Large Scale Cognitive Modeling

October 27th 2011

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Integrity ★ Service ★ Excellence

Acknowledgements

- **Dr. David Luginbuhl**
  - Previous AFOSR Systems and Software PM
  - Current Assistant Chief Scientist, 711 HPW
- **Dr. Saurabh Mittal**
  - Co-PI: L3 Communications, 711 HPW/RHAC
- **Christopher Bogart & Dr. Margaret Burnett**
  - Academic Collaborators: Oregon State University

Outline

- **Problem**
  - **Systems of Systems (SoS)**
  - **Human Components of SoS**
- **Solution**
  - **Meta-Modeling**
  - **Net-Centric M&S**
  - **Model Behavior Analysis & Visualization**
- **Progress**
  - **In Meta-Modeling and Net-Centric M&S**

[Transition to Chris]

SoS/Cognitive Models Developing in Warfighter Readiness Training Research

Live, Virtual and Constructive Modeling and Simulation

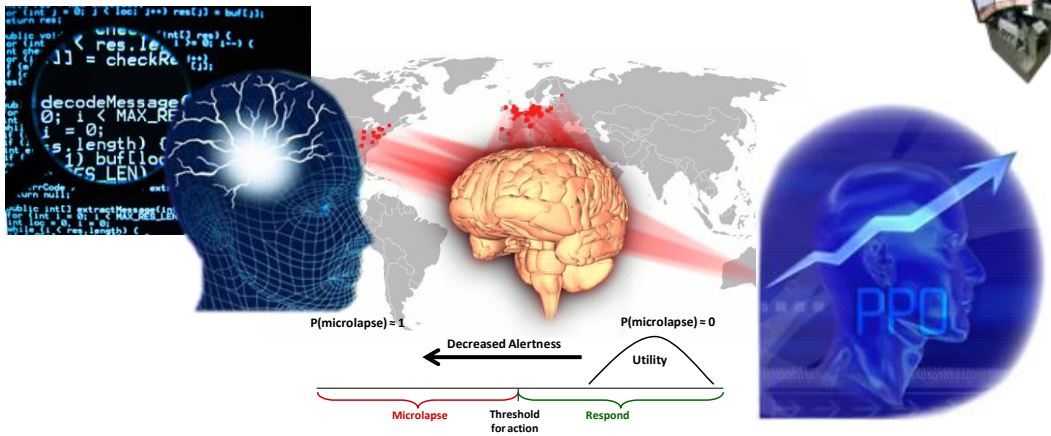
LVC Training and Aiding Methods

Immersive Technologies

Performance Measurement and Tracking

Performance Prediction Tools

Training Test Dummies



Synthetic Teammates

Intelligent Tutors

Challenges of Capturing the Operator/Trainee

Aspects of the Human that Require Cognitive Fidelity

Operator/trainee *memory* is massive, associative, and sensitive to the information structure of the environment

Retrieval is influenced by operator/trainee intention and contextual priming

Frequently remembered and used knowledge can be more rapidly and reliably retrieved

Challenges of Capturing the Operator/Trainee

Aspects of the Human that Require Cognitive Fidelity

Operator/trainee *actions* are based on changing combinations of procedure and memory use

