Human Sensing for Tabletop Entertainment System

Hafizuddin Yusof[1(✉)], Eugene Ch'ng[1], and Christopher Baber[2]

[1] IBM Visual and Spatial Technology Centre, do.collaboration, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK
hafizuddin.yusof@gmail.com, e.chng@bham.ac.uk

[2] School of Electronic, Electrical and Computer Engineering, University of Birmingham, Edgbaston, Birmingham B15 2TT, UK
c.baber@bham.ac.uk

Abstract. Tabletop displays are gaining interests in gaming environments. Computer Game in the genre of board games, competitive actions, real-time strategies are amongst those that are suitable for tabletop displays. Currently most games developed for tabletops use physical objects with markings as the controllers and standard touch and gestures as the inputs. To extend the present limits of gestures and touch, we present an implementation of high performance sensor-based input modality as an extension to tabletop displays. The additional input modality has the capability to sense and track users' bodies while they are interacting with the table. This paper outlines the configuration of the sensors, the tracking accuracy test result and informal evaluations of the system. We emphasise the simplicity of sensor configuration, cost, robustness and high performance in the design of tabletop sensor systems. To demonstrate the capability of our system, we developed a computer game "Body Pong" where each player controls a paddle assigned automatically to him/her by moving his/her position left and right. The game demonstrates how context-awareness adapts when number of users changes during game play.

Keywords: Human-aware · Tabletop · Games · Input devices · Interaction modality · Sensor · Proximity

1 Introduction

Entertainment systems designed in the present generation's tabletop computers consist of a horizontal computer screen or monitor and CPU unit. Players normally interact with the system via input devices such as the conventional keyboard and mouse, or with gestures and touch [9]. Players sit or stand around the table facing other players similar to traditional games played on a physical table. In this sense, tabletop systems are suitable for competitive or cooperative multi-player gaming [11]. Computer games in public entertainment outlets provide various interaction styles that involves body and limbs movements; these are dance mat, card based input and controllers such as joystick, gun, steering wheel, and etc. [9]. Tabletop entertainment systems however, are currently restricted to inputs from forelimbs such as hands, fingers and tangible

P.C. Vinh et al. (Eds.): ICCASA 2013, LNICST 128, pp. 283–292, 2014.
DOI: 10.1007/978-3-319-05939-6_28,

objects with markers. To explore research in tabletop interaction modalities, we investigated a new interaction technique that uses players' positional information around the tabletop. Our proposed system is aware of human presence and is able to track the number of users standing at proximity from the table, with accurate positional information for each user. Two pieces of information is available for game use:

1. The presence of a player at allocated spots.
2. The continuous body position of a player along its defined path on the table's edges.

This extended modality can potentially provide for new forms of player experience. In our experiments, we performed an accuracy test on the sensor setup to observe the optimum interaction envelopes around the table. This is presented in the later section of the paper. To demonstrate the robustness of the system, we developed a game application called "Body Pong" to evaluate the robustness, responsiveness, accuracy and smoothness of the application using the tracking system we developed. Body Pong is a tabletop game inspired by the popular classic Pong game. The plan was to demonstrate the capability of the table's tracking system by allowing a maximum of six persons to play simultaneously. In summary the game has the following features:

- The user's body (or torso) is the controller for the game. The paddle position derives its position directly from the user's body along the edges of the table. The paddle is always positioned at the front of the player.
- The game can have up to 6 players due to the size of the tabletop display (65" diagonal, 138 cm length and width of 76 cm). The game changes its state automatically depending on the number of players playing at the time. As an example, if two players are playing at the long sides of the table (Fig. 1), the game keeps scores only for each player. If a new player joins in on the long side of the table (say the left side), the game automatically divides the table's side into two equal sections and begins to keep the scores for the new player.
- The objective of the game is to collect as many points as possible by preventing the ball from hitting the edge of the table. Two scores are collected for each player: (1)

Fig. 1. Two players playing the BodyPong game. Dashed arrows indicate players' moving direction.

the reward points are awarded when the ball bounces off the paddle, (2) one penalty point is given when the player misses the ball.

