A HUMAN PERFORMANCE SIMULATION TOOL

D. Dahn

Micro Analysis & Design Inc.

INTRODUCTION

A new computer modeling tool, the Integrated Performance Modeling Environment (IPME) focuses on simulation of humans in different environments. The IPME was developed in support of the United Kingdom's Centre for Human Sciences (CHS) to support analysis of human performance prediction in military systems. The CHS has been using the IPME for the past year in studies supporting the Combined Operational Effectiveness and Investment Appraisal studies for proposed weapon systems.

To introduce the capability and capacity of the IPME, a simplistic exemplar model of a Naval Anti-Air Warfare Center (AAWC) operation was formulated to demonstrate how human performance in adverse or harsh environmental conditions can be modeled. The exemplar will study the effects of sea conditions on radar operators.

OVERVIEW

The IPME is an integrated modeling system that provides a graphical interface to improve the ease in constructing simulations to predict human performance.

The IPME allows construction of component models that are tied together in a plug-n-play simulation environment to represent a System description. The IPME has 5 component models and a measurement suite that can be used for blocked design of experiments. These models focus on the human and depict the (1) task network—procedures the human performs in support of a goal, (2) operator model—describes each operator in a crew, (3) environment model—the environment in which the crew operates, (4) performance-shaping model—a set of performance stressors and (5) external models—an interface for communicating with 1 or more external simulators or programs. ams.

The IPME also introduces the 1st practical application of a new workload measurement method called Prediction of Operator Performance (1) developed by CHS. The algorithm is a performance-based prediction not dependent upon specific interface knowledge like that required in multiple resource theory.

Results from an IPME simulation include built-in data collections as well as analyst-defined measurements. Multiple analyst-defined data collection sets are supported.

IPME is based on the Micro SAINT (2) (System Analysis of an Integrated Network of Tasks) Monte Carlo simulation engine. From its origins, IPME is well suited for modeling, simulation and analysis of complex human-machine systems (3). The resulting IPME human performance models support a variety of simulation analyses such as studying relationships among system entities, events and processes; helping with function allocation in system operations; conducting sensitivity analysis; and even performing human error studies.

COMPONENT MODELS

The task network model supports construction of procedures needed to achieve an operator goal or objective. The basis of the method for the task network uses an empirical task analysis describing the properties of the tasks and their logical and sequential relationships. This set of information is then combined through a graphical modeling interface (Fig. 1) into a process (task network with queues) or sets of human/system processes (multiple network hierarchy). Operators can be assigned to tasks dynamically through conditional expressions or statically through functional assignment. For our exemplar model, we created a simple network representing a tracking procedure for the AAWC radar operator.

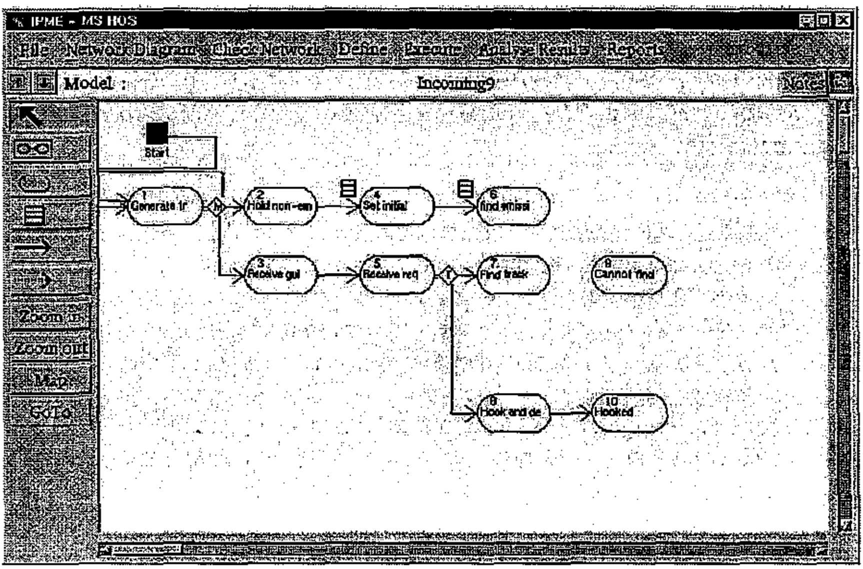

Figure 1. Task Network

Changing variables within scenario events at a specific time or model state condition can alter situational goal states. Situational goal states are different than the operator goal modeled in the task network. In our exemplar we could control whether the ship is at normal quarters or under attack, or we could increase the Sea State over time. Logic within the task network would then uniquely adjust each operator's goal state.

