

# Mobile Augmented Reality as an Orientation Aid: A Scavenger Hunt Prototype

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**Abstract**—This paper suggests the use of pervasive augmented reality as the foundation of a serious game to teach navigation in a public environment. We introduce and discuss the game concept underlying our work-in-progress. Finally, we report upon the implementation of a first prototype in the form of an augmented reality scavenger hunt, and its preliminary evaluation as proof of concept.

## I. INTRODUCTION

Serious games have been the focus of increasing attention in the past years. Research has investigated ways to convey knowledge, skills, and values in a multitude of subjects, ranging from languages and scientific knowledge to health problems and awareness of social issues (see [1]). However, to our knowledge, few serious games explicitly focus on teaching the navigational skills required in a specific environment, such as a large building complex, or city area. For new arrivals to large public environments (e.g. newcomers to a city, or first-year students at university), orientation is an important skill that is traditionally gained only through time-consuming trial-and-error, or aided by introductory tours.

We suggest that serious games that focus on orientation may benefit from a pervasive game design. Pervasive games are defined by their transcendent interpretation of traditional game settings in the form of spatial, temporal, or social expansion: “pervasive games embrace their environments and contexts” [2]. As such, this type of game quite naturally aligns with a navigational aspect of play. Most pervasive games either assume these navigational skills, or teach them as a side effect of their primary goals. Our concept intends to focus on explicitly relaying the navigational skills required for a specific public environment.

## II. RELATED WORK

Over the past decades, pervasive games have been studied in games research from a variety of perspectives (see also [3]). They can be defined as follows: “a game that has one or more salient features that expand the contractual magic circle of play spatially, temporally, or socially” [4]. The spatial expansion, in particular, lends itself to navigational tasks, many of them in combination with augmented reality (AR) approaches. A popular genre is thus that of scavenger or treasure hunt games, such as, for example, Human Pacman [5]. An overview of existing AR games and the corresponding challenges of their implementation can be found in [6].

The term serious games (see [7]) applies to games with a primary goal of education, i.e. imparting some skill or knowledge. In order to facilitate the positive effects of motivation on learning, serious games often employ gamification elements, i.e. “the use of game design elements in non-game contexts” [8]. For instance, an AR treasure hunt game was used in the psychotherapeutic treatment of children [9], while the Via Mineralia museum game [10] imparts information about minerals. Similarly, the SecretSLQ AR game [11] was designed to promote library exploration. Thus, many serious games include location-based approaches and/or AR techniques, but few combine the two in order to teach navigation in a specific place or institution.

In the following, we discuss two games that have focused more closely on the intersection of serious and pervasive games. One is Orientation Passport ([12], developed and evaluated further in [13] and [14]), a mobile pervasive game designed to help first-year students with orientation at university. It applies gamification in the form of an achievement system, and investigates the effect this has on players’ engagement and motivation. The game objectives consist of encouraging participation in orientation events, meeting fellow students, and the exploration of the campus. Thus, the navigational skills are included in the goal objectives, but form the means to an end rather than the main focus of the application.

A similar project, also intended to support university orientation, is MobileGame [15]; a mobile application that combines elements of a scavenger hunt with the assassination genre (see [2] for an overview of pervasive game genres). The game objectives thus consist of finding locations, answering questions related to these, and hunting one of the opposing teams (while evading another). The tasks presented by the application differ, depending not only on the location they are triggered in, but also on the time of day, or the previous activities of opposing groups.

Both of these projects offer detailed research into the design, implementation, and challenges of navigation-based pervasive games, as well as user reception thereof. However, neither project examined the effects an AR approach might have on the results of such an orientation aid. To the best of our knowledge, the combination of a serious game focusing explicitly on navigational skills while utilising augmented reality as part of a pervasive game has not been studied.

### III. CONCEPT

This paper introduces a concept for a pervasive serious game with AR to convey navigational orientation skills in a public environment. For example, newcomers to a city often take a long time to be able to navigate efficiently. Similarly, people joining a large public institution (e.g. first-year university students) often lose their way or run late while searching for important points of interest. The focus of this serious game thus lies on navigation - teaching players how to navigate between the points of interest in a public environment. In the following, we outline the core aspects of our game concept:

*a) Navigational Serious Game:* The objective of the game consists of teaching players how to navigate between points of interest, utilising gamification elements to increase and maintain player motivation and engagement. The game mechanics are thus composed of quests that link points of interest, rewards for successful navigation, and a help functionality (e.g. in the form of hints). This approach lends itself to the pervasive scavenger hunt genre, wherein the user can collect rewards along the way for correct routes.