2 Related Work

Tabletop gaming was mostly developed for multiplayer to encourage social interactions utilising the large display space it offers. It can be observed that multiplayer tabletop gaming has been a popular topic of research on tabletop since decades ago and we try to look at how sensing technology has been developed for tabletops to enhance users' experience when working on them.

2.1 Multiplayer Tabletop Gaming

Aside from information retrievals and educational applications in museums and public spaces [4, 5], tabletop games are increasingly becoming popular as tabletop displays becomes affordable. Social gaming experience can be improved with a tabletop setup that combines the advantages of a digital environment [15] and tabletops are generally well suited for games due to its similar setting with traditional board games [6]. Examples of tabletop game prototypes developed for tabletop includes False Prophets [16], Tankwar [17], Entertaible [10], Marble Market [13], PAC-PAC [9], RealTimeChess [6], Weathergods [2], Surface-Poker [7] and SIDES [18]. Existing digital tabletop games mostly use turn-based interaction as in traditional games where each player must wait before others have finished their turn. Our literature review reveals that there is very little research on synchronous interactions for tabletop games. This is unfortunate as the effects of simultaneous interactions can be used as an advantage to support good collaboration [12]. However we think that although the many aspects of simultaneous interactions is important, they may not necessarily be the most beneficial for computer games as they are for work. Synchronous interactions on a tabletop may be better executed if the system is aware of the identity of the users or at the very least, the number of users and their positions around the table.

2.2 Proximity-Aware Tabletop

Research in human sensing systems are not new [3]. There have been a number of developments in the sensing of human presence in tabletop human-computer interaction research. Here, we will briefly list these related developments. Bootstrapper [20] recognises users by their shoes. The table needs to be raised from the floor with lights fitted at the bottom of the table to allow the cameras to 'see' the shoes. A total of four Kinect sensors are used around the table to get the depth and color image of the shoes as a method of identifying the users. Others, such as Ewerling *et al.*'s system [8] detects and tracks the hands and fingers of users of a table. The system heuristically locates the positions of users around the table. The system however only suits tables with projection displays as it uses optical infrared cameras fitted at the back of the screen. Another vision-based tabletop systems named "See Me See You" [25] uses

Finger Orientation (FO) of the touch gesture to deduce the location of the user around the table. The system assumes that users perform touches with a certain angle of orientation and this is a known limitation of the system. Carpus [19] recognises users through the observation of the dorsal region of users' hands with a high-resolution camera mounted above the table. One of the limitations of the system is the difficulty of installation at places with high ceilings, mobility is another issue. Ewerling *et al.* [8], Zhang *et al.* [24] and Ramakers *et al.* [19] require users to perform touch gestures on the table before the system begins to locate users' positions.

DiamondSpin [21] was one of the earliest systems that tracked users' positions around a tabletop but requires users to be seated statically on a chair fitted with sensors. Tanase *et al.'s system* [23] tracks users with a very low resolution of five user positions on each side using twelve infrared (IR) sensors, three on each side facing away from the table's edges. Medusa [1] was constructed to sense users' presence and track users' positions around a tabletop using an array of 38, out of the total 138 IR sensors. The other 100 sensors are used to track the upper limbs (hands and arms) above the display. The cost and the crowded arrangements of sensors make it difficult to duplicate on alternate tables. A similar system, Klinkhammer *et al.* [14] uses a similar configuration as Medusa's but with an additional 58 IR sensors in order to achieve a higher resolution of user tracking).

3 Methodology: Human-Aware Sensor-Based Architecture

The proposed technique recognises users' positions when they are at proximity, along the edges of the tabletop display. The system continuously tracks user's position by sensing the torsos as they stand or move along the edges of the table. The sensors coordinate the body positions and stream the information to a separate game application via UDP sockets. Our tracking system is designed with simplicity, low cost, and ease of assembly in mind. A simple do-it-yourself (DIY) instruction is sufficient to have this tracking system attached to a tabletop display. Our experience showed that the system could be installed within an hour.

