PlayTogether: Playing Games across Multiple Interactive Tabletops

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ABSTRACT
Playing games together can be surprisingly difficult – people have limited free time and are tending to live live farther away from friends and family. We introduce PlayTogether, a system that lets people play typical (and as-yet-unimagined) board games together even when they are far away from each other. We have adapted the PlayAnywhere tabletop system so that multiple remotely located people can engage in game-play. PlayTogether enhances the play experience by exchanging carefully composited video of remote players' hands and real game pieces. The video that is transmitted mimics a player's viewpoint via careful camera location. Because PlayTogether's camera senses in the infrared, it is easy to distinguish between objects in the camera's view and projected imagery. These capabilities create an interesting and engaging way to blend the virtual and real in multi-player gaming.

Categories and Subject Descriptors
H.5.2 [Information Interfaces and Presentation]: User Interfaces—*Input devices and strategies*
H.5.3 Groups and organizational interfaces*: Computer supported cooperative work.*

General Terms: Algorithms, Design, Human Factors, Mixed presence groupware

1. INTRODUCTION
People who want to play games together can't always be in the same place. We are developing an interactive tabletop system to allow multiple people to play typical (and not-so-typical) board games from multiple remote locations. Our system, PlayTogether, uses off-the-shelf projectors and cameras and turns nearly any flat surface into an augmented play area.

There is an emerging field of real-world surface based applications that are enabled by novel sensing and projection techniques. This includes systems that use cameras and video projectors, flat-panel displays with embedded sensors, and tangible objects with active or passive tags. Typically these systems have focused on multiple co-located users on single device. In this paper we describe PlayTogether, a system that allows multiple non-co-located players to interact via multiple interactive tabletop systems. Using our system we have explored different degrees of sensing and sharing. This can best be understood in the context of a board-game, such as checkers or chess.

Figure 1. Playing checkers and chess with a remote player using PlayTogether. The remote player's game pieces and hands are projected, superimposed on the local player's real board and pieces. In both cases, hands and pieces on the far side of the table are projected. Hands and pieces on the near side, and game board, are real.

PlayTogether focuses on enabling game playing between people at a distance through manipulation of real game pieces on real game boards. Camera-based sensing is used to enable synchronized sharing with appropriate compositing. Because of our use of video, the representation of players and game pieces is much more realistic than if we used synthetic virtual objects. This helps the player by providing rich non-verbal cues, unique player identification, and seamless gestures.

When an environment effectively supports play or pleasurable work ("flow" [4]) participants engage in graceful choreography

[15]. Players stop thinking about how they are moving their own hands and instead concentrate on the game and other players. Our main goal with PlayTogether is to give players an unconscious sense of immediacy so that they can focus on the game and not on the mechanics of distant collaboration. To do this we are developing a tightly-coupled real-time system that does not tether players to input devices such as mice or other hand-mounted sensors. In essence there is no user interface: players pick up and move their own physical games pieces, gesture to the other players' pieces, and immerse themselves in the game. Players don't have to identify themselves, pick a cursor color, or select "rules of interaction." They just sit down and play.

2. RELATED WORK

PlayTogether is inspired by the large body of work on multi-user interaction both in shared physical spaces and at a distance [3] [9][10]. We are especially interested in systems that give a high-fidelity impression of remote users.

ClearBoard [8] maintained remote awareness by compositing video of a remote participant behind a shared virtual workspace. Related systems use various video techniques to subtract out extraneous portions of the video feeds [13] [1]. Each focuses on collaboration with purely virtual content such as virtual whiteboards or PowerPoint slides.

There is much recent work on the use of interactive surfaces to support real-time collaboration [2] [8] [11] [14]. This work has generally focused on: 1) merging real with the virtual, 2) facilitating interaction between people who are collocated and sharing one active work-space, and 3) enabling people at a distance to collaborate in shared virtual environments.

