iGameFloor
- a Platform for Co-Located Collaborative Games

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ABSTRACT

This paper introduces a novel interactive floor platform for social games and entertainment involving multiple co-located users in a collaborative game environment. The interactive floor used as the prototype platform, is a 12 m^2 glass surface with bottom projection and camera based tracking of limb (e.g. foot, hand, and knee) contact points. The iGameFloor platform supports tracking of limb points for more than 10 users at the same time. This paper describes the technological platform and the interaction techniques used for social gaming and entertainment. Three iGameFloor applications are discussed with the purpose of displaying the potential of the physical computer game platform. Experiences and perspectives for further development of the iGameFloor platform are discussed.

Author Keywords

Social gaming and entertainment, interactive floor, vision based tracking, co-located collaborative games.

ACM Classification Keywords

H.5 [Information Interfaces and Presentation]. H.5.1 [Multimedia Information Systems] augmented reality; H5.2. User interfaces.

INTRODUCTION

The work reported was conducted in the "Wisdom Well" project under Center for Interactive Spaces, University of Aarhus Denmark The objective was to create new types of IT-based learning and entertainment experiences for school children. Traditional computer games, running on PCs and laptops only challenge limited parts of the human body - usually only eyes, ears, and the pointing finger. But the theories of aesthetic interaction [13,20,24] call for more rich interaction paradigms for social games.

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The work was inspired from two main sources namely empirical research in school environments [8] and literature studies within multiple learning styles, social gaming [5], tangible interaction [3] and movement based interaction techniques [11,16]. The empirical research revealed challenges in moving it-support for multiple learning styles beyond the pure audio/visual styles and take advantage of kinesthetic and social learning styles. This challenge made us look into the field of interactive floors [4,9,11,12,14].

The iGameFloor developed in the project is a 12m^2 bottom projected interactive floor with vision based tracking of user movement. The floor has been established as an experimental gaming platform at a nearby public school. The iGameFloor being available in a real school context, made it possible to experiment with the hardware platform for developing multiplayer co-located games with a high degree of user involvement.

Figure 1: iGameFloor in use at a local public school

The iGameFloor applications were developed in a participatory design process [1] with both children and their teachers as participants. We particularly used 'Fictional Inquiry' [8]. Fictional Inquiry establishes a shared narrative design space between stakeholders in the design process; in this case among teachers, children and designers. During these activities we have learned useful lessons for designing social games for school environments.

As the location of the iGameFloor was at a school department square, we focused on *collaborative and co-located games.* The large projection surface and the multi-user interaction techniques support collaborative games, where kids work together through direct communication and bodily interaction on the shared surface.

The paper is organized as follows. First, we discuss interactive floor research. Second we discuss motivations for body movement in gaming environments. Third, we discuss the physical and software infrastructures of the iGameFloor platform. Fourth, we discuss limb-tracking based interaction and its applications in three different games tailored to the iGameFloor platform. Furthermore, we evaluate experiences and future work. We conclude the paper with the main findings of the research into iGameFloor as a platform for social games and entertainment.

INTERACTIVE FLOORS

Interactive floors have emerged in recent years, and can be divided into two main categories: sensor-based and vision-based interactive floors.

Sensor-based interactive floors are typically utilized in dance and performances like set-ups e.g. the prototype Magic Carpet [19] and Litefoot [4]. The prototypes are sensor intensive environments for the tracking movements of feet and in the case of the Magic Carpet the sensor floor has been supplemented with sensor technologies for tracking the movements of the upper body and arms. To serve different shaping and sizes of an interactive floor the Z-tiles concept [14,23] was developed. As the above-mentioned systems the Z-tiles interactive floor is based on sensor technologies. Input from the sensors is used to control and manipulate sound providing the idea of playing an instrument with body movements. Another system exploring multi-user spatial interaction by means of a sensor-based floor is the Virtual Space project [12]. The sensors are here used to enable spatial interaction and control of a computer game projected on a vertical positioned display. BodyGames [9] is a system consisting of tiles with weight sensors and light diodes supporting games where players have to invoke certain light patterns to gain points in the game. These sensor-based floors are typically limited to a discrete interaction with relatively large floor tiles. Finally, the LightSpace™ technology[1] is a commercial product based on tiles and sensors to provide entertainment environments like dance floors.