Recall Replacing a Process

An Alphanumeric Addition Verification Task

A + 2 = C ✓

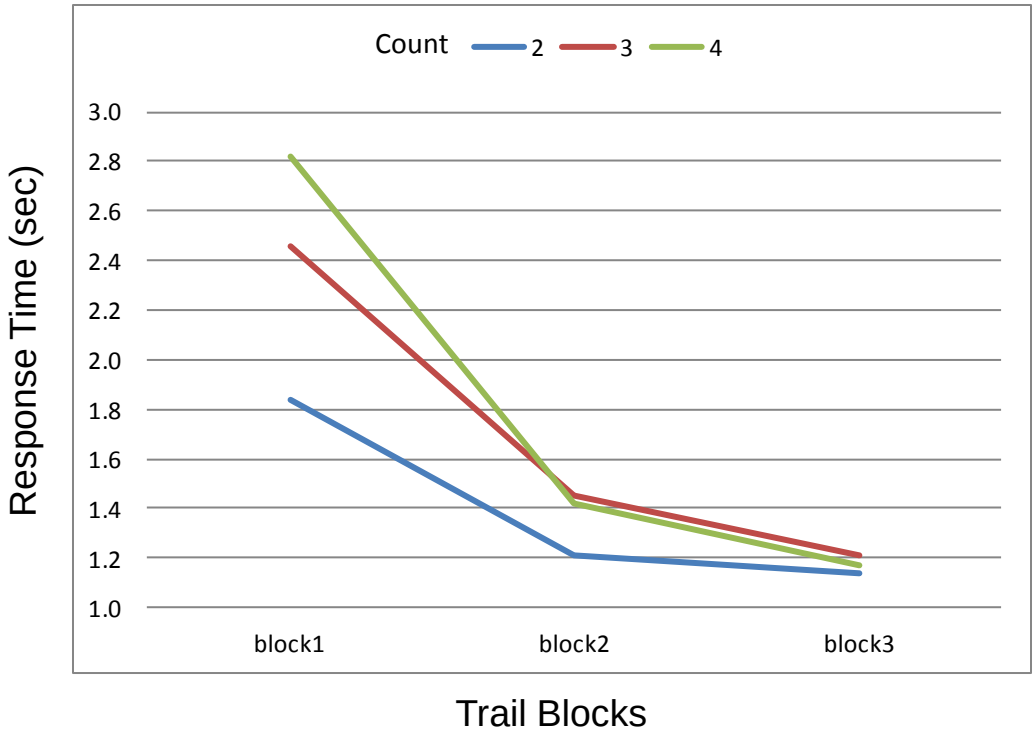
A + 2 = D ✗

F + 4 = J ✓

…

A + 2 = C ✓

…



Challenges of Capturing the Operator/Trainee

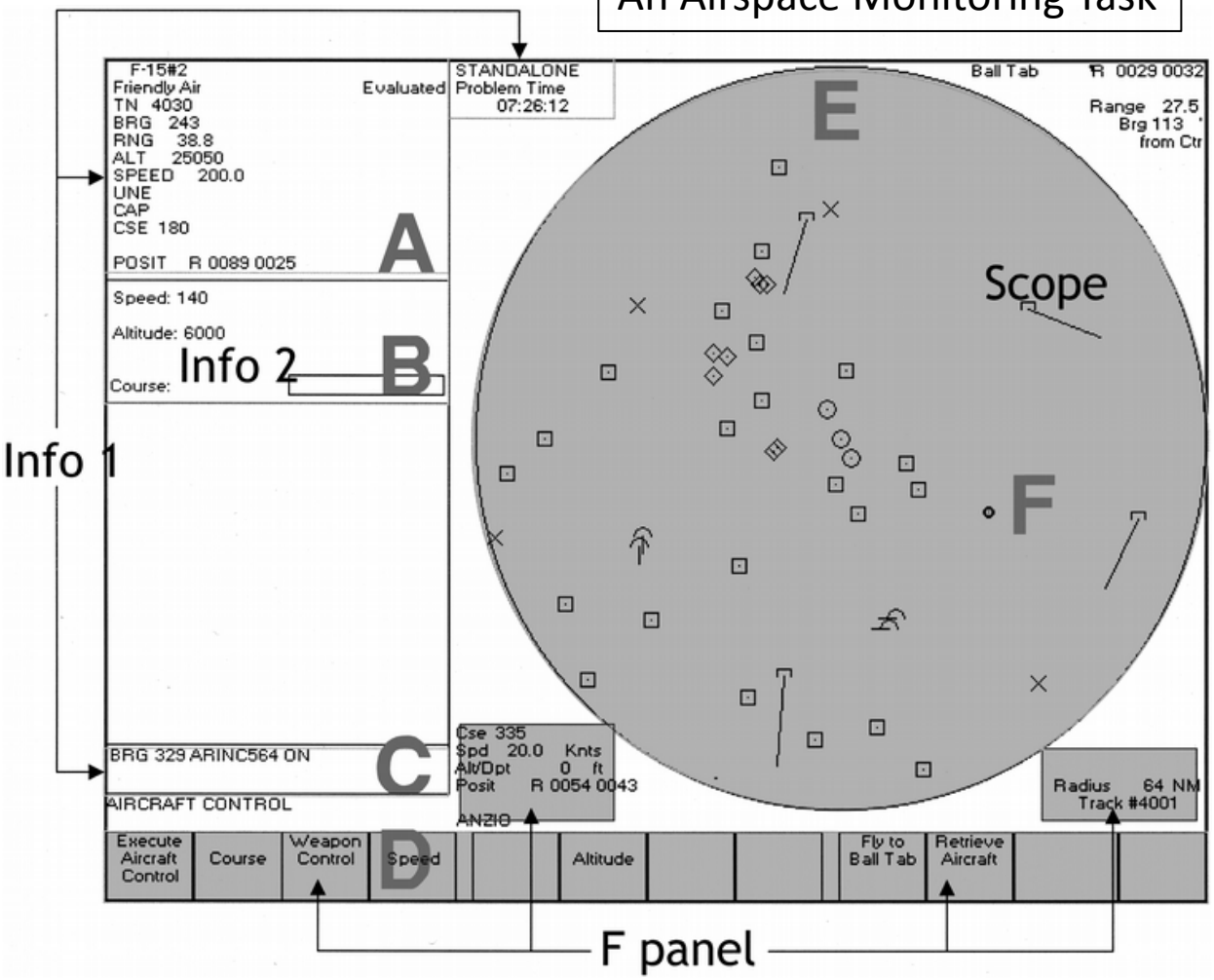
Aspects of the Human that Require Cognitive Fidelity

Operator/trainee *actions* are based on changing combinations of procedure and memory use

