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E-kayak: a wireless DAQ system for real time performance analysis

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Abstract

The use of microelectronic measurement systems properly designed for sport performance monitoring is, in recent years, increasingly common to give helpful feedback in training of professional athletes. Different are the systems today available, some of them make use of video analysis while others are based on the measure of specific kinematic or dynamic parameters. In this paper, we present a study on a new portable data acquisition system (E-kayak – ApLab Rome Italy) for real time monitoring of the boat and paddling dynamics. The system gives real time feedback to the athlete during the training session. Moreover, the training data can then be downloaded to a PC for further analysis from the coach. The acquired data can help evaluating the paddling technique and spotting technical flaws, to improve performance. A first prototype of the system has been manufactured and at the moment is still in the testing phase. Some results of the preliminary tests are presented in this paper.

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Keywords: Biomechanics, Sprint kayaking, Instrumentation, Measurement

1. Introduction

The performance of kayak athletes mainly depends on their strength and a proper paddling technique [1–6]. This is why, in order to obtain a significant improvement in the performance, it is necessary to carry out an accurate analysis of the action of the athlete. There is a difference to be made, in motor learning, between "knowledge of result" and the "knowledge of performance" [7]. The former represents the assessment of the quality of a trial based on the overall outcome, while the latter represents the assessment about how such a result has been achieved. For this reason, in order to obtain improvements in the overall performance, athletes and the coaches need to receive live feedback during the training session and then after it for a more detailed analysis. Therefore, the study of the parameters of the performance to find the best indicators able to give practical tips is a very interesting challenge.

In the kayaking field, the parameters of the paddling performance can be acquired by means of an instrumented ergometer rowing or by using an on-water logging system. In particular, among the latter ones, the paddling parameters can be evaluated by means of video and biomechanical analysis as well as by measuring several kinematic and dynamic parameters [8]. In the kayaking, the main kinematic parameters include speed, acceleration, intra-cyclic velocity, roll and pitch of the boat, while the dynamic parameters include stroke frequency, force acting on paddle and foot brace, the symmetry between the right and the left paddle and, finally, the synchronization among the forces.

The goal of this study is to present some measurement results from a multichannel portable data logger in a flat-water kayak training environment. The system gives real-time feedback to the athlete, to improve his/her knowledge of performance. This translates into increased control of the learning process and its effectiveness. The system, which has been designed to be easy to use in day-to-day training, can also provide coaches, researchers and boat designers with a great wealth of useful data.

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2. System description

The E-kayak system is a new multichannel wireless real time data logger well suited for race kayaks. The system includes a high frequency GPS (Global Positioning System) receiver, a six DoF (three linear accelerometers and three gyroscopes) Inertial Motion Unit (IMU) and two force channels for the paddle and foot brace. Moreover, it is able to synchronously acquire the data from each of the channels, elaborate them on a microprocessor unit and, finally, send, in real time, the reconstructed parameters to a proper portable terminal unit (i.e. an Android as well as Windows based smartphone or tablet) via a Bluetooth radio link. On this terminal unit, that can be placed on the cockpit of the kayak, a purpose-built app receives the data, stores them on a flash memory and presents some of the main parameters (i.e. time, speed, stroke frequency, force symmetry) in real time to the athlete. Moreover, at the end of the training session, the whole amount of the acquired data can be displayed on the terminal unit itself or downloaded to a Personal Computer for further more detailed analysis.

The system, depicted on Fig. 1, is composed of:

1. A microcontroller unit (uC-1) placed under the foot brace connected to the following sensors:
    a. The force channel able to measure the force applied on the foot brace.
    b. The high frequency (i.e. 10Hz) GPS receiver
    c. The tri axial linear accelerometer
    d. The tri axial gyroscope
2. A microcontroller unit (uC-2) connected to a force channel to measure the force applied on the paddle.
3. A terminal unit (i.e. a smartphone or a tablet)

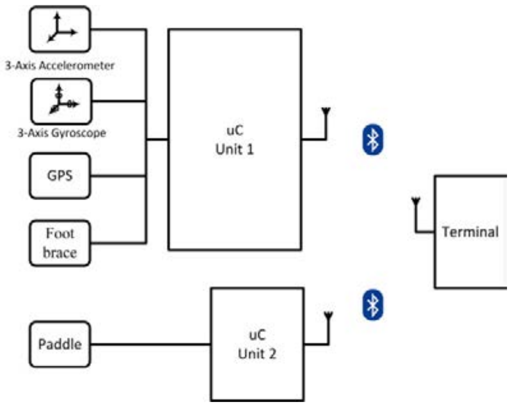


Fig. 1. E-kayak System block scheme.

