Technical Factors Affecting Augmented Reality User Experiences in Sports Spectating

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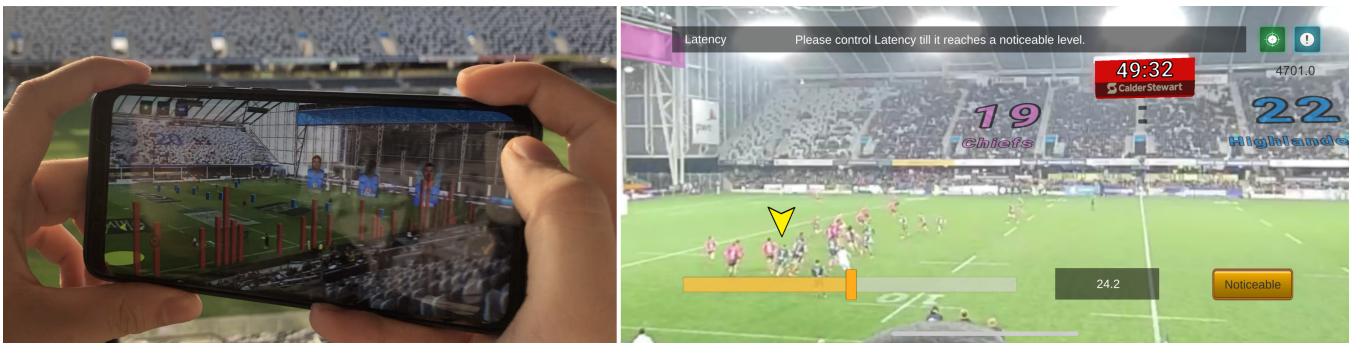

Figure 1: Left: Using our indirect AR prototype in the stadium. Right: Our user study prototype showing the latency factor delayed by 24 frames (1 second) via a slider. Optimally the arrow should exactly point at the referee (in white outfit).

ABSTRACT

The maturity of augmented reality (AR) technology and research now paves the way for dissemination of AR outside of the laboratory. However, it is still under-explored which factors are influencing the user experience of an AR application. In this poster, we describe some of the technical factors that could influence the user experience. We focus on a use-case in the field of on-site sports spectating with mobile AR. We present a study design which analyzes the influence of latency, registration accuracy, and jitter as factors on AR user experience.

CCS CONCEPTS

• **Human-centered computing** → **User studies**.

KEYWORDS

augmented reality, situated visualization, user experience

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1 INTRODUCTION

In recent years, research in AR has been advancing with the development of better hardware with a wide range of use cases developed. However, there is only limited research on large-scale environment AR. Furthermore, the user experience of an AR system and the technical factors contributing to it are still not well understood. In this work, we explore the user experience in a large-scale AR environment of a stadium in a sports spectating use case.

Our sports spectating use case involves mobile AR to enhance on-site spectators' user experience by providing data in a situated visualization format [10]. While relevant technical factors for such an AR experience were identified, it did not further investigate the influence of these factors on user experience. This raises the question of which optimizations are required to make a large scale AR experience effective for the user. Hence, we identified an important question: How do technical factors, such as system limitations or errors, affect the user experience of a large environment AR system, especially with dynamic content?

This work intends to serve as a starting point for research on improving user experiences that are influenced by technical factors and their limitations. The goal is to provide a first guide on what levels of latency, registration accuracy, and jitter are acceptable in a large-scale AR environment. To our best knowledge, there are no previous studies that look into the tailored manipulation of technical factors in AR. We believe this research will fill the gap where there is a lack of user evaluations in AR solutions.

2 RELATED WORK

Prior work mostly focused on the influence of human factors in AR [7] where a product is engineered to suit the target audience while technical papers historically focused on performance measures

such as task completion rates and registration accuracy [2]. These investigations were mostly separate. A survey of evaluation techniques from the early 90s to the late 2000s shows only a few user evaluations in AR research (around 10%) [1]. To our best knowledge, there is a gap to investigates how these technical aspects affect the user experience.

Tracking and localization methods in AR are part of the most popular topics of research for over two decades, which still poses challenges [4]. While tracking is an important technical factor to consider for user experience, these papers usually feature technical accuracy results that do not translate to user experience measures. Latency is also related to the tracking of AR applications in the form of AR head-mounted display (HMD) latency [6] to stimulated AR latency [5]. Similar to tracking and localization, most of the evaluations conducted are technical and do not involve users.

3 TECHNICAL FACTORS IN AR

Olsson et al. [8] did a large scale online survey on mobile AR applications and found that one of the main reasons why users stop using AR applications is due to deficiencies of software and inaccuracy of the hardware, like our targeted registration accuracy, latency and jitter factors.

Modern smartphone cameras have a relatively low latency, therefore we are not interested in the camera latency. The latency we are interested in is the relative latency, which is the latency between two streams of data causing mis-registration [3]. In our use case, this is more likely due to delays from the computer vision system that tracks a player and then transmits it to the client device. This latency will affect dynamic content on field, especially visualizations that follow a player, such as an arrow or highlight.

Registration accuracy in our scenario aims to mimic inconsistencies in tracking and initialization. In real applications, this could be due to a misalignment in the initialization phase, but is often present especially in image-based registration where if the scale of the object is slightly off, it is causing the visualization to appear with an offset. The registration accuracy is stimulated by a consistent offset of visualization from the original location due to an error in placement or alignment.

Jitter is a slight irregular movement of the visualizations due to precision errors in the tracking and anchoring of visualizations. We are interested in the jitter from the camera registration and from the player tracking system. We are aware of other jitter sources, including arm movements of the user holding the smartphone, however we are currently only interested in technical factors. Jitter from the camera would affect all visualizations while jitter from the player tracking would only affect tracking visualizations.

4 EVALUATION OF AR TECHNICAL FACTORS

We designed a mobile AR user study to evaluate a selection of technical factors in AR with regards to user experience. In order to avoid any confounding factors during a live sports game, we decided to replicate an AR stadium experience in a laboratory setting using an indirect AR approach [9]. This approach allows for more accurate alignment of real world and virtual content while effectively controlling parameters such as registration accuracy, jitter and latency, making it a suitable choice for our experiment.

To evaluate if the prior factors are of actual impact on the user experience, we designed a within-subject study where participants could manipulate the factors. Apart from determining which factor has the greatest impact on user experience, we also want to see what are the noticeable and disruptive levels for each factor. There are two dependent variables for this study: the user experience and the value in which a factor is noticeable and disruptive. The independent variable would be the three factors that affect the AR user experience, which are latency, registration accuracy, and jitter.

Participants first experience an optimal condition of the indirect AR and fill in a User Experience Questionnaire (UEQ). They then go through the difference factors and input their value where the factor is noticeable and disruptive via a slider which manipulates the factor (Figure 1, right). This is repeated for all the factors with ratings of how disruptive a factor is appearing after each factor. Participants then fill in another UEQ after the last factor was evaluated. Finally, written feedback regarding the experience were collected.

5 FUTURE WORK

We have started filling in a gap in AR UX research with our user study and narrowed down to three technical factors which we think are potentially disruptive to a users' experience in sports spectating. After conducting the study we would further analyze our results and find insight that might suggest which technical factors are the most disruptive and recommend improvements for further studies of a similar nature and for the design of AR systems.

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