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Humanoid Robot Control With SSVEP on Embedded System

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Abstract. In this study we implemented a low-cost, single EEG channel brain computer interface (BCI) running on an embedded computer. The BCI uses steady-state visual evoked potentials (SSVEP) to control the motion of the Kondo KHR-3HV humanoid robot. The subject attends to one of the flickering LEDs attached to the arms of the robot in order to move an arm. SSVEPs are identified by a simple spectrum analysis of the EEG signal.

Keywords: EEG, SSVEP, Robot Control, Emotiv, Raspberry Pi, Python, Linux

1. Introduction

Brain computer interfaces (BCI) are devices which create a communication channel between human brain and the outside environment by observing the brain activity with invasive or non-invasive methods. [Wolpaw et al., 2002]. This can assist people with neurodegenerative diseases in moving their wheelchairs, using a robot to grasp a glass of water and even in spelling a word using several cognitive paradigms.

Steady-state visual evoked potentials (SSVEP) are potentials elicited by the brain of a subject who is presented a flickering visual stimulus. They contain the fundamental frequency of the flickering rate and also some of its harmonic components depending on the stimulation frequency [Herrmann, 2001]. SSVEP can be detected using non-invasive electroencephalography (EEG) with frequency spectrum analysis methods.

Recent studies regarding humanoid robot control with SSVEP are based on display units which stream live video of the robot's view using cameras. The stimulation is either done by overlaying flickering patterns on the stream [Gergondet et al., 2011] or by placing LEDs around the display unit showing the stream [Bryan et al., 2011]. This study proposes a single channel, low-cost and wireless BCI based on SSVEP for controlling the arms of a humanoid robot using an EEG headset and an embedded computer. The frequency spectrum of the captured EEG signal is analyzed to discriminate between two possible SSVEP frequencies that may be elicited by the flickering LEDs attached to the arms of the robot, if the subject attended to one of them.

2. Material and Methods

2.1. EEG Setup

We used Emotiv EPOC, a battery-powered headset which can acquire 14 channels of EEG signal and transmit them wirelessly to its USB dongle. The headset internally applies a notch filter (At line frequency 50 or 60 Hz) and a 5^{th} order band-pass filter (0.2-45 Hz) to the signal. Although the internal sampling rate is 2048 Hz, the data is delivered with a rate of 128 samples/second.

For this study, only single channel of EEG is acquired through the occipital region where SSVEP response is prominent [Herrmann, 2001].

2.2. Humanoid Robot

Kondo KHR-3HV is a battery-powered humanoid robot with 17 degree of freedom which can mimic human movements. It has an embedded microcontroller board RCB-4 which can be driven using its serial USB dongle.

2.3. Embedded Hardware

Raspberry Pi Model B, a 35$ low-cost embedded computer with 700MHz ARM11 CPU, 256MB RAM and 2 USB ports, is used as the processing unit of the BCI. The board attached to the back of the robot, can be powered using a battery pack through its USB power input.

2.4. BCI Design

The whole software is written in Python programming language and runs on Debian Linux. We picked Python as it is a free, open-source and platform independent programming language with strong scientific computing capabilities.

The software runs in three concurrent processes: SSVEP stimulator which flickers the LEDs at 7.5 Hz and 10 Hz respectively for the left and right arm using the general-purpose I/O (GPIO) pins of the board; decryption process which decrypts the packets encrypted by the USB dongle; main process which performs an FFT using SciPy (Scientific Python Suite) on the acquired signal and sends a left or right arm command to the robot if an increase in power is detected at 7.5 Hz or 10 Hz. The concurrency is required in order to not miss the tagged samples sent by the headset. Tagging is done by the headset by simply enumerating each packet with a sequence number between 0-127.

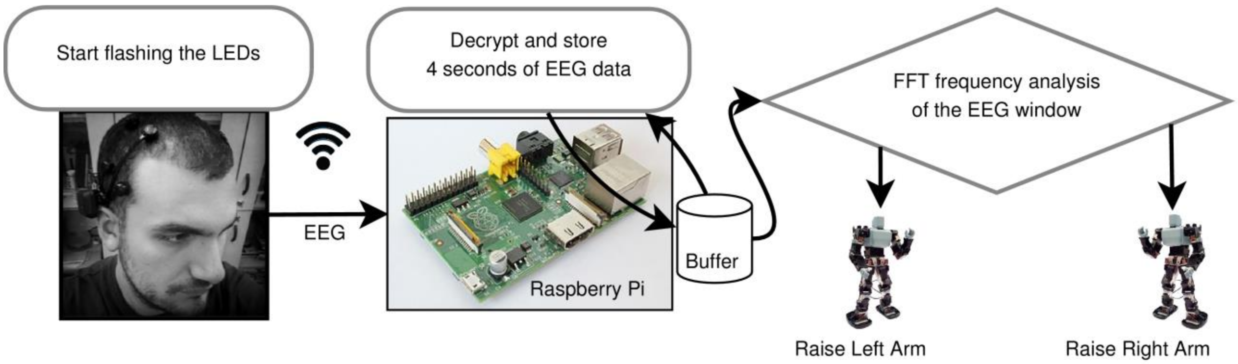

Figure 1. *Flow diagram of the BCI system.*

3. Results

In this study, we demonstrated a very low-cost BCI system for controlling the arms of a humanoid robot using a cheap embedded computer which runs Linux. The system has been successfully used by a single healthy subject to control the arms of the robot.

Usage of an embedded system is also the key to support ultimate portability: The computer can be attached to the back of the robot without causing any problem of balance. The developed BCI software is practically guaranteed to run on any operating system and architecture as Python is an interpreted language, e.g. there is no need to build the software against a specific architecture.

4. Discussion

Although the processing capabilities of Raspberry Pi are quite limited, there may be still room for performance improvements during EEG analysis. Linear classification performance of SSVEP on this platform should be investigated in order to possibly realize a faster BCI. Finally, more control over the movement of the robot can be achieved using additional LEDs.

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References

Bryan M, Green J, Chung M, Chang L, Scherert R, Smith J, Rao RP. An adaptive brain-computer interface for humanoid robot control. In *11th IEEE-RAS Int Conf Humanoid Robots (Humanoids)*, 199-204, 2011.

Gergondet P, Druon S, Kheddar A, Hintermuller C, Guger C, Slater M. Using brain-computer interface to steer a humanoid robot. In *IEEE Int Conf Robotics and Biomimetics (ROBIO)*, 192-197, 2011.

Herrmann CS. Human EEG responses to 1–100 Hz flicker: resonance phenomena in visual cortex and their potential correlation to cognitive phenomena. *Exp Brain Res*, 137(3):346-353, 2001.

Wolpaw JR, Birbaumer N, McFarland DJ, Pfurtscheller G, Vaughan TM. Brain-computer interfaces for communication and control. *Clin Neurophysiol*, 113(6):767-791, 2002.