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TAPS - AN AUTOMATED TOOL FOR IDENTIFICATION OF SKILLS, KNOWLEDGES, AND ABILITIES USING NATURAL LANGUAGE TASK DESCRIPTION*

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ABSTRACT

A prototype, computer-based tool (TAPS) has been developed to aid training system developers in identifying skills, knowledges, and abilities (SKAs) during task analysis. TAPS uses concepts of flexible pattern matching to evaluate English descriptions of job behaviors and to recode them as SKA lists. This paper addresses the rationale for TAPS and describes its design including SKA definitions and task analysis logic. It also presents examples of TAPS's application.

INTRODUCTION

Task analysis is typically a highly subjective process that draws on observations of job performers' behaviors, and combines them with a training analyst's expert knowledge of systems, to infer a functionally useful set of skills, knowledges, and abilities (SKAs). These inferences are very sensitive to the experience of the analyst, the adequacy of the job description, and the observation sample used. The process is often more of an art than a science and, as a result, is open to a number of shortfalls which are characteristic of highly subjective procedures.

Because SKA data are used for a variety of purposes including courseware development, entry level skill identification, performance standards development, and performance selection, large variations in task analysis quality can be very costly in training developer time and other resources. Unanticipated costs often occur as a consequence of repeated site visits to extract missed information, correct erroneous assumptions, or modify incorrect courseware materials. As a result there is a real need for faster, more economical methods to support training system development.

A prototype task analysis tool called TAPS (task analysis profiling system) was developed at Oak Ridge National Laboratory (ORNL) for the Office of Nuclear Regulatory Research of the U. S. Nuclear Regulatory Commission (NRC) to remedy these problems (Ref 1). TAPS links the behaviors of nuclear power plant (NPP) personnel in performing their tasks and the measurement tests necessary to evaluate their in-plant performance. TAPS was designed to accept normal English descriptions of reactor operator/maintainer actions and automatically generate a preliminary list of SKAs along with associated human factors application principles. The development of TAPS used artificial intelligence concepts of pattern matching and knowledge representation techniques.

DESCRIPTION OF TASK ANALYSIS INFORMATION

SKA Definition

A new, more precise way had to be found to describe SKA elements that would be suitable for machine analysis of behavioral task descriptions. For example, a taxonomic definition of a human ability such as "perceptual speed" has generally relied upon loose verbal descriptions such as the following:

"Perceptual speed is the ability to compare sensory patterns quickly in order to determine identity or similarity."

Although appearing adequate, such a definition can lead to a great deal of disagreement over what constitutes perceptual speed. For example, it could be interpreted that perceptual speed is only a visual ability combined with a cognitive activity of recognition or recall. It is not clear, however, if "sensory patterns" could also refer to the other senses, e.g., auditory recognition of Morse code strings or tactual recognition by a pilot of changes in g-forces.

The developers of TAPS took another approach in recognizing from the onset that the resource demands on the user are a critical component in the ultimate implementability of a task analysis tool. The potential success of the TAPS approach lies in its ability to define task instances in a flexible manner capable of recognizing many different sentence variations of the same underlying idea. Thus, "rapidly spotting a change in a temperature gauge" or "detecting a meter deviation in less than ten seconds" are both recognized as instances of the same perceptual restriction by the TAPS program.

TAPS gains flexible sentence recognition through an approach analogous to choosing dinner items from a "Chinese-style restaurant menu". In a typical Chinese dinner, an acceptable "meal" is defined by picking an item from column A, one from column B, and another from column C. For example:

		A	B	C
"meal"	=	Item 1	Item 1	Item 1
		Item 2	Item 2	Item 2
		Item 3		Item 3
		Item 4		

If item A4 was fried rice, item B1 was pepper steak, and item C2 was lychee, a "meal" would be [fried rice, pepper steak, and lychee]. On the other hand, another perfectly acceptable instance of "meal" could have been [chicken chow mein, white rice, and sherbert] which would represent a different path through the columns. A similar logic may be applied to describe SKAs. For example, another way to define perceptual speed could be:

		A	B	C
"perceptual speed"	=	Sees	In Less Than	Visual Acuity Test
		Hears	Before	* Auditory Reaction Time Test
		Spots	In Under	
		Notices		
		Observes		

where one acceptable instance of perceptual speed is [spots in less than].

