Enhanced/Operator Machine Interface Phase I SBIR TOPIC N96-232 Final Report

December 22, 1997

Sponsor:

Naval Air Warfare Center Aircrafts Division
LCDR Robert Lockerby (AIR 4.5.1.2)

Contract No. N00421-97-C-1148

Competitively Awarded

Contract Value: $70,000

Prepared By:
Digital System Resources, Inc.
Suite 500
12450 Fair Lakes Circle
Fairfax, VA 22033

Table of Contents

List of Figures

List of Tables

1. OVERVIEW AND REPORT ORGANIZATION

This report provides a proposed architecture for an adaptive Operator-Machine Interface (OMI) applied to the specific objectives of this Phase I SBIR effort. The features of an adaptive OMI and other considerations that must be addressed are also included. We present a methodology for using advanced cognitive modeling techniques to identify the knowledge and skill requirements for the SH-60R Sensor Operator (SENSO). We describe the potential problems confronting the SENSO with the increased sensors and capabilities of the SH-60R Multi-Mission Helicopter Upgrade (MMHU). An adaptive OMI is proposed as a method to alleviate these problems.

We propose an Integrated Intelligent Tutoring Environment (IITE) as an environment that allows for the development of an adaptive OMI as well as an Intelligent Tutoring System. This environment will use a Cognitive Task Analysis (CTA) to identify the expertise required of the SENSO on this newly evolving platform. Although the military has used CTA techniques to identify the skill and knowledge of Subject Matter Experts (SMEs), these techniques can be very costly. We provide a description of an automated tool that can be used to conduct a CTA and detail how this tool can be used to capture the SENSO's expertise.

Implementation of an adaptive OMI also requires a means for capturing each user's current knowledge state. A component of DSR's Integrated Training System (ITS) is presented as an option to achieve this goal. The ITS, developed under SBIR N91-052, has a diagnostic component that describes the user's skill level as compared to the expert model. Specific techniques for adapting the OMI are addressed including embedded coaching, electronic references, help tools, and customized tools such as automation techniques. The expert model developed for the adaptive OMI can also be used as the backbone for an intelligent tutoring system and an expert system to support decision-making tasks. We further describe the hardware and software required to implement such a system. The implementation and training of an adaptive OMI present a unique challenge. Our recommendations for achieving these tasks are also presented.

A summary of the Phase I SBIR is presented in Section 2. We found that an OMI that adapts to the current user has great potential and application for the SH-60R sensor operator station. Our recommendations for Phase II research are presented in Section 3. We propose to develop a prototype adaptive interface for the SENSO. By conducting a cognitive task analysis on an existing sensor subsystem, the expert's mental model of that subsystem will be specified. That model can then be used to adapt the subsystem's interface to the user's skill level.

Section 4 describes the components of an adaptive OMI. Considerable detail is provided on the cognitive task analysis process and the Cognitive Analysis Tool (CAT) that can be used to conduct the CTA. A thorough description of the potential design options for an adaptive OMI are also presented in this section. These include techniques that can be used when the system infers that the current user has acted erroneously.

Section 5 describes the conceptual architecture of the proposed system. Development of the adaptive OMI software is best completed concurrently with the tactical software. This is a Phase II issue and one which includes careful analysis and consideration of software and hardware development and hosting techniques which maximize the use of COTS and software transportability, such as Middleware used by DSR in the Multi-Purpose Processor (MPP) acoustic processing program. The implementation of an adaptive OMI is described in Section 6. Significant detail is provided on the most effective way to train the users to efficiently use an adaptive system. In Section 7, future directions as applied to the SENSO's adaptive OMI are discussed.

1.1 Introduction

The last two decades have produced major increases in the sensitivity, reliability, efficiency, and complexity of sensors available to Navy operators and tacticians. While those increased capabilities have provided distinct attendant warfighting advantages, the sensor processing and management requirements now needed to counter today's threats pose a major challenge to the air avionics sensor operator due to both the complexity of the sensors/weapons systems and a greatly increased task loading.

Airborne avionics sensor operator tasks are complex and severely loaded by time limitations and high information flow and presentation. The recent emphasis on Littoral Warfare, with even higher contact information rates and rapidly changing threats, requires yet even faster operator decisions and improved operator-system performance. Examples of the different missions that the SENSO may engage in include Anti-Submarine Warfare, Anti-Surface Warfare, Over-the-Horizon Targeting, and Search and Rescue. As an example of the complexity involved, these tasks can be characterized as typical of an ASW acoustic sensor operator simultaneously monitoring all or some of the narrow band, broad band, transient and active receive buoy processing modes for from between 8 to 32 independent buoys each with 1 to 4 beams of data. In addition, each of these modes has many processing parameter options - such as frequency resolutions, integration times, bandwidth searched, time resolutions and active signal designs - that must be selected based on the environmental and tactical scenarios. Uncertainty as to which parameter value should be chosen often leads to parallel processing of multiple parameter values, which in turn increases the data rate of the information that the operator must monitor. Paging through gram data for detection purposes with multiple narrow band frequency resolutions and broad band delay grams for multiple beam buoy data can, just by itself, all too easily overload sensor operators. Additional operator tasks including system processing mode setup (processing mode and parameter selections), classification, tracking and localization will force operators to compromise performance on some tasks in order to complete the required string of tasks.

This SBIR seeks to reduce this problem of operator workload/efficiency by increasing operator skill levels through continually tracking the operator's performance, comparing that performance to an ideal performance model and using that comparison to provide the operator real-time and after-the-event assistance.

Today's SENSO has limited opportunity for realistic Anti-Submarine Warfare (ASW) practice and experience through actual "cold war" encounters. Training for new operators provides the SENSO with basic system operation capability. Moreover, in environments where experienced mentors (watch supervisors, etc.) are available, these new operators are assisted while they gain the experience needed to perform the complex tasks required to quickly and accurately detect and classify contacts. The SENSO operating environment in the helicopter requires additional independence and more rapid decision-making. This motivates a need for a flexible SENSO OMI matched to individual operator capabilities for multiple sensor systems. A flexible OMI can assist the SENSO in making rapid, appropriate, real time decisions for detection, contact evaluation, tracking, localization, and operational mode. While adaptive interfaces have been a research subject for several years, they have not been widely applied. Recent studies have shown that participants tend to have much greater task performance and task satisfaction when using adaptive interfaces (Gong & Salvendy, 1995).

This Phase I report describes a proposed adaptive OMI technique to enhance the performance of the inexperienced SENSO by adapting the OMI to match the operator's skill level. This will be accomplished using a cognitive task analysis approach derived from research done by several experts in the Cognitive Science field (Kieras & Polson, 1985; Anderson, 1983, Williams & Reynolds, 1990). The essential information required for a cognitive task analysis is obtained from experienced, highly skilled SENSOs. This skill information establishes the ideal or expert model against which each individual operator is compared - providing a diagnosis of each SENSO's skill level. The individual operator's skill level will feed an Adaptive OMI Processor that enhances the system's interface. The goal of this adaptive interface is to improve the overall performance envelope by providing optimal mode configuration and automated, on-screen operator aids.

2. PHASE I SUMMARY

2.1 Objectives

DSR's Phase I SBIR objective was to provide a proposed baseline architecture that maximizes system performance through an operator-machine interface that adapts to different operator skill levels and varying degrees of system automation. Recent technological advances have resulted in increases in system capabilities and system complexity. This increased complexity, however, has not necessarily been accompanied by increased support for the system user. Military tactical systems in particular have significantly increased in complexity. One way to assist the SENSO in efficiently utilizing these systems is to provide a flexible user interface. A flexible interface is one that adapts the presentation of information and/or the methodology for obtaining inputs from the user based on the specific tasks to be accomplished or the characteristics or preferences of the user.

There are two types of flexible interfaces: adaptable and adaptive. An adaptable system provides the user with the tools to change the system setup. Many of today's programs written for the Microsoft Windows Operating System would be described as adaptable since the user has the option to display the buttons that activate the preferred functionality. An adaptive interface, on the other hand, changes its own characteristics automatically depending upon the needs of the user. Evidence indicates that users either have difficulty using, or choose not to use, adaptable features (Oppermann, 1994). Self-adaptive systems, on the other hand, bring inherent problems such as determination of the best way to adapt the system given the current circumstances.

2.2 Phase I Summary

The objective of this Phase I effort was to describe a methodology for developing an adaptive OMI for the Sensor Operator station on the SH-60R MMHU. At the kick off meeting for this effort the government informed the Phase I SBIR contractors that considerable uncertainty existed in the SH-60R system definition. It was recommended that the effort under this Phase I focus on the characteristics of the SENSO operators and deal more generically with the system interface which would be more in focus for the Phase II effort. This was accomplished by reviewing existing research in several areas including:

- Cognitive Task Analysis techniques
- Adaptive User Interfaces
- Intelligent User Interfaces
- Performance Support Systems
- Expert Systems
- Intelligent Tutoring Systems

The research revealed that although adaptive interfaces have been the focus of research for many years, they have not been widely implemented. The main reason for this is the difficulty involved in conducting the cognitive task analysis. Moreover, the integration of such a system involves complicated training and implementation issues.

There are several goals that can be achieved with the implementation of an adaptive interface, including:

- Enhanced user productivity in that users are provided with the optimal level of assistance in their transition from novice to expert.
- Increased suitability of the system for specific tasks in that users could more easily access functions and perform tasks they may be weak in.
- Optimized workload.
- Increased user satisfaction in that users may have access to different functions without extensive training.

Each of these goals is certainly relevant and desirable in most situations involving complex tactical equipment. The increased complexity of the SENSO's watchstation has the potential to significantly impact the user's productivity. The increased workload that will accompany the multiple and varied sensor systems that are to be integrated on this new helicopter variant must be handled proactively. An adaptive interface is one method that can help achieve this.

The proposed structure of this adaptive OMI utilizes an automated tool to perform a CTA. The CTA provides the content of an expert model of the SENSO's domain. This expert model is, in turn, used as a comparator to determine each user's skill level with respect to that expert model. The information gleaned from this comparison can then be used to optimize the interface to the capabilities of the current user. This report details the processes and architecture proposed to accomplish this task.

