Mobile Augmented/Virtual Reality Interface Design and Evaluation

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Abstract

Nowadays we are surrounded by various visual data, for example medical images, geographic data and online videos. In the meantime, mobile personal devices are ubiquitously available. From handheld devices to wearable equipments, technology advances have brought us to a wide range of miniature hardware which used to be only in science fictions but now carried by us everyday everywhere. Following these trends, a new challenge arises: How can we present huge amount (and categories) of visual content to users via resource limited mobile devices while still achieving good user experience. There is no straightforward solution to this question in practice, because we are facing challenges from three aspects: Mobile Devices, Visual Data and User Factors.

First, although modern mobile devices are equipped with fast processors and various sensors, they are still resource limited devices and have many inherent constraints, such as screen size, 3D-2D ambiguity, memory restriction and system latency. Despite the fact their resolution (or pixel density) have been increased, the screen physical dimension has to be restricted to handheld size. Also a mobile screen is a 2D surface. When showing 3D content, it suffers from 3D-2D ambiguity in both input and output. Moreover, although we can use up to several gigabytes of memory on a mobile phone, certain visual content, like city reconstruction data, can easily exceed this bound, which causes issues in data transmission and storage. Last but not least, system latency is unavoidable due to network delay, hardware update rate and computing tasks.

Second, visual data has huge diversity and thus conventional visualization approaches may not be suitable for mobile devices. Increasing quantity and quality of visual data requires novel approaches to visualize and interact with the data. Materials (such as high definition images/videos and complex 3D scenes) are widely available today. New methods are desired to efficiently visualize these data and create intuitive interfaces.

Third, different user scenarios request different mobile user interface design. As known from the concept of user centered design, we must take user factors as input to the design cycle, understanding what users need and what users perceive. Without such knowledge, a design will result in failure.

In this thesis we are going to answer these challenges by exploring the design of mobile augmented reality (AR) and virtual reality (VR) user interfaces. Instead of designing a universal solution, which is hardly possible, we investigate fundamental components in

designing mobile AR/VR interfaces. Our goal is to provide guidance for future mobile AR/VR visualization/interaction design. To handle the challenges of Devices-Data-Users, we have three fundamental requirements. First, we need novel approaches to deliver large, complex visual data, like 3D scenes, to mobile devices. Second, we have to handle inherent constraints of mobile devices to support intuitive interaction. Third, we need formal user studies to evaluate user experience of novel interfaces. This thesis is organized into three parts accordingly: Visual content generation and transmission, interaction with visual content, and user perception of visual content. In each part we focus on a fundamental question of designing mobile AR/VR interfaces and provide several techniques to handle different scenarios.

In the section of visual content generation and transmission, we present a solution to transmit and visualize complex visual data on resource limited mobile devices. We shift computing complexity from local mobile devices to a remote server via network and trade-off between computing time and transmission latency. The major effort concentrates on server-side visualization, screen space feature extraction, data transmission and client-side image re-synthesis.

In the section of interaction with visual content, we explore several mobile AR/VR interface designs to show visual content to users more intuitively and interactively. We first present techniques that combine multiple mobile displays together to create a large display surface. Using easy and flexible localization and tracking methods, we can build planar or non-planar displays from commodity mobile devices, supporting static or dynamic configurations. Second, we show several mobile AR interfaces in navigation scenarios, where we apply emerging display techniques in AR navigation and explore visual design of AR navigational information.

In the section of user perception of visual content, we investigate the design of mobile AR interfaces from users' perspective. In particular, we evaluate the influence of system latency to user performance and perception in a representative AR scenario. By understanding the relationship between system latency and user factors, we can better distribute computing resources of a mobile AR system.

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