Collaborative Augmented Reality Tracking, Interaction, and Display for Mobile Game

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1. Introduction

1.1 Background

Although Augmented Reality (AR) technology has existed for decades, it is by far one of the hottest tech topics in 2016. AR is hanging in there and gaining traction in flashy ways. AR is a technology which allows computer-generated virtual imagery to overlay physical objects exactly in real time. Unlike virtual reality (VR), where the user is completely immersed in a virtual environment, AR allows the user to interact with the virtual images using real objects in a seamless way. Azuma [1] provides a commonly accepted definition of AR as a technology which (1) combines real and virtual imagery, (2) is interactive in real time, and (3) registers the virtual imagery with the real world. As such there are many possible domains that could benefit from the use of AR technology such as engineering, entertainment and education.

Many early users who experienced AR technology mainly through the games, so game maybe the most interesting and efficiency channel to popularize the AR to the public. One example is Pokémon GO, which has been a huge phenomenon with gamers all over the world reliving their childhood through the AR game. However, as an AR product, Pokémon Go just adapts location-based service (LBS) and basic vision-based tracking techniques in AR. Since co-located collaboration Augmented Reality can blend the physical and virtual worlds so that real objects can be used to interact with three-dimensional digital content and increase shared understanding, which significantly enhances face-to-face collaboration. This is the technology that current mobile game could apply to improve the AR game development furtherly.

This research focuses on the field of how collaborative AR application could be used in the mobile game industry based on previous collaborative AR studies.

1.2 Prior Work

Although single user AR applications were studied for decades, it was not until the mid-nineties that the first collaborative AR applications were developed. The Studiersube [2] and Shared Space projects [3] showed that AR could support remote and co-located activities in ways that would otherwise be impossible. Since that time there have been some excellent examples of collaborative AR interfaces presented.

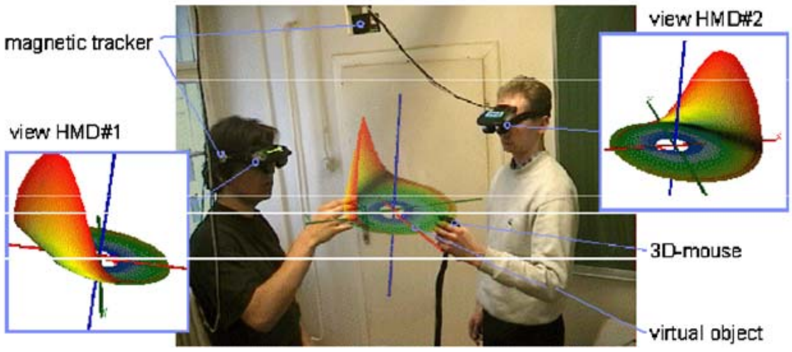

Figure 1: One of the first interfaces to show the potential of AR for face-to-face collaboration (Studierstube project) [2].

For co-located collaboration, AR can be used to enhance a shared physical workspace and create an interface for 3D computer supported cooperate work (CSCW) [5]. In testing with the Shared Space application, users found the interface very intuitive and conducive to real world collaboration, because unlike other interfaces, the groupware support can be kept simple and mostly left to social protocols [5].

The StudierStube researchers identify five key features of collaborative AR environments:

1. Virtuality: Objects that don't exist in the real world can be viewed and examined.
2. Augmentation: Real objects can be augmented by virtual annotations.
3. Cooperation: Multiple users can see each other and cooperate in a natural way.
4. Independence: Each user controls his independent viewpoint.
5. Individuality: Displayed data can be different for each viewer.

The value of these characteristics is shown by several user studies that compare collaborative AR interfaces to other technologies. Kiyokawa et. al. [8] have conducted an experiment to compare gaze and gesture awareness when the same task is performed in an AR interface and an immersive virtual environment. Similarly, collaborative AR interfaces can produce communication behaviors that are more similar to unmediated face-to-face collaboration that to screen based collaboration.

