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Coach-Swimmer communications based on wrist mounted 2.4 GHz accelerometer sensor

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Abstract

Two way real time communications during swimming is important for coaches and swimmers in order to reach optimum performance. This paper presents a 2.4 GHz wireless communication system to send acceleration data to a coach tablet at the pool side and allow active interactions between swimmers and their coaches. The radio frequency signal does not propagate effectively underwater because of the high attenuation. Therefore the wireless transmitter sends data only when the swimmer’s wrist is outside the water. The y-axis acceleration data provides stroke rate SR, stroke length and swim velocity. The experimental results showed that the link is operational 28% per stroke in freestyle swimming. This is more than enough to send important data from the swimmer and reply with the coach’s feedback.

Keywords: Body sensor networks; real-time communication; gesture identification; acceleration measurements; swimming.

1. Introduction

Real time feedback for swimmers and their coaches is helping both to achieve the training target. On body and off body wireless communication is important during swimming. In training and longer swim events, instantaneous feedback from a coach to a swimmer can improve performance. The challenge is implementing a reliable communication system and to achieve the required distance between swimmer and coach [1]. This is especially true, when there is water between the transmitting and the receiving end of the links. Normal body movements can also

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interfere with the line of sight (LOS) in the propagation path. The resulting multipath fading and scattering effects make it very hard to sustain continuous wireless communications [2].

Accelerometer data is used in many sports including swimming to measure parameters such as stroke rate, stroke length and swim velocity [3]. Off body wireless communications between a sensor with an RF transceiver on a swimmer’s wrist and another RF transceiver on a coach tablet can be used to provide two way real time feedback. A wrist-mounted accelerometer can provide this swim data which can be used to improve the swimming techniques and strategies [3].

On body communication was achieved using optical communications [4] to send the stroke rate from a wrist-mounted sensor to a heads-up display on the swimmer’s goggles. However, long range optical wireless communications needs a high power light source which means bigger and heavier components and batteries which may affect the swimmers’ performance. This also presents a distraction and perhaps a hazard to the swimmer’s eyes.

Radio frequency suffers from severe attenuation in water [5]. However, this communication scheme works well in air. A wearable sensor was designed [5] to monitor swimming performance such as pitch and roll angles to recognize the stroke type. The system includes an inertial sensor mounted on the swimmer’s goggles. The sensor contains a three axis accelerometer, 2.4 GHz RF transmitter and 2 MB on board memory. The sample rate was 50 Hz and the sensor could either save data on the sensor or send it in a real time to a base station (RF link will not function through water). No real time interaction between the coach and swimmers was reported.

A wearable sensor network for monitoring body kinematics [6] uses three axis accelerometers and magnetometers connected to a microcontroller embedded in the swim suit. The sensors measured heart rate and temperature and transfers the data to a base station using a 2.4 GHz transceiver. The sensor network can distinguish between motion and rotation. No real time interaction in this system was reported.

A wearable monitoring system for swimming performance and health purpose analysis was reported in [7]. The system was based on three main units: sensing including MMA7260QT accelerometer and IDG-300 gyroscope, processing including a MSP430F2274 microcontroller with built in CC2500 radio frequency transmitter for data transmission on the same board. The sensor weighted approximately 65.6 grams and measured 57 ×90.5×24 mm³. The sensor was located at the dorsal zone of the frontal plane, within the vertebral region at the inferior scapular section of the swimmer to obtain parameters including style, strokes and end of pool recognition. The raw data was sent to a base station for recording and analysis. No real time interaction reported.

The twistthink company [8] supplies “avidasports” as a training wearable system to give feedback to swimmers and their coaches. The system includes five sensors (two worn on wrist watch-type bands, two for ankles and one that is placed under the swim cap) with an earbud for audio feedback to the swimmer. Swim data is accumulated while the device is underwater and transmitted via RF when a device is above the water. The system is very expensive and uses acoustic feedback. Acoustic feedback has proven very difficult as the response from swimmers is low in the presence of high acoustic noise levels.

This paper describes a novel feedback communication system based on RF and the data is sent as a burst when the swimmer’s wrist is out of water.