For example, in VideoArms [15], video representations of remote users' arms are shown alongside virtual content within the context of *Mixed Presence Groupware* (MPG). We resonate with and take advantage of the concepts of virtual embodiments as discussed in this work. VideoArms' authors propose four principles for virtual remote embodiments. These principles are meant to give a sense of presence, encourage decorum, and enable rich interaction between remote participants. PlayTogether differs from VideoArms in the manner which local and remote scenes are sensed, processed, and combined.

3. PLAYTOGETHER

PlayTogether builds upon the infrastructure and technological innovations of the PlayAnywhere interactive tabletop system [16]. PlayAnywhere combines a commercial front-projector with a co-located camera and infrared (IR) emitter that works on most any flat surface. PlayAnywhere focuses on the technology behind compact and reliable table-top sensing, and includes techniques for "green-screen" keying, real-time tracking of rectangular objects, rectification, visual tag recognition, optical-flow based motion tracking, finger tracking, and shadow analysis based touch recognition.

As with PlayAnywhere, we illuminate the scene with an IR source and block all but IR light to the camera with an IR pass filter. The projected image is thus easily removed from the scene, thus avoiding the dynamic range constraints acknowledged in the VideoArms system. We currently use a short-throw (NEC WT600 DLP) projector.

The current PlayTogether configuration employs two PlayAnywhere devices, each exchanging grayscale video over a

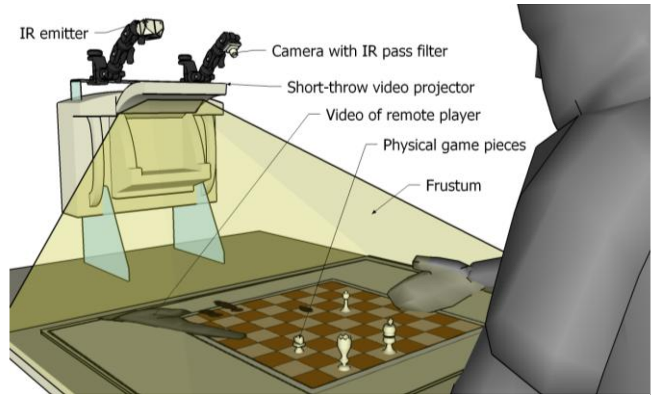

Figure 2. The main elements of the PlayTogether system are a camera, IR emitter, and projector.

local gigabit network. This video is projected onto the local desktop: the remote user's hands and game pieces are visible, superimposed on the local user's tabletop. In the case of two-player board games, it is desirable to rotate the projected video 180 degrees so that the remote user's hands and pieces appear on the opposite side of the table, as if the remote user were sitting across the local user.

Rotating the incoming video has other consequences for viewing. In the PlayAnywhere configuration the camera is mounted onto the projector such that it mimics the general eye position of a player seated at the table. It was only when we networked multiple PlayAnywere systems together that we noticed that objects in the remote video are automatically shown with the correct perspective foreshortening for the local user seated at the table. See Figure 1 for an example of this effect, and Figure 3 for an illustration.

While PlayTogether's projection can include a graphical depiction of the game board, we have explored superimposing video onto real game boards on the tabletop. A real game board may be moved on the table, causing the remote (projected) game pieces to no longer appear at the correct location on the local game board. We address this by tracking the position and orientation of the local game board, and transmitting this information with the video. This information is then used to precisely warp the video onto the remote user's tabletop, such that the remote and local game boards precisely overlap. Aside from shifting shadows and perspective, players are not even aware of remote players adjusting their game boards. PlayAnywhere's board tracking algorithm requires some contrast between the board and the tabletop.