In contrast to the sensor-based floors, vision based floors support a more fluid and natural interaction on a floor surface. Krogh et al. [11] introduce an interactive floor (iFloor) facilitating debate based on SMS and email contributions. A projector mounted on the ceiling is connected to a local computer to provide a display on the floor. The floor interaction works on the basis of a vision-based tracking package [26] analyzing the rim of the interface based on a video feed from a web-cam also mounted on the ceiling. The tracking of people's position and movement are interpreted as "magnetic" forces attracting a cursor with its home position at the center of the floor display. The force is proportional to the size of the shadow blob generated by a person moving under the projector. iFloor maintains a precise tracking of up to 10 people at one time in a 4*5 m rectangle. People are tracked in a one-meter band surrounding the display, which is 3*4 m in size. A visual feedback is given in form of a projected string connecting the cursor and the user while being in the tracked area, thus people were made aware that they were taking part in the interaction. Finally, Natural Interaction[2] has under-taken a number of projects resulting in prototypes of interactive floors based on tracking by means of vision technology.

The iGameFloor is developed from the iFloor principles, but utilizing tracking of limb contact points from the bottom of the display. In the following, we will present the supported movement-based interaction technique in relation to children learning.

BODY MOVEMENT FOR GAMING ENVIRONMENTS

In recent years there has been a focus on children and body movement. The tendency towards sedentary game playing in front of TV or computer screens has generated a focus on lack of body movement and exercise. These gaming activities have been related to an increasing obesity problem.[3] One way to address this problem is to combine body movement and the attractive digital game elements. EyeToy Play™ from Playstation2™, Nintendo Wii™ application and pervasive games as in e.g. [27]

Body movement is a central learning area for children – especially in the pre-school age. But the body is not limited to be a basis for movement activities [5]. Children experience and perceive the surrounding world, themselves and others through the body, which forms the basis for reflection and abstraction and in this way body movement is related to cognition (ibid). Merleau-Ponty's phenomenology [15] of body gives the body an essential significance in relation to the individual's recognition of her/himself and others. Body movement is social constructions and through these social constructions, body movements are important to the child's identity formation.

Within the HCI community, human-computer interaction has primarily been discussed from a cognitive concern. In recent years tangible interaction has given physical form to digital information, making bits directly manipulable and

[1] www.interactivefloor.com

[2] www.naturalinteraction.net

[3] E.g. http://www.msnbc.msn.com/id/7722888/

perceptible with the aim of increasing the understandability of a user interface (e.g. [7]). With the rapid penetration of technology into everyday life and the following “aesthetic turn” in HCI [25] a concern for the human body as a locus of sensory-aesthetic appreciation is gaining acceptance. Moen [16] provides an account of design aspects of human movement when used as interaction modality between people and technology. She calls this modality for kinaesthetic interaction. An examples is, the BodyBug, being a way to experience and interact with technology by use of the full faculty of the human body [17].

IGAMEFLOOR INFRASTRUCTURE

In this section we describe both the physical infrastructure and the software architecture.

Physical Infrastructure

The iGameFloor is built into the physical floor of a school department square. It is built in a 3 m deep hole covered with a projection surface. The projection surface is 3*4 m glass of approx. 9 cm thickness divided into four tiles. The glass surface consist of 8 cm carrying glass, 3 mm Fresnell diffusion layer, and a 6 mm hard protection surface glass. The four tiles are supported at the outer edges and with an internal conic frame resting on a pillar in the center.

