SwimSight: Supporting Deaf Users to Participate in Swimming Games

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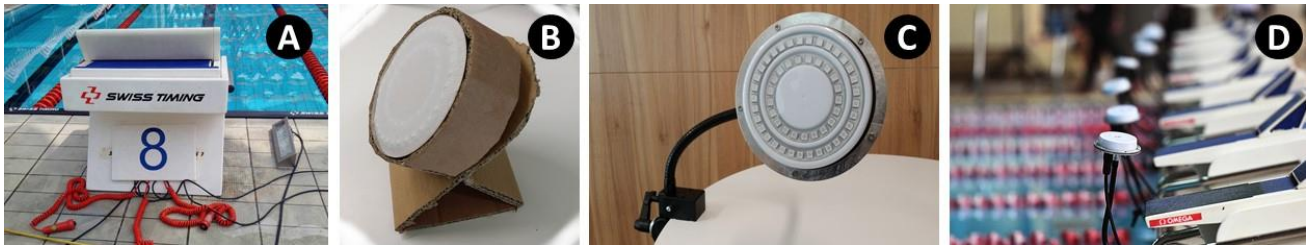

Figure 1. (a) Existing solution, (b) proof of concept prototype, (c) final design, (d) in use at national deaf games

ABSTRACT

We believe sport should be more inclusive, and assistive devices deserve more design and innovation. In this paper we present *SwimSight,* a start time indication system for deaf swimmers that overcomes the limitations (inappropriate feedback, cumbersome) of existing solutions. Specific features such as providing appropriate feedback and compatibility with existing professional timing systems differentiate *SwimSight* from existing state-of-the-art solutions. We discuss the design goals, implementation, and deployment of *SwimSight* in a national deaf swimming competition.

Author Keywords

Information visualisation, Assistive Technology, Deaf

ACM Classification Keywords

H.5.m. Information interfaces and presentation

INTRODUCTION AND RELATED WORK

In sports competitions '*On your mark*', '*Set*', and '*Go*' represent different stages of mental and physical preparedness of getting alert and ready. Current professional timing systems for swimming and track and field are primarily designed to provide auditory signals to athletes. These timing systems sometimes come with a single LED that flashes for the '*Go*' signal. However, athletes with hearing impairments need additional visual indicators to provide complete mental and physical preparedness given by '*On your mark*', '*Set*', and '*Go*'. Visual cues provided by existing systems are often not sufficient, as they do not provide athletes with the necessary mental and physical cues to ensure they are alert and ready. Thus, in competitions like swimming, athletes who have hearing impairments find it difficult to participate. Such systems do not only affect the performance of the swimmers, but violate the very right to participate in recreational activities without limitations[1].

Prior work investigated visual representation of sound for deaf people across different environments. For example, *StickEar* by Yeo et al. (2013) features a distributed set of network-enabled sound-based sensor nodes. It converts a door knock into a visual signal that can be easily identified by a person who has a hearing impairment. Ho-Ching et al. (2003) developed two visual displays to provide awareness of environmental sounds such as ringing phones and knocking in a work environment for deaf individuals. Similarly, Matthews et al. (2005) have investigated peripheral visual displays to help deaf people maintain an awareness of sounds in their environment. A mobile application to analyze audio context and issue visual and tactile alerts has been developed by Ketabdar et al. (2009). This application was designed for deaf or hard of hearing people to be alerted of audio events happening around them. Matsuda et al. (2014) developed a luminous device for deaf people that converts non-speech audio information into visual information, providing the direction of the sound source by using a light. Harrison et al. (2012) discuss the viability of using small point lights to convey different type of information.

