Embedded systems and machine learning techniques for controlling motor physiotherapy rehabilitation devices

SCHOOL OF ELECTRICAL & COMPUTER ENGINEERING
ARISTOTLE UNIVERSITY OF THESSALONIKI

Using embedded systems on processing EEG towards control of continuous passive motion devices

Gregory Kalogiannis (1); George Hassapis (1)
Organization(s): 1: Aristotle University of Thessaloniki, Department of Electrical and Computer Engineering, Greece
1: gkalogiannis@ece.auth.gr, 2: chasapis@eng.auth.gr

Introduction

Injuries and trauma to the human joints commonly require surgical treatment followed by **post-operative physical therapy rehabilitation**. Devices, such as **continuous passive motion machines** (CPM), are used for rehabilitation in hospitals, clinics or general practices and they are important supplements to medical and therapeutic treatment.

Their mode of operation is to move injured joint over a range of motion in a **circular periodical** way defined by the physician. For example in case of elbow and fist joints, these devices impose movement via flexion/extension and/or pronation/supination to the injured joint (*Figure 1*).

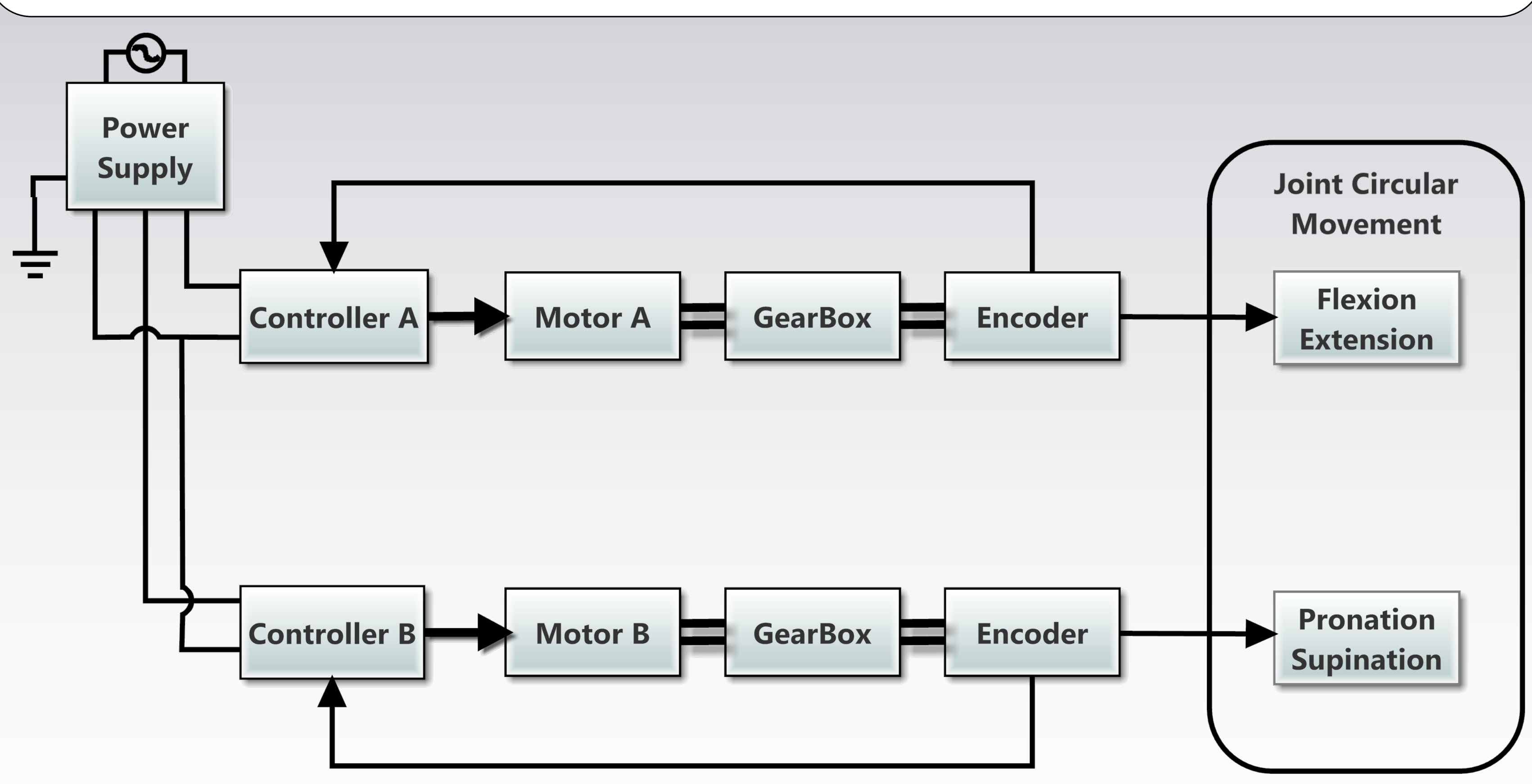

Figure 1. A typical structure of a commercial CPM device for joint rehabilitation