*b) Augmented Reality:* With the objective of teaching navigational skills in a real-world public environment, we suggest that the game design should attempt to resolve two potentially conflicting goals: (a) upholding the sense of immersion in the game (which previous research indicates may increase motivation, and thus engagement [16]), and (b) utilising the sense of presence in the real world to ensure that the skills gained are not far removed from real-world orientation. As such, virtually augmenting the real world with guidance elements (e.g. navigational hints) appears to be a promising approach in the interest of balancing both goals.

*c) Adaptivity:* One of the primary advantages of serious games over traditional learning methods is their potential for adaptivity. The game should therefore be adaptive to the needs and interests of users. For example, users with disabilities may require more accessible routes and points of interest. Similarly, based on the user interests or demographic information, the system should be able to generate a route customised to maintain the player's motivation. For instance, in the city-newcomer scenario, the route generation could concentrate on areas in which the player lives and works. In the university orientation setting, routes might differ based on the subject the player studies.

### IV. PROTOTYPE

In order to determine if the enhancement of a serious game with augmented reality is a viable concept for conveying navigational skills, we implemented a first prototype called *UniRallye*. An Android application was implemented in combination with the *Vuforia* SDK [17] as a computer vision framework. Augmented reality techniques were used to guide players along the correct path; the video stream of the integrated camera was displayed on the smart phone screen, but augmented by virtual objects upon detection of previously defined AR markers (detected via *Vuforia*). While not required by *Vuforia*, the markers differed in their colour in order to indicate their intended purpose to the player (see Figure 1). For instance, these AR markers were used to show navigation



(a) AR marker for treasure chests. (b) AR marker for navigational hints.

Fig. 1. The different colourings of AR markers indicate their difference in purpose for the user.



Fig. 2. The UniRallye interface displays a navigational hint in the form of an AR arrow element upon detection of the corresponding AR marker.

hints (as shown in Figure 2), or that the player had arrived at the correct destination (see Figure 3). Due to the focus on the applicability of AR, the prototype implementation did not yet facilitate adaptivity in the quests' route generation.

As the name indicates, the prototype was implemented for the university orientation scenario, in order to facilitate multiple aspects. Quests were easy to prepare, due to the authors' familiarity with the environment. Additionally, participants for the user study are more easily recruited in a university setting, and the installation of AR markers seemed likely to be less complicated than this would have been in a different public institution, or the city itself.

The *UniRallye* game scenario features a number of quests that consist of simple navigational tasks, e.g. finding the way from point A to point B. To fulfil these tasks, the players have to find and scan AR codes at a specified target location, or answer questions that require them to have completed a certain path. As the quests are intended to convey orientation skills, efficacy is rewarded; the players are awarded more points for quick task completion. Further game-like elements are used to create a more complete game experience, and encourage successful navigation. To promote exploration along the correct routes, AR elements in the form of treasure chests were added to the virtual paths, earning the player bonus points upon scanning the associated real-world marker. If the player lost their way, they could view a map for a limited number of times. Finally, a high score system was implemented in order to increase competition and motivation.



Fig. 3. The UniRallye interface displaying a destination flag AR element at the final target of a navigation task.

### A. Preliminary Evaluation

As a first step in evaluation, a preliminary user study was conducted to answer questions regarding users' overall experience of the usability of the developed prototype and its design. Existing studies purporting to users' experiences with learning technologies in an early developmental state have focused primarily on their effectiveness in terms of learning performance, rather than eliciting users' perception of usability [18]. Therefore, testing the usability of learning tools in an early developmental state may help to better understand users' needs, and to adapt the interface design accordingly.

