On-line detection of cyclical motion tasks: an oscillator-based approach

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Abstract—This work introduces an oscillator-based approach to on-line detect the phase of a periodic motion task. The preliminary results of its application with a pair of wearable sensitive plantar pressure sensors are here presented.

I. INTRODUCTION

Development of smart interfaces able to intend and to adapt to the voluntary motion of the user is a critical challenge in the design of lower-limb assistive devices [1]. In literature several methods have been used during years to detect the gait phase during walking [2]. Gait segmentation methods often relies on heuristic threshold algorithm also named as Finite State Machines (FSMs) or stochastic models such as Hidden Markov Model (HMM). Despite the opportunity of being involved in real-time application, they require large dataset for training the system in recognizing states [2].

In this work we present an oscillator-based method to extract in real-time the phase of a periodic motion task. The oscillator system can be coupled to several sensory apparatus in order to synchronize with several sources of information about the gait cycle.

II. MATERIAL AND METHODS

The adaptive oscillator (AO) is a mathematical tool derived from the more known Hopf oscillator. Owing an inherent stable limit-cycle, its dynamical system is capable to learn and synchronize with periodic and rhythmic trajectory extracting its mean features, such as the phase, frequency and even the envelope [3]. Since human walking can be modeled as a rhythmic task oscillator-based strategy showed to be suitable for lower-limb assistive purposes.

In the specific case of the CYBERLEGs Active Pelvis Orthosis (APO) [4], the phase of the walking task learned by the AO was coupled with a non-linear filter to obtain a zero-delay estimate of the hip joint trajectory and of its predicted envelope. Similarly to the work of Ronsse et al. – conducted on LOPES platform - reported in [5], these elements are combined to generate an attractive field that guide the lower limb towards its future position.

A RT Labview routine has been developed in order to implement AO system and to extract the phase of ground level walking from sensitive plantar pressure insoles developed at Scuola Superiore Sant’Anna and described in [6]. The ground reaction force (GRF) collected from the sensitive insoles in a ten-minutes walking session was the input for the AO. A proper tuning of the parameters was performed to achieve the phase estimate of the walking task.

III. RESULTS AND CONCLUSIONS

Variable collected from the experimental session – specifically the GRFs from both the left and right insoles and the learned phase from AO - were segmented from the 0 to 100% of the stride duration being the 0% associated to the right heel strike.

Fig. 1 – Segmented variables vs. the percentage of gait cycle. In the upper graph, the vGRF from right foot (red line) and left foot (blue line) are reported along with the standard deviation contour. In the lower graph the segmented phase learned by AO is reported.

As it can be seen in Fig. 1, the phase learned from the AO is the normalized timescale of the stride cycle duration in the range [0; 2\(\pi\)] rad; outside from an offset in the instant of the reset - namely the consecutive stride initiation – it is aligned with a certain instant of the gait cycle (10 % of the gait cycle). Even if the reset is not associated with a relevant biomechanical event, the phase is stable and repeatable over all the segmented strides. From this result we can conclude that the AO system can be coupled with wearable sensors to extract the phase of a periodic motion task. The system is reliable from the first utilization without needing of training dataset. In future works the system will be extended to dynamically align the offset of the phase-reset with a biomechanical event of interest, e.g. the heel strike.
REFERENCES


