SMoBAICS: The Smart Modular Biosignal Acquisition and Identification System for Prosthesis Control and Rehabilitation Monitoring

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ABSTRACT
Simulation and modelling are powerful methods in computer aided therapy, rehabilitation monitoring, identification and control. The smart modular biosignal acquisition and identification system (SMoBAICS) provides methods and techniques to acquire electromyogram (EMG) and electromyogram (ENG)-based data for the evaluation and identification of biosignals. In this paper the author focuses on the development, integration and verification of platform technologies which support this entire data processing. Simulation and verification approaches are integrated to evaluate causal relationships between physiological and bioinformatical processes. Based on this we are stepping up of efforts to develop substitute methods and computer-aided simulation models with the objective of reducing animal testing. This work continues the former work about system identification and biosignal acquisition and verification systems presented in (Bohlmann et al., 2010), (Klinger and Klauke, 2013), (Klinger, 2014). This paper focuses on the next generation of an embedded data acquisition and identification system and its flexible platform architecture. Different application scenarios are shown to illustrate the system in different application fields. The author presents results of the enhanced closed-loop verification approach and of the signal quality using the Cuff-electrode-based ENG-data acquisition system.

KEYWORDS
ENG-Based Prosthesis Control, Rehabilitation Monitoring, Simulation and Modelling in Computer Aided Therapy, Robot-Manipulators, Simulation Framework, System Identification, System Verification

1. INTRODUCTION
The use of electrical biosignals, like electroencephalogram (EEG), electromyogram (EMG) and electromyogram (ENG), gain a lot of importance for the assessment of functions in the human body. These signals are used as major indicators for medical professionals, patients or professional athletes during diagnostic and monitoring processes. Furthermore, the biosignal-based intelligent control of prostheses or handicapped limbs is a key challenge in medical technology. In particular EMG and ENG are used to get information about the peripheral nervous system including information transfer due to sense data and motion control by peripheral nerves. Based on these signals a multitude of applications are existing or in the future envisaged; they range from the achievement of therapeutic objectives up to prosthesis control, for example, to operate an artificial hand or forearm. There are several requirements on a system existing to realize these functionalities:

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• Data acquisition and stimulation
  The EEG, EMG or ENG data has to be acquired and sampled according their signal characteristics, given in Table 1. In particular, additional applications, like a stimulation, are necessary, for example providing the measurement of the nerve conduction velocity.

• Data processing
  The acquired data (action potentials) are disturbed by intrinsic noise. In addition, they are overlaid by a substantial extrinsic noise, originated for example by EMG from surrounding muscles. Therefore, we have to filter the recorded data with integrated analog filter and additional digital filter. There are several specific high-pass, low-pass, band-pass and notch filters available. A further data processing is necessary, on the one hand to improve the data condition due to asynchronous and aperiodic samples, and on the other hand to generate events from the action potentials like the activity level of a muscle group or the detection of an exposure scenario.

• Identification
  The identification feature is required for prosthesis control or any type of high level signal evaluation and correlation. The identification is based on machine learning and recognizes movement commands and inherent feedback signals (Verdult, 2002), (Wodlinger and Durand, 2011). The identification method and the corresponding verification scenario have been introduced in (Klinger and Klaue, 2013), (Klinger, 2014) based on results in [Bohmann et al., 2010], [Bohmann et al., 2011]. In this paper, we focus on the closed-loop verification approach.

• Data archiving
  After data acquisition and data processing the results have to be saved locally if there is no direct data transmission for an evaluation possible or if local data are required due to an offline analysis. Furthermore, for identification a certain data amount is necessary during the operating phase (Klinger and Klaue, 2013).

• Data interfacing
  Data has to be transmitted for evaluation or monitoring purposes to a host system.

• User Interfacing
  To select and execute certain functionalities and for online information an user interface must be available.

• Configuration
  Due to the different application scenarios and system functions a configuration is necessary.

  With regard to many different application scenarios and their corresponding requirements, the embedded system architecture of SMoBAICS is based on a modular hardware and software platform.

  We present the system architecture and its characteristics including data acquisition, identification and data exchange in section 2. In section 3 we discuss specific applications to illustrate the platform character of the system. The results given in section 4 focus on the enhanced overall verification method, using modelling and simulation techniques and the verification of the accuracy of the frontend data acquisition for ENG-based data.

2. SYSTEM ARCHITECTURE

Figure 1 shows the overall system architecture in a block diagram. Two central components are to be recognized on this level: The data acquisition and signal conditioning in the analog frontend as well
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