Wall Play: A Novel Wall/Floor Interaction Concept for Mobile Projected Gaming

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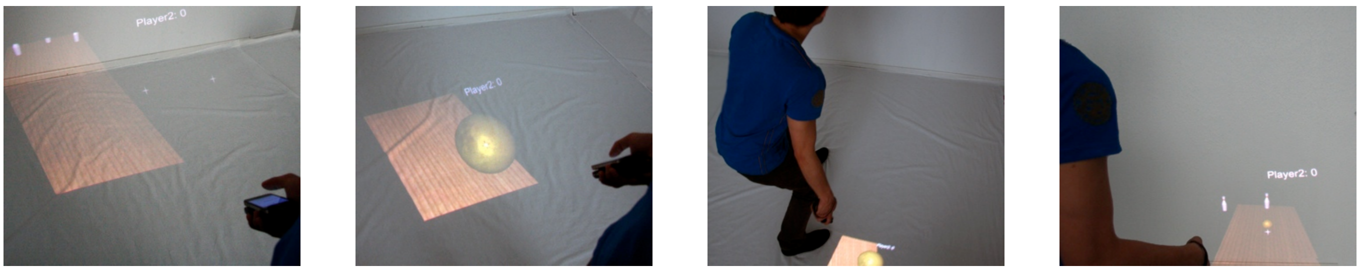

Figure 1: The steps of aiming, throwing, watching the ball and hitting pins.

ABSTRACT
Currently we see the emergence of the first commercial projector phones. Besides the standard use case of projecting media content, they are also promising as a platform for new types of mobile gaming. In this paper, we present a novel interaction concept for mobile projected gaming which leverages specifically a wall and the floor in the environment to provide a new type of semi-realistic augmented gaming. We discuss the challenges of the required sensing and present a preliminary bowling game prototype.

INTRODUCTION
Recently, more and more projector phones or accessory projectors that can be connected via TV-out to a conventional phone have become available. While the current marketing of hardware manufacturers mainly targets the broadcasting of media content from the mobile phone, projector phones also enable new types of mobile gaming as e.g. shown in [3,4]. An inherent advantage of mobile projections is their publicity, which enables both collaborative gaming [3] as well as to include real world objects into the game [4,5]. An inherent disadvantage of mobile projections however is their limitation to a usually two-dimensional projection surface which constrains its applicability by default to two-dimensional games. The use of anamorphous 3D projections, i.e. pre-warped images that only seem realistic from the user's point of view, can mitigate this to some extent. However, if the projected content does not completely occlude the projection surface, these projections may still not seem very realistic.

In order to create a more realistic gaming experience, our idea was to combine projected content on the floor and a nearby wall to create a novel interaction concept. It can enhance a set of games, which – from a player perspective – include a horizontal ground element and a vertical wall element.

We explain the novel wall/floor interaction concept in more detail by closely examining the gameplay of a bowling game. Then we generalize the concept by example of a mini-golf game.

BOWLING
In the bowling game (see Figure 2), the bowling alley is displayed on the floor. Aiming and seeing the result of the bowling ball hitting the pins requires the player to look at the pins displayed on the wall on the vertical plane. Using a mobile projection, we can show either parts of the horizontal plane on the ground or the vertical plane on the wall depending on where the user points the projection. This projection changes according to the location of the users hand and the orientation of the projector phone. It builds on the spotlight metaphor [2] and can be implemented using the built-in gyroscope, accelerometer

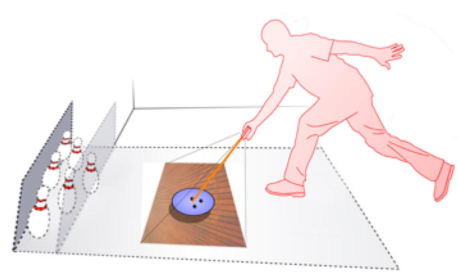

Figure 2: A user playing a bowling game which is continuously projected on the floor and the wall depending on the location and orientation of the user's hand.

and magnetometer to compute the orientation and movement of the projector phone.

