needed, no matter whether they aim to verify the usability of a new design paradigm or to study the long-term effect of using AR in navigation.

With the purpose of using AR as a navigation tool, testing a realistic situation, i.e. ecological validity, should be prioritized. In other words, user behaviors or experience in the field may be quite different from what users behave or perceive in labs. However, how to design experimental environments to achieve high ecological validity without sacrificing internal validity or external validity is still challenging.

User-centered design and evaluation approaches are increasingly important for the AR system development [9, 10]. In navigation scenarios, AR users can be diverse in terms of their experience, age and gender. Besides, compared to the standard WIMP (i.e. window, icon, menu, pointing device) based interfaces, AR interfaces are relatively rare and new to many users. That means users usually have little knowledge or experience in interacting with AR systems. These characteristics add the challenges on how to design an intuitively operable interface and evaluate its impacts on diverse users. [11]

Different from the standard WIMP-based systems, the AR based navigation application is more than the effective accomplishment of tasks. It is more focused on how to help users improve their spatial cognition. Therefore, different evaluation techniques should be developed to study the user experiences, which go beyond the self-report evaluation such as post-study questionnaires or interviews [12].

Eye tracking technology, which is based on eye-mind assumption, is widely used in researches about spatial perception process [14, 15, 16] and design [17, 18, 19]. Hepperle and von Stülpnagel [20] conducted an eye-tracking-based experiment and found that during retrieval of the incidental learned route, participants fixated more on landmarks compared with intentional learned ones. Liao, Wang [21] used eye movement data to assess the influence of map label density on a perceived complex. Eye tracking is also applicable to AR applications. It is possible to do foveated rendering (i.e. only to show users the portion of what they are looking at in full detail [22]), to enable better graphics quality and to identify users [23]. Eye tracking can also help researchers to identify the key information in AR-based navigation, thus developers can provide the minimized sufficient information for both navigation and spatial awareness. The AR-leading companies, such as Microsoft, Facebook and Apple, all investigate in eye-tracking for AR [23]. Even though none of current devices provides eye tracker, Lee and Hui [24] emphasized eye tracking in their summary of interaction methods of AR smart glasses.

Psychophysiological measurement tools may help monitor users' emotions during the process of experience [13]. These technologies are used for spatial cognition research, such as fMRI (functional magnetic resonance imaging) and EEG (Electroencephalography). Although they may be difficult to be applied for real-time data collection, it is worthwhile to conduct research about the long-term influences of AR-based navigation systems on spatial cognition.

SUMMARY

In this paper, we set the focus on the design paradigms of AR-based navigation system for spatial cognition rather than mobility promotion. If AR navigation eventually becomes a part of our daily life, we want to know "how would AR affect our mental health in the long run?" The concern may rise similarly to the worries about the smartphones, social media, and other pitfalls of the digital world today. Robust evidence is needed from the collaboration of researchers from different disciplines.

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