Complex Recall/Procedure Changes

Recall Replacing Search; Acquired Skill Replacing Instruction Following

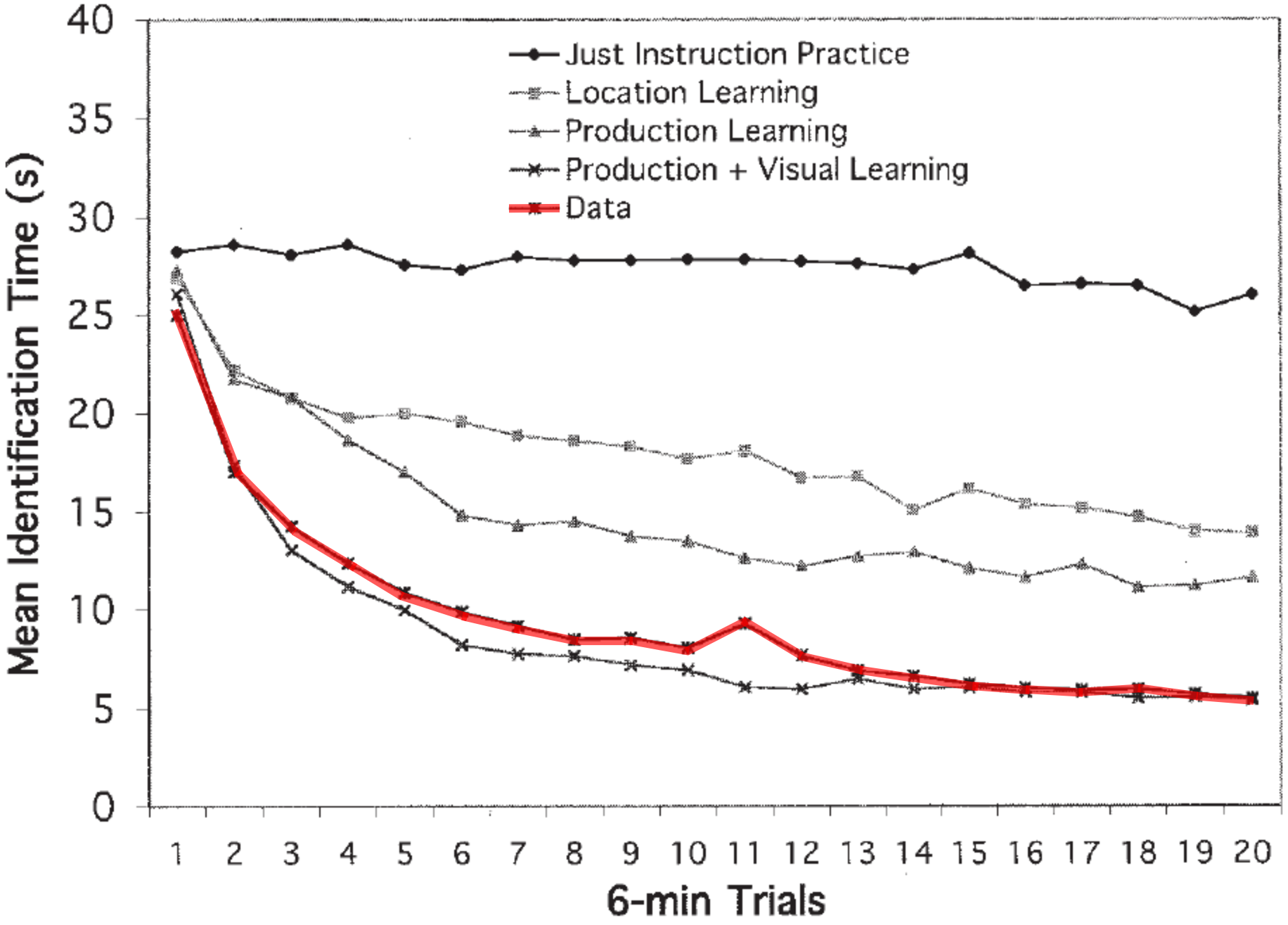
An Airspace Monitoring Task



Sources of Information

A: Selected Track/Plane
B: Changes
C: Radar and Visual ID
D: Available Actions
E: Radar/Airspace
F: Selection Cursor

Anderson, J. R., Bothell, D., Byrne, M. D., Douglass, S. A., Lebiere, C., & Qin, Y . (2004) *"An integrated theory of the mind."*


Just Instruction Practice
Location Learning
Production Learning
Production + Visual Learning
Data
Mean Identification Time (s)
0
5
10
15
20
25
30
35
40
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
6-min Trials

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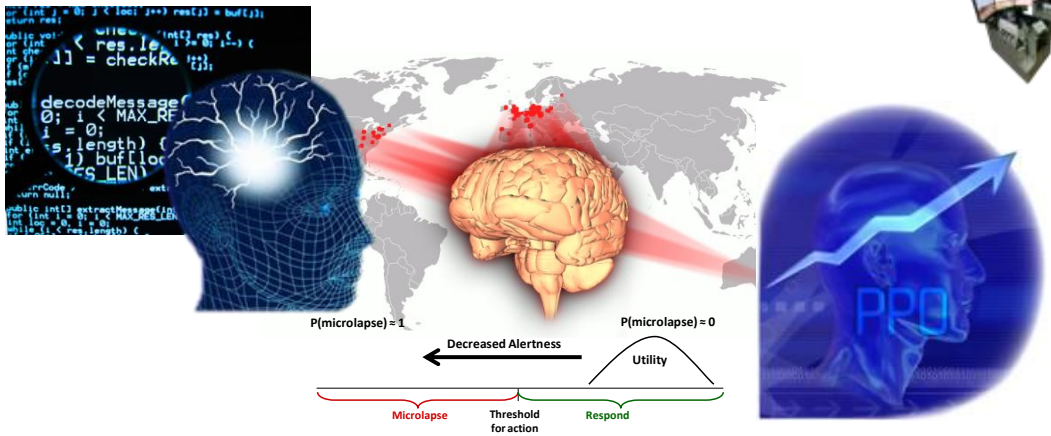
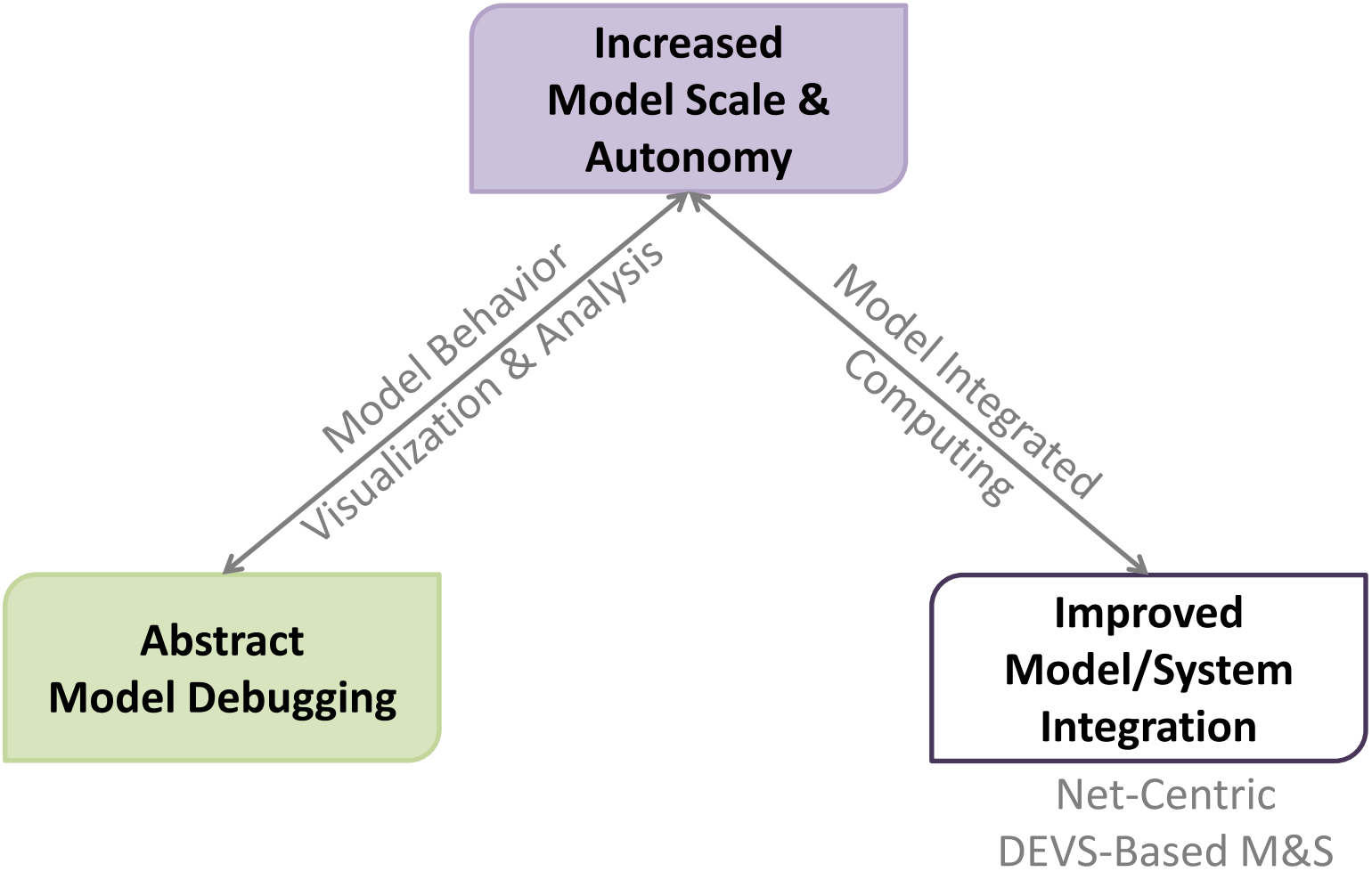