Augmented Reality techniques can be used to develop fundamentally different interfaces for face-to-face and remote collaboration [8]. This is because AR provides:

- Seamless interaction between real and virtual environments
- The ability to enhance reality
- The presence of spatial cues for face-to-face and remote collaboration
- Support of a tangible interface metaphor
- The ability to transition smoothly between reality and virtuality

Another important milestone for the combination of VR and Scientific Visualisation was the development of the virtual wind tunnel at NASA-AMES by Steve Bryson. Using a BOOM device and a data Giove as an interaction tool, scientists were able to see and interact with true stereoscopic images of a flow field visualization. A follow-up project, the distributed wind tunnel [10] was developed, which divided computation in a distributed system for better efficiency and allowed multiple users to experience the simulation at the same time. Collaboration in a distributed virtual environment, not necessarily limited to scientific visualization has been proposed by Fahlen et. al. [10].

One of the most useful reference projects is the collaborative ARvita [7] (Figure 2) developed for the engineering education and practice. ARvita provides a fundamental framework of the collaborate AR software structure (Figure 3).

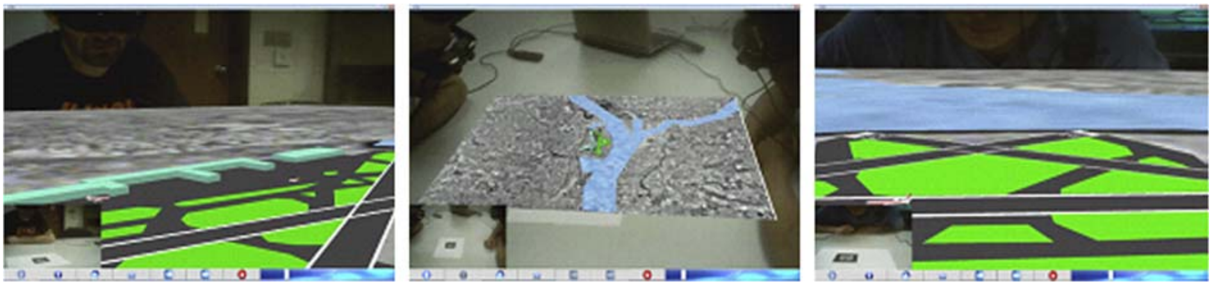

Figure 2: Two users are observing the animation lying on the table through the ARvita [7].

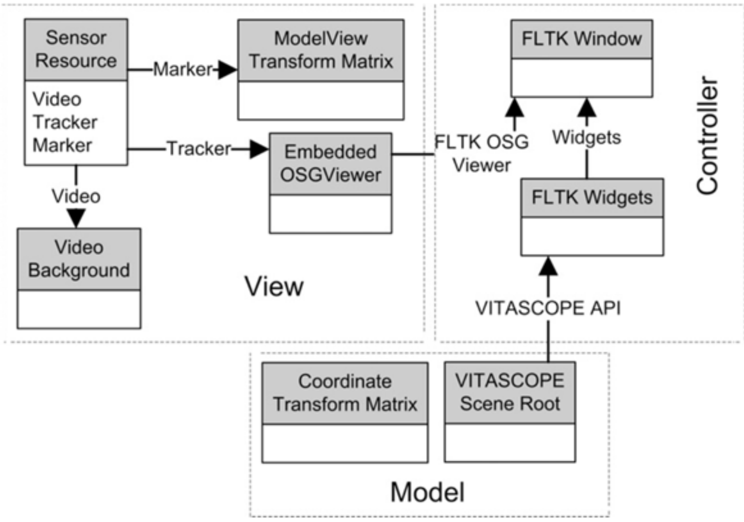

Figure 3: The software architecture of ARVita conforms to the model-view-controller pattern. The arrow indicates a 'belongs to' relationship [7].

In the field of games, aimed to explore the different perception of situational awareness and presence in a physical and an AR environment, Dragos Datcu [4] employed a collaborative game whose goal is to jointly build a tower with virtual blocks. The study further identifies necessary future research concerning the perception of presence and awareness in AR.

