Running or Gaming

[*][1]Miru Ahn[−], [2]Sungjun Kwon[+], [3]Byunglim Park[−], [4]Kyungmin Cho[+], [5]Sungwon Peter Choe[+],

[6]Inseok Hwang[+], [7]Hyukjae Jang[+], [8]Jaesang Park[#], [9]Yunseok Rhee[&] and [10]Junehwa Song[+]

CS Dept.[+], GSCT Dept.[−], KAIST

Hankuk University of Foreign Studies[&], R1Solution Co., Ltd[#]

{[1]mrahn, [2]sjkwon, [3]blpark, [4]kmcho, [5]sungwon, [6]ishwang, [7]hjjang, [10]junesong}@nclab.kaist.ac.kr
[8]jspark@frevola.com, [9]rheeys@hufs.ac.kr

ABSTRACT

We developed Exertainer, a sensor-enabled, interactive running entertainment system to support advanced exercise applications. We designed Exertainer to be used in urban environments where outdoor running is often not convenient or practical; as such, Exertainer and Exertainer running applications represent an attractive alternative to traditional treadmill running. Exertainer effectively creates a robust design space around treadmill running. Developers can leverage Exertainer's components, an advanced treadmill called Interactive Treadmill, Sensor Bracelet and the PSD game platform, to design interactive and immersive running games and other advanced running applications. We also developed Swan Boat, a multiplayer team racing game making the treadmill running an exciting social activity, and conducted a user study.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces, J.4 [**Social and Behavioral Sciences**]: Sociology, B.4.2 [**Input/Output and Data Communications**]: Input/Output Devices

General Terms

Design, Experimentation, Human Factors

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1. INTRODUCTION

Recent progress in ubiquitous computing has brought new

[*]**Authors are listed alphabetically for the first three authors.**

opportunities to redesign characteristics of exercises and games, and to create new synergies between them [14]. Sensor technology can be considered a notable driving force which is rapidly leveling the separation between physical exercise and computer games. Those two activities, once clearly distinctive, are now sharing more and more of each other's characteristics.

We envision that, in the future, diverse advanced exercise applications will emerge, featuring much richer interactivity and more immersive game play. We propose *Exer*tainer, a sensor-enabled, interactive running entertainment system to support such applications. We expect Exertainer to be an effective replacement for traditional treadmill running. Although people can run in different environments, we target treadmill running since it is a common, convenient, widely deployed and safe way to exercise especially in urban environments. There is a large population of treadmill runners today, especially with growing attention to fitness and the obesity epidemic. While treadmill running is an easy and convenient choice of exercise, it reduces the fun of physical exercise, easily resulting in isolated, bland activity. Exertainer is designed to transform monotonous treadmill running into a highly interactive and social experience. The core of Exertainer to realize this design goal is Interactive Treadmill, an advanced treadmill with rich human- and application-interactivity. Exertainer also consists of runner-wearable Sensor Bracelets and Player Space Director, a game platform for supporting gestural interaction [12].

We developed Swan Boat, a pervasive game built upon the Exertainer, making the treadmill running an exciting, enjoyable social activity. Swan Boat is a multiplayer team racing game that uses hand and arm gestures as well as running itself as game inputs, while providing physical feedback such as variation in treadmill speed and incline. Swan Boat is also designed to facilitate intensive social interaction. For example, a high degree of coordinated collaboration between team-mates, i.e., runners in different treadmills in possibly different locations, similar to that in three-legged races, is required to steer their boat.

The rest of this paper is organized as follows: In section 2 we discuss the related works. Section 3 introduces our Exertainer system and elaborates on Interactive Treadmill as well as the other major components. In section 4 we discuss Swan Boat including the supported types of gaming interactions and the

intensive social collaboration we expect. Section 5 discusses the results and lessons from a brief user study we performed. Finally, we conclude our paper in Section 6.

2. RELATED WORKS

There have been a number of academic efforts to make monotonous exercises like running more enjoyable. Earlier works employed virtual environments to mitigate the tediousness of stationary cycling and help players become more immersed in the exercise [4][13].

The advance of ubiquitous technologies enabled wide adoption of sensory devices. Auditory feedback or stimuli are utilized along with sensed data representing the runner's performance. Nike+ iPod incorporates a pace-detecting sensor with a portable music player, giving real-time voice feedback about the runner's performance [9]. MPTrain stimulates the runner to help her achieve goals easier, by selecting and playing a song which may be effective for her current physiological condition such as heart rate and speed [11].

Measuring exercises and giving incentives accordingly could be a promising strategy to motivate people to exercise. Doing real exercises may be followed by some incentive in cyberspace ex post facto [1][3], or may trigger interesting effects on mobile devices or displays which is immediately noticeable by those who are exercising [2][8].

Computer games, powered by sensor technologies, are adopting new modes of game controls, particularly those requiring physical exertion and simulating realistic movements [10]. Recent studies have shown that the benefits from networked play of games featuring exercise could not only make the games more enjoyable, but also enhance social interaction among the players who are possibly geographically distant from one another [5][6][7].

