Evaluating Mobile Applications in Virtual Environments:
A Survey

Ioannis Delikostidis, Institute for Geoinformatics (ifgi), University of Münster, Münster, Germany

Thore Fechner, Institute for Geoinformatics (ifgi), University of Münster, Münster, Germany

Holger Fritze, Institute for Geoinformatics (ifgi), University of Münster, Münster, Germany

Ahmed Mahmoud AbdelMouty, Institute for Geoinformatics (ifgi), University of Münster, Münster, Germany

Christian Kray, Institute for Geoinformatics (ifgi), University of Münster, Münster, Germany

ABSTRACT

Context plays a central role in mobile applications but is very difficult to control, and therefore, the evaluation of context-aware applications can be challenging. Traditionally, researchers had to choose either field-based or lab-based studies but recently, virtual environments have been proposed as a middle-ground between those two methods. In this paper, the authors review previous work on using virtual environments to evaluate mobile applications. the authors identify and classify different approaches to simulate specific aspects of the real world, and analyse their relative properties with respect to evaluating different facets of context-aware mobile applications. Based on this analysis, the authors derive criteria and selection strategies that can help researchers in picking specific evaluation approaches. The authors also point out a number of research challenges in this area as well as a number of promising areas for future research.

Keywords: Evaluation Methodologies, Mobile Applications, Survey, User Studies, Virtual Environments

INTRODUCTION

In the field of Human Computer Interaction (HCI) and mobile HCI in particular, there has been a long-running debate regarding the relative benefits and drawbacks of two main methods for evaluating interactive systems with users: field-based and lab-based studies. The underlying reason is that both methods offer distinct benefits and drawbacks depending on the experimental context. Field-based studies, for example, are held in the real world and therefore offer a high degree of ecological validity. This benefit comes with downsides

though: usually field studies require more effort and are subject to unpredictable context changes. Conversely, lab-based studies allow for better control of the experiments – thus ensuring repeatability – but they usually lack a realistic context and thus ecological validity.

Possibly due to these considerations but also due to the fact, that contextual factors have only recently become more relevant in mobile HCI, the majority of user studies during the last decade were tightly controlled lab-based experiments (Kjeldskov & Paay, 2012). Only longitudinal studies have predominantly been carried out in the field, i.e. in real contexts of use (e.g. Chervest, Mitchell, & Davies, 2002). Recently however, promising "hybrid" approaches have been developed that combine elements from lab- and field-based studies: Virtual Environments (VE) in various flavours have been applied successfully in several user studies, for example, in Psychology (Van Veen, Distler, Braun, & Bülthoff, 1998). One of the most recent efforts to use VEs for the evaluation of mobile applications was carried out by Hühn, Khan, Lucero, and Ketelaar (2012), who particularly investigated the field vs. lab issue and the potential of VEs to address it. VEs have also been used in a variety of contexts to simulate relevant aspects of the real world in the lab by immersing participants in computer-synthesized or video-based virtual worlds. Hühn et al. (2012), for instance, implemented a synthetically modelled supermarket environment, to assess the User experience (UX) of location-based targeted advertising.

In this article we review this type of evaluation environment, identifying key properties, drawbacks and benefits, and considering it as a potential approach to evaluating mobile applications. The term "mobile applications" here refers to applications designed to run on mobile devices, such as smartphones and tablets, usually in a dynamic contexts of use. Location-based services, mobile games, and mobile online banking are some popular examples of these applications.

The following section starts out by describing basic principles and categories relevant to this area. We then present a structured and comprehensive review of previous work in the subsequent section. This analysis is followed by a discussion of insights gained during the review, including guidelines for choosing the most feasible method for a particular evaluation goal and scenario. The article concludes by summarizing our main findings and points out promising directions for future research in this area.

BACKGROUND

Virtual Environments (VEs) are relatively new communication and interaction media, developed to convincingly simulate reality and enable a broad range of different applications in a variety of fields. Example uses include gaming (e.g. Second Life, 2012), flight and driving simulators, planetariums, and military training systems. Overall, they provide a different kind of experience to users than what is possible, for example, on a desktop PC or a gaming console (Bowman & McMahan, 2007).

Experiencing Virtual Environments and Psychological Effects

The terms *Virtual Environment* and *Virtual Reality* (VR) are often used interchangeably with other terms such as virtual worlds, simulated realities, artificial realities or synthetic environments in order to describe the same phenomenon (Biocca, Kim, & Levy, 1995). The experiences gathered in such environments can be described as different manifestations of the concept of presence. Heeter (1992) introduced the psychological framework of *presence*, which defines a state where people feel as if they were actually present in a mental world. Such a mental world as portrayed, for example, in books, movies or in a VE can draw the user's attention completely away from the physical world (Witmer & Singer, 1998). This

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