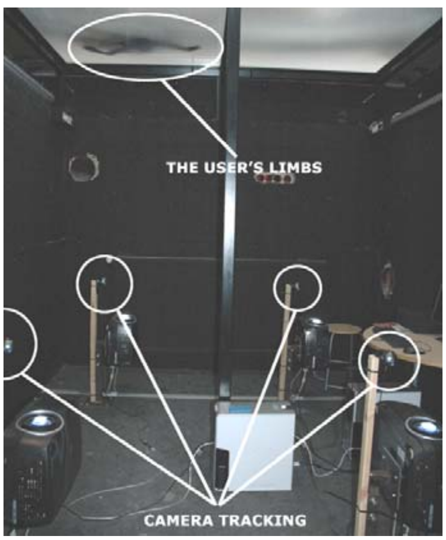

Figure 2: The physical setup of the iGameFloor

The projection is created by four ProjectionDesign F3 projectors with 5500 lumen light power and a resolution of 1024*768 pixels. The projectors are placed vertically covering each their tile of glass. The projectors are driven by a Dell 9150 with a Matrox QID LP PCIe graphics board with four DVI outputs. Each projector is associated with a Logitech Quickcam; tracking limb contact points on the tile covered by the given projector (see Figure 2).

The four Web cams associated with the projectors are managed by a Tracking Client running on a Dell 9150 that runs the vision software supporting fine-grained tracking of limb positions. The limb-positions are communicated to the application machine feeding the four projectors. The Tracking Client can be switched to a mode, in which it uses a ceiling mounted wide-angel Creative webcam for coarse-grained tracking of body contours from above.

The iGameFloor supports sound through ceiling integrated loudspeakers and a subwoofer placed nearby.

The start-up/shut-down of computers and projectors is controlled by a Creston control panel on a wall close to the floor. The Creston panel also controls lighting and curtains. Having powered up the iGameFloor from the Creston panel, it can be fully controlled by body movement on the surface. A traditional keyboard and mouse is located on a nearby shelf ready to be used for editing purposes.

Software Architecture

The basic architecture is inspired by context-aware hypermedia architectures [2], but it is simplified to three layers: Server layer, client layer and a sensor layer as depicted in Figure 3. The essence of these layers will be described in the following section.

The Server layer

The server layer consists of a database, a web-server, and a FTP server. The FTP server is used for storing resources like images and sounds and the web-server is used to access these resources in the applications.

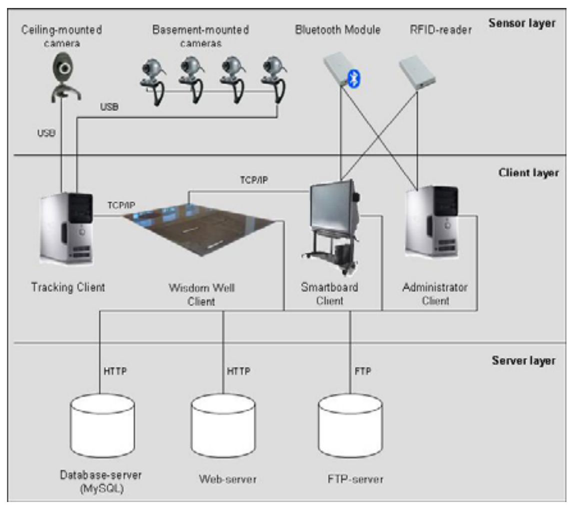

Figure 3: iGameFloor architecture

The database, implemented in MySQL, holds data and settings for the game applications and more general objects that can be referenced across applications like gaming themes, levels and digital resources. E.g. when a game is created in an application the user can choose what subject the game is for (e.g. Sport, Geography, Fashion etc.) and the level of difficulty for the children (e.g. from the 4th to the 7th grade). The creator of the game can also set permissions for other users in the system.

The Client layer

The client layer consists of a number of game applications written in Flash wrapped in a .NET application. The communication between .Net and Flash is done through the ExternalInterface API provided by Flash. In this way Flash can tap into the power of .Net for storage connectivity, user interface widgets and operating system integration while maintaining the power of Flash for 2D game development. The general UI object selection principle used is time-out based, e.g. standing on a UI object for some seconds makes it a selection, and sticking to a selection for a few seconds starts the invocation of an action. In the following we describe how to navigate between applications, how to administer content at a general level, and at an application-specific level. Finally, some of the game applications developed for the floor will be presented.

Navigating Using the Dashboard

To avoid the use of mouse and keyboard for controlling applications for the iGameFloor platform, a Dashboard has been developed. The Dashboard is capable of performing standard tasks like switching between applications. Further, it contains basic controls for the current application.