Synthetic Teammates

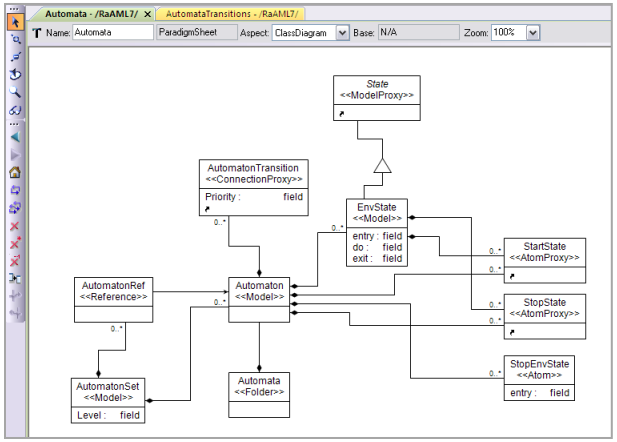
Intelligent Tutors

Large Scale Cognitive Modeling



Model Integrated Computing

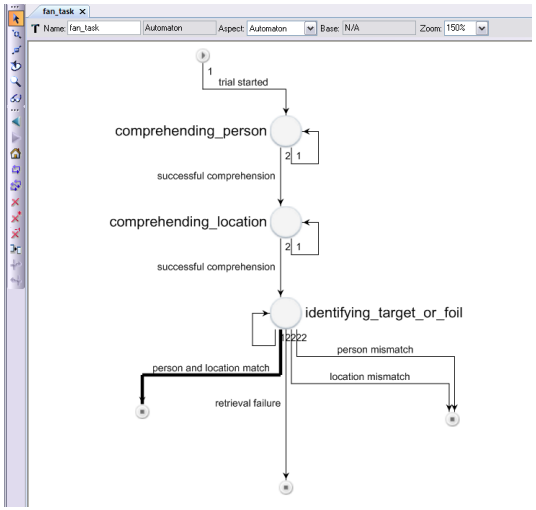
1. Meta-Modeling -- *DSL Development*



GME 10

Sztipanovits and Gabor(2002)
"Model-Integrated Computing."

2. Modeling -- *DSL Use*



3. Model Integration and Simulation -- *DSL Transformation, Integration and Execution*

- General Systems Theory
- DEVS: Discrete Event System Formalism
- HLA/DEVS Integration

