Building a Table Tennis Game for Three Players

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ABSTRACT
Physical leisure activities such as table tennis provide healthy exercise and can offer a means to connect with others socially; however, players have to be in the same physical location to play. Networked computer games support players in geographically distant locations, but their communication channel is often limited to text or audio only. Furthermore, recent input devices that encourage exertion often do not support adequate force-feedback. We have developed a networked table tennis-like game that is played with a real paddle and ball, augmented with a large-scale videoconference. Similar to networked computer games, this concept can support more than two locations, while simultaneously aiming to provide similar benefits known from traditional physical leisure activity such as exercise, enjoyment and bringing people together to socialize.

Categories and Subject Descriptors
H5.2. Information Interfaces and presentation (e.g., HCI): User Interfaces.

General Terms
Human Factors, Design.

Keywords
Table-tennis, ping pong, Exertion Interface, physical, tangible, videoconferencing, sports, active, exhausting, sweat, team spirit, social interaction.

1. CASUAL LEISURE GAMES
Casual leisure activities, such as table tennis, are an important part of people's lives. The benefits of leisure activities on personal well-being have been widely discussed: from a mental health perspective, leisure is believed to have a beneficial effect on psychological well-being by promoting positive moods [3]. From a physical health perspective, athletic leisure activities contribute to a healthier body, reducing the risk of obesity, cardiovascular disease, diabetes, and more [17][1].

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Figure 1. Table Tennis for Three.

Table tennis is a popular leisure activity, played worldwide by players of all ages and capabilities. Table tennis helps to develop hand-eye coordination, agility and reflexes and can contribute to general fitness [9] [18]. Due to its relatively low entry barrier, it can also serve as an ice-breaker for social interactions. In fact, research has shown that many of the benefits of leisure are the result of its capability of fostering companionships and friendships [3]. However, the players have to be in the same physical location to play a game.

2. NETWORKED GAMES
One way of allowing family and friends in geographically distant locations to enjoy leisure activities together is through networked computer games. These games offer players a shared experience, but often fall short in providing a personal, casual interaction, characteristic to collocated leisure activities. The interaction support is often limited to text- or audio-only communication. Computer games with their gamepad interaction are often criticized for their support of a sedentary lifestyle and social isolation of their players. Latest developments use accelerometers in game controllers [21] or track player's movements via a webcam [6] in order to encourage physical activity, however both approaches lack adequate force-feedback when the player's avatar collides with a virtual object.

3. CASUAL LEISURE NETWORKED GAMES

In order to provide an opportunity to maintain connections with distant friends and relatives, we have incorporated mental and physical interactions similar to a table tennis game with videoconferencing technology to create a new experience that allows participants to enjoy an exerting leisure activity together although geographically apart.

Breakout for Two [12] has demonstrated that a physical leisure activity (kicking a soccer ball) can be enjoyed by two geographically distant participants. With our current work, we are aiming to show that the concept combines the advantages of networked computer games (supporting multiple geographically distant players) with the advantages of traditional exerting leisure games (health and social benefits). Instead of relying on expensive and complex force-feedback technology, we are utilizing the affordances of traditional leisure game equipment which we augment with videoconferencing technology and networked gameplay. Our latest prototype demonstrates that this concept scales to three locations easily.

4. TABLE TENNIS FOR THREE

We are presenting a networked game that is based on table tennis, but can be played by players in three geographically distant locations. Although it has different rules than table tennis, the use of a table tennis table, a paddle and ball inspired us to name it *Table Tennis for Three.* The gameplay is based on the successful elements of *Breakout for Two*, with a focus on the *Exertion Interface* [12], and an extension to three locations. *Table Tennis for Three* provides a health benefit by encouraging physical activity and training reflexes as well as hand-eye coordination. Just like table tennis, it is easy to learn and supports a sense of achievement quickly. Through the inclusion of a videoconference, we aim to support similar benefits known from traditional physical leisure activities such as exercise, enjoyment and bringing people together to socialize.

5. GAMEPLAY

Each player has a table tennis table, a paddle and a ball. The table is set up so that the ball can be hit against the vertically positioned opposite half of the table [Figure 1]. This setup is familiar to table tennis players who practice on their own by playing the ball against the board. The vertical part of the table is painted white to also serve as projection surface for a videoconference of the other two players. Projected on top of the videoconference are eight semi-transparent targets that players have to hit with their ball. These targets, or blocks, “break” when hit by the players. The blocks are synchronized across the three tables, so the other players see the same block layout and the same block states. If a block is hit once, it cracks a little. If it is hit again (regardless by which player), it cracks more. If hit three times, it breaks and disappears, revealing the underlying videoconferencing completely: the player has broken through to the remote players. However, only the player who hits the block the third and final time makes it disappear and receives the point. This adds an element of strategy to the game: a player can try to snatch away points by hitting blocks that have already been hit twice by the other player. Each broken block scores one point, and once all blocks are cleared, the player with the most points wins the game.

