

Towards determining absolute velocity of freestyle swimming using 3-axis accelerometers

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Abstract

Investigating the performance of an athlete and monitoring them is important to athletes and coaches. Coaches are not always on side when athletes doing their training, so a device which is small and easy to use will increase the monitored training sessions significantly and allow the athlete to compare multiple training sessions. In this research a small, portable inertial sensor platform was used to investigate the movement of swimmers and was set to record data at 100 Hz. The experiment was undertaken in an indoor pool with the sensor attached to the swimmer's sacrum, a velocity meter (Speed Probe 5000 – SP5000) attached to the swimmers suit with a video camera capturing the swimmer over the whole lap. The SP5000 measures the velocity directly and provides a synchronised video with the gathered velocity data. This system was used as main reference as it is already proven as a robust method and provides data files which can be directly imported into Matlab. The swimmer was asked to push-off with both feet against the wall and perform one freestyle stroke lap, which was repeated at different speeds. The timing parameters of the lap (i.e. start time, end time, stroke frequency) can be identified from the acceleration data. The acceleration data was then passed through a 0.5 Hz low pass filter to gain the sensor orientation, which was then removed for further processing. The velocity profile was calculated using the acceleration in swimming direction (a_y) and the total acceleration (a_{tot}). The mean velocity from the SP5000 was 0.964 ± 0.086 m/s whereby the mean velocity derived from the accelerometer was 1.331 ± 0.207 m/s and 0.944 ± 0.119 m/s for a_y and a_{tot} respectively. This research has shown that velocity information can be derived from acceleration data but there is still a difference in comparison to the SP5000 velocity. Future work needs to find a better approach in removing the sensor orientation.

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1. Introduction

The velocity of swimmers in training and competition is of major interest to coaches to monitor training load and assess and compare different training sessions. Accelerometers can provide accurate stroke rate and lap times [2], there has been some research done in the investigating swim velocity using tethered devices [3] and video recordings [4], but the calculation of swim velocity variations within one lap has not been achieved. The derivation of velocity for a swimming lap using a small, low cost, portable accelerometer will be of significant benefit to help understanding and increasing the performance of the sport. It will provide coaches with important information and help them to individualize the training for each swimmer.

2. Methods

In this study, an 3-axis accelerometer logging unit [1] was taped to the swimmers sacrum where the effect of body roll on the acceleration direction is minimized. The sensor was set to record data at 100 Hz. The position of the sensor and the coordinate system of the three axes are shown in figure 1. The y-axis represents the acceleration into the swimming direction, the x-axis the mediolateral and the z-axis the vertical direction. The total acceleration a_{tot} was calculated using:

$$a_{tot} = \sqrt{\sum_{i=1}^3 a_i^2} \quad (1)$$

The velocity meter used for this research is the Applied Motion Research Speed Probe 5000 (SP5000). These devices can be used to measure velocity profiles of straight motion events such as running or swimming. The system uses a very thin nylon line which was attached to the swimmers costume as close as possible to the sacrum. The device determines the velocity by measuring the time it takes for 1cm of line passing by an optical sensor. It is attached to a computer which runs the logging software and synchronizes the video with the velocity data.

A 25 years old recreational swimmer was informed of the reasons for the study and signed a consent form to participate in the study. The study was approved by Griffith University Ethics Committee with the approval number ENG/05/10/HREC.

Following a warm up, the swimmer was asked to perform multiple single freestyle laps at different speeds using an in-water push-off at the start. The experiment was performed in a 25m heated indoor pool.

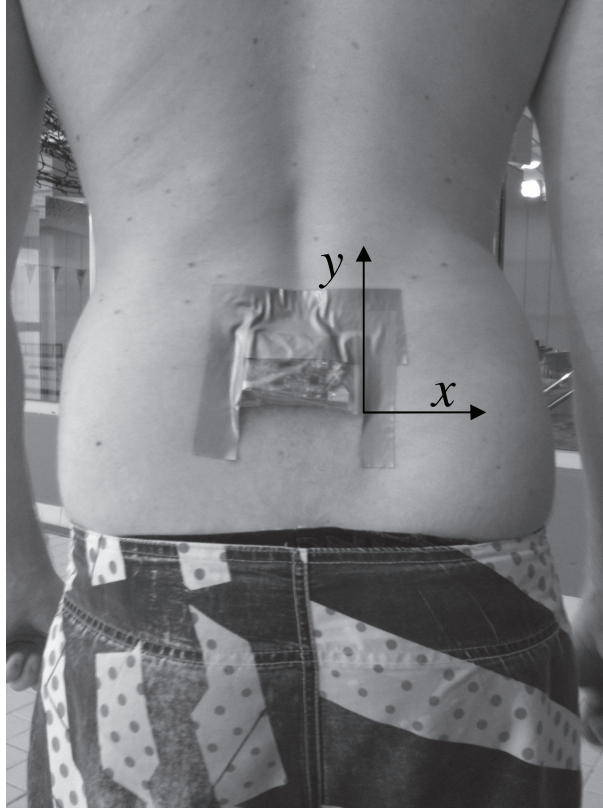


Fig. 1. Taped accelerometer platform and acceleration directions.