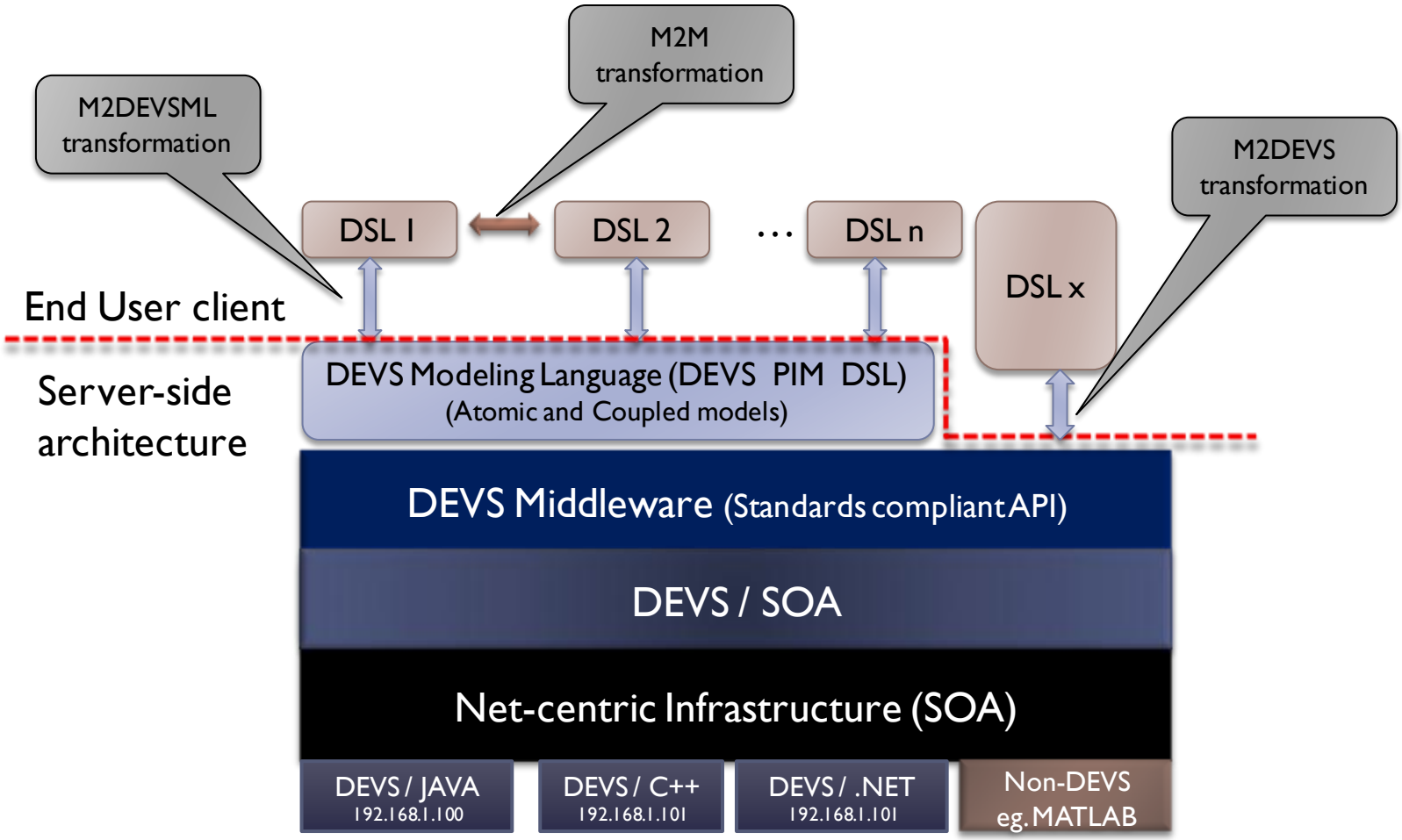
Wymore, A. W. (1967)
"A Mathematical Theory of Systems Engineering the Elements."
Zeigler, Kim, & Praehofer (2000)
"Theory of Modeling and Simulation."

$$SYS \equiv \langle T, X, \Omega, Q, \delta, Y, \lambda \rangle$$

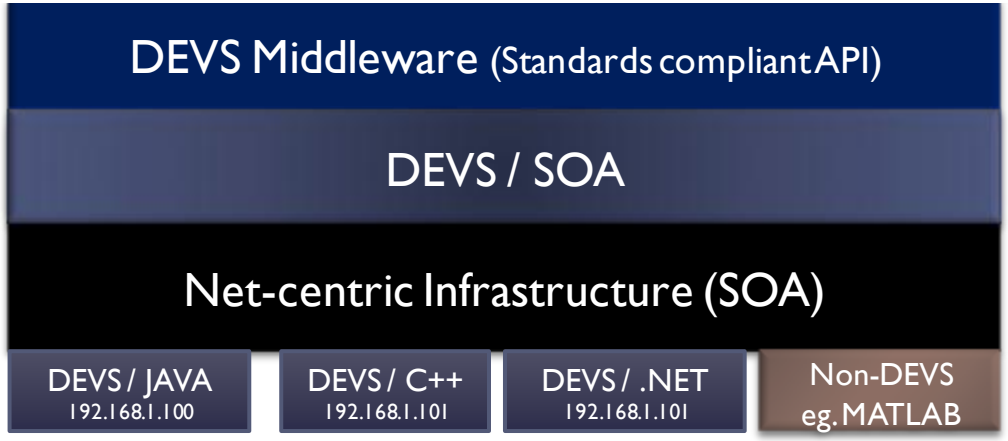
T	Time base
X	Input set
Ω	State
Q	State set
$\delta : \Omega \times Q \to Q$	Transition function
Y	Output set
$\lambda : Q \to Y$	Output function

AFRL

Net-Centric DEVS-Based M&S



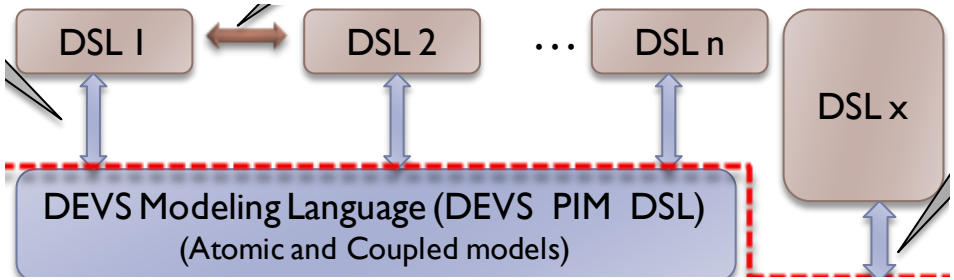
Year 2 Progress



1. Net-Centric DEVS

- Mittal, S., & Douglass, S. A. (2011). *Net-centric ACT-R-Based Cognitive Architecture with DEVS Unified Process*. Proceedings of the DEVS Symposium, Spring Simulation Multiconference -- SpringSim'11. Boston, MA.

