Intelligent Interface for Biomedical Systems

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ABSTRACT: The research work described in the paper is focused on the problem of stress identification, estimation of psychical states and influencing the psychical load in the feedback. The problem is being solved both experimentally, and in simulation. Estimation of psychical states of a tested person is based on measurement of psychosomatic quantities and their successive parametrisation. According to the values of variables, level of psychical load is chosen for excitation or suppression of stress level. We have decided to make a comparative study of systems used for estimation of psychical states from psychosomatic parameters of a tested person. Three systems have been chosen, namely a neural network, fuzzy system, and an expert system. Cardiovascular, respiratory and other non-invasively measurable psychosomatic quantities are measured as psychosomatic quantities. Proposed testing, evaluation and control system (intelligent interface of biotechnical systems) is applicable for training and monitoring of operators in control rooms, in educational process ("dosing" of amount and difficulty of studied stuff from a hypertext textbook while keeping psychical strain of the student at a very low level) and last but not least for diagnostic purposes in medicine.

KEYWORDS: controlled test choice, measurement of psychophysiological quantities, parametrisation of psychophysiological quantities, estimation of psychosomatic states, biofeedback, intelligent interface, modelling and simulation of biomedical systems, fuzzy system, neural network, expert system

INTRODUCTION

Since long ago mankind has been closely linked with technological development. For effective cooperation of technological systems and human beings, mutual interactive adaptation is necessary. Recently, there has appeared trend of adaptation of technical systems to humans, based on analysis of their behaviour. Such a system must manifest features of adaptability, learning and intelligent behaviour while fully respecting standards of work safety and ergonomic principles. With regard to variability of biotechnical systems, this problem is very difficult and must be solved in its complexity.
Progress in research and technological development increases demand on psychical functions of humans and on their resistance to stress factors caused by technical systems. Adaptation ability of humans is not fast enough to follow dynamic changes of life conditions that are produced by humans themselves. It concerns especially emotional-vegetative sphere that is less adaptable than the cognitive sphere. Excessive demands on adaptation ability of emotional-vegetative sphere may result not only in negative subjective states, but also in more frequent physical diseases and problems that emerge as a consequence of long-term stress.

Technological development increases human psychical load because it restricts conditions for spontaneous activity, increases demand on information reception and processing, enforces certain life rate on people and makes background for rise of sense of uncertainty and anxiety. Excessive psychical load evidently aggravates preservation of dynamic balance of psychosomatic functions of human organism.
Subjectively, negative effects of psychical load are reflected mostly in useless, as a rule unpleasant feeling of mental tension or excessive irritation, in sense of mental resentment, anxiety, discomfort, ending up with limpness and fatigue. It is important to realise that long-term stress weakens natural defence mechanisms of an organism. Therefore stress is considered to be a potentially significant factor for rise of various diseases (e.g. hypertension, ischemic heart diseases, ulcerous diseases, allergy). Stress itself does not represent a direct cause of cancer but it plays a significant role at creating inner conditions that may influence malignant growth.
All stated facts lead to search for possibilities how to help humans to resist better growing psychical load, to keep better their emotional balance and not to give in to tendency to maladaptation.
In the paper we describe briefly design of an environment (see Figure1) that may simulate intelligent interface of a biotechnical system - Kubo (1993), Tkahashi (1993), Tkahashi (1995), Yoshikawa (1983), Yoshikawa (1994). This environment will enable (in full functionality in the future) testing, evaluation and control of human psychical states based on measurement of psychosomatic quantities.