The operator (crew) model allows a description of individual operators using traits, states and physical properties that can be used as performance criterion in the task network model. Traits are those human characteristics that are not expected to change as a function of simulation time and include items such as mental aptitude, experience and training. States are those human characteristics that do change as a function of simulation time and include items such as fatigue and mental alertness. These human characteristics can be used within expressions in the task network model to dynamically alter the process based upon who is performing the task. For our exemplar, we created a single console operator and entered an expression using 'if-then' conditionals to set the operator's comfort level as a function of Sea State (which is defined in the environment model).

The environment model allows the user to define physical conditions to which the operator will be exposed. The IPME supports placing each individual operator into same or different work zones where each work zone has it's own unique environment. Environment element relationships between the physical environment and each work zone can then be established through mathematical expressions. Our exemplar model uses a quantification of the physical Sea State that is used in the operator model to effect operator comfort.

The performance-shaping model uses environmental stressors and operator characteristics to modify human performance at the task level. For each task within the task network model, the user identifies the atomic behaviors from a 9-element taxonomy and the percentage that each of these behaviors contributes to the task. Then, in the performance-shaping model, the user can create mathematical expressions for each taxonomy that will improve or degrade the time to perform or error probability of a task. The equations developed in the performance-shaping model are developed once but applied across all tasks within the simulation model. For our exemplar, operator time performance of all tasks containing the atomic behavior 'fine continuous motor skills' was degraded based on a simple algorithm as a function of operator comfort. Error probability for tasks containing atomic behaviors 'spatial' and 'verbal/numeric cognitive ability' were also degraded. This degradation resulted in additional missed tracks. Algorithms of this type are generally taken from literature or developed from empirical studies. The concept is complicated: the application is powerful.

The external models interface supports integration of other simulations through an inter-simulation protocol that allows sharing simulation state variables between simulators existing on the same platform or connected across a network. These external simulations can be other IPME models or specialized models utilizing the protocol. Our exemplar does not use any external simulators but there are times when multiple work centers are modeled and interactions between these work centers need to be studied.

The resulting combination of the component models formulates a time-based discrete event simulation of a complete System.

EXECUTING THE SIMULATION

We can now execute the completed System model. For the exemplar, we wanted to capture the number of radar tracks missed by an operator as a function of sea conditions and the operator's susceptibility to seasickness. We used IPME's measurement suite to construct a blocked design and varied the Sea State and the operator's trait describing the susceptibility to seasickness and collected data on the measure of performance. To represent expected human variability, each experimental condition was set up to execute multiple times. Once the blocked experiment information was entered into the measurement suite, the model executed unattended. Results were saved in ASCII files. Final presentation was a set of graphs showing the relation between Sea State and the operator's resulting performance in terms of missed tracks. The experiment can be further expanded to multiple blocks of different operator susceptibility levels.

Extension of the IPME's modeling and simulation application in other situations or environments is easily imagined. The focus of the study could be on operator performance in different environments. Two environmental models can be constructed describing conditions in Desert and Arctic climates. The Desert environment can then be plugged into the System, the experiment run and data collected. The Arctic environment can then be plugged into the System, and the experiment can be run again. The resulting data will provide a clear contrast between performance in different environments with the same control description of the operators and their procedures. The interchange of component models within IPME is referred to as plug-n-play modeling.

The IPME is available for Silicon Graphics™ and Intel™ Linux platforms.

CONCLUSION

IPME introduces a plug-n-play constructive simulation environment that helps the practitioner build simple or complex simulations that can be easily reconfigured. 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.

REFERENCES

1. Farmer, E.W., Belyavin, A.J., Jordan, C.S., Bunting, A.J., Tattersall, A.J. and Jones, D.M. 1995, Predictive workload assessment, Final report DRA/AS/MMI/CR95100/1.
2. Hood, L., Laughery, K.R. and Dahl, S. 1993, Fundamentals of simulation using Micro Saint, Micro Analysis & Design.
3. Luczak, H. 1997, Task Analysis, in G. Salvendy (ed.), Handbook of Human Factors and Ergonomics. (USA: John Wiley & Sons, Inc.), 396.