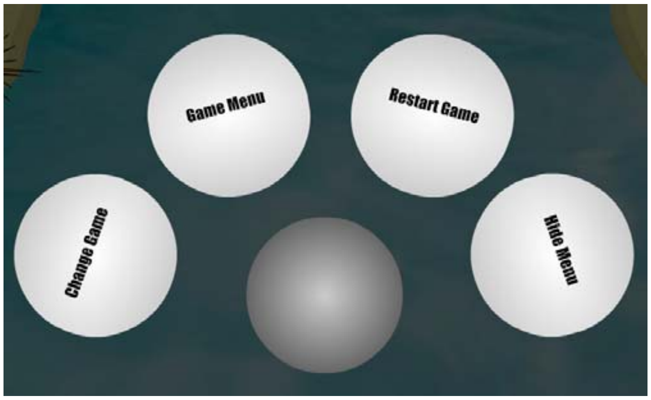

Figure 4: iGameFloor Dashboard for application management

Performing a three-step walk-sequence regardless of the current application running on the iGameFloor platform activates the Dashboard. A variant of a pie menu [6] will fold out and the user can now select which action to take. The following options are available: “Change Game” “Game Menu”, “Restart Game” and “Hide Menu”. When the “Change Game” option is triggered, another menu will fold out with other available games. If desired the Dashboard can also be available on a nearby SmartBoard for more detailed interaction with the applications, e.g. modification of game settings.

Administration of content is possible both at the physical installation and on a traditional PC, if the user has the suitable permissions. In general, new subjects, levels and users can be administrated using the application while content for the various game applications can be edited using their built-in editor.

The Sensor layer

The sensor layer in the iGameFloor platform consists of a ceiling mounted camera and four basement mounted cameras. The cameras track the locations of the users and send locations to the client game running on the floor. The ceiling mounted camera tracks the location of the users from above. More cameras could be added to improve the resolution but is not necessary in the current setup since one camera can track users on the entire floor. The basement mounted cameras also track the location of the users but do so by tracking the silhouette of the user’s limbs through the glass plates on the floor. The limb-based interaction technique is described in more detail in the following section.

Data from the cameras is sent to a tracking machine in the client layer that processes the data and applies an algorithm for giving the users identifiers between frames for use in the applications running on the floor. The algorithm compares the previous frame with the current frame of the camera input. If the two tracked limbs are within a specified number of pixels from each other, they are most likely the same limb and will thus be assigned the same identifier between frames. Otherwise the limb will be assigned a new unique identifier.

LIMB-BASED INTERACTION TECHNIQUE

One of the major findings in the iGameFloor platform is the use of the basement mounted cameras for tracking the user’s limbs and processes them as input to the applications running on the floor. The ceiling mounted cameras (known from iFloor project [11]) are well suited for moving along a ribbon around the projection, but they are not suitable when tracking the accurate position of the user in order to e.g. click a button on the floor. Another issue regarding the ceiling mounted cameras is that users are seen in perspective and not directly from above. This makes it difficult to separate multiple users' contours from each other. However, the ceiling mounted camera set-up is inexpensive and easy to apply for light-weight versions of the iGameFloor installation [11].

The limb-based interaction technique with tracking from basement mounted cameras offers a solution to these problems even though it is not as light-weight as the ceiling mounted approach. One of the main advantages in the approach is the elimination of the perspective problem (as mentioned above). The user’s limbs are in direct contact with the glass plates and only limbs in contact with the glass surface are tracked from below. The limb tracking occurs when contact points with the iGameFloor surface create a sufficient contrast from both the projection and the rest of the body. Limb positions are piped via TCP/IP to the applications. It is thus possible to hit a button in an application even though other users are standing close. Since only the center and not the contour of the limbs are being tracked the users are much less likely to disturb other users while interacting with the application. Figure 5 shows a user’s feet being tracked on the floor. The black circles indicate the center position of the user in the application and are accurate mappings of the location of the user.