Although their indisputable contribution to rehabilitation, it is believed that the overall treatment time can be reduced and the overall rehabilitation could be improved if the patient interacts with these devices and their motion is determined according to patient's will. **These devices allow their easy connection with controllers which can make the devices to follow trajectories determined by processing the generated by the patient brain signals** in order to extract the patient's intensions and will. The implementation of such an architecture requires fast recognition of the motor imagery movements of the joint in order to create the appropriate control signals. **This can be done by processing the Electroencephalography (EEG) data with the purpose of removing the noise and information that is not essential for creating the control signal.**

In this study we propose a new embedded system that focuses on processing EEG, fast enough to run within the time limits imposed by the on-line control of the continuous passive devices. This system use machine learning techniques such as Support Vector Machine (SVM) in order to classify human will to move its limb and translate it to the control signal required to drive the motor of the rehabilitation device.

Processing of EEG signals

Processing of inspected EEG for making easier the extraction of desired features is ponderous. There are methods that are used to improve the quality of Signal to Noise Ratio (SNR), such as Common Average Referencing (CAR). Resampling the data, filtering, bad channel detection, Independent Component Analysis (ICA), epoching continuous data, and epoch rejection are the most common techniques in the processing stage of EEG recordings.

During imagery motor movement tasks, the so called *mu* and *beta* **event-related desynchronization (ERD) and event-related synchronization (ERS)** are taking place. **Recognizing** these ERD/ERS patterns (*Figure 2*) inside the recorded EEG, that can be brief movement imagery or continuous movement imagery, allow us to recognize allow us to determine human patient imaginary movement.

During this study we he have **implemented** and **tested** a new EEG processing technique, focused on event related desynchronization and synchronization (ERS/ERD) phenomena, **fast enough to run within the time limits imposed by the on-line control of the continuous passive devices**. The processing technique is based on **locating feature vectors** that correspond to power and energy spectrum of the identified ERD/ERS pattern in the EEG signals. **The amplitude of these vectors can be used as a feature to stop or adjust the motion angle of the CPM device**.

Application Links

YouTube presentation

Author contact details

Supervising Learning Models

Classification of human will movement, is implemented using machine learning techniques such as **Support Vector Machines**. The SVM algorithm has been widely applied in the biological and other sciences. Support Vector Machines are based on the concept of decision planes that define decision boundaries. A decision plane is one that separates sets of objects having different class memberships. **Binary Support Vector Machine** (SVM) was used as the supervised learning model. During the **offline** procedure, prerecorded EEG data is used as training data to produce supporting vectors for human movement classification. **Online** procedure focuses on capturing, processing and classifying the real time potential movement and creating out of this information the signal that controls the motors of the rehabilitation device.

