

Wearable multi-sensor system for embedded body position and motion analysis during cycling

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Abstract

Purpose: The purpose of this study was to validate the AREM system in laboratory conditions. AREM is an embedded electronic system for motion tracking and movement analysis, based on Micro Electro Mechanical Systems (MEMS) sensors and a reconfigurable hardware/software electronic architecture including FPGA + PSoC embedded boards for real time acquisition and signal processing.

Methods: AREM sensors were installed on cyclist before performing on a test in which other measurements were made to analyse efficiency of standing position.

The position of cyclists during whole test was measured by both AREM and a Kinematic Arm and verified by video systems. The protocol included 13 elite participants on a motorised treadmill with their own bike during which they rode in a randomized order seated vs. standing positions with several slopes (5, 7.5 and 10%) and intensities (3.8, 4.2 and 4.6 W.kg⁻¹). GE was calculated for each condition using the ratio of power output (PO) measured with a Powertap G3 hub (CycleOps, Madison, USA) and the oxygen uptake (VO₂) measured with a portable gas analyzer (Metamax 3B, Cortex, Leipzig, Germany).

Results & Discussion: The synchronised data of 8 inertial sensors was retrieved and combined to obtain joint positions of shoulders (2), waist (3), middle and lower trunk (2) on cyclist. 1 sensor was installed under the saddle of the bike. The position data was compared between the two systems, and result on validation of AREM for 3-axis displacements (up to 40cm on X axis). We also compared the accelerations (+/- 2 m.s⁻² seated to +/- 6 m.s⁻² in standing position, errors up to 10% between both systems), power and energies for each cyclist during test steps (kinetic energies variation from 1.1 J/Kg to 3 J/Kg in a pedal stroke). Moreover, the acceleration and orientation data on cyclist and bike revealed different approaches on effort management during the test, and were compared to videos to obtain sensors data according to different "standing position" techniques. This data is an interesting indicator of the cyclist fatigue during a test, and is being crossed with PO and VO₂ data.

Conclusion: The validation of AREM system offers the possibility to extend our measures on real cycling locomotion in outdoor conditions, replacing the kinematic arm with AREM.

Despite the 3D movement analysis of the cyclist on a standard protocol, first results suggest a position adjustment according to the technique of each cyclist, but also an impact of the mechanical response of the system tires-bike frame. The main perspective of these works is to include the Structure Health Monitoring analysis (SHM) on bike and to synchronise it with the cyclist activity and motion analysis during outdoor training. With both data, we expect to develop a reliable monitoring and optimisation system of the bike-cyclist couple in different course conditions.

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