The real time assessment of the paddling is evaluated by the measure of the bending of the paddle due to the force applied on each of the blades during the pull phase of a stroke. For this purpose, four strain gages, connected to form a full Wheatstone bridge have been mounted on the paddle at an appropriate distance from the blades. Fig. 2 shows a particular of the placement of one of these strain gages. The force on the blade through the pull phase flexes the paddle modifying the value of the impedance of the strain gage. Consequently, the induced imbalance in the Wheatstone bridge (proportional to the force applied to the blade) produces a signal that can be detected by the electronic system. This signal, after an appropriate amplification and filtering, is sent to one of the analogue input channels of a microcontroller unit where is sampled at a frequency rate of 50 Hz. Furthermore, in order to achieve an overall assessment of the performance the paddling data have to be synchronized with those obtained by the other sensors. For this reason, they will be transmitted via a Bluetooth link to the other microcontroller unit (uC-1).

Fig. 2. Detail of the strain gage placement and the Bluetooth module on the paddle.

This unit (shown in Fig.3) is placed under the foot brace and is connected to the IMU, the GPS receiver and the force channel from the foot brace. The accelerometer signals are useful to monitor the acceleration of the boat as a function of the force applied to the paddle, while the gyroscope is used to the monitor the roll and pitch of the boat. The acquisition of these six channels from the IMU (the tri-axial linear accelerometer and the tri-axial gyroscope) and of the force channel is performed at a sampling rate of 50 Hz. On the contrary, the GPS signal, useful to measure the displacement and the instant speed, is sampled at a rate of 10 Hz due to limitations of the sensor. Finally, the uC-1 performs the synchronization of the acquired data with those received by the uC-2 on the paddle and then arranges the transmission of the reconstructed data (again by using a Bluetooth link) to the terminal unit for displaying. The same unit manages the storing of the raw data in a SD memory card to make them available for download on a Personal Computer.

Fig. 3. E-kayak system – cabled version: control unit, foot brace and GPS antenna.

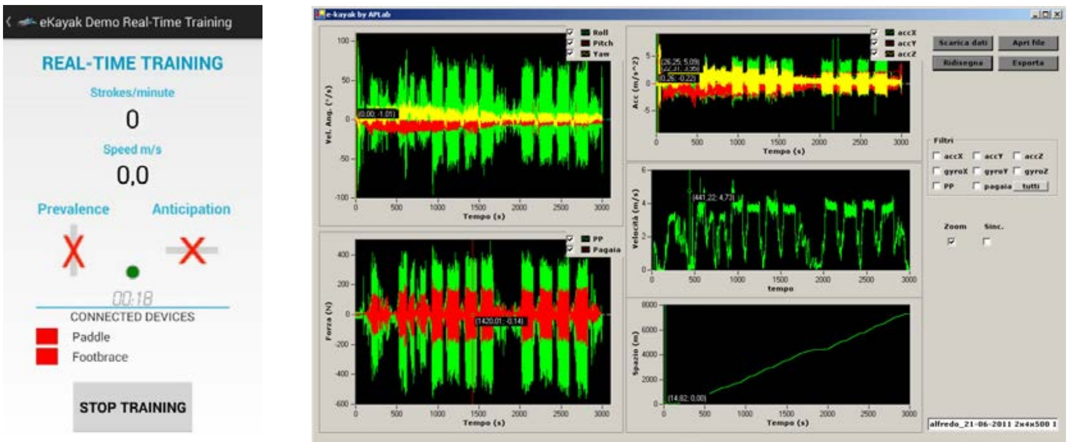
System specification

The IMU (Invensense MPU6050) used in this system is a MEMS (MicroElectroMechanical Sensor) device with an acceleration range up to ±16g and a gyro range up to 2000°/s. It presents a built-in 16bit AD converter, 16-bit data output and it is able to transfer up to 400 kHz through the I2C (i.e. a particular serial communication bus) or up to 20MHz via SPI (Serial Peripheral Interface, another communication bus).

The strain gage used for monitoring the force of both paddle and foot brace are KFW-5-120 (Kyowa). These are strain gages (120 Ohm resistance value) devices with the surface covered with a special resin for waterproofing.

The device used in the both the microcontroller units is the ATmega168: an 8-bit Advanced RISC architecture able to work at 20 MHz@5V able to process data up to 20 MIPS. Moreover, it is provided of an eight channel 10-bit 15 kbps ADC (Analog to Digital Converter), presents 23 I/O Pins and 1 Kbytes SRAM. Finally, the uC-1 will manage the download of the complete raw data from the training session stored on the SD card toward a portable terminal unit (e.g. a tablet or a smartphone) as well as a Personal Computer for a more exhaustive offline analysis.

