CheckMate: Exploring a Tangible Augmented Reality Interface for Remote Interaction

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Abstract

The digitalized world comes with increasing Internet capabilities, allowing to connect persons over distance easier than ever before. Video conferencing and similar online applications create great benefits bringing people who physically cannot spend as much time as they want virtually together. However, such remote experiences can also tend to lose the feeling of traditional experiences. People lack direct visual presence and no haptic feedback is available.
In this paper, we tackle this problem by introducing our system called CheckMate. We combine Augmented Reality and capacitive 3D printed objects that can be sensed on an interactive surface to enable remote interaction while providing the same tangible experience as in co-located scenarios. As a proof-of-concept, we implemented a sample application based on the traditional chess game.

Author Keywords

Tangibles; 3D Fabrication; Augmented Reality; Mixed Reality; Tabletops; Chess; Remote Collaboration

ACM Classification Keywords

H.5.2 [User Interfaces]: Interaction styles; H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

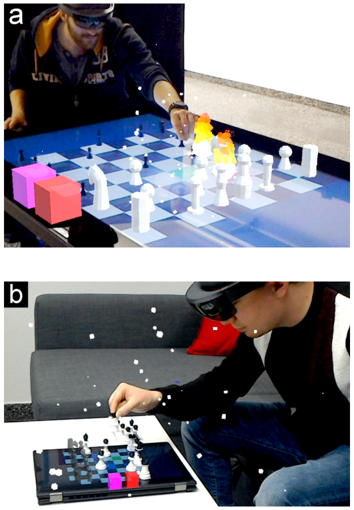

Figure 1: Mixed Reality capture view through Hololens showing two players using our proof-of-concept chess application. (a) The first player is using a large tabletop, while (b) a second player is using a touch-enabled notebook. Solid pieces are 3D printed while translucent pieces are augmented.

Introduction

In the age of digitalization and broad Internet coverage, connecting multiple remote persons with each other becomes easier and commonplace. Video conferencing and entertainment applications allow users to communicate and interact over a distance. Hence, persons can virtually share time together, even if they are not co-located, and the world gets more connected.

However, creating such remote experiences may result in a loss of closeness. As a solution, the community provides a large body of research establishing more natural user experiences that resemble co-located communication by bridging the gap through modern technologies. For instance, Augmented Reality (AR) allows users to have a digital representation of distant physical worlds [2]. This enables to seamlessly blend in virtual contents into the own local environment [12].

In cooperative entertainment applications, AR is often used to increase immersiveness [11]. For instance, Chen et al. [4] created a Chinese version of a chess game in AR that can be played over distance using mobile phones. However, while being highly interesting, there is no tangible sensation involved and users only interact virtually.

Similar to Brave et al. [3], we think that tangible objects affected by users feel not distant, but connected to where you are. The authors, therefore, presented an early tangible interface for remote collaboration that provides haptic interpersonal communication over a distance. Further, tangibles allow users to have physical-embodied user interfaces to interact with the digital world [6, 8, 9]. As an example, Pan et al. [13] used tangibles to improve communication of long distance relationships through an interactive puzzle application that can be played by two remote located persons. Other examples, e.g. in gaming, use AR with movable markers as manipulatable tangibles to place virtual game objects or utilize them as input devices [5, 15].

While this is great towards tangible user interfaces (TUI) in AR scenarios and allows users to physically interact with their environment, we have the impression that those tangible objects are often too abstract. Hence, they do not resemble their physical counterpart. To tackle this issue, tangibles close to their physical appearance can be created through 3D fabrication and enable rapid and low-cost interactive objects [14].

In this paper, we present CheckMate, a tangible AR interface for remote interaction. Concluding from a lack of research done on linking those strands into a single interface, we combine modern AR technologies with 3D printed tangibles sensed on touch-enabled surfaces in remote scenarios. We envision a connecting user experience that gives distributed access to shared physical digital environments to benefit from both, local haptic experiences and dynamic interactivity through virtual representations and supporting animations. As a proof-of-concept, we introduce an application based on the traditional chess game (see Figure 1). For this, we use custom 3D printed chess pieces as a tangible user interface on an interactive game board displayed on digital surfaces. To visualize the counterpart's moves and for supporting additional virtual animations, we use head-mounted displays (HMD).

