CONTROL AND SIGNAL PROCESSING CONCEPTS FOR A MULTIFUNCTIONAL HAND PROSTHESIS

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INTRODUCTION

The loss of an arm means drastic reduction of live quality for affected people. To compensate the lost live quality myoelectric hand prostheses have been developed, that can be controlled by muscle contractions in the patients stump. Besides cosmetical aspects the acceptance of these hand prostheses depends on functionality, weight and user-friendliness. Concerning these items, international studies demonstrated, that about 30% of the users of functional prostheses are not using them regularly [1, 2].

Recently, the FZK (Forschungszentrum Karlsruhe) presented a light-weight artificial hand, that is able to move all finger joints independently [3]. To control this large variety of movement possibilities the principal task is to establish a control that has an extended functionality but is easy to handle.

This paper presents:
- a control concept that is able to perform various grip types using the same sensor configuration like commercial products and
- a software platform to individually adapt necessary parameters to the users needs.

CONTROL CONCEPT

To gain information about muscle contraction activity the surface scan of myoelectric (EMG-) voltage is applied. Basically, a transformation of the scanned signal into a certain amount of grip types for a prosthesis requires the same amount of unique signal patterns. The major problem using myoelectric signal patterns is the patients' deficiency to contract more than two muscles independently. Additionally, the EMG-signal is no pure signal of one specific muscle but contains information about all contracted muscle fibres in the range of the sensor. Thus, signal quality is reduced drastically and the success of a discrimination of different signal patterns decreases. Several groups made promising attempts to increase the corresponding classification rate via preprocessing or sophisticated classification algorithms [4, 5], however no control using more than two to three movements is commercially available.

Thus, we propose a fragmentation of the patient's control signal in two phases. Therefore, the flexor muscle groups and the extensor muscle groups are scanned for myoelectric activation - equivalent to commercial prostheses [6] - and filtered with different IIR-filters to gain significant features [7].

Starting in a neutral state (prosthesis opened) the user may generate a switch signal by contracting one of the two scanned muscle groups. The characteristic of the signal specifies a certain grip type.

As soon as the system detects a known switch signal the prosthesis moves into a preshape state, serving

- to give a feedback to the user, which kind of grip type was identified and

- to move the fingers of the prosthesis into an optimal position concerning movement possibilities associated with the identified grip type.
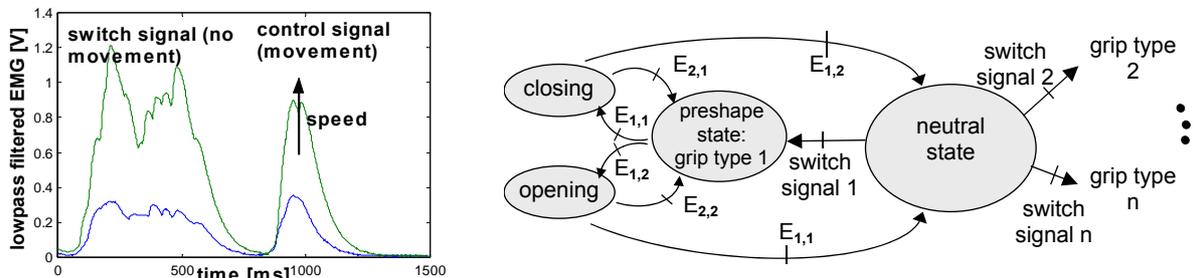

Figure 1: left: EMG-signal for execution of a prosthesis movement, right: control scheme with control signals derived from two muscles: $E_{1,1}$: contracted flexor muscle group; $E_{2,1}$: relaxed flexor muscle group; $E_{1,2}$: contracted extensor muscle group; $E_{2,2}$: relaxed extensor muscle group.

The muscle contraction following the switch signal represents the control signal for the movement and leads to a closing or opening speed of involved finger joints proportional to the signal's amplitude (proportional control). The direction of the movement (closing/opening) is specified by the contracting muscle group (flexor/extensor), see Fig. 1.
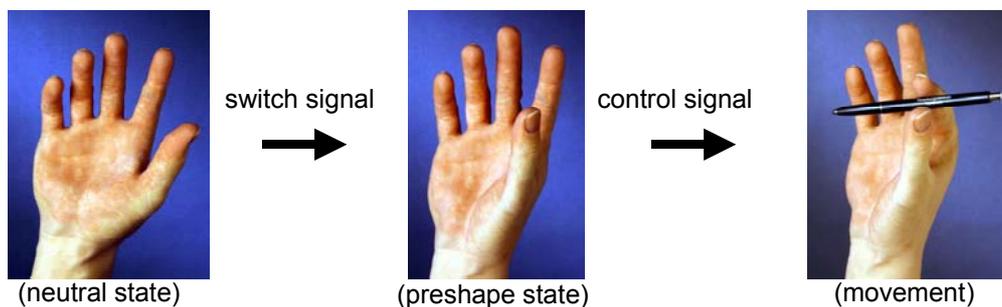

Figure 2: FZK-prosthesis: Starting from a neutral state, a switch signal moves the joint angles in a preshape state. Depending on a control signal the chosen grip type may be opened or closed proportionally.

