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THE INTEGRATED PERFORMANCE MODELING ENVIRONMENT - SIMULATING HUMAN-SYSTEM PERFORMANCE

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ABSTRACT

The British Centre for Human Sciences and Micro Analysis and Design Inc. have collaborated to develop a more complete environment for modeling human performance.

The Integrated Performance Modeling Environment (IPME) integrates and synthesizes a base of international human performance modeling technologies evolved over the past ten years into a single modeling environment. The IPME has provided the British Government a means to determine cost-effective balances between human and equipment contributions to future military system performance for use in Concept, Operations Analysis (OA), and Balance of Investment studies. Their research approach has been to develop and evaluate a research methodology designed to provide controlled progression through a cycle of human performance modeling, prediction, and model verification and utilization in both synthetic and operational environments.

In this paper, we discuss the IPME architecture and human performance modeling paradigm.

1 INTRODUCTION

The Integrated Performance Modeling Environment (IPME) is a Human Performance Modeling (HPM) simulator consisting of an integrated environment of models intended to help the human factors practitioner analyze human system performance. IPME provides:

- a more realistic representation of humans in complex environments
- interoperability with other model components and external simulations
- enhanced usability through a user friendly graphical user interface

These capabilities help the practicing professional solve their problems by providing answers to questions involving human performance.

Individual components or models included in IPME are:

- a Model of the Environment
- a Model of Operators
- a Task Network Model using a Monte Carlo discrete event simulation engine
- a Model of the Workspace
- a Model of Performance Shaping Functions
- a Communications Module
- a Measurement Suite, and
- Support Utilities

These individual components can be combined in different combinations to quickly realign simulations to use different environments, operator profiles, task sequences, and external simulations into a single "System."

The flexibility introduced by the IPME's reconfigurable model relationships allows construction of a complete simulation environment. When combined into a System, tools are available to measure operator workload using a new method developed and introduced by the British Centre for Human Sciences called Prediction of Operator Performance (POP).

To help with data analysis, custom audit files can be generated to collect information on intermediate values of variables and functions. IPME also includes various tools and methods for importing and exporting both data and models.