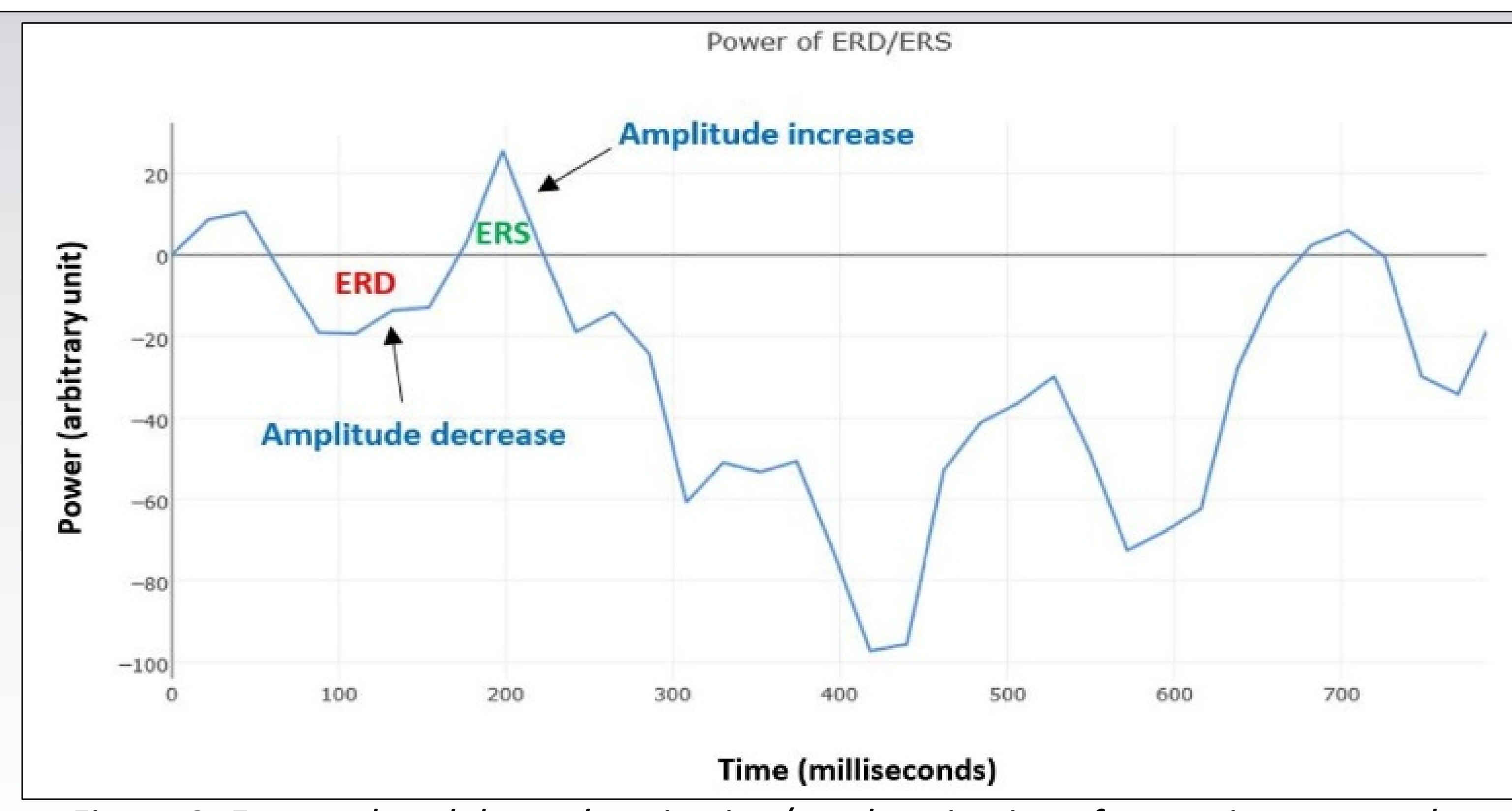

Figure 2. Event-related desynchronization/synchronization of motor imagery tasks

System implementation

For the implementation of the proposed system (*Figure 3*), the **Raspberry Pi 2** single-board computer was used. This system features a **Broadcom** system on a chip (SoC), which includes an **ARM** compatible central processing unit (CPU, quad-core **Cortex-A7 CPU** running at 900 MHz) and an on chip graphics processing unit (GPU, a VideoCore IV). Secure Digital (SD) card is used to store a **UNIX** based (Ubuntu Desktop 14.04 LTS) operating system, where training data is stored on an external solid state hard drive. For communicating with the **MAXON** type motors of the CPM device, two **EPOS** motor positioning controllers are connected to the system using the **RS-232** protocol. These two controllers are used to transfer the control signal to the motors of the rehabilitation CPM device. EEG data is captured using the **Emotiv EPOC Headset**, a 14 channel wireless EEG, designed for **Brain Computer Interface** (BCI) applications. The headset creates dense array of high quality raw EEG data. System programming is performed using the **Robotics Operation System** (ROS, Version Indigo), a collection of software frameworks for robot software development, providing operating system-like functionality and C++ programming language.