1.2.1 Tracking

Tracking is acknowledged as the fundamental challenge in the AR community. Technically, the position of objects is determined by a dedicated tracking sensor, and a representation of the physical model is rendered in background color to resolve the occlusion problem among physical and virtual objects. Without a highly accurate estimation of the position and orientation of the camera, it is impossible to render a spatially correct overlay of graphical information. Jan Fischer [19] presented a hybrid tracking scheme for medical augmented reality based on a certified medical tracking system. Moreover, The fiducial marker tracking method and the natural marker tracking method are both options for the tabletop augmented reality software ARvita, where the natural marker offers the advantage of not depending on special predefined visual features.

Naturally, first inroads in tracking on mobile devices themselves focused into fiducial marker tracking. Tracking fiducial markers is a common strategy to robustness, and computational efficiency achieves simultaneously. While the visual clutter resulting from the fiducial markers is undesirable, the deployment of black-and-white printed markers is inexpensive and quicker than accurate off-line surveying of the natural environment. By encoding unique identifiers in the marker, a large number of unique locations or objects can be tagged efficiently. These fundamental advantages have led to a proliferation of marker-based pose tracking despite significant advances in pose tracking from natural features [27].

Nevertheless, only a few solutions for mobile phones have been reported in the literature. In 2003 Wagner et. al. ported ARToolKit to Windows CE and thus created the first self-contained AR application [26] on an off-the-shelf embedded device. This port later evolved into the ARToolKitPlus tracking library [27] (a successor to the popular ARToolKit pose tracking library). In 2005 Henrysson [28] created a Symbian port of ARToolKit, partially based on the ARToolKitPlus source code. In 2004 Möhring [29] created a tracking solution for mobile phones that tracks color-coded 3D marker shapes. Around the same time, Rohs created the VisualCodes system for smartphones [30]. Both techniques provide only simple tracking of 2D position on the screen, 1D rotation and a very coarse distance measure. Similarly, TinyMotion [6] tracks in real-time using optical flow but does not deliver any kind of pose estimation. Takacs et al. recently implemented the SURF algorithm for mobile phones [17]. They do not target real-time 6 degrees of freedom (DOF) pose estimation, but maximum detection quality. Hence, their approach is two orders of magnitude slower than the work presented here.

New opportunities in mobile phone interaction have emerged with the integration of cameras into the phones. By analyzing the video stream captured by the camera, using simple image processing on the phone, it is possible to estimate the movement of the device. This can be used in some ways such as providing a 6 DOF interface or recognizing objects to make the phone context aware. Anders Henrysson et. al. [16] provided the first example of using phone motion to manipulate graphical objects in 6 DOF to create virtual scenes. By analyzing the video stream captured by the camera, using simple image processing on the phone, it is possible to estimate the movement of the device. This can be used in several ways such as providing a 6 DOF interface or recognizing objects to make the phone context aware.

Many mobile systems already exist that offer Location Based Services (LBS) with a variety of services (from only visualization and navigation to update of information) for different applications. All of them, however, rely on GPS positioning. How to use LBS as a tracking method for the collaborative augmented reality is a new field need to be focused on. Zlatanova [18] presented New ideas for users tracking for LBS, which are motivated by and linked to the OpenGIS Consortium (OGC) specifications for Location Services and related OGC specifications for Web Services in an outdoor AR reality system.

Point-based approaches use interest point detectors and matching schemes to associate 2D locations in the video image with 3D locations. The location invariance afforded by interest point detectors is attractive for localization without prior knowledge and wide-base line matching. However, computation of descriptors that are invariant across large view changes is usually expensive. Tracking from natural features is a complex problem and usually, demands high computational power. It is, therefore, difficult to use natural feature tracking in mobile applications of Augmented Reality (AR), which must run with limited computational resources, such as on Tablet PCs. Two techniques (SIFT and Ferns) for natural feature tracking in real-time on mobile phones was presented by Daniel Wagner et. al. [20]. They achieved interactive frame rates of up to 20Hz for natural feature tracking from textured planar targets on current-generation phones.

Kyungyeon Moon et. al. [9] selected a pragmatic and inexpensive solution with a Creative Interactive Gesture Camera that detects the nearest hand in front of the camera. They found that interacting augmented objects with human hands in the system strengthened the basis of how to control games. Their method is more powerful than the conventional immovable-video game using cumbersome equipment and mobile game. By combining several tracking technologies, it is possible to deliver robust and accurate live video augmentation via a tablet PC without the use of artificial fiducials in the scene [13].