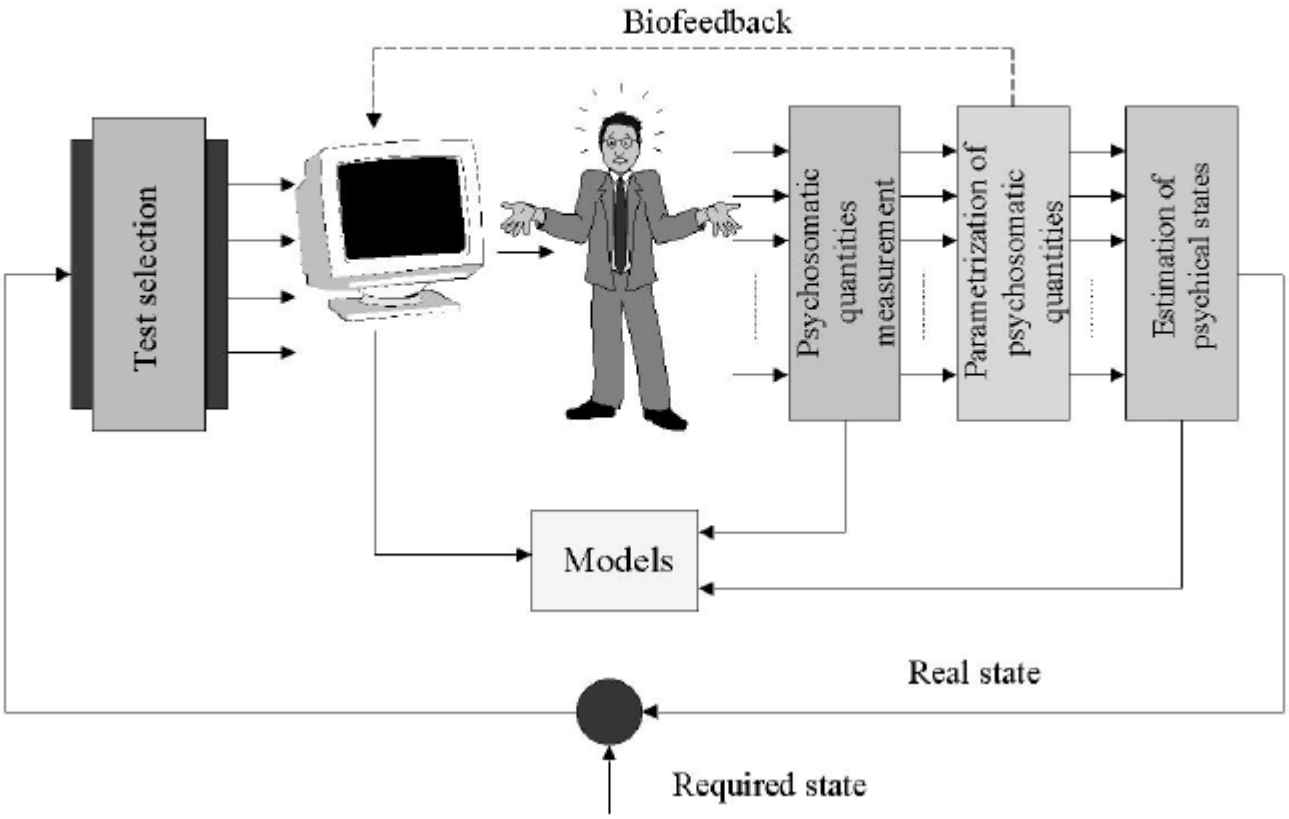

Figure 1: Block Diagram of the Intelligent Interface of a Biomedical System

In following paragraphs we will describe individual subsystems of the biomedical system.

TEST SELECTION

The selection of psychodiagnostic tests has been made from the catalogue of the Psychodiagnostika Ltd. for 1998. There have been used following three criteria (at least one of them must be satisfied):

- Tests evaluating long-term psychical characteristics of an adult
- Tests evaluating immediate or short-term psychical state of an adult
- Tests causing psychical load of an adult

Psychical load Grossman (1986) in our experiments has been generated using two tests. The first one can be characterized as fullfilling a number of more or less demanding tasks aimed at determination of logical, graphical and technical abilities of the tested person. The second test has been so-called "seven" test. Basic principle of this test is repeated subtraction of the number 7 from a number greater than 100. This test has been chosen because there is known the possibility of influencing the functions of attention and memory at stress stimulation. Indicators of attention and memory states are regarded for sensitive indicators of brain state. Both these functions are stressed during performing the chosen "seven" test. Before measurement of the psychosomatic quantities, the tested person has filled in the following questionnaires (for determination of basic health and personality characteristics - Bakan (1960)):

- anamnestic questionnaire,
- Bortner scale,
- Eysenk's questionnaire.