In a task analysis, this process is reversed and one is presented with some job performance descriptions which may involve perceptual speed. The taxonomy items are embedded in other information such as:

"I must hear a change in charging pump frequency in in less than 10 seconds."

In this case perceptual speed must be inferred from the task description by using a reversal of the technique to spot the underlined word combinations and recognize that they correspond to an acceptable path through columns A and B. To go further, however, once perceptual speed is identified, the ability name is really just another pattern that points to an acceptable performance test such as the "auditory reaction time test" in column C or other training information.

To accomplish the needed pattern matches, the definition-processing procedures were developed in a computer language suited to manipulation of sentences. Because of its ease of use and highly readable code, TAPS was first programmed in a simplified version of the LISP language called LOGO. It was programmed to run on an IBM personal computer or a compatible MS-DOS system. A high-speed version of TAPS was also coded in FORTRAN on a mainframe (IBM 3033) for experimental purposes.

Development Rationale and Model

Since off-the-shelf SKA lists did not exist in "Chinese menu" form, they had to be generated. Existing taxonomies were surveyed and evaluated as to their usability. It soon became apparent that criteria for inclusion or exclusion had to be specific, and in some cases, e.g., cognitive skills, entirely new elements needed to be produced. To facilitate this process a model of skilled human performance was developed. The model separates performance factors into seven areas: senses, operations, knowledges, plans, resource needs, physical/emotional charactertistics, and actions. Relationships between processes are represented by information flows shown in Figure 1 as arrows. Some of these flows are particularly important because they terminate in goal requirements which will affect operator performance and decision making. They are noted in the figure by the letter 'G' surrounded by a circle.

The "senses" block refers to the sensory channels of sight, touch, smell, hearing, taste, and kinetics, which serve as a human's mechanisms for information gathering. "Operations" are the cognitive activities used internally to manipulate sensory information; "knowledges" are the information in memory which can be utilized by "operations". "Plans" involve the way in which goals are attained or the structured attempts made to attain them. They are also sets of "operations" ordered in such a way as to produce the object of a goal as an end product. The "resources needs" block corresponds to other provisions required by operations in addition to "knowledges". Humans

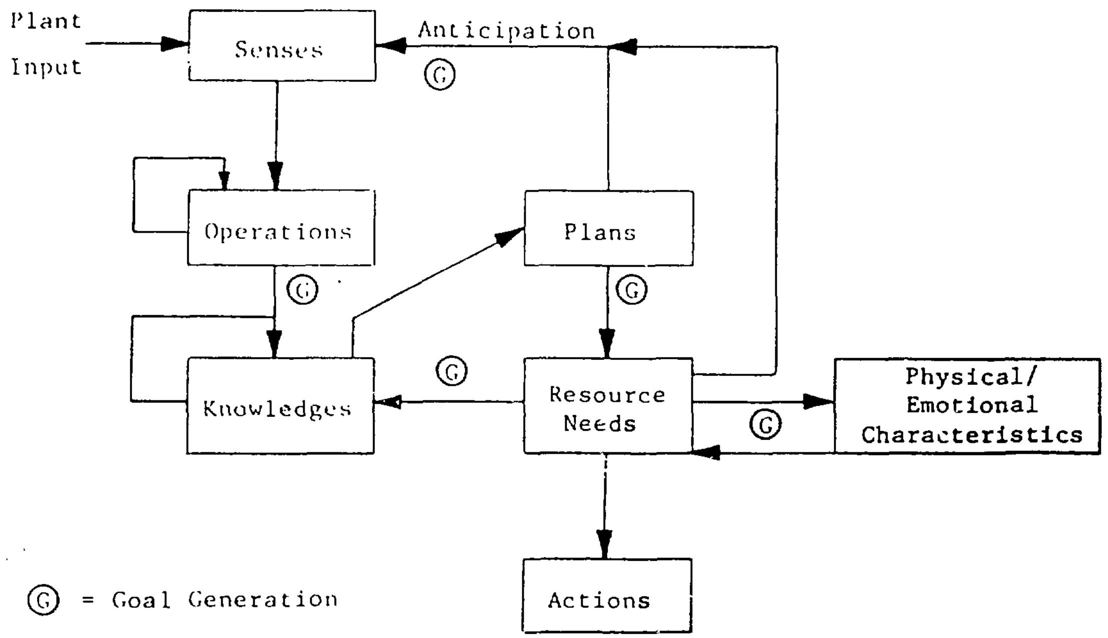

Fig. 1. A schematic of the model developed to select taxonomic items.

consume energy, be it "intellectual", "physical", or "emotional" as a result of performing work. The "actions' block deals with the visible result of an internal plan in operation.