One drawback of the current configuration is the introduction of

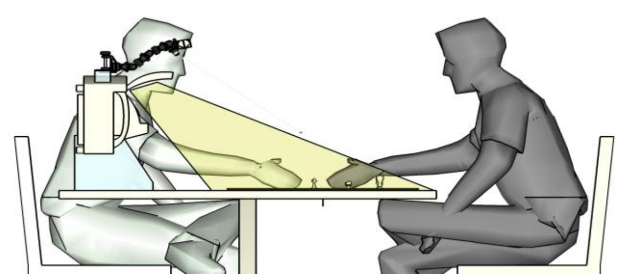

Figure 3. Local camera is at approximately the same point as (imaged) position of remote player (on left).

shadows cast by tall objects (with the projector as the main light source). This can obscure the projected video. Shorter and/or translucent game pieces may help. Contrast is also important in terms of perceiving top-bottom relationships. Physical objects, including hands and game-pieces, almost always appear to be on top of objects in the remote video. Most of the time this is acceptable but it can create unusual situations such as when one user attempts to put their hand "on top of" a remote user's hand. Each user will see their own hand on top!

4. NEW EXPERIENCES

4.1 Game Experiences

PlayTogether supports different levels of intervention on the part of the application. PlayTogether does not necessitate application controlled mechanisms for enforcing etiquette. Many existing CSCW systems impose turn-taking. "Out-of-turn" participants' cursors are disabled or preventing from acting on certain elements in the shared space or the cursor color may indicate state. In shared space systems such as DiamondTouch [5], the actual physical presence of other participants' hands discourages conflicting interactions. A game designer could also borrow from work in the area of *proxemics* to design sharing cues [6] [7]. In our distributed system we capitalize, as much as possible, on this kind of real-world presence based turn-taking. Our hope is that the more realistic the transmitted representation of remote participants is, the higher the inclination for participants will be to use real-world etiquette.

Very quickly, questions of how to synchronize two physical worlds arise. For example, in the case of checkers and chess, each player is responsible for removing their own pieces from the board (which is opposite from usual play). There are a class of very complicated research systems that use actuators to enforce bi-directional synchronization between the real (phicons) and the virtual [12]. Since our goal is to make a self contained system that works on nearly any tabletop, we have not explored actuators.

One way to partially address synchronization in a future version of PlayTogether is to offer visual cues ("halos") around game pieces. These cues would indicate needed updates on the part of the player. If a player places a piece in a position that violates game rules, a visual cue would then pop-up around the offending piece. The system could also intervene and remove undesired elements by video processing. In practice this might work like this: Player 1 moves their piece. Player 2 then "jumps" player 1's piece. If each piece is tracked as distinct objects, Player 2 can then press their finger down on the jumped piece and drag the image of the piece off the board. Consequently, Player 1 would see a red X projected over their physical piece. At that point it would be up to Player 1 to physically remove the jumped piece to maintain synchronization. If they did not do this, Player 2 might never know because of its having been removed from the presentation.

Because this is a networked system we can also enable new twists on familiar games. We can imagine a democratic game of group chess where multiple players on each side implicitly vote the next move by simultaneously placing pieces. As players move their pieces, real-time feedback gives a notion of what all other teammates are doing – modulated to reduce visual noise. If the game designer so chooses, opposing teams may only see a blur during voting but then get a clear image when voting is complete. In the real world, whoever "goes first" has an unconscious and undue influence over other players. The simultaneity enabled by

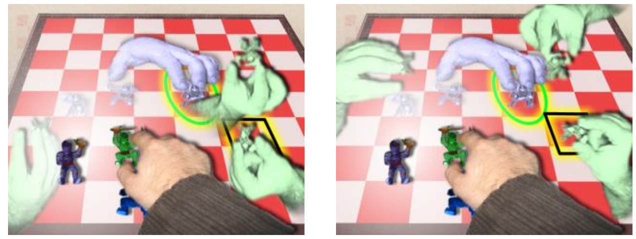

Figure 4. Simulated view of a multi-player team scenario where teammates are shown tinted differently than the opposing side. At left teammates' hands are shown on the same side as the local player. At right, teammates' hands are distributed around the game board.