The Integrated Intelligent Tutoring Environment (IITE) proposed by this report has benefits in that it capitalizes on existing tools. Specifically, the more complex processes involved in the development of this adaptive OMI can be accomplished using existing software. Therefore, the structure and design of the adaptive interface can be the focus of development. Namely, we recommend conducting a CTA using the Cognitive Analysis Tool (CAT). CAT is a software product that essentially automates the CTA process. As the CTA can be the most time-consuming aspect of such an endeavor, this tool can result in significant savings. The other difficult aspect of developing an adaptive OMI is assessing the knowledge state of the current user. This component can be accomplished using DSR's Integrated Training System (ITS). Given the appropriate testing mechanism, this software can assess a user's skill level as compared to that of an expert.

Edmonds (1987) described five areas a system can take into account to achieve adaptivity:

- user errors,
- user characteristics
- user performance,
- user goals, and
- the information environment.

The system proposed in this report has the potential to adapt based on each of these system areas, thus providing a great deal of flexibility. The expert model, which is resident in the background, monitors the system state and the user's actions, determines the user's intentions based upon these, and determines if the user needs assistance. The system also understands the user's skill level and can tailor that assistance accordingly.

Figure 2-1 is a simplified diagram depicting how this system could function. The expert model will be a by-product of the CTA. The expert model can be used to develop a skills analysis test that assesses the user's capabilities with respect to that expert model. Representations of the expert model and the user model will then be accessible to the tactical system.

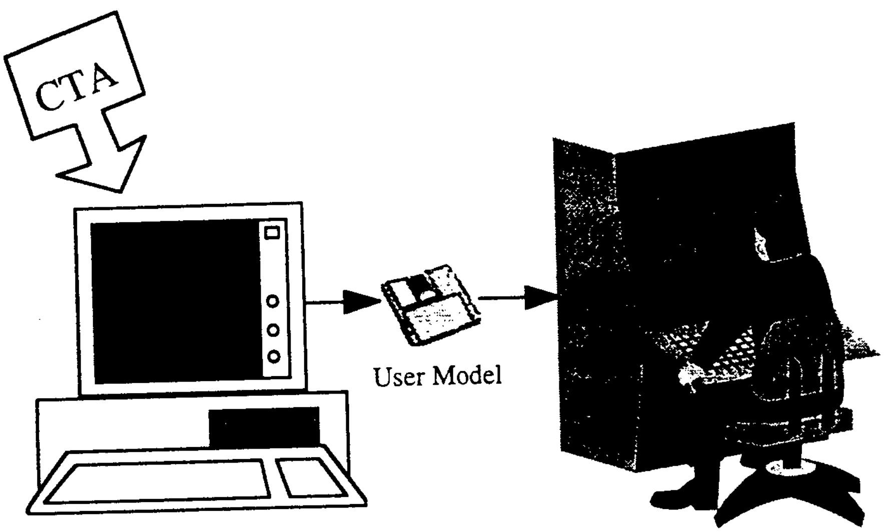

Figure 2-1 Adaptive OMI Functionality Diagram

3. PHASE I CONCLUSIONS AND PHASE II RECOMMENDATIONS

The review and analysis lead us to conclude that the mental model obtained from a cognitive task analysis could provide a viable mechanism for adapting the operator-machine interface for the SH-60R helicopter sensor operator station. With the advances that have been made in cognitive science and the advent of automated tools to assist in the CTA process, the most complex and costly component of a CTA becomes more feasible at a time when technology offers the greatest potential for developing such a capability.

In keeping with our recommendation to implement an adaptive interface aboard the SH-60R helicopter, we propose that the Phase II effort consist of prototype development and evaluation of an adaptive OMI. Specifically, we recommend that a prototype adaptive interface be developed for a specific sensor subsystem. Since the SH-60R has not been fielded, we recommend developing this proof-of-concept on an existing version of the selected sensor subsystem and that this prototype be implemented in either an embedded system on the SB-60B or a training system setting.

We propose using the Cognitive Analysis Tool (CAT) to conduct the CTA on the selected sensor subsystem. This prototype will use the output of a cognitive task analysis to define the expertise required to utilize the sensor system. With the assistance of an expert in CTA, a Subject Matter Expert (SME) will be trained to operate the CAT. The SME will interact with CAT to specify the goals, subgoals, procedures, etc. that are performed on the sensor subsystem. This expert model can then be validated by other SMEs to ensure its accuracy. Upon completion, CAT will generate the task-goal hierarchy for that subsystem and the underlying production system architecture.

The content specified by this cognitive model generated by CAT will be used to develop scenarios that assess the user's skill level. It is proposed that the diagnostic component of DSR's Integrated Training System (ITS) be used to develop and implement the skill assessment portion of the adaptive interface. We specifically recommend using a current COTS authoring system to develop the tests and scenarios that can be associated with each node of the expert's task-goal hierarchy.

Once the interface between CAT and the diagnostic component of the ITS has been created, the heuristics for adapting the system can be established. These heuristics must take into account several variables including:

- the current user's skill level,
- the current goal,
- environmental circumstances, etc.

It is imperative that any proposed modifications to the OMI be tested to ensure they achieve the desired results. To this end, we propose to develop a research plan that allows for the systematic evaluation of any proposed adaptations. The heuristics for adapting the interface will be based on research conducted that identifies the differences in knowledge representation, problem-solving strategies, etc. between individuals who are considered experts, intermediates, and novices. While there are several theories on the nature of these differences (e.g., Zachary, 1997), this information has not been applied to an adaptive interface environment. The adaptation heuristics will also be based on an analysis of the subsystem to determine where performance decrements are most likely to occur and, therefore, where the adaptive OMI would be most valuable. To test the various adaptation configurations, we propose developing test screens for some prompts, advisories, etc. and testing their effectiveness in an operational or simulated situation.

4. ADAPTIVE OPERATOR-MACHINE INTERFACE

This section of the report describes the foundation that underlies the proposed approach to match the operator's skill at various tasks and subtasks to the appropriate OMI. This process will maximize the overall operator-system performance through improved operator-system interaction. The underlying concept is to identify a SENSO's skill level on a particular system or function and, from that, adaptively change that system or function's OMI to match that skill level.

There are three components to an adaptive interface. These are:

- an expert model that represents the domain knowledge,
- a user model that represents the knowledge of the current user, and
- a reasoning module that interprets user actions in an attempt to infer their intentions and modifies the interface features accordingly.

These components are encompassed in an architecture known as the Integrated Intelligent Tutoring Environment (IITE). The IITE provides the following benefits during development:

- an automated, state-of-the-art knowledge engineering process that results in a sophisticated expert model,
- advanced testing techniques that develop a roadmap depicting the student's current understanding of the domain,
- a rule-based architecture that monitors the procedures conducted by the operator during a watch and provides relevant and timely performance metrics,
- sophisticated, user-friendly COTS authoring software to develop the potential adaptations,
- a "middleware" architecture that allows for system reuse on multiple platforms, for multiple applications.

Figure 4-1 depicts the high-level structure of the IITE. A CTA (1) using an automated tool will result in an expert model (2) of the domain. Ideally, that expert model will be accessible to the authoring environment (3) such that adaptation frames can be associated or linked to the nodes of the expert model. These structured frames (4) that contain the expert model, adaptation frames, tests, and the student model are then presented to the student.

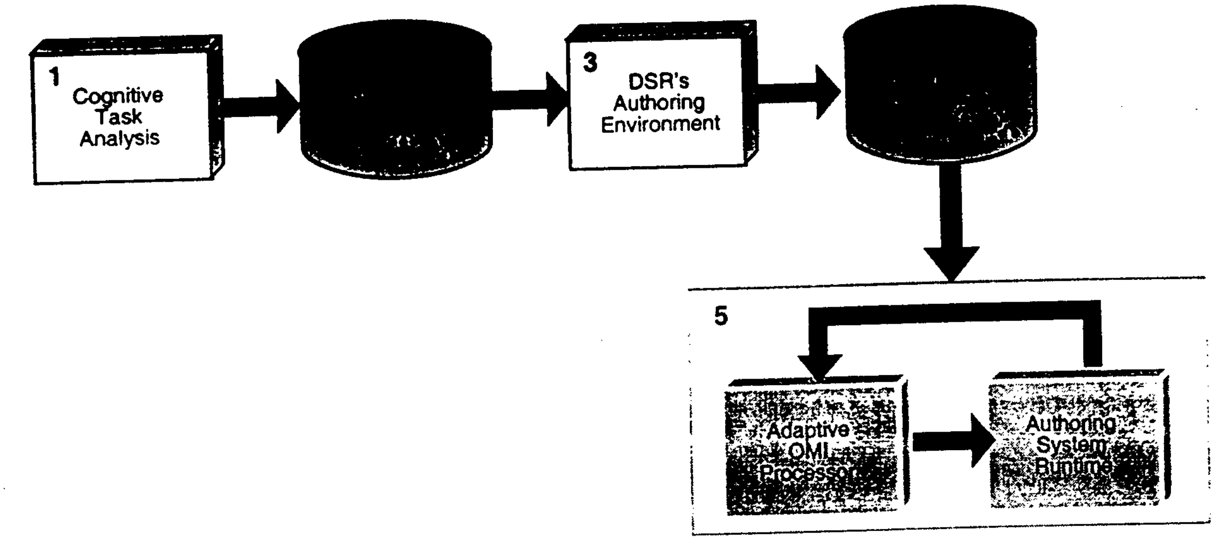

Figure 4-1 High-level architecture of the Integrated Intelligent Tutoring Environment

The individual components of the IITE are discussed in detail below.

4.1 Development of an Expert Model

Cognitive task analysis (CTA) is a methodology for developing a detailed description of the knowledge base and cognitive processing embodied in expert performance of a task. While the traditional methods for analyzing a task decompose it into subtasks, skills, and knowledge, CTA includes an analysis of the thought processes of the task performer. According to Gordon and Gill (1997), a CTA provides specific insight into the following types of information as related to a person's job:

- Concepts and principles, and their relationship to each other and the task(s).
- Task goals and goal structures, including methods of achieving the goals, and initiating conditions or "triggers" for goals and methods.
- Cognitive skills, rules, strategies, and plans applicable to the job.
- Perceptual learning, pattern recognition, and implicit or tacit knowledge associated with the job.

