Haptic Feedback in Pervasive Games

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Abstract. Physical interaction is a key aspect of pervasive games. Although physical affordances are exploited, games are missing certain kinds of feedbacks on the interface and/or interaction levels: Haptic feedback in pervasive games is still an open issue. This paper discusses feedback in pervasive games. To illustrate the ideas, our work on Haptic Airkanoid, an extension to Airkanoid, is presented. Finally, the impact of the haptic interface is discussed and our early observations are highlighted.

1 Introduction

Pervasive games merge real and virtual elements offering a new interaction space fostering bodily action (compare Magerkurth et al. [1]). *Our bodies are what give us access to the experience of space in the first place, through our sensorium, nervous system and brain.* O'Keefe as cited in [2]. Feedback is an essential concept not only in computer games [3], but also for our physical interaction with the environment. Touch and physical interaction are among the fundamental ways in which humans understand the world and effect changes in it [4]. Haptic feedback therefore offers an advanced interaction concept for games.

Haptic feedback in virtual environments is manifold. For example, Lindeman and others investigated how vibrotactile feedback improves task performance [5]. Four kinds of feedback are identified, with two of them relevant: First, they can be used to provide a sense of virtual contact; and second it can be used to increase the overall realism of a simulation by improving the *user experience*. Haptic feedback in pervasive games is different. Whereas in virtual environments haptic feedback had to be explicitly created through technical devices, pervasive games offer an implicit feedback as well.

Following Nilson's discussion in [6] we'll take over their categories of game experience: A games **physical** aspect includes the physical feeling of playing the game, the physical skills a player must use, and the games use of physical artefacts. The **mental** aspect of a game concerns problem solving, deductive thought, and reason. The **social** aspect of a game is the way in which players play with each other. See [7] for a discussion if a high quality visual presentation can compensate for the missing physical proximity between players in shaping their social experience. **Emotional** concerns the way a game affects a player emotionally, by the sympathies they develop with game characters or players and the emotions brought forth by immersion in the game world.

The physical aspect of a game includes two aspects: Use of the real world as a gaming environment and/or use of physical objects for interaction. Examples of games using reality as an environment are: Pirates!, ARQuake and CanYouSeeMeNow?. Interaction is taking place in the real world using dedicated devices like PDAs and Joysticks. Games using physical objects as interaction elements are: STARS[8] and Airkanoid [7]. The STARS platform uses augmented reality technology to enhance traditional interaction in tabletop gaming. Players are represented using graspable models on the tabletop surface with the virtual game board. In addition, handheld devices are used for private communication between real players and for character configuration. In most cases the interaction space is limited to a room. An exception is CanYouSeeMeNow? which utilizes cite-wide gaming.

Tangible user interfaces in general provide multimodal feedback creating a deeper sense of "being" in control of the game. Especially through the use of real objects haptic feedback is implicitly provided, but this kind of feedback is not always directly related to game actions.

After introducing related work, the concept of Airkanoid is presented. Section 3 focuses on our ideas on haptic feedback. A final section highlights the conclusions and summarises the further development plans.

1.1 Related Work

Players like to get some bodily feedback, be it vibration, movement, or even electro shocks. Vibration feedback joysticks are widely used input devices in current games. Walters describes in [9] the technical background of haptics and games: i.e. mechanics, design, and programming libaries. The article is interesting as it shows the first steps of integrating haptics in PC based games. He concludes positively by stating: *Force-feedback devices are now readily available to consumers looking for good force response in their games.*

The *PainStation* [10], based on the all time favorite Pong, was developed by the German artist group fur. Instead of incrementing a virtual highscore, physical punishment (heat, electro shocks, and beats) is used. *Tekken Torture Tournament* [11] was developed by C-Level, an American group of artists. They modified the Tekken game and replaced the vibration functionality of the joypads with electro shocks. *Haptic Battle Pong* [12] is a pong clone with haptic control through the Sensable Phantom device. Force-feedback is used to haptically render the contact between the ball and the paddle. Although it povides force to the user it does not allow free bodily action because of the device's restrictions.