6. TECHNICAL IMPLEMENTATION

6.1 Videoconferencing

The videoconferencing implementation is deliberately kept independent from the technical gameplay component in order to provide an optimal videoconference experience. Developing a videoconferencing system is not a trivial task, and many open-source and commercial systems claim to offer the best compromise between bandwidth limitations and image and audio quality. These software (some of them are hardware) implementations balance the most effective compression codecs with en- and decoding CPU requirements, deal with varying network throughputs, provide circumventions for firewall issues, and minimize noise- and echo effects. In order to utilize the always latest advances in videoconferencing technology, we implemented the *Table Tennis for Three* gameplay independently and placed it on top as a separate half-transparent layer. This ensures that any researcher who wants to recreate the system can take advantage of their own existing videoconferencing infrastructure and is not locked into a proprietary system that might be outdated quickly. For our implementation, we used ConferenceXP [10], which provides support for multiple locations and offers high-resolution video transmissions in local area networks. The gameplay software is programmed with a transparent background which allows the players to see the underlying videoconference, however, the hardware-acceleration of the graphics card needs to be turned off to allow for this transparency effect to work. We are not using any special graphical effects that require the hardware acceleration, and have not noticed any delay affecting the gameplay due to the deactivation.

In our current setup, we are using a videoconference resolution of 640x480 pixels with 25 frames per second to support the fast moving actions the players exhibit during game play. The images are captured by consumer webcams; we found the quality of recent models suitable for our purposes. The audio is captured with the Bluetooth headsets which the players are wearing. We were experimenting with directional microphones, however, the impact noise of the table tennis ball was often captured on top of the players’ voices. Furthermore, the nature of the game requires the players to move around intensively and talking when collecting balls behind the table or at the remote end of the room was hardly picked up by stationary microphones. We therefore decided to ask the users to wear a Bluetooth headset which presents a low-cost wireless transmission of audio for our purposes. Due to the fact that we only used the microphone functionality of the headset, the user could also wear the device on their shirt’s collar, often preferred to the time-consuming adjustment and positioning to the ear. The audio-out is sent to speakers located under the table in order to allow spectators to hear and for us to observe (with a hand-held video camera) what was being said during the evaluation. This setup however often created echo issues, with the microphone picking up the audio coming from the speakers. Several users commented on this, and a proposed alternative setup would be to route the audio through the headset to avoid this issue. We are aware that we compromised our initial goal to provide a non-technical approach for the user, similar to table tennis, where she or he can just show up, grab a paddle and start playing. Although we carefully trialed several models, we found none very suitable due to battery issues,

inconvenient buttons, pairing issues after recharge with the PC and awkward fit to the ear.

6.2 Gameplay

The game of hitting the blocks and the accompanying score is implemented in Flash, which synchronizes its game state through a Flash media server. Flash provides a familiar visual development environment for Internet-based game developers, and hence our choice of framework makes developing additional games for our platform appealing for other game designers. Each table acts as one client, which talks to the server that is responsible for distributing the latest block states and scores amongst the other clients. Our approach also supports uncertain networking conditions across various implementation conditions, because we are using an HTTP fallback mechanism in case ports are unavailable due to firewall restrictions. Although we have not tested our system across large distances, the aforementioned provisions of using external software packages that support varying network conditions and can circumvent firewall restrictions make a public Internet-based implementation feasible.

6.3 Impact Detection Mechanism

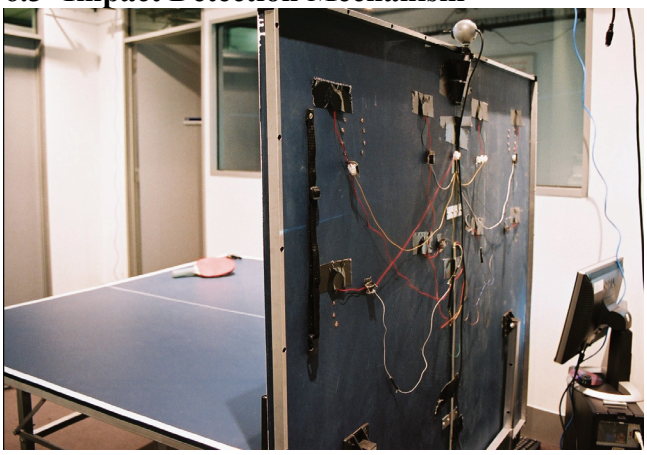

Figure 2. The sensors attached to the back.