Figure 4-2 depicts a simplified tree structure for the job "Tracking Targets" on a tactical computer console. The main goal has several subgoals including "Acquiring Targets," Maintaining Course, Speed, and Position," and "Classifying Targets." These subgoals can be further broken down into lower level goals.

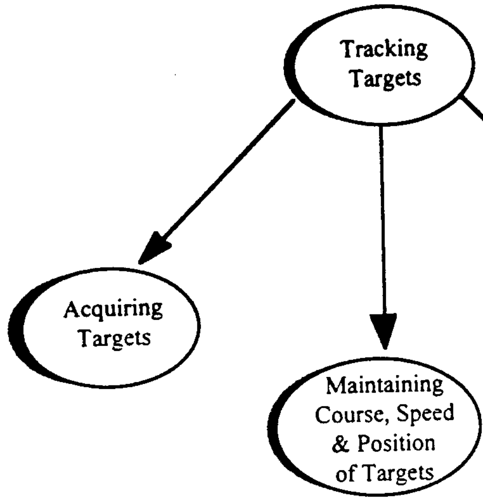

Figure 4-2 A Sample Task-Goal Hierarchy

The children of any node can be grouped together in three ways, either ANDed, ORed, or both. Figure 4-3 depicts these three possible groupings of children of a node.

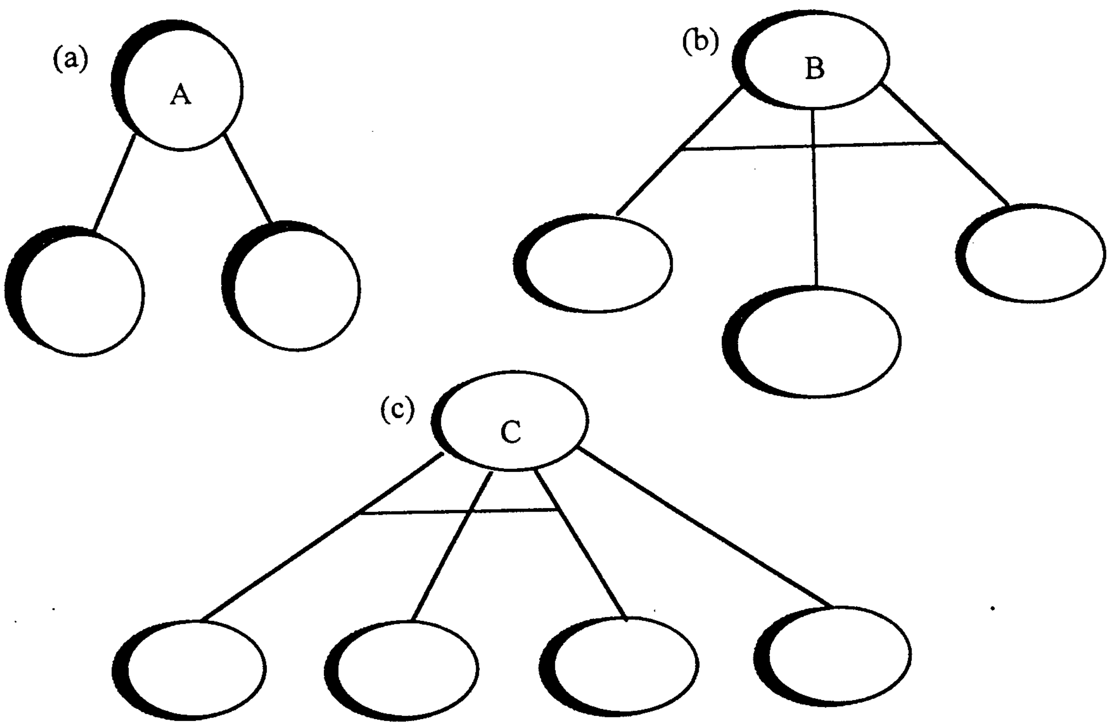

Figure 4-3 (a) is an ORed grouping of children; (b) an ANDed grouping of children; and (c) an AND/ORed grouping of children.

Notice that in Figure 4-3 (a) there are 2 children of node "A", and, unlike Figure 4-3 (b), there is no arc connecting the links into node A. This absence of an arc means that the children of node "A" are ORed. Either child of node "A" contains the needed information upon which node "A" is formulated. The arc connecting the links into node "B" indicates that the children of node "B" are ANDed. All of the children of node "B" are required to formulate the information represented in node "B". Lastly, Figure 4-3 (c) depicts a combination of ANDed and ORed children. In this case, the information of node "C" can be formulated simply by one single child beneath it OR by combining the information from the other three children which are joined by the AND arc.

To be of use as an aid to developing computer-based software for diagnosing skill deficits, and for designing decision support systems and intelligent tutoring systems, the units of knowledge that comprise the model must conform to a "production system" architecture of cognition first introduced by Newell and Simon (1972; see also Newell, 1973). A production system is characterized by a set of production rules in combination with working memory and takes the form of IF/THEN (condition/action) pairs. The IF (condition) side of the rule specifies the content of working memory and the THEN (action) side corresponds to overt behaviors that are "executed." By executing a set of production rules, one can simulate how to do something, including complex tasks.

The cognitive model of the knowledge required to perform the task expertly is represented in the AND/OR graph as previously described. One popular methodology for conducting a CTA is the GOMS process. This process involves specifying four types of components:

- Goals – what needs to be accomplished;
- Operators – the steps which must be taken to accomplish a goal;
- Methods – a collection of steps which must be executed in some specified order to accomplish a goal; and
- Selection rules – a set of conditions that determine which methods to select if more than one method can be executed to achieve a specific goal.

Figure 4-4 depicts the relationship of these components in a "goal-method hierarchy." Results of a CTA represent a cognitive or mental model that represents the knowledge required to perform a task or set of tasks. The top-level node in the tree represents the top-level goal/objective. It will encompass many lower level components. Branching down from each node are component elements that need to be mastered in order to accomplish the node above. At the lowest level of the tree are the "primitive operators" or the actions that cannot be decomposed any further.

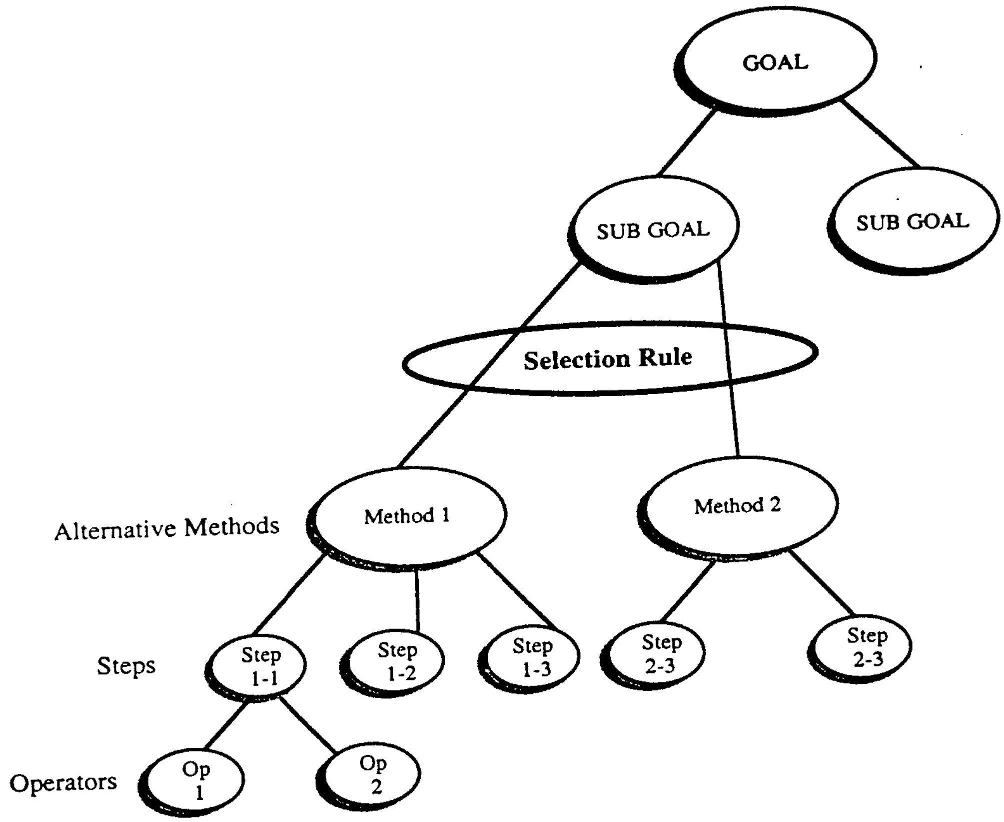

Figure 4-4 An Example of a GOMS Hierarchy (Abstracted from ideas of Card, Moran, and Newell, 1983; Kieras, 1988; Kieeras and Polson, 1985; Williams, 1993)

Figure 4-5 depicts a high-level tree structure for the job of the Sensor Operator. In this tree structure, the highest level goal is to perform the Sensor Operator job. The first-level subgoals include the different missions that the SENSO may engage in including Anti-Submarine Warfare, Anti-Surface Warfare, Over-the-Horizon Targeting, and Search and Rescue. These subgoals can be further broken down into lower level subgoals or methods (e.g., Identify a Track, Hook a Track) and the operators required to accomplish these subgoals (e.g., Ball Tab the Contact and Press the Hook FAB).