A user-reset may be executed all the time by co-contracting both muscle groups and leads to the neutral state, opening all fingers.

At the moment, switch signals are taught to system by defining a membership between the value of several features and a certain grip type. For instance, an easy possibility to define switch signals would associate one muscle impulse with grip type 1, two impulses with grip type 2, etc. Using this scheme, the following grip types are implemented and can be performed by the patient:

- Cylindrical grasp,

- lateral grasp,

- bracing the pointing finger,

- hook grasp, and

- pincer grasp.

ADAPTATION

A negotiation of the presented algorithm with different subjects shows, that

- scanned signals differ in time and amplitude,

- locations of sensor positions influence signal amplitude and quality, and

- different muscles may have to be scanned with respect to the length of the arm stump.

To use a unified control scheme that is independent from the mentioned differences the algorithm has to be designed adaptable. Therefore a software platform was developed to validate the algorithm and its parameters, see Fig. 3. The aim was

- to create an easy and precise way to adjust parameters (e.g. filter constants) while the patient is practising,

- to give the patient the possibility to simulate the prosthesis, and

- to practise new parameters by controlling a video game (TETRIS).

When proper parameters are found, the control algorithm with adapted parameters is flashed on a microcontroller to process data online. Additionally, to record microcontroller input (sensory data) and output (control signal for prosthesis) an interface was integrated to gain information about signal differences between simulation and operation of the prosthesis.

The presented procedure was first implemented and tested with patients in May 2002 and was well accepted by the patient.
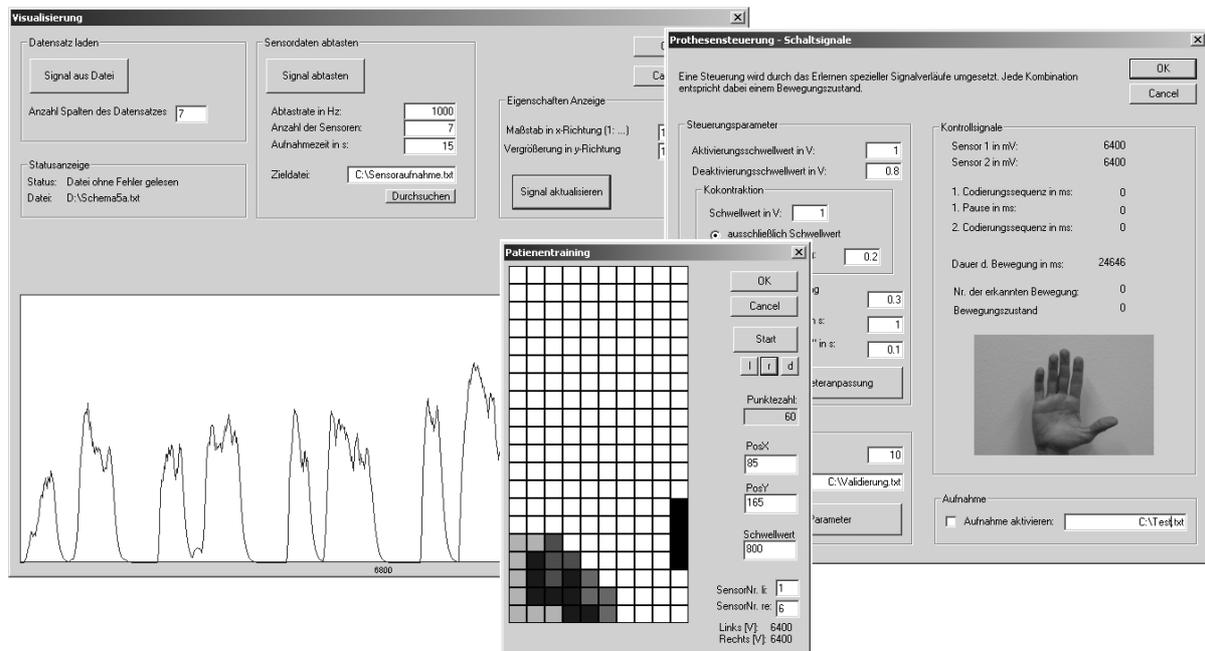

Figure 3: software platform to adapt control parameters individually and to validate and test corresponding control strategies.

DISCUSSION

The quality of a control scheme depends on the quality of the data it is processing. To rise data quality there is effort to adapt myoelectric sensors especially to the problems occurring with this control scheme and automatically detect optimal locations on the arm stump to scan for myoelectric data. Additionally, works including a teaching of switch signals to the prosthesis have started.

An upgrade of the presented control scheme is the use of fuzzy rulebases, automatically built out of relevant features of the myoelectric signal [8].

To gain improved signals and in this way to approach to the functionality of the human hand different groups are investigating brain and nerve activity [9, 10, 11].

CONCLUSION

This paper presents a new approach to multifunctional control of hand prostheses. The user has to generate switch signals in order to specifiy a desired grip type. The following muscle contraction serves to move the fingers proportional to the EMG-signal amplitude. This control scheme has already been tested with patients. To implement this strategy independent from diversities in anatomy and signal quality, a software platform was developed to adapt, validate and train the control strategy.

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