Smartphone Sensing for Distributed Swim Stroke Coaching and Research

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Abstract
Current methods of swim stroke learning rely on a combination of external observation by coaches and repetitive drills performed by swimmers. At elite levels, these may be augmented using complex and expensive augmented pool environments and video analysis, but these are not available to most non-professionals.

In this paper, I argue that with the wide range of sensors and outputs on a current smartphone, and existing sports-targeted waterproofing, commodity mobile hardware may allow even un-coached amateur swimmers to access timely feedback on their stroke and to improve their swimming. An early prototype of a swim-sensing system demonstrates the potential of mobiles to sense aspects of the swimming stroke. By using commodity hardware it is open to many potential learners, who may in turn provide high quality data to feed back into the development of swim coaching techniques by sports researchers and practitioners.

Author Keywords
Swimming, stroke, mobile, water, training.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

Introduction
For most people, swimming is a skill which they acquire as a child [4], during which they essentially acquire a rudimentary ability to swim some or all of the four major strokes (front crawl, breaststroke, backstroke and butterfly). Beyond the basic ability to swim, training an efficient stroke was in the past typically done as part of a swimming club, with group coaching.

More recently, particularly with the growth of triathlon as a sport, and the resulting need for cyclists and runners to learn to swim, many adults without club swimming backgrounds developed an interest in achieving an efficient swimming stroke. This led to the development of new methods of swim teaching, such as 'Total Immersion' [6] and 'Swim Smooth' [7]. These are for people with an ability to stay afloat, but who wish to move faster and more efficiently in the water. Whilst workshops and training groups which practice these methods exist, most users of these methods are self-motivated, using instructional videos or books.

Drill Sets and Coaching
Both modern and traditional methods of swim stroke learning are essentially based around 'drills'. In a drill, swimmers do repetitions of movements which are designed to focus on certain aspects of a stroke, such as the entry of the hand into the water, or the leg kick. For example, swimmers may stretch their arms out and just kick up and down the pool, to improve leg kick.

The major difference between self-motivated and coached approaches is in the evaluation. In coaching, a person on the pool-side watches swimmers as they swim, and provides feedback on the quality of their stroke when they stop. In self-directed approaches, swimmers use times for a certain distance, and simple efficiency measurements such as strokes per length in order to evaluate their stroke. Technological devices such as 'swim watches' exist which measure these variables, removing the need to manually count strokes or watch a clock, but not essentially performing any task that a human cannot do themselves.

Why is Swimming Hard
A fundamental problem of swimming, is that people do not know what their body is doing whilst in the water, due to the buoyancy and resistance of the water, and the unnatural body position of a swimmer in the water. Because of this, current swimming teaching methods are all based essentially on external feedback as to how efficient a swimmer's body position is or second order variables such as strokes per length.

In elite swimming, it is common to use video analysis software such as Dartfish [3] in order to analyze in detail what swimmers' bodies are doing, with the help of experienced coaches. Regular use of this technology is out of reach of all but the most committed amateurs, and still relies on the human expertise of the coach.

The Opportunity of Mobile Devices
Current smartphones have a wide range of sensors to sense the body of a swimmer. Waterproof cases for swimming with them worn on the body are also widely available (eg. [8]). They also have the potential to provide realtime feedback to swimmers, through waterproof headphones and vibrotactile feedback. Bright screens on phones, typically visible through the waterproof case, also provide a beacon which potentially may be visible to people watching a swimmer, or to other swimmers.

