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Motion estimation for gait rehabilitation of hemiplegic patients using principal components analysis

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In gait rehabilitation of hemiplegic patients by means of a robotic orthosis, a major challenge resides in cooperative control. The patient should not simply be moved, but rather be assisted in his motions. Ideally, the controller should thus detect the patient's intention and actuate his paretic limbs coordinately. Recently, good results have been achieved with impedance control, which gives the patient a variable amount of freedom to diverge from a physiological reference trajectory [1]. However, a modification of this reference trajectory itself is limited, complicating an instantaneous reaction on the patient's motion intention. In this paper, we propose a generic approach that uses the synergistic coupling of degrees of freedom (dofs) in healthy human gait, described in [2], for motion intention estimation. First, an analysis of the coupling in comparable healthy subjects is performed using Principal Components Analysis (PCA). This coupling information is then used to reconstruct ``missing'' dofs in hemiplegic patients. Thereby, the patient's motion intention for his paretic limbs can be deduced through an observation of residual body motion. For a first evaluation of the method, sagittal hip and knee joint trajectories of healthy gait patterns are eliminated and subsequently reconstructed from contralateral leg data, based on averaged coupling information from other healthy subjects. Even though the coupling between upper and lower extremities is thereby not exploited, due to the impractible requirement of normal arm motion in stroke patients, these simulations show a highly promising reconstruction success. The proposed method permits an on-line generation of reference trajectories. The resulting controller will be highly cooperative and support and reinforce a physiologically correct synergistic gait pattern.

Reference: *1. S. Jezernik, G. Colombo, and M. Morari, Automatic gait-pattern adaptation algorithms for rehabilitation with a 4-dof robotic orthosis. IEEE Transaction on Robotics and Automation, June 2004; 20(3): 574-582.*
2. N. St-Onge and A.G. Feldman, Interjoint coordination in lower limbs during different movements in humans. Exp Brain Res, 2003; 148(2): 139-149.