Our prototype setup was configured on a 65-inch multitouch table. The measurement of the table is 172 cm (length) × 108 cm (width) with screen's length of 138 cm and width of 76 cm. A total of 12 Sharp IR distance sensors are used, 8 of which are for medium range 10–80 cm (**2Y0A21)**, and the remaining 4 are for long range 20–150 cm (**2Y0A02)**. The reason for using two types of range sensors was to combine the optimum working distance from both types of sensors. All the sensors connect to I/O processing boards, **PhidgetInterfaceKit 8/8/8.** Figure 2 illustrates the sensors setup.

The algorithms for processing signals from the sensors are programmed in C# with the Phidgets library for Windows environment. Two Phidgets I/O boards (PhidgetInterfaceKit 8/8/8) are used to connect all the sensors. The eight medium distance IR sensors are connected to the first I/O board and the remaining four long range sensors are connected to the second I/O board. The sensors are sampled at 20 Hz and a simple Moving Average [22] filter was applied to the readings with a window size of 5 readings used to minimise noise and stabilise tracking. A Moving Average Filter was

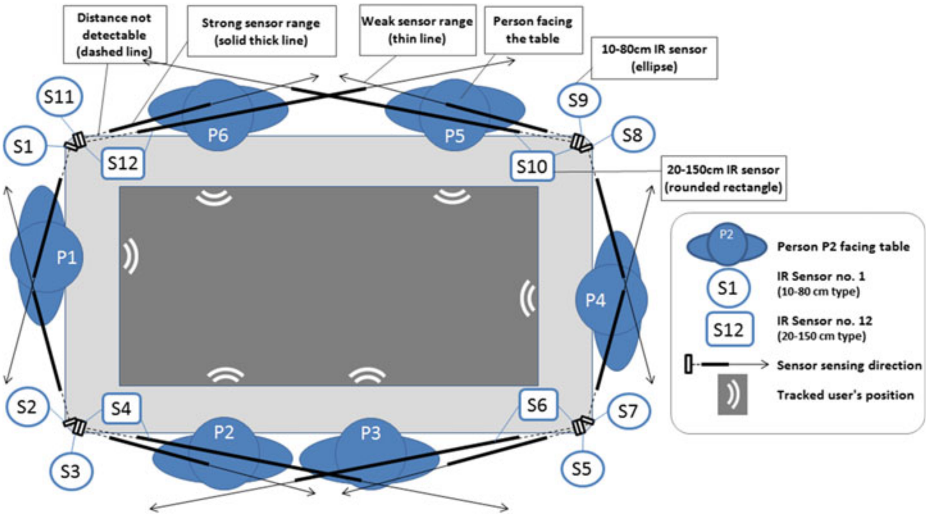

Fig. 2. Diagram shows placement of sensors around the table and range of sensing distance for each sensor.

found to give acceptable performance (compared to other more complex filters) and was used because of its simplicity. Window size of 5 is selected to maintain the responsiveness of the system while giving smooth and stable sensor readings.

4 Sensor Accuracy and Interaction Scenarios

4.1 Tracking Accuracy

We performed an evaluation test to measure the accuracy of body position when a user standing around the table. The purpose of this test is to find the ideal positions where users should be standing around the tabletop display to get the most accurate tracking. The floor parallel to the edges of the table is labeled with the white stickers separated by 5 cm horizontally, and 10 cm between the first row and the second, first row being the closest to the table's edge (Fig. 3).

