Social playware for mediating tele-play interaction over distance

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Abstract
We suggest that novel playware technology can function as a mediator for playful social interaction over distance, where people are separated by physical distance but feel the presence of each other mediated through the interaction with the playware technology. In order to investigate such social playware, we developed the Playware Soccer game and tested this with more than 1,000 users during the FIFA World Cup 2010 in South Africa. The test was conducted in townships, orphanages for HIV/AIDS children, markets, FIFA fan parks, etc. along with simultaneous tests with similar set-ups in Europe and Asia. With the social playware, players would compete against each other simultaneously in the three continents, Africa, Europe and Asia, and feel the presence of the competitors on the other continents expressed through the playware. The playware game is set up to motivate players to engage in training of technical soccer skills by receiving immediate feedback and offering challenges to players of all skills on the soccer playing on a modular interactive wall composed of modular interactive tiles that respond with coloured light, sound and scores on the players performance. This paper outlines the concept of social playware and physical-virtual teleplay, and exemplifies this with the playware soccer game.

Social Playware

Playware is defined as intelligent hardware and software that creates play and playful experiences for users of all ages [1]. In this paper, we suggest that novel playware technology can function as a mediator for playful social interaction over distance, where people are separated by physical distance but feel the presence of each other mediated through the interaction with the playware technology. Often, human-machine interaction is viewed as a 1-to-1 interaction between an individual human being and the technological artefact, and a lot of research within the fields of human-robot interaction, social intelligent robotics, and human-computer interaction has put focus on the individual relationship and interaction with the technology (e.g. [2, 3]). In many cases, the creation of playful technology, e.g. robotic toys and interactive playgrounds, has taken its inspiration from such human-machine interaction research. Based on this, the research community has also gained knowledge on how the individual interacts and plays with such playware products (e.g. [4, 5]).

In our point of view, it is important to expand the playware research to focus on the social interaction, so that the starting point for the research and development becomes the *social interaction* mediated by the technology rather than the individual interaction mediated by the technology. We can define social playware as follows: *social playware is playware which aims at creating playful social interaction between several users*.

Such playful social interaction can, for instance, be play between children in a kindergarten mediated by an interactive playground, multiplayer games with a physical game platform like Nintendo Wii, and interaction of a team of elderly performing games for health e.g. with Dance Dance Revolution, i.e. in all cases a free activity that the users engage in for the pleasure of play and social interaction in itself. Hence, this is in accordance with the definition of play, which can be defined as "*Play is actions which we undertake and participate in with the purpose to create a reality-sphere within which we are free and independently can create and regulate moods (physical and mental states of tension) which provides us with specific, wanted experiences (of delight), socially and individually*" [6]. The definition underlines that play is submitted to free will, and that human beings play because we want to play. At the same time it underlines that we, in the act of playing, manage our lives at our own choice, as we create the special form of lived life outside the "regular" life where (lust for) life and happiness as the essence of play rules. By building on this play definition, the definition of social playware simply focuses on the human desire to engage in social interactions and to live as a social being. It can therefore also be argued that social playware is included by playware. Indeed, we view social playware as a sub-discipline of playware, which however allow the research community to direct focus on the social interaction mediated by playware, and thereby provide further understanding on how to create social interactions that are playful and which the users engage in for the pleasure of the social interaction.

We will exemplify the social playware in this work with physical-virtual *teleplay*, which allow users to engage in social interaction over distance mediated by the playware technology. In such a case, we can view the playware technology to mediate a playful tele-presence between people interacting with each their playware tool through which they sense the presence of the other people (in essence, presence removes the impression of mediation from a mediated experience). Examples of teleplay and social playware are seen in the form of massively multiplayer online games (MMOG), which are multiplayer video games which are capable of supporting hundreds or thousands of players playing together simultaneously over the Internet. However, such games do not allow for extensive physical and natural interactions (other than e.g. pressing keyboard and speaking). Some physical interaction is promoted with some multiplayer online games, e.g. in the Japanese and Korean arcade halls, in the form of interaction with game cards (e.g. soccer cards). For a more natural and physical interaction, tele-presence has been studied intensively e.g. by Ishiguro with the studies of humanlike presence using tele-operated androids [7, 8]. Such studies have promoted a humanlike technology to study presence, and some large videoconferencing set-ups have allowed for a soccer teleplay [9]. We, on the other hand, have made a first step with a much simpler, yet playful technology for mediating social interaction (in the line of the simple, yet effective FeelLight technology for mediating social interaction by Suzuki and Hashimoto [10]). Hence, we will study tele-presence without a large and bulky infrastructure, and without any anthropomorphic expression, but a simple expression of simple light patterns, sound, and score. In the specific example, we made social playware connecting players in Asia, Africa, and Europe in a soccer game on a playware technology in the form of modular interactive tiles.

