IDeA Competition Report

Electronic Swimming Coach (ESC)

for

Athletes who are Visually Impaired

Project Carried Out Under:

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Introduction

Visually impaired athletes often enjoy swimming but this exercise poses certain challenges for them. One of the challenges is pool space, as they require a separate pool lane or at least one with fewer swimmers than what is typical. Another challenge is veering too close to the boundaries of the pool lane, and in some cases even hitting the lane boundaries. Furthermore, knowing when to turn around also poses a significant problem. These athletes would have to rely on physical and/or audible commands given by their instructors. However, their most vital aid for training sessions and competitions have been people called ‘tappers’. The tapper’s job is to indicate to the swimmer that they are coming close to the end of the pool with a single tap on the head, as shown in the figure below:

Figure 1: A ‘Tapper’ Notifying a Swimmer

Using tappers has its own limitations. Firstly, it is difficult to find an individual(s) to fulfill this role because they need to be professionally trained and the swimmer needs to be comfortable with their technique and timing. Also, multiple ‘tappers’ need to be trained in order to ensure that there will always be one at hand when needed.

The Electronic Swimming Coach (ESC) is a multi-year initiative to develop a non-contact low-cost automated system to permit visually impaired athletes to swim safely and independently. The system comprises of a laptop/tablet that runs the software, which is connected to two wireless cameras, placed on either end of the pool. These cameras are used to track the swimmer and determine the pool lane boundaries. The system also comprises two Radio Frequency (RF) transmitters placed on either end of the pool, which communicate with the system via Bluetooth. The RF communication link is used to communicate with a receiver module that is located on the swimmer. Figure 2, below, displays how all of the various components contained within the ESC system work together:

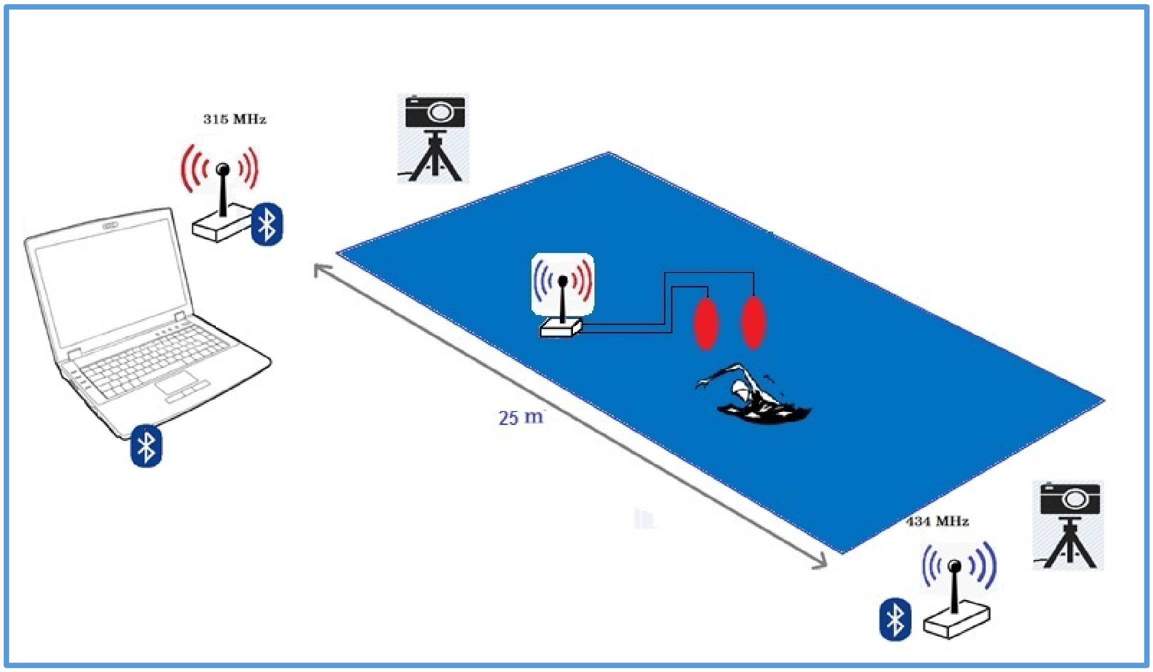

Figure 2: An Outline of the Entire ESC System

The swimmer's coach interacts with the ESC system using a new and improved Graphical User Interface (GUI). Minimal intervention is required from the coach and only during system calibration at the start of a swimming session.