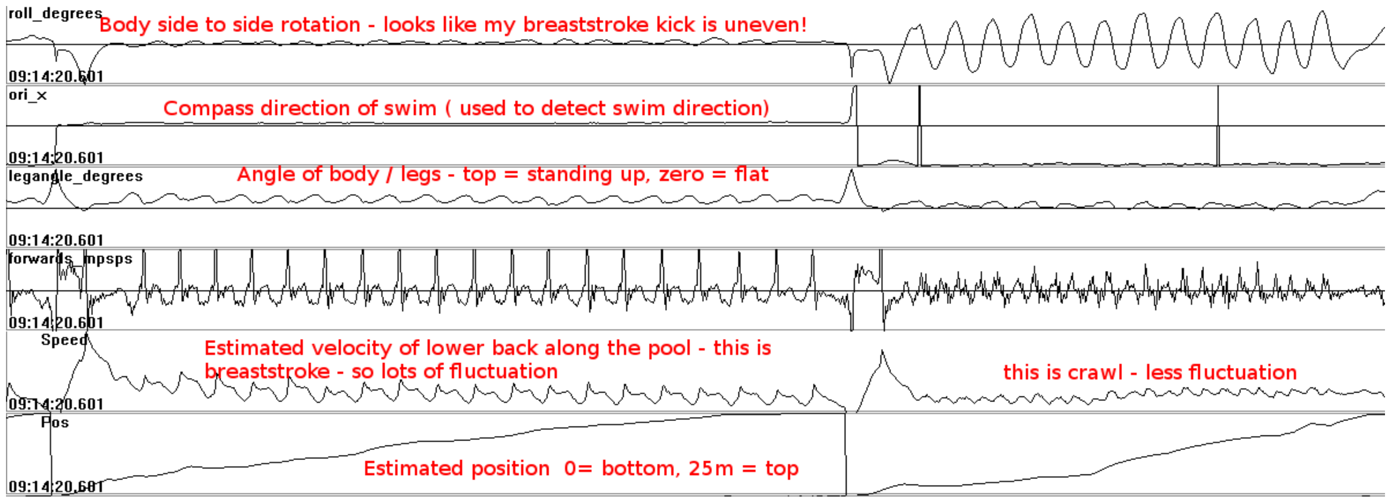

Figure 1. Swim Sensing Technology example data

Our Swim Sensing Technology

To explore the feasibility of smartphone based swimming support, we produced a swim sensing system to detect and analyze swimming. This early prototype demonstrates the rich data which may be available using commodity hardware. Due to space, we present only minimal technical details of the system.

Our system uses a Google Nexus 4 smartphone, mounted on the small of the back in a waterproof case. The system uses the accelerometer, gyroscope and magnetometers in the device in order to detect body orientation and short term variations of swimming velocity. It also uses ambient magnetic positioning [5] to detect absolute position in the pool. As well as not requiring custom hardware, this system goes beyond previous work which either restricts itself to detecting body posture [1], or only estimates velocity by post-processing data after a length has been swum [2].

This system allows us to detect in real time an accurate body posture and velocity for the swimmer, to which we can respond. The data in Fig. 1 shows the author swimming 2 lengths, one breaststroke, which can be seen in the velocity profile, with strong pulses as the legs kick and one front crawl, which can be seen by the characteristic left to right body roll of the stroke.

Case Study: My breathing

This section presents an example of what this data could provide which is not possible with current non-professional coaching systems. During front-crawl, the swimmer takes breaths on some strokes and not on others. Pedersen & Kjendlie [9] used dedicated pool sessions and an expensive computerized swim-tether system which allowed them to extract velocity measures for swimmers while they were both breathing and not breathing. This kind of measuring equipment is only available to elite swimmers, and severely restricts swimming. In contrast, the author swum with our system in a public swim and a brief section of the data is shown in Fig. 2 with strokes annotated. We can see clear differences in velocity profile during breathing strokes, in comparison to non-breathing strokes, demonstrating that the author is far from having what Pedersen & Kjendlie call "*effective breathing technique to avoid velocity reductions due to breathing actions.*" [9]. Presenting real-time feedback of the impact of each stroke on swim velocity would allow the swimmer to be aware of this, and experiment with their breathing method in order to improve their technique.

Figure 2. Differences in velocity during breathing strokes

Using Swim Sensing To Enable Distributed Swim Coaching and Research

Key to the future success of this system as a learning tool is whether the feedback provided by the system successfully prompts people to improve technique. Our system has a flexible approach to feedback, with the potential to load new 'patches' into the system which give different types of feedback. Current coaching systems are developed over a slow process of iterative refinement from in person coaching, with limited feedback from the majority of self-directed users. In our system, the complete data from any user's swims is available and already on a network connected device. This could allow fast iteration, deployment and testing of new feedback schemes by sports scientists and practitioners. The easy availability of data could also enhance remote coaching (such as that offered by swimsmooth.com), as coaches may be able to elicit from the data aspects of the swimmer's technique which require work. It also has potential for creating a large database of common swimming styles and of common swimming errors which could be highly useful to sports scientists and coaches.

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