Playware Soccer

During the FIFA World Cup 2010, we ran a RoboSoccer World Cup in Asia, Europe and Africa, amongst other places in townships, orphanages for HIV/AIDS children, markets, etc. in South Africa. As an example of playware, the game is set up to motivate players to engage in training of technical soccer skills by receiving immediate feedback and challenge players at different levels on the soccer playing on a modular interactive wall composed of modular interactive tiles that respond with coloured light, sound and scores on the players performance. The soccer game was developed together with professional soccer players Laudrup and Høgh for promoting playful soccer skills. For the test conducted during the World Cup tournament, the soccer wall was composed of 3*4 modular interactive tiles. It is a distributed system as each tiles has its own processor, battery and communication to neighbouring tiles. The distributed nature of the system aimed at allowing the system to be easily set up and taken down within minutes anywhere and by anyone. Indeed, the flexibility obtained with a modular and distributed processing system should provide the opportunity to bring the new playware technology out to any township, market, and village in Africa and on other continents since there was no demand for any physical infrastructure whatsoever.

Often, other technological systems for physical interaction are characterised by being based on a centralised processing system making the systems fixed sized (and sometimes large and bulky), and/or they are characterised by the demand for some kind of infrastructure, e.g. electricity, access to screen/projector, or similar. Examples include Lightspace, Makoto, Sportswall and even DanceDance Revolution with more participants, which needs to have a centralised control station. This makes it somewhat difficult to apply the traditional technology for any user anywhere, since in many places of the World, the necessary infrastructure is not readily available to allow such technology to be applied. This is, for instance, the case many places in Africa, and even in a comparably developed country like South Africa, where the FIFA World Cup 2010 was held, there are townships with no electricity (Fig. 1).

Fig. 1. Playware soccer in the township Atteridgeville, South Africa, during FIFA World Cup 2010.

If, on the other hand, we take as point of departure for our technology design that no infrastructure is available, it will lead to technology that is free from infrastructure demands and which thereby possibly can be applied and used anywhere. It gives the possibility to bring technology to anybody anywhere, and thereby help in contextualising both technology development and education in developing countries. The advantages of such technology outcome may not be limited to the developing part of the World, but the freedom from infrastructure requirements may also have important impact on the distribution and use of technological solutions in the developed part of the World (e.g. for home care in the private homes of elderly). Even in a private garden or a football training field in the developed World, the necessary infrastructure such as electricity outlets or computer monitors may not necessarily be available. Therefore, it is interesting to research the flexibility of the modular playware for allowing the technology to be set up and used anywhere within minutes.

Hence, the playware soccer game was developed with the modular interactive tiles system [11], which is an example of modular playware [12]. The system is composed of a number of modular interactive tiles which can attach to each other to form the overall system. Each modular interactive tile has a quadratic shape measuring 300mm*300mm*33mm. It includes an ATmega 1280 as the main processor in each tile, and each tile can communicate with infra-red (IR) to its four neighbouring tiles. Each side of a tile is made as a jigsaw puzzle pattern (see Fig. 2) to provide opportunities for the tiles to attach to each other. A force sensitive resistor (FSR) is mounted as a sensor on the center of a raised platform underneath the cover. This allows analogue measurement on the force exerted on the top of the cover.

On the PCB, a 2 axis accelerometer (5G) is mounted, e.g. to detect horizontal or vertical placement of the tile. Eight RGB light emitting diodes (LED SMD 1206) are mounted with equal spacing in between each other on a circle on the PCB, so they can light up underneath the transparent satinice circle.

Fig. 2. Assembly of the modular interactive tiles as a jigsaw puzzle.