Concept

In the following, we introduce the concept of our interface. We envision a combination of the benefits of tangible interfaces on interactive surfaces with the current advantages of AR. In linking those strands, we aim to be highly flexible and provide an immersive, though, natural experience with the goal to enrich user experiences over a distance.

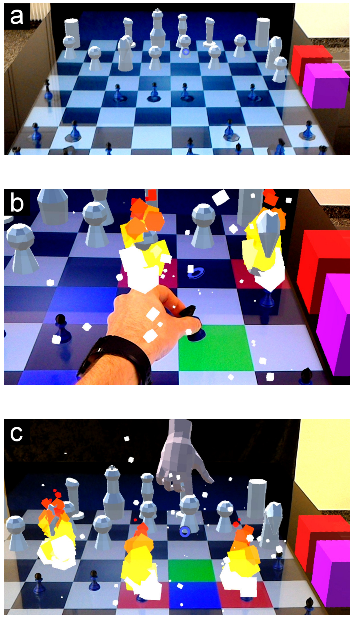

Figure 2: Mixed Reality capture view through HoloLens. (a) Full game board on a tabletop, (b) a player moving a chess-piece, and (c) an opponent visualized with an animated hand moving a piece. Green tiles highlight the current position, blue possible moves, and red tiles together with a flame animation indicate attacks.

Tangibles are a very natural form of user input and, thus, make interaction less artificial. Detecting a touched physical object, we can use it as a direct tangible user interface to interact with digital contents. We identify active objects, and how they are manipulated or relocated on the surface. Further, we communicate that information to a remotely located party to synchronize both spaces. To create our tangible objects, we use 3D fabrication that allows users to have individual and personalized interfaces. By using conductive materials, we are able to easily detect them on any touch-enabled capacitive surface. Further, users benefit from a low-cost production and rapid prototyping.

Taking another step towards an improved user experience, we add a virtual dimension to the interactive surface with the use of HMDs, similar to [1, 10]. Most importantly, we can augment interaction steps of a remotely located user to a second user's view. For example, if the distant user moves a tangible, it is visualized as animation on the other's HMD. This also allows for auxiliary features, such as highlighting important situations, making them more immersive. To address current AR devices' limitations in terms of opacity or lighting conditions, we reduce the amount of augmented content through a fixed display as surface and by using physical tangible objects for the local user. In Figure 3, we show a high-level overview of our concept with two exemplary users over a distance.

Tangible Chess Game

As a proof-of-concept for our proposed design, we demonstrate our tangible AR interface for remote interaction with an application based on the game chess. It combines interactive surfaces with 3D printed tangible chess pieces and the power of current AR technology. It can be played by two remote located users on any touch-enabled device running our software, e.g. a tablet or tabletop (cf. Figure 1).

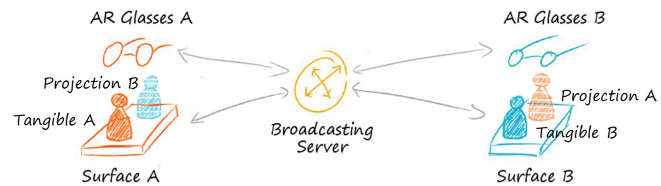

Figure 3: Simplified concept of our interface. Each user has a separate touch-enabled surface, HMD and 3D printed tangibles. Orange indicates user A, blue is user B, and yellow is a broadcasting server. The transparent objects represent digital visualizations of their physical counterpart.

We equip all players with HMDs, and after starting our application, the players have to initially calibrate the digital game board to the interactive surface. Afterwards, the players need to connect to the broadcasting server. Once both are connected, the game starts with the first player.

In theory, players are physically not limited in executing their moves. However, our application keeps track of every piece on the board and only allows valid moves according to the classic chess rules. Moreover, we added a feature that colors the board tiles with regards to possible moves. If a player picks up a piece, the tile beneath turns green and every granted target tile is highlighted in blue. If a player can attack an opponent's piece, the tile turns red and a fire animation simulates the ignition of the piece (cf. Figure 2). As auxiliary and positive side-effect, highlighting tiles provides a tutorial for unexperienced players supporting them to identify possible moves.

