On Modeling Human Performance Reliability

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Over the past two decades, the pragmatic aspects of man-machine technology have forced increasing attention to the development of mathematical models of human performance. The bulk of this development can be traced to the independent research of system scientists, cyberneticists, and behavioral scientists, each holding a man-machine view most compatible with his or her own discipline and hence each propounding different models.

The system scientist's view of the human operator in a man-machine environment is most compatible with optimal control theory, and hence, his models are to be found largely, but not exclusively, in the analytic or numerical deterministic domain [1]. Typically, the operator is viewed as an element in a control subsystem tracking loop performing a compensatory or pursuit tracking task. The operator is required to minimize the difference between system output and system random disturbance by manipulating some element whose output affects the system subject to control.

The cyberneticist's view is more compatible with system identification theory, and his models are more likely to be propounded in the analytic or numerical stochastic domain [2]. Typically, the operator is viewed as a structural model with a finite number of unknown parameters, subject to internal and external stresses while performing some task having an observable input signal. Once the structural model of the operator is chosen, the problem is reduced to one of parameter estimation.

The behavioral scientist's view parallels more closely that of reliability theory, and hence, his models are to be found mostly in the stochastic domain [3]. Typically, the man-machine system is viewed as consisting of n independent subsystems: m hardware subsystems, each having reliability $R_i(t)$, and a human subsystem having reliability R_h which is either cascaded with, or interconnects in the decision sense, the hardware subsystems. The man-machine system reliability model takes the form $R_h \Pi_i^m R_i(t)$. Due primarily to mathematical complexities concomitant with molecularization of human tasks, the human reliability models thus used are mostly discrete point probability functions derived from the limit function of the ratio of successful trials to the total number of trials. Such isomorphic models serve as a useful approximation in describing time-space discrete tasks. In time-space continuous tasks such as vigilance, stabilizing, or tracking, modeling of the human performance reliability function follows closely the system approach of classical reliability theory. Thus, for example, the human performance reliability function in stochastic notation is defined in [4] by

$$R_h(t) = \Pr\{\text{Errorless task performance in } (t_0, t) \mid \text{stress}\};$$

its quantified version is

$$R_h(t) = \exp\left(-\int_0^t e(t)dt\right)$$

where $e(t)$ is the instantaneous error rate and is analogous to the hazard function in classical reliability theory.

The papers appearing in this special issue represent the points of view of the disciplines described, but not necessarily in the order presented, above. The introduction of each paper given below is purposely brief. It brings out some salient aspect of the paper in a tantalizing dosage hopefully sufficient to induce the readers of this TRANSACTIONS to peruse the paper in toto.

In the first paper, author D. Meister gives an excellent survey of some 22 human performance reliability predictive models, 8 of which are given a critical review. The paper is a condensation of an ambitious study entitled Comparative Analysis of Human Reliability Models [5] stemming from the U.S. Navy sponsored Human Reliability Workshop held in 1970 in Washington, D.C. [6].

Lees, in his paper, follows with an equally excellent survey focusing on quantitative estimates of human performance error exclusively in process control. Lees submits that in process control greater task taxonomy is needed and suggests such a taxonomy as well as a scheme for collecting human error data generated by tasks unique to process control.

Lamb and Williams test the validity of the assumption that dual operator performance can be predicted from data generated by a single operator performing in a realistic maintenance situation. Their results raise some interesting conjectures and equally interesting conclusions.

Authors Nowrocki, Strub, and Cecil propound for a man-computer *communication system* a procedure for error categorization that is particularly useful when the system modus operandi requires the operator to transform and to input data. It is envisioned that such categories can provide the designer with error causes and their immediate consequences on the basis of which designs can be appropriately altered or existing systems modified.

Another classification scheme is presented in the Bailey, Demers, and Lebowitz paper which deals with man-computer *information systems*. Seven major causal factor categories which tend to increase the probability of human error occurrence in such systems are identified. The causal approach, it is argued by the authors, changes the emphasis of human reliability research from prediction of human error to pragmatic improvement of human reliability.

In the next two papers the techniques of optimal control theory, estimation theory, and human performance theory are blended together in a system approach to the modeling of human performance tasks in the time-space continuous domain. In the first of the two, coauthors Sriyananda and Towill present a fascinating idea that learning curves can in fact be identified with the same algorithms as physical systems. In a highly detailed development, it is shown that a recursive Kalman filter technique can be applied to problems of predicting human operator performance of tasks described by an exponential improvement model. Drawing upon system identification theory, the extension to models other than the exponential is possible as well as to parameters which are time variant. In the second of the two papers, author Baron gives an excellent treatise on the optimal control model of the human operator in a man-avionic machine system. Readers will find a succinct description of model philosophy, discussion of its application and verification of its validity. Of particular interest is the STOL landing approach example used for predicting the pilot performance and workload.

Halpin, Johnson, and Thornberry uncork a new and exciting concept which they call cognitive reliability. They develop it in terms of types of human errors and in terms of factors which affect the occurrence of these errors. Means of classifying cognitive errors are discussed and factors likely to influence cognitive errors are examined and then illustrated by means of a recent study by one of the authors.

The remaining two papers deal with human performance in inference tasks, a relatively new area of inquiry. The central objective of the first paper by Schum and Pfeiffer stems from the fact that the nature of the relationship between human observer (sensor) unreliability and evidence impact (diagnosticity) has not been subjected to the rigor of formal analysis. This the authors do elegantly. The resulting analytic formulation suggests strategies which allow decision makers to cope more successfully with man-machine unreliability in inferential situations. In the second (and last) paper, Johnson, Cavenagh, Spooner, and Samet show how quantified human sensor reliability can be incorporated in Bayesian inference models. They discuss the sensitivity of the human sensor to reliability data and the strategies used to process such data in making inferences. The authors conclude that when compared with a Bayesian model, human inference-makers generally overestimate the evidence impact of less than perfectly reliable data.

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Guest Editor

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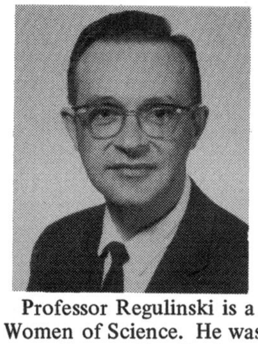

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