1.2.2 AR Mobile Games

There are several examples of camera-based interaction with mobile devices. One of the best known is “Marble Revolution” [16]. In the “Marble Revolution” game the player can steer a marble through a maze by moving the phone and using motion flow techniques. Neither have 3D registration of the graphics overlaid on the real world. The virtual soccer game of KickReal [16] allows people to see a virtual ball superimposed over video of the real world and kick it with their feet, but there is no 3D object manipulation. Klein set a game on a tablet PC [13]. The movement of the character is controlled with a stylus. The user can also toss plastic tokens in the game area to create effects.

A first step to towards interaction with 3D data using an AR-enabled mobile phone was two players sitting face-to-face played tennis using the mobile phones as rackets [28]. The interaction is limited to the collision between the device and a virtual ball being simulated in the marker space between the players. Tennis was chosen because it could be played in either a competitive or cooperative fashion, awareness of the other player is helpful, it requires only simple graphics, and it is a game that most people are familiar with.

There are several examples of 3D graphics applications on mobile phones. The vast majority are games that provide joystick type control of vehicles and objects in 3D environments. For the PDA there is also “3D Blockout” [16], which is a falling block game similar to Tetris. Since the block is falling, there is only need for 5 DOF. The interface consists of a menu bar to the right of the screen. The user can move and rotate the block while it is falling to the floor.

1.2.3 Mobile CAR applications

Any collaborative augmented reality (CAR) application needs a device equipped with an on-board camera, CPU, and display. The most common devices used for CAR applications are Tablet PCs or mobile phones. Mobile phones are an ideal platform for AR thanks to the integrated camera that allows high-quality optical tracking. In addition to integrated cameras, the current generation of phones have full-colour displays, fast processors and even dedicated 3D graphics chips [16]. Moreover, mobile phones are more wearable devices than tablet PCs and, therefore, they are more suitable for many CAR applications designed for daily life common situations. Mobile augmented reality systems such as the Touring Machine [22], and the applications developed within the OCAR project [23] provide information about the mobile environment by superimposing text into the user’s view.

The Augmented Reality marker tracking process in CAR applications can be split into four stages: the first stage is denoted as image acquisition stage, and it consists of obtaining an image from the camera’s flow. In the second stage, markers are detected from the image obtained before. Using the position of this markers, the third stage consists of drawing a 3D object on the image. Finally, in the fourth phase, this information (for example, the position(s) of the mark(s)) is sent to the other application nodes through some broadcast communication. The first three phases are similar to any AR application [20], but the last one can be performed by using different technologies like Wi-Fi, 3G or Bluetooth. Although there are some classic CAR applications that uses Bluetooth, usually Wi-Fi or 3G technologies are used, since the use of Bluetooth severely limits the spatial range of transmission.

One approach to overcome the resource constraints of mobile devices is to outsource tracking to PCs connected via a wireless connection. All of these approaches suffer from low performance due to restricted bandwidth as well as the imposed infrastructure dependency, which limits scalability in the number of client devices. The AR-PDA project [21] used digital image streaming from and to an application server, outsourcing all processing tasks of the AR application reducing the client device to a pure display plus camera.

1.2.4 Collaborative Interaction and support

Natural communication can be supported in the virtual reality environment with the combination of aura and distributed services [11]. In a distributed virtual reality environment, where the different participants are represented as stylized 3D icons, it is possible to implement a flexible and powerful proximity/presence variant of in a room/context/space metaphor. In collaborative AR systems, multiple users share at least one common place within the environment. The users can collaborate in two ways: either face-to-face or remote or in a combination of both ways. Each user has his or her own view on the private and shared objects of the augmented space. Holger and Michael [24] relayed on tangible interaction techniques based on props to establish the “Magic Meeting” collaborative interaction system.

Software researchers have developed several shared virtual environments (SVEs) to support flexible spatial collaboration [25], which include multiple mental models as well as multiple visual viewpoints, allow virtual reality to be applied in the earlier, more creative, phases of the design process, rather than just as a walkthrough of the final design. These provide adaptable control over the location and scale of their coordinates. This flexibility helps coordinate different activities in 3D collaborative design. However, due to poor information about remote participants and communication delays, each participant has significant difficulty recognizing what other partners are doing.

