Self-adjusted Data-Driven System for Prediction of Human Performance

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Abstract. Design principles and the data-driven system to assess and to predict an operator readiness-to-perform are discussed in the article. Principles of construction and performance of the system are formulated. The main focus is on data organization (time line, date set for the model construction) and adaptive algorithm construction. High level of the prediction accuracy for an operator readiness-to-perform (85-90%) was achieved because of use data stored (parameters of time and cognitive tasks performance by user) the system to control its performance, as well as its self-adjusted algorithm of functioning.

Keywords: Data-driven • Cognitive performance • Self-adjustment • Adaptive models

1 Introduction

To date, emergent technologies and education are based on information and communication technologies with increasing role of artificial/hybrid intellect, as well as Self-Organizing Human-Centered Systems [1]. Appropriate systems need to be anthropocentric ones and need to register big amount of data to be effective in real settings [2]. Implementation and use of adaptive automation of control systems in industry clear demonstrated the need to create adaptive, self-organizing and/or self-adjusted construct of such systems [3]. The greatest problem of this task consists in self-learning of the system (or machine learning, in today's terminology), and we strongly believe that the

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effective way is to use concepts of data-driven systems [4], when algorithm of the system's behavior is quite flexible [5] and use data concerned human (operator) and adaptive technical parts' performance [6].

Purpose. To design principles and the data-driven system (DDS) to assess and to predict an operator readiness-to-perform.

2 Method

To date, education moves into digital environment, becomes more individually oriented, learner changes his status from object to subject of education and needs more flexible and adapting tools for learning, his/her learning activity acquires traits of operator-researcher. Thus, design principles and the data-driven system to assess and to predict (DDS-AP) an operator readiness-to-perform (O-RtP) are valid for learning activity as well [7], if we consider a learner activity as a type of operator work (operator-researcher). Multiple regression models are used for assessment and prediction of operator performance. This approach uses preliminary findings of authors [8].

3 Results and Discussion

In general case the system developed for a pre-shift assessment of power plant O-RtP should meet the following *modified* requirements [7]:

- The prediction of the O-RtP should be constructed accounting his/her individual psychophysiological and performance features with automatic construction and change of individual "norm" in correspondence the O-RtP changes over year and age, i.e. adapting to slow changes of the human psychophysiological status. Special attention is paid to individual nature of the functional state changes [9] and cognitive workload of operator under influence of internal and external factors [10].
- It is generally recognized that any type of professional work and type of learning need some preliminary "training and a human adaptation to specificity of problems to be solved, parameters of test performance as a model of professional work vary in due course as well" [7]. To solve this problem, the model of the O-RtP should assess the operator's level of training to perform tests and should be corrected in accordance to this level.
- In accordance to the Godel's external complement principle, correcting of the O-RtP model, parameters of his/her real work (successfulness of professional duties performance) or achievements in learning process should be applied.
- The system can be applied by both the operator himself to correct his functional state, and his supervisor (chief operator, teacher) to make organizational decisions.

Principles of Functioning of the System. The active current structure of the DDS-AP (active sub-systems) is determined at every use in dependents on results of test performance and the current model of the operator performance. "In other words, the information which deals with the current operator state and is received by the system (task performance time and number of errors) determines change of internal structure of the system" [7]. At the same time, the information associated with efficiency of professional duty or learner performance is used to make changes in models of the O-RtP adjusting them to the current functional state of the operator. In other words, DDS -AP provides permanent matching of the external and internal information. The appropriate principles of the system functioning were developed and considered [7]:

- Use of individual models and individual "norm" of the operator psychophysiological state.
- The multivariate analysis of test performance parameters.
- Regular verification of the prognosis according to external criterion.
- Model adaptability to slow changes of the operator functional state.

We recommend using as external parameter the most informative one in relation to the particular field of the system use that contains an "integrated" evaluation of the operator professional performance efficiency of conducting technological process by the operator. In process of improvement of technological estimations of the operator professional work efficiency, the external criterion is improved as well. Thus, the system "is retrained" over monitoring time accordingly to this criterion and is stable at the level of functioning and prediction concerning a new technological parameter ("commander mark" can be used as the expert mark of the learner supervisor in the sense of technological parameter).

