AwareCycle: Application for Sports Visualization Using an Afterimage Display Attached to the Wheel of a Bicycle

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Abstract. In this study, we define a method that allows the real-time presentation of a sportsman's physical status to an audience as the AwareSports concept. In particular, we focus on cycling to illustrate the AwareSports concept and develop an AwareCycle system to show the sportsman's status on the wheel, which has not been utilized previously as a display area for presenting the sportsman's status in real-time to the audience. We also implement an iPhone software application that is connected to the wheel component in order to monitor and display the sportsman's heart rate.

Keywords: Afterimage display, Bicycle, Cycling, Heart rate, Physical information, Sport-Augmented, Wheel.

1 Introduction

Recently, people have become more interested in watching and participating in various sports to improve their health. Alongside the popularization of mobile computing, some systems that log a sportsman's physical status (e.g., speed and heart rate) have been proposed[1, 2]. The detected information can be analyzed by users (sportsmen) and coaches to improve sports performance and strategy, as well as for motivating training. However, such information is usually presented to users (sportsmen) and their coaches. Thus, it is not utilized to provide real-time feedback to an audience. This might be beneficial because some sports are not only a means of exercise but also can be enjoyable to watch. Some services provide the sportsman's information to the audience by displaying additional information on a TV or PC screen. However, these types of projects require that the audience need to have a device (e.g., TV, PC and smartphone) for increasing the enjoyment while watching sports.

[1] http://www.nike.com/jp/ja_jp/c/nikeplus-fuelband (Nike+ FuelBand by NIKE Inc.).
[2] http://www.fitbit.com/jp (fitbit by Fitbit, Inc.).

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Again, sports might be more attractive to watch if the audience could observe the physical status of sportsmen during games. Thus, we focus on developing a method that facilitates the presentation of the actual physical status of a sportsman to the audience without any devices. In this study, we propose a new method for sports visualization, which represents aspects of a sportsman's physical status (e.g., position, speed, and heart rate) that cannot be determined simply by watching.

We define a method that allows the real-time presentation of a sportsman's physical status to observers as the AwareSports concept. As one possible example, we focus on cycling to illustrate this new visualization method, where AwareCycle displays a sportsman's physical status to an audience on the wheel of a bicycle, which has not been utilized previously as a sports visualization display area (Figure 1). LEDs are placed on the wheel, which allows its use as a display based on afterimage effects.

We also focus on the heart rate as a major indicator of the physical status and we implement a convenient smartphone software application that changes the contents displayed on the wheel based on the sportsman's heart rate. The heart rate is an important parameter in sports and it changes frequently [1]. For example, an analysis of various data related to each participant in the Tour de France showed that the heart rate differed markedly among subjects[3].

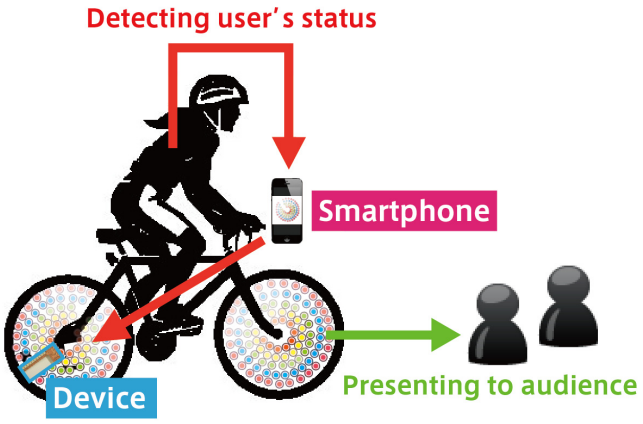

Fig. 1. Overview of the AwareCycle system

2 Related Work

2.1 Availability of Physical Information During Sports

As stated previously, human-computer interaction (HCI) studies have focused on log-based systems for detecting the physical status of sportsmen (users). They can detect and log the actions of users and then publish the data via web services. In addition,

[3] http://velonews.competitor.com/2013/07/tour-de-france/pro-power-analysis-stages-18-19-at-the-tour-de-france_296653 (Pro Power Analysis: Stages 18-19 at the Tour de France by Velonews).

some studies have employed the user's status data as a motivational tool in sport. For example, Mueller et al. proposed a system that allows long-distance joggers to listen to specific types of sound based on the heart rates of other people [2]. HeartLink [3] is a user system that collects real-time heart rate information and transmits this data online via the user's smartphone. The web audience provides feedback based on the data, which can be transformed into real feedback via vibrations of the user's smartphone. These projects are focused on providing feedback to the user (sportsman). By contrast, our method aims to display the physical status of the user (sportsman) to an audience in real time.