Thirty participants (11 female, 19 male) were recruited at the university to play through the scenario implemented with the prototype. As the prototype of *UniRallye* was developed to enhance navigational skills of new arrivals to the university buildings, the sample consists of first-year university students. The age ranges between 19 and 35 with the mean age equal to 23.13 years ( $SD = 3.14$ ). Before starting to play the *UniRallye* prototype by navigating through the main university building, all participants completed a survey on their demographic background, their affinity for technology [19], and their current motivation [20] (not reported for this paper). Students were then introduced to the game mechanics and objectives, before each of them played a scenario consisting of the six tasks described above. Afterwards, participants completed the PSSUQ survey [21] in order to measure the degree to which the *UniRallye* prototype satisfies basic usability criteria. The questionnaire consists of 19 items on a 7-point Likert scale ( $\alpha = .74$ ) divided into 3 subscales to measure the system's usefulness (9 items,  $\alpha = .96$ ), quality of information (7 items,  $\alpha = .92$ ), and quality of the interface design (3 items,  $\alpha = .83$ ). Further, to assess disadvantages in the usability of the game, an opportunity for open-ended comments was provided.

The preliminary results show that the participants rated the overall usability of the game highly ( $M = 6.29$ ,  $SD = .44$ ). The information quality ( $M = 5.89$ ,  $SD = .60$ ) was rated as the lowest of the subscales. However, the system's usefulness ( $M = 6.45$ ,  $SD = .51$ ) and interface quality ( $M = 6.70$ ,  $SD = .46$ ) was experienced as very satisfying.

The high satisfaction of participants is also reflected in their open-ended comments. For example: "Perfect! Great introduction for the new ones and great entertainment" and "Super great game!" (translated from German) show that users

approved of the game's general concept. This follows user reactions to similar scavenger hunts. Further evaluations of the data collected in this study, e.g. the system's influence on user motivation, and whether the players improved their navigational skills, will be the focus of future work.

## V. FUTURE WORK

The current *UniRallye* prototype is only a proof-of-concept, and still needs to be evaluated in terms of its efficacy in teaching navigational skills. Furthermore, a lot of features are yet to be added in future work in order to accurately portray the concept we envisioned above. First, the use of AR needs to be examined more closely. For instance, a subsequent user study should examine whether the AR approach produces beneficial results (in the form of increased motivation, or more efficient navigation) when compared to related orientation aid tools without AR. Furthermore, we intend to test the concept with a second prototype study in an outdoor environment, as orientation in a public city consists of quite different challenges than those discovered in the first study's university setting.

Similarly, we have considered extending the concept in the manner of the two related projects Orientation Passport and MobileGame. Although the current prototype uses AR elements only for imparting navigational information, a future implementation of the game could also convey additional knowledge. For example, in the city context one could imagine that historical anecdotes could be illustrated with AR techniques, and thus potentially increasing motivation. AR has already been used to convey additional information in serious games (e.g. [11]), and to convey historical information (e.g. [22]). This approach would have to be used sparingly, however, in order not to lose the focus on imparting navigational skills.

As previously discussed, the game concept intended for the generation of routes to be adaptive, in order to provide paths suited to user requirements and interests. A more final version of the game would therefore have to consider methods of detecting information about the user. The adaptive routes will also require a re-structuring of the game architecture in order to provide multiple routing options, and switch out tasks as needed. As a precursor to the next iteration of the prototype, we will conduct semi-structured interviews to determine what kind and what extent of adaptivity is desirable to users.

Furthermore, we would like to apply the game concept to head mounted displays (HMD), because they intuitively qualify for augmented reality and pervasive gaming (e.g. [23]). The current state of the art (e.g. Microsoft HoloLens [24]) seems to indicate that future HMDs will be well suited for the implementation of AR. Although they may introduce issues of user acceptance, they also free up the users' hands and can provide a more immersive AR experience. A further study might examine the trade-off between the sense of immersion gained through improved AR, and the sense of presence from applying real-world navigational skills.

## VI. CONCLUSION

In this paper, we introduced our concept for a pervasive serious game that uses augmented reality techniques as an orientation aid. The concept envisions an adaptive generation

of routes in order to explicitly train users in navigating a public environment, using augmented reality techniques to guide the user towards successful navigation. An AR university orientation scavenger hunt was implemented as a first prototype in order to verify the general concept in a constrained setting. Although the full analysis of the prototype's evaluation is still ongoing, we report upon the users' assessment of the game concept's usability, and discuss how the concept will be further implemented and tested in a subsequent prototype in future work.

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