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Edited by

Arie Hasman

Department of Medical Informatics, University of Maastricht, The Netherlands

Bernd Blobel

Medizinische Fakultät, Otto-von-Guericke-Universität, Magdeburg, Germany

Joachim Dudeck

Institut für Medizinische Informatik, Justus-Liebig-Universität, Gießen, Germany

Rolf Engelbrecht

MEDIS–Institut für Medizinische Informatik und Systemforschung, GSF–Forschungszentrum für Umwelt und Gesundheit, Neuherberg, Germany

Günther Gell

Institut für Medizinische Informatik, Statistik und Dokumentation, Universität Graz, Austria

Hans-Ulrich Prokosch

Institut für Medizinische Informatik und Biomathematik, Westfälische Wilhelms-Universität, Münster, Germany

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Virtual training simulator - designer of EEG signals for tutoring students and doctors to methods of quantitative EEG analysis (qEEG)

Oleg Yu. MAYOROV
Kharkiv Medical Academy of Postgraduate Education, Ukrainian Institute of Children and Adolescents Health Protection, Ukrainian Association of Computer Medicine, P.O.BOX 7313, Kharkiv 61002, Ukraine; e-mail: **nresearcher@yahoo.com**

Abstract. Within the framework of the system for computer diagnostics of EEG (qEEG) NeuroResearcher™ 5.2 is created virtual training simulator - designer of EEG signals and models multidimensional neurodynamic systems of the brain. It is intended for tutoring with minimum engaging of mathematical formulas of doctors and students to comprehension of essence of mathematical methods (classical correlation and spectral analysis and newest methods of multi-dimensional analysis of neurodynamic systems of the brain), which are successfully used for quantitative EEG (qEEG).

1. Introduction

The prompt development of possibilities of computers has revived interest to potent method of diagnostics and research of the brain - electroencephalography (EEG) [1].

Besides it has allowed to insert in clinical practice and researches of the brain new potent mathematical methods.

In this connection there is a problem physiological/diagnostic interpreting of new secondary EEG indexes [2-5], and also study, how the performances of EEG signals influence on these indexes. Besides it is necessary to train with minimum engaging of mathematical formulas of doctors and students to comprehension of essence of mathematical methods of analysis, which are used for quantitative EEG analysis (qEEG).

2.Method

Within the framework of the system for computer diagnostics of EEG (qEEG) NeuroResearcher™ 5.2 [6, 7] is created the virtual training simulator -designer of EEG signals and models multi-dimensional neurodynamic systems of the brain.

The virtual training simulator-designer NeuroResearcher™ 5.2 comprises two units: 1. "Spectrum" unit; 2. "System analysis" unit. First of them is intended for doctors of all specialities, EEG specialists, students who want to master and 'feel' correlation and spectral-coherent analysis of biosignals (not only EEG, but ECG, EMG, etc., as well), which is widely used in various computer diagnostic technologies; for clinics, functional diagnosis rooms, institutes of advanced medical training, medical universities and colleges.

Second of them is intended for doctors and biologists, EEG specialists, neurobiologists, neurophysiologists, neurology and psychiatry investigators, psychopharmacologists, students - for all who wants to master and 'feel' the multidimensional spectral -coherence analysis of biosignals (EEG). This approach

is modern development of possibilities of classical methods - correlation and spectral-coherence analysis, practical implementation of that has become possible with appearance of modern computers.

3. Results

Creation of artificial "EEG - signals" with specified properties

At first stage of simulation an user has a possibility select of initial signals, construct of artificial "EEG - signals" from various initial incoherent signals of white noise consisting of different frequency bands with given frequency and phase characteristics in each of standard ranges of EEG (delta, theta, alpha, beta-1, beta-2) (fig.1, row A from window *Mixed signals*).