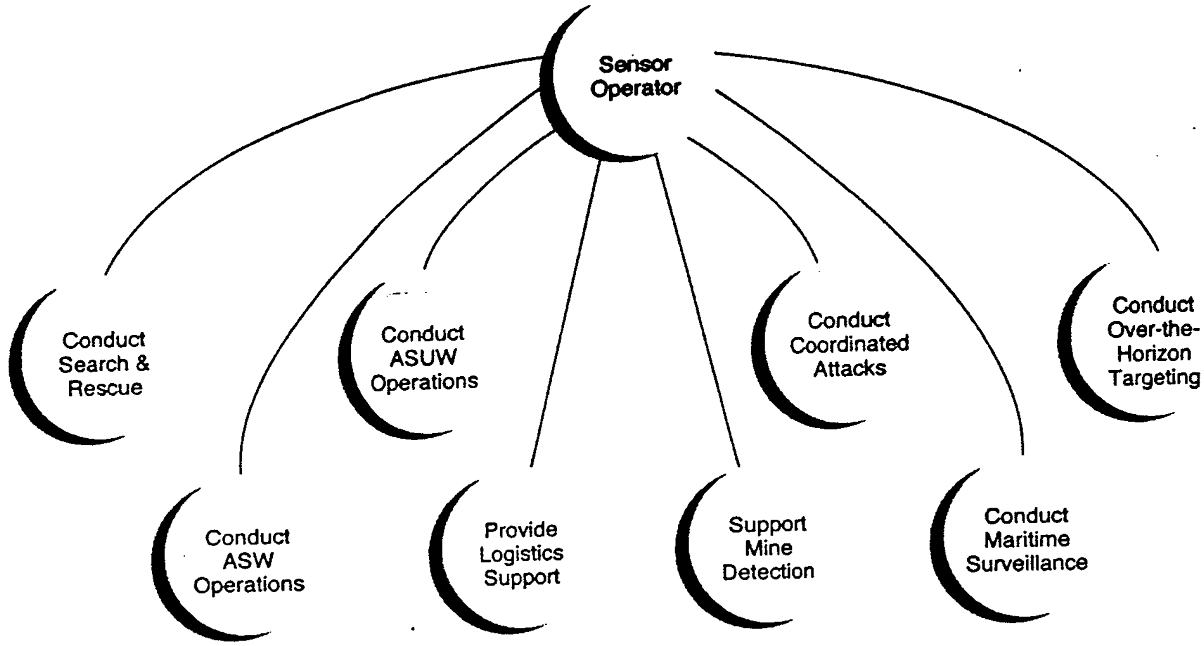

Figure 4-5 High Level Hierarchy for the SH-60R Sensor Operator

Gott (1994) suggested that a CTA is most appropriate when a task is complex, when it is difficult to learn because action goes on in the head of the performer, and when tasks are not pre-sequenced but instead are dynamic and ill-structured. Each of these qualities is characteristic of the SENSO's job.

4.1.1 Cognitive Analysis Tool (CAT)

Since the level of information provided by a CTA is incredibly detailed, the knowledge acquisition process is cumbersome and labor-intensive. Moreover, there are a limited number of individuals qualified to conduct such analyses. For this reason, Williams (1993) created a Cognitive Analysis Tool (CAT) to assist in the CTA process. CAT is an automated tool that operationalizes the GOMS analysis process. It can be used by an SME to develop the cognitive models representative of that expert's domain. The software essentially "walks" the user through the CTA process by providing prompts and menu options with which the user can specify the goals, subgoals, and primitive operations required to accomplish each task.

Using a "Guidance Mode," the user is constrained to follow a specified process for capturing his/her knowledge. After the definition of a step, the system queries the user to determine if:

- the step described requires that a decision be made,
- the step described requires that information be stored in memory for later retrieval, or
- the step requires that some information be recalled from a memory store.

For each of these circumstances, the user is prompted to provide the appropriate information at the appropriate level of detail. For example, if a step description is indicative of a decision, the system queries to determine if the user's step description implies that a decision must be made. If so, the system presents a Decision Step Dialog box similar to the one shown in Figure 4-6. This dialog box imposes the IF-THEN-ELSE structure in order to identify the specifics of the decision to be made by the decision step.

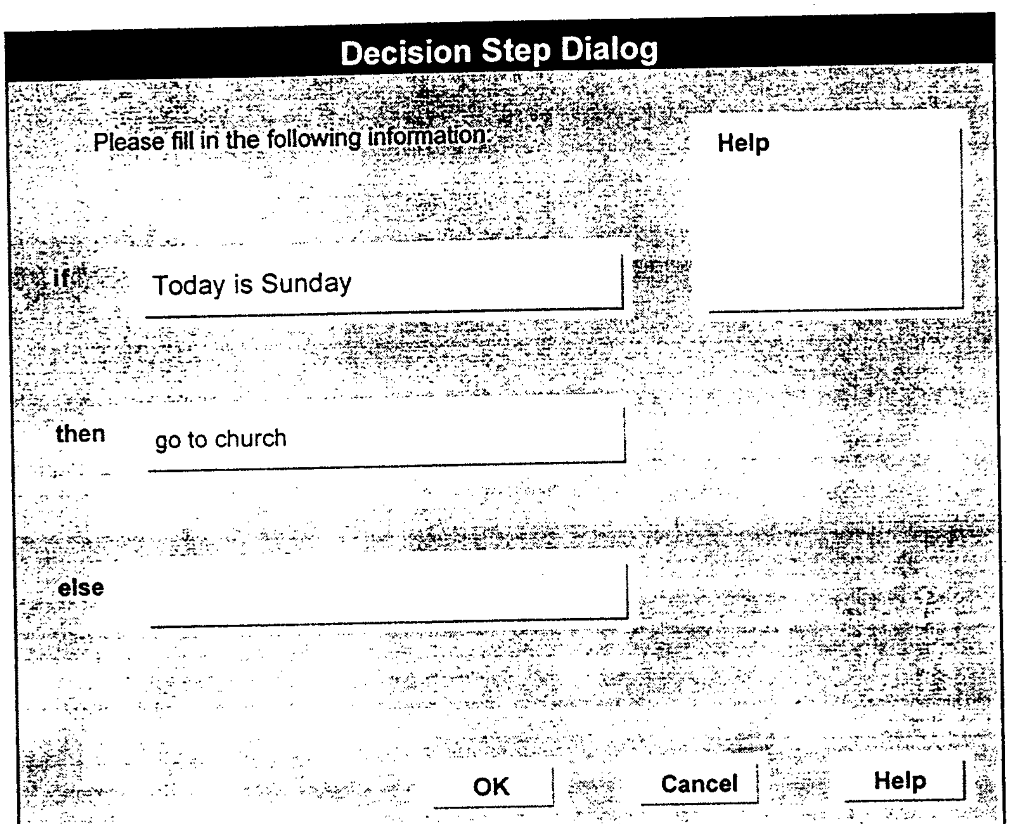

Figure 4-6 Decision Step Dialogue Window

After all the methods or set of methods for the specified goals have been defined, the system determines if more than one method has been defined for a goal. For all goals that have more than one method, the user must specify the selection rules – the condition or set of conditions that must be met for each method to be triggered.

In addition to the goal hierarchy, CAT also generates the production system associated with each goal. More specifically, CAT generates the IF-THEN-ELSE rules associated with the specified goals. Depending on the constraints imposed by the tactical software, the production system structure may be adaptable to a form that can be utilized by a tactical system, potentially reducing implementation time.

The end result of the CTA will be a complete set of production rules that represent the SENSO's mental model of the goals, the tasks, the environment, etc. This "expert model" will be used as the ideal against which each individual operator will be compared. This model could also be used to determine the actions the user should be taking at any given time. That is, many of the "triggers" that activate a goal are contacts detected by the system. If such a trigger occurs and the user does not take any action, the system could prompt the user to begin the necessary procedures. Therefore, the system could detect errors of omission in addition to errors of commission.

4.2 Development of a User Model

The CTA involving SMEs described previously will provide a model of expert performance as well as provide task and performance information for developing a diagnostic assessment instrument for determining the skill strengths and weaknesses of Sensor Operators. As part of the IITE development environment, a COTS authoring system will be interfaced to the expert model to allow for the development of test questions and scenarios. These diagnostic instruments will be used as the basis for the "User Model" for each user. The results of these diagnostic instruments will be a knowledge and skill profile or "User Model" for each user. The Adaptive OMI Processor (AOP) will modify the OMI with the User Model to match the capabilities of the particular user. The skill level analysis technique that will be used to develop this User Model was developed as a part of DSR's Integrated Training System (ITS) developed under SBIR N91-052. The ITS is a training system employing advanced cognitive recognition algorithms and embedded techniques that diagnose trainee weaknesses as part of its adaptive training procedure. It is used to train operators the complex knowledge and skills required to effectively utilize their consoles. The ITS can be used to maps the skills of the operator (the user model) to the expert model.

The assessment mechanism must be detailed enough to develop a comprehensive User Model. The assessment would probably consist of a series of scenarios that progress in complexity, each focusing on one or more of the goals contained in the expert model. The two critical elements required for an effective skill analysis are: a) identifying appropriate situational factors that influence SENSO performance (Ikomi & Tirre, 1994; Jacobs & Dempsey, 1993), and b) identifying appropriate performance/process measures and criteria (Konrad, Kramer, & Watson, 1994; Dickinson & Teachout, 1993; Frenkel, 1996). By incorporating key situational factors into scenarios or simulations used to assess the skills of SENSOs, the predictive ability of the overall assessment instrument is enhanced. For example, providing scenarios involving multiple incoming enemy targets that must be identified and prioritized may result in task overload for some Sensor Operators, thus reducing their performance. Alternatively, partial communication failures (due to equipment malfunction) or communications that are incongruent with sensor readings may cause momentary confusion and performance breakdowns. Skill deficits can be determined in a reliable manner by comparing performance deficits across scenarios and by looking at process variability of individuals relative to the CTA-generated expert model. There are a number of performance indicators that can be measured and assessed that will provide the necessary information to accurately diagnose skill deficiencies. For example, time lag and number and type of errors between initial stimulus event and response may provide valuable performance information

The activities required for developing a SENSO skill diagnostic instrument include:

- Conduct interviews, surveys, etc. with SMEs as well as non-SMEs for the purpose of identifying key situational factors that influence performance and as a pre-cursor to developing scenarios/simulations that can be integrated into the skill assessment,
- Develop and validate the skill assessment scenarios/simulations as well as the associated performance and process measures,
- Implement the scenarios into the ITS so that the User Model can be created.

Ideally, the authoring system component of the IITE can also be used to present the scenarios. This system has templates for creating multiple-choice questions as well as performance-based scenarios. These assessment instruments are linked to the nodes in the expert's task-goal hierarchy such that the User Model will reflect the user's mental model as compared to that of the expert. Figure 4-7 depicts this relationship between the expert and the User Model. Note that the User Model is created as a subset of the expert model. Figure 4-7 shows a hypothetical expert model and a User Model of the same domain. Note that the user's model consists of the nodes of the expert model but the skill assessment test determined which of those nodes the user understands.

