Background for

Cognitive Models of Operators

16.459 Humans & Automation Seminar
February 6, 2002

Miwa Hayashi
Purpose of Operator Modeling

Human-Machine System Design
- To provide rapid prototype simulator to examine human operator performance as a function of human interface design.
- To provide human-factors-related design requirements input from earlier stage of system concept development.

Decision Aiding
- To design intelligent, adaptive operator decision aiding system.

Training
- To improve existing operator training material based on the cognition model of skilled operator.

..., And

Application for Artificial Intelligence (AI)??
Model Types (1) : Normative v.s. Descriptive

*Normative Model*
- describes how people ought to perform cognitive tasks

*Descriptive Model*
- describes how people actually perform cognitive tasks

Ex.: Conjunction Fallacy (Tversky & Kahneman, 1983)

Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student, she was deeply concerned with issues of discrimination and social justice, and also participated in anti-nuclear demonstrations.

Which statement has higher probability of being true?
A. Linda is a bank teller.
B. Linda is a bank teller and active in the feminist movement.

The statement A always has higher probability than (or equal probability to) the statement B because of joint probability theory \( P(X) \geq P(X \& Y) \); thus A is the correct answer.
Model Types (2) : Modeling Approach

Reductionist Model
- uses human/system task sequence as the primary organizing structure.
- Task Network Model (e.g., Micro Saint), Petri Net

First Principle Model / Cognitive Process Model / Production System Model
- is structured around an organizing framework that represents the underlying goals and principles of human performance.
- MIDAS, COGNET, ACT-R, EPIC, SOAR

Connectionist Model
- Attempts to find some mathematical relationship between input and output.
- Neural Network, Regression
Typical Model Structure

Sensing and Perception → Working Memory → Cognition
- Learning
- Decision Making
- Situation Awareness
- Planning
- MultiTasking
→ Motor Behavior

Long-Term Memory
- Mental Model of the World
- Other Declarative Knowledge
- Procedural Knowledge

Tasks
- Manage battle space
- Evaluate track
- Plan specific threat response
- ---
- ---

Internal System of Operator

Stimuli → External World (System, Situation, Environment, etc.) → Responses
## Various Operator Models

<table>
<thead>
<tr>
<th>Model</th>
<th>Original Purpose</th>
<th>Application Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Micro Saint</td>
<td>Evaluate systems and procedures</td>
<td>Military simulations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automated bank teller system design</td>
</tr>
<tr>
<td>ACT-R</td>
<td>Modeling problem solving and learning</td>
<td>Various problem solving models</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Human memory</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Learning</td>
</tr>
<tr>
<td>COGNET</td>
<td>Develop user models in intelligent interfaces, surrogate users and adversaries</td>
<td>Vehicle tracking</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Intelligent tutoring system for military</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Military simulations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Teamwork and cooperation simulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Workstation design for telephone operator</td>
</tr>
<tr>
<td>EPIC</td>
<td>Develop and test theories of multiple task performance</td>
<td>Dual tracking/stimulus-response task</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Computer interface menu search</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Telephone operator call-completion task</td>
</tr>
<tr>
<td>MIDAS</td>
<td>Evaluate interfaces and procedures</td>
<td>Military simulations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Flight deck, ATC procedure simulations</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Space shuttle cockpit display improvement</td>
</tr>
<tr>
<td>SAMPLE</td>
<td>Evaluate crew procedures, equipment</td>
<td>Airliner cockpit procedure examination</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Nuclear power plant automation evaluation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Air combat situation awareness analysis</td>
</tr>
<tr>
<td>SOAR</td>
<td>Model problem solving and learning</td>
<td>Problem solving</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Learning</td>
</tr>
<tr>
<td>Neural Net</td>
<td>Multiple constraints, satisfaction in memory, language, thought, pattern recognition</td>
<td>Unsupervised learning model</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pattern recognition</td>
</tr>
</tbody>
</table>
Papers

Micro Saint, MIDAS:

Laughery, K. R., Jr., & Corker, K. (1997)
“Computer Modeling and Simulation”

COGNET:

“Cognitive Task Analysis and Modeling of Decision Making in Complex Environment”
Developed and supported jointly by the U.S. Army and NASA.

Aims to
- reduce design cycle time
- support quantitative predictions of human-system effectiveness
- improve the design of crew stations and their associated operating procedures.
Developed by CHI Systems Incorporated, PA

Original purpose was to develop an intelligent decision-making support system in real-time multi-task environment based on the knowledge of the task domain and the operator's decision-making process.

Three requirements for the system

- psychological (i.e., descriptive)
- computational (i.e., unambiguous)
- operational

“Pandemonium” metaphor

- “shrieking demons” model for attention switching in multi-task situation
- “blackboard” model for global problem representation
- “perceptual demons” for changing problem representation by perceptual event
Limitation of Cognition Model

Each of operator cognition models is tailored for a specific purpose by simplifying the system structure and restricting operation domain, and captures only subset of human behavior. These models are not meant to create a complete replica of human in software form.
Other References

Summary of various operator cognition models

MIDAS
- http://caffeine.arc.nasa.gov/midas/index.html

COGNET