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[1] Section 504 of the Rehabilitation Act of 1973. Available at www.dol.gov/oasam/regs/statutes/sec504.htm. Accessed October 16, 2016

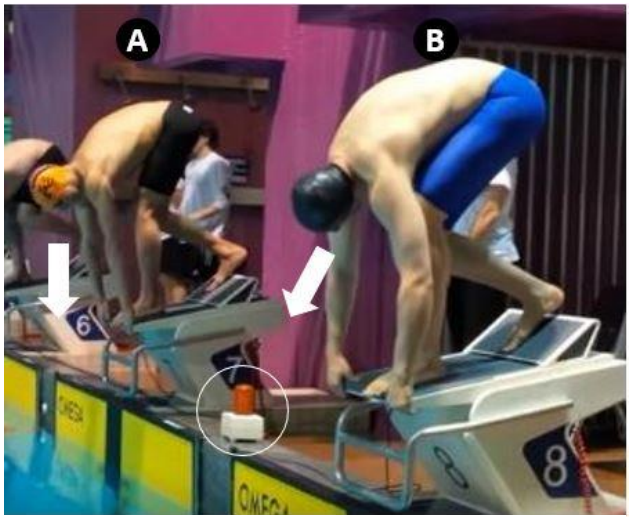

Figure 3. (a) A hearing swimmer with natural posture, (b) swimmer who has hearing impairment with an unnatural posture (bending his head to look at visual indication)

In addition, several systems with visual indicators have been proposed specifically to support deaf swimmers. For example, *Strobe lights*[2] provide visual signals to indicate '*Go*' by illuminating a light. However, this system does not provide anticipation, as it does not visualize the '*Ready*' command. *Swimming reaction lights*[3] is a standalone system that has taken the three separate states '*On your mark*', '*Set*', and '*Go*' into consideration. However, this system is not compatible with professional timing systems typically used in swimming competitions.

Inspired by the prior work and with a vision to bridge the existing gaps in start time indication systems for deaf swimmers, we designed and deployed *SwimSight* to support Singapore's 2nd National Deaf Games. The main contributions of this paper are:

1. the **design goals** for a start time indication system to support swimmers with hearing impairments,
2. the technical details of the **proof of concept prototype** and design for **manufacturing process** of *SwimSight*,
3. the deployment of *SwimSight* at the National Deaf Games as well as **preliminary user feedback**.

Figure 2. (a) Starting posture for freestyle/breast stroke/butterfly, (b) starting posture for back stroke

[2] https://youtu.be/JP_TI_F2QbI

[3] http://srlofny.com

DESIGN GOALS

We collaborated with the Deaf Sports Association Singapore to involve the end users in the design process right from the beginning. Through our initial interviews with deaf swimmers and technical staff, we derived the following design goals for *SwimSight*:

Compatibility

Competition swimming pools are built with professional timing systems and the technical staff are well trained to operate and maintain them. Therefore, in order to get technical staff to buy in to any new start indication system, it needs to be compatible with the existing commercial timing systems and should be ideally plug-and-play, so as to be easily incorporated into the technicians standard operating procedures.

Timing accuracy

The visual alert system has to synchronize with the professional timing device in order to avoid any time delays that can affect performance.

Anticipation

As mentioned before, providing the sense of anticipation (similar to '*On your mark*' and '*Set*') was one of the most important requirements from the end user perspective.

Rugged design

In swimming events, any technology is exposed to water, such as water splashes when the swimmers dive into the water. Hence, a rugged design that can withstand rough use is an important practical consideration. In addition, during swimming competitions, the starting location (i.e. side of the pool) has to be changed according to the length of the event. Therefore, the system needs to be portable and set for quick assembly/disassembly.

Providing appropriate feedback

To provide appropriate feedback, the device has to be in the swimmers' line of sight; otherwise they would be forced to deviate from their natural starting posture (Figure 2b). There is a possibility that this unnatural starting posture may negatively affect a swimmer's performance.

In addition, different swimming styles have different starting positions (Figure 3). Hence, the visual indication system should be adjustable to support multiple swimming styles.

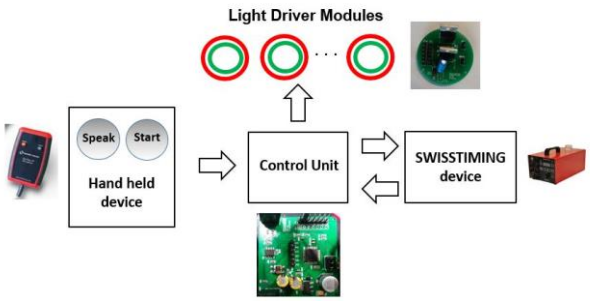

Figure 4. System architecture

Figure 5. Manufacturing process a) Formech 686 vacuum former with mould, b) moulded and cut PVC parts, c) waterjet-cut aluminum plates and rings, d) process of cutting the inner PVC parts

SWIMSIGHT

SwimSight has been designed to be compatible with a professional event timing system called *STARTTIME III*[4]. The *STARTTIME III* system has an external handheld device that consists of two buttons, '*Speak*' and '*Start*'. The *Speak* button allows the referee to provide commands such as '*On your mark*'. The *Start* button then is pressed to trigger the '*Go*' whistle and start the clock.