For the ball, in contrast, we can use the MotionBeam metaphor presented in [4]. It virtually makes the bowling ball stick to the player's hand until it is released. Then the ball becomes part of the static part of the projection, causing it to run along the alley towards the pins. The following scenario (see Figure 1) shows the course of action in the proposed concept:

1. The user points the projector to the wall to see the (remaining) pins.
2. From there she slowly moves the projection together with her field of view along the alley to its start, just as in the preparation for throwing a real bowling ball. At the end of this step, she looks and points the projection downwards, seeing the start of the alley below her and the bowling ball lying on the ground.
3. Now she presses and holds down a button on the phone to pick up the ball. This button is easily accessible and is the only input mechanism used in the game aside from motion input. The bowling ball is shown bigger now and sticks to the middle of the projection. She winds up by moving the projector further back, thus showing the ball further behind her. Due to the wide angle of the projection, the start of the alley directly below her may still be shown to help with orientation.
4. While moving forward again, she releases the button – i.e. the ball – in front of her at the usual point when playing bowling. The ball drops on the alley and becomes part of the static projection, but at the same time has its own inherent speed with which it moves towards the pins. The speed was computed by inertial sensing of phone movement while holding down the button. In order to get usable results, the portion of the acceleration that comprises gravity is subtracted from the measured force.
5. After releasing the ball the user can now follow the ball along the alley until it reaches the vertical plane where the pins are positioned. The ball hits the pins. The user can continue with the next shot, i.e. aiming and then moving the projection to the start of the alley where the ball is waiting to get picked up again.

MINI-GOLF

The mini-golf game (Figure 3) mainly comprises horizontal and vertical elements as does the Bowling game. Winding up and shooting the ball happens in the horizontal plane. More difficult lanes include obstacles in the vertical plane the ball has to pass. Successfully mastering a course therefore can be divided into a sequence of horizontal lane and vertical obstacle parts.

During the concept phase, we opted to implement the bowling game we described before on a mobile device. The implementation using a handheld device posed some

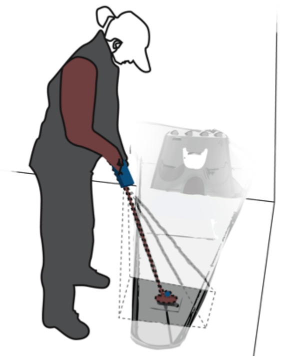

Figure 3: A user playing mini-golf. As in the bowling example, the lane leading to the obstacle is projected on the ground, the obstacle on the wall.

significant challenges which we will discuss in the next section.

TECHNICAL CHALLENGES

While developing the first prototype version of the proposed concept, we defined the following requirements:

Ground/Wall Alignment

For the user to experience the advantages of the added third dimension, the alignment of the game output has to fit the actual environment and transition between ground and wall quite accurately. We envision two different solutions to this problem: The first requires no additional hardware but lets the user do the calibration herself. By projecting two alignment pictures (Figure 4) on the top and bottom edge of the wall and measuring the angle of the device during the calibration, the distance to the wall can be estimated. If small hardware modifications are acceptable, two infrared or ultrasonic range sensors attached to the projector – one looking to the front, one to the ground – can measure the distance to the wall or to the ground respectively. Together with the known orientation of the phone, we can build a model of the environment to align and pre-warp the projected image accordingly. The idea of our Mini-Golf implementation was to make the camera follow the ball (position-wise) after each swing. This feature presents a whole new problem though. In our current prototype, we put the player at a fixed position in the virtual world and ask him to adjust his position in the real world accordingly. This is not possible when the distance between the virtual player and his virtual target changes after each swing. Also,

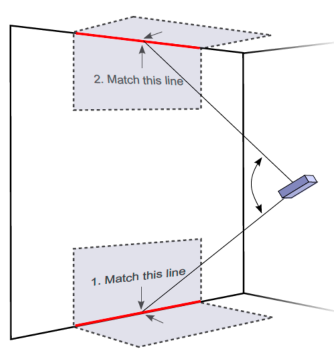

Figure 4: The user lines up two calibration pictures that allow the system to compute the distance to the wall.