Anamnestic questionnaire contains basic data about personal and family anamnesis and about present health conditions of the respondent. Bortner scale is used for search for person with risky type of behaviour and attitude (irritability, tension, hostility, interpersonal sensitivity, life events and frustration). Eysenk's questionnaire is used for determination of measure of neurotic tendencies as personality factor and measure of willingness to respond truthfully about himself/herself.

MEASUREMENT AND PARAMETRIZATION OF PSYCHOSOMATIC QUANTITIES

The following psychosomatic quantities have been measured and parametrized:

- blood pressure,
- pulse frequency,
- movement activity,
- skin galvanic reaction,
- muscular activity,
- chest electrical bioimpedance.

BLOOD PRESSURE

The FINAPRESS device measures blood pressure. Its principle is based on continuous measurement of blood pressure using follower. Based on the information from the plethysmographic sensor, it continuously regulates pressure in cuff in such a way that the starting conditions of tested persons are maintained. Parametrization is performed by calculation of mean values, dispersion (diversion) on the interval and classification of data into predefined levels.
Performed experiments have verified reaction of human organism to psychical load represented by changes of parameters of cardiovascular system. Further there have been made experiments to influence cardiovascular system by psychical state (biofeedback).
Blood pressure has been measured by the CH-DRUCK device as well.
Measurement results have proven reaction of blood pressure to psychical load. In most cases, the blood pressure reaches higher values during the "seven" stress test (second test) than during the first one. The increase of average values during the first stress test has been in the interval 3-11 mmHg at systolic pressure and 2-12 mmHg at diastolic pressure. During the second stress test the average values raise by 6-22 mmHg at systolic pressure and by 0-35 mmHg at diastolic pressure. It has proven that reaction of blood pressure to psychical stress is very individual.

PULSE FREQUENCY

Mean value of pulse frequency has increased by 0-10 pulse/minute during the first test in comparison to values at rest and by 1-14 pulse/minute during the second test.

MOVEMENT ACTIVITY

Measurement and evaluation of movement activity of individual respondents have been performed. With respect to the character of stress tests and impossibility to keep standard conditions during measurements, it has been impossible to evaluate this factor in corresponding way.

SKIN GALVANIC REACTION

Results of evaluation of response of skin galvanic reaction to psychical stress have been in correspondence with evaluation of reaction of cardiovascular factors. Practically all respondents have reacted more considerably to psychical stress generated by the "seven" test than by the first stress test. Values of skin galvanic reaction have been in the interval 0 - 6.9% for the first test, and 2.8 - 12.3 % for the second test. Values of reaction measured during the first test have not differed significantly from values in phases at rest of the measurement. More significant differencies have been observed during the second test.

MUSCULAR ACTIVITY

Mean value of muscular activity during both stress tests has increased by 2-26μV. Increase of muscular activity during psychical stress is very individual. The highest increase of mean values (compared to values at rest) measured at one of the respondents has been 10.3μV during the first test and 26μV during the second test.

CHEST ELECTRICAL BIOIMPEDANCE

Experiments measuring chest electrical bioimpedance have mapped mutual relations between impedance and ECG, blood pressure and pulse frequency.

ESTIMATION OF PSYCHICAL STATES

We have decided to make a comparative study of systems used for estimation of psychical states from psychosomatic parameters of a tested person. Three systems have been chosen, namely

- neural network,
- fuzzy system, and
- expert system.

EXPERT SYSTEM

Estimation of psychical states has been performed by the FEL-EXPERT system (a rule-based expert system) Marik (1992). We have designed a knowledge base for this expert system. Input data have been the measured psychophysiological quantities (blood pressure, pulse frequency, muscular activity, skin galvanic reaction and movement activity). A written test has simulated psychical load during measurements. The knowledge base consists of 5 leaf nodes (input data), 15 intermediate nodes (for reasoning) and 6 goal hypotheses (defining psychical states of the tested person) and 54 inference rules.