In order to detect the impact point of the table tennis ball on the vertical part of the table, we experimented with high-speed vision detection cameras. However, the fast speeds a table tennis ball can reach [20] require a high shutter speed, which in turn profits from bright illumination of the area. Additional lighting affects the projection of the videoconference, so we decided against this approach, and chose an audio-based detection system. Eight piezoelectric sensors are attached to the rear of the backboard in locations corresponding to the gameplay blocks projected on the front of the backboard [Figure 2]. The sensors detect the sound vibrations in the wooden board created by the ball striking it. This approach is similar to the system described in [7], however, we were not able to achieve a highly accurate system with four sensors (which should cover the entire surface through interpolation), and therefore opted for the use of eight sensors. Preliminary tests revealed that it was very important for the players that all of their hits were properly counted by the system, and consequently we focused on reliable, accurate detection. We can report results of a simplified test which showed that over 95% of hits were detected, and the location was identified correctly in over 90% of these hits.

The one sensor that receives the vibration signal first, exceeding a certain threshold, determines the location of the impact. After an A/D conversion and data acquisition with 25 kHz into a PC, software concludes which of the bricks should be cracked, and sends it to the game engine.

6.4 Network Delay

Due to the separation of videoconferencing component and gameplay engine, we are able to update the videoconferencing software if any technological advances become available. Any networking delay is therefore determined by the quality of the implementation and the condition of the network. The additional bandwidth which will be required when game data is transmitted consists of a few bytes and is therefore negligible. We therefore expect no further lag than in a traditional videoconference that is conducted over an Internet connection.

7. RELATED WORK

An example of a networked physical activity experience is *Haptic Arm Wrestling* [5], which is installed in museums across the USA. The device includes a videoconference to arm-wrestle other visitors over the distance. The *Virtual Fitness Center* [11] is a research project that uses networked exercise bicycles to motivate distributed cyclists; Fitcentric [4] offers a similar commercial product, but without video or audio support. The *Wii* game console comes with a controller that contains accelerometers to support physical activities in its games; however, it does not support the inclusion of a videoconference as yet [21]. *PingPongPlus* [7] utilizes a table tennis table: a projection is augmented on the table that reacts to the impact of the ball; however, it supports only two collocated players. Three players can play ping pong with *TriPong* [19], but they need to be around the same table.

Airhockey over a Distance [13] is a leisure game that is playable by players in different locations: it uses a physical puck that is shot out at the remote end by puck cannons. *Push'N'Pull* [15] is a networked exercise machine, which the players use as interface for a cooperative game, supported by a high-definition videoconference. *Virtual Tug-of-War* [16] is a physical group activity in which two teams were involved in a tug-of-war 13 miles apart from each other. These examples support a communication channel between the participants; however, they are limited to two locations.

Several researchers have built virtual reality [8] and augmented reality versions [2] [22] of table tennis. However, they either lack force feedback of the ball hitting the paddle, or are not playable by distributed participants. Our approach does not require the players to wear any technology that covers their eyes, because we believe wearing devices such as head-mounted displays might negatively affect the social interaction between the players.

8. Future Work

Having utilized various technologies and techniques to allow for running *Table Tennis for Three* over a public Internet connection, it is now time to test the system in three geographically disperse locations. Evaluation of the user experience will show if the game can establish a sense of connectedness between players who have never met before the game and possibly never will in the future. One possible indicator could be how long for participants play the

game. Moreover, the scalability of the concept needs to be tested with four or more stations, supporting several players at once.

9. Conclusion

Table Tennis for Three aims to combine the advantages of networked computer games (supporting multiple geographically distant players) with the advantages of traditional exerting leisure games (providing a social and health benefit). We present a gaming system that is oriented on traditional table tennis, but scales to three players in three locations. *Table Tennis for Three* uses an acoustic-based detection system to determine the ball's impact, and combines gameplay with a videoconferencing component in order to support social interaction between geographically distant participants. We believe the physical activity with the force-feedback of a real ball can add to the experience of playing a casual game together, although being apart. We hope to inspire designers of other augmented leisure games to include connectivity beyond two locations and integrate social interaction support between geographically distant players.

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