The following figure illustrates the flow of information throughout the system:

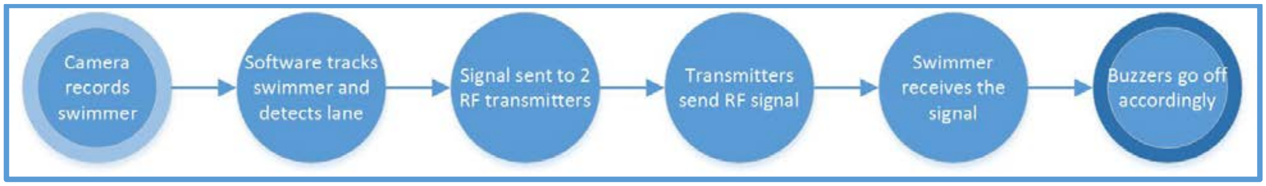

Figure 3: The Flow of Information for the ESC

System testing has demonstrated that the ESC system is capable of tracking the swimmer to within +/- 1m up to a distance of 25m. If the swimmer is in nearing the pool boundaries, rapid notification is assured since the RF channel was demonstrated to be highly robust to swimmer depths of up to 15 cm.. Human tests were also performed in order to ensure that the commands were accurately identified by the swimmers upon application of the physical stimulus.

Project Background

The ESC is a multi-year student-driven project with the purpose of building a fully functional electronic swimming aid for visually impaired athletes. This project is currently in its fourth year; the groups from the first three years accomplished the following:

- Program Implementation in MATLAB then partially in Java
- Manual specification of swimming pool boundary
- Visual display of swimming pool
- Colour detection system to detect the swimmer’s cap
- Functionality of receiver up to 20 cm in depth underwater
- Single transmitter built on an Arduino Uno microcontroller
- Camera inputting data to software in real time
- Performance metrics including lap counter, average speed, etc

The improvements made by our group this year are listed below:

- **Automatic Pool Corner Detection** during system calibration for a quick and easy setup procedure by the swim coach

- **Swimmer Position Tracking** that ensures continuous detection over the whole 25m length of the swimming pool
- Addition of a **second camera and transmitter**, one at each end, to facilitate the continuous detection and communication
- **On-circuit LEDs** to indicate when the vibrotactile actuators are being energized (for troubleshooting purposes).
- Designing a **dual band receiver** to communicate with the two transmitters operating on different frequencies
- Eliminating on-going software and wireless licensing costs (**low cost solution**)
- A **portable system** that could be transported and set up with ease

The following figure displays a modular breakdown of the ESC system:

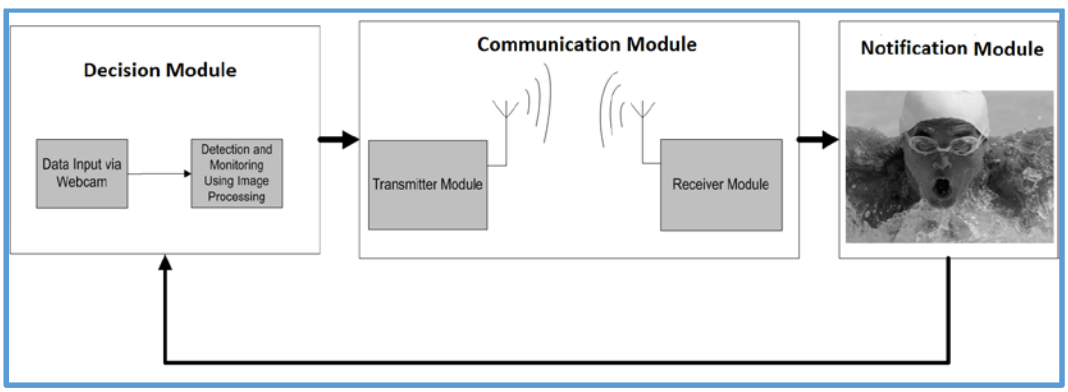

Figure 4: Modular Overview of the ESC

Decision Module

The decision module consists of a laptop or tablet that is running the ESC software, a webcam that is placed on one end of the pool, and an internet protocol (IP) camera placed on the other end. The purpose of this module is to track the swimmer and to determine whether or not they are approaching a predefined 'Red Zone' (*See Figure 5*). If the system detects an impending collision, a corresponding signal is sent to the swimmer alerting them to the danger thereby telling them whether or not they need to go left, go right, or initiate a flip-turn. In the event that the detection module is unable to detect the swimmer for a prolonged period (>1s), then an emergency buzz patterns is invoked to warn the swimmer.

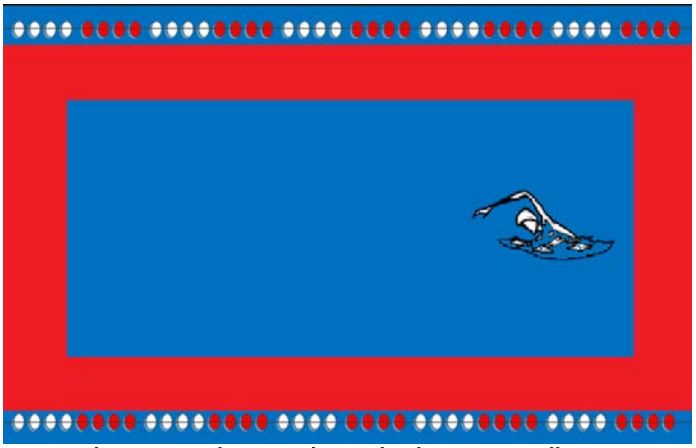

Figure 5: 'Red Zones' that make the Buzzers Vibrate

Communications Module

The communication module consists of two transmitters which are placed at either end of the swimming pool and are connected to the laptop via Bluetooth (*Shown in Figure 6 Below)*. The dual RF channel operates at frequencies of 315 MHz and 434 MHz and utilizes Manchester encoding to increase the fault detection and tolerance of the wireless channel. Dry-land testing of the RF link showed that it had a maximum message error rate of approximately 3% at a distance of 50m in air. The message error rate increased to a maximum value of approximately 4% at a distance of 25m in water (at a depth of 15 cm). When two transmitters are used, the maximum distance between the swimmer and the nearest transmitter is reduced to 12.5m. At that distance and at a depth of 24 inches underwater, the RF link had a maximum message error rate of approximately 8%.

The specifications for the RF transmitter modules can be found in the table below:

Operating Frequency (MHz)	434	315
Transmitting Power (mW)	10	10
Operating Voltage (V)	3.5 - 12	3.5 - 12
Type of Modulation	Amplitude Shift Keying	Amplitude Shift Keying

Transfer Rate (Bit/second)	4000	4000

Table 1: Specifications for the Transmitters

Figure 6: Final Circuit - Image of 434MHz (Left) Transmitter & 315MHz Transmitter (Right)

Notification Module

The notification module consists of a dual-channel RF receiver module and an ATMega 328 microcontroller which are placed inside small a waterproof pouch worn under the swimmer's swim cap (*Shown in Figure 7 Below)*. The microcontroller is used to decode the wireless signals and alert the swimmer via two vibrotactile actuators worn on the temples under the swim cap. Once the receiver obtains a signal it is mapped onto a specific buzz pattern which is acted out by the buzzers, these patterns tell the swimmer how to proceed. The specifications for the RF receiver modules can be found in the table below:

Operating Frequency (MHz)	434	315
Transmitting Power (mW)	10	10
Operating Voltage (V)	5	5
Quiescent Current (mA)	4	4
Receiver Sensitivity	-105 dB	-105 dB