Jiang et al. [13] modified Half-Life and added force and vibration feedback. Their aim was to find out the effectiveness of feedback in a virtual reality training environment. The study concluded that haptic feedback plays an important role as it reduced the error rates of the players. In *Haptics Techniques for Media*

Control [14] Snibbe et al. describe a set of techniques for manipulating digital media with force feedback. Hayward et al. [15] provide an introduction to *haptic interfaces* and a summary of devices. A recent article from Salisbury et al. [16] surveys haptic systems and discusses some underlying *haptic-rendering algorithms*.

2 Airkanoid

Back in 1985 Taito released Arkanoid, an arcade game based on the Breakout idea. It is a ball-and-paddle game where you hit bricks in a wall with a ball. When a brick is hit, it disappears and the ball is reflected. When all bricks are cleared you advance to the next level. A user controlled paddle prevents the ball from getting lost.

Airkanoid[1] is a mixed reality remake. It takes over the main concept of bricks and paddles, but extends it with a more general and natural interaction style. Graspable Airbats are used as interfaces for controlling the virtual paddles. In contrast to Breakout and Arkanoid, the horizontal movement restriction is released. Bats can be moved up-down as well as left-right at any orientation. In addition Airkanoid is a collaborative multiplayer game for up to 4 players (two at each local site).

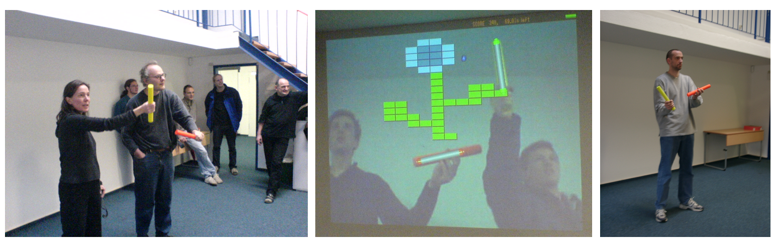

Fig. 1. Airkanoid: Two Airkanoid players with Airbats, the projected screen and one player with two bats simultaneously. Images taken at the Animotion Festival, 20.11.2005, Bremen, Germany

The most obvious difference is that the player is no longer sitting still in front of a computer screen. Instead he has to act in reality to control the game. The position and pose of the bat are directly mapped onto the virtual paddles. A player may even play with two bats at the same time (see Figure 1). The tangible AirBat allows a huge degree of freedom that can be exploited by the user. It utilizes a physical mapping: position and orientation of the physical object directly relate to the virtual bat. Therefore, it removes a level of indirection that occurs from mapping symbols of real devices (e.g. Joystick) onto virtual actions. Additional players can join the game on-the-fly as they only need another bat

[1] Airkanoid's Website can be found at http://www.e56.de/Airkanoid.html

Fig. 2. Airkanoid Photo Highscore

and the software does not restrict the number of players. In Airkanoid a bat made of rolled colored paper is a sufficient and working interface device.

2.1 User Comments

Airkanoid was showcased on several occasions including the Animotion Festival in Bremen. The overall feedback was very positive. Some remarks from the users:

- There is no feeling of the ball impact / A ball-bat-hit should have a noticeable sound effect.
- It was unusual that the ball was reflected at the bottom of the screen.
- More features (i.e. enemies, speed change) after some time.
- Airbats had the right size and weight.
- Highscore photo is a good idea (See Figure 2).
- Smashing of the ball would be nice to have.
- Extra points for speed were motivating.

One major improvement was the photo highscore which was very attractive for players. They tried to express themselves in the photos by being funny, acrobatic, or cool. Players were frequently looking at the images to see if someone they know is better than them. Last but not least, the highscore is published on the Internet combining the data from all showcases. It follows the idea of CanYouSeeMeNow? that used images of the real place where the player was caught to connect distant players with the town the game was played in.

