sis of the diagnostic value is formed on the basis of the diagonal cross section of the Volterra kernels of the second order of feature spaces showed that the initial region of intersection corresponding to the first three samples has the highest informative value.

Keywords: *information technologies, diagnostics of continuous systems, diagnostic models, Volterra models, identification, classification, reliability of diagnosis.*

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CUSTOMIZABLE ADAPTIVE USER INTERFACES IMPLEMENTATION IN CONTROL AND LEARNING AUTOMATED SYSTEMS AS WAY OF INCREASING THEIR RELIABILITY AND EFFICIENCY

In modern automated systems users are often facing the information overload problem because of ever increasing volumes of information requiring treatment in short time. Working in these conditions affects the system operator's work quality and the systems' reliability. One possible approach to solving the information overload problem is to create personalized interfaces that take into account the user's information management particularities. System operator's features, which determine their preferred information representation shape and pace, form the user's cognitive portrait. Cognitive portrait is built as a result of user interaction with the software diagnostic tools that are based on the cognitive psychology methods. The effect of using personalized user interface in an automated system can be estimated by quantifying how exactly a reduction in user response time to critical events affects the reliability and efficiency of the system. To do this, the formulae in the theory of reliability of complex automated systems are used, showing the dependency between the system reliability and critical event response time.

Key words: *automated system, user interface, personalization, interface adaptation, cognitive portrait.*

Introduction. Reliability and efficiency of the modern automated systems largely depend on operators' manual actions. Nowadays, because of the constant complications of automated systems operators are in a situation of information overload that affects the focus on workflow and response time to critical events.

To solve this problem in modern computer systems attempts have been made to increase the effectiveness of user interaction with the workplace interface. A variety of approaches is used: organizational, ergonomic and more. However, they do not always give satisfactory results because they do not take into account the individual characteristics of users, focusing on some «average» user account.

Consequently, it was necessary to create system that allows you to personalize the user interaction with the system, implements the mechanism of diagnosing physiological and cognitive user characteristics to take them into account together with the user actions peculiarities in the construction of the adaptive interface.

Method. Message formal characteristics include: content, form, tempo and rhythm of the flow of information (intervals between individual messages, regularity of income, etc.) [6]. Fig. 1 shows the stages of human information processing of information from the external environment (or by the user — from the system)

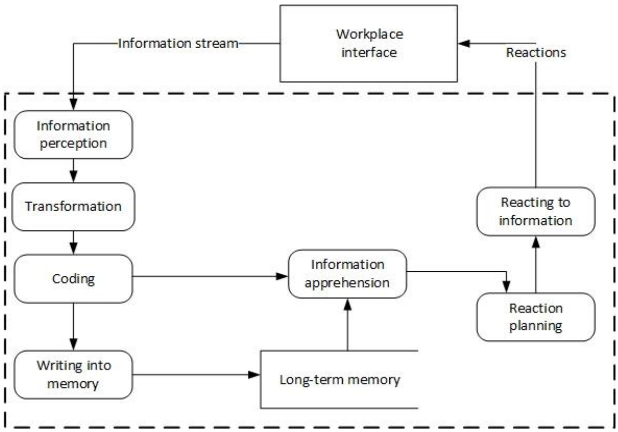

Fig. 1. *Process of human perception of information from the environment*

The results of experimental studies suggest that the phase of the initial situation representation holds a special place [5].

Thus, as the form of information representation is an essential factor that provides the perception, understanding and assimilation of information from the system, it can be seen as a way to manage the activities of the user. It is known that, while studying the material, people treat its content, form and shape selectively [1–3].

In addition to the preferred information representation form, each user possesses a number of characteristics that affect the pace and intensity of information flow from the system to the user.

These characteristics are divided into cognitive, physiological and intellectual.

Cognitive characteristics largely determine the speed at which the user is guided in the new information and switch between different types of activities. They are field dependence, equivalence range, impulsiveness and intellectual lability.

For each of these characteristics within cognitive psychology have been developed appropriate diagnostic techniques, many of which are sufficiently formalized to be implemented as a part of the automated characteristics diagnostic subsystem.

To assess the psychophysiological state of the user often are uses options such as his attitude to risk, quality of memory and attention. In this case, the testing impact reaction time and the responses errors should allow to evaluate concentration and coordination of user actions, because these depend on personal characteristics [7].

Intelligent features include the level of IQ and EQ (intelligence and emotional intelligence quotient, respectively) [4]. Although the coefficient of emotional intelligence is associated with the value of IQ, there is no direct relationship, namely the value of EQ determines predisposition to creativity when working with information. This characteristic is very important for users of design and training systems.

Nowadays cognitive portraits of the automated systems users are created based on professional psychological testing. But this method has two major drawbacks. First, it requires the participation of a professional psychologist, and the number of automated systems and their operators is growing faster than in an equal number of professional psychologists can be prepared. Secondly, this testing is not operational, it is a separated from the user's work process and workplace.