Table 2: Specifications for the Receivers

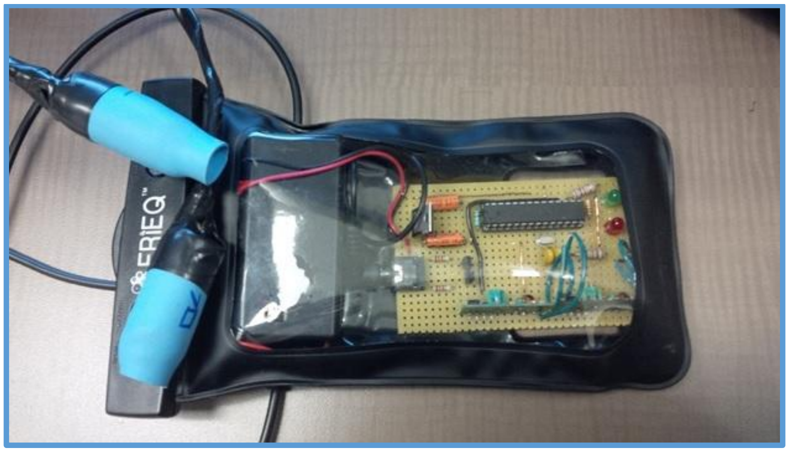

Figure 7: Final Circuit - Dual Band Receiver Module in Waterproof Pouch

Project Accomplishments

1. Improving the GUI

Improvements were made to the current coach's interface of the project and an Android version was made suitable for deployment on low-cost tablet devices. The previous GUI had multiple windows being displayed for the same program. The aim this year was to make the program work with only one functioning window, in order to make it more user friendly, and provide a more professional appearance. The following figures illustrate the new ESC GUI:

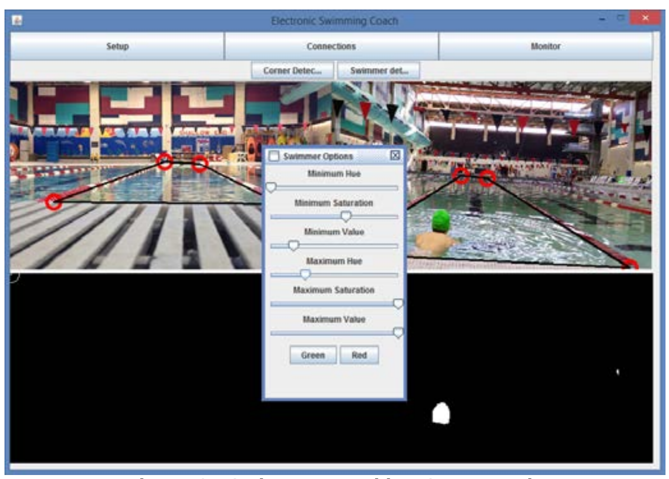

Figure 8: Swimmer Tracking Setup Mode

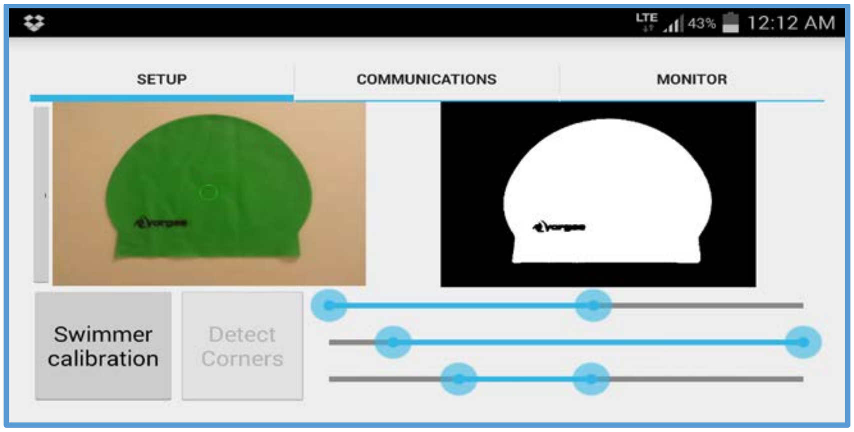

Figure 9: Green Colour of Swim Cap Extracted on the Android Version of the ESC Software

2. Increasing the Swimmer Tracking Accuracy of the System

Our second goal was to improve the system's swimmer tracking accuracy by employing a second camera at the far end of the pool lane. In this way, the system obtains two estimates of the swimmer's location, and the estimate from the camera closest to the swimmer can be used. A wireless internet-protocol (IP) camera was used to avoid running long cables along the pool deck. The software also uses improved algorithms for the calculation of the swimmer location.