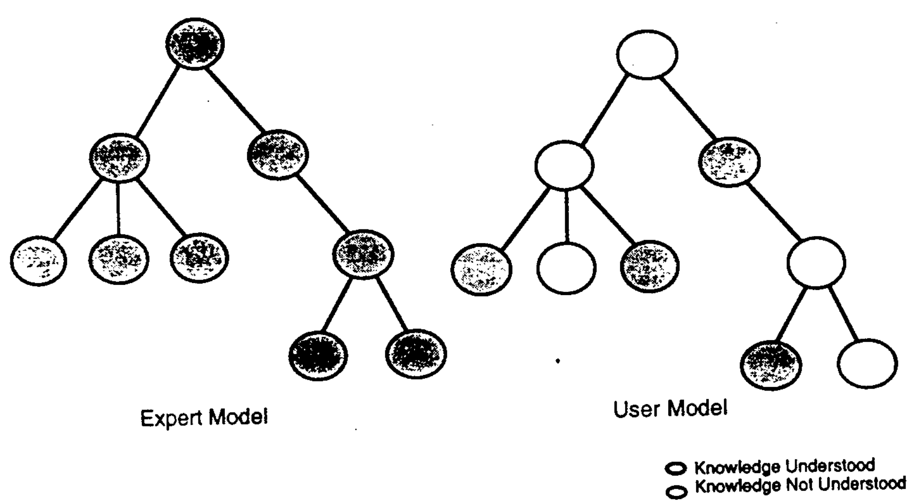

Figure 4-7 Depiction of the Comparison Between an Expert and User Model

4.3 Development of the Adaptive Operator Machine Interface Processor

The Adaptive OMI Processor (AOP) will utilize the User Model and a set of Adaptive OMI rules to form an initial Adaptive OMI configuration. This AOP will identify what changes should be made to the system's OMI in order for the current SENSO to more effectively perform the required tasking.

The task of establishing rules for improving specific weaknesses in an operator's knowledge should be based on studies showing improvements in overall performance as a function of specific OMI changes. These features should be proven to enhance performance in designated areas of weakness. An expert operator would be expected to outperform the inexperienced operator that is given these aids, but there is strong evidence that providing this machine level "mentoring" enhances the level of performance from inexperienced operators. The results of this effort will quantify the improvements achievable.

The AOP will be designed to adapt the OMI based upon the results of the skill level analysis and a predefined set of context-sensitive aids established and tested to ensure that the desired enhanced operator effectiveness and performance are achieved. For example, if the operator exhibited difficulty in performing a task - like updating track histories - this would show up as a weak method in the User Model. The associated context-sensitive advisories would be mapped by the processor for the OMI to adapt by providing a checklist of correct steps and concepts related to the knowledge required to perform this task. In most cases, the OMI would be adapted to provide additional advisories, prompts, or aids that will help the operator do a better job in the areas in which experience is lacking. The capability would be available to limit specific actions that could result in serious impacts to mission success or damage to equipment.

The SH-60R has been designed to provide the operator with a great deal of functionality that will assist in accomplishing the requisite tasks. Features such as the Weapon and Sensor Envelope display will allow the novice operator to make effective tactical decisions. Additionally, there is a proposed Decision Support System (DSS) that will provide even more tools to aid the SENSO's decision-making process. A user model that describes the skill level of the user will also provide valuable information about that user's decision-making capability, and therefore, his/her reliance upon the tools resident within the system. This User Model information can be used to provide an automatic invocation of those tools for the novice user. Specifically, it is envisioned that if the DSS comes to fruition, the AOP could be interfaced to it such that it will invoke the required DSS feature when the User Model indicates it is necessary. Figure 4-8 shows the possible relationship between the AOP and the DSS. Once the expert model is developed, goals, subgoals, or procedures that are aided by some DSS functionality can be identified (the goal structures with bold outlining in Figure 4-8. If a user is weak in that particular goal, the DSS could be automatically activated.

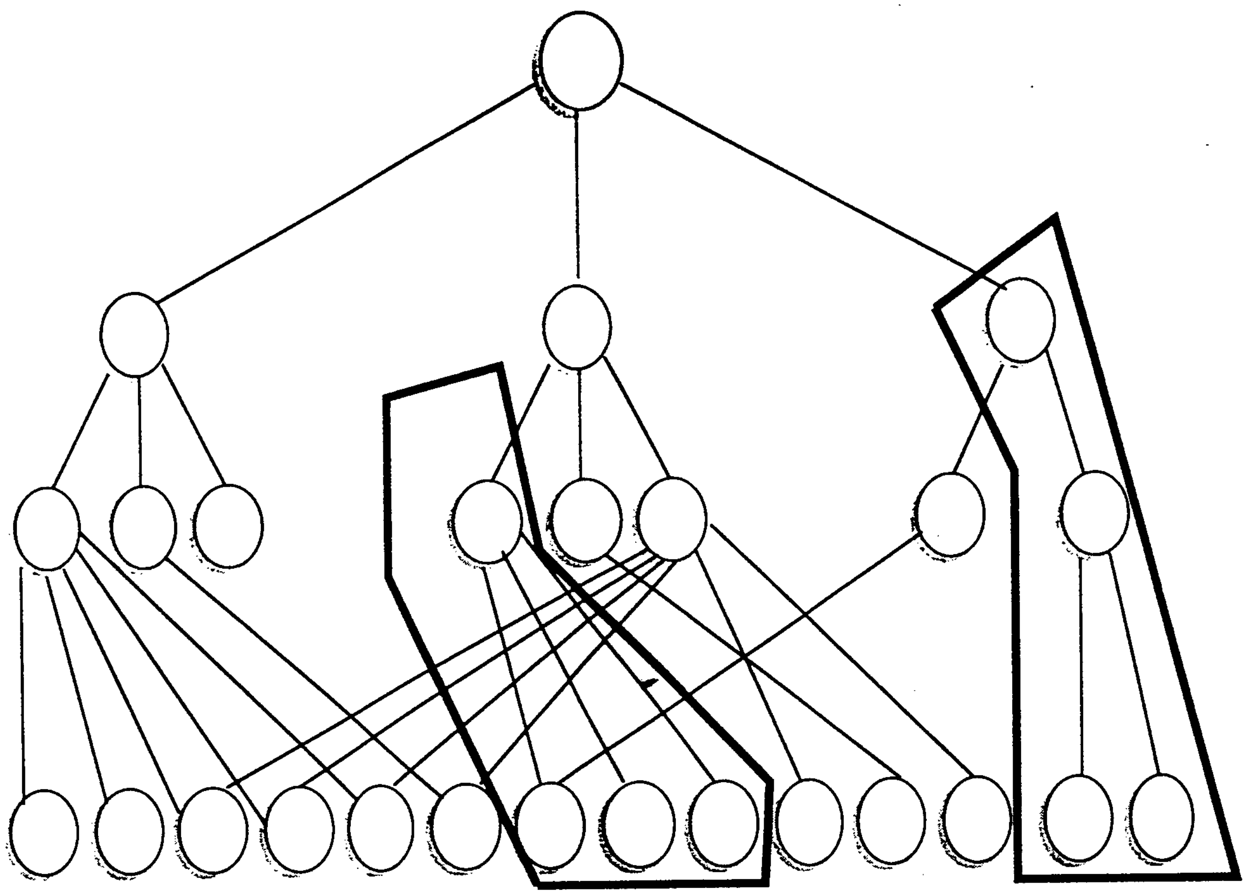

Figure 4-8 Relationship between the AOP and the DSS

Embedded coaching is on-line assistance that could be used when the system infers that the user has performed a procedure incorrectly, missed an important event, or is performing an unnecessary procedure. This would include the pre-programmed cues, prompts, advisories, and help screens that will assist the user in overcoming any performance obstacles.

Several representative system help aids must be defined that provide operator cues in order to improve her/his ability to perform the mission effectively. Figure 4-9 shows several display help items that were designed for adapting the OMI. These examples show a simplistic system presentation feature that is automatically adapted as the operator performs the functions associated with these presentation items. More complex features and graphics can be associated with these items and presented to the operator as audio and/or graphics overlays.

