Identification of Motion-Based Action Potentials in Neural Bundles

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ABSTRACT

Realizing a nerve signal based prostheses control or limb stimulation is a great challenge in medical technology. It requires a recording and an identification process of the motion-based action potentials of motor and sensory nerves within the corresponding neural bundle. Two additional key factors are used by multi agent-based learning algorithm: The anatomical disposition of the nerves within the neural bundle and the inverse kinematic. In this paper the authors introduce the Smart Modular Biosignal Acquisition, Identification and Control System and its application environment. They present the different process levels and their characteristic identification contribution and they give an overview of the multi-agent based identification framework. The authors show the verification environment and present results regarding the first-level identification procedure.

Keywords: Agent-Based Evolutionary Computation, Embedded System, Machine Learning, Platform Design, Prosthesis Control, System Identification

1. INTRODUCTION

Today prosthesis is even more than only easy spare parts for the human body. From the simple wooden butts of the past ingenious high-tech constructions have become. However, the modern medicine can substitute even more than only arms and legs. The main problem 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. Several possibilities are existing to realize such an interface: The electroencephalogram (EEG), the electromyogram (EMG) and the electroneurogram (ENG). The use of electroencephalogram-signals (EEG) is not applicable in the most cases due to the fact, that the EEG-signal is buried within other brain activity (general background brain activity), as well as within electrical and muscle activity from different sources outside like movement of the jaw or neck. Another option is the sampling of the electromyographic activity (EMG) of several selected muscles. This option has several disadvantages: At first looking at the right arm as an example the signal activity responsible for

DOI: 10.4018/ijphim.2014070102
the movement of the forearm and the hand is distributed over lots of muscles. But the major drawback of this method is that the muscles may be not existent in the case of an amputation. Our approach is the direct use of the action potentials of peripheral neural bundles via an ENG (Gold et al., 2007; Neymotin et al., 2011). Based on these signals, a prosthesis, for example, an artificial hand or an artificial forearm, can be controlled specifically. An interesting side effect when the ENG is used directly is a high probability that the nerve functionality can be preserved from degeneration in the case of an amputation. In addition by using a direct nerve interface it is possible to realize a bidirectional interface, not only for the actuator data but for the reactive and sensory signals.

The acquisition and interpretation of nerve signals is one key challenge to realize an intelligent control of prostheses or handicapped limbs. The interpretation is one central aspect due to the high information density within a nerve. To record the very small signals, which are only of the order of a few microvolts, we have designed a special front-end hardware/software system as a first system prototype (Klinger et al., 2013).

At first we present the overall concept integrating the acquisition, the identification and the control within a mobile system, whereby mobility is an essential requirement. Then a few background applications and the used measuring electrode. In the following section we introduce the whole smart modular biosignal acquisition, identification and control system (SMoBAICS) and several aspects of the system, for example the verification concept. In this paper we focus on the three-level identification process transforming the action potentials into an movement information. This work continues the former work about system identification presented in (Bohlmann et al., 2011), (Bohlmann et al., 2009) and (Bohlmann et al., 2010).

2. OVERALL CONCEPT

In Figure 1 the overall concept is shown in a block diagram. Two central components are to be recognised in this level: The data acquisition and signal conditioning in the analog frontend as well as the data evaluation and identification (Pattern Recognition, Learning).

In the data acquisition the action potentials of the nerves are captured by a so called cuff electrode, we explain it in more detail in section 3.2. Following this the analog signals are being amplified and digitalized. Afterwards there occurs a two-stage evaluation and identification step of the data [1, 2, 3, 6]. This subdivision in two phases is necessary to allow a learning phase and an operation phase. In the learning phase the base identification which allows a correlation between nerve signal and movement is carried out. The operation phase is using the...
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