Reliable real-time limb tracking

There are some conditions that need to be fulfilled for the system to track the user's limbs in a reliable way. One is calibration of the tracking software based on various factors in the environment like ambient light and shadows. Another demand is that the light from above the floor must be strong enough to reduce the light emitted from the projectors in order to give the required contrast on the user's limbs when standing on the glass surface. Tests performed in our installation set-up indicate that at least 300 lumen ambient light are required to obtain the desired contrast for tracking. Otherwise the dark areas in the projected interface will be tracked as input to the applications. This means the iGameFloor must be put in a controlled environment where the light on the floor is adjusted according to changes in the environment. A way to achieve this is to use indirect light on the floor since the reflection from direct light can be disturbing for perception of the iGameFloor.

When the system has been calibrated and adjusted to the light settings in the environment, it is robust and able to track multiple users accurately. Tests have shown that at least 40 limb contact points can be tracked concurrently on the floor though space is limited.

Figure 5: The black dots show the location of the user in the system and can be used as input in applications.

There are a few technical concerns in the system to be aware of when designing the game play for applications using the iGameFloor platform. One issue may occur when the user places limbs directly on the reflection from the projector lens in the glass. In this way the silhouette of the user's limb will be lighted up and cannot be tracked by the system. This means there are four dead spots in the current setup – one for each projector. Another issue for the game play of the applications is the current lack of identifiers for identifying individual players. Identifiers are relevant if the system was to keep track of the individual user's score. However, we have made collaborative gaming applications that get around the identification issue either by associating a location to a specific player or to make the game a complete collaborative endeavor for a group of players to solve a common mission. However, the identification issue is addressed in one particular application. In this application, we provide all users with a unique home base. This associates the user with a specific and limited part of the surface. Thus, a score can be related to interaction occurring on the particular selection of the surface.

SOCIAL GAMES FOR THE IGAMEFLOOR

Below, we present three initial examples of games built on the iGameFloor platform. The games were implemented on the platform to get a first hand insight into co-located collaborative gaming and entertainment in a physical and computational environment.

Pong

We implemented a well-known and very simple 'Pong' application (a classical videogame) on the iGameFloor. Originally, two participants play Pong - each controlling an interactive 'bat' on opposite sides of the TV screen. In the interactive floor version, the participants are placed in the opposite sides of the floor. A counter keeps track of the players' score and in parallel to the video game version, the player who first scores ten points has won the game.

Figure 6: Children playing 'Pong'. Three pupils are waiting in line to participate

Evaluating the Pong application with pupils on the iGameFloor, we discovered that the number of participants engaged in the game escalated dramatically. Children did play one against one, but oftentimes the number of participants was above six. At one occasion three pupils controlled the bat in each site simultaneously, at other occasions turn taking was brought into the game on their own initiative in order to increase the number of active participants in the game.

iFloorQuest

iFloorQuest is a floor game similar to the board game Trivial Pursuit. The objective of the game is to negotiate the right answers to a series of questions displayed at the iGameFloor. The game is intended for four participants, but as indicated above, the number of participants was often higher. If a correct answer is selected both the player and the team will score a point since there is both an individual and collaborative score. In this way players can both play with or against each other.

Figure 7: iFloorQuest in use with 8 players

When evaluating the iFloorQuest application in the school environments, we noticed that the negotiation aspect of the game play was extended to both players and spectators. Occasionally, the entire department square participated in the game. Observers were lining up in queues to take turn as active players. The collaborative aspect of the iGameFloor was significant.

Stepstone

Stepstone is a multi-player and co-located learning game that can be played with participants as a group aiming at a collective high-score, as group against group, or finally as individuals against individuals (up to four participants). By placing limbs at different 'stones', participants select the right answers to a question posed in the Stepstone application. As an illustrating example, the participants are exposed for a short segment of a Madonna tune and are encouraged to place their limbs on pictures of the instruments that are utilized in the Madonna tune. The Stepstone visualizes a number of 'correct' and 'incorrect' answers and the participant are awarded with points according to their number of correct and incorrect answers.

Simultaneous reactions and quick bodily action is required on the floor to answer the challenges in Stepstone. A challenge can be to construct a sentence, recognize and combine a pattern or object, recognize a sound and match it to objects or associations. The hypothesis is that the participants struggle to physically touch the right combinations of stones may help them memorize the results, since they were coupled to a fun bodily and intellectual experience.

