ON SOME NEW ASPECTS IN ACQUISITION AND ANALYSIS OF BRAIN ELECTRICAL ACTIVITY

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Abstract

We give a description of a portable system for continuous acquisition of the brain electrical activity based on ARM microcomputers driven by Linux and discuss some problems which arise while developing, implementing, and fine-tuning the system.
Keywords: data science, brain electrical activity, ARM microcomputer, continuous acquisition

We developed, implemented, and fine-tuned a portable system for continuous acquisition of the electrical activity of a brain. The key features of the system consist of the following: high sensitivity (μV); high-resolution measurement (discretisation up to a hundred kHz per channel); presence of no filters of the input signal in both the analogue-to-digital converter and amplifier modules; this results in the near absence of analogue data loss while acquiring the real time brain bioelectrical activity. The problem to prevent garbling of the input data due to intense electromagnetic pollution of the environment was solved by making use of a multilayer shielding of the analogue part of the system and by using an autonomous direct current power source to feed the whole system.

We investigated the role which the brain cortex plays in formation of the nociceptive reactions by means of analysis of the electroencephalogram and the evoked potentials (EPs) acquired in the somatosensory S_1HL and the anterior cingulate Cg areas of cerebral cortex in the right hemisphere in immobilised Wistar male rats before the intraperitoneal injection of a lipopolysaccharide (LPS) and at the 1st, 3rd and 7th days after it upon an electrocutaneous stimulation of the tail. The stimulation of the rat tail was by single rectangular current impulses. The EPs were then averaged. In [1, 2], we give an example of dynamics of nociceptive EPs registered in the S_1HL area of rat's cerebral cortex. We thus came to the classical biostatistics problem to find whether there was an effect of a single administration of a drug or not (see, e.g., [7]); to solve it, we made use of the non-parametric Wilcoxon test; this test uses only the information on the differences between values of the parameters and their signs, and there is no need to make assumptions concerning the laws of distribution of the differences of the parameters under investigation upon the action of the drug. The parametric tests based on the normal approximations appear to be of little use in our case.

If one takes the laboratory animal as a "black box" whose input is some external stimulus while the output yields a high-volume data flow, then the aim of the experiment consists of separating the response to the input stimulus in this flow.

Because of inevitable wear and outdating to which the computer and other laboratory equipment is subject to, we have to go through a severe upgrade and modernisation of the system described in [1, 2, 3, 4, 5].

The stimuli routed to an experimental animal via the constant current isolator unit A365D (World Precision Instruments, Inc.) are now precision-controlled by a Raspberry Pi 3B+ 64-bit quad-core ARM Cortex-A53 microcomputer (shielded in a metal enclosure) by means of its very well documented General Purpose Input/Output (GPIO) interface; we use the `wiringPi` library. The start of acquisition of the electrical activity of the rat brain is triggered by the synchronising impulse issued at a fixed (maybe zero) time interval before the leading front of the stimulus impulse.

The acquisition of electrophysiological data with the use of a 16-channel analogue-to-digital converter `usbdux-fast` (Incite Technology Ltd.), and the visualisation of the acquired electroencephalogram and EPs are now carried out by another Raspberry Pi 3B+ microcomputer loaded with modified Raspbian Stretch Linux with the `COMEDI` project open-source drivers, tools, and libraries for data acquisition implemented as core Linux kernel modules suitable for real-time tasks. This unit is complemented by a high-speed SATA 2.5" hard disk drive of large enough capacity coupled with X820 interface board by SupTronics Ltd. enclosed together in a metal heat-dissipating electromagnetic shielding case.

The Motorola LapDock display/keyboard unit can be successfully used to operate the whole system.

Since the libraries and the firmwares source codes are open source, we succeeded in implementing necessary corrections and revisions in minimal time.

The input electroencephalogram is visually monitored in real time with the use of `xoscope`. In order to capture the data, we use `ktimetrace`; it permits to capture samples from desired channels of our data acquisition device in a given time interval starting either from an arbitrary time instant or from that governed by the external synchronising signal and to save it to a file while providing a real-time graphing display. The data thus obtained form a text file whose each row consists of numerical values captured from the channels at the corresponding time instants. The size of the file can grow to an extremely large value, so we have to use the appropriate file system (`ext4`).

A key feature implemented is visualisation of the electroencephalogram and the results of averaging the EPs as the data are collected in the course of the experiment.

With the use of the `FFTW` library (developed in Massachusetts Institute of Technology) to implement the discrete Fourier transformation and a series of complex wavelet transformations, we are able to observe and analyse the spectrum of the electroencephalogram we acquire.

The complex of solutions we have used while developing and setting up this system allow us to deal with a wide range of problems of electrophysiology, including electromyography, electrocardiography, electroencephalography, and recording of neuronal activity in the brain.

All investigations were carried out on male Wistar rats in compliance with the GLP principles.

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