3D analysis of gait using accelerometer measurements

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This work is part of a project that deals with the three-dimensional (3D) analysis of normal and pathological human motion based on a newly developed system for clinical applications, using wireless accelerometers and signal processing algorithm. Neurologists specialized in human motion disorders are indeed very interested in the development of innovative, quantitative techniques, and their possible use in clinical practice, e.g. in the diagnostic and analysis of Parkinson disease.

Our research aims at the extraction of gait parameters from measured acceleration signals to contribute to the understanding of these motion disorders as well as to the critical analysis and development of new therapeutic strategies. For this purpose, we have successfully developed and used a wireless 3-axis accelerometer-based hardware system to measure gait acceleration signals. We have also developed a signal-processing algorithm capable of automatically extracting, from these measurements, on a stride-by-stride basis, four consecutive fundamental events of walking, heel strike (HS), toe strike (TS), heel-off (HO), and toe-off (TO). The developed signal processing algorithm extracted HS, TS, and TO in local acceleration signals defined by heel and toe flat phases. This extraction was performed without any need for critical filtering of these local acceleration signals. Thus, the physical significance of these signals was not altered. An original piecewise linear fitting technique automatically identified HO using only the boundaries of the associated local acceleration signals (i.e., without the need of experimental filtering coefficients). The detection of these four gait events leads to a straightforward computation of relevant gait parameters such as stride cycle, stance, swing, loading response, foot-flat, and push-off. Detection of the same parameters of both feet can provide information about left-right asymmetry of stance, swing, and sub-stance phases.

Our hardware and algorithm have been validated by comparing the times of occurrence of each of these gait events with reference measurements provided by a force plate, a kinematic 3D analysis system, and video camera. The experimental results show the potential of the developed accelerometer-based approach to be used in neurology (ex. characterization of Parkinsonian gait: slowness, shuffling, short steps, freezing of gait, asymmetries in gait), rehabilitation, geriatrics (ex. monitoring activity parameters in the elderly), orthopedics, sport and motion capture (ex. physical movement or facial expressions of an actor equipped with this technology can be recorded and used to animate a digital avatar such that it mimics the actor’s actions).