Stepstone has a game editor in the left sidebar to allow teachers and children if allowed to edit the games (see Figure 8). The content is displayed in a tree-view where questions and answers can be created or edited. Games can also be previewed and played using the mouse to test the gameplay before publishing the game to the floor. The Stepstone editor can be operated either on the floor itself or in a Web-browser on a separate workstation. Thereby, the making of the game is integrated into the game itself. Observing the construction of Stepstone, questions and answers seemed to be entertaining in it self and – as proposed by teachers a learning experience.

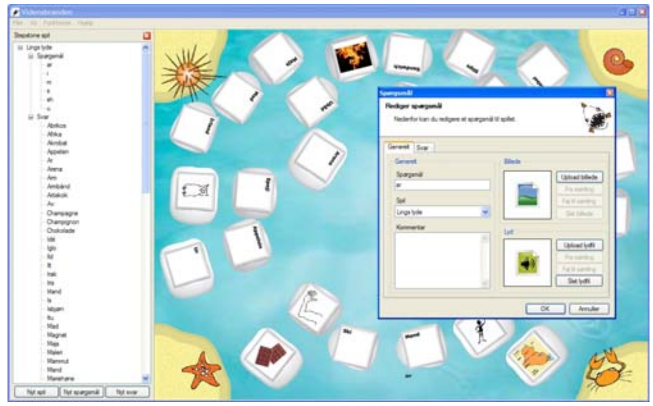

Figure 8: The Stepstone application. Content can be edited in game editor.

A variant of Stepstone has also been developed specifically for hearing impaired children, as described in [9].

EVALUATION OF THE IGAMEFLOOR

In the following, we describe qualitative lessons learned from the research and development phase. During the first months of the design project, participant observations of children's interacting on the iGameFloor were initiated. Preliminary analysis of the observations brought about some general hypothesis regarding iGameFloor applications and the iGameFloor in general. As regarding the applications, our analysis indicated that:

- The physical setting at the department square of the school with the large projection surface sets the scene for co-located collaborative gaming environments. Even though the games are intended for a fixed number of participants – e.g. two or four – many more children were incorporated in the game play.
- The iGameFloor applications provide the children with outlets for their energy that are neither countered in class nor by interacting with a traditional computer game environment.
- Children help each other throughout the game, negotiating game elements with each other to increase their common score. Thereby, the collaborative co-located setup initiates knowledge sharing and communication among the children.
- The fact that the children are able to construct their own games adds a dimension to the gaming experience. Preparing a game can be equally entertaining as playing the game.

Regarding the iGameFloor platform, our preliminary analysis indicates that:

- Children are able to interact with the iGameFloor platform using body movement as the only mean of interaction.
- Children were generally motivated by the use of bodily interaction and described the social games as 'fun', 'motivating' and 'a good playground'.
- Children assumed that they could interact with the iGameFloor using their feet as point and click/drag and drop. This observation calls for taxonomy of bodily interaction regarding interactive floor in general.
- Children required the computer to "be aware" of their gestures in addition to their foot and hand prints

COMPARISON TO RELATED WORK

This section gives a brief comparison of the iGameFloor to the two main categories of interactive floors.

BodyGames [9] and LightSpace™[4] are two sensor and tile based floors with abstract light diode feedback. Compared to BodyGames and LightSpace™ the iGameFloor provides a much richer visual multimedia feedback with better guidance on the activities undertaken.

Compared to the vision based iFloor system [11], the iGameFloor supports tracking of multiple users directly on the projection surface. iFloor only facilitated tracking on the edge of the floor. The iGameFloor also reduces the problems of shadowing the projection; since the projection comes from beneath the users' bodies do not disturb the projection except from what they hide with their feet on the surface. The iGameFloor also provides a much more fine-grained and precise tracking of users. The tracking is targeted to the contact points of limbs and not just the contour of the entire body as was the case in iFloor.

FUTURE WORK

We have developed the first iGameFloor, but we see many perspectives to the platform, and a few are described here.