2 HUMAN PERFORMANCE MODELING - OVERVIEW

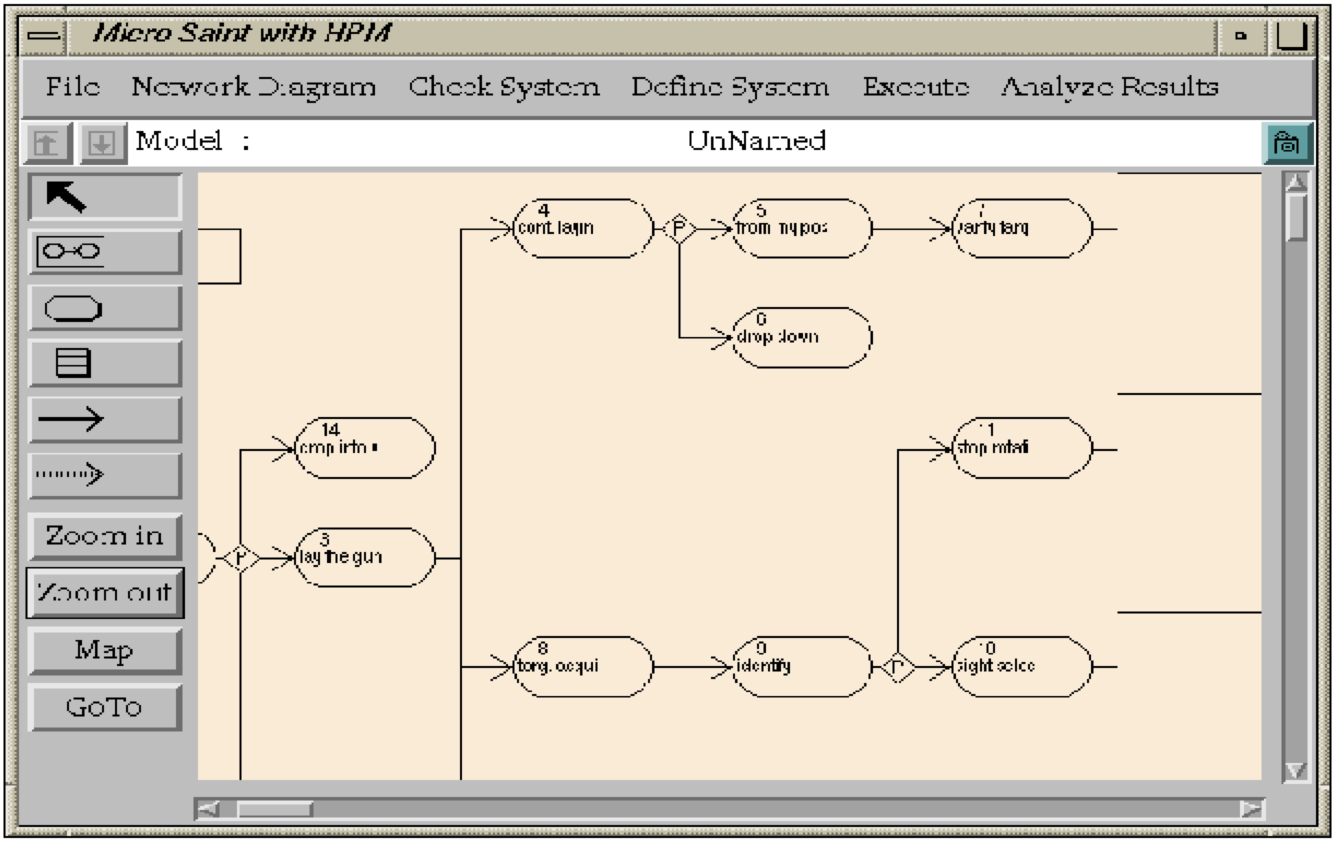

Figure 1 - Example of a Task Network for Part of an Armor Engagement

The human performance modeling technology that has had the greatest use and acceptance in the United Kingdom Ministry of Defence and United States Department of Defense has been task network modeling. In a task network model, human performance of an individual performing a function (e.g., loading a round into a turret) is decomposed into a series of subfunctions which are then decomposed into tasks. This is, in human factors engineering terms, the task analysis. The sequence of tasks is defined by constructing a task network. This concept is illustrated in Figure 1 which presents a portion of a network for an armor engagement.

Task network modeling is an appealing approach to modeling human performance in complex systems for several reasons. First, it is a sound means for extending task analysis. Task analyses organized by task sequence are the basis for the task network model. Second, in addition to complex operator models, task network models can include sophisticated submodels of the system hardware and software to create a closed-loop representation of the human, equipment, and environment. Third, task network modeling is relatively easy to use and understand. Finally, task network modeling can provide reasonable input to many types of issues. With a task network model, the human factors engineer can examine a design enhancement or change (e.g., control panel replacement) and address questions such as "How much longer will it take to perform this function?" and "Will there be an increase in the error rate?" These questions can be answered in less time and with far less effort than would be required if a prototype were developed and human subjects used.

Another problem often encountered when constructing a simulation model is the analyst’s ability to make good time estimates of atomic elements of human behavior without a large investment in data collection and task analysis. Another modeling environment, known as the *Human Operator Simulator* (HOS), was developed by the United States Navy to provide a database of these time estimates, thus allowing modelers to build higher fidelity models. Previously, for an analyst to set human performance model parameters, such as task time and accuracy, the user was required to collect data, make estimates, or search the literature themselves. HOS, on the other hand, provided an aggregation of the research knowledge base of human performance data and models.