The remote player sees a selected and picked up chess piece floating above the corresponding tile together with an animated hand and white particle effects (cf. Figure 2c). Once a player made their move, the distant player will see the piece animating towards the target tile. If the player successfully attacks an opponent's piece, an explosion ani-

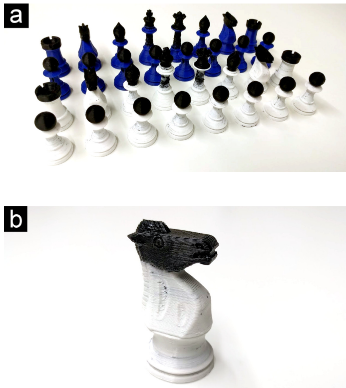

Figure 4: (a) Two sets of 3D printed chess pieces, and (b) a single knight. White parts are made of regular plastic, black parts are made of conductive material.

mation is shown for both parties. The turn then ends and the attacked player has to remove the lost piece from the surface before continuing with their own move.

Once a player wins, loses or both agree on draw according to the traditional chess rules, the game is over.

Implementation

We use 3D printed tangible objects that are recognizable on standard touch-enabled surfaces through conductive materials embedded inside. The fabrication process is based on Capricate, a 3D fabrication pipeline for touch-enabled tangibles [7, 14]. We printed two sets of 16 capacitive chess pieces each using the dual extrusion printer BCN3D Sigma that allows printing conductive and insulating materials simultaneously (see Figure 4a). The conductive electrodes consist of carbon-doped Proto-pasta Conductive PLA. For insulating parts, blue and white Verbatim PLA was used. By using conductive materials, objects are recognized as individual touches as soon as they are touched by a person. In Figure 4b, we show a closeup of a knight piece fabricated with white insulating and black conductive material.

Our application is implemented in Unity allowing us cross-platform compatibility on capacitive touch-enabled devices. Therefore, we decided to use a touch-enabled convertible for one player and a custom-built tabletop for a second player. The tabletop features a large 65-inch ultra HD screen with a hardened glass mounted on top. A large capacitive touch matrix is attached to the glass' bottom side. Both, the touch-sensor and screen, are connected to a workstation located beneath.

For visualizing the remote player's interactions and animations, we use two Microsoft HoloLens HMDs which have robust environment tracking. In addition, we use Vuforia[1] for an initial tracking of the surface to accurately place and scale the chess board. For the communication between players, we implemented a broadcasting server that redirects every interaction to both parties and keeps the HMDs synchronized with the logic running on the digital surface.

Early User Feedback

To gain insights of our concepts in a real-world scenario, we conducted an informal pre-study. Therefore, we deployed our prototype application in our lab located in Germany and in a partner lab based in South Korea with a total of 7 participants (G1-G3 located in Germany, K1-K4 located in South Korea). We decided to use a tabletop on the German side and a touch-enabled convertible on the Korean side (Lenovo Yoga 460) to identify how the participants interact with different devices. While both used a full set of 3D printed chess pieces, the pieces differed in size to fit the underlying surfaces. On both sides, the participants wore a HoloLens and all were connected to a server located in Germany.

During this exploratory study, we gathered the participants' comments and identified valuable feedback. The participants agreed that the combination of TUIs, 3D fabrication, interactive surfaces and AR in form of a chess game feels close to playing traditional chess ("It is great that my chess pieces are real“, K2). In addition, the participants appreciated that they can easily create own chess pieces that not only fit different screen sizes but can also have individual shapes ("I could create figures (pieces) that look like my colleagues“, G3).

The participants told that they feel strongly connected to their remote counterpart since they see every activity in real-time through their HMD. However, some were missing

[1] http://www.vuforia.com, last accessed 02/22/18

a virtual representation of the opposite user, such as ”having a video feed to actually see the other player“ (K1). As an alternative, K4 further told that it ”could be interesting to indicate emotions, such as anger or laughing“.

Conclusion and Future Work

In this paper, we presented CheckMate, a tangible Augmented Reality interface for remote interaction. We introduced a concept linking those strands and demonstrated them in proof-of-concept based on the traditional chess game. We combined Augmented Reality with 3D printed conductive objects sensed on touch-enabled surfaces to overcome a lack of visual presence and enabled tangible user interaction.

As future work, we want to conduct a larger user study to evaluate how remote experiences can be improved through our system and how users effectively cooperate in shared physical digital environments. Therefore, we plan to implement a broader spectrum of applications not limited to gaming, such as city planning or meeting scenarios. In addition, we plan to add a video feed to enhance the social connectivity between the users.

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