A potential solution to the identification problem, for users moving freely on the floor, is to attach a kind of identifier to the user like a LED-light with a different color for each user similar to MultiLightTracker [18]. If the user interacts with both hands and feet this will involve marking up both hands and feet of the same user with the same unique color. The iGameFloor would then not be as walk-up-and-use-like as intended. Another approach to identification could be shape or visual tag tracking. E.g. it could be possible to distinguish users having a unique shape at their limb contact points. Another possibility using shape tracking could be to use different objects in the games like boxes used as obstacles or input devices in applications.

The difference between hands and feet could be detected in order to invoke different actions in the applications depending on which limb being in contact with the surface. Another potential is the use of gestures to interact with the application. One possibility could be the position of the user's feet to invoke certain actions. E.g. it could be possible to zoom in or scroll on a map below the user's feet.

Since the interaction techniques in iGameFloor, are new there is a need for a taxonomy of limb-based interaction. We will look into the interaction techniques applied in commercial entertainment products to address the standards applied here. However, the interaction techniques special to the iGameFloor platform will be essential in the development of novel iGameFloor applications.

[4] www.interactivefloor.com

CONCLUSION

This paper has introduced a novel gaming platform on a 12m2 interactive floor installation. The iGameFloor provides a high resolution floor display with rich narrative and interaction feedback potentials. The iGameFLoor platform also introduces vision-based limb interaction techniques based on tracking from the bottom of the interactive floor. Four cameras provide fine-grained tracking of limb (e.g. foot, hand, knee, and elbow) contact points. The setup allows real-time concurrent tracking of 40+ limb contact point, thus providing large scale multi-user interaction in an interactive space. Three initial social games for the iGameFloor platform were presented and evaluations indicated that the platform supports and stimulates co-located collaborative gaming with many participants. The games are collaborative and user identification is based on their location on the iGameFloor surface. Several new applications for the iGameFloor are under development, and applications are not limited to school environments – entertainment and experience environments like museums, attractions, and playgrounds or shopping malls are among the prospective application domains.

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REFERENCES

1. Bødker, S., Grønbæk, K. and Kyng, M. (1995): Cooperative Design: Techniques and Experiences from the Scandinavian Scene. In Baecker et al. (eds.) Readings in Human- Computer Interaction: Toward the Year 2000, Morgan Kaufman Publishers, San Francisco, USA, 1995.
2. Bouvin, N.O., Christensen, B.G., Grønbæk, K., Hansen, F.A. (2003): HyCon: A Framework for Context-aware Mobile Hypermedia. In The New Review of

Hypermedia and Multimedia (NRHM) journal volume 9. Taylor & Francis, Abingdon, UK. Pp. 59-88.

3. Djajadiningrat, T., Wensveen, S., Frens, J., and Overbeeke, K. (2004) Tangible products: redressing the balance between appearance and action. *Personal Ubiquitous Comput.* 8, 5 (Sep. 2004), 294-309

4. Fernström, M., Griffith, N (1998): Litefoot – Auditory Display of Footwork. Proc. of ICAD'98, Glasgow, Scotland

5. Gardner, H. (1993): Frames of Mind: The Theory of Multiple Intelligeces, 2nd Edition, New Your, Basic Books. In Britan by Fontana Press

6. Hopkins, D. (1991): The Design and Implementation of Pie Menus, in Dr. Dobb's Journal, Dec. 1991.

7. Ishii, H. and Ullmer, B. (1997): Tangible bits: towards seamless interfaces between people, bits and atoms. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (Atlanta, Georgia, United States, March 22 - 27, 1997). S. Pemberton, Ed. CHI '97. ACM Press, New York, NY, 234-241.

8. Iversen, O.S. (2005): Participatory Design beyond Work Practices - Designing with Children, Ph.D. dissertation, Dept. of Computer Science, University of Aarhus

9. Iversen, O.S., Kortbek, K.J., Nielsen, K.R., and Aagaard, L. (2007) Stepstone- An Interactive Floor Application for Hearing Impaired Children with a Cochlear Implant. To appear in proc. of IDC07 6th International Conference on Interaction Design and Children June 6-8, 2007, Aalborg, Denmark

10. Jessen, C., Nielsen, C.B., Lund, H.H. & Klitbo, T. (2004): Playing with Communicating Tiles. Third ACM Interaction Design and Children Conference, Maryland.