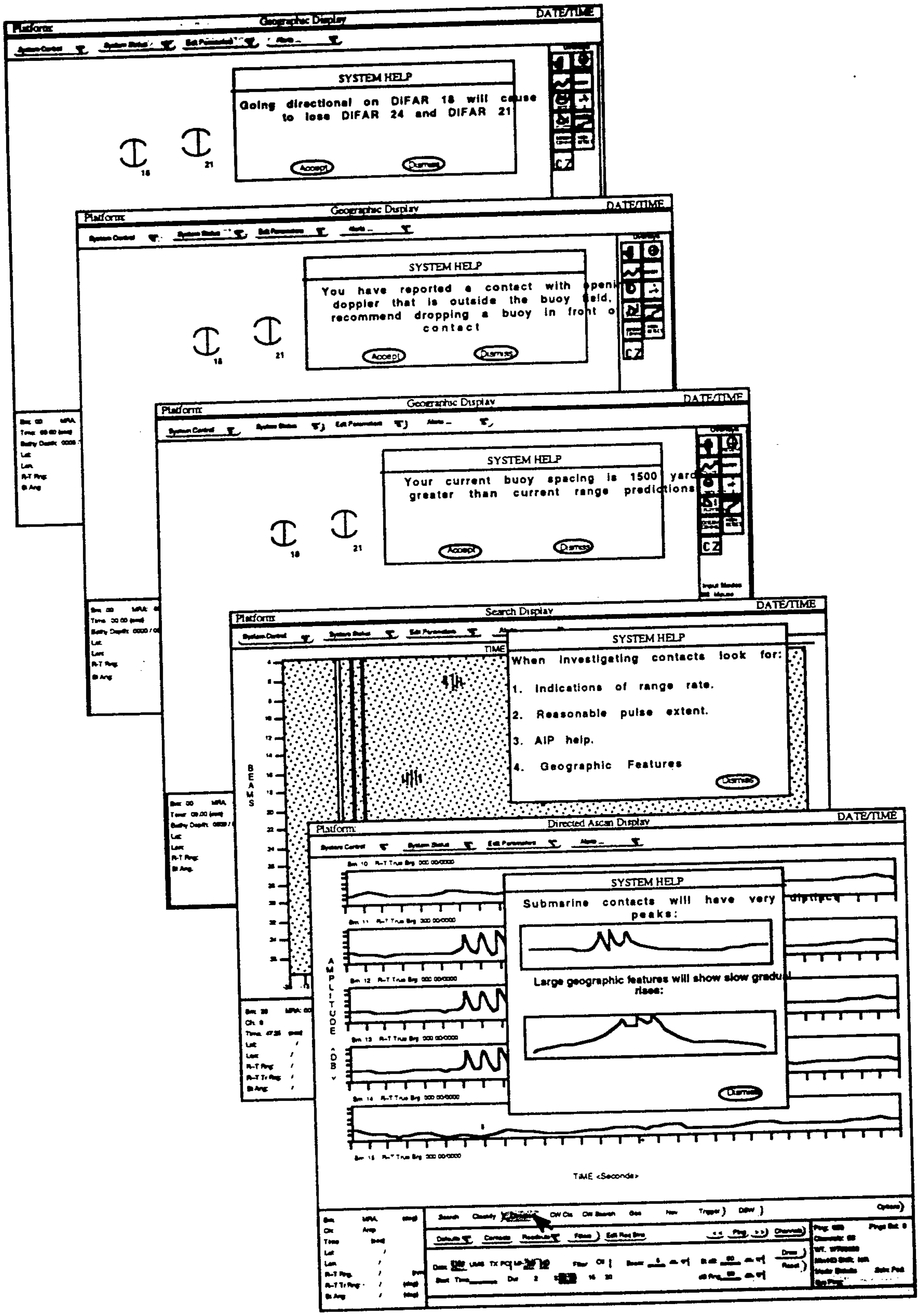

Figure 4-9 System Help Features for Adapting the OMI

An adaptive OMI could also prove valuable by providing access to electronic resources. The sensor operator uses many sources of information to successfully complete the various missions and must carry in the aircraft the many manuals/reference materials that may be required. Typically, these references are selected prior to flight, after the mission prebrief. The adaptive OMI system could be designed to unburden the operator and make him better able meet the unique demands of the operating environment by providing immediate access to the required information electronically. However, this information in its "raw" form could be overwhelming to a novice. Therefore, the OMI could also individualize the presentation of that information to the knowledge level of the current user. For example, the experienced user could be presented with information summaries (e.g., graphics or tables), while the novice may require the prerequisite information that went into building the graphic or table. Some information that could be accessible to the SENSO includes the Electronic Order of Battle, the Rules of Engagement, etc.

Table 4-1 delineates the potential ways in which users could be provided with assistance depending upon their individual categorization as an expert or a novice. This table is not all-inclusive but, instead, presents a few representative samples. Basically, the expert has a comprehensive representation of the domain while the novice may only understand basic facts or concepts. Presentation of information to help the novice should attempt to strengthen the links in the novice's representation.

Adaptive OMI Assistance	**Expert** Knowledge representation consists of highly-elaborated conceptual structure or mental model based on underlying generative principles	**Novice** Knowledge representation consists of basic facts, concepts, in declarative form
Help	Clear succinct; upon request only	Expanded help; upon request or when needed
Checklists	Statement of steps	Statement of steps with cues to appropriate button actions
Prompts	If time lag for execution occurs	When User Model indicates weak skill; if time lag for execution occurs
Presentation of Electronic Information	Upon request only	When User Model indicates weak skill; upon request

Table 4-1 Sample Adaptation Rules

5. SYSTEM ARCHITECTURE

5.1 Conceptual Architecture

The proposed system architecture is founded on the three-tier model. This model allows for the isolation of the User Interface from the adaptation components and any storage mechanisms used. This type of approach also allows for a tremendous amount of software re-use by isolating key components of the system. An example of this of architecture is found in Figure 5-1.

The three-tier model is broken into the following components:

5.1.1 User Interface Tier

- Multiple User Interfaces Required
  - CAT
  - Authoring Tools
  - Tutoring
  - Training
  - System
- User Interfaces Should Leverage Off Of Training Tier

Provides Maximum De-Coupling Of User Interfaces With Training Logic

5.1.2 Training Tier

- All Logic Resides In This Tier
  - Adaptive Functions
  - Authoring Functions
  - Training and Assessing Functions
- Middleware Component Provides Stable API For Adaptive Training Components
  - Provides For The Isolation Of Adaptive Logic From The Base Hardware and Operating System(s)
  - Allows Development Independent Of System Hardware
  - Provides A Structured Mechanism For The Support Of 'Technology Refreshment'
  - Provides Growth Path For Both New and Legacy Systems
- Logic Is Isolated From Other System Components
- Provides Structure For Maximum Re-Use Of Components

5.1.3 Database Tier

- Repository For All Data
- Isolation Allows For A Hardware Independent Architecture
- Makes Data Available For All Training Tier Components
- Provides Flexibility For Future Storage Mediums
  - Smart Cards
  - PC Cards
  - IR/Wireless Technologies

The proposed system architecture involves the following aspects:

- Population of knowledge database with an expert model.
- Analysis of a trainee/student in relation to the knowledge database.
- Inference Engine
- Training Middleware

Using a tool like the Cognitive Analysis Tool (CAT), the subject matter expert can develop an expert model that populates a given knowledge database with specifics about a given task. A trainee/student would then undergo an evaluation in relation to the expert's knowledge base. To successfully perform this task we recommend that a series of questions/scenarios be presented to the user such that a determination can be made about his/her knowledge of a given subject area. To this end, a tool like DSR's Integrated Training System (ITS) could be used. ITS provides an efficient method for assessing a student's current knowledge of a given task. The output of this process would be a User Profile which contains all the details necessary for correlating a User's skill level as compared to that of an Expert.

The above tasks provide a means to evaluate a given user against an expert and determine how the interface should be adapted to meet his/her specific needs. In order to complete the Adaptive OMI process, a software inference engine will run on the tactical system itself. This engine will make inferences based upon scenario triggers as well as operator actions by making an evaluation of the student User Profile versus the expert knowledge base. The output of this process would be the adaptation of the interface to meet the users specific needs.

The final component of the proposed architecture is the Training Middleware layer. This layer is meant to separate the adaptive and training components from both the hardware specifics and the underlying user interface application. By providing a middleware component, the entire architecture becomes portable across hardware and system platforms. In addition, it provides a stable application programmer's interface (API) for building future user interfaces. By writing these future user interfaces to the Training middleware API, systems will be able to take advantage of this type of adaptive user interface and training capabilities without having to re-develop them on their own.

Use of Training Middleware provides for the following:

- Provides For The Isolation Of Adaptive Logic From The Base Hardware and Operating System(s)
- Allows Development Independent Of System Hardware
- Provides A Structured Mechanism For The Support Of 'Technology Refreshment'
- Provides Growth Path For Both New and Legacy Systems

In previous systems developed by DSR, such as the Multi Purpose Processor (MPP) system, use of Middleware has proved that the above principles can be realized. To date, that system has been ported to five different hardware platforms and four different Operating Systems. In all cases, the amount of code that Application Developers were required to change was zero, while the amount of code change to the Middleware layer was less than 1%. This has allowed that program to truly isolate the work of Application Developers from the decision of which hardware and operating system to support.

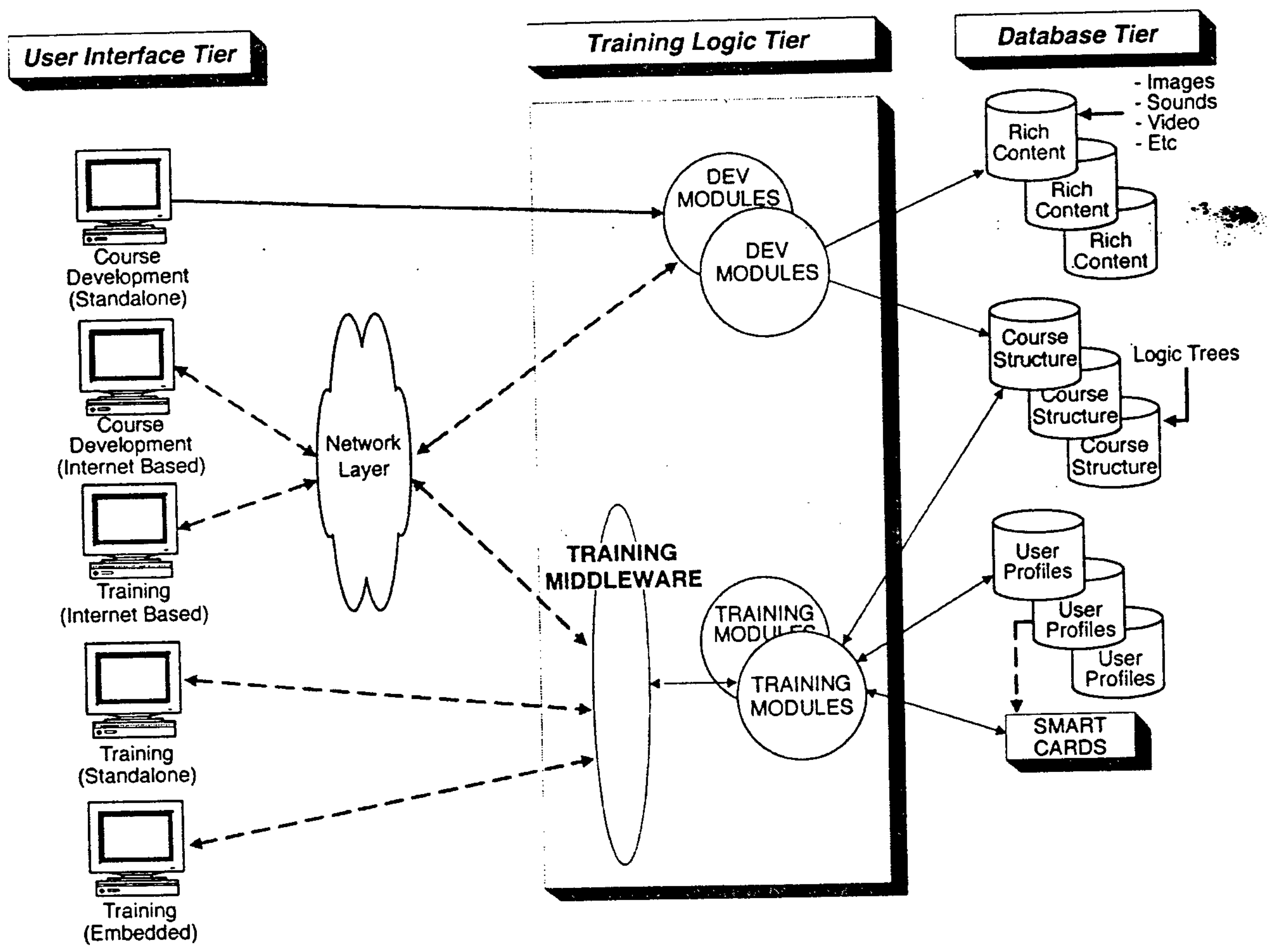

Figure 5-1 System Architecture

6. IMPLEMENTATION AND TRAINING

6.1 IMPLEMENTATION

The true value of an adaptive OMI will be realized only if is used throughout the SENSO's career. To provide maximum exposure of the OMI to the user and, in the corollary, the user to the OMI, the OMI should be introduced in the first phase of SENSO training as a specific curriculum item.