Hardware Design

The final version of *SwimSight* (Figure 1c) consists of a control unit, LED driver units, concentric LED rings, and an adjustable flexible arm. In order to be able to provide anticipation and alert on '*Go*', we needed to identify the signals generated when the *Speak* button and the *Start* button of the *STARTTIME III* handheld device are pressed. Following, we designed a custom-made control unit to capture these signals and generate control signals to drive LED illuminators (Figure 6). Control unit and LED driver are designed as a plug-and-play add-on, in order to be compatible with the *STARTTIME III* system.

Control Unit

The control unit (Figure 6a) consists of a custom designed analog circuit based on an ATMEGA328 microcontroller. Typically, in swimming events, the referee would press and hold the *Speak* button of the *STARTTIME III* handheld device and provide the voice commands '*On your mark*' and '*Set*'. The *SwimSight* control unit now captures the signal which is generated and immediately sends a control signal to the LED driver modules (Figure 6b), triggering the illumination of an *orange* LED indicator. This supports the anticipation of the start signal (Figure 7a). The referee then would press the *Start* button to trigger the '*Go*' whistle, starting the race. The control unit captures the emitted '*Go*' signal and sends a control signal to now illuminate a *green* LED ring instead of the *orange* one.

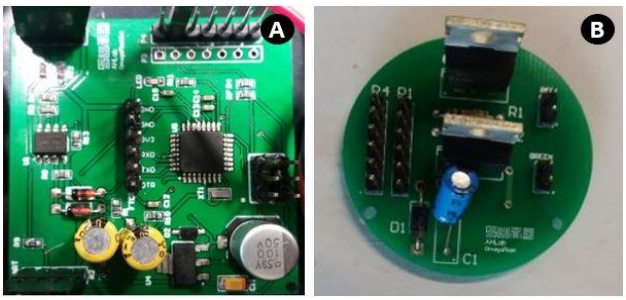

Figure 6. (a) Control unit, (b) LED driver module

[4] http://www.swisstiming.com/sports/swimming/

LED Driver Module

We designed a custom PCB (Figure 6b) to drive the light module which has two surface-mount LED rings. These LED driver modules can be cascaded to support the number of deaf swimmers in an event. No external power supply is needed, as it has been designed to be compatible with same power source as the *STARTTIME III*. The circuit includes IRFZNN power MOSFET and additional diodes to isolate the control unit from the main supply in order to provide additional protection.

Form Factor Design

Form factor design was another important consideration in the design process of *SwimSight*. One of the design goals was to provide appropriate feedback to the swimmers. For this, proper positioning of LED indicators is necessary. We thus decided to use concentric LED rings. Concentric LED rings help swimmers focus their eyes on one location without having to move their head. We piloted this idea with a cardboard prototype (Figure 1b). In the final design (Figure 1c) LED lights were mounted on an adjustable handle that allows users to adjust the location of the light. This arrangement supports multiple swimming styles such as freestyle and backstroke (Figure 8b and 8c).

Design for Manufacturing

All design and production steps, except for the PCB manufacturing, were done in-house (Figure 5). The casing of *SwimSight* is made of (1) waterjet-cut aluminum plates as a base, (2) two vacuum-formed PVC parts: an inner part (Figure 5c) holding the LED rings (1mm white PVC, Figure 5b) and an outer casing (2mm transparent PVC), (3) a laser-engraved acrylic sheet as light diffuser, (4) custom-cut rubber sheets to provide water-protection to the electronics circuits, (5) an aluminum ring, (6), and a custom aluminum adapter providing *SwimSight* with a standard ¼" tripod socket.