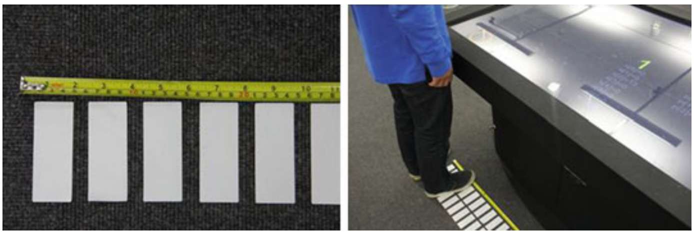

Fig. 3. Left: User positions spaced by 5 cm labeled with white stickers. Positions displayed on screen are recorded for each user position. Right: User is standing on one of the labels.

The test procedure is as follows: The user stood at the bottom left corner of the table at the start. The user is then asked to move right on the side by an increment of 5 cm each step. The accuracy of the positioning in relation to the markers is determined by visual inspection. If the tracked position matched exactly with actual user position, then “0” is recorded. If the tracked position was not showing at the actual position, then the offset (difference between the tracked position and actual user position) is recorded. For example if the tracked position shown on the table is 5 cm to the left from the actual user position, we recorded it as “5”. After the first round of measurement, a second test with similar procedure is measured. The user now keeps at a larger distance from the table, at 10 cm away from the table’s edge. This is iterated with a further 5 cm (to become 15 cm) distance in the third test. The final result of the accuracy test is given below (Fig. 4). The white area indicates the ideal positions where users should be standing to get the most accurate tracking positions.

We plotted a graph (Fig. 5) to show how accurate the computed positions were when compared to the actual physical body position on one of the table’s long side. The test confirms that the accuracy of the tracking system are robust when the distance

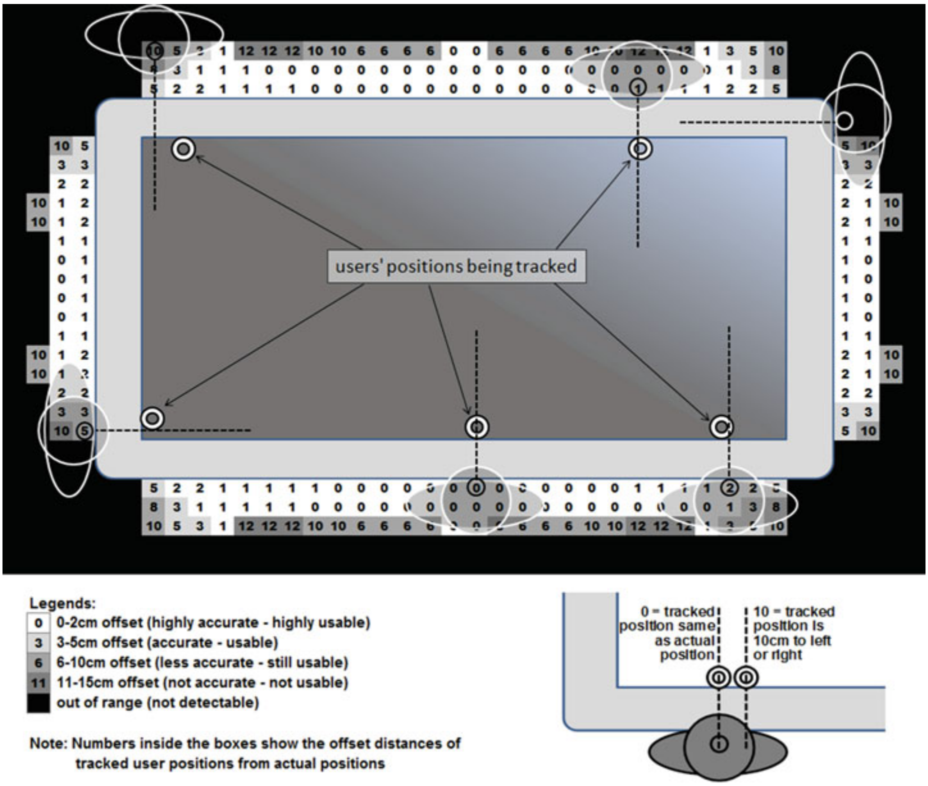

Fig. 4. Accuracy test results show the optimum and ideal positions (indicated by white area) where users should be standing when using the tracking system of the table.