Conversely, researchers have recently made several attempts to construct more informative and natural collaborative workspaces [14] for co-located collaboration. Such workspaces permit face-to-face interaction and still support real-time 3D computer graphics from each participant’s viewpoint. By using optical see-through head-mounted displays (STHMDs) in a setup referred to as a shared augmented environment (SAE), participants can show virtual objects at any location. Kiyokawa and Yokoya [8] discovered that designers should use the same coordinates in their workspaces to enhance collaboration efficiency so that they can communicate with each other using their proprioception. Though there have been many shared workspaces for collaborative 3D design, few of them considered these findings.

2. Problem Definition

While it may be some time before AR technology becomes mature, there are many issues, both technical and social, that should be pursued in the meantime. One of the important aspects is creating appropriate interaction techniques for collaborative AR applications that allow end users to interact with virtual content in an intuitive way. Most existing augmented applications are single user setups or do not exploit the multi-user character of their systems [2]. Exceptions are the CAVE- System [12], the Responsive Workbench [14] and the Shared Space [3] which are examples of multi-user augmented reality systems. More recently researchers have begun exploring how mobile AR platforms can be used to enhance face-to-face collaboration. In this case, how to combine these research with the mobile game development needs to be probed furtherly, after all, there are some of the limitations of current collaborative interfaces.

There are shortcomings with most current collaborative technology, especially when used to interact with spatial content [5]. In face-to-face collaboration, people use speech, gesture, gaze and non-verbal cues to attempt to communicate in the clearest possible fashion. However, in many cases, the surrounding real world or real objects play a vital role, particularly in design and spatial collaboration tasks. Besides, none of the previous methods can combine the LBS service and Tracking method together in a single CAR.

To overcome these weaknesses, the collaborative AR application in mobile game should have the following characteristics:

2.1 Quality of tracking

Mobile phones are very inexpensive, attractive targets for AR, but have even more limited performance than the aforementioned Tablet PCs. Phones are embedded systems with severe limitations in both the computational facilities (low throughput, no floating point support) and memory bandwidth (limited storage, slow memory, tiny caches). Therefore, natural feature tracking on phones has largely been considered prohibitive and has not been successfully demonstrated to date [20].

Overlaying virtual objects in the real world can potentially create a good deal of confusion if they interfere with the user's view of the real world and each other. Although the approximate tracking can be extremely useful, there are many applications that require precise tracking. Better outdoors position tracking can be addressed through real-time kinematic GPS systems, which can achieve centimetre-level accuracy. Camer-based approaches are a promising way to address the problem. While GPS does not present any practical range restrictions for our work, it does not work if an insufficient number of satellites are directly visible. GPS satellite signals are weak and are blocked by intervening buildings and even foliage [22].

2.2 Independence

Investigated models are, in general, shared among users, in the sense of visibility, this means that all participants can see the same coherent model, consistent in its state over time. By presenting the visual sensation directly to each user with the cellphone screen (camera), the displayed data set can also be different for each viewer, as required by the application's needs and the individual's choice. Unlike the CAVE [12] and the Workbench [14], the control is not limited to a guiding person, while other players act as passive observers. Each player has the option to move freely and independently of the other players. In particular, each player may freely choose a viewpoint with stereoscopy for correct depth perception. But not only is observation independent, but interaction can also be performed on a personal base. How to keep human communication channels open, thus improving the quality of collaboration is a big issue for the collaborative AR games.

2.3 Mobile Related Problems

In recent years mobile providers have started providing navigation and other cell-based services. The popularity of such services has also increased with the introduction of new connectivity technologies such as WiFi, WiMax, and UMTS. However, most available devices and systems share these problems [21]:

- Compared to having a real assistant, many tasks are very cumbersome and time- consuming, due to the limited user interface provided by the devices.
- The range of applications and services are limited, due to limits of the existing devices and displays used in them.
- Existing devices are difficult to use if you want to use your hands for another task or if you need them free.
- Users do not benefit appropriately from available location information, as it is mostly not integrated with the organizer functionality.

