Available online at www.sciencedirect.com

ScienceDirect

Procedia Engineering 2 (2010) 2707–2712

Procedia Engineering

www.elsevier.com/locate/procedia

8th Conference of the International Sports Engineering Association (ISEA)

Development of a real time system for monitoring of swimming performance

Tanya Le Sage[a]*, Axel Bindel[a], Paul Conway[a], Laura Justham[a], Sian Slawson[a], Andrew West[a]

[a]*Loughborough University, Loughborough Park, Loughborough, LE11 3TU, UK*

Received 31 January 2010; revised 7 March 2010; accepted 21 March 2010

Abstract

This research was conducted to allow real-time transmission, processing and presentation of data to swimming coaches and subsequently their swimmers in a training environment. This was done using an integrated system which comprised of a wireless sensor node, vision components and both force and pressure measurement technologies. Filtering approaches and signal processing algorithms were used to allow real-time data analysis on the node. Immediate feedback to the coach and sports scientist on poolside allows for a swimmer to be given quantifiable coaching tips and enables them to adjust their performance based on the results obtained. The system has reduced the time for processing acquired data and has delivered novel monitoring devices suitable for the harshness of the pool environment.

Keywords: swimming; embedded programming; real-time; stroke recognition

1. Introduction

The four competition strokes in swimming can be identified as front crawl, butterfly, backstroke and breaststroke. These strokes can be characterized by four basic sweeps of competitive swimmers' arms [1]:

- Outsweep: initial underwater sweep in butterfly and breaststroke
- Downsweep: initial underwater sweep in front crawl and backstroke
- Insweep: second sweep used in all competitive strokes
- Upsweep: final sweep of front crawl and butterfly

The relative durations of each phase alter depending on the duration of the swim, the amount of fatigue experienced by the swimmer and on the stroke being used.

* Corresponding author. *E-mail address*: T.Le-Sage@lboro.ac.uk.

1877-7058 © 2010 Published by Elsevier Ltd.
doi:10.1016/j.proeng.2010.04.055

Research has been conducted in a number of areas to enable analysis of the swimming stroke. In swimming, velocity depends on stroke rate and stroke length (the number of metres the swimmer's body moves forward during each stroke cycle, measured in metres per stroke cycle). Maglischo produced typical velocity profiles of a swimmer's hand for each individual stroke [1]. Seifert used such profiles to identify that an abrupt change in the coordination pattern of the front crawl occurred at the critical velocity of 1.8m/s, which corresponds to the 100m pace for elite swimmers, and at this stage they switch from catch-up (which consists of a lag time between the propulsive phases of the two arms) to relative opposition (i.e. one arm begins the pull at exactly the same time as the other finishes the push phase) [2]. Thompson used velocity profiles to demonstrate that as the pace of breaststroke trials increased, the stroke rate was found to increase proportionally with stroke count [3]. All of these studies have focused on post processing of the data rather than in real-time.

The majority of methods used to analyse swimming technique are vision based or sensor based systems. Quintic is an example of vision-based software where the analyst uses a pre-recorded video file and then manually digitizes key occurrences within the recording [4]. The disadvantages of this and other such systems are the parallax errors induced by the use of video cameras, inaccurate measurements due to light reflection on the water surface and the large amount of time it takes to process the data. Manual digitization is a time consuming process and does not allow real-time feedback to the coaches or swimmers. Wireless sensor devices have also been developed for use in a swimming environment. An example of this was presented by Davey [5], where a system was developed using a tri-axis accelerometer to monitor stroke technique. An algorithm was determined which allowed a positive peak to be counted when a maximum occurred, and which stated that another maximum couldn't occur until a minimum had been counted. Ohgi used a similar system to measure wrist acceleration of swimmers [6]. Although both these systems used sensor devices for monitoring the swimmer, neither used a wireless sensor network (WSN) nor embedded processing to analyse the stroke technique in real-time. Both systems used a data logging accelerometer to capture the data, which meant that the data could not be viewed in real time. These systems focus on post processing that increases the analysis time significantly and subsequently coaches are unable to offer immediate feedback to the swimmers based on these data.

The research presented within this paper has been carried out at Loughborough University, UK, and has been based upon real-time monitoring of elite athletes in water. An initial feasibility study was conducted, considering a variety of different sensing and measurement devices and an integrated system was constructed to capture the data. The system was comprised of a WSN, a vision analysis system using real-time image processing, and both force and pressure measurement technologies. Force transducers have been embedded into a swimming start block and pressure transducers into a pad which can be attached to the pool walls. The focus of the current paper was the development of the node that was developed in-house and based upon the identified user-requirements. In accordance with these requirements, the node included a tri-axis accelerometer and a dual-axis gyroscope. It was developed to provide real-time data feedback to the poolside for ongoing analysis, and it was designed to be as non-invasive to the swimmers as possible. It was developed to operate as a network of nodes to allow analysis of multiple swimmers performance during a training session. The prototype node was packaged to ensure it was waterproof for the application. Initial validation testing was then carried out at the pool. A Butterworth filter and signal processing algorithms were embedded onto the node that allowed the coach to extract useful data with regards to each individual swimmer's performance. These algorithms provided the coach with the stroke rate, stroke duration and lap count of the swimmer.

2. Methods

To develop the WSN a suitable Microcontroller (MCU) with integrated transceiver was chosen. The transmission range was tested in water and shown to be robust upto 35m at 25cm depth, which was found to be suitable for the application. The integrated MCU contained an in-built wireless protocol stack used for the development presented within this paper. The topology of the chosen network architecture was a star configuration with multiple sensor nodes acting as End Devices (ED) and a single coordinator node or Access Point (AP). The sensor nodes transmit the data at a configurable sampling rate (currently set to 50Hz) with 10bit resolution. The current protocol is based on a single-hop network, which has been adapted for the swimming application. The protocol stack is presented in Figure 2.