3. Results

The raw acceleration data was converted to gravitational units (g). The three acceleration components a_x , a_y , a_z and the total acceleration a_{tot} are shown in figure 2. The body roll can be seen on the x-axis which is the mediolateral direction. The acceleration into the swimming direction can be seen on the y-axis. The total acceleration (a_{tot}) shows 1g if the swimmer experiences no acceleration apart from the gravitational acceleration.

As the accelerometer changes orientation during the swim, the can contain an orientation error. In order to remove the sensor orientation from the acceleration data, a low pass filter with a cut off frequency of 0.5 Hz was used. Figure 3 shows the filtered acceleration data which was used for further processing. There can also be drift and noise, when integrating the acceleration. The drift has been considered as not significant, due to the short durations of the experiments and therefore no corrections have been applied to the data.

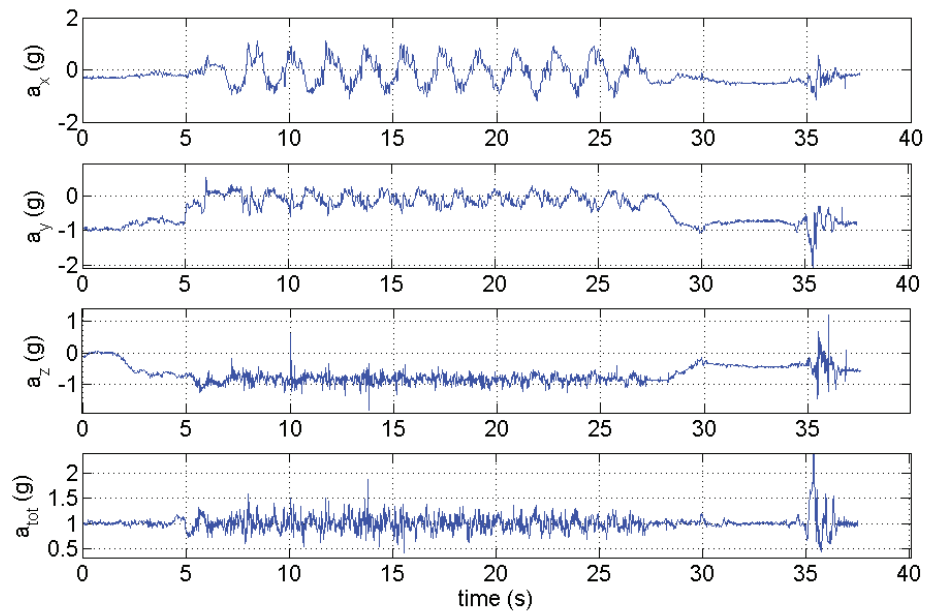


Fig. 2. Acceleration data for a single 25m lap using freestyle swimming.

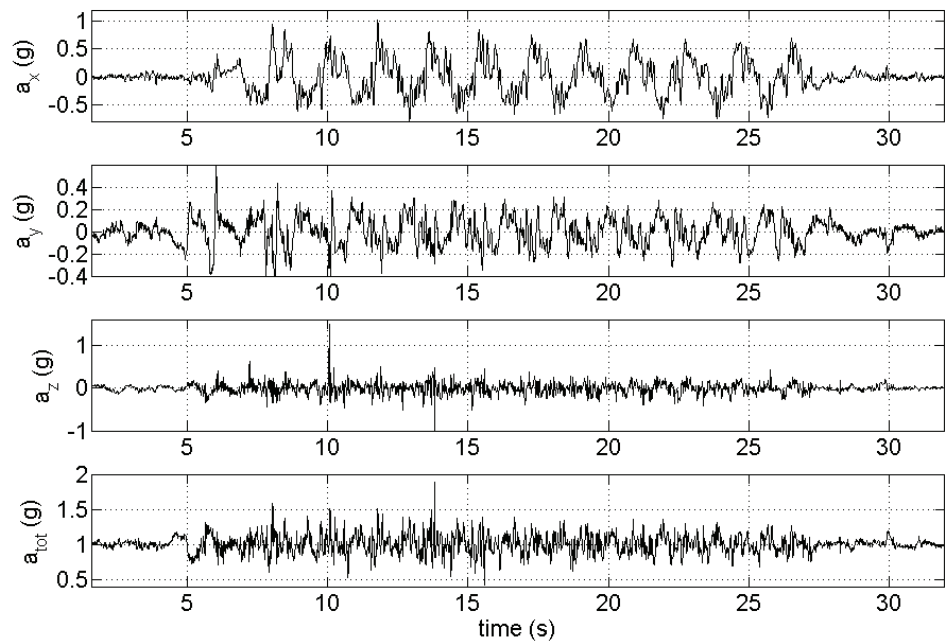


Fig. 3. Filtered acceleration data using the raw data shown in Figure 2.

