Dungeons & Swimmers: Designing an Interactive Exergame for Swimming

Haechan Lee*
Dept. of Computer Science
KAIST
Daejeon, South Korea
haechan@nclab.kaist.ac.kr

Inseok Hwang
Center for Mobile SW Platform
KAIST
Daejeon, South Korea
inseok@nclab.kaist.ac.kr

Miri Moon*
Div. of Web Science Technology
KAIST
Daejeon, South Korea
miri.moon@nclab.kaist.ac.kr

Uichin Lee
Dept. of Knowledge Service Engineering
KAIST
Daejeon, South Korea
uclee@kaist.edu

Taiwoo Park
Dept. of Computer Science
KAIST
Daejeon, South Korea
twpark@nclab.kaist.ac.kr

Junehwa Song
Dept. of Computer Science
KAIST
Daejeon, South Korea
junesong@nclab.kaist.ac.kr

* The first two authors are listed in alphabetical order.

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Abstract
We propose *Dungeons & Swimmers*, an interactive audio- and motion-based exergame for swimming. As the first of its kind, we explore its design considerations and opportunities stemming from swimming. We gamify the four different stroke types with an auditory feedback. For minimal interference, we develop a single sensor-based wearable prototype detecting the strokes and stroke types in real time. We conduct a pilot deployment to study initial user experiences.

Author Keywords
Swimming; Exergame; Audio game; Physical activity

ACM Classification Keywords
K.8.0. Personal computing: General. Games; C.3. Special-purpose and application-based system: Real-time and embedded systems.

Introduction
Swimming is a widely played recreational and athletic exercise with a number of unique benefits, such as cardiovascular endurance and reduced risk of joint injuries. It has been reported that swimming is one of top 3 popular exercises in the U.K. [6]

The solitude and tediousness easily demotivate many casual exercisers to continue monotonous aerobic exercises such as running [10][12]. We find such a problem would be more intense in swimming. Common

practices like watching a TV in a treadmill running or doing exercise with close friends do not help much in swimming; even one cannot talk to a friend swimming just a couple of meters apart.

In this poster, we propose *Dungeons & Swimmers*, the interactive audio and motion based exergame playable along with swimming. To the best of our knowledge, it is the first attempt to design and develop an exergame for swimming. We believe the game to be an initiative extending UbiComp-enriched entertainment into an unexplored our daily life facet – swimming.

We first address unique challenges stemming from swimming; an exergame for swimming requires well-tailored interaction modalities and in-depth technical considerations for underwater whole-body exercise. Based on the design and engineering considerations, we develop Dungeons & Swimmers, an interactive exergame carefully designed and engineered to enrich swimming activity naturally and unobtrusively. We report our pilot user study results from the deployment.

Dungeons & Swimmers

Design Considerations and Technical Challenges

The notion of exergame has been enriching many monotonous exercises such as running [9][12], manipulating the original exercising motions (e.g., changing the speed [10]) or overlaying additive gaming motions (e.g. punching while running [1]). However, we first address that an exergame for swimming requires unique design considerations.

- **Little Rooms for Additional Motions.** Swimming inherently allows very slim motions to be altered or added for gaming input. Synchronous and continuous coordination of all four limbs, breathing, and the rest of body is crucial for the swimmer's balance and locomotion [8]. Interfering with such activities, e.g., requiring clapping in the water, may result in an abrupt stop or even falling into water.
- **Feedback Channels.** The available channels for feedback of gaming output to the swimmer are highly limited. Visual feedback would be only possible with specially engineered hardware such as display-embedded swimming goggles. Tactile feedback would be little receptive due to the water streaming along the whole body. Auditory feedback may be a feasible choice but still require empirical study due to the prominent water-splashing noise.
- **Wearability.** Wearable sensors are commonly employed in many exergames to monitor the player's exercising motions. However, designing a wearable device for swimming requires extra consideration regarding its impact on balancing, buoyancy, and water-resistance. In addition, all the devices must ensure waterproof.

Game Design

We design Dungeons & Swimmers, an audio and motion based exergame playable while swimming. In the game, the swimmer plays a blind warrior, fighting against a virtual dragon based on what she hears. Based on the design considerations above, we designed the key features of Dungeons & Swimmers as follows:

Stroke type and count-based design: Instead of requiring modifications in the original swimming motions, we leverage the four different stroke types – freestyle, backstroke, breaststroke, and butterfly – as a major variable for gaming input. We empirically studied that average amateur swimmers are well capable of swimming three stroke types (except butterfly) and changing the stroke type mid-swimming, while the butterfly is mostly the last one they master. These

Figure 1. A smartphone in a waterproof housing with an elastic belt; the earphone jack comes out through a hole caulked with silicon.

observations brought us an inspiration of a turn-based game; a game consists of three different turn-types – attack, defense, and heal. A single turn lasts for a one-way travel of the pool, and the swimmer changes the stroke type depending on the turn-type. Considering the higher level of mastery of butterfly, we adopt butterfly as an (optional) advanced attacking skill. Within a turn, the action of stroke adds points. The detailed game plays in each turn are as follows:

- **Attack turn**. A player can attack the dragon by swimming freestyle or butterfly strokes. One freestyle stroke gives 2 points of damage to the dragon. One butterfly stroke gives 10 points.
- **Defense turn**. The player should take a defensive position by swimming breaststroke. The dragon attacks the player by breathing fire at a regular interval. The player can minimize her damage by interlacing her own breathing with the dragon's fire; i.e., remain in the water upon attack and breathe otherwise. The dragon fires every 2.8 seconds by default but it is individually customizable.
- **Heal turn**. The player can heal herself as the dragon has disappeared in this turn. Swimming backstroke heals the player's HP most quickly.