3 Haptic Feedback

In his discussion on AR^{2}Hockey Nilson states: *Despite the fact that it was missing haptic feedback players were able to play it as naturally as in the physical game* [6]. The same holds true for Airkanoid. The graspable interface of Airkanoid provides an easy and convenient way to interact with the game although haptic feedback is missing. So why should we use haptic feedback?

Feedback in pervasive applications in general is different compared to mainstream computer games. Through the integration of the real world, new kind of concepts and possibilites are available. Bodily action itself offers a lot of feedback like touch, exhaustion, and sweat.

Following the interaction model introduced by Ullmer and Ishii [17] two different kinds of haptic feedback can be identified. The physical representation itself provides haptic feedback through the objects (also referred to as tokens) of the interface. Grasping a bat or a figure (e.g. in the STARS environment) creates immediate feedback through the body's sensory organs. In contrast, the digital representation alone is intangible. The focus is to provide feedback at the interacion level where physical objects and digital information are interacting. Airkanoid for example requires the players to hit a virtual ball with a graspable bat. When the ball is hit, a sound is played with the ball being reflected. Visual and aural feedback is utilized but the user does not feel the impact. Haptic feeback serves for two purposes: to bring in another dimension into the interface by simulating the impact and to create a stronger bonding between real objects and digital information. The following subsections are describing two different ways of improving feedback not only in Airkanoid but also in other games.

3.1 Sound

Sound is an important feedback channel. For example non-breakable bricks have a special sound associated with them that indicates that they are unbreakable. A simple and easy solution is to make use of bass sounds. Bass sounds have a special impact on the player. Psychoacoustics[2] distinguishes between:

- LOW BASS - 1st & 2nd octaves (20Hz to 80 Hz)
  Gives sound fullness and power: explosions, thunder, heavy traffic, dinosaurs.
- UPPER BASS - 3rd & 4th octaves (80Hz - 320 Hz)
  Sound produced from instruments like drums, bass, cello, tuba.

Low bass sounds can be felt by the player through his body. This fact is used to provide a hard hit that normally occurs in bat-ball-hits (i.e. in Tennis). Although the real sound of the impact may be at a higher octave this solution simulates the impact quite well but still misses the force aspect. The currently used sound for ball-bat-collision was not sufficient as it does not fall into one of the mentioned categories. A full and saturated bass sound brought us nearer to our goal.

3.2 Haptic

If a ball hits a bat we feel the rebound of the impact. Following Nathan's discussion on the physics of baseball [18] we know that hit energy is also converted into vibrations. Vibration is a practical and important way of providing haptic feedback to users. It requires a minimal interface design and has low complexity and cost. Nevertheless, the vibration bat can transform a reaction force –rising from a collision between the virtual ball and the (virtual) Airbat– into a real vibration torque.

[2] Compare Steve Donofrio: Psychoacoustics and the Grammar Of Audio, http://www.natf.org/documents/psycoa.pdf

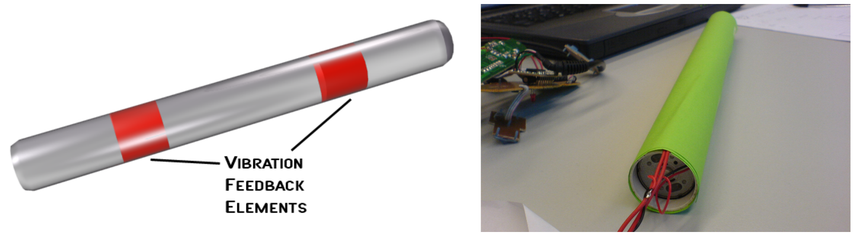

Fig. 3. New Airbat Concept and Prototype

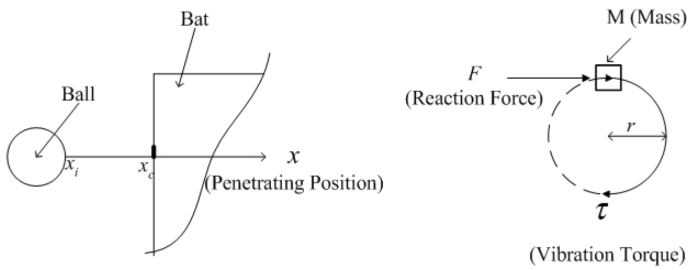

Fig. 4. Impedance Haptic Mechanism and the Transform from Force into Vibration

Figure 3 shows the concept of the modified Airbat. It contains two vibration elements to provide a sense of haptic feedback. Tracking the bat is still done optically to enable cordless interaction. This allows also a mixed configuration of the old and new devices with participants joining even using rolled paper bats. In the following paragraphs the physical foundations of our concept (force feedback through vibration) are derived.

