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On the use of inertial sensors in educational engagement activities

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Abstract

Wearable sensors have been successfully used for a few decades in different sporting applications and its use has been constrained mostly to research projects. However, its positive impact has been recently adding other directions towards education, commercial and servicing. The establishment of Sports Engineering as a discipline is playing an important role in Australian universities where relevant material and emerging technologies are required to be taught and in certain circumstances developed. Some of these technologies include the adoption of inertial sensors (accelerometers and gyroscopes). This paper shares the impact of inertial sensors in building engagement in different educational activities at secondary level, with the purpose of engaging them into Sports Engineering disciplines, and at tertiary level through teaching undergraduate and post-graduate programs.

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Keywords: Education; sports engineering; wearable technology; inertial sensors; accelerometers, gyroscopes.

1. Introduction

Inertial sensors are increasingly used to monitor human movement, biomechanics and relate this data to the tasks associated with every-day living. These sensors have been successfully utilised in different sports related monitoring research projects [1], and its positive impact is adding other directions towards education, commercial and servicing [2].

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This paper shares the impact of inertial sensors in building engagement in different educational activities at secondary level, through experience and science days for high school students, with the purpose of engaging them into Sports Engineering disciplines, and at tertiary level through teaching undergraduate and post-graduate programs, i.e. practical sessions to look at symmetry in movement patterns in resistance training exercises. For that purpose, a recently developed platform has been employed as a teaching tool by a numbers of different Australian universities in research and teaching [2,3].

Within the exercise and sports sciences program, the technology is being used for the assessments of strength and conditioning exercises as well as assessments of movement competency and control that have relevance to performance and injury prevention.

The technology employed consists of wearable inertial sensors that respond to minute changes in inertia in the linear and radial directions. The sensor collects data from digital MEMS (Microelectromechanical systems) inertial sensors (accelerometer, gyroscope) and a digital magnetometer. This wearable technology provides the user with the freedom to move both indoors and outdoors, thanks to the data being stored locally on the sensors, and controlled wirelessly using a comprehensive Matlab educational toolkit, together with a powerful graphical user interface. The toolkit allows the control of multiple sensors.

This paper presents a survey of different educational activities at secondary and tertiary level using the in-house wearable technology as a teaching and as an engagement tool.

2. Sensor platform

A rise of inertial sensors in sport science is well described in [2], where an analysis about the growth of wearable technology and its application to different sports fields is presented. A 3rd generation inertial sensor was employed in this paper and it consisted of a 3-axis accelerometer, a 3-axis gyroscope and a 3-axis digital magnetometer used for calibration, with dimensions 55mm × 30mm × 13mm (L×W×H) and a weight of approximately 23g. The data is stored locally on the sensor, so participants can move both indoors and outdoors, it is also controlled wirelessly by a Matlab-based graphical comprehensive toolkit, which can be used for data visualization and analysis of multiple sensors.

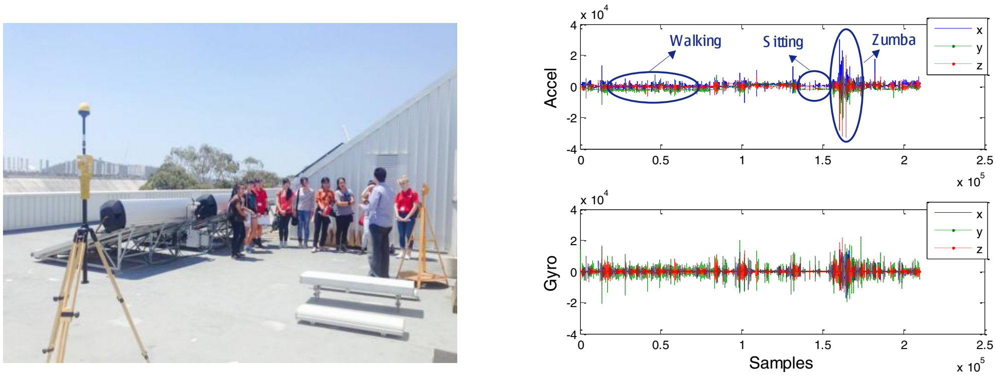
3. Educational levels

3.1. Secondary level

Every year, Griffith University organizes Engineering engagement events designed for high school students, with the purpose of engaging them into different disciplines including Sports Engineering. Some of these events include 'Experience/Science/Girl's days'. The latter consists of a full-day program designed for female High School students in Years 10 to 12, which provides a hands-on overview of practical engineering applications.