2.2 Methods for Presenting Sports to Audiences

Some projects attempt to make sports more enjoyable and meaningful by improving the realism of sport. Similar to our approach, some services provide information about sportsmen to an audience by displaying additional information on a TV or PC screen. Sportvision Inc.[4] is a visualization system that displays the speeds of yacht races on TV. Hallberg et al. also proposed a system that provides the real-time position status of sportsmen on the Web during cross-country races [4]. Nilsson et al. produced a system that detects the positions of players during basketball and ice hockey games using a portable PC [6]. However, these services require additional devices such as a TV or a PC to obtain the status of sports participants. In our method, however, the real-time physical status of a cyclist is displayed to the audience on the bicycle's wheel. Thus, we propose a new sports visualization method that represents the physical status of a sportsman, where the audience does not require a special device.

2.3 Application of Afterimage Displays

Similar to our method, some products are available (e.g., Monkey Light[5]) that embed an LED array on the wheel of a bicycle to augment cycling. Most of these products are intended to improve the aesthetics and design of cycles. By contrast, our wheel-type LED array can change the pattern displayed in a dynamic manner depending on the physical status of the cyclist.

3 AwareCycle

The AwareCycle system is based on the AwareSports concept and it has three main features.

3.1 Aims of the Presentation System

The visualization of a sportsman's status (i.e., the user's status) may have two main applications: (1) displaying information to the user while practicing and (2) display-

[4] `http://www.sportvision.com/` (Sportvision, Inc.).
[5] `http://www.monkeylectric.com/` (MonkeyLectric).

ing the user's status to an audience to enhance the realism of a sporting game. In the present study, we focused on the latter application, i.e., presenting the real physical status of a sportsman to an audience. Thus, we propose a new method for sports visualization.

3.2 Types of Information Displayed

In general, sports visualization comprises two main content types: (1) presenting data related to the game, such as the number of fouls in basketball and strikes in baseball; (2) presenting data on the individual status of each sportsman, such as their speed, heart rate, and level of perspiration. In the present study, we focused on the latter content. By providing information about the physical status of sportsmen during sports games, the audience may acquire original insights that enhance their appreciation while watching, such as: "*Does the lead runner still have enough strength?*" and "*Only a pro could do that! Even with a low heart rate!*" Our method can present the sportsman's status to the audience, i.e., the heart rate in the present study.

3.3 The Method of Presentation

Various methods have been developed for sports visualization. For example, some methods add information on the screen, such as by publishing the sportsman's information (e.g., position) on the Web. Thus, these methods display information on the screen of a TV or PC, so the audience must use a device such as a smartphone even if they are in the stadium. However, the major events in games may occur within the space of a few seconds and the use of a device may be a burden that spoils the enjoyment for the audience. Therefore, our proposed sports visualization method detects and displays the sportsman's status without any special device, simply by using the bicycle's wheel as a display unit.

4 Implementation

As shown in Figures 2 and 3, the system comprises the wheel part (the main circuit board, the reed switch and the battery) on the wheel that displays the sportsman's status, a heart rate monitor on the sportsman's chest, and an iPhone, which is connected to the main circuit board and the heart rate monitor via Bluetooth 4.0.

The user fixes the box that contains the main circuit board, the reed switch and the battery onto the wheel and wears the heart rate monitor on the chest. The user activates the AwareCycle's iPhone software application to connect with the main circuit board and the heart rate monitor via Bluetooth 4.0. When the user starts cycling, the reed switch on the wheel detects its rotation and the LEDs on the main circuit board attached to the wheel flash to display the user's heart rate status (Figure 4).