Advanced pervasive applications require a sophisticated framework to continuously monitor users' contexts. There have been several contributions in this area [15][16]. Such works enable applications that proactively understand users' contexts and react appropriately.

3. EXERTAINER

Exertainer is an interactive running entertainment system for new exercise applications. It features intuitive interfaces involving the running pace, hand gestures and realistic feedback. Exertainer facilitates development and employment of various Exertainer applications that entertain treadmill runners. Figure 1 shows the architecture of the Exertainer system which consists of three major components: *Interactive Treadmill* with a built-in PC and networked connectivity, a pair of runner-wearable Sensor Bracelets, and PSD (Player Space Director). We developed Swan Boat as an example application running on Exertainer.

3.1 Interactive Treadmill

We developed Interactive Treadmill, a new type of treadmill distinguished by rich human- and application-interactivity. A runner on Interactive Treadmill continuously interacts with the treadmill; it detects the runner's position using an embedded ultrasonic sensor and adjusts its speed automatically to the

runner's pace. This feature allows the player to run naturally, rather than merely following the pace set by the treadmill.
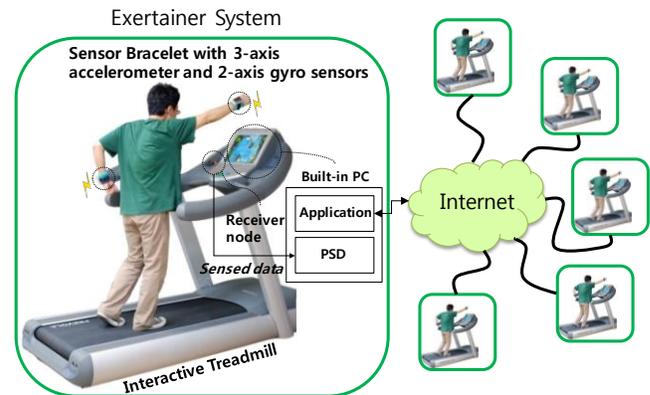

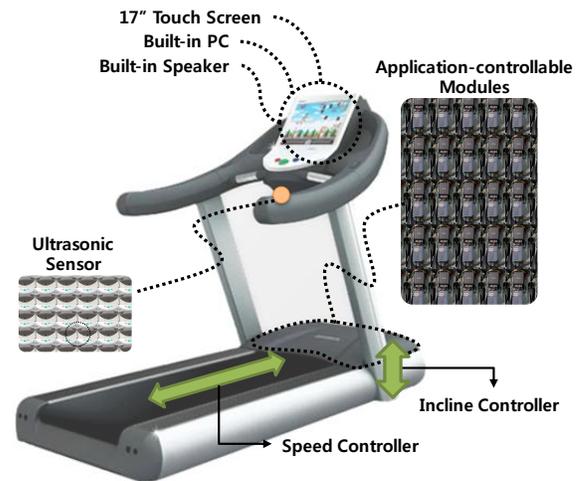**Figure 1. Architecture of the system**

Figure 2. Interactive Treadmill

Interactions with an Exertainer application also give realistic feedback to the runner. Interactive treadmill periodically reports the runner's information, including current speed, mileage, total calories burned and current incline, to the application. An Exertainer application actuates the incline or speed motors using application-controllable modules according to its application logic. (see Figure 2)

Interactive Treadmill contains a built-in PC which provides a programmable environment and network connectivity. Exertainer applications can be developed as multiplayer online applications with the support of network connectivity, PSD and the built-in PC. Interactive Treadmill is additionally equipped with a 17" touch screen and a built-in speaker.

3.2 Sensor Bracelet

Sensor Bracelet is a custom-designed wearable device where various types of sensors can be mounted. Figure 3 shows a Sensor Bracelet like that used with Swan Boat.

Each bracelet is equipped with a 3-axis accelerometer and a 2-axis gyro sensor to utilize player's gestural inputs such as punching, shaking, and flapping. These gestural inputs enrich the application's intuitive interface and improve the user experience.

We designed the sensor node hardware for Sensor Bracelet. It runs TinyOS as the operating system on an ATMega128L MCU. It supports various wireless network protocols including Zigbee and Bluetooth via the CC2420 RF module, Bluetooth module. We used an internal chip antenna so as not to interfere with bodily movement.

Figure 3. Sensor Bracelet

3.3 PSD, Player Space Director

PSD is a game platform supporting gestural interactions and facilitating the development and operation of diverse pervasive games. PSD can easily define a number of gaming interactions and interpret raw sensed data as those interactions. More specifically,

- PSD recognizes player's gestures, actions, and surrounding contexts and abstracts them as meaningful game state and input.
- PSD communicates with the game logic.
- PSD abstracts and manages a large number of heterogeneous sensors/actuators in pervasive game spaces.
- PSD delivers feedback from the game logic to the player.

