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Multi-Channel Surface Electromyography for Simultaneous and Proportional Control of Prostheses

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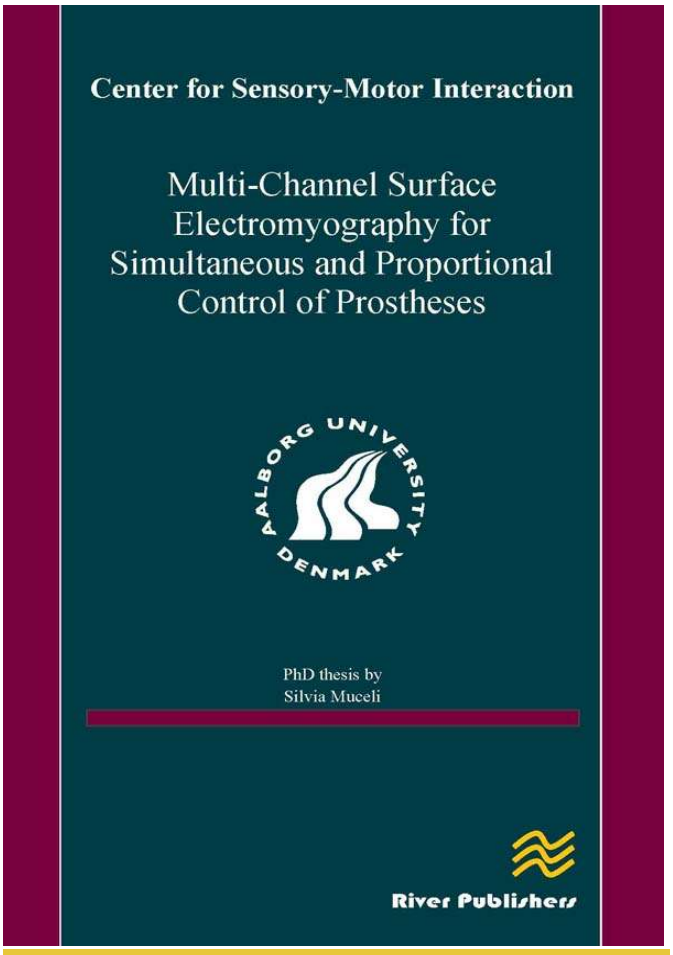
The loss of an upper limb affects task functionality, grasping patterns and dexterity abilities. Intensive research has been devoted to restore multiple functions. However, most commercial hand prostheses are simply grippers. In the best case scenario, wrist rotation is also provided, but the two functions can only be activated sequentially. Upper limb prosthesis users are urgently requesting for additional wrist functions, more intuitive control and simultaneous articulation of multiple functions.

In research settings, pattern recognition-based myoelectric controllers achieve impressive accuracy in classifying tasks involving several types of contractions. However, results are often obtained from intact limb subjects in very controlled laboratory conditions. Classification accuracy degrades in real life scenario, due for example to use of the prosthesis in multiple positions or to electrode shift.

The aims of this thesis were to propose myoelectric control systems for continuous, simultaneous and proportional control of the wrist/hand functions during dynamic movements (Studies I-IV) and to test the robustness of such systems with respect to the number of EMG channels used to infer the user intents (Studies I and IV), to variations in limb position (Study III), to electrode shift (Study IV), when applied to amputees with respect to normally-limbed subjects (Studies II-III).

Study I proposes a method based on artificial neural networks to estimate kinematics of the complex wrist/hand from multi-channel EMG electrodes during movements in free space. The system was tested in able-bodied subjects to provide a benchmark for successive validation in amputees. To simulate a training strategy applicable with unilateral amputees, subjects performed mirrored bilateral movements while kinematic and EMG data were acquired from an arm each. The system proposed in Study I was validated in Study II in transradial amputees with amputation proximal or distal to the elbow. Performances were different depending on the stump length. Kinematics estimation was accurate in case of individual with distal amputation. Study III showed that the system is also robust to variations in limb position if accounted during training. Therefore, the system proposed in Study I and validated in Studies II and III can be used for providing proportional and simultaneous control of multiple functions in unilateral amputees. However, it cannot be applied to bilateral amputees because of the need of kinematic data. This limitation was circumvented in Study IV by using a control system based on factorization of the EMG signals. The system does not require kinematic data and was proven to be robust to the number of EMG channels and to electrode shift.



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