Figure 5: The prototype hardware. An iPhone4 affixed on top of a SHOWWX+ laser projector, connected via cable.

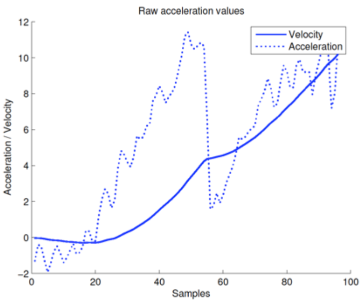

Figure 6: During the swing phase raw accelerometer values are logged and then integrated to compute the current velocity of the device which is applied as impulse to the bowling ball.

displaying several obstacles in a row on a Mini-Golf course could be difficult without losing the game's three-dimensional impression.

Position Tracking

Another major problem are the limitations of player movement in the current Bowling prototype. The player is stationary in the game, which means that he can turn, but he cannot move. Implementing small movements during a limited amount of time (like the in-game camera following the controller's movement during a swing) using accelerometer data would have been the limit in this regard. In a game like Mini-Golf, one would have to auto-place and –align the user for the next shot, which is a noteworthy limitation.

A first improvement would be to use range sensors, as described above. The accuracy and usability in more advanced situations depend on the number of sensors that are used. We proposed to use two sensors (at the front and on the bottom), lateral movement would be possible with optical flow tracking, but only in near-horizontal phone postures. The next step would be to use an in-door tracking system, which would also remove the need for dedicated range sensors. This approach would also allow for simpler design of multiplayer games, where not only the direction of view but also the player's position can be important to adjust the rendered picture.

Input

Another challenge poses how to give input to the system. The spotlight metaphor to reveal different parts of the virtual world, and the MotionBeam metaphor to move the ball or club, already provide a way of controlling the game. However, as they are always present, they do not allow giving input to the system that is independent from the virtual world. It is suited to perform the throwing gesture with the bowling ball for instance, but not for releasing the ball through an independent movement gesture. Hence, we need additional modalities to perform these kinds of standard game actions. The touchscreen and hardware buttons of the smartphone are still available for additional input modalities. However, one should take care not to use too many buttons on the device, as this might require many annoying context switches of the user between the projection and the device, which in turn may have the negative impact of frustrating the players.

IMPLEMENTATION OF THE BOWLING GAME

Hardware

We used an *iPhone4* connected to a *Microvision SHOWWX+* to build a first prototype of the described system. The *iPhone4* features 3-axis accelerometer, gyroscope and magnetometer, which are required for estimating the phone's attitude. The accelerometers yield the orientation against earth gravity while the gyroscope and magnetometer values can be fused to estimate the current absolute orientation around the earth's gravity vector. We have chosen the *iPhone4* platform also because of the fact that it provides a convenient way to control input and output on the mobile phone screen and the projection separately – a feature which is still not available on Android or other smartphone platforms.

The *SHOWWX+* projector from Microvision is a laser projector which renders the projected image always in focus. This is crucial for the presented ground/wall interaction concept, as even with an autofocusing non-laser projector system, ground and wall cannot be in focus at the same time.

As both devices are of roughly the same size, the projector can easily be attached below the phone to make the two devices appear as a single device (see Figure 5).

Software

The software has been developed in Objective-C using the iOS SDK and several libraries as described in the following. The main tasks of the software are:

- *Measuring the attitude of the system*. The iOS-SDK already provides the required libraries to perform these operations (e.g, CMAttitude).
- *Render the 3D scene according to the current attitude*. For 3D rendering, the Cocos3D engine[6] has been used. It provides a scene manager that manages the perspective transformations from the view camera. It also supports importing 3D models that have been created with the *Blender* 3D modeler, which we used to create the bowling model parts.
- *During the swing phase,* the linear acceleration of the device is logged separately and integrated over time from the start of the swing (pressing the touch screen) to the end of the swing (releasing the touch screen) for each axis (Figure 6). The resulting velocity vector is multiplied with the bowling ball's virtual mass and applied as an impulse to its representation in the physics engine.
- For *physical computations* we relied on the *Bullet* physics engine[7] which was favored because of its ease of integration. The bowling alley, the pins and the ball have been extended by a rigid physics body. Collisions are detected between these three components, which result in points for the player. No gravitational force is applied.