Following initial accession training, the OMI should form the core capability in the Fleet Replacement Squadron (FRS). FRS training should provide the new SENSO with maximum exposure to every reasonably possible tactical environment and scenario and build his/her skills database as much as possible before assignment to an operational squadron. To provide enhanced training for the SENSO "community", the FRS should carefully examine the feasibility/desirability of using the OMI capability to monitor FRS training itself. In addition, the FRS should address issues surrounding OMI control, such as maintaining master skill level and individual student profile databases.

The OMI should be used in all squadron operations. Whether during predeployment training or embarked training/operations, the OMI system embedded in the SENSO's workstation will be the only continuously available and non-subjective capability to measure operator performance. OMI should be included as a critical functionality for all related task trainers, whether as part of a training capability embedded in the aircraft or in stand-alone systems.

The OMI skill-level database must maintain its identity with the respective individual SENSO operator throughout his/her career. To that end, the database must transfer with the individual with all the import as that person's service record.

6.2 System Training

Although the goal of an adaptive OMI is to simplify a system for the user, it will still require extensive training to ensure the user understands the adaptive functions. The user must be trained to operate an interface with the potential to change constantly. Krogsaeter, Oppermann, and Thomas (1994) recommended that training should include an introduction to the rationale behind the adaptation. In this way, instead of training on the potential adaptive screens the user is provided with an understanding of the underlying logic.

Adaptive OMI system training needs to be embedded in every phase of sensor operator training, from elementary familiarity at the accession level, to full system understanding in the FRS and operational squadron. Training for OMI system maintenance needs to be incorporated in the respective equipment training conducted in the FRS for both organizational and intermediate level maintenance.

The OMI systems must also be incorporated in the respective SH-60R NATOPS and its use and functionality be made an integral part of squadron training.

6.3 Configuration Management

DSR's CM Program utilizes an integrated product team approach to creating, managing and controlling all products developed under our contracts. DSR's CM Program requires overall project participation by all the engineering and service organizations. All the project participants (Program Management, SW Engineering, Systems Engineering, Quality Assurance, Integrated Logistics Support, Testing & Integration) comprise an informed and involved unified project team. The CM Program at DSR is always coordinated and consolidated with the corresponding CM Program of our subcontractor, if applicable.

The CM Program includes controlled, tiered, on-line libraries for SW development, an on-line Trouble Reporting System for cataloging, correcting and reporting defects, an on-line database for CM data collection, mechanisms for identification and control of all HW and SW, a chartered Configuration Control Board (CCB) for both HW and SW, and a documented product release and delivery process. The specifics of the CM Program can be found in the appropriate CM Plan and its derivative documentation.

6.4 Data Management

The data management effort is a subset of the CM Program. It is conducted in accordance with the documented Data Management Procedures. All data produced on the project will be uniquely identified, managed and controlled, and appropriately baselined for archiving and delivery using the on-line CM System mechanisms as appropriate. All data received, created and delivered on the project is managed within this established DM process.

6.5 Software Quality Assurance

A Quality Assurance (QA) program is conducted on the project by a designated QA representative. The QA function operates on behalf of the corporation. Each software project is required to conduct its activities in accordance with a documented and approved engineering process. QA personnel ensure that the project follows its documented process and that artifacts exist on the project to demonstrate compliance for purposes of accountability and audit. QA has full and open access to all project data for purposes of reviewing and auditing its activities. The Program Manager is responsible for ensuring that QA has appropriate access to all project data as required. QA conducts and documents periodic evaluations and audits during the life cycle of the project.

7. FUTURE DIRECTIONS

7.1 Investigate Potential to Apply to Multiple Stations (AOMI in a Distributed Environment)

A sophisticated AOMI could also allow for consideration of multiple operators or computer actions in a distributed environment. Each operator's AOMI could be sensitive to the performance and skill level of the other operators within the aircraft and reflex accordingly to provide a complementary capability. This complementary capability could provide the ability for the AOMI to operate in a system environment.

Additionally, as the SENSO is performing in a tactical data link environment (Link 11/16) the AOMI could be reactive to other platform actions or information provided from these external participants. The AOMI could automatically solicit additional operator or computer information via the tactical Link if it senses the SENSO could be aided by this additional information.

7.2 Investigate Potential for Real Time Updates to User Model

A flexible AOMI could allow for changes in its functionality based on changes in operator performance and skill level. This flexibility can be dynamic to readily respond to changes in operator performance in real time. The AOMI could monitor the operator's performance during a particular mission and adjust its functionality as it detects fatigue, stress, information overload, or conversely as it detects increases in the operator's performance level due to proficiencies gained and skills learned during a particular mission or exercise.

7.3 Potential Application to Common Platforms

The final architecture proposed for the AOMI will be modular and structured in a "middleware" concept. As a result, this architecture can be transportable to most platforms providing a consistent AOMI capability as we approach a common cockpit design for Naval aircraft. A consistent AOMI would minimize life-cycle and training logistics across platforms.

7.4 Development of an Operator Workload Evaluation System

An important variable that should be considered for the design of any interface is the amount of workload experienced by the operator. Cognitive process measures could be used to determine individual capability with regard to overall processing capacity, ability to focus attention when confronted with multiple distracters, ability to share attentional resources across various sources, and the ability to quickly and efficiently switch attention in response to changing situation dynamics.

During times of intense workload, even the most experienced operator may display performance decrements. However, the measurement of workload, particularly in an on-line environment, can be a difficult task. Frenkel (1996) described a Pilot Evaluation System (PES) developed as a screening device for potential pilots. The system is a self-contained, autonomous system that performs evaluations objectively – without instructor intervention. The

PES consists of 17 3-minute scenarios that progress in complexity from simple to complex. As scenario complexity increases, the candidate's workload also increases, typically causing a performance decrement. The PES was developed based partially on the information obtained from a CTA.

This system is designed to measure various cognitive process measures including:

- the individual's capability with regard to overall processing capacity,
- the ability to focus attention when confronted with multiple distracters,
- the ability to share attentional resources across various sources, and
- the ability to quickly and efficiently switch attention in response to changing situation dynamics.

While the measurements obtained from this system have been successfully applied to the selection of potential ATC candidates, similar measures could also be applied to the design of an adaptive OMI. More specifically, a Workload Evaluation System (WES) could be developed to identify processes or procedures that are consistently difficult for most users to complete because of the workload demands they impose. In circumstances such as this, the interface could be modified to automate some component of the process or present additional information to help the operator get through the difficult process by reducing the required workload.

7.5 Intelligent Tutoring System

As shown in Figure 7-1, the domain knowledge specified for the adaptive OMI can also be used as the knowledge base for Intelligent Computer-Assisted Instruction (ICAI) or for an Expert System.

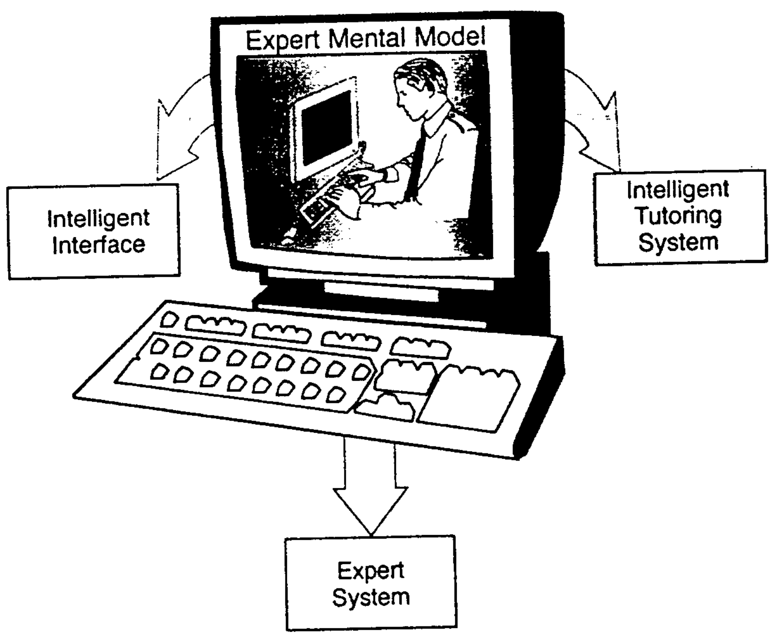

Figure 7-1 Other Applications of the Domain Knowledge Base

In ICAI, the courseware would be structured according to the task-goal hierarchy. More specifically, each node could contain information representing the information content to be incorporated in an exercise. An exercise could consist of a packet of information that specifies:

- the goal or objective of the exercise,
- an exposition of the information content and the inference which is made given that information,
- a problem which requires that the student apply the inference which is presented in the exposition, and
- a set of diagnostics which test the students' knowledge about the elements of information making up the exercise exposition.

Figure 7-2 presents a simplified graphic of a partial AND/OR graph with its exercises portrayed as nodes.

