Chapter 29
Data Driven Symbiotic Machine Learning for the Identification of Motion-Based Action Potentials

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ABSTRACT

Understanding and modelling technical and biological processes is one of the basic prerequisites for the management and control of such processes. With the help of identification, the interdependencies of such processes can be deciphered and thus a model can be achieved. The verification of the models enables the quality of the models to be assessed. This article focuses on the identification and verification of motion and sensory feedback-based action potentials in peripheral nerves. Based on the acquisition of action potentials, the identification process correlates physiological and motion-based parameters to match movement trajectories and the corresponding action potentials. After a brief description of a prototype of a biosignal acquisition and identification system, this article introduces a new identification method, the symbiotic cycle, based on the well-known term symbiotic simulation. As an example, this article presents a data-driven method to create a human readable model without using presampled data. The closed-loop identification method is integrated into this symbiotic cycle.

1. INTRODUCTION

Identification of technical processes for analysis, optimization and control is a major challenge. This focus also includes the use of identification methods and applications for the biotechnology sector. In this project identification in particular plays an important role in enabling an interface between the brain and the control of movement based on data from peripheral nerves.

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So, the identification of motion- and sensory feedback-based action potentials in peripheral nerves is a great challenge in medical technology. It is the prerequisite for applications like prosthesis control or limb stimulation. Based on the acquisition of action potentials, the identification process correlates physiological and motion-based parameters to match movement trajectories and the corresponding action potentials.

The identification method used in this context is based on the continuous mode symbiotic cycle, combining a physical system, a simulation system and an agent-based machine learning system. As an example, a data-driven method to create a human readable model without using presampled data is presented. All components in the system interact in a symbiotic way. The result of each component is used as an input by the others and vice versa.

First of all, the prototype of biosignal acquisition and identification system using a multistage agent-based solution builder identification method is introduced (Klinger and Klauke, 2013) and then the closed-loop identification method, implemented using a symbiotic continuous system (Aydt, Turner, Cai and Low, 2008; Aydt, Turner, Cai and Low, 2009) is presented. The prototype is acting as the physical target system in the symbiotic cycle, presented subsequently. This paper focuses on the interaction between the identification method, based on a data driven approach and its verification. We present the closed-loop identification method, implemented using a symbiotic continuous system (Aydt, Turner, Cai and Low, 2008; Aydt, Turner, Cai and Low, 2009), consisting of a robotic based trajectory generation, the nerve simulation and an agent-based machine learning system. We introduce the model generation process and show the closed-loop verification approach of the identification method.

1.1. The Prototype for a Biosignal Acquisition and Identification System

The key challenge is the human machine interface of prosthesis and its movement control. The objective is to use biosignals for the information transfer between human being and prosthesis. So an interface is needed to interfere between the command-level and the actuator- and sensor- level. The approach discussed in this paper is based on the direct use of the action potentials of peripheral neural bundles via an electroneurogram (ENG) (Gold, Hence, and Koch, 2007; Neymotin, Lytton, Olypher, and Fenton, 2011). So, the employment of invasive intra-neural sensors (Micera, Carpaneto, and Raspopovic, 2010; Micera, Citi, Rigosa et al., 2010; Raspopovic, Capogrosso, Petrini et al., 2014) is in this project not in the focus, but the identification (Cesqui, Tropea, Micera, and Krebs, 2013) of motion-based action potentials is the proposal to realize a smart minimal-invasive solution. To record ENG-signals with a very low amplitude, which are only of the order of a few microvolts, a special frontend-hardware/software system has been designed, realized in two different Hardware- and Software-prototypes, introduced in (Klinger, 2015) and (Klinger and Klauke, 2013). In this paper, the focus is on a new combined identification and verification method, taking advantage of a continuous symbiotic system (Aydt, Turner, Cai and Low, 2008; Aydt, Turner, Cai and Low, 2009). This work continues the former work about system identification presented in (Bohlmann, Klauke, Klinger, and Szczerbicka, 2011; Bohlmann, Klinger, and Szczerbicka, 2009; Bohlmann, Klinger, and Szczerbicka, 2010).

The prototype of a Smart Modular Biosignal Acquisition, Identification and Control System (SMoBAICS), shown in Figure 1, integrates all necessary tasks (Hazan, Zugaro, and Buzsáki, 2006).

The biosignal acquisition is done by the Modular Biosignal Acquisition System (MBASY)-subsystem, the next generation of our own frontend-hardware/software-system. The MBASY is redesigned to get a better functionality and to optimize the modular concept (Klinger, 2015). The central part of the iden-