The utility of this model came from the fact that it clarified how different task descriptive words should be attached to taxonomic labels. The model was used with other input to establish operational definitions of terms and to group and select taxonomic lists.

The transformation of existing taxonomic elements into "menu" forms involved two steps. First, all currently available SKA definitions were compiled along with an analysis of key word patterns which occurred in the examples presented by various authors. Second, key word patterns were subjected to a computerized thesaurus to find as many equivalent terms as possible. The resulting lists were then screened for applicability and entered into a structured data base. The product was a large set of potential "menu" definitions. Lists of usable measurement tests were selected and rank ordered by factor loading. The TAPS code was written to automatically reference these lists whenever a task analysis identified a particular ability as being present. In order to illustrate the potential of the tool, other types of lists were also generated for the SKAs. These lists include training evaluation principles and potential safety risks. Information was developed for every taxonomic item; however, a rigorous compendium of human factors research insights was not attempted within the scope of this effort, since the primary purpose was only to demonstrate concept feasibility.

SKA Lists

Abilities included in TAPS were for the most part drawn from Fleishman's earlier taxonomy (Ref. 2). They are shown in Figure 2. Ability tests were selected using the following process. When tests were available for specific abilities, they were placed into a preliminary selection pool. Since not all abilities have equal amounts of empirical support, a logic was designed to select among possible alternatives and, in some cases, to reduce the number. Performance tests also vary including length, feasibility of plant implementation, degree of research support, and factor loading.

ABILITIES

Arm-Hand Stability
Category Flexibility
Control Precision
Deductive Reasoning
Dynamic Flexibility
Dynamic Strength
Explosive Strength
Extent Flexibility
Finger Dexterity
Flexibility of Closure
Fluency of Ideas
Gross Coordination
Gross Equilibrium
Inductive Reasoning
Information Ordering
Math Reasoning
Memorization
Multi-Limb Coordination
Number Facility
Oral Comprehension
Oral Expression
Originality
Perceptual Speed
Problem Sensitivity
Rate Control
Reaction Time
Response Orientation
Selective Attention
Spatial Orientation
Speed of Arm Movement
Speed of Closure
Stamina
Static Strength
Time Sharing
Wrist-Finger Speed
Written Expression

Fig. 2. A list of abilities currently analyzed by TAPS.

The present effort was kept within reasonable bounds by using some preliminary "rules of thumb". A maximum of 3 tests were selected for each ability. In cases where there more than 3 potential tests available, those having the highest factor loadings were selected if the research data existed for the dimension of interest.

The knowledges and skills incorporated in TAPS are presented in Figures 3 and 4, respectively. The knowledges were generated largely through an analysis of NPP operator training courses; the skills were in general drawn from the Air Force handbook on instructional development (Ref. 3). These lists received minor development effort and, although realistic, should be regarded only as illustrative.

METHOD FEATURES

TAPS has several features which are designed to simplify the task analysis process. A brief example is provided below. Figure 5 displays part of an actual output for a sample task. At the top of the figure is an original sentence which has intentional errors in capitalization and puntuation. The sentence also includes technical abbreviations. The second sentence is the result of the first TAPS analysis step in which obvious user errors have been corrected and abbreviations have been expanded to their full length. Thus HPci becomes high pressure coolant injection, capitalization is normalized, and punctuation is removed. Although the example uses only one sentence, TAPS is not text limited and works just as efficiently on paragraphs or miltiple pages of typed task descriptions.

Next, TAPS systematically searches for skills and the information associated with them, knowledges, and finally abilities. The skill detected in Figure 5 (diagnosis) exemplifies the ability of the program to also serve as an automated source of expert guidance to a training developer because it prints human factors insights associated with skill categories. The "knowledge requirement for" section illustrates another capability of the program. After a general knowledge category such as "regulatory guides" is detected, the program retains specific information about the particular instance of regulatory guidance that is

Administrative Information	Optical Aids
Calculation Aids	Plant Controls
Communication Aids	Plant Displays
Detection Devices	Protective Clothing
Historical Information	Regulatory Guides
Major Tools	Small Tools
Operational Procedures	Test Devices
Operation References	

Fig. 3. A list of knowledges currently analyzed by TAPS.