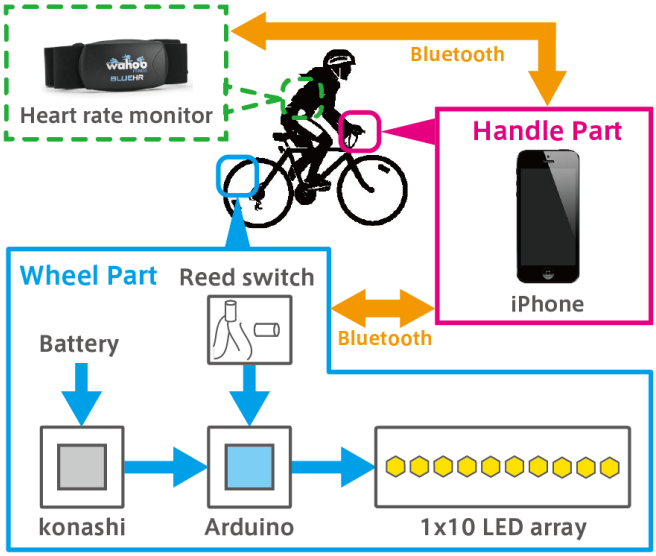

Fig. 2. System configuration

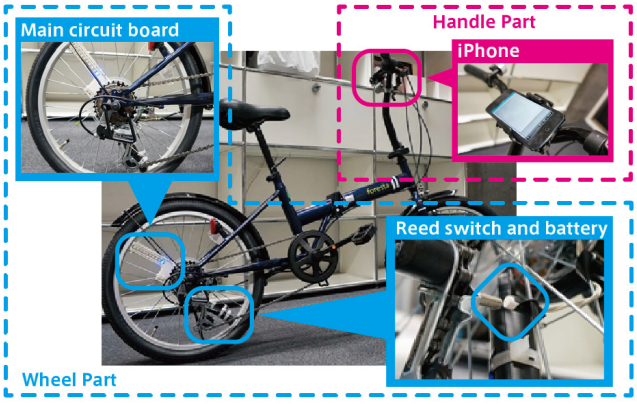

Fig. 3. Prototype system installed on an actual bicycle

4.1 Wheel Part

The main circuit board on the wheel comprises a reed switch, 10 full-color LEDs (LED array), two microcomputers (Konashi[6] and Arduino Pro Mini[7]), and a battery, as shown in Figure 5. The reed switch is fixed on the frame adjacent to the wheel by a magnet and it is used to detect the rotational speed of the wheel, thereby measuring

[6] http://konashi.ux-xu.com/ (YUKAI Engineering Inc.).
[7] http://arduino.cc/en/Main/ArduinoBoardProMini

the speed of the bicycle, and to control the LED display timing. The LED array, Konashi, and Arduino are fixed to the main circuit board. The main circuit board has multiple holes to fix to the wheel using cable ties and is housed in an ABS (acrylonitrile butadiene styrene) resin box with holes. The LED array is perceived as a circular display because of the afterimage effect created by the rotation of the wheel. Thus, full-color images can be displayed within the 24-inch diameter of the wheel (Figure 6). Konashi has a tool kit that can be controlled by the application on the iPhone and it connects to iPhone on the handle via Bluetooth 4.0. Konashi sends the sensed data (the measured rotational speed of the wheel) to the iPhone and it also sends operation commands to the Arduino Pro Mini via serial communication at the same time. Each full-color LED on the LED array can be controlled individually by Arduino pro Mini.

