Poster: Pervasive Augmented Reality for Indoor Uninterrupted Experiences: a User Study

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ABSTRACT

Augmented Reality (AR) adds additional layers of information on top of real environments. Recently, Pervasive AR extends this concept through an AR experience that is continuous in space, being aware of and responsive to the user's context and pose (position and orientation). This paper focus on an exploratory user study with 27 participants meant to better understand some aspects of Pervasive AR, such as how users explore, select, recognize and manipulate virtual content in uninterrupted AR experiences, as well as their preferences. The approach used to provide this sort of engaging experiences allows the creation of indoor persistent location-based experiences, with a high level of accuracy and resilience to changes in dynamic environments. Results concerning user acceptance of uninterrupted AR experiences were encouraging. In particular, users were positively impressed by the continuous display of virtual content and were willing to use this technology more often and in different contexts.

AUTHOR KEYWORDS

Pervasive Augmented Reality; User Study; Uninterrupted Experiences; Context-sensitive Computing.

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Human-centered computing→Mixed/augmented reality; Empirical studies in HCI.

Figure 1: Content placing – user interface during the positioning of a virtual 3D model in the environment. It is possible to rotate, scale and move all virtual objects, to properly include them in the surrounding environment.

Figure 2: Exploration – user interface during the exploration of the virtual content in the environment.

INTRODUCTION

AR is gaining relevance due to the appearance of new, more powerful and affordable devices with more sophisticated sensors [1], making them adequate platforms for rich AR solutions [2]. Despite the recent success of AR applications, most of them require the detection of a visual marker to show the virtual content, serving only a single purpose. These applications are typically used for short amounts of time, and do not provide a continuous AR experience. Recently AR has started to be extended according to the concept of Pervasive AR, which is defined as "continuous and pervasive user interface that augments the physical world with digital information registered in 3D, while being aware of and responsive to the user's context" [3].

This paper focus on an exploratory user study with 27 participants meant to better understand several aspects of Pervasive AR, for example: how users explore, select, recognize and manipulate virtual content, as well as to learn about users' preferences regarding different methods of display and interaction in uninterrupted AR experiences.

CHALLENGES OF AR APPLICATIONS

AR applications may include a significant amount of added digital information and require adequate mechanisms to display, filter and select the relevant information at a given moment [4]. Understanding how to display information without interfering with the users' task is a long-standing problem. Another challenge in AR is precise tracking of the user [5]: although several mobile devices are already capable of tracking their 3D location in indoor spaces, they still present limitations, as the vulnerability to environment changes, which may cause significant location errors, hindering an accurate localization of the virtual content and continuous experiences. Moreover, these continuous AR experiences raise challenges concerning display and interaction with information, appropriate tracking of the user position, adequate configuration of virtual content, uninterrupted display of information, and use of suitable interaction methods [3]. These challenges motivate our work towards the creation and evaluation of an approach to provide accurate, easy to use and setup continuous indoor AR experiences.

UNINTERRUPTED AR EXPERIENCE

To obtain an uninterrupted experience, we used an approach meant to create and deploy AR experiences in indoor scenarios. The approach uses a mobile application to support configuration of augmented indoor spaces with several types of virtual content (3D models, text, sound, video, etc.) (Fig. 1), as well as their exploration as a continuous AR experience (Fig. 2). The applications (configuration and exploration) were developed using the Unity 3D game engine, C# scripts, the Tango SDK, and fiducial markers (in our case QR codes).

The Tango platform motion tracking allows devices to track its position and orientation throughout 3D space. Since the Tango tracking capabilities have some limitations (namely cumulative errors and limited tracking when few visual features are visible), some fiducial marker were added to the scene to allow recalibration of the tango tracking with the real world. This combination makes the localization method robust enough to deal with uncontrolled indoor environment changes such as illumination and geometry.

Figure 3: Task 1 – user interface while selecting virtual objects (pumpkins) placed in the environment. Since the study was performed in October, Halloween was used as theme to provide context and motivate the participants.

Figure 4: Task 3 – user interface with different methods denoting interactive content.

Figure 5: Task 5 – user interface during content separation: users are supposed to place pumpkins in right box and candy in the left box.

To increase resilience to these changes, fiducial markers were sparsely used as world anchors, enabling re-calibration of virtual content pose if necessary resulting in an accuracy of 0.006m indoors [6]. In the configuration phase, virtual content can be attached to the real world at a specific position and orientation. After the environment configuration, users can experience it uninterruptedly visualizing and interacting with virtual content overlaid on the real world. The only requirement is the initial detection of a marker so that the application aligns its pose in the environment.