Using PSD, we could easily experiment with a number of gestural interactions, and have identified that gestures using hands and arms, such as punching, flapping, and shaking, are most appropriate for Swan Boat. Further details of PSD can be found in [12].

4. SWAN BOAT

We developed Swan Boat fully utilizing the functionalities provided by Exertainer. Figures 4 and 5 show a team playing of Swan Boat and a screenshot of the screen seen by the players, respectively. Swan Boat is a racing game where teams compete against each other by collaboratively controlling the speed and direction of their boat using running itself as a main game interaction. Hand gestures are also used as input for additional game activities such as attacking opponents.

Swan Boat enhances the bland experience of running on a treadmill with rich social interaction among players, encouraging intensive collaboration with their team-mates as in three-legged races. The difference in speed between team members determines the direction of their boat, so if a team wants to steer their boat to port, the member in charge of that direction should

run faster than her teammate. A player continuously changes her running speed, to the degree of fine-tuning the speed of her individual steps to adjust to the running pace of her teammate; this is possible because of the speed of Interactive Treadmill is automatically adjusted to the pace of runners. She excitedly communicates with her teammate to coordinate the steering of the boat together. This kind of close synchronized interaction immerses the players in the game experience.

Figure 4. A team playing Swan Boat

Figure 5. A screenshot of the game display shown to the player in Figure 4

There are a number of game components to increase fun of Swan Boat. Runners may suddenly increase the extent of their interaction to change the direction of their boat to acquire or dodge special game items, like obstacle items that can slow down the boat. If weighed down by such an obstacle, the team members can both flap their arms like wings to get free of it.

Swan Boat promotes social interactions with other runners in distant locations over the Internet; players meet other runners of various skill levels and styles in Internet virtual communities, and make teams with them and compete against others.

5. USER EXPERIENCE

We conducted a two-week preliminary user study of Swan Boat with 11 university students and 6 professors. Before the test, each player answered a pre-test questionnaire to profile his/her usual exercise patterns and attitudes, such as favorite exercise, frequency, degree of affinity, and so on. During the first week, they ran on treadmills without Swan Boat. We used this information to construct the comparison basis including the distances and calories of their usual exercises. During the second week, they played Swan Boat. During the course of the whole

Table 1. Selected questions and the number of answers (DD: strong deny, D: deny, N: neutral, A: agree, AA: strong agree)

Question	DD	D	N	A	AA
Is Swan Boat more fun than just treadmill running?	0	0	0	8	3
Is Swan Boat easy to learn?	0	0	0	5	6
Is it dangerous to play games while running on a treadmill?	0	1	3	6	1

study, each player completed a form asking about their impression every time before and after every run. After the final test, we also had group interviews with four players in each group.

Table 1 shows selected results from user interviews. Many participants said that the interaction methods in Swan Boat were enjoyable and interesting. They even said that while playing Swan Boat, they became unaware of the passage of time. One participant said that he would be more motivated to run on treadmills if he could play Swan Boat. Our quantitative observations also supported the statements above. When just running without Swan Boat, participants ran or even walked at average speeds of 4~10 km/h. They, however, ran surprisingly faster while playing Swan Boat at 11~14 km/h for men, and 10~12 km/h for women. We even observed average speeds as high as 17~18 km/h from a few athletic participants. It is noteworthy that some participants raised safety issues. 7 of 11 participants agreed or strongly agreed that safety was a concern for the Swan Boat game. Future versions of Exertainer need to consider safety mechanisms, for example, by limiting the speed of running more conservatively while playing Swan Boat.

Several participants provided valuable comments about Swan Boat. One said that those who cannot run well would lose his or her interest in Swan Boat due to losing repeatedly, and suggested that if players are allowed to choose whether to play with a handicap or not, it would be helpful for beginners or slow players to enjoy the game consistently. Some participants also mentioned that they usually go to a fitness center alone, and that they normally run on a treadmill by themselves. Swan Boat allows players to play together via the Internet, and thus it can provide plenty of anonymous teammates required to play the game.

6. CONCLUSION & FUTURE WORK

We developed Exertainer, which is an interactive running entertainment system supporting advanced exercise applications. Exertainer's Interactive Treadmill, Sensor Bracelet and PSD platform together constitute a rich design space for developers of indoor exercise applications. We developed Swan Boat as an example application demonstrating how our system can support such new advanced exercise applications that incorporate intuitive input, realistic feedback and close collaborative social interaction. Our preliminary user study of our example application suggests that the capabilities supported by our system can be used effectively to develop engaging and exciting applications.

We plan to conduct larger and more extensive user studies in the future, as well as quantitative user studies to evaluate our Swan Boat example application and our Exertainer system.

In future work, we will address safety concerns by building in safeguards to the Exertainer system to help prevent any potential injuries. Finally, we plan to explore other applications for Exertainer. Existing alternative methods of exercise using traditional treadmills other than normal running, such as walking or jogging backwards, carrying dumbbells and jumping at regular intervals, suggest promising directions for diverse new games and applications.

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