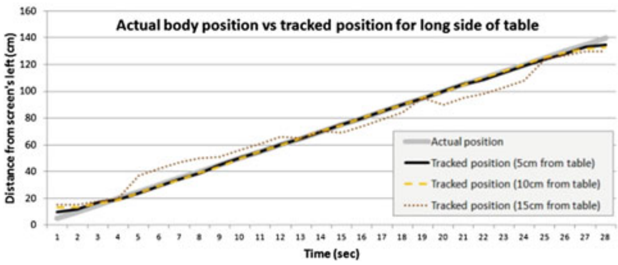

Fig. 5. Graph showing distance (recorded every second) of actual body positions versus tracked (computed) positions when user moves from left of table to the right.

between table's edge and the user is less than 15 cm. Tracking accuracy drops from a distance of 15 cm and beyond because of the design arrangement of the sensors.

4.2 Interaction Scenarios

In this section, we demonstrate the different scenarios of the human-aware sensor-based tabletop system using the game we developed. The table is programmed to allow six maximum players playing synchronously. Each of the players gets equivalent space partitions of the table when they play the game (Fig. 6: Top left).

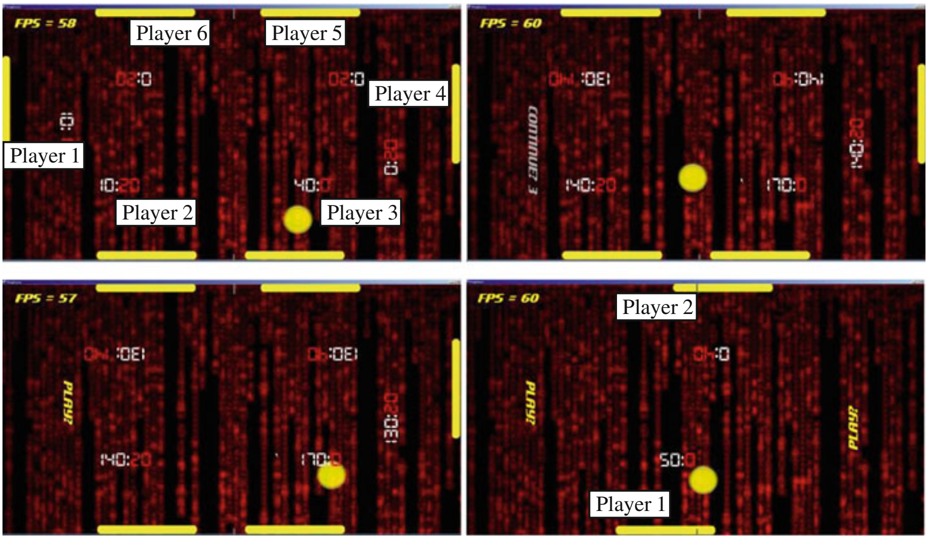

Fig. 6. (**Top left**): Six players standing around the table playing. (**Top right**): Player 1 steps back from the table, a "*Continue?*" message is displayed at his position. (**Bottom left**): 10 seconds has elapsed, a "*Play?*" message is displayed to invite new player to join. (**Bottom right**): Two players are playing. The game automatically keeps scores for Player 1 and Player 2 if there are two players playing, one on each long side of the table. The same applies if there are two players playing, each on the left and right of the table (Color figure online).

Individual scores are displayed in front of the player (Reward scores are coloured white, and penalties are red. ***10:20*** means 1 ball-paddle hit collected and 2 misses).

When a player joins the table, a new paddle is created and positioned in front and his/her score starts immediately. New paddles are created for additional players until the maximum of six is reached. Each player interacts with the game by moving his/her body left or right and the system reacts by positioning the paddle at the centre of the player's body position. The tracking is instantaneous and continuous throughout the gameplay.

