Available online at www.sciencedirect.com
ScienceDirect
IFAC-PapersOnLine 49-32 (2016) 107–112

Application of System Identification Techniques to Revealing Professional Skills of Teams of Human-Operators

K.R. Chernyshov
V.A. Trapeznikov Institute of Control Sciences, 65 Profsoyuznaya, Moscow 117997, Russia
(e-mail: myau@ipu.ru)

Abstract. The paper is devoted to a methodology oriented to eliciting professional skills of a team of human-operators of a technological plant by applying system identification techniques. Within the frameworks, the aim is to derive an input/output model that might reflect the actual level of group professional competences and skills. Deriving the required input/output model is based on applying such a kind of the "proxy", that is indirect, variables as the time. Namely, there is applied the *time* that is needed to the team of human-operators to make a decision on the plant process behavior using information provided by information sources distributed over an information&control board, such as, say, group view displays (GVD). In turn, these times are proposed to be fixed by use of eye trackers. Obtained in such a manner and calculated by use of data of observation of actual algorithm of experienced human-operator team performance, the model characteristics represent a tool for evaluation of human-operator team experience.

Keywords: Human-operator, Team, Professional skills, Measures of dependence, Shannon mutual information, Eye tracker

1. PRELIMINARIES

Numerous papers are devoted to investigation of various issues of design and performance of human-machine systems with regard to the human factor (Celik and Ertugrul, 2010, Damveld et al., 2010, Dismukes, 2010, Doman and Anderson, 2000, Ertugrul, 2008, Ho Bin Yim et al., 2013, Iiguni et al., 1998, Kanki et al., 2010, Kontogiannis and Malakis, 2009, Lee and Sanquist, 2000, O'Connor et al., 2008, Ramesh and Sylla, 1990, Redling, 2001, Rouse et al., 1989, Shorrock and Kirwan, 2002, Sutton, 1990, Tsvetkova, 1999, Xu et al., 2002, Yinhua Jin et al., 2004) paying special attention to revealing/identification of human-operator skills and experience.

The present paper deals with a conceptual approach to algorithmic identification of input/output models of group human skills and knowledge, that is consideration of "capturing" group human skills and knowledge in the sense of developing models that provide a way of a unified description of group human behavior under solving specific tasks within a decision making process.

This is of particular importance with regard to evaluation of activity of teams of human-operators of technological plants, since solving complex control tasks may require intelligent actions of human-operators, which are not envisioned by regular algorithms of the human-operator performance (Tsvetkova, 1999). Thus, group human-operator actions will unavoidably involve a heuristic behavior, imposing, in accordance, a creative feature of the decision making process.

Eliciting and investigating an actual algorithm of the common group human-operator performance under solving a complex task possesses certain methodological difficulties.

Investigations have shown that actual algorithms of the human-operator performance differ considerably from the normative, standard regular algorithms developed by technologists and appointed to human-operators (Tsvetkova, 1999). Naturally, the problem becomes more complicated under investigating the group performance of a team of human-operators.

Traditional training procedures are based on a strong algorithmic description of the human-operator performance disregarding specific features of the human mentation. At the same time, data gathered up to day give evidence that an important factor that cumbers solving complex tasks is certain non-correspondence between procedures set in the form of a strict sequence of actions and the dynamic nature of actual situations (Tsvetkova, 1999). This nature is concerned, first of all, with unpredictability of time instants of receiving different kinds and forms of current information.

One may assume that essential issues of receiving information on task elements pass out of clear recognizing them by the human solving the task. A part of actions, especially those ones that are inappropriate from the point of view of the decision maker, are not reflected in oral and written reports and comments at all.

Within a training process, being as a rule passive, one attempts the human-operator to elaborate automatic skills of solving specific tasks. Meanwhile, these attempts require performing a normative algorithm as fast as possible, disregarding all accompanying events, situations, signals, etc. Any violations from the normative algorithm are considered as inadmissible, caused by insufficient training (Tsvetkova, 1999). Group human-operator performance is evaluated in

Peer review under responsibility of International Federation of Automatic Control.
10.1016/j.ifacol.2016.12.198

accordance to the final results that do not provide information to analyze reasons of unsatisfactory performance.

At the same time investigations also show that violations of the human-operator from an appointed solution algorithm are causal and are not necessarily concerned with his insufficient training, but reflect essential human, heuristic features of the operative human mentation.