The modular interactive tiles are individually battery powered and rechargeable. There is a Li-Io polymer battery (rechargeable battery) on top of the PCB. A fully charged modular interactive tile can run continuously for approximately 30 hours and takes 3 hours to recharge. On the PCB, there are connectors to mount an XBee radio communication chip. Hence, there are two types of tiles, those with a radio communication chip (master tiles) and those without (slave tiles). The master tile may communicate with a game selector box (game card reader) and initiates the games on the built platform. Every platform has to have at least one master tile if communication is needed e.g. to game selector box or a PC.

With this specification, a system composed of modular interactive tiles is a fully distributed system, where each tile contains processing (ATmega 1280), own energy source (Li-Io polymer battery), sensors (FSR sensor and 2-axis accelerometer), effectors (8 colour LEDs), and communication (IR transceivers, and possibly XBee radio chip). In this respect, each tile is self-contained and can run autonomously. The overall behavior of the system composed of such individual tiles is however a result of the assembly and coordination of all the tiles.

Connectivity

In order to develop teleplay for social interaction it is important that the physical interactive platforms can communicate with each other, locally and globally, so that the social interaction can be mediated through the playware.

Local connection

For creating local communication between physically separated groups of modular interactive tiles, and between a group of tiles and a PC, we used the XBee with the ZigBee radio communication protocol. In each group of tiles, there is one tile (master tile) with the XBee radio communication chip. This tile can collect and send information. The information can thereby be communicated between two "islands" of tiles, i.e. between the master in one island and the master in another island. For communication to and from a host computer, we designed an XBee USB dongle to be connected to the host computer, which then can communicate with the master tile using the same protocol.

Global connection

With the local communication allowing easy communication between tiles and a host computer, e.g. a laptop/netbook, we were able to relay the global communication over laptops connected to the internet, e.g. laptops with 3G wireless connection, so that the teleplay could happen on platforms that communicate to each other over the Internet. A Java program was

designed to run on the laptop, which was connected to the tiles with the XBee. The Java program kept track of the hits on the tiles, played feedback sounds, showed the time and score of the game at run-time, and kept the total score of each game. At the end of each game, the program sent information to a web-site that saved it together with a username, password and location on a highscore list which was updated immediately. The highscore list updates would be visible on internet connected computers at different locations, anywhere globally, at run time.
With the design of both local and global connectivity, it is possible to create both local and global physical interactive games. The local connectivity was used to create feedback from a local host computer in the form of time and score displayed on a monitor, and sound from a loudspeaker connected to the host computer. The global connectivity was used to allow feedback in the form of run-time score updates in competition between users playing the same physically interactive game in different parts of the World, i.e. allowing for social interaction over distance.

Soccer Game

The game content was crucial to ensure training of soccer skills in a playful manner, so we collaborated with professional soccer players Laudrup and Høgh, in order to create an appropriate game utilizing just 3*4 tiles. In the soccer game, a specific number of tiles light up in different colours. Each of them counts down with their eight LEDs. The player has to hit the tile before the LEDs are all turned off, and gets points for how many LEDs are turned on at hit time, and points are multiplied by a factor for how high the tile is positioned (row 1, 2, or 3). Also, at random time, one of the tiles will have its LEDs making a fast spinning pattern, indicating that if the tile is hit, a bonus round will be initiated, during which the player can gain extra points when hitting the tiles that are lit up.
Preliminary testing with a number of adult players showed that the soccer game could be set to an appropriate difficulty level that was both easy enough to play for all the test persons and difficulty enough that all would be challenged to obtained higher score. This difficulty level was set experimentally by investigating the time needed for people to kick the ball and hit a tile, so as to set the LED countdown time to an appropriate level (the time used from all 8 LEDs were turned on, until all LEDs were turned off, and the light would jump to another tile).