If a player steps out of the game, the message "Continue?" prompts the player for action to continue the game with his current scores. After 10 seconds have elapsed the message switches to a "Play?" prompt that invites new players. Figure 6 illustrated some of the game scenarios.

4.3 Evaluation and Observation

Behaviours of the participants are observed from several informal tests where the game was demonstrated:

- The Heritage and Cultural Learning Hub's Open Day 2013 (28 people aged 20–50 years old)
- Birmingham Science and Art Festival 2013 (16 people aged 20–45 years old).
- CAKE (Collaboration and Knowledge Exchange) events at Chowen and Garfield Weston Prototyping Hall (11 people aged 30–45 years old).

4.3.1 Interactions

We found that the users' past experience with interaction modalities with touch-based interfaces were transferred. When visitors first played the game, there was a tendency for some to attempt to move the paddle by the touch even though they were briefed earlier on the body-movement interactions. A short period of time (2–3 min) were needed for them to get used to the new style of interaction. It was also observed that they moved around and seemed to use their hips as if they were 'hitting' the ball. Once they got used to it, excitement and discussions follow.

4.3.2 Subjective Evaluation (Participants' Responses)

All initial users were surprised at the new interaction modality and expressed excitement at the possibility of application areas. The responses were positive: "This is cool!", "This could be turned to an exercise game", "I want this game at my home", "This is weird, swaying my hip left and right like this, but it's pretty cool", "This is so much fun", "I wish I could have more time playing this", "This is very clever", and "Wow I like it!". Most comments were made by different people during their initial experience of the game and they played for approximately 3–4 min before moving on to check out other exhibits in the hall.

5 Conclusion and Future Work

In this article, we proposed a new interaction modality within the research area of human-aware systems. The proposed area of research attempts to extend the functionality of tabletop computers to modalities that are beyond touch gestures. We proposed a system that uses twelve low cost IR distant sensors attached to the corners of a tabletop display. Adaptive algorithm uses distance information to continuously track human body along the edges of the table and streams the coordinates of bodies' positions to other application via UDP. Our system when compared to existing systems uses minimal sensors but provides for maximum resolution and efficiency in user positional tracking due to our method of coupling sensors and algorithms.

This low cost setup has a simple configuration making it easy to implement and assemble on existing tabletops. We developed a game application using the tracking system and the system has been on display at several events such as University of Birmingham's Heritage and Cultural Learning Hub's Open Day 2013 and Birmingham Science and Art Festival 2013.

The implications of the robustness, reliability, accuracy, and cost effectiveness that we have demonstrated showed great potentials in the system's potential application in gaming, and also other areas that involve the personalisation of user experience in shared public spaces such as Galleries, Libraries, Archives and Museums (GLAMs).

Future work will involve the extension of the tabletop's spatial functionality to include a much larger context of sensing equipments for enhancing inter-table and inter-room interaction modalities.

References

1. Annett, M., Grossman, T., Wigdor, D., Fitzmaurice, G.: Medusa: a proximity-aware multi-touch tabletop. In: Proceedings of UIST 2011, pp. 337–346 (2011)
2. Bakker, S., Vorstenbosch, D., van den Hoven, E., Hollemans, G., Bergman, T.: Weathergods: tangible interaction in a digital tabletop game. In: Proceedings of TEI 2007, pp. 151–152 (2007)
3. Ballendat, T., Marquardt, N., Greenberg, S.: Proxemic interaction: designing for a proximity and orientation-aware environment. In: Proceedings of ITS 2010 (2010)
4. Ch'ng, E.: New ways of accessing information spaces using 3D multitouch tables. In: Proceedings of the Art, Design and Virtual Worlds Conference, Cyberworlds2012, 25–27 September 2012 (2012)
5. Ch'ng, E.: The mirror between two worlds: 3D surface computing interaction for digital objects and environments. In: Digital Media and Technologies for Virtual Artistic Spaces. IGI Global (2013)
6. Chaboissier, J., Cnrs, L.: RealTimeChess: lessons from a participatory design process for a collaborative multi-touch, multi-user game. In: ITS 2011 (2011)

