Pre-Impact Fall Detection Architecture based on Neuromuscular Connectivity Statistics

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This work proposes the preliminary version of a novel pre-impact fall detection (PIFD) strategy, optimized for the early recognition of losses of balance. The technique has been implemented by using a multi-sensing architecture aiming to jointly analyzes the muscular and cortical activity [1, 2]. The physiological signals were acquired from 10 electromyography (EMG) electrodes on the lower limbs [3] and 13 electroencephalography (EEG) sites all along the scalp [4]. Recorded data are numerically treated by an algorithm composed of two main units: the EMG computation branch and the EEG one [5-8]. The first one has two main roles: (i) it treats the EMGs, translating them into binary signals (ii) it uses these signals to enable the EEG branch. The EEG computation branch evaluates the rate of variation of the EEG power spectrum density, named $m$, to describe the cortical responsiveness in five bands of interest [5]. The classification phase has been realized by correlating the data from the system calibration and the current measurements, via a logical network that operates on statistic-based thresholds [6]. The proposed architecture has been validated on five tasks: walking steps, curves, Timed Up&Go (TUG) test, obstacle avoidance and slip-induced loss of balance. Experimental validation on nine subjects showed that the system can identify a potential fall in $370.62 \pm 60.85$ ms, with a sensitivity of the 93.33 ± 5.16 %. The system robustness against activities of daily life (ADL) showed a specificity of 98.91 ± 0.44 % in steady walking steps recognition, 99.61 ± 0.66 % in sudden curves detection, 98.95 ± 1.27 % in contractions related to TUG tests and 98.42 ± 0.90 % in the obstacle avoidance protocol. These promising accuracies and the high robustness against false alarms, jointly with the system wearability (wireless acquisition devices), make the system potentially suitable for daily life applications. Moreover, the reached detection time (i.e., ~371 ms), below the maximum intervention limit for the implementation of actions aimed to recovering balance, ensures the architecture applicability as main computation core in system based on wearable.

References