11. Krogh, P.G., Ludvigsen, M., Lykke-Olesen, A. (2004): "Help me pull that cursor" - A Collaborative Interactive Floor Enhancing Community Interaction. In proceedings of OZCHI, 22-24 November, 2004. University of Wollongong, Australia. CD-ROM. ISBN:1 74128 079.

12. Leikas, J., Väätänen, A. & Räty, V. (2001): Virtual space computer games with a floor sensor control: human centred approach in the design process. In: Brewster, S., & Murray-Smith, R. (Eds.) Haptic human-computer interaction: First intl. workshop, Glasgow, UK, Aug. 31 – Sept. 1, 2000, Proceedings. (LNCS; Vol. 2058) Berlin: Springer-Verlag. Pp. 199-204.

13. McCarthy, J., and Wright, P. (2004) Technology as Experience. MIT Press

14. McElliot, L., Dillon, M., Leydon, K., Richardson, B., Fernstrom, M., Paradiso, J. (2002): ForSe FIElds – Force Fields for Interactive Environments. In Proc. of Ubiquitous Computing 2002: 4th International Conference Göteborg Sweden pp. 168 – 175.

15. Merleau-Ponty M. (1945) Phenomenology of Perception translated by Colin Smith, (New York: Humanities Press, 1962) and (London: Routledge & Kegan Paul, 1962).

16. Moen, J. (2006): KinAesthetic Movement Interaction: Designing for the Pleasure of Motion, dissertation from KTH, Numerical Analysis and Computer Science, Stokholm, Sweden

17. Moen, J. and Sandsjö, J. (2005): BodyBug - Design of KinAesthetic Interaction, in Digital Proceedings of NORDES In the Making, Copenhagen, Denmark.

18. Nielsen, J. & Grønbæk, K. (2006): MultiLightTracker: Vision based simultaneous multi object tracking on semi-transparent surfaces. In proceedings of the International Conference on Computer Vision Theory and Applications (VISAPP 2006), 25 - 28 February, 2006 Setúbal, Portugal.

19. Paradiso, J., Abler, C., Hsiao, K., Reynolds, M. (1997): The Magic Carpet - Physical Sensing for Immersive Environments. Proc. of CHI' 97, Atlanta, GA, USA

20. Petersen, M. G., Iversen, O. S., Krogh, P. G., and Ludvigsen, M. (2004) Aesthetic interaction: a pragmatist's aesthetics of interactive systems. In *Proc. of the 2004 Conference on Designing interactive Systems: Processes, Practices, Methods, and Techniques* (Cambridge, MA, USA, August 01 - 04, 2004). DIS '04. ACM Press, New York, NY, 269-276.

21. Petersen, M.G. (2004): Remarkable computing: the challenge of designing for the home. In Proceedings of CHI'2004, ACM Press, pp. 1445-1449.

22. Rashid, O., Mullins, I., Coulton, P., and Edwards, R. (2006) Extending cyberspace: location based games using cellular phones. *Comput. Entertain.* 4, 1 (Jan. 2006), 4.

23. Richardson, B., Leydon, K., Fernstrom, M., Paradiso, J.A. (2004): Z-Tiles: building blocks for modular, pressure-sensing floorspaces. Extended abstracts of the conference on Human factors and computing systems

24. Shusterman, R. (1992) Pragmatist Aesthetics. Living Beauty, Rethinking Art. Blackwell.

25. Udsen, Lars Erik & Jørgensen, Anker Helms (2005): The aesthetic turn: unraveling recent aesthetic approaches to human-computer interaction. In Digital Creativity, Vol 16, No. 4, 205-216.

26. Valli, A., RETINA - video tracking software available at http://alessandrovalli.com/retina/ (2004-06-18)

27. Verhaegh, J., Soute, I., Kessels, A., and Markopoulos, P. (2006) On the design of Camelot, an outdoor game for children. In *Proc. of the 2006 Conference on interaction Design and Children* (Tampere, Finland, June 07 - 09, 2006). IDC '06. ACM Press, New York, NY, 9-16.