Playware Soccer – flexibility through modularity and layered multi-modal feedback

HENRIK HAUTOP LUND
Center for Playware
Technical University of Denmark
Building 325, 2800 Kgs. Lyngby
DENMARK
hhl@playware.dtu.dk http://www.playware.dk

Abstract: - We developed the Playware Soccer game and tested this with more than 1,000 users during the FIFA World Cup 2010 in South Africa in townships, orphanages for HIV/AIDS children, markets, FIFA fan parks, etc. The playware game is set up to motivate players to engage in training of technical soccer skills by receiving motivating, immediate feedback 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 flexibility of the system was designed for with the modular interactive tiles and the layered multi-modal feedback design, which together aimed at creating a system that could be setup 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.

Key-Words: playware, teleplay, games, soccer, modular technology, multi-modal feedback

1 Introduction

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. As an example of playware [1], the game is set up to motivate players to engage in training of technical soccer skills by receiving motivating, immediate feedback 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 football players Laudrup and Høgh for promoting playful soccer skills. In the World Cup tournament, being a distributed system, the soccer wall was composed of 3*4 modular interactive tiles, each with 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 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. 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.

2 Modular Interactive Tiles

The playware soccer game was developed with the modular interactive tiles system [2], which is an example of modular playware [3]. The system is composed of a number of modular interactive tiles which can attach to each other to form the overall system. The tiles are designed to be flexible and in a motivating way to provide immediate feedback based on the users' physical interaction with the tiles, following design principles for modular playware [3].

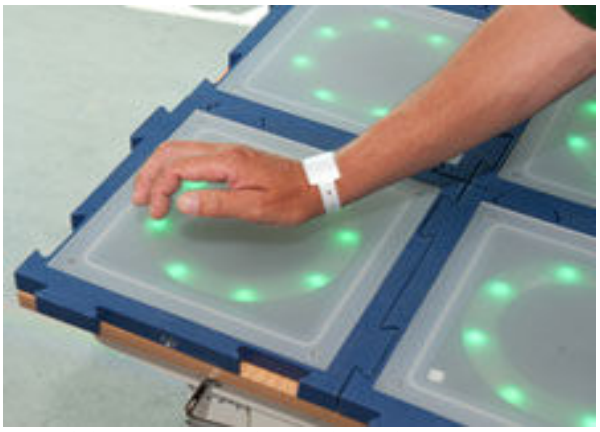

Fig. 2. Modular interactive tiles used for playful physiotherapy, in this case for stroke patients.

Each modular interactive tile has a quadratic shape measuring 300mm*300mm*33mm – see Fig. 1. It is moulded in polyurethane. In the center, there is a quadratic dent of width 200mm which has a raised circular platform of diameter 63mm in the centre. The dent can contain the printed circuit board (PCB) and the electronic components mounted on the PCB, including an ATmega 1280 as the main processor in each tile. At the center of each of the four sides of the quadratic shape, there is a small tube of 16mm diameter through which infra-red (IR) signals can be emitted and received (from neighboring tiles). On the back of a tile there are four small magnets. The magnets on the back provide opportunity for a tile to be mounted on a magnetic surface (e.g. wall). Each side of a tile is made as a jigsaw puzzle pattern to provide opportunities for the tiles to attach to each other. The jigsaw puzzle pattern ensure that when two tiles are put together they will become aligned, which is important for ensuring that the tubes on the two tiles for IR communication are aligned. On one side of the tile, there is also a small hole for a charging plug (used for connecting a battery charger), including an on/off switch.
There is a small groove on the top of the wall of the quadratic dent, so a cover can be mounted on top of the dent. The cover is made from two transparent satinice plates on top of each other, with a sticker in between as visual cover for the PCB.

Fig. 3. PCB and components of a modular interactive tile.

A force sensitive resistor (FSR) is mounted as a sensor on the center of the 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.
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. The battery status of each of the individual tiles can be seen when switching on each tile and is indicated by white lights. When all eight lights appear the battery is fully charged and when only one white light is lit, the tile needs to be recharged. This is done by turning of the tiles and plugging the intelligent charger into the DC plug next to the on/off switch to recharge each tile.

On the PCB, there are connectors to mount an XBee radio communication add-on PCB, including the MaxStream 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 the game selector box 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 contain 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.

Fig. 4. Assembly of the modular interactive tiles as a simple jigsaw puzzle.

The modular interactive tiles can easily be set up on the floor or wall within one minute. The modular interactive tiles can simply attach to each other as a jigsaw puzzle, and there are no wires. The modular interactive tiles can register whether they are placed horizontally or vertically, and by themselves make the software games behave accordingly.

Also, the modular interactive tiles can be put together in groups, and the groups of tiles may communicate with each other wireless (radio). For instance, a game may be running distributed on a group of tiles on the floor and a group of tiles on the wall, demanding the user to interact physically with both the floor and the wall [xx].