Year 2 Progress

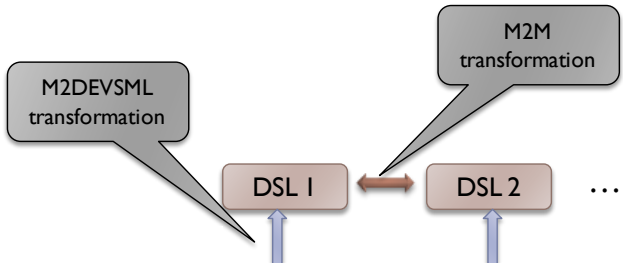


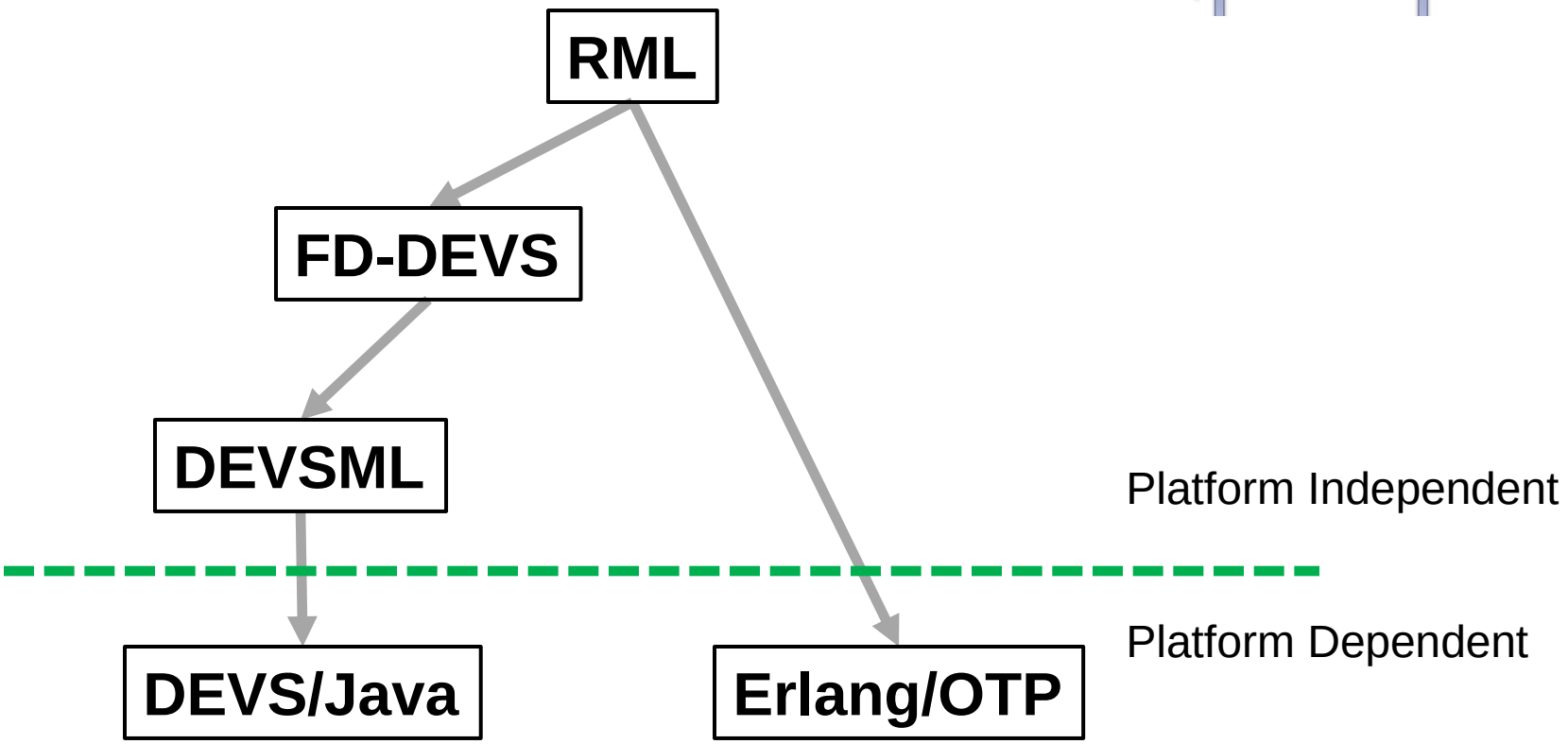
2. Domain-Specific Languages

- **DEVS Modeling Language (DEVSML)**
- **Finite/Deterministic DEVS (FD-DEVS)**
  - Mittal, S., & Douglass, S. A. (2011). *From Domain Specific Languages to DEVS Components: Application to Cognitive Modeling and Simulation*. Proceedings of the Workshop on Model-driven Approaches for Simulation Engineering -- SpringSim'11. Boston, MA.
- **Research Modeling Language (RML)**
  - Douglass, S. A., & Mittal, S. (2011). *Using domain specific modeling languages to improve the scale and integration of cognitive models*. Proceedings of the 20th Annual Conference on Behavior Representation in Modeling and Simulation (BRIMS'11). Provo, UT.