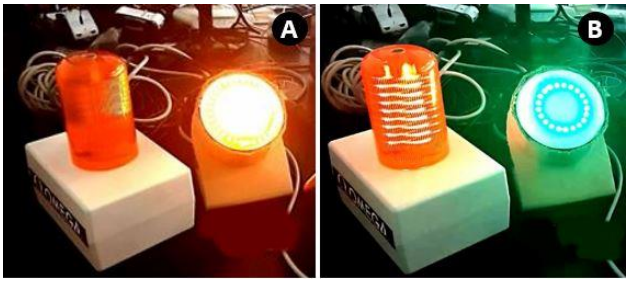

Figure 7. Existing system vs. *SwimSight* prototype. (a) '*Ready*' state: The existing system (left) provides no feedback whereas *SwimSight* provides an orange signal to get ready. (b) '*Go*' state: The existing system (left) provides an impulsive signal that might be missed whereas *SwimSight* changes to green and remains green

Figure 8. SwimSight at National Deaf Games 2016, (a) installation before the games, (b) use in backstroke event, (c) use in freestyle event, (d) swimmers adjusting the light location

The entire *SwimSight* light was 3D-modelled in SolidWorks. We used a waterjet to cut the aluminum plate and ring (Figure 5c), and vacuum-formed the PVC parts on a Formech 686 Vacuum Former (Figure 5a). The moulds were CNC milled from Obomodulan 302 tooling foam, with an added laser cut plywood base (Figure 5a). Drilled holes ensured for an optimal airflow into cavities. For cutting the outer casings from the moulded PVC sheets, we built a tool for cutting them precisely on the band saw, and used a cutting wheel on a mill for precisely cutting the inner parts (Figure 5d). All the parts were stacked and screwed together with M3 bolts and nuts.

To attach *SwimSight* to the rails of the starting blocks, we mounted the lights on Manfrotto 237HD Heavy-Duty Flex Arms and clamped them to the rails with Manfrotto Super-Clamp 035 (both professional lighting/camera equipment). For electrical connection, we used the same waterproof connectors the *STARTTIME III* system is equipped with (EcoMate C16 series). Additionally, we purchased a water-tight plastic housing for the control unit, and added the necessary connectors.

DEPLOYMENT AT NATIONAL DEAF GAMES 2016

SwimSight was successfully deployed in Singapore's 2nd National Deaf Games which were held at the Singapore Sports Centre in July 2016 (Figure 8). The transportation and the deployment process were easy, as we had designed *SwimSight* in a modular way, so that it easily disassembled into small parts. The complete system can be assembled within 15 minutes by any technician who has basic knowledge about standard connectors.

Preliminary User Feedback

After the National Deaf Games, we collected feedback from seven deaf swimmers (3 male, 4 female). This was done through an online questionnaire where they had to indicate their opinion about *SwimSight* using a five-level Likert scale as well as open ended questions to provide additional detail about their experience with the system.

All of them agreed that the different light signals of *SwimSight* were easy to understand. Five of them agreed that having their own start signal light allowed them to react faster to the '*Go*' signal than with systems they had previously used. Six swimmers strongly agreed that *SwimSight* was easy to adjust to their preferred position, so that they could get appropriate feedback. One of them stated: "*It improved concentration and adjustability.*"

In addition, six participants strongly agreed that *SwimSight* allowed them to anticipate the '*Go*' signal. In their words: "*It was truly amazing: By looking at it, having the confidence of getting ready to start swimming when the light turns green*". These initial user reactions suggest that design goals such as providing appropriate feedback and anticipation have been recognized. For the future, we plan to run a comparative study to evaluate the reaction time (time to take off after the '*Go*' signal) with and without the *SwimSight* system.

LIMITATIONS AND FUTURE WORK

Currently, *SwimSight* is only compatible with the *STARTTIME III* professional timing system. We envision it to soon be compatible with other professional timing systems. The form factor of *SwimSight* has been designed for swimming events. However, there are many other sporting events that need visual indication for athletes who have hearing impairments. For example, in track & field events a similar type of visual indication would be useful. We hope to design further sound-to-visual substitution systems to support other sports events.

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