Applying Internal Models to Gait-Aware Neuro-Control in a Knee-Ankle-Foot-Orthosis

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A Knee-Ankle-Foot-Orthosis (KAFO) is a modular lower-extremity orthosis prescribed to people with gait disability. The KAFO should support, correct and assist the movement of the corresponding affected joints. Traditional KAFOs are restricted by a gait depending switch of the joints. The switch is based on (electro-) mechanic non-adaptive switches; therefore, common disturbances (floor unevenness, obstacles, ramps) cannot be mastered in a satisfactory way. Novel approaches include active elements into the orthosis, which do not directly act on the movement. Instead they adjust the compliance leading to new challenges for the controller of such actuators, which are difficult to handle with traditional approaches.
To take advantage of the fine grained control of the active element and overcome shortcomings of traditional control approaches, adaptive methods like artificial neural networks (ANN) can be applied. These methods can cope with the flexibility of the active elements and allow an individual support of a wider range of patients. The high neuromuscular variability within a specific patient group (Yakimovich et al., 2009) creates specific constraints on the support supplied by the orthosis. Therefore, the development of advanced devices is imposing the need for individual (online) adaptation of gait parameters to allow adaptation (1) to changing environments like slopes, stairs etc. as well as to gait parameters like stride length/frequency and (2) to the individual patients with respect to physiological conditions. To do so, we have employed a reflexive, modular neuro-controller inspired by the RunBot controller (Manoonpong et al., 2007), embedded to a KAFO based on a controllable hydraulic damper, derived from OttoBock's C-Leg©.
This study evaluates internal motion models implemented with artificial neural networks to distinguish different gaits as the patient reacts to changes in his environment. A set of these models have been trained to predict a certain gait, each, like stairs or slopes. Investigated is the the controller's ability to detect gait changes and the current gait using these models. Thereby we focus on the ability to make a decision early in the first step of the step sequence following a gait change while the rate of misclassification should diminish. These properties reflect that the process of gait parameter adaptation should take no more than one step and supports the current gait in an optimal manner.
Our preliminary results indicate, that the motion models are an accurate and fast adaptive method for this purpose. It fits well into and extends the used paradigm of adaptive modular neuro-control.

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