Year 2 Progress

3. Automated Transformations

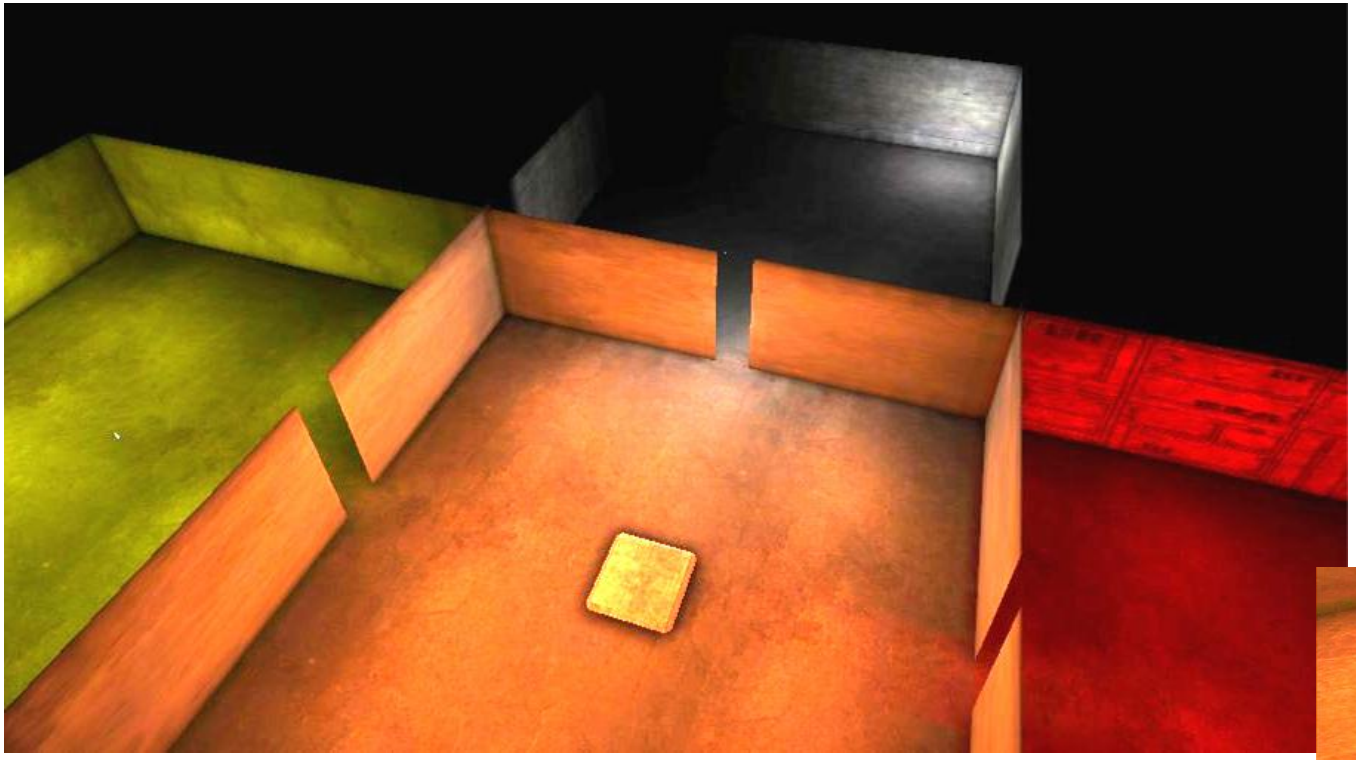




Year 2 Progress

4. Verification of RML's Cognitive Fidelity

- "Coverage" of key ACT-R properties/capabilities
  - Declarative knowledge structure/complexity effects
  - Procedural to declarative shift
  - Impact of human/device interface
- Persistent agents in synthetic task environments
  - Sensitivity to the information structure of the environment
  - Learning to navigate in virtual worlds



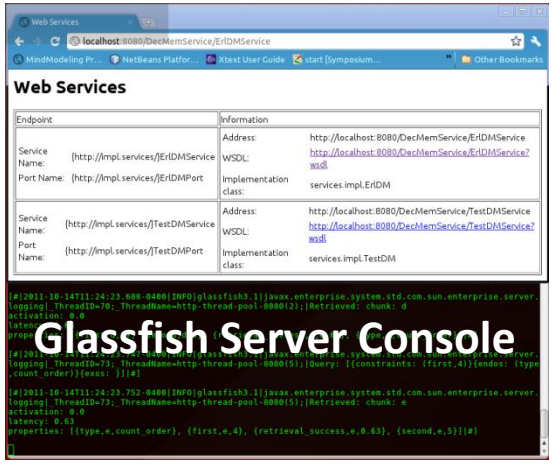
- “Reward” randomly appears in 3 rooms
- Probability of room/reward varies

	green	blue	red
period1	0.6	0.3	0.1
period2	0.2	0.2	0.6
...			

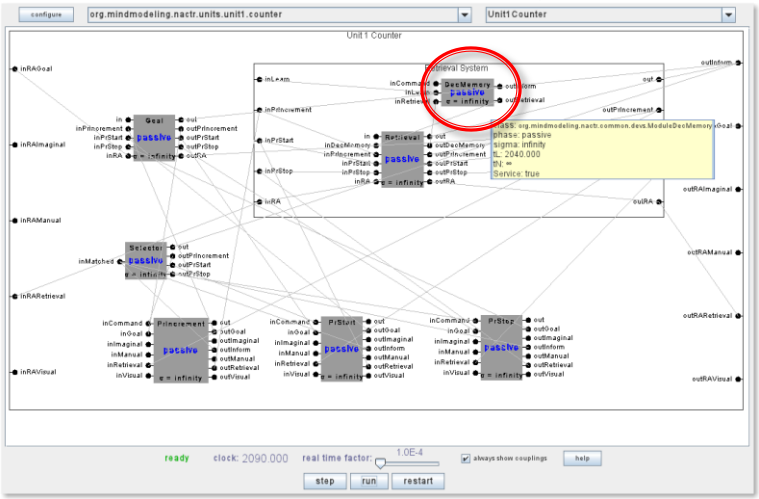
- Agent’s room preferences adapt to match reward probabilities
- Agent learns to realize its choices in synthetic task environment

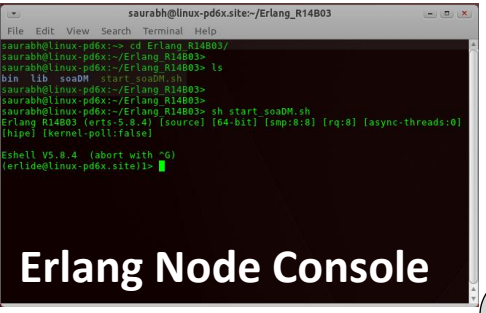
Year 2 Progress

5. Declarative memory SOA appliance (soaDM)
   - Replicates the retrieval calculus of ACT-R
   - Service in the net-centric M&S framework
   - Exploits multi-core architectures
     - Semantic network realized as Erlang processes
     - Map-reduce using Erlang/OTP
       - Spreading activation achieved through concurrent message passing