2. System design

The off body RF wireless communication used in this system achieves two way interaction between swimmers and their coaches. The transceivers are based on the wireless sensor (nCore 2.0) [9] to generate the acceleration data with the RF transceiver (NRF24L01P) for communications. The hardware and software modifications of this sensor included the RF system and a UART interface which allows data transfer between the sensor and the coach tablet. Fig. 1 shows a windows operating tablet (Dell SP) connected to a wireless sensor node through the USB interface to allow displaying of the received data using a communication program.
A method of data retransmission was adopted to increase the link reliability to recover lost traffic and increase network reliability [10, 11]. This ensures that the data is delivered to the receiver by acknowledging the received packets, if the transmitter does not receive the acknowledged packet it will continue to retransmit the data until reception is acknowledged or the maximum number of retransmission attempts has elapsed.

3. Experimental design and results

Experiments were conducted in air and water. The air experiment was undertaken in order to investigate the RF link in air without attaching the system to a swimmer. In air the distance achieved was 12m with error free transmission. This range can be increased by using an RF amplifier or by using a small external antenna on the tablet sensor. Fig. 2 compares the packets transmitted and the packets received as a function of range. The link is not very reliable at distances greater than 12m.

The water test was undertaken by attaching the modified nCore 2.0 sensor to the wrist of a recreational swimmer. The swimmer was asked to swim freestyle in a 25m pool. Fig. 3a shows the system during the swimming test and fig. 3b shows the orientation of the sensor. Y axis acceleration was used to extract key swimming data [3] and is plotted as relative acceleration units. Fig. 4 shows the water transmission results for free style continuous
swimming. The stroke characteristics are clearly evident. The RF link is broken regularly when the wrist is under the water surface. The test was conducted while the coach was moving along the pool with the swimmer, ensuring that data loses occurs only when the sensor is inside the water. The maximum transmission distance in this test was estimated to be approximately 10m. (Fig. 2).

Fig. 3. (a) The system during the water test with the tablet on poolside and the sensor on the swimmers wrist out of the water (b) sensor orientation.

![Image](image1.png)

![Image](image2.png)

Fig. 4. The y-axis transmitted acceleration units (blue) and the received acceleration (orange) during freestyle swim.

Table 1 was derived from the results shown in Fig.4. It shows a sample of five strokes with the time above water for successful communication and the time underwater for no RF connection. The results shows that of an average of 28% the hand is outside water which is enough for two way interaction between a swimmer and his/her coach. This information can be very helpful for training purposes as the coach will be aware of the stroke rate and the time spent under and above water for each stroke. This ratio will change with swim style and swim stroke.
Table 1. Stroke number with the time above water for successful communication and the time underwater for no RF link.

<table>
<thead>
<tr>
<th>stroke count</th>
<th>Tx time above water (ms)</th>
<th>Tx time under water (ms)</th>
<th>Stroke Time (ms)</th>
<th>wrist above water percentage with respect to stroke time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>380</td>
<td>1290</td>
<td>1670</td>
<td>29%</td>
</tr>
<tr>
<td>2</td>
<td>320</td>
<td>1290</td>
<td>1610</td>
<td>25%</td>
</tr>
<tr>
<td>3</td>
<td>350</td>
<td>1240</td>
<td>1590</td>
<td>28%</td>
</tr>
<tr>
<td>4</td>
<td>320</td>
<td>1150</td>
<td>1470</td>
<td>28%</td>
</tr>
<tr>
<td>5</td>
<td>390</td>
<td>1270</td>
<td>1660</td>
<td>31%</td>
</tr>
</tbody>
</table>

Mean ± SD 352 ± 32.71  1248 ± 58.48  1600 ± 80.00  28 ± 2.16 %

4. Conclusions

A wireless communication system between a swimmer and pool side was designed, implemented and tested based on using a 2.4 GHz RF wireless communication system. The system was tested in air and water. The air test range was 12m error free. This can be increased by using an RF module with amplifier or using a small external antenna. The water experiment was conducted by asking a recreational swimmer to swim freestyle in a 25m pool. The results showed that 28% is the percentage of a swimmer’s wrist outside the water during the stroke which can achieve RF communication link. This is expected to be more than enough for two way interaction between a coach and a swimmer. The acceleration data was displayed on a tablet computer.

Future work can be focus on increasing the pool wireless coverage and enable coach to collect information form more than one swimmer at the same time. And deployment of more than one movement sensor located in different places on the body such as (ankle, sacrum and wrist), the variation in the stroke and different swim style. This will give more important information about the swimmer coordination, movement and speed. Multiple swimmers can be monitored by a coach simultaneously. The coach feedback to the swimmers can be converted to an optic [1] or a sound signal to inform the swimmers.

References