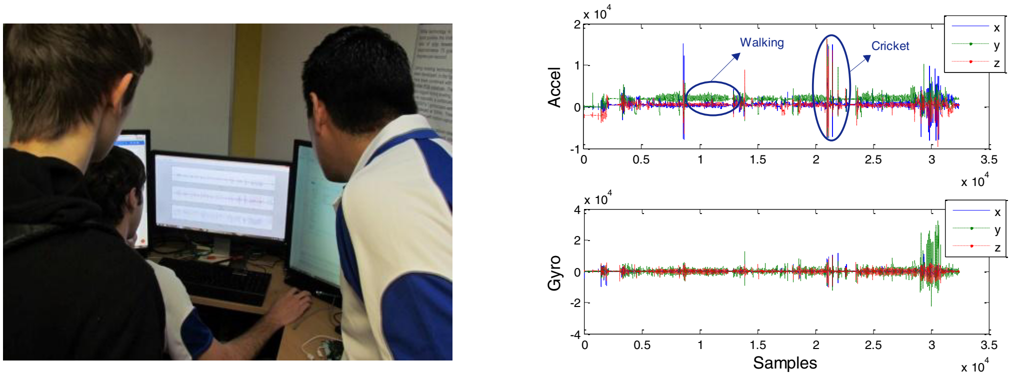
At the beginning of the activity, students receive an overview and introduction to inertial sensors and its application to different sport fields, afterwards, a sensor is placed on each student's wrist or ankle using a provided fabric armband fitted with Velcro, the students are then taken on a tour around campus (Fig. 1a), visiting engineering facilities such as electronics laboratories, roof antennas, an anechoic chamber, meeting with students and researchers for a Q&A about Sports and Electronics Engineering, etc., and performing throughout the activity, light/physical movements. At the end of the activity, the sensor data is downloaded using the Matlab-based toolkit, it is then analysed and interpreted, where some of the student's movements, such as walking, running, climbing upstairs, etc., are identified. The students take with them a printed version of the sensor data with the classification analysis. Figure 1b shows an extraction of the sensor data (accelerometer and gyroscope) where movements such as walking and dancing Zumba can be easily observed. The activity intends to engage students by learning the electronics/communications behind the inertial sensors and its application to different fields in sports science.

'Experience day' is a mixed activity that provides a similar approach to students by wearing inertial sensors on their body and performing light/physical movements as well (Figs 2a and 2b). The difference is that in this activity a motion caption is employed where the student wears reflective markers and participate in different tests to measure gait, stride, distance run, etc. The data is then synchronized with the data extracted from the inertial sensors from the tour activity. Figure 2b shows an extraction of the sensor data (accelerometer and gyroscope) placed on the student's wrist on three axis (*x*, *y* and *z*). The accelerometer data clearly identifies his movements during the activity (walking, playing cricket, etc.).



(a) (b)

Figure 1. Students participating in Griffith University Girl's day event. (a) Students attending an explanation about wireless communications. Every student had a wearable sensor placed either their wrist or ankle (b) data extracted from the inertial sensor (3-axis accelerometer/ gyroscope) with activity classification.



(a) (b)

Figure 2. Students participating in Griffith University Experience day event. (a) A student receiving an interpretation on his sensor data extraction (b) data extracted from the wearable sensor (3-axis accelerometer/gyroscope) with activity classification.

The wearable sensors and the user friendly visual tools used in these interactive activities, allow secondary education stakeholders to have a taste of an emerging technology with the intention of engaging them into Sports Engineering disciplines.

3.2. Tertiary level (Undergraduate programs)

The use of inertial sensor technology in undergraduate programs at Charles Darwin University is both in undergraduate research and teaching. A successfully completed Honours Degree, validating the effectiveness of inertial sensors to monitor spinal position during lifting activities. Not only does this benefit lifting sports, other sports as well as safe lifting in working environments will benefit. Currently, there is development of inertial sensors as a teaching tool in biomechanics (Fig. 3a). Inertial systems form part of the applications of technology in sport and based on research in specific areas, students are using inertial sensors to measure temporal kinematics of walking and running gait [4], as well as predictions of height reached during a vertical jump (Fig. 3b) [5]. In recent years, assignments and reports on technology used in sport have increasingly seen students choosing inertial and disruptive technologies as chosen topics. Students identify that these technologies are growing in use and popularity for performance analysis, somewhat in line with the technological growth in the sporting industry.