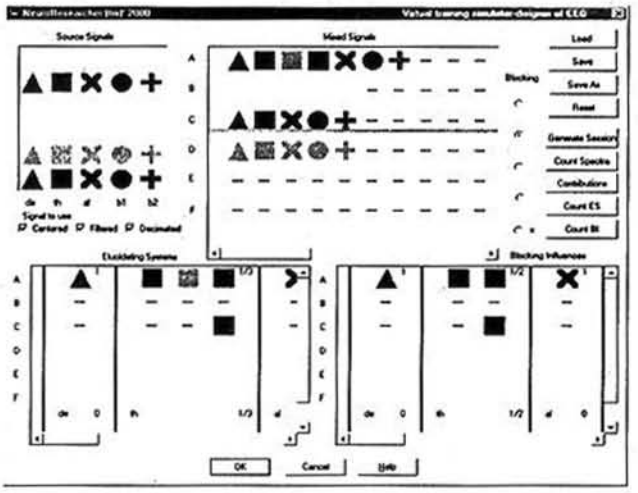

Fig. 1. Creation of artificial EEG - signals and systems with specified properties - selection of initial signals, construction of signals from various initial signals consisting of different frequency bands.

After designing (projection) of signals is completed, the system begins preparation of artificial "EEG signals". At this time system admixes various signals, and makes mathematical filtration by a set of special filters. This makes it possible to create signals with marked spectral and phase characteristics at user's choice by mixing and converting initial signals.

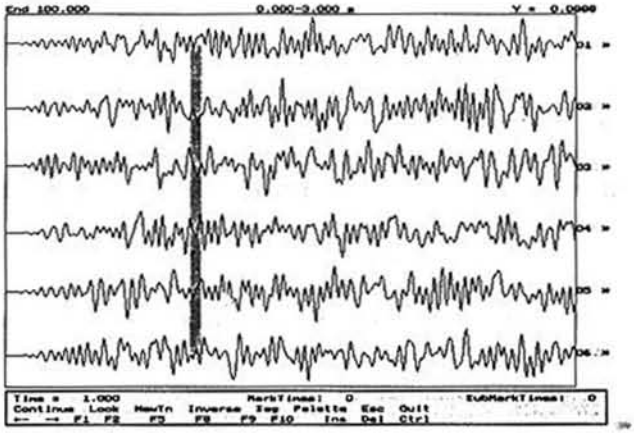

Fig.2 Visual checking of constructed "EEG - signals" - editor for viewing test signals.

Mastering by classical methods of correlation and spectral-coherent analysis of "EEG - signals"

At this stage EEG expert uses available in NeuroResearcher™ 5.2 mathematical means for mastering by classical methods of correlation and spectral analysis artificial EEG - signals and construction of the graphs of spectra (Fig.3).

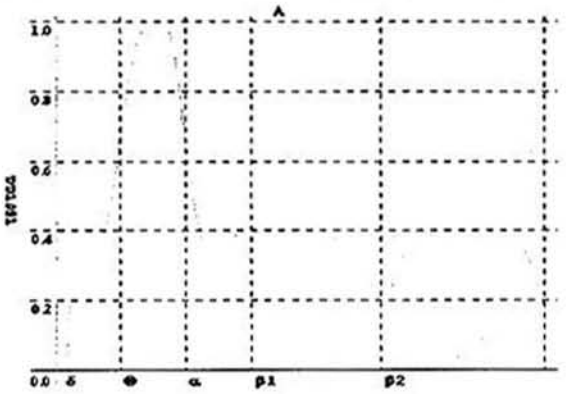

Fig.3 The graph of a spectrum of artificial EEG signal

This permits to understand how dominating rhythm is formed, what influences a value of one or another rhythm, how to treat phase relations (coherency) of two regions of the brain. It is possible also to compare advantages and disadvantages of spectral estimation on basis of Fast Fourier transform of signals and covariance-based spectral analysis. In the latter case it is possible to select any of 6 spectral windows and comparison of the spectral analysis results when using various spectral windows.

Besides at this stage it is possible to master delicacies (nuances) of correlation analysis of EEG - to carry out investigation of correlation analysis parameter influence - length of analysed EEG section (T), a value of the maximal time shift of correlation function (τ-max) etc. [9].