Layered Multi-Modal Feedback

For increasing the motivation to play the game, we designed a multi-modal immediate feedback, so that the player would not only receive immediate feedback directly from the tiles in terms of the changing coloured light, but we also added sound feedback and graphical feedback in terms of time and score via a host computer, to enhance the system as social playware. When a player would hit a lit tile, the light would turn off on that tile and jump to another tile, a sound would be played from a loudspeaker, and the increase in score would be shown on a monitor. And when the game ended, the position on the high score list would be shown on a monitor.
It is noteworthy, that the game design was made so that the game can run as an interesting game even without these additional feedback modalities. Both the additional immediate (sound, score, time) and delayed (local highscore list and global highscore list) feedback modalities can be added as layers on top of the basic game that runs on the modular interactive tiles only (see Fig. 3). Hence, with this layered design of feedback modalities, it is possible to (i) run the game as a simple game with only the lowest level of feedback (coloured light) on the modular interactive tiles, (ii) run it with higher levels of feedback (sound, score, time) by adding a laptop PC, or (iii) run it also with the highest level of feedback (global highscore list) by adding an internet connection. This third option (iii) was used for the teleplay experiments to create the soccer game as a social playware.

Layer	**Platform**	**Type**
5	Internet	Global highscore list
4	PC monitor	Local highscore list
3	PC monitor	Time & Score
2	PC loudspeaker	Sound
1	Tiles	Light

Fig. 3. The layered multi-modal feedback design for the playware soccer game.

The layered structure in designing feedback modalities may resemble the layered design in much behavior-based robotic engineering [13]. For instance, the original subsumption architecture by R. Brooks [14] defines that behaviors can be designed to run in parallel on top of each other, starting from the design of the simplest behaviors. Once the simplest behavior is designed, implemented and debugged, this behavior can run by itself, and a behavior can be designed, implemented and debugged to run in parallel on top of the simple behavior. So forth continues the design with layers of behavior on top of the previous ones that all run in parallel, and the lower levels continue to function as originally designed. The design of multi-modal feedback, which we propose here, works with the same principle. First, a simple feedback is designed which can run by itself, and then new layers of feedback can be added on top to run in parallel. In the present case of the soccer game, the simplest feedback is designed to be the change of light on the modular interactive tiles when a tile is hit. Once this feedback modality was designed, implemented and debugged, on top of this, we designed, implemented and debugged the sound modality, which would run in parallel with the light feedback. Then, on top of this, we designed, implemented and debugged the time and score feedback from a monitor. On top of this, we added the local highscore list feedback. And on top of this, we designed, implemented and debugged the global highscore list.

As with the original subsumption architecture where different behavior modules can run on different time scales, also with this layered multi-modal feedback design, the different layers may run on different time scales, with the lower levels executing with the fastest feedback time cycle and the highest levels the slowest feedback time cycle. The lower level behaviors / feedback modalities need to give a very fast response for the system to work, whereas the higher level behaviors / feedback modalities can give response once in a while.

The advantage of this layered multi-modal feedback design is that it is possible to create simple layers of feedback, that can run by themselves and work at their own right, and then add new layers to run in parallel on top of the previously designed layers, and when the user is executing the system, it is possible to add/remove layers (feedback modalities) from the top. Essentially, this can even be done at run-time, adding and removing new feedback modalities, since the lower levels will keep running and working whatever is added on top of them. This gives a high flexibility of the system for both the designer and the user of the system.

Tests

In order to explore social playware and the potential of such social playware mediating social interaction, we needed to test broad ranges of cultural differences in users and environments. Therefore, we tested the system simultaneously in Denmark (Europe), South Africa (Africa), and Japan (Asia) during the FIFA World Cup 2010. For instance, in Asia the system was tested in highly metropolitan areas, such as in Shibuya, Tokyo, whereas in South Africa we tested in a variety of places, including an orphanage, numerous townships, a public market, a village, an official FIFA Fan Park, a science discovery centre, a university, a fan bar, a public park in Soweto, etc. This variety of places was selected in order to ensure the broadest possible test in terms of variation on the environment, the social status, the age group, the educational level, the technology interest, and the soccer interest of the users. Indeed, users were from 3 years old to 80 years old (see Fig. 4), they were from orphanages with children from families with HIV/AIDS to adult soccer fans from high income areas, and they were ranging from people with no education to people with university degree.

The system was designed for flexibility with the modular interactive tiles and the layered multi-modal feedback design, which together aimed at creating a system that could be set up and used by anybody anywhere within minutes. The modular interactive tiles can be viewed to provide hardware building blocks, and the layered multi-modal feedback design to provide feedback building blocks, and simple construction with these building blocks should give a high degree of flexibility for the designer and the user to create various set-ups and interaction possibilities in an easy manner.