DEVS ACT-R Model Components





Service Provider Interface

Abstract Declarative Memory Interface

- ConnectHost, disconnectHost, resetHost
- startApp, closeApp
- loadOntology, uploadOntology
- buildQuery, resetQuery
- execRetrieval
- setProperty, getProperty

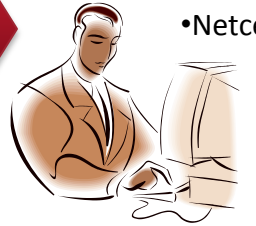
Service Producer

Service Consumer

WSDL

CONSUMERS

- Net-centric Systems
- Browser
- Rich Thin Clients
- Netcentric DEVS ACT-R



JInterface (Java)

Erlang OTP

Service Endpoint (JAX-WS)

Enterprise Web Server

OS/Linux

Hardware (Multi-core, PetaByte RAM)

Network

OS/Linux,Win,OSX

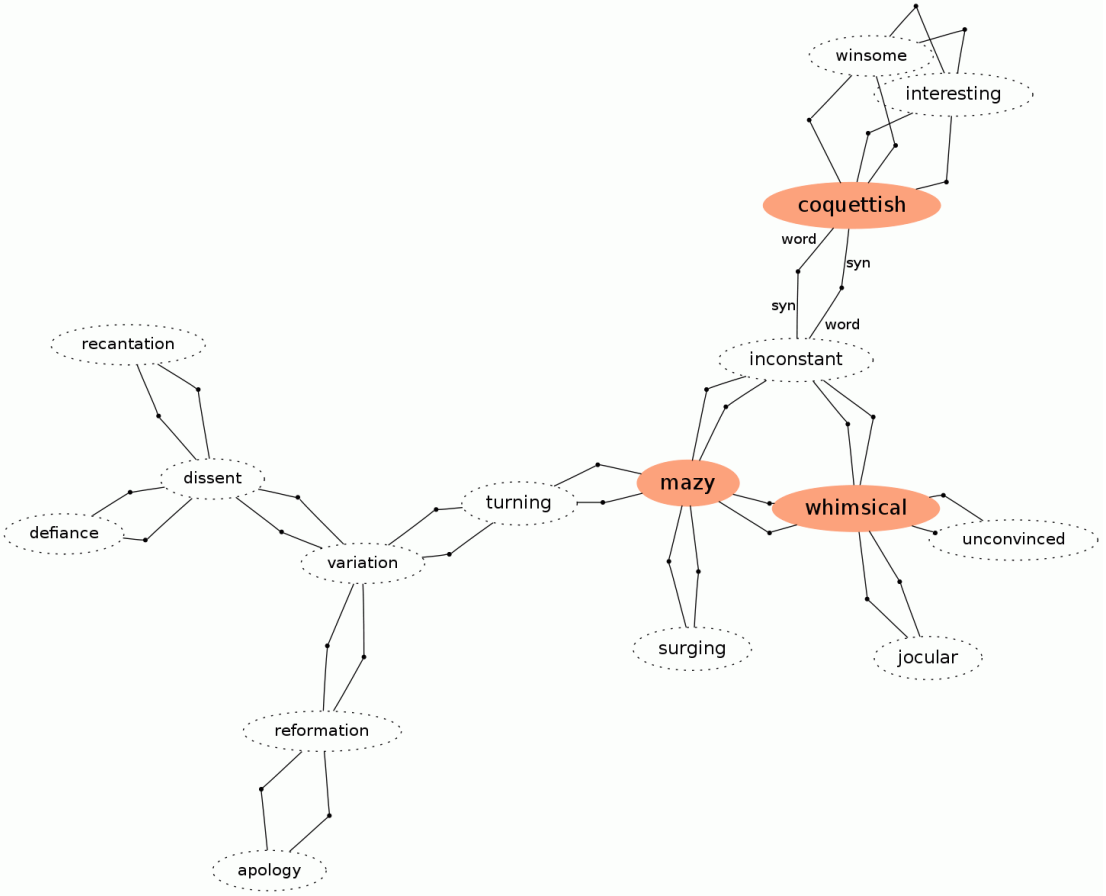
Hardware

Associative Memory SOA Appliance

Moby Thesaurus II

[http://icon.shef.ac.uk/Moby/]

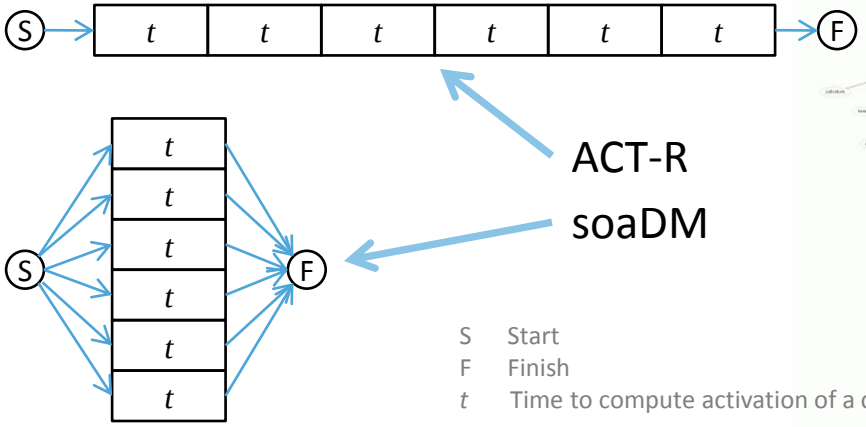
- 30K root words
- 2.5M synonyms
- 83 synonyms per root word



Douglass, S. A. & Myers, C. W. (2010). *Concurrent knowledge activation calculation in large declarative memories*. In D. D. Salvucci & G. Gunzelmann (Eds.), Proceedings of the 10th International Conference on Cognitive Modeling (pp. 55-60). Philadelphia, PA: Drexel University.

Associative Memory SOA Appliance