Fig. 5. Physical interaction with the modular interactive tiles placed on the ground.

3 Connectivity

In order to develop teleplay, it is important that the physical interactive platforms can communicate with each other, locally and globally.

3.1 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.

3.2 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. 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.

4 Game Design

In order to investigate the interaction patterns and skill level needed, we designed a range of soccer games for the modular interactive tiles. An important design criterion was to develop soccer games that could run on a platform of 2*4 tiles, 2*5 tiles or 3*4 tiles, making it easy to transport to any environment. At the same time, 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. Hence, the following soccer games were designed and implemented on the modular interactive tiles:

Precise Shooter - a specific number of tiles light up (e.g. 3 tiles), and the player has to hit all of these, before the player goes to next round with other (e.g. 3) tiles lighting up, which has to be hit.

Soccer Pair - all tiles light up in different colours in pair, e.g. two tiles light up in blue, two tiles light up in red, two tiles light up in green. The player has to hit a pair of tiles in the same colour one after another to obtain points.

Side Shooter - In each row, one tile light up, and the light travels from one tiles to the next in the row. The player has to hit the light that moves across the row in order to obtain points.

We made the distinction between design of static patterns (first two games) and design of dynamic patterns (third game). The static games challenge the player on precision, whereas the dynamic games challenge the player on precision, prediction and coordination. With the dynamic game, the player has to anticipate the movement of the light and the movement speed to coordinate this with the player's kick of the ball.

The testing of these different soccer games led to a fourth soccer game which can also run on the relative small platform:

Street Soccer - 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 Street 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).

The preliminary user tests showed that it was comparably easier for any player, also those with no soccer skills, to play the Street Soccer game than the other three games. Precision Shooter and Soccer Pair demand a sequential high precision of kicks, and Side Shooter demands precision, anticipation, and coordination at the same time. This can be some of the reason why these games seem more challenging and demand higher soccer skills (i.e. higher entry level for the game) than the Street Soccer game.

5 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. 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. 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.

The layered structure in designing feedback modalities may resemble the layered design in much behavior-based robotic engineering [4]. For instance, the original subsumption architecture by R. Brooks [5] 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.

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

Fig. 6. The layered multi-modal feedback design for the playware soccer game.

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.

6 Tests - Flexibility

The flexibility of the system was designed for 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.

We explored this flexibility by testing the system in a very diverse set of environments. During the FIFA World Cup 2010 in June 2010, we tested the system in South Africa 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, user were from 3 years old to 80 years old, 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.

Fig. 7. An older man playing the playware soccer at a taxi rank in Randburg, South Africa.

Further, to explore the flexibility in even broader ranges of cultural differences in users and environment, we also tested the system simultaneously in Denmark (Europe) and Japan (Asia) during the FIFA World Cup 2010. In these cases, the system was tested in highly metropolitan areas, such as in Shibuya, Tokyo.

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 within minutes anywhere. 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 within minutes on the grounds in townships such as Soweto and Atteridgeville, in public parks in Soweto, markets and busstation 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 highscore list via internet connection). 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. 8. The global highscore list on the internet (www.playwaresoccer.com).

7 Discussion and Conclusion

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. But also we linked the events together with a novel kind of physical-virtual live competition, which can be termed teleplay. 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 playware teleplay technology, feel the direct, physical competition from the other continent. We elaborate on the teleplay in subsequent publication.

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

Acknowledgement

The work was performed with the help of colleagues at the Center for Playware, Technical University of Denmark and Danish School of Education (AU). Tumi Thorsteinsson, Baldur Bjarnason, Niels Sandmann, Jacob Nielsen, Steffen Andersen and Bjarke Pedersen made highly valuable contributions. Also thanks to local organizers including A. Smith, Meraka Institute, B. Windram, Junior Engineers for Africa, Royal Danish Embassy in Tokyo, Brian Laudrup, Lars Høgh.

References:

[1] H. H. Lund, T. Klitbo, and C. Jessen. Playware Technology for Physically Activating Play, *Artificial Life and Robotics Journal, 9:4,* 2005, 165-174.

[2] H. H. Lund. Modular Robotics for Playful Physiotherapy, in *Proceedings of IEEE International Conference on Rehabilitation Robotics*, IEEE Press, 2009, 571-575.

[3] H. H. Lund, and P. Marti. Designing Modular Robotic Playware. In *18th IEEE International Symposium on Robot and Human Interactive Communication (Ro-Man 2009)*, IEEE Press, 2009, 115-121.

[4] R. C. Arkin. *Behavior Based Robotics*, MIT Press, Cambridge MA, 1998.

[5] R. A. Brooks. A robust layered control system for a mobile robot. *IEEE Journal of Robotics and Automation, 2(1),*1986, 14-23.