Audio-based feedback: Using audio as a major gaming feedback has been explored to design accessible games for those with visual impairments [2][3][4][7]. A common feature of these approaches is to leverage the directionality of sound for 2D- or 3D-navigation. However, we empirically found that the water splashing noise is quite prominent in swimming, hindering the player from carefully perceiving the spatial origin of sound. Coordinating the synchronous motions over the whole body also diverts the player's attention from differentiating subtle changes in the sound. We thereby designed Dungeons & Swimmers to be a zero-dimension game [11] with no concept of navigation either horizontal or vertical. The essential interactions consist of attack, defense, and heal, with auditory feedback narrating the game progress and delivering sound effects.

Wearable device design for minimal interference: Wrist-type sensors are commonly employed for simple stroke counting purposes [5]. However, a single wrist-type sensor is insufficient to differentiate the stroke types. Wearing multiple devices may increase discomfort to the player as well as cause balancing or water-resistance issues. Moreover, a voluminous sensor at the far edge of the arm may quickly aggravate the player's fatigue due to increased moment of inertia.

Dungeons & Swimmers employs a single, lower back-mounted 3-axial accelerometer for the player's comfort and minimal interference. Unlike the arms, mounting a sensor at the lower back of the swimmer greatly suppress the increment of moment of inertia. Moreover, we investigated that a single lower-back mounted sensor is sufficient and reliable for real-time detection of each stroke as well as the associated stroke type. We elaborate the detailed implementation below.

Prototyping

We develop a prototype device as shown in Figure 1. The prototype includes an Android smartphone (Samsung Nexus S), a waterproof housing, earphones, and an elastic belt. The device is attached on the lower back of a swimmer using the belt. The game application runs on the smartphone, and we take advantage of the built-in 3-axial accelerometer for stroke detection.

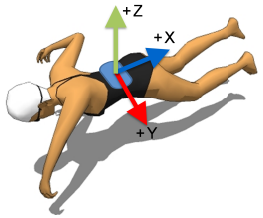

Figure 2. 3-axial accelerometer orientation with respect to the swimmer.

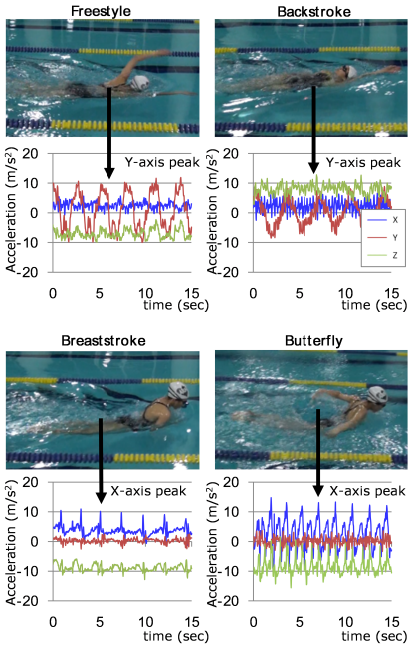

Figure 3. Snapshots of the accelerometer readings from four stroke types.

Single-sensor based stroke & stroke-type detection
We analyzed that each stroke from four different stroke types generates clearly differentiable signature in the accelerometer. Figure 2 shows the sensor orientations with respect to the swimmer's body. Figure 3 illustrates the snapshots of accelerometer readings from each stroke type.

Interactive feedback
To let players get senses that they are controlling the game through their strokes, we design the game to give auditory feedback, i.e., playing stroke type-specific sound clip, when the players stretch their arm forward. To do this, we additionally utilized gyroscope sensors in the smartphone to precisely detect the timing when the players feel that they are stretching their arms.

Pilot study

In order to evaluate validity of the game design, we tested the game play with 13 students recruited from a university amateur swimming club. All participants reported that the game is intuitive and enjoyable to play while swimming.

Conclusion and Future work

We have presented *Dungeons & Swimmers*, an exergame designed for swimming context, and supporting hardware. During the design, we identified swimming-specific limitations and opportunities, and carefully tailored a game using physical swimming actions and audio feedbacks. Through a preliminary user study, we evaluated validity of the early-stage design of the game. We are planning to design a multiplayer game based on the proposed game. To realize this, we are exploring underwater network communication in swimming context and working on designing details of the multiplayer game.

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References

[1] Ahn, M., et al. Running or gaming. *ACM ACE 2009.*

[2] Andresen, G. Playing by Ear: Using Audio to Create Blind-Accessible Games. http://www.gamasutra.com/resource_guide/20020520/andersen_01.htm

[3] Chion, M. *Audio-vision : Sound on Screen*. Columbia University Press. 1994.

[4] Friberg, J., and Gärdenfors, D. Audio games: new perspectives on game audio. *ACM CHI 2004.*

[5] Garmin Swim™, http://www.garmin.com/

[6] Jones, H., et al. Adult participation in sport Department for Culture, Media and Sport, UK. (2011).

[7] Miller, D., et al. Finger dance: a sound game for blind people. *ACM ASSETS 2007.*

[8] Morelli, T., et al. VI-Tennis: a vibrotactile/audio exergame for players who are visually impaired. *ACM FDG 2010.*

[9] Mueller, F., et al. Jogging over a distance between Europe and Australia. *ACM UIST 2010*.

[10] Park, T., et al. Transforming solitary exercises into social exergames. *ACM CSCW 2012.*

[11] Schell, J. The Art of Game Design: A book of lenses. Morgan Kaufmann Pub. (2008).

[12] Park, T., et al. Exerlink: enabling pervasive social exergames with heterogeneous exercise devices. *ACM MOBISYS 2012*