Both of these drawbacks can be eliminated by introducing an automatic testing subsystem into the interface adaptation system. Scheme of a possible implementation of this subsystem is shown in Fig. 2.

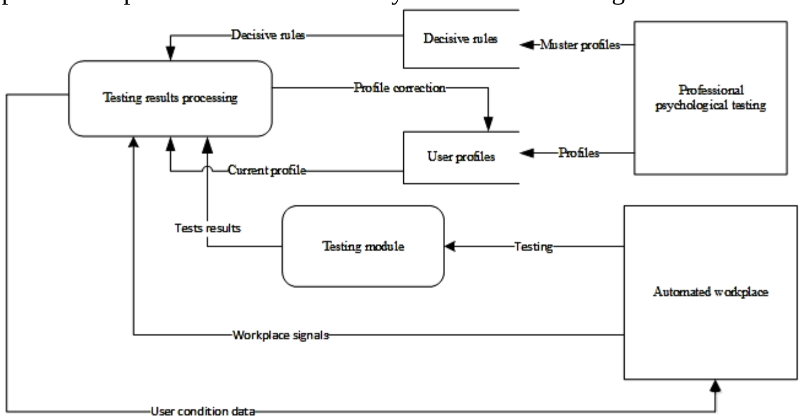

Fig. 2. *Users’ characteristics’ diagnostics system*

User testing is conducted both explicitly (during performing of tests) and in the background when on the computer workstations are monitored indicators such as speed of action or response to the changing situation. In both cases, user characteristics information is treated by a separate testing system module and supplements or modifies an initial cognitive profile that is used for further user interface management system work. This way — through modifying user interface and observing the performance changes with it (which is reflected in increasing responsiveness and reducing the number of errors when dealing with information) can the finite number of steps of the iterative process be taken to optimize the form of the interface for a particular user (in the case of interfaces with automatic adjustment).

To evaluate the effect of the use of the adaptive user interface in the automated system, we have to determine how reducing user response time to critical events affects reliability and efficiency of the system.

Let us assume that the automated system is effective if time T_1 actually spent on handling critical events does not exceed the maximum allowable time T_2. Moreover, the time T consists of the time of critical events occurrence and time of reacting on them. Then the condition of system efficiency can be written (T and T_2 are considered random values) as the probability P:

$$P\{T_2 - T_1 \geq 0\} \geq a, \tag{1}$$

where a is a probability with which the efficiency of the system is guaranteed.

The values of T_1 and T_2 are determined by skills and cognitive and psychophysiological state of the staff. On the basis of (1) we have

$$P\{T_1 < T_2\} = \int_0^\infty F(t)\,dG(t) = \int_0^\infty F(t)\,g(t)\,dt, \tag{2}$$

where the distribution function of the random variable $F(t)$ and $G(t)$ are defined as follows:

$$F(t) = P\{T_1 < t\};\ G(t) = P\{T_2 < t\};\ g(t) = G'(t). \tag{3}$$

Formulas (2) and (3) can be used with any laws of distribution of random variables T_1 and T_2, taking only positive values and have a density distribution of zero for negative values of the argument. However, these formulas are derived based on the fact that there is no more than one critical situation during the operation or task.

In the real conditions during the task with duration t critical situation may occur repeatedly. In this case, the performance of the automated system for a given time of the assignment will be provided with the following possible events: no critical situation, there is one critical situation that has been processed in the allowable time, there were two critical situations, each of which has also been removed in the allowable time.

Let's define ξ_i (i = 0, 1, ...) as the time interval between the i-th and the (i + 1)-th event, and $F_i(t) = P\{\xi_i < t\}$ — as the distribution function of ξ_i. Let's assume that the flow of events forms a stream with limited after-effect (ξ_i are independent in total). Then according to the definition of system failure by the formula of total probability the probability of the functioning over time t can be written as:

$$P(t) = \overline{F_1}(t) + \sum_{k-1}^{\infty} \int_0^t \int_0^{t-x_1} \cdots \int_0^{t-\sum_{s=1}^{k-1} x_s} \overline{F_k}\left(t - \sum_{s=1}^{k} x_s\right) \prod_{s=1}^{k} dF_s(x_s) W\left(t - \sum_{l=1}^{s} x_l\right), \quad (4)$$

wher e $\overline{F_i}(t) = 1 - F_i(t)$.