7. Dang, C.T., Andr, E.: Surface-poker: multimodality in tabletop games. In ITS'10, pp. 251–252 (2010)
8. Ewerling, P., Kulik, A., Froehlich, B.: Finger and hand detection for multi-touch interfaces based on maximally stable extremal regions. In: Proceedings of ITS 2012, p. 173 (2012)
9. Fukuchi, K., Sato, T., Mamiya, H., Koike, H.: PAC-PAC: pinching gesture recognition for tabletop entertainment system. In AVI 2010, pp. 267–273 (2010)
10. Hollemans, G.: Entertaible: the best of two gaming worlds. MST NEWS **3**, 9–11 (2006)
11. Gerard, H., Bergman, T., Buil, V., van Gelder, K., Groten, M., Hoonhout, J., Lashina, T., van Loenen, E., van de Wijdeven, S.: Entertaible: multi-user multi-object concurrent input. In: Proceedings of the 19th Annual ACM Symposium on User Interface Software and Technology, pp. 55–56 (2006)
12. Isenberg, P., Fisher, D., Morris, M.R., Inkpen, K., Czerwinski, M.: An exploratory study of co-located collaborative visual analytics around a tabletop display. In: 2010 IEEE Symposium on Visual Analytics Science and Technology, pp. 179–186 (2010)
13. Kentaro Fukuchi, J.R.: Marble market: bimanual interactive game with a body shape sensor. In: ICEC'07 Proceedings of the 6th International Conference on Entertainment Computing, pp. 374–380 (2007)
14. Klinkhammer, D., Nitsche, M., Specht, M., Reiterer, H.: Adaptive personal territories for co-located tabletop interaction in a museum setting. In: Proceedings of ITS 2011, p. 107 (2011)
15. Leitner, J., Haller, M., Yun, K., et al.: Physical interfaces for tabletop games. Comput. Entertain. **7**(4), 1 (2009)
16. Mandryk, R.L., Maranan, D.S., Science, C., Inkpen, K.M.: False prophets: exploring hybrid board/video games. In: CHI 2002, pp. 640–641 (2002)
17. Nilsen, T.: Tankwar - AR Games at GenCon Indy 2005. In ICAT 2005, pp. 243–244 (2005)
18. Piper, A.M., Brien, E.O., Morris, M.R., Winograd, T.: SIDES: a cooperative tabletop computer game for social skills development. In: Proceedings of CSCW 2006, pp. 1–10 (2006)
19. Ramakers, R., Vanacken, D., Luyten, K., Coninx, K., Carpus, J.S.: A non-intrusive user identification for interactive surfaces. In: Proceedings of User Interface Software and Technology 2012 (2012)
20. Richter, S.R., Holz, C., Baudisch, P.: Bootstrapper: recognizing tabletop users by their shoes. In: Proceedings of SIGCHI 2012, pp. 2–5 (2012)
21. Shen, C. DiamondSpin: an extensible toolkit for around-the-table interaction. In: Proceedings of CHI '04 6, 1 pp. 167–174 (2004)
22. Smith, S.W.: The Scientist and Engineer's Guide to Digital Signal Processing, 2nd edn. California Technical Publishing, San Diego (1999)
23. Tănase, C.A., Vatavu, R., Pentiuc, Ş., Graur, A.: Detecting and tracking multiple users in the proximity of interactive tabletops. Adv. Electr. Comput. Eng. **8**, 2 (2008)
24. Zhang, H., Yang, X., Ens, B.: See me, see you: a lightweight method for discriminating user touches on tabletop displays. In: Proceedings of CHI 2012, pp. 2327–2336 (2012)
25. Zhang, H., Yang, X.-D., Ens, B., Liang, H.-N., Boulanger, P., Irani, P.: See me, see you: a lightweight method for discriminating user touches on tabletop displays. In: Proceedings of CHI 2012. ACM Press, p. 2327 (2012)