Two approaches were used to calculate the velocity. The first was to use the acceleration into forward direction (a_y) [5], the second to use the total acceleration (a_{tot}). Figure 4 shows the tethered device velocity (black), the velocity calculated from the forward direction (blue) and the calculated velocity from the total acceleration (red).

The velocity determined from the forward direction acceleration has a push-off velocity of 1.45 m/s which is close to the velocity of 1.74 m/s measured by the SP5000. The variation in velocity during the swim is large compared to the SP5000 velocity variations. Comparing these results with the velocity calculations from the total acceleration shows that the velocity variations are within the same range as the SP5000 velocity variations.

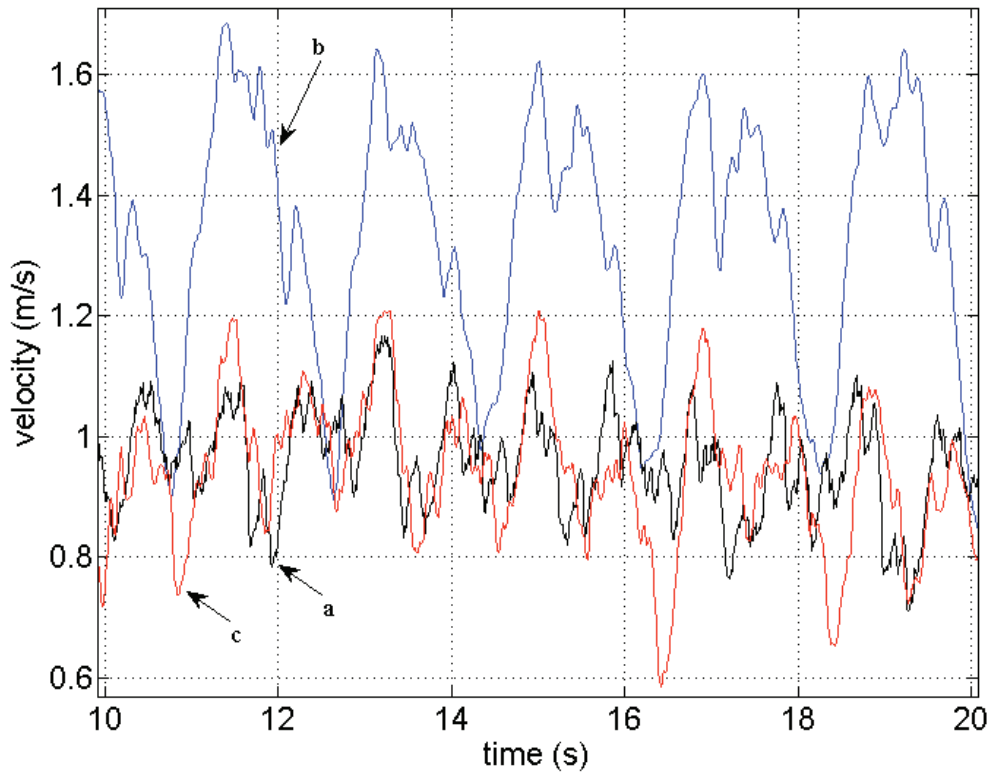


Fig. 4. Velocity comparison for the lap data shown in Figures 2 & 3. (a) SP5000 velocity, (b) a_y velocity and (c) a_{tot} velocity.

4. Discussion and Conclusion

The mean velocity for the time window shown in figure 4 was 0.964 ± 0.086 m/s for the SP5000, 1.331 ± 0.207 m/s and 0.944 ± 0.119 m/s for a_y and a_{tot} velocity integration respectively. Craig et al [6] found a velocity variation of $\pm 20\%$ for freestyle swimming. Our results shows a velocity variation of $\pm 8.9\%$ for the SP5000, $\pm 15.6\%$ for the a_y velocity integration and $\pm 12.6\%$ for the a_{tot} velocity integration.

The freestyle stroke was choosen as freestyle swimming has a more constant velocity during the lap and therefore less velocity variations on a stroke by stroke basis as the other swimming styles. Stroke patterns are different from swimmer to swimmer and even within a single swim of one swimmer.

This research has shown velocity can be derived from accelerometers, but there are still more investigations necessary to solve the explained issues.

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