(a)

(b)

Figure 3. Students participating in a Chales Darwin University biomechanics class. (a) Performing a teaching exercise to assess gait data and (b) performing a vertical jump with an inertial sensor positioned on the forearm (visible), and one placed at the sacrum (obscured by clothing).

Charles Darwin University has large numbers of externally enrolled students with in excess of 75% enrolments by this method. Labs typically contain equipment such as motion capture systems and force platforms, which are only accessible to those on campus. Inertial sensors provide opportunities for students to practice laboratory work and not simply having largely theoretical work to complete. This can be by students using accelerometers and gyroscopes incorporated in smart phones.

3.3. Tertiary level (Post-graduate programs)

Inertial sensors will be incorporated into a PhD research project at Bond University. This investigation into the biomechanics of the BMX Supercross gate start aims to describe the human and bike kinematics during the first three cranks of a supercross race. The gate start is considered crucial in BMX races as being the first of the eight competing cyclists allows the first rider to pick their course and reduce their risk of crashing into other cyclists [6]. The environmental conditions present unique challenges for field data collection, but also make replication of a supercross race in laboratory unfeasible. The ease of use, small size, robustness and ability to store data locally mean that field data collection with these inertial sensors has minimal impact on the rider motion. The ability to store data locally rather than use a radio signal is an advantage in the field as it eliminates the issue of interference with timing transducers used on the track and other measurement equipment that may be used, such as for electromyography.

BMX riding is a whole body activity [7]. Inertial sensors on the torso will be used to describe upper and lower body movement relative to each other, and the bike. Two inertial sensors will be placed on the rider, one each on the lumber and thoracic spine. Another will be placed on the bike frame. The accelerometry data will show horizontal movement of the body relative to the bike and vertical movement of the body relative to the bike. This will help to identify the nature of the 'sling' action used by individual riders to propel the bike over the gate as it drops and then to push down the ramp. Multiple trials across a number of training sessions will highlight the degree of natural variation of technique for each subject. The degree of variation will also be compared between athletes in order to describe common expected variation of movement patterns during any given training session. The quantification of this natural variation for each writer is crucial for coaches and sport scientists to be certain that any observed changes in movement patterns they observe are true changes that reflect training or injury and not just measurement error.

The gyroscope information will be used to show axial rotation. This is valuable information as only 2D motion capture giving sagittal motion will available for kinematic analysis in this context [8]. The degree of axial rotation of the rider about the spine will inform assumptions about movement in the sagittal plane. Gyroscopic information from the bike matched against this will reflect lateral movement of the bike, that is a rocking motion from side to side, giving an indication of mechanical efficiency.

These sensors are also used in laboratory sessions as a part of the Bachelor of Sports and Exercise Science and Masters of Sport Science degrees at Bond University in Advanced Biomechanics and Motor Control, and Performance Analysis in Sport courses, respectively. These practical classes use the sensors to quantify measures relevant to movement efficiency and injury risk and easily allow comparisons of left to right side so to determine if there are any bilateral asymmetries. For example, with sensors applied to both knees and hips, a student will be instructed on how to perform a full squat. Graphed accelerometry data from the inertial sensors can then been viewed to determine any deficiency in the kinematics of the bodily segments. Jumping and landing activities are also performed, with the accelerometry data from the ankle, knee and hip joints allowing insight into the joint forces based on Newton's second law of acceleration. This data can then be used as a form of augmented feedback, whereby the student participants will try to modify aspects of their performance in order to improve performance or reduce injury risk.

These applications to sporting performance enhancement and injury risk prevention appear exciting and with further improvements in technology and cost, such sensors are more likely to play major roles in high performance sport and physiotherapy practice.

4. Conclusions

The use of inertial sensors as an educational base platform has been presented in this paper. A 3rd generation wearable sensor that collects data from digital MEMS inertial sensors (accelerometers and gyroscopes) was used in different educational levels, as an engaging tool for secondary level through 'Experience/Science/Girl's days', where students get a taste of an emerging technology and promotes their interest in Sports Engineering disciplines, and as a teaching tool for tertiary level, where undergraduate and post-graduate students from different Australian universities have the opportunity to employ the technology through different courses including, Biomechanics and Sports Instrumentation.

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