Fig. 4. Basic usage

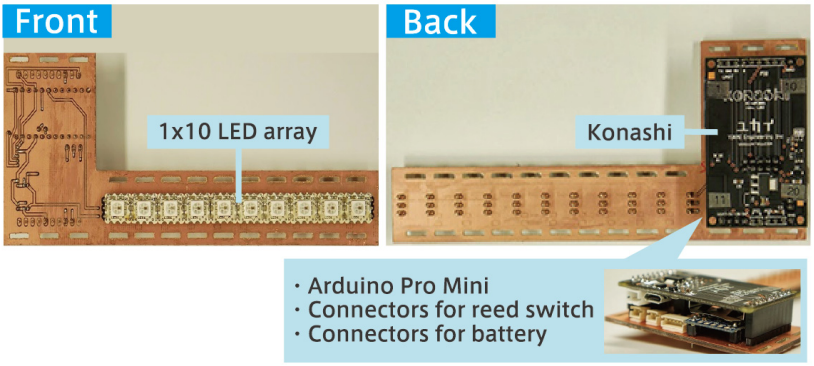

Fig. 5. Main circuit board

Fig. 6. Full-color image displayed within the 24-inch diameter of the wheel

4.2 Heart Rate Monitor

In the present study, our prototype used a heart rate monitor produced by Wahoo[8], which is worn on the chest by the user. The heart rate monitor is connected to the iPhone via Bluetooth 4.0. Using Wahoo's API, an iPhone app was written in Objective-C to allow the display of the sportsman's (user's) heart rate on the wheel.

We tested four types of visual pattern for displaying the heart rate: (A) numbers, (B) heart symbols, (C) a vertical bar graph, and (D) a horizontal bar graph (Figure 7). The each pattern changes based on the cyclist's real heart rate.

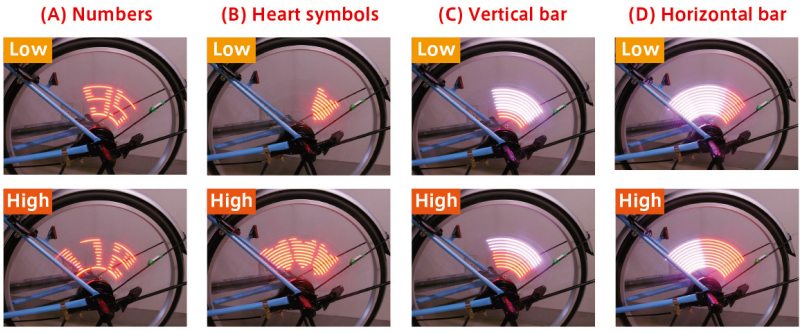

Fig. 7. Four types of visual patterns used to display the heart rate

[8] `http://www.wahoofitness.com/` (Wahoo Fitness).

5 Evaluation

To assess the performance of the AwareCycle system, we conducted an evaluation in the university grounds on a sunny day at 13:00. We recruited four subjects (women aged in their 20s) who observed the different displays on the wheel. One of the authors wore the heart rate monitor on her chest, which was connected with the AwareCycle's devices, and she cycled around the subjects 36 times (distance from the observers = radius 5 m × 12 times, radius 10 m × 12 times, and radius 20 m × 12 times). The system displayed four different visual patterns, each on three occasions. The percentages of correct answers at each distance were 80% at radius = 5 m, 81% at radius = 10 m, and 66% at radius = 20 m. This evaluation was limited but it helped us to assess the system's performance, which was better in the dark (in the evening and at night).

6 Discussion

6.1 Application to other Sports

In this study, we focused on cycling as an example of the AwareSports concept, but this method could be applied to other sports. However, the sportsman would have to wear an addition device to display their status in sports that do not utilize equipment (e.g., swimming and running). Although the application of the AwareSports concept has various limitations, we consider that the AwareSports concept has other applications in addition to cycling.

6.2 Comparison with other Visualization Methods

During the sports that do not need special equipment (e.g., swimming and running), other visualization methods, such as AR technique, are considered for displaying information. However, the methods require that the live audience watch sporting events through devices such as a smartphone. By embedding the device on the sportsman's equipment (a bicycle in the present study) and using it as a display, our system can present information to an audience without requiring any devices.

6.3 Reducing the Additional Weight Burden for the Sportsman

In the present study, the device was attached to the wheel of a bicycle. Therefore, it is possible that the speed of the cyclist would be reduced due to the additional weight of the device. Thus, to reduce the moment of inertia, we placed the heaviest part of our device at the center of the wheel. We aim to make further improvements, however, such as developing a lightweight device.

7 Conclusion and Future Work

In this study, we proposed and developed a sports visualization system, AwareCycle, which detects the physical status of a cyclist (i.e., heart rate) and displays this information on the wheel using a device attached to full-color LEDs. In our future research, we plan to improve this system by allowing the visual pattern to display further aspects of a sportsman's status and by making the device waterproof. We also plan to evaluate this device in a real environment. Our system includes a smartphone, which means that is connected to a network; thus, we aim to develop an application for multiple users. We will also explore the application of this concept to sports visualization in other sports.

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