ERGONOMIC MODEL OF THE HUMAN OPERATOR

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Problem and Needs

We need systematic and comprehensive representations of three separate aspects of the human operator within a technological system:

(a) Model of body dimensions, "Anthropometric Model"

(b) Model of physical activity characteristics, "Biomechanical Model"

(c) Model of operator-equipment interactions, "Interface Model".

These submodels should be integrated for the "Ergonomic Model". This shall be a "proactive" (predictive) model, as compared to existing "reactive" (passive) models.

Many approaches for model subsystems or components of this overall problem exist. However, they do not fit into an common framework, and have different, often noncompatible outputs. Furthermore, the input requirements are usually different (resulting from analytical or systematic approaches of different disciplines) and do not rely on a common data base.

The lack of a systematic, comprehensive, and quantitative ergonomic model brings about incomplete understanding of the human operator as a system component, who is often the main determiner of the system output. Thus, technological systems relying on the human as a system component may be laid out less than optimal with respect to system performance and, therefore, are sub-optimal in their output.

Such systems are military or civilian. Typical examples in the military domain are aircraft cockpits, tank interiors, work stations on surface ships, or submarines. Search and rescue ships used by the U.S. Coast Guard are notorious for the lack of human engineering in their design. Typical civilian applications are in the automobile industry, both in passenger vehicles or trucks, and very prominent in construction and agricultural equipment. Acute industrial problems relate to control rooms, or visual display terminals.

Thus, development of a comprehensive and systematic Ergonomic Model of the Human Operator would benefit military as well as civilian populations and applications.

Background

The knowledge required to solve the problem extends over several scientific domains, e.g. anthropometry, physiology, psychology, biomechanics, computer science, and engineering. It includes the need to establish a common reference system, a convenient notation system, and the development of special research methods and of related measurement techniques.

Thus, the problem is mostly one of basic research, of data organization and primarily of establishing the conceptual framework. Development of work on computer software is also needed but does not seem to be a major problem. Application needs and possibilities are obvious.

A vast number of publications exist on this topic. Its collation and evaluation is a basic task of the model development. A first step towards the concept of an Ergonomic Model described here was discussed a decade ago by this author:

K. H. E. Kroemer. COMBIMAN-Computerized Biomechanical Man-Model. AMRL-TR-72-16, WPAFB, OH: Aerospace Medical Research Laboratory, 1972.

Review and detailed papers regarding anthropometric, biomechanical, and interface submodel are contained in:

R. Easterby, K. H. E. Kroemer, and D. B. Chaffin (eds.): Anthropometry and Biomechanics. Proceedings of the NATO Conference, July 1980, in Cambridge, England. New York, NY: Plenum (in press).

H. Schmidtke, K. H. E. Kroemer and P. L. Walraven (eds.): Ergonomic Data for Equipment Design. Proceedings of the NATO Advanced Research Institute, March 1982, in Munich, Germany. London: Plenum (in press)

Approach

Subsystem 1: Anthropometric Model

A comprehensive model of human body dimensions, particularly of the human body in motion, is lacking and needs to be developed.

The problem can be subdivided into four areas:

1. Lack of a reference system. For example, standard anthropometry relies on measurements taken in front view, side view, or top view, usually without interrelating the measurements taken in each plane.

2. Lack of a suitable measurement technology. For example, measurements are still generally taken with the clasical anthropometer, instead of using photography or other advanced techniques.

3. Lack of adequate notation. Standard medical terminology is gross, clumsy and ambiguous. Detailed systems such as used in choreography are cumbersome and non-scientific.

4. All of the above lead to a lack of information on human body dimensions, reaches, and mobility particularly of the human body in motion (dynamic anthropometry). One sub-problem is predicting unknown body dimensions from measured ones. The lack of information is particularly obvious with respect to civilian populations.