- *Help the user* orientating, identifying selactable objects, and providing feedback on user actions through orientation arrows, selection highlights and cursors (Figure 7).

After explaining our own concept, we want to present some related systems and games that were developed for use with handheld projectors.

RELATED WORK

This section will focus on mobile projected gaming. The Moject project [8], an abbreviation for "motion projection", enables users to project a section of the game world onto an arbitrary game surface. It uses the device's built-in motion sensors to accommodate for user input. Much like our proposed bowling game, it uses the MotionBeam-metaphor to enable the user to control a spaceship in a three-dimensional virtual world.

Yoshida et al. developed the game Twinkle[5] that lets players project a virtual character into the physical world. This character can interact with and react on objects that are drawn on a flat surface. Objects that can be interactive include simple lines, shapes (both solid and non-solid) and even natural elements like fire and water, which are detected by color.

Side-by-Side [3] developed by Willis et al. also uses a camera on its controller device. Here, the camera is an infrared camera that detects fiducial markers projected by an IR projector, which encode position and action that can be decoded by similar devices around. It is thereby well suited for multiplayer gaming.

Although the above projects are more mature than our presented bowling game, and in the case of Twinkle even infer more information about their environment, their projections are always rather independent from the projection surface and do not leverage the intrinsic advantages of different surfaces for the projected content like our game does.

One of the most impressive examples to date for handheld projectors interacting with the real world is the Augmented Projectors project [1]. This technology makes it possible for users to dynamically create virtual objects, like balls, that behave naturally and – to a certain extent – physically correct in the real world. It would be interesting to merge this technology with our proposed concept as it would allow, for instance, to play bowling with a real ball on virtual projected pins.

CONCLUSION

We presented a novel wall/floor interaction concept for mobile projected gaming; showed its usage via the games bowling and mini golf, discussed the involved challenges in terms of the interaction and the implementation and

Figure 7: Cursors, highlights, and orientation arrows help the user in the unusual game world.

demonstrated the first prototype of a projection based bowling game.

Our concept is one of the first that considers not only one plane in this context but which actively involves two planes. This provides significant advantages as we actually live in a three dimensional world and might be the starting point for other application areas taking advantage of more than one plane. However, to reach its full potential, especially if to be used in ad-hoc situations, we require a significant leap in mobile sensing of the immediate environment, both in the numbers of sensors provided by the phone as well as the sensors' accuracy.

In the future we will work on more elaborated versions of our prototype focusing mainly on the challenges raised by the inertial sensing and the interaction design.

REFERENCES

1. David Molyneaux, Shahram Izadi, David Kim, et al. Interactive Environment-Aware Handheld Projectors for Pervasive Computing Spaces. *Pervasive 2012*, Springer (2012).
2. Rapp, S. Spotlight Navigation: a pioneering user interface for mobile projection. *Proc. Ubiprojection 2010, Workshop on Personal Projection at Pervasive*, (2010), 4.
3. Willis, K.D.D., Poupyrev, I., Hudson, S.E., and Mahler, M. SideBySide: ad-hoc multi-user interaction with handheld projectors. *Proceedings of the 24th annual ACM symposium on User interface software and technology*, ACM (2011), 431–440.
4. Willis, K.D.D., Poupyrev, I., and Shiratori, T. Motionbeam: a metaphor for character interaction with handheld projectors. *Proceedings of the 2011 annual conference on Human factors in computing systems*, ACM (2011), 1031–1040.
5. Yoshida, T., Hirobe, Y., Nii, H., Kawakami, N., and Tachi, S. Twinkle: Interacting with physical surfaces using handheld projector. (2010), 87–90.
6. cocos3d « The Brenwill Workshop. http://brenwill.com/cocos3d/.
7. Bullet Physics Simulation. http://bulletphysics.org/wordpress/.
8. Moject | Motion Projection by D&A. http://moject.com/.