The gap between the physical world surrounding the user and the virtual world is narrowed by offering a natural way of “picking up” data in everyday situations [30]. Information becomes collocated with physical entities and is thus situated and grounded in the real-world context.

Most AR systems work with small manually entered data sets. Therefore, only a little research has been done in the field of databases for mobile AR applications or in the use of environment models and the management of such systems [21]. However, as the trend towards location-aware services and assistants grows there is a need for research into storing location-based information. The problem with many of the environment models created so far is that they often only contain geometric and physical data, so data about meanings etc. has to be added manually using keywords.

2.4 AR Games

The rapid development of AR technologies has raised profound interests in the design of AR games, but the existing games have not provided realistically felt game environments because the way to play games remains the same when the platform is changed. In addition, studies in this field did not fully utilize AR technologies, so that inherent characteristics of AR game do not impact user experience and draw attention explicitly on design concepts [9].

On players' demand, game console makers have made an effort to mix the reality and virtual reality. So Nintendo 'Wii', Sony 'Move' and Microsoft 'Kinect' are developed. Developed AR games were based on motion recognition technologies. However, there are some problems. First, these devices can recognize big motions like dancing or boxing. Thus, in small residential space or public places such as apartment and café, people have trouble with using it. Also, people who are wearing heavy clothes or skirts that hide body parts cannot use it because the devices cannot recognize gamers. Therefore, small motion or elaborate control has difficulty handling the system embedded in these devices. The third problem is game controllers. Existing system needs to have traditional game controllers, which means that if people sit far from game devices, they cannot play with it. Also, if users want to play tennis or guitar game, they should buy tennis racket controller or guitar controller that is suitable for specific device [9]. Finally, gamers cannot interact with game objects in 3D space. The game objects remain to be still locked in the monitor.

3. Aims, Relevance and Significance of Project

3.1 Aims

The main objectives of the paper are as follows:

1. Investigate the trend of collaborative AR technologies application, AR games and how to combine them together as well as the influence of mobile phone games on collaboration and social interaction of physically co-located players, instead of focusing on the collaborative AR itself.
2. Building system that users would collaboratively interact with virtual objects in 3D space using mobile phones. For testing effectiveness and usefulness of our system, which estimates how comfortable users use and how easy users play, we should measure what users feel by qualitative and quantitative methods.
3. Evaluate the system performances, user interface performances and the usability of mobile games for collaborative AR. Then, we analyze the result and adjust the system for maximizing user satisfaction and immersion.

3.2 Relevance and Significance

The research in this proposal contains contributions that are relevant and significant to both the collaborative AR and mobile game development. This section of the proposal aims to elaborate upon the specific contributions of developing a new position tracking technique based on the location-based service and cell phone camera, and subsequently vastly increasing the accuracy of data which multiple users can share with through a collaborative AR mobile game.

4. Research Plan and Methodology

The main method used in this research is to review previously published conference papers and other related material. In the future paper, I will provide a comprehensive review of analyzing various tracking methods, interaction techniques and user interfaces in AR, which are very important areas for future research. Then, I will present several research topics presented on the AR and games' combination. Next, I focus specifically on the important topics of AR tracking, interaction, and display technology, discussing research developments, the main problems explored in the field and current and future AR game research directions. After the implementation, there is also an evaluation procedure. The evaluation focused on both the functionality of the system and the interaction methods used. The second part of the evaluation will be the completion of a questionnaire. The subjects will be asked to rate individual aspects of the user interface as well as the sustainability of the overall approach.

5. Project Plan

The following table 2, highlights a brief and approximate overview of the proposed research. However, it should be noted that the time allocated is subject to change according to unforeseen difficulties or extenuating circumstances.

	2016 Period 2					2017 Peroid 1					
Schedule (per month)	8	9	10	11	12	1	2	3	4	5	6
literature review											
1st Seminar											
establish develop environment											
develop foundamental functions											
research/program											
test											
write 1st draft thesis											
final thesis											
final seminar											

Table 2: Proposal Research and Writing Timetable

Reference

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