A Visual Method for Data Interpretation

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Abstract
A major challenge in the successful transfer of technology to sports and in particular swimming is taking scientific measures and translating them into terms suitable for the serious swimmer. Our work with inertial sensors has demonstrated that the measures can obtained elite level instrumented pool variables from a single wearable sensor. This paper introduces visualization methods in order for coaches and athletes to use often complicated technical data. Options currently at hand are various 2D plots and a small number of 3D options.

Key Words: Athlete performance, External feedback, Inertial sensor, Skill, Visualisation technology.

1. Introduction
In many cases a laboratory environment is used for testing athletes [1], so that rigorous testing of physiology can take place. Laboratory testing however may place limits on how the athlete performs, especially if the testing environment is sufficiently different to the training environment [2]. Moreover, one may consider that laboratory type testing is even further removed from the training environment when water based sport and exercise is being assessed. While video measures may show general swimming kinematics, similarities between dry land simulation and in-water swimming, it has been shown that there are measurable differences [3] that indicate a need for actual in-water assessment. Additionally, typical performance analysis in an aquatic environment requires the instrumentation of pools. This usually means video analysis that is post processed to obtain the desired kinematics. For accurate analysis, an analysis expert is usually required for assessment. Such people are not always available to coaching staff, especially away from national elite training environments. Furthermore, performance characteristics are augmented during competition when compared to regular training. By better understanding athlete performance in the competitive environment coaches can more effectively work with athletes to improve their performance [2, 4].

Over recent years, sporting endeavors have been assessed using inertial sensors [5-8]. Within sports, swimming parameters have been the focus when using inertial sensor technologies [4, 9, 10]. The bulk of the outcomes has resulted in further research and development with some applications aimed at elite level swimming. However, the aim of most research should be an outcome to benefit the greater community. In this case swimming performance across a range of abilities. To provide technology to coaches from elite level to those at local clubs would assist improvement of all swimmers. This would be to provide feedback that coaches and their athletes can understand.

From early stages of learning to swim through to elite athletes, information given to swimmers is critical for continued improvement. Providing methods of feedback on athlete performance is varied. Simple instructions or information such as verbal interaction from a coach to a swimmer would be the most common. This could be from basic information such as a lap time, or more complex feedback such as stroke correction. The information given

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to swimmers would usually result in an increased level of skill. The more skilled an athlete becomes, there is less reliance on having to think about what they have to do [11]. Therefore performance becomes a product of efficient swimming.

Visual feedback can provide immense benefits when learning a new, or improving an existing skill [12]. Providing external feedback has shown to benefit athletic performance [13]. This means that feedback that highlights the outcome, rather than the action results in better performance outcomes. If a swimmer thinks about their stroke action, it may result in negative achievements. If a swimmer focuses on bringing their stroke action to within the boundaries similar to that of elite athletes, this would be external focus.

This paper reports the progress at the Queensland Sports Technology Cluster (QSTC) in taking inertial sensor data and changing the visual output. The aim of this research is to provide coaches and swimmers with understandable data that can be used to improve swimming performance.

2. Technology

The hardware used at QSTC is custom built by engineers within the cluster. The sensing devices are housed in a dimensionally small (~50 mm × ~30 mm × ~10 mm) lightweight (~ 20 g) waterproof container. The devices contain a triaxial accelerometer and gyroscope, wireless transmission and receiving, and data logging capabilities. Full specifications have been previously reported [14]. The dimensions of each device allows for relatively easy placement on selected points on the body with minimal interference to function or performance by a swimmer.

The supporting software that has been developed is based on the Matlab™ environment [15]. This provides complex analysis and visualisation tools to be used by engineers and human movement researchers alike. More importantly, the visualisation has been aimed to assist coaches in swimming assessment. It gives them the opportunity to assess swimming strokes and identify any differences in particular strokes or if variables such as fatigue has an effect on swimming performance of an athlete.

3. Technology Outputs

Typical data from inertial sensors can be displayed in the form of continuous data in a plot (Figure 1). In this figure, data collected from a sensor placed at S1 of the sacrum, gives outputs (after 4 Hz Butterworth filtering) from a triaxial accelerometer. Outputs from the three channels can be seen with data from X channel depicting direction of travel, Y channel roll to the left (positive peaks) and right (negative peaks), and Z channel anteroposterior accelerations. The Z data is offset from the other data due to the effects of gravity. Identification of body roll relative to breathing strokes was achieved from events in the Y channel and Z channel data. This was confirmed using a fusion system [16] to identify the breathing and non breathing strokes. The Y channel data shows greater body roll on every third roll to both the left and right. Being a bilateral breather, this is in line with the athlete breathing on those strokes. For a sports scientist, the data at this stage can easily be taken for further analysis. To an untrained person, this direct output data would most likely mean little.

![Triaxial accelerometer data](image.png)

Fig. 1. Triaxial accelerometer data. The small dotted line oscillating around zero represents the X channel. The solid line represents Y channel data. The large dotted line oscillating around 1 represents Z channel data.

This data can be taken and put into an overlay plot. As an example, left sided breathing strokes were decided as the
focus of attention (Figure 2). Here it can be seen how consistent the body roll is during the breathing action when compared to the non-breathing body rolls. From this, a coach could get a sense of consistency by a swimmer. It may also be possible for the coach to determine whether the swimmer's breathing strokes affect subsequent non-breathing strokes.

![Fig. 2. 2D overlay of body roll. Body roll associated with breathing strokes are in solid lines.](image)

A coach may wish to observe changes over time e.g. the effect of fatigue on body roll. A 3D overlay is an effective option (Figure 3). In such a plot, a coach may be able to identify which strokes that might be affected during the course of a swim. Symmetrical pattern changes would identify where a coach may have to target a swimmer's training. Whether it was for a higher level of conditioning, or to teach the athlete to hold their technique once in a fatigued state.

![Fig. 3. 3D representation of body roll. The four left side breathing strokes can be easily detectable with the peaks rising above the non breathing strokes.](image)

**4. Discussion**

The purpose of this paper has been to report the development and direction of technology developed at the QSTC in relation to an outcome to benefit coaches and athletes. The paper presents different options available. The correct option would be dependent on what is to be analysed for performance improvement.

The outputs displayed in figures 2 & 3 indicate identifiable differences of body roll between breathing and non-breathing strokes when using different visualisation techniques. This will enable different feedback options to athletes and coaches. The blending of this with other developed research within QSTC [14, 17, 18] means that effective real time feedback can occur. Athletes receiving feedback promptly results in better performance improvement [12].

Because the visualisation is not exactly the image of the athlete's action, the feedback would be considered an external focus. External focus methods of performance feedback have been shown to be more effective for skill improvement [13] this means providing a focus on an effect rather than actual body movements. Therefore feedback in the nature of understandable plots instead of straight video of a body action would most likely be more efficient in aiding performance improvement.

**5. Conclusion**

This paper has demonstrated the need for a visual method for data interpretation and demonstrated an approach applied to freestyle swimming using inertial sensors. What have been presented are examples in both 2D and 3D form. These visualisation methods allowed information about the body roll to be extracted. Overall the paper shows that various visual methods can be applied successfully for data interpretation from inertial sensor data.

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