<u>Subsystem 2: Biomechanical Model</u>

Current models of physical performance characteristics of the human operator are largely restricted to three aspects:

1. Static measurements, as traditional in physical anthropometry, of body segments in common "frozen" postures.
2. Voluntary strength and power capabilities under laboratory conditions (physiology) or for extreme achievements (sports events).
3. Passive responses of the body to force fields, or impacts.

A systematic breakdown is missing that describes active voluntary physical performance characteristics needed as design inputs for manned systems. Such performance characteristics could refer to dynamic mobility including reach, to dynamic muscular strength, and to energy and power output capabilities. These variables should be subdivided into output capabilities of the whole body, or of trunk, limbs, or hands in particular. Furthermore, they should be described along the time axis, such as one-time all-out-efforts compared to short or medium time endurance. Finally, long term capabilities need to be described, which would take into account training, skill acquisition, and/or fatigue, in various environments.

Part of the problem is the determination of suitable assessment methods and techniques. Physiology has largely used oxygen consumption and heart rate. Psychology has developed various methods to assess mental and physical strain. Emerging psychophysiological (psychophysical) approaches combine several approaches.

<u>Subsystem 3: Interface Model</u>

Models are largely missing that determine how human operated equipment should be designed and arranged so that a best match between the operator, and hardware or software, is achieved for maximum output, safety, reliability, comfort, etc. This optimization of the operator-equipment interface requires a clear understanding of which variable or variables should be optimized, and of the optimization criteria.

Within limits, existing models indicate suitable approaches. The U of Nottingham SAMMIE model is used for workstation design. The USAF COMBIMAN establishes geometry interfaces betwen a seated operator and an aircraft cockpit. The USN CAPE and CAR models are crewstation design tools. NASA uses combinations of these models, and others such as PLAID in the design of space ship interiors.

Interface points used in various models are either the eye, the buttocks, or the feet (see, e.g., AFSC Design Handbook, Military Standard 1472, Military Handbook 759) Usually, these models are simply intercept or clearance models determining the space needed by the operator. They have implicit and often unclear optimization goals with respect to system performance. This is obvious if one considers the fact that the hands as the single most important interface links between operator and equipment are usually not part of the design models, or only in a very indirect sense, e.g. is using only the maximal reach envelope .

<u>The Integrated Ergonomic Model</u>

Obviously, the subsystems (the anthropometric, biomechanical, and interface models) are hierarchical in nature. Therefore they should follow a common concept, and use compatible inputs and outputs. This common framework will be provided by the Ergonomic Model. Thus, definition of objectives and design of the Ergonomic Model determine the subsystems. Hence, goals, strategies, approaches, and measurement techniques for the Ergonomic Model must be determined first so that the submodels can be adjusted to fit the common purpose. One the other hand, experiences made so far with the subsystems provide valuable information for the establishment of a feasible and efficient comprehensive model.

Recommended Course of Action

It is not useful to simply continue the peace-meal approach taken so far in which the branches of the armed forces, different universities, and various other research institutions work in separate areas, on separate topics, in separate ways, without a common guiding concept. While these approaches have lead to valuable information in selected areas, the results cannot be combined to yield an overall picture and model.

The statements regarding problems and needs in the preceding text indicate appropriate goals and strategies of this work. The solution requires:

First: An overall concept and framework, with common directions and strategies to be followed

Second: Detail research along common guidelines to develop the subsystems

Anthropometric Model
Biomechanical Model
Interface Model

Third: Integration of these into the Ergonomic Model of the human operator within a technical system.

The First Step:

It is proposed that an expert meeting be organized. It should consist of perhaps 10, certainly not more than 20 persons. This meeting can rely, at least in part, on the results of the 1980 NATO Symposium on Anthropometry and Biomechanics and on the 1982 NATO ARI on Ergonomics. Using the results of these meetings, a steering panel should develop a general concept, and guidelines.

The Next Step:

After the systematic approach has been established, parallel research can be stimulated to establish compatible models that describe human body dimensions (Anthropometric Model), physical performance characteristics (Biomechanical Model), and operator-equipment interactions (Interface Model).