CONTROL AND DESIGN OF AN ACTIVE PROSTHESIS BASED ON ADAPTIVE OSCILLATORS

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Abstract

Currently transfemoral prostheses are almost exclusively passive such that the user spends up to 60% of additional metabolic energy with respect to a healthy person [1]. This contribution introduces the design of an active prosthesis whose interface is driven by an adaptive oscillator (AO).

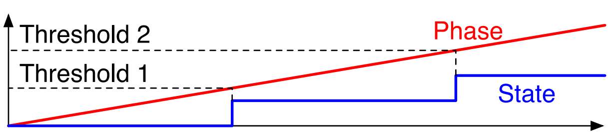
Keyword: biomechanics

1 Control method

Our controller is based on an oscillator having two different adaptation mechanisms: a **continuous adaptation** of the controller frequency to the user gait frequency and a **discrete adaptation** to the user gait morphology.

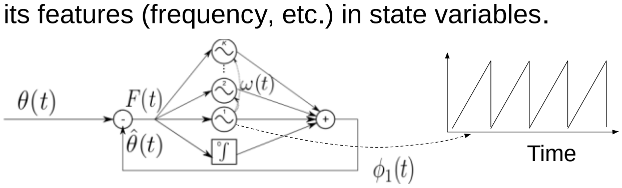
1.1 Oscillator-based FSM control

The gait is separated in four states – 2 stance states and 2 swing states – each obeying a different impedance law [2]. The transition between different states is triggered when the oscillator phase reaches a given threshold.



1.2 Continuous adaptation

The controller phase is the output of an AO [3]. This is a set of differential equations having the capacity to synchronize to an external signal $\theta(t)$ by learning its features (frequency, etc.) in state variables.



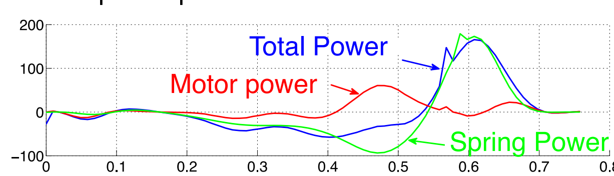
In this application, the external signal is the knee position. Once this knee signal is learned, the gait phase $\phi_1(t)$ is extracted from the AO. Adaptation to changes in the user gait features (e.g. cadence) is guaranteed by the AO convergence properties.

1.3 Discrete adaptation

Thresholds governing the transition between the controller states are further adapted to the user gait morphology. This is done by using foot sensors detecting heel strike and toe-off, and by adapting the phase thresholds accordingly.

2 Prototype

To test our controller, we developed a prototype inspired by the design of Sugar et al. [4], exploiting the principle of series elastic actuator (SEA). SEA consists in introducing a compliant element (e.g. a spring) between the actuator and the load (i.e. the foot). As such, the spring stores energy during early stance and releases it during late stance. Therefore, it is possible to use a smaller actuator requiring a smaller power peak.



We have now assembled the first prototype. The next step will be to embed our controller and put it to test with patients.

References

[1] Sup, F. et al. Design and control of a powered transfemoral prosthesis. *Int J Rob Res*, 27(2): 263-273., 2008.

[2] Eilenberg, M.F. et al. Control of a powered ankle foot prosthesis based on a neuromuscular model. *IEEE Trans Neural Syst Rehabil Eng*, 18: 164-173, 2010.

[3] Righetti, L. et al. Dynamic Hebbian learning in adaptive frequency oscillators. *Physica D*, 216: 269-281, 2006.

[4] Hitt, J. et al. Robotic transtibial prosthesis with biomechanical energy regeneration. *Industrial Robot: An International Journal*, 36(5): 441-447, 2009.