Important also, to train EEG expert to application of pair coherent analysis, which allows quantitatively to estimate interactions of two areas of the brain on each of frequencies from 0 up to 30 Hz. With its help a contributor can estimate of the direction of information flows in the brain depending on initial signals from which an user forms the initial test task, changing of coherence when the test conditions are changed.

Simulation multi-dimensional neurodynamic systems of the brain

As it is known, any activity of the brain has systemic character.

At the third stage of simulation an user has a possibility from a set of incoherent signals of white noise to construct artificial "EEG - signals" with given frequency and phase characteristics in each of standard ranges of EEG (delta, theta, alpha, beta-1, beta-2). It is possible to construct multidimensional neurodynamic system consisting from output (A) and 5 entering signals (B, C, D, E, F) (fig.1, window *Mixed signals*).

"System analysis" unit includes the following modes: 1. Elucidating systems; 2. Blocking influences. 3. Determining of contributions.

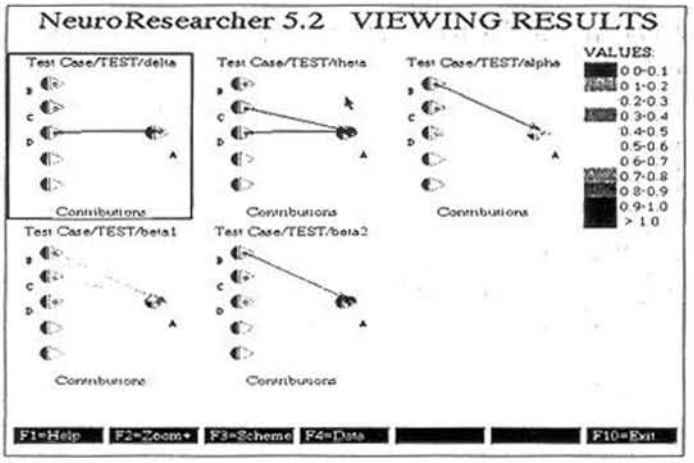

Fig.4 Outcomes of estimation of "contributions" in output process

1. *Elucidating systems* mode serves for investigating neurodynamic systems of the brain. It makes possible to investigate simultaneously several (more than 2) artificially created 'input' and 'output' signals; it is possible to create and then investigate systems consisting of various combinations of 6 such simultaneous signals; to reveal fine structure of interactions in various frequency bands; to solve problems of identification of signal propagation channels location of one or more signal sources (Fig.2, in the left lower window *Elucidating systems* are prognosticated results of systems analysis in each researched frequency range schematically represented).

2. *Blocking influences* mode serves for investigating system interactions in 'pure' form, eliminating (blocking) influence of separate signal sources or whole systems on *intra-system* interactions, in other words to simulate mathematical 'cutting' of *intra-* and *intersystem* influences, which makes it possible to evaluate in 'pure' form *intrasystem* interactions and *intersystem* influences; to solve problems of identification of signal propagation tracts; locate one or more signal sources (Fig.2, in the right lower window *Blocking Influences* are prognosticated results of systems analysis "blockade of influences " of some signals on "output" process in each researched frequency range schematically represented.

3. *Determining of contributions mode.* We recommend to use this mode after 'Elucidating systems' and 'Blocking influences' modes. It makes possible to quantitatively estimate real 'contribution' of separate signals in 'output' process; to detect a set of structures that actually take part in system activity under investigation; to detect fine neurodynamic structure of brain interactions (Fig. 3).

4. Conclusions

Circumscribed training simulator - designer of EEG signals and models multidimensional neurodynamic systems of the brain is equally effective for initial EEG experts, and for experienced clinicians. It allows to understand a genesis of a parentage of this or that EEG waveform, to apply methods of quantitative EEG analysis (qEEG) and to understand influence of brain bioelectrical activity character on a modification of secondary EEG indexes. Experienced clinician can use training simulator - designer for best interpreting of outcomes researches of neurodynamic system of the brain.

5. Summary

Thus, the creation training simulator - designers of various electrophysiological signals of man is perspective direction for implantation of new medical educational (learning) technologies.

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