Several years ago, MA&D integrated *Micro Saint*, a graphical task network modeling environment, and HOS. Micro Saint HOS (MS HOS) added a needed Human Performance Module to Micro Saint to illustrate, predict, evaluate, and describe human/ equipment/ environment interactions during a system's life cycle.

The procedures or activities that the human operator must perform are represented by a network simulation model that is, in essence, a Micro Saint model. In order to calculate task performance times, MS HOS accesses a library of micro models that calculate various types of human performance times for general classes of activities including cognitive, perceptual, and psychomotor activities. These models have been derived from many diverse sources including human factors literature (e.g., Fitts Law), established data sources (e.g., MTM data), and other models (e.g., Xerox PARC's GOMS model). They use parameters of the work space design to make human task time and error estimates. Through this link, the design of the modeled controls and displays affect how quickly and accurately the modeled operator performs a particular task sequence.

3 IPME MODELS

IPME built from the foundation of the graphical task network / Human Performance modeling environment established by MS HOS to provide analysts with a plug-n-play modeling capability. For the first time, analysts are able to fully define components such as an environment, validate the relationships within the model, and then re-use the validated model to dynamically interact with other independent models. This sections gives a brief example of how the use of integrated modeling components advance the state-of-the-art.

Modeling Scenario. A company is developing an armored vehicle. Human Engineering Assessments of predecessor armored vehicles identify there is a significant health hazard for operators and passengers in the vehicle. The client has asked for an estimate of expected operator performance under extreme conditions. The client is attempting to establish an investment analysis to determine whether an expensive environmental control system is needed.

An analyst is tasked with determining long duration heat and cold effects on crew performance working in an armored vehicle. The task requires expensive field experiments with humans-in-the-loop. However, safety restrictions restrict exposing human subjects to the extreme conditions needed for the assessment. The analyst decides to construct a simulation of some critical maneuvers. She will use the simulator to reduce and focus the confounding factors needing data collection during the human experiments.

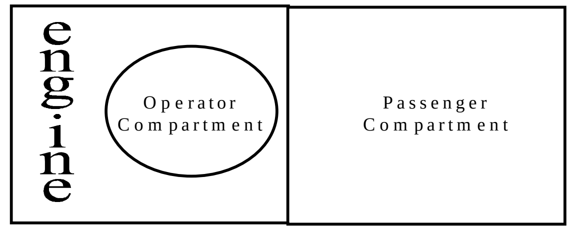

Figure 2 - Sample Workspaces

To answer the problem, the analyst uses IPME to create two *Environment Models* that represent the extreme desert summer heat and polar arctic cold conditions. Since the study is dealing with long duration effects, the analyst builds relationships for temperature that depend on effects of environment model stressors such as time-of-day, illumination, and weather conditions.

For the model to be realistic, operators and passengers must be modeled in different compartments of an armored vehicle. This vehicle has a large engine in the front, with the operator turret on top and just behind the engine. Behind that is the passenger compartment as depicted in Figure 2.

Workspace temperatures are dynamically updated during the simulation by establishing functional relationships that relate workspace temperature to the physical outside temperature and the temperature of the surrounding compartments or objects. For example:

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Op_Comp.Temperature = 0.36*Engine.Temperature +
0.36*Pass_Comp.Temperature +
0.40*Physical.Temperature;
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might represent the temperature of the operator compartment scaled by the insulation provided by the walls and ceiling.

These functional relationships are evaluated for every task processed in the simulation. Therefore, once the modeler has established the relationships, the environmental variables are automatically updated as the simulation progresses without having to manually insert discrete events that will change the temperature stressor.

Not all armored vehicle operator performance is affected in the same way or by the same amount based on inherent traits of the individual. The analyst needs to reflect these differences across a representative sample of the expected target population. The analyst now creates a few *Operator Models*, each containing a different crew of operators. Each operator within the crew is given unique characteristics that describe the differences in operator physical properties, traits and states.