SKILLS

Associating	Problem Solving
Chemistry	Procedural Compliance
Classifying	Reading
Concept Application	Reasoning
Diagnosis	Rule Using
Discriminating	Speaking
Equipment Operation	Team Interaction
Managing	Tool Use
Mathematics	Verbal Chaining
Motor	Writing
Nucleonics	

Fig. 4. A list of skills currently analyzed by TAPS.

The original typed task was:

Based on aBnOrmAl soNic PrOBE readings, iNfeR from NrC buLletins on CorrOSion thaT. HPci, safety Limits reQuire circuit bREaker MAiNte-NAnce!

The TAPS expanded task used for computer analysis was:

based on abnormal sonic probe readings infer from nuclear regulatory commission bulletins on corrosion that high pressure coolant injection safety limits require circuit breaker maintenance

Skill detected: diagnosis

*** some important principles are: ***

-----Be particularly careful of this task if it involves maintenance; diagnostic skills can have wide individual differences

Knowledge requirement for: regulatory guides

Relation of nuclear regulatory commission bulletins to plant operations. Literacy level for proper reading of nuclear regulatory commission bulletins.

Attitude detected: personal responsibility *** points to consider and possible impacts are: ***

This task probably involves unsupervised action; careless individuals may not be suited for it.

Be alert for emotional situations that could impact safety such as marital problems.

Ability detected: deductive reasoning

*** some acceptable tests are: ***

---- Complex deduction test #181

---- Logical reasoning test #168

Fig. 5. A sample exert from a TAPS Sentence Analysis.

found. It then inserts the information into a general sentence so as to produce customized textual material specific to the task being analyzed. The advice can be as detailed or general as desired, but only very simple advice is used in the present TAPS version. The "ability detected" (deductive reasoning) shows that TAPS can be used to produce customized test lists as well.

CONCLUSIONS AND FUTURE APPLICATIONS

TAPS provides the first step towards performing task analysis in a faster and more standardized manner. This prototype development furnishes a promising indication that automated task analysis is reasonable and can be structured in such a manner as to be generalizable. Considerable work needs to be done to examine extensions of a "menu" approach for linking existing bodies of human factors principles to taxonomies.

Dramatic enhancements of TAPS, e.g., new SKAs, greater system detail, or information for training developers, are possible since the specific application information (the SKAs) can be separated from the program code and, as a result, the code does not need to be reprogrammed. The ease of adding new information means that if TAPS is implemented in high-speed form, the program can serve as a powerful expert system for training-related information. Once entered, equipment names, control types, specialized knowledges, new skills, and any of the other types of information present in TAPS will never have to be entered again for another plant (although new knolwedge may). TAPS has the potential of becoming an operational repository of training development information specific to nuclear power operations but in a form which is available to users immediately in job-relevent contexts rather than distributed throughout large data bases of information.

TAPS is designed to be used in systems approach to training processes requiring task analysis information. Its ability to connect SKAs to measurement tests, however, adds potentials which are not currently being used. For example, TAPS categories of SKAs could point to specific questions for training course examinations instead of lists of suggestions or test names. In that form, the output from TAPS could be a customized set of test questions generated in real time for task sequences in plants or for the component tasks present in accident transients. In such a form, TAPS could serve as an aid to a training instructor in test construction.

In another application, TAPS could print human factors guidance drawn from the literature, including cautions about man/ machine interactions in design, equipment layout, control principles, instructional principles, or many of the other associated areas of human factors expertise. In this way, human factors information could be brought directly into the hands of NPP personnel to aid them in assessing whether or not a specific plant had incorporated known areas of human factors engineering. Similarly, experience relevant to safety concerns could be highlighted.

The final form of TAPS would be transportable. In this configuration, a training developer or analyst could use a remote terminal device to "dial up" a mainframe computer from the plant site. Information could be entered and a real time TAPS evaluation provided during on site job analysis. Preliminary tests at ORNL have already verified the feasibility of this option.

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