The uC-2 is mounted on the kayak paddle via silicon strap close to the paddle's center point, between the athlete's hands. In this way, the peripheral mass is reduced making the paddle easier to move.



a) b)

Fig. 4. (a) App screenshot on the tablet for live monitoring; (b) Screenshot of the Software for the data analysis on the PC

The figure 4 shows two different screenshots of the App on a portable terminal unit (fig. 4a) and of the software program on a Personal computer (fig. 4b), respectively. In particular, the App on the portable shows to the athlete only a few parameters (strokes/m, speed, prevalence and anticipation) and it has been designed to give to him only the real-time feedback of the performance which can be translated into corrective actions. In particular, the prevalence parameter shows the lack of synchronization between the forces applied to the paddle and foot brace (i.e. the push of the foot on the foot brace with respect to the force of the arm on the paddle). Furthermore, the anticipation parameter gives to the athlete the information about the lack of symmetry between the force applied on the paddle by right and left arm respectively. The screenshot of the software interface available on the PC shows, clockwise from the upper left side of the screen:

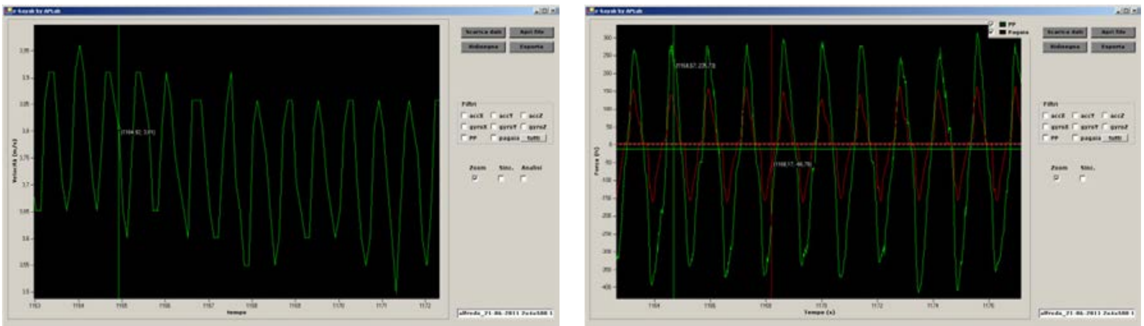
- Tri-axial angular speed
- Tri-axial accelerations
- Speed
- Distance
- Force on the paddle

The software on PC can analyze in detail every phase of the training session by measuring and comparing the information acquired by the different sensors.

3. Results

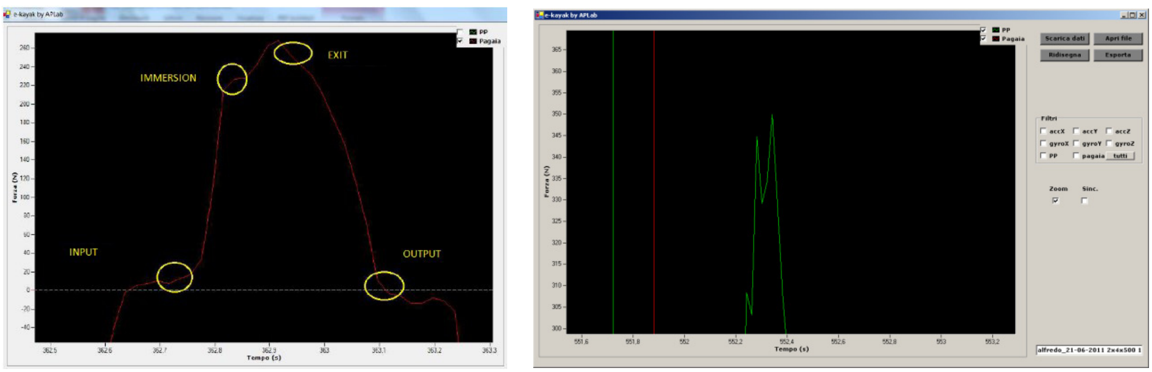
The system prototype has been manufactured and is currently undergoing the testing phase. Several preliminary tests have been carried out. In this paper, we present some test results illustrating its use during a flat-water training session. The following figures are screenshots showing details of data acquired during the sessions.

Figure 5a shows a detail of a speed waveform. It is worth noting that the high refresh frequency of the GPS module (10Hz) reveals the variations of the intra-cyclic velocity. This is not possible with standard 1 Hz modules. Figure 5b shows a detail of the force waveform on both paddle and foot-brace. Such technical flaws as, for example, anticipation and prevalence, if they occur, can be observed in this chart.



a) b)

Fig. 5. (a) Speed; (b) Detail of force on paddle (red) and foot brace (green)



a) b)

Fig. 6. Detail of force on paddle: (a) a stroke; (b) a typical double peak shape

Figure 6 shows some details in the waveform of the force on the paddle. In particular, Fig. 6a shows the sequence of the stroke movements and it is possible to recognize the typical four phases: paddle entry (catch), pull phase, paddle exit and air phase. Finally, Fig. 6b shows the typical double peak shape of the force during a stroke of the paddle. The analysis of these details can give useful tips to both the athlete and the coach for the improvement of the paddling technique. Furthermore, by comparing the strength chart on paddle with the accelerations on the x-axis, it is possible to verify when, during each stroke, the highest acceleration occurs. In this way, the system allows both the athletes and coaches to monitor the effectiveness of the entire kinematic chain of the athlete as well as his ability to better control the performance of the kayak.

4. Conclusions

In this paper, we have presented a real-time wireless DAQ (Data Acquisition System) intended for dynamic and kinematic measurements during kayaking on flat water. The system features and functionality have been verified in some preliminary tests during training sessions. The feedback effects during the training are still being tested. Further developments are expected in the near future.

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