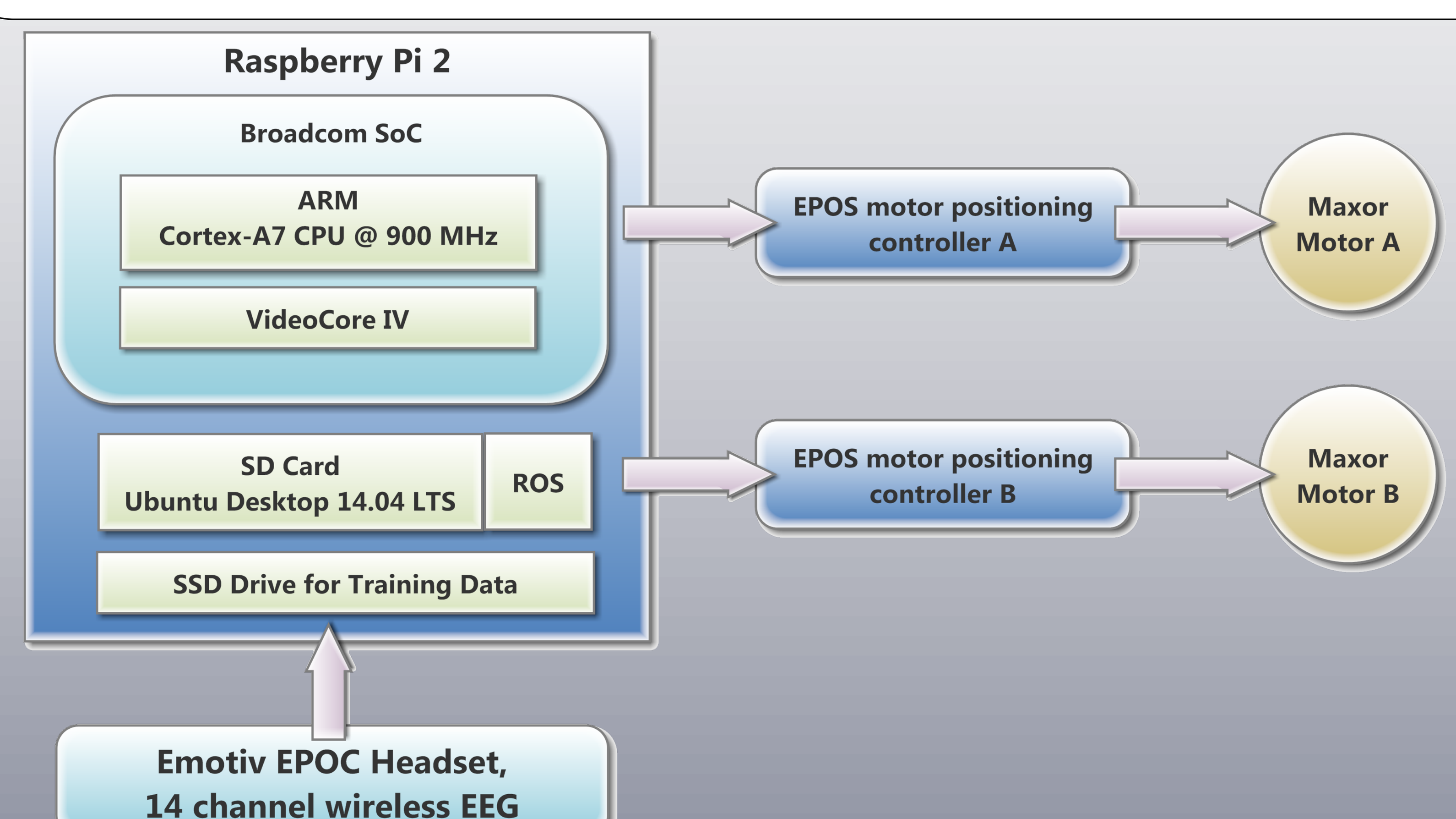

Figure 3. The proposed system architecture

Future Work

Processing of EEG signal and Supervising Learning Models are time consuming procedures. In order to create signal controls within the time limits imposed by the requirements of real-time control of rehabilitation devices, different and faster hardware implementation must be used. In future work we proposed the transformation of the current architecture, using different hardware implementation such as the **ZYNQ SoC** architecture.

Zynq®-7000 All Programmable SoC (AP SoC) devices integrate the software programmability of an **ARM®-based** processor with the hardware programmability of an **FPGA**, enabling key analytics and hardware acceleration while integrating CPU and mixed signal functionality on a single device. This programmable SoC integrates the software programmability of a processor with the hardware programmability of an FPGA whilst providing us with system performance, flexibility, and scalability.