FUZZY SYSTEM

Simulation of the fuzzy system has been done with the MATLAB Fuzzy Toolbox. Universum of individual quantities of the fuzzy system has been the set <0, 1>, their membership functions have been denoted μ(KT), μ(TF), μ(FD) - representing blood pressure, pulse frequency and respiration frequency respectively. In our case membership functions Γ, L and Π have been used. 27 fuzzy rules have been formulated for description of the designed system. They have been derived from described dependencies between stress (output of the fuzzy system) and psychosomatic parameters (inputs of the fuzzy system).

NEURAL NETWORK

Further a neural network has been used for estimation of psychical states. It has been realised as three-layered network of the Back-propagation type in MATLAB SIMULINK environment using Neural Toolbox. Input layer contains 3 neurons (input vector consists of blood pressure, pulse frequency and respiration frequency), hidden layer is made of 7 neurons and output values representing psychical state are characterised by continuous values from the interval <0,1>. Values close to zero correspond to low psychical load, values around 0.5 to medium load and values close to 1 to high load.

CONCLUSION

This research work has concentrated on problems of determination of stress state of a person by a computer. There have been suggested methods for measurement and evaluation of various psychosomatic quantities that may characterize stress of the tested person. Suggested system uses for evaluation of psychosomatic data a neural network, fuzzy system, and an expert system.
Utilization of neural network for estimation of psychical states of the tested person seems to be very suitable. Achieved results show that this way of estimation of psychical states is realizable. The fuzzy system and the expert system have achieved similar results. Detailed comparison of all three approaches is being done. However, there is one major obstacle to realization of similar systems, namely high computational demands caused by requirement of real-time evaluation of psychosomatic data.
Proposed testing, evaluation and control system (intelligent interface for biomedical and biotechnical systems) is applicable for training and monitoring of operators in control rooms, in educational process ("dosing" of amount and difficulty of studied stuff from a hypertext textbook while keeping psychical strain of the student at a very low level) and last but not least for diagnostic purposes in medicine.

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REFERENCES

2300 Finapress Blood Pressure Monitor, Ohmeda Operation and Maintenance Manual, Printed in the USA.

American Heart Journal, 1993, vol. 126, no. 3, part 1, pp. 607-6018.

Bakan, P., 1960, "Extraversion – introversion and improvement in an auditory vigalance task", Brit. J. Psychol., 50, pp. 322 – 325.

Grossman, P. et al., 1986, "Cardiorespiratory and Cardiosomatic Psychophysiology", Plenum Press, New York.

Kubo, O.; Tkahashi, M.; Yoshikawa, H., 1993, "Mutual Adaptive Interface: Laboratory Experiments for Human State Estimation", Institute of Atomic Energy, Kyoto University Press.

Marik, Vl., Vlcek, T., Kouba, Z., Lazansky, J., Lhotska, L., 1992, "Expert System FEL-EXPERT version 3.5: Description and User's Manual", Report TR-PRG-IEDS-6, FAW Linz-Hagenberg-Praha-Wien

Tkahashi, M.; Kitamura, M.; Yoshikawa, H., 1995, "Development of a Real-Time Cognitive State Estimator", Institute of Atomic Energy, Kyoto University Press.

Tkahashi, M.; Kubo, O.; Yoshikawa, H., 1993, "Mutual Adaptive Interface: Basic Concept", Institute of Atomic Energy, Kyoto University Press.

Yoshikawa, H.; Kitamura, M.; Tkahashi, M., 1985, "Development of Biocybernetics Analysis System (BIOCYS) for MMI-Related Cognitive Factor Analysis", Institute of Atomic Energy, Kyoto University Press.

Yoshikawa, H.; Tkahashi, M.; Arai, T., 1994, "Concept on Mutual Adaptive Interface and Related Experimental Study", Institute of Atomic Energy, Kyoto University Press.