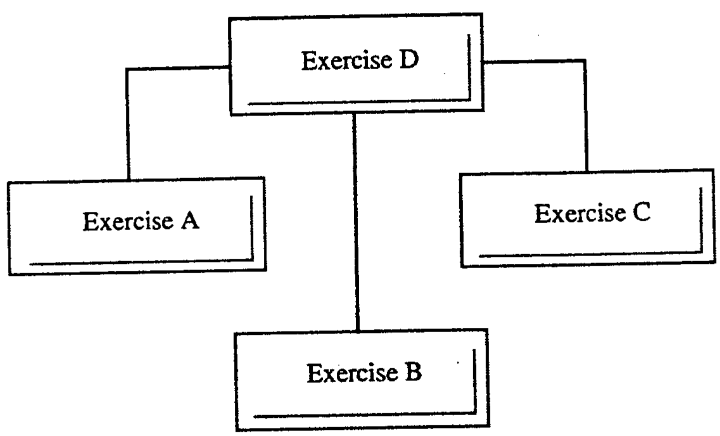

Figure 7-2 The Composition of Exercises in a Partial Graph

Exercise D in this case might portray the objective of performing an addition of two counting numbers such as 2+2=4. In order to perform this simple task, one needs to understand the concept of a number that is represented, for example, in Exercise A. The concept of summation, as indicated by the plus operator "+", represented in exercise B; and the concept of equality, as indicated by the equal sign (i.e., =) as represented in Exercise C. Each of the exercises A, B, and C may be further broken down into those attributes which make up their respective concepts. The exposition of Exercise D would provide several examples of addition and how the concepts in Exercises A, B, and C are put together to formulate the equations portrayed. Following the exposition of the exercise objective and the way in which the concepts which were learned previously are put together to formulate a solution to our equation of the form 2+2=?, the student is required to solve a set of problems of a similar form. If the student can successfully solve the problems posed, then one can infer that the student knows how to compute summations of this form. If the student fails to solve the problems posed, then the set of diagnostics are presented to the student to determine which concepts, as represented in Exercises A, B, or C, the student is having difficulty with. This simple example is meant to describe the components of an exercise associated with each node in the graph and not meant to minimize the difficulty with which an instructor or tutor is faced when attempting to teach such abstractions as the concepts of number, addition and equality.

A complete cognitive model consists of all of declarative facts and the ways in which they are combined. These declaratives can be combined to form concepts and condition-action pairs called rules which govern how system components interact to produce a function; condition-action rules which prescribe what action to take, given a certain set of conditions; or condition-action rules which prescribe what operation to apply (i.e., as in the addition example) given a specific set of symbols. Virtually any domain of knowledge can be structured in this way to form a model of the knowledge which must be acquired in order to perform a specific task. Each node representing an exercise may also be associated with alternative portrayals of that information employing multimedia and/or may be associated with alternative problems. These alternative problems could be used to provide practice in the application of a fact, concept, or rule, which is represented by the node. The alternative media portrayals of the information represented in a node could also be used to facilitate how well someone understands the information content of a node.

7.6 Expert System

An expert system could be developed using the knowledge base of the expert SENSO and a set of rules, which define how this expert uses the knowledge base to solve problems. An expert system has a great deal of applicability to the SH-60R sensor operator. It could provide individualized assistance in tasks that require a decision. The expert system could use the established production system architecture to infer the most appropriate decision based on the current task environment.

7.7 Note-Taking Utility

Sensor operators use several paper-based resources in their day-to-day work. One such resource includes a "gauge sheet." A gauge sheet is essentially a set of personalized notes that the SENSO has found useful for conducting his/her job. If the tactical system allows, one potential option is to provide the capability for the user to view, and possibly record, personalized notes for use in a job task.

If a note-taking capability was embedded in the application, the user could immediately input any information that he or she learned from a coaching pop-up window. In fact, it could be extremely useful if the SENSO could "copy" text and graphics from a reference and "paste" them into his or her on-line gauge sheet.

7.8 COTS Applicability

COTS hardware and/or software based prototype and production systems are attractive hosts for integrated training systems and Adaptive OMI. COTS based simulators, training techniques and Adaptive OMI interfaces can be efficiently rehosted on production systems providing new functionality for improved sensor operator performance. The on-line embedded training systems can be used for initial training and/or for upgrading operator skills on a continual basis with recorded or simulated data inputs. Measurements of skill levels with various system configurations can be used to recommend system OMI appropriate to the skill level of the individual operator so that total system performance is enhanced. This capability would be particularly useful in dynamic high contact rate littoral air ASW environments where operator skill levels at configuring buoy and processing modes and decision processes through detection, classification, tracking and localization can have critical impact on mission performance.

REFERENCES

Anderson, J.R. (1983). *The Architecture of Cognition.* Cambridge, MA: Harvard University Press.

Card, S., Moran, T.P., & Newell, A. (1983). *The Psychology of Human-Computer Interaction.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Dickinson, T.L., & Teachout, M.S. (1993). *Validation of occupational learning difficulty against task learning parameters.* Paper presented at the Annual Meeting of the American Psychological Association.

Edmonds, E.A. (1989). Adaptive man-computer. In M.L. Coombs & J.L. Alty (Eds.), *Computing skills and the user interface.* London: Academic Press, Inc.

Frenkel, J. (1996). Pilot evaluation system – PES. *Modern Simulation and Training*, May Edition, pp. 37-41, Jules Perel's Publishing Company.

Gordon, S. E., & Gill, R. T. (1997). Cognitive task analysis. In C. Zsambok & G. Klein (Eds.), *Naturalistic Decision Making* (pp. 131 – 140). Hillsdale, NJ: Lawrence Erlbaum Associates.

Gott, S. (1994, June). Cognitive task analysis. Panel discussion at the Second Conference on Naturalistic Decision Making, Dayton, OH.

Ikomi, P.A., & Tirre, W.C. (1994). *A realistic multi-task assessment of pilot aptitudes.* (Summer Faculty Research Program Final Report). Bolling AFB, DC: Air Force Office of Scientific Research.

Jacobs, J.W., & Dempsey, J.V. (1993). Simulation training and gaming: Fidelity, feedback and motivation. In J.V. Dempsey & G. Sales (Eds.), *Feedback and Interactive Instruction* (pp. 197-227), New York: Education Technology Publications.

Kieras, D.D. (1988). Towards a practical GOMS model methodology for user interface design. In Hilander (Ed.), Handbook of Human Computer Interaction (pp. 135-157). Amsterdam: Elsevier Science Publishers.

Kieras, D.D., & Polson, P.G. (1985). An approach to the formal analysis of user complexity. *International Journal of Man – Machine Studies*, *22*, 355-394.

Konrad, C.M., Kramer, A.F., & Watson, S.E. (1994). *A comparison of sequential and spacial displays in a complex monitoring task.* Proceedings of the 38th Annual Meeting of the Human Factors and Ergonomics Society, Santa Monica, CA: Human Factors and Ergonomics Society.

Newell, A. (1973). Production systems: Models of control structures. In W.G. Chase (Ed.), *Visual Information Processing*, pp. 463-562. NY: Academic Press.

Newell, A., & Simon, H.A. (1972). *Human Problem Solving.* Englewood Cliffs, New Jersey: Prentice Hall.

Oppermann, R. (In Press). Adaptively supported adaptability. *International Journal of Human Computer Studies*.

Oppermann, R. (Ed.) (1994). Adaptive User Support: Ergonomic Design of Manually and Automatically Adaptable Software. Hillsdale, NJ: Lawrence Erlbaum Associates.

Williams, K.E. (1993). *The Development of an Automated Cognitive Task Analysis and Modeling Process for Intelligent Tutoring System Development*. Final report for the Department of Navy, Office of Naval Research (NR 4428031-01), Virginia Tech., Department of Industrial Systems Engineering, Blacksburg, VA.

Williams, K.E. & Reynolds, R.E. (1991). The acquisition of cognitive simulation models: A knowledge-based training approach. In Fishwick and Mojeski (Eds.), *Knowledge-Based Simulation: Methodology and Application*. New York: Springer-Verlag.

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (*Leave Blank*)

2. REPORT DATE
22 Dec 1997

3. REPORT TYPE AND DATES COVERED
Final 16 Apr 67 - 18 Sep 97

4. TITLE AND SUBTITLE
Enhanced/Operator Machine Interface
SH-60R Operator Machine Interface Enhancements
TOPIC NUMBER: N96-232

5. FUNDING NUMBERS
N00421-97-C-1148

6. AUTHOR
Dr. JoAnn Patton, Principal Investigator
Mr. Glenn Barnett

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Digital System Resources, Inc.
12450 Fair Lakes Circle, Suite 500
Fairfax, VA 22033

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Naval Air Systems Command
1421 Jefferson Davis Hwy
Arlington, VA 22243-5120

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
A. Approved for public release: distribution is unlimited.

12b. DISTRIBUTION CODE
A

13. ABSTRACT (*Maximum 200 words*)

Airborne avionics sensor operator tasks are greatly increasing in complexity, time limitations and high information flow and presentation. This investigation proposes an adaptive OMI technique using a cognitive task analysis (CTA) approach derived from research by several experts in the Cognitive Science field. The research reveals that adaptive interfaces have not been widely implemented due to the difficulty of the cognitive task analysis. Moreover, the integration of such a system involves complicated training and implementation issues. The methodology proposed by this report capitalizes on existing tools. A CTA is conducted with the Cognitive Analysis Tool (CAT), a software product that automates the CTA process, addresses the most time-consuming aspect of such an endeavor, resulting ins significant savings. DSR's Integrated Training System (ITS) is used to assess the knowledge state of the current user, addressing the other difficult aspect of developing an adaptive OMI. The review and analysis show that the mental model obtained from a CTA would provide a viable mechanism for adapting the operator-machine interface fro the SH-60R-SENSO station. The recommendation for the Phase II effort is the prototype development and evaluation of an adaptive OMI for a specific sensor subsystem for an embedded and training capability for the SH-60R.

14. SUBJECT TERMS
Operator Machine Interface, SENSO, Cognitive Simulation Modeling, Cognitive Skill Analysis
Cognitive Task Analysis, Intelligent User Interfaces, Expert Systems, Task Analysis
Ideal User Model, Cognitive Recognition Algorithms, Expert Model Development

15. NUMBER OF PAGES
36

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT
Unclassified

18. SECURITY CLASSIFICATION OF THIS PAGE
Unclassified

19. SECURITY CLASSIFICATION OF ABSTRACT
Unclassified

20. LIMITATION OF ABSTRACT