Cognitive Virtualization: Combining Cognitive Models and Virtual Environments

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Where are Idaho and the INL?
Where are Idaho and the INL?

Idaho Falls

Monterey
The Idaho National Laboratory

A DOE National Laboratory located in Idaho

- Facilities located in Idaho Falls and on the 890 square mile reservation located 40 miles away
- Work force of 3,300 people ~ 7,000 total employees with all contractors
- Historically focused on nuclear reactor research
- Operated by Battelle Energy Alliance
Performance Modeling

- Cognitive modeling has been an increasingly popular approach (in aviation, military, and process industries) for its computational power to simulate human behaviors

- 3D visualization has been used to visualize and evaluate design configurations

- GOAL – combine the two methods
Advance Control Room Design
Transitioning to new domains of Human System Interaction

**Research Issues**
- Role of the operator
- Staffing levels
- Situation Awareness
- Error Modes & Recovery
- Level and role of automation
- Modes of operation

**Research Issues**
- Multiple module (distributed) control
- Control room design
- Maintenance during operation
- Online diagnostics
- Complex information processing, visualization, and analysis
Cognitive Modeling

Cognitive modeling is an area of computer science that deals with simulating human problem solving and mental task processes in a computational model. These models can then be used to simulate or predict human behavior or performance on tasks similar to the ones being modeled. It has been used to:

- Determine how humans interact with novel and advance technology (i.e., vigilance, decision-making, trust, etc)
- Evaluating individual workload
- In determining appropriate staffing models and roles
- Identifying and predicting error and performance risks
- Addressing team/crew situation awareness and performance
- Simulating “What if” scenarios to increase explanatory power.
Cognitive Modeling

Currently, there are approximately a dozen cognitive modeling approaches each with its strengths and weaknesses as well as its alliance to a particular theoretical cognitive camp. In the Spring 2007 issue of *Ergonomics in Design*, a short summation of the more developed cognitive models was given, as presented below.

<table>
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<tr>
<th>Modeling Tools</th>
<th>Feature</th>
<th>Focus of Usage</th>
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<tbody>
<tr>
<td>iGEN (Emmerson, 2000)</td>
<td>A modeling tool based on cognitive task analysis</td>
<td>Analyzing operational effectiveness in different domains (e.g., a battlespace) and decision aiding in human-machine interfaces (e.g., an interface for aircraft pilots)</td>
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<tr>
<td>Micro Saint (Laughery, 1989; Schunk, 2000)</td>
<td>A modeling software package based on the task network modeling method to predict human performance</td>
<td>Modeling human operator performance and interaction under changing conditions (e.g., modeling crew size for a helicopter)</td>
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<td>MIDAS (Gore &amp; Corker, 2002)</td>
<td>An agent architecture composed of physical component agents and human operator agents</td>
<td>Modeling and predicting human error, especially in the aviation domain</td>
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<td>CSEES (Bolton &amp; Bass, 2005)</td>
<td>An integrated toolset designed to facilitate curricula and education related to human judgment and decision-making performance modeling and evaluation</td>
<td>Facilitating learning how to model air traffic conflict judgment task, decision making, signal detection, and rule-based navigation of agents</td>
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Cognitive Modeling

• No “magical” bullet in cognitive modeling
  – i.e., a perfect model that can stimulate human cognition across a broad range of human behaviors
MIDAS: cognitive model example

- Current MIDAS models used:
  - To model crew-system interaction in Space Shuttle

Astronaut visual processing

“Eye Cones” denote attentional focus

Virtual workload measures including sensation (inputs), cognitive processing, and behavior (outputs)
MIDAS: cognitive model example

- **MIDAS currently supports:**
  - Workload modeling based on Wickens’ Multiple Workload Model (MWM; 1984)
    - Mental abilities exist in four separate functional areas
      - Visual (Perception)
      - Auditory (Perception)
      - Cognitive
      - Psychomotor (Behavior)
    - These areas are largely independent, not shared
MIDAS: cognitive model example

• Gaps
  – While Wickens’ MWM accounts for some decrements to human behavior, workload is but one of many performance shaping factors
  – Other performance shaping factors considered in human reliability analysis (HRA) models
    • HRA models can be used to determine improvements and decrements over nominal behavior
    • Can be used to estimate human error probabilities (HEPs) in variety of scenarios
Integrated Performance Modeling (IPM)

Hardware in the loop simulations (simulators)

Cognitive Modeling
(MIDAS, MicroSaint, ACT-R, SOAR, EPIC)

Manikin Modeling

Integrated Performance Model (IPM)
Anticipated Benefits and Application of IPM

• Advancement of Human Reliability Analysis as a potential data collection source.

• Tool to Examine Next Generation Control Room and near term design considerations in terms of:
  – Staffing models
  – HIS designs
    • Design interfaces
    • Level of automation
    • System configurations and control layout
    • Computer-based procedures
  – Operating and emergency procedures – information retrieval and flow

• High-Fidelity Training
Conclusion

• Advanced reactor systems and even near term systems can and will present human factors concerns that must be addressed before the full benefits of such a system can be realized.

• The INL has initiated a multi-year project to integrate cognitive model with ergonomic models in a virtual and interactive framework. In a “best of breed” approach, the INL is teaming with the cognitive modeling expertise of NASA and Alion Science and Technology (the Micro Analysis and Design Division).

• Virtualization is one tool that can offer rapid insight into both design and performance issues, but it must be integrated with actual human performance testing.