Here $W(t)$ — the probability that an event that occured at some time, will not lead in time t to irreparable situation. Let's determine this probability. Obviously,

$$W(t) = P\{T_2 > t\} + \int_0^t P\{T_1 < u\} dP\{T_2 < u\} = \overline{G}(t) + \int_0^{\infty} F(u) dG(u). \quad (5)$$

Expression (5) is obtained under the assumption that every event is handled independently. It is often assumed that the flow of critical system events forms the simplest form of flow with parameter λ. In this case,

$$F_i(t) = \begin{cases} 1 - e^{-\lambda t} & \text{for } t \ge 0, \\ 0 & \text{for } t < 0. \end{cases} \quad (6)$$

Substituting (6) into equation (4), we obtain the desired probability:

$$P(t) = e^{-\lambda t} + \sum_{k-1}^{\infty} \lambda^k e^{-\lambda t} \int_0^t \int_0^{t-x_1} \cdots \int_0^{t-\sum_{s=1}^{k-1} x_s} \prod_{s=1}^{k} W\left(t - \sum_{l=1}^{s} x_l\right) dx_s. \quad (7)$$

In the real conditions, sometimes there is a situation where only one event can be treated and the presence of two critical events in the system leads to failure. Obviously, the appearance of some events at the moment $\sum_{l=1}^{s} x_l$ will not result in an accident either when $T_2 > t - \sum_{l=1}^{s} x_l$ while $x_{s+1} \ge t - \sum_{l=1}^{s} x_l$, meaning more critical events have not appeared within time t and the allowable time T_2 is large enough, or when the next event happens before the moment t, i.e. $x_{s+1} < t - \sum_{l=1}^{s} x_l$, but previous event has been so far treated before allowable time T_2. In other words, in this case there is a situation

$$\left\{T_1 < \min\left(x_{s+1}, T_2\right)\right\}. \qquad (8)$$

In the first case, the probability of failure equals $W\left(t-\sum_{l=1}^{s} x_l\right)$, in the second case the probability of situation (8) is as follows:

$$W^*\left(x_{s+1}\right) = \int_0^{x_{s+1}} \overline{G}(x)\,dF(x). \qquad (9)$$

Equations (7) and (4) take the form

$$P(t) = \overline{F_1}(t) + \sum_{k-1}^{\infty} \int_0^t \cdots \int_0^{t-\sum_{s=1}^{k-1} x_s} \overline{F_k}\left(t-\sum_{s=1}^{k} x_s\right) \prod_{s=1}^{k} dF_s\left(x_s\right) \prod_{s=1}^{k-1} W^*\left(x_s\right) W\left(t-\sum_{s=1}^{k} x_s\right),$$

$$P(t) = e^{-\lambda t} + e^{-\lambda t} \sum_{k-1}^{\infty} \lambda^k \int_0^t \cdots \int_0^{t-\sum_{s=1}^{k-1} x_s} \prod_{s=1}^{k-1} W^*\left(x_s\right) W\left(t-\sum_{s=1}^{k} x_s\right) dx_1 \cdots dx_k .$$

Result. Probability (9) is an important component in both final expressions. It depends on the values of T_1, T_2 and values of moments $\sum_{l=1}^{s} x_l$. The values of moments are random, the value of T_2 is defined by the organizational requirements and features of the workflow. The easiest way to influence the performance efficiency of the automated systems is by changing (decreasing) values of T_1. This value depends on the specifics of processing information from the system by the user and the comfort level of the working with information. Since user interacts with the information in the s through the user interface interact, the convenience and efficiency of the interface affects the important parameter T_1.

Discussion. Proposed approach to the personalized user interfaces construction allows automated systems to be tailored to suit specific cognitive portraits and adapt interaction with information in the system to these features. This can increase the user's comfort level when working with information, reduce information overload, improve concentration and time of reaction to critical events. As the value of user response time affects the overall reliability and efficiency of the system, we can expect that the use of adaptive personalized user interfaces will increase the reliability and efficiency of automated systems.

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ЗАСТОСУВАННЯ НАСТРОЮВАНОГО ІНТЕРФЕЙСУ КОРИСТУВАЧА В АВТОМАТИЗОВАНИХ СИСТЕМАХ КОНТРОЛЮ ТА НАВЧАННЯ ЯК ШЛЯХ ДО ПІДВИЩЕННЯ ЇХ НАДІЙНОСТІ ТА ЕФЕКТИВНОСТІ

В сучасних автоматизованих системах користувачі часто стикаються з проблемою перевантаження інформацією через все зростаючий обсяг інформації, що потребує обробки за обмежений час. Робота в цих умовах впливає на роботу оператора та надійність системи. Одним із можливих підходів до вирішення проблеми інформаційного перевантаження є створення персоналізованих інтерфейсів, які враховують роботи користувача з інформацією. Особливості оператора системи, які визначають її бажану форму та швидкість подання, утворюють когнітивний портрет користувача. Когнітивний портрет будується в результаті взаємодії користувача з діагностичними інструментами програмного забезпечення, що базується на методах когнітивної психології. Ефект використання персоналізованого користувацького інтерфейсу в автоматизованій системі можна оцінити, кількісно визначивши, як саме зменшення часу відгуку користувача на критичні події впливає на надійність та ефективність системи. Для цього використовуються формули в теорії надійності складних автоматизованих систем, що показують залежність між надійністю системи та критичним часом реакції на події.

Ключові слова: *автоматизована система, інтерфейс користувача, персоналізація, адаптація інтерфейсу, когнітивний портрет.*

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