3. Improving System Calibration

To minimize setup time and simplify the system calibration process, image processing algorithms were developed to automatically detect the pool and lane boundaries. Furthermore, the coach is able to confirm and, if necessary, manual override the lane boundaries using a touch screen interface. The auto-detection and manual calibration features are displayed in the following figures:

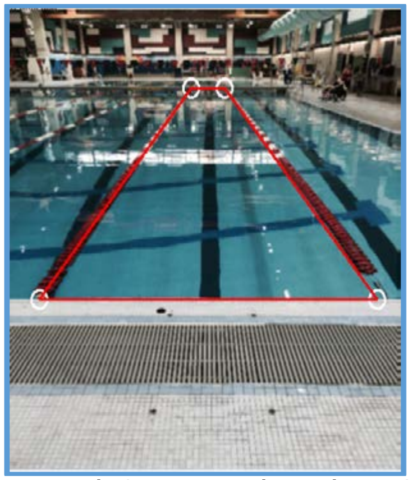

Figure 10: Automatic Corner Detection and Lane Calibration

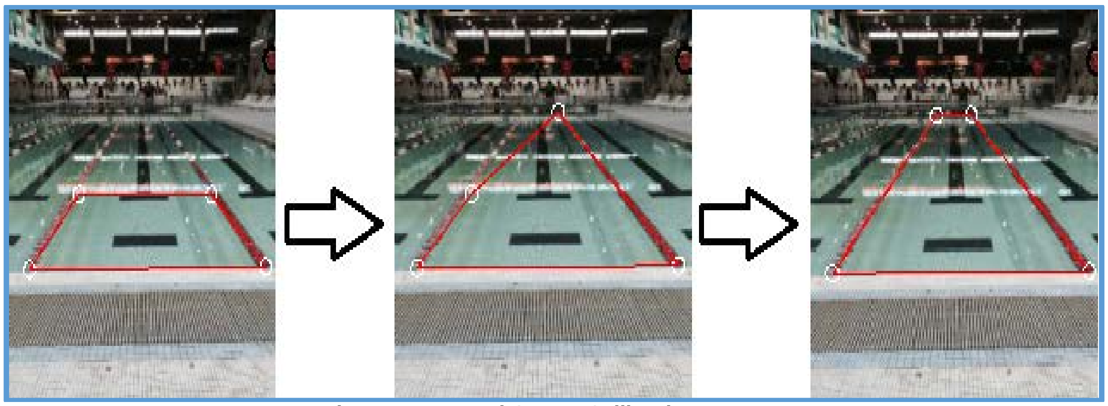

Figure 11: Manual Corner Calibration Process

4. Improving the Transmitter/Receiver Module

The error rate of the transmitter/receiver module rises with distance and with submersion depth. As mentioned previously, Manchester Encoding is used to identify faulty packets and ignore them which prevents erroneous signals being passed on to the swimmer. However, as the distance increases beyond 25m (e.g. for an Olympic-sized pool) and as the swimmer's depth increases, the number of erroneous packets will begin to compromise the ability to correctly notify the swimmer. The aim this year was to implement two RF transmitter-receiver pairs to effectively half the maximum distance between the swimmer and the nearest transmitter. These transmitters use appropriately low frequencies (315 MHz and 434 MHz) to guarantee signal penetration underwater.

Conclusions and Future Work

The Electronic Swim Coach for Visually Impaired Athletes is able to detect and track a swimmer within a pool lane, and alert the swimmer of impending collisions with the pool walls or lane markers. In this way, athletes who are visually impaired are able to swim independently without the requirement for volunteer “tappers”. With the system improvements described in this report, the ESC system has become sufficiently compact and robust to permit user testing with actual athletes. Future work will include the addition of a battery level detection circuit to warn users of low batteries and further miniaturization of the wearable notification device. The software aspects of this project will be released as open-source to promote adoption and improvement from the community at large. It is estimated that this system can be produced for approximately $100 (excluding the tablet) once production volumes reach at least 100 units.