Fig. 4. An older man playing the playware soccer at a taxi rank in Randburg, South Africa.

In total, the system was tested with more than 1,000 users during the FIFA World Cup 2010. The distributed nature of the system (each tile with its own processor, battery and communication to neighbouring tiles) allowed the system to be easily set up and taken down. Indeed, the flexibility obtained with a modular and distributed processing system gave the opportunity to bring the new playware technology out to any township, market, and village in Africa since there was no demand for any physical infrastructure whatsoever. It proved possible to set up the system in a very fast manner on the grounds in townships such as Soweto and Atteridgeville, in public parks in Soweto, markets and bus station in Randburg, and in remote villages such as Phokeng. At some places, the system was run with only part of the layered multi-modal feedback, and in other places it was run with all layers active. The layered multi-modal feedback allowed a set-up with e.g. just layer 1 or just layer 1-4 in some places, and in other places to run the full system with layer 1-5 (including global high score list via internet connection, see Fig. 5). Therefore the system proved flexible to make fit to the time available, the local use and the aim of the game at a particular place with a particular set of users.

Fig. 5. The global highscore list on the internet (www.playwaresoccer.com).

When running the system with all five layers and in different locations at the same time, the system became a social playware which mediated social interaction over distance. Most often, social interaction would happen around the single set-up e.g. in a township or a market with lots of people gathering around the playware soccer set-up cheering, helping, and interacting socially around the playware and the individual player (e.g. see Fig. 1). So it was evident from the test observations that even with the playware soccer set-up utilizing only the lower layers of feedback modality, it became a social playware. However, this was reinforced to a large degree when the game was set up with all five layers and run in parallel at different locations, e.g. simultaneously in the small village of Phokeng in South Africa and in Shibuya in the center of Tokyo in Japan. In such cases, the players were observed to engage in a competition over distance: in one location (on one continent) they would see the scores of players in the other location (on another continent) playing with the playware soccer. The players would experiencing the high score list change minute after minute depending on the score at their own location and the score at the other location (visualized and continuously updated on the monitor next to the playware soccer set-up). In all cases, players engaged immediately in trying to get higher scores than in the other location, and cheering and shouts related to the scores of the remote location on the other continent allowed us to observe the emotional engagement and social bonding both locally around the game, player and audience, and also between the remote competitors who were invisible and unknown to each other.

Discussion and Conclusion

As a test of social playware, during the FIFA World Cup 2010, we ran a RoboSoccer World Cup in Asia, Europe and Africa, most notably in townships, orphanages for HIV/AIDS children, markets, etc. in South Africa. We linked the events together with a novel kind of physical-virtual live competition, which can be termed teleplay, and which as a social playware mediated social interaction. The teleplay took place between people in these African environments and metropolitan fans in larger cities in the developed World, e.g. in Tokyo, thereby trying to create a social bond and feeling between the fans world-wide during the World Cup through the physical-virtual teleplay. The social bonding was mediated through the physical football game between players on different continents who at the same time, through the teleplay with social playware, can compete directly and physically between the continents.
The flexibility of the modular interactive tiles and the layered multi-modal feedback design, allowed the creation of a system that could be set up and used by anybody anywhere within minutes, and it was therefore possible to test the system with more than 1,000 users during the FIFA World Cup 2010. Videos of some tests are available at: www.playwaresoccer.com
In general, the advantages of the proposed modular, social playware can be summarized to a flexible set-up, independence on context, runtime feedback, competition as a motivation factor, framing of the game (World Cup soccer where one country wants to beat another country), audience friendly game through sounds and score which can be followed by the audience, and where the audience can take on roles and feel as a part of the game (cheering, collect balls, make indications on bonus rounds, etc.). Hence, the layered multi-modal feedback in the playware set-up can mediate both local social interaction and global social interaction. The disadvantages of the set-up as proposed here are that this is not in-game presence (the tele-presence is not immediate but delayed), it is a single-player game, physical differences may mean that players are not competing on equal footing (e.g. the physical status of the opponent on the other continent is unknown to the player). Another disadvantage of the presented study is that we only have "event-based" observations and no long-term observations. We will elaborate further on these issues and on social playware in general in future work.

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