Haptic interfaces in virtual environments have been intensively studied in the past decade. A distinction of haptic interfaces is their intrinsic mechanical behavior (compare [16]). Admittance type haptic is based on the principle of sensing force and generating position or velocity. It offers distinct advantages, such as high damping and stiffness display, particularly in applications requiring precise motion control. In the impedance type haptic, position or velocity is captured and force is generated. This kind of haptic is most common because it measures only position or velocity and does not require an additional force sensor.

The impedance haptic mechanism is used for calculating the reaction force of the bat. Reaction force F, which rises from a collision between the virtual bat and the ball, can be calculated by:

$$F = \begin{cases} K(x - x_c) & : \quad x > x_c \\ 0 & : \quad otherwise \end{cases} \tag{1}$$

Where F is the reaction force of the bat, K the average stiffness of the ball and bat, x_i the initial position, and x the behavior of the ball. Therefore, the key value of the reaction force-rendering algorithm is how far the ball has penetrated into the bat.

The haptic bat (Figure 3) contains two vibration feedback elements. The relation between penetrating position x and vibration torque of the motor τ can be described as: $\tau = M \cdot \frac{d\omega}{dt} + D \cdot \omega = r \cdot F = r \cdot K(x - x_c)$. Where M is mass, ω angular velocity, and D the damping coefficient of the motor.

The implementation is designed based on this model. A problem is that dt is high because the camera operates at 30Hz. Therefore we were not able to provide the high update rates that are normally required in haptic-rendering. Instead of measuring constantly the force F we are evaluating it only when a hit occurs. The calculated torque is scaled to match the DirectX interface and then sent to the motor to excite vibration.

3.3 Early Observations

Haptic Airkanoid is a work in progress. We informally evaluated the early protoype with students and colleagues in order to improve the design and implementation. We used a two player setting with an old Airbat and the new haptic version. Two rounds were played, switching bats after the first round. Afterwards, we interviewed them and asked them for their impressions of the game and the interface.

Feedback was very positive, and in addition many ideas of improving the interface were named. All participants agreed that it was more fun playing the haptic version. They mentioned that this version provides a more direct interaction scheme with the feeling of hitting the virtual ball. A negative aspect were the wires that restricted bodily movement too much. Nearly all players compared the feedback with real sport bats (i.e. tennis or table tennis) and stated that the vibration feedback is good but not realistic.

4 Conclusion

This paper focused on haptic feedback in pervasive games. It was discussed on two levels, interface and interaction, in relation to Ullmer and Ishii's model-control-representation model. Whereas haptic feedback is inherent in the interface, it is missing at the border between reality and virtuality. In Airkanoid the graspable Airbat provides haptic feedback to the user on the interface level, but there is no feeling of the ball impacting the bat while interacting with virtual objects.

Two approaches for providing feedback were introduced: use of low frequency sounds and vibration. In the first step, a deep and saturated bass sound made the impact more noticeable. In the second step, a haptic Airbat was developed with vibration for haptic-rendering. The second idea was play tested for early feedback from users. A common agreement between test players was that Haptic Airbat provides a greater sense of immersion. The feeling of the hit provided an additional clue beside sounds and graphics.

In conclusion, we think that vibration is an easy to use and very powerful feedback element that can also be applied to other games (i.e. baseball or tennis). Although it only provides a sense of haptic feedback, the performance of the interface is significantly improved. For the near future, it is envisaged to build a wireless Airbat for unrestricted body movement.

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