Data-Driven Organization of the System Functioning. An example of the result of the transformation of a management system using such information technology is the implementation of a self-tuning system for the alternate control of the operability of the SPORO operator, which is intended for use at complex technological objects and, in particular, at power plant and railway [11].

System reliability, accuracy and robustness of prognostic estimates are ensured by the implementation of the following principles:

- autonomous management of the system;
- modeling of dynamics of operator activity;
- test results usage as an external criterion for the activation of functional subsystems;
- adaptive forecasting of external performance index.

An operator performance reassessment system is designed to collect objective information about operators in a real production environment, where the efficiency of the information received, and the ease of data manipulation are essential factors. Therefore, as a database, a relational type database was developed to support the SPORO information system, the structure of which is a set of interconnected files that have a unified internal structure and are implemented as direct access files.

Each file (or relation over the parameters of the operator in the model conditions and the parameters of the effectiveness of his professional activity), which is an information model of psychophysiological characteristics of the functional state of the operator, has a logical data structure that is understandable for the personnel operating the system and medical researchers. This is an m-ary relation, the degree of which depends on the specific conditions of use (in existing implementations varies from 34 to 60). Tuples are datasets that characterize the parameters of information processing time in test tasks, the reliability of work, the operator's performance of his professional tasks. In order to automate the administration (administration) of the database, two domains are allocated for the date and time of testing.

Each tuple is the result of displaying in the database the original time series (TS) of the test indicators. In time series, compression of information to save not only the original TS{V} but only its essential m characteristics is important in displaying in the database. Then

$$\{v\}_1^k \rightarrow \{x\}_1^m \mathrm{S},$$

where S is the set of parameters that describe the current functional state of the operator.

In this case, the overall model of the functional state and operator performance is described as

$$y_N = \Phi_N(x^p \in X),$$

where p $\leq$ m, has an error ε, depending on the exponent p and the number of observations N included in the model.

Since the parameters depend on the time x = x (t), ε can increase due to the "aging" of the data, that is, if $x_j(t) = F(x_1, x_2, \ldots, x_{j-1})$, то $\varepsilon_j \geq \varepsilon_{j-1}$, then εj $\geq$ εj − 1 for all p.

There is an optimum N at which εj = min. The values of p and N for practical purposes are determined experimentally on a case-by-case basis. The number of tuples is constant for all database files and allows to store a volume of information enough for continuous support of the dynamic model of the managed object (operator) and is selected depending on the equipment used.

The database management system includes tools both traditional for the database management system (DBMS) and included in applications. Due to this, in DBMS automatic mode defines the following functions, implemented by the system at each operator testing session: testing (including the degree of operator's training with the system); processing of information and formation of information model of the operator functional state at the time of testing; estimation of necessity of correction of dynamic model of forecasting of efficiency of professional activity, necessity of correction of a condition of a DB. Accordingly, the system DDS-AP used data control of their work to adjust it to every user and to his/her fitness-for-duty depending on data stored related to past and present parameters of operator's cognitive test performance and external ("technological") information related to his/her performance.

By using direct access binary data as a physical structure, economical use of the external memory of the database is achieved (which allows the system to be used even on old computers that are still in use at the factory), it reduces the time of access to information elements and provides access authorization.

Applied results of use of the preliminary system demonstrated high relationship between indices of operators' task performance and indices of their professional work that were registered by the technological automatic system of the plant (multiple relationship ratio R = 0,7-0,9) [7]. And the most important result was the accuracy of the prediction by the system (85-90%).

4 Conclusion

The results of the DDS-AP in real settings (high accuracy of prediction of the O-RtP) were achieved because of use data stored in the system to control its performance, as well as its self-adjusted algorithm of functioning. This could be a tool to improve operator performance using predictive models and control by the system's data, as well as a tool for systems of adaptive learning.

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