With the help of the client, the analyst constructs network representations of several critical operational scenarios using the *Task Network Model* in Figure 1.

Next, the analyst constructs the *Performance Shaping Functions (PSFs) Model*. PSFs dynamically affect simulated Operator performance by applying PSF equations to the simulation.

PSF equations are user defined functions which dynamically modify individual operator task "Time to Perform" and "Probability of Failure" values. These PSF equations define how the synergy of stressors or performance shaping factors (environment variables or operator characteristics) affect operator performance.

The PSFs are linked to individual tasks through a task taxonomy allowing one PSF function to be dynamically applied to any similar task in a model. Since PSFs can use operator states as expression variables, simulations can be built that have two operators performing the same task type with different, and therefore more realistic, "Time to Perform" and "Probability of Failure" values.

During research, the analyst discovers two different theories on how heat affects performance. One is based on temperature and the other is based on temperature and circadian rhythms. The analyst constructs two different PSF models to represent the different theories. Later, she will validate against data collected during field tests to correlate the better method.

The analyst now constructs a blocked experiment using the IPME's *Measurement Suite*. Here she identifies the nuisance, response and dependent variables to collect within a data file for later evaluation. Multiple trials are defined within each block and multiple simulation runs (or iterations) are specified for the experiment.

As part of the measures of effectiveness established by the analyst, estimated operator workload needs to be measured. A workload increase as temperature and stress increase would represent the diminishing ability of the operator to perform the mission. IPME contains the *Prediction of Operator Performance (POP)* workload measure, a new algorithm for estimating operator workload. The results of the measure show when an operator's task demand exceeds capacity.

The analyst starts the experiment with the "System" using the Desert Summer Environment, Crew1 Operator Model, Engage Enemy Task Network Model, and PSF model based on temperature effects only. Her experiment consists of 100 runs for each trial in the experiment and the blocked design contains two blocks with 8 trials each. She starts execution and goes to lunch while IPME runs the 1600 simulations necessary for experiment.

After lunch, she reconfigures the "System" description to contain the Arctic Cold Environment Model by simply assigning it to the "System." She then re-executes her experiment and another 1600 simulations are run for the different environment.

Similarly, different Operator Models and PSF Models are configured into the "System" and the experiment is repeated. Other features, such as a communication protocol allowing interactive simulations hosted on different platforms are also available within the IPME framework.

IPME is hosted on Silicon Graphics IRIX 5.3 or 6.2 machines running X11R5 or later with the Motif 1.2.3+ or later window manager and a minimum of 16MB of RAM. IPME also runs on Linux distributions for *any* hardware using X11R6 and Motif 2.0.

4 CONCLUSION

IPME introduces a plug-n-play constructive simulation environment that helps the practitioner build complex simulations that can be easily reconfigured. Experimental design methods can be used to construct low-cost simulations that can help focus human-in-the-loop experiments. The unique ability to distinguish differences between Operators and Environments improves realism of the simulation models and helps the practitioner answer the tough questions when many stressor effects need evaluation.

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DAVID DAHN is a principal at Micro Analysis & Design, Inc. He has a Master's Degree in Computer Engineering. Mr. Dahn is project leader to develop the Integrated Performance Measurement Environment (IPME) for the United Kingdom's Defense & Evaluation Research Agency's Centre for Human Sciences. Mr. Dahn manages a team of engineers, analysts, and programmers who are building a modeling tool for a discrete event network simulation. This tool, named the Integrated Performance Modeling Environment, will include a model of environmental factors, a model of work-space layout and environment, a model of individual operator traits and states, a model to adjust human performance based on environmental factors, hooks for linking to other simulations. Before coming to Micro Analysis and Design Mr. Dahn was in the United States Air Force, as Human Resources Directorate Project Manager/Function Chief. Mr. Dahn was the Project Manager for the Manpower, Personnel, and Training Decision Support System.

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