In practice, the human-operator transforms the tough normative algorithm appointed to him into unrecognized algorithm with elements of a heuristic structure. Such a structure is characterized by violations from the strict sequence of steps of the normative algorithm, appearance of multiple returns to preceding steps, appearance of interlacing normative steps with heuristic ones.

2. TOWARDS GROUP HUMAN BEHAVIOR MODELING

Generically, the goal of the input/output modeling of group human behavior is the processes that intervene between inputs to humans and outputs from humans. Thus the concern of the present paper is deriving input/output relationships enabling one to elicit distinctions in available skills and knowledge of humans with regard to a professional activity domain. Understanding input/output relationships for particular types of tasks may serve as a basis of comparing professional skills and knowledge of different humans and, consequently, to serve as a basis of evaluation of the quality of their professional training and experience. When this is the goal, the relationships identified should reliably describe the dependence of inputs and outputs, but need not be explanations in a scientific sense (Rouse et al., 1989). As it will be shown below, just proper eliciting such dependence will be the key issue of deriving a model capturing human skills and knowledge.

There are several general steps involved in capturing human skills and knowledge in terms of input/output relationships. While the particulars of the steps depend on the reasons for which one is pursuing this information, the general outline is the same regardless of purpose (Rouse et al., 1989).

The first, and probably, the most crucial step is choosing a form of representation for the input/output relationship to be modeled. Three elements of representational form are conventionally concerned. Namely, these are: variables, relationships among variables, and parameters within relationships. As the parameters, within the present paper consideration "hidden" parameters will be introduced and explained.

The choice of representational form determines what data should be collected to "fit" the form of the behaviors of interest. An obviously crucial step is defining the behaviors to study. For example, the nature of readily observed behaviors (for instance, keys pressed or words spoken) may result in using representational form that does not inherently fit the ultimate but unobservable phenomena of interest (for instance, mental models). In other words, there is a strong (and usually appropriate) tendency to model, for instance, those cognitive mechanisms that are associated with observable inputs and outputs (Rouse et al., 1989).

Because studies of cognition cannot directly access the phenomena of interest, there is some freedom in choosing which variables should be studied. With this freedom the risk of making inadequate or inappropriate choices of variables comes. It is therefore possible to end up with a well-done model of relationships among wrong variables. Of course, such "false starts" may subsequently be quite useful as steps in the direction of eventual understanding. This dilemma is not unique to the study of cognition. All branches of science that are dealt with phenomena that are not directly observable must face this problem (Rouse et al., 1989, Davis and Park, 1987).

The choice of variables of interest is not as easy when the primary concern is with the mechanisms underlying behavior rather than the behavior itself. Meanwhile, many, if not most, cognitive phenomena do not have obviously associated measurable entities. As a result, considerable attention is to be paid to define the *"proxy"* variables that are used to provide *indirect* insights into cognitive phenomena. For example, speed and accuracy are often measured in studies of memory, perception, and reasoning. Metrics such as time and error are obviously not direct assessment of cognition. And namely a kind of the "proxy" variables will be used within the present paper considerations.

A unique measure of human attention behavior may be implemented by use of eye tracking. This is of particular importance with regard to evaluation of present and future environments, in which humans do and will work, and just eye tracking can provide insight into the visual, cognitive, and attentional aspects of human performance (Duchowski, 2002, 2007, Duchowski et al., 2002).

In accordance to above reasoning, the problem of assessment/identification of team skills of human-operators is to be considered, from a system theory point of view, as a problem of deriving a model of a mildly formalized system. Consequently, the model of a team of human-operators may be considered in terms of system input/output description, with available for observation input and output variables reflecting significant features of the model. Even if no exact analytical model of the input/output relationship between the variables is stated, obviously, there always exists an inherent link which reflects dependence of the output variables from the input ones.

Thus, by virtue of the considerations presented, one may state a problem of algorithmic identification of a model of professional skills of a team of human-operators of industrial plants. If such a model is derived, skills of teams of experienced human-operators may be considered as basic reference knowledge with regard to a given task of the plant control.

3. DERIVING AN INPUT/OUTPUT MODEL

Deriving the required input/output model is based on applying such a kind of the "proxy", that is indirect, variables as the time. Namely, there is applied the *time* that is needed to a team of human-operators to make a decision on the plant process behavior using the information provided by information sources distributed over an information&control board, such as, say, group view displays (GVD). The information sources on the GVD are associated in *couples* in accordance to types