USER STUDY

An exploratory study was performed including five tasks relevant in a AR environment. The objective was to assess users' difficulties, preferences and acceptance regarding different aspects of uninterrupted AR experiences, namely:

- **Task 1 - Selection:** Explore the environment to find and select several virtual objects (pumpkins) to make them disappear (Fig. 3).
- **Task 2 - Space Exploration**: Explore the environment and count all virtual objects (spiders) and input the number of objects found.
- **Task 3 - Call of attention**: Find which virtual objects are interactive. Several call of attention methods were used to indicate interactive virtual objects (size change, the picture increases and decreases over time, a 3D frame, or two arrows pointing to the picture) (Fig. 4).
- **Task 4 – Navigation and information collection:** Follow arrows indicating a specific path to a virtual object and read an inscription.
- **Task 5 - Manipulation**: Separate different objects into specific boxes (Fig. 5 & Fig. 6).

Tasks 1, 2 and 3 were meant to observe how easy it was to navigate the environment and find virtual objects. Task 1 also assessed the difficulty in selecting virtual objects, and task 3 the difficulty in reading text. Task 4 assessed the intuitiveness and participants' preferences concerning affordances, indicating the presence of interactive virtual objects and finally task 5 was aimed at understanding the ease of interaction and manipulation of virtual objects.

Experimental protocol and participants

The tasks were performed by 27 participants (9 females). Most participants (22 out of 27) had already used AR. The environment included virtual arrows as navigation aids. During the experiment an observer registered participants' difficulties, interaction issues with the virtual content and other observations. Several variables were also logged by the application. Participants were required to answer post-questionnaire including three parts: 1- Demographic and relevant data concerning the participants' profile; 2- System Usability Scale (SUS) questionnaire; 3- Questions concerning characteristics of continuous AR applications. The protocol and questionnaire were approved by the Council of Ethics and Deontology of the University.

Experimental setup

The experiment was conducted indoors with constant artificial light. Participants trailed a 38m long path while they performed the tasks following virtual arrows (Fig. 7). The layout was static, without changing neither the geometry of the environment or the position of the virtual objects. The device used was a 2016 Lenovo Phab2 Pro.

Figure 6: Task 5 – participant separating virtual objects. A handle was provided to make the tasks easier to perform while holding the device, adding comfort and reducing fatigue.

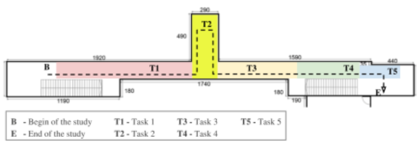

Figure 7: Plan of the building where the study was conducted. The path followed by the participants is marked in grey. The area associated to each task is highlighted with a different colour.

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RESULTS AND DISCUSSION

Results show most participants were able to easily navigate the environment. The median number of virtual objects captured was 11 out of 14. Some objects were intentionally placed in less obvious locations, to assess how thorough was the exploration of the environment. At the end of the task the number of missed objects was indicated to the user. As a result, most participants performed a more exhaustive search in the following tasks. In addition, all participants successfully detected the interactive content, although some (9 out of 27) also tried to select non-interactive content. The preferred method of denoting interactive content was size change (16 out of 27 participants). Likewise, all participants were able to separate the virtual objects in the respective boxes. The average SUS score was 82, implying an above average usability. All participants were willing to use this type of experience often, stating it provided an interesting, fun and interactive way to guide them through the environment, while being easy to use. Despite the average duration of the experience (~13 min), most participants (24 out of 27) did not report fatigue. Using a handle probably helped. Several participants stated the virtual content was convincingly superimposed over the real world.

CONCLUDING REMARKS

Pervasive AR has the potential to help AR evolve from an application with a unique purpose, to a multi-purpose continuous experience changing the way users interact with information and their surroundings. The approach presented in this paper allows to easily create and deploy uninterrupted AR experiences, supporting adaptable and flexible interaction techniques. Participants selected size change as the preferred method to denote interactive content. Overall, participants were willing to use this type of experience often and were positively impressed by having the virtual content displayed in a continuous and convincing manner. Future developments will include integration of spatialized audio content and user identification to enable adapting the experience to the user profile. Additionally, a new study must be designed to specifically explore issues having to do with persistence and pervasiveness and be set over larger areas and longer periods of time.

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