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Title
Multidegree of Freedom Simultaneous Control of Arm Prosthesis - a Natural Motion Case Study

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Summary
Current myoelectrical prostheses allow single control of the joints only. The aim of this work is to enable a new control. In a unique pan-European case study a 17 year old shoulder-ex-amputatee underwent surgery in order to achieve a novel prosthesis-control: “thought-controlled prosthesis”.

Introduction
Typically, there are two rudimentarily muscle groups, the flexor- and the extensor muscle group, in the stump of an amputee that control flexion and extension of a myoelectrically controlled prosthesis. State of the art arm prostheses have up to three active joints. By co-contraction control switches to another joint. In a unique pan-European case study a patient with shoulder-ex-amputation underwent surgery in order to achieve intuitive prostheses control by re-use of his hand nerves: targeted muscle reinnervation (TMR). The benefits of this approach are significant for high amputation levels. With special pattern recognition procedures, based on artificial intelligence methodologies, prostheses control becomes intuitive as the prosthesis executes exactly the same movements as intended in the phantom limb. Tis leads to an unprecedented improvement of a patients life quality.

Methods
The Patient (17 years) lost both of his arms due to a high voltage accident: Left shoulder-ex-amputation, right transhumeral amputation. The neural supply of M. Pectoralis major, which had lost its original function to bend the upper arm, was dissected and replaced by the four essential arm nerves: N. Radialis, N. Ulnaris, N. Merdianus und N. Musculocutaneus. Additionally, the muscle itself has been divided into appropriate segments. When the reinnervation of the M. Pectoralis major with the new nerves was completed EMG-Signals were measured by surface

electrodes. In the first training step the patient was shown videos such as open/close the hand, flexion/extension the wrist, supination/pronation the hand, flexion/extension the elbow, flexion/ extension the shoulder, innerrotation/ outerrotation the upper arm. In the second training step the patient had to cope with the task to imitate the videos only by moving his phantom arm while the EMG-patterns were stored in the prostheses.

Results

First results of the case study indicated that TMR leads to a significant improvement of the rehabilitation of arm amputees. The phantom limb movement could be recognized on-line by analyzing the corresponding EMG-pattern in signal processing procedures based on pattern recognition methods. The first impression was described by the patient as follows: “the arm prosthesis follows the movement of my phantom arm. I find it is a part of my body”. The pattern recognition system has to be trained prior to each use of the prosthesis. A daily training program was started. At the end of the program the patient was able to eat, to dress up, to go to the bathroom without any help. It was intended to use the prototype of multidegree of freedom arm prosthesis -7DOF- only in the laboratory of Otto Bock. Actually, the patient is fitted with a 3DOF prosthesis for his daily use at home based on the same intuitive control strategy as the 7DOF prototype for the laboratory.

Conclusion

The case study showed a promising outcome for an improved prosthesis control, resulting in a better quality of life for the patient. It showed also that in every day life a series of additional challenges had been met for a successful fitting. But some challenges still remain. These include that more than two electrodes have to be integrated into the socket to record the EMG-pattern. Furthermore, for successful daily use the training process has to be simplified, the training frequency has to be minimized and electrode placement must be reliable. The medical requirements for such a fitting, the fitting process itself and especially the physiotherapeutic training have been defined so that the unique prosthesis control satisfies the needs of a wide range of people.

References

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