PlayTogether's virtual space may have the benefit of freeing each player this order based influence. A team-member could also indicate disagreement with another team member's move by placing a "delete" phicon on top of the image of the other teammate's piece. This message would then be sent to the appropriate teammates.

Using a vision system gives us a great deal of choice in how to display each stream. To accommodate multiple players we choose a metaphor of people sitting around a table and we radially distribute each stream (see Figure 4b). We can thus fit more people around the board then could actually fit in a single shared physical space. Players who have finished their move, but whose hands are still in the camera field of view, can also have their video stream dimmed or even removed to help de-clutter the view. To be fair, there are several tricky visual issues that come up when implementing team style games. Because our camera is looking from a ¾ view rather than top-down, there is an implicit orientation in each exchanged video stream.

4.2 Collaborative Drawing

We have implemented a basic artistic collaboration application in which each participant draws on a real piece of paper placed on the desktop. All participants can see each person drawing with real writing instruments on their own pieces of paper. Because of the automatic paper registration, each participant can continuously adjust the angle of their paper to suit their own comfort, and the projected video is precisely aligned (see Figure 5).

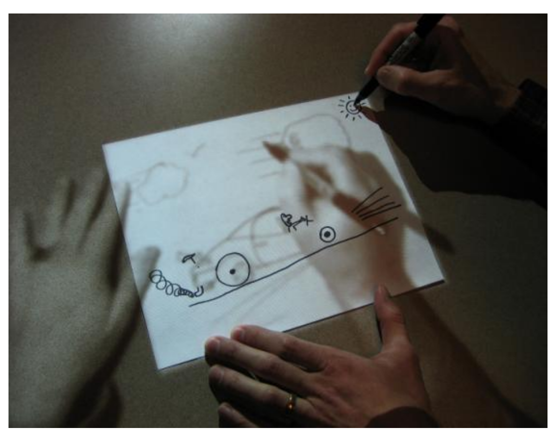

Figure 5. Example drawing application superimposes remote participants' drawing, and hands entering from the local participants' side of the table.

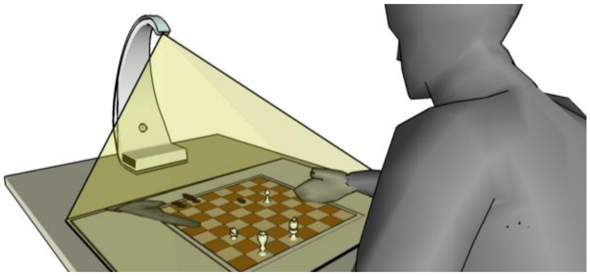

Figure 6. Future configuration using laser projector with collocated camera and IR source

5. FUTURE WORK

Our current implementation of PlayTogether is limited to exchanging grey-scale video. It may be possible to enable the exchange of color video by adding a color camera to the configuration: the IR camera feed would be used to calculate a "mask" indicating the real objects on the table (hands, game pieces, and game board). This mask would then be combined with the color image input to determine the natural color of the real component of the input, as well as determine where it is safe to project color graphics so as to not conflict with the color video. With more processing each player could also use different size game boards and the systems would adjust appropriately, sending scaled video to the other player. With object tracking capabilities, the system could add dynamic annotations and synchronization cues. More than two players could also be supported with more networked PlayTogether systems and/or multiple players in the same shared physical space.

The current video projector is quite expensive and fairly large. We are investigating an emerging crop of lower-cost LED and laser-based projectors that can easily be mounted on light-weight booms. These advances in projection technology might allow a much smaller device, such as that depicted in Figure 6.

6. CONCLUSION

We have introduced PlayTogether, an interactive tabletop system that enables multiple remotely and co-located people engage in games with real games pieces. A combination of sensing capabilities and real-time video give players a strong sense of remote players and an immediacy of interaction. This technology suggests new experiences in the domains of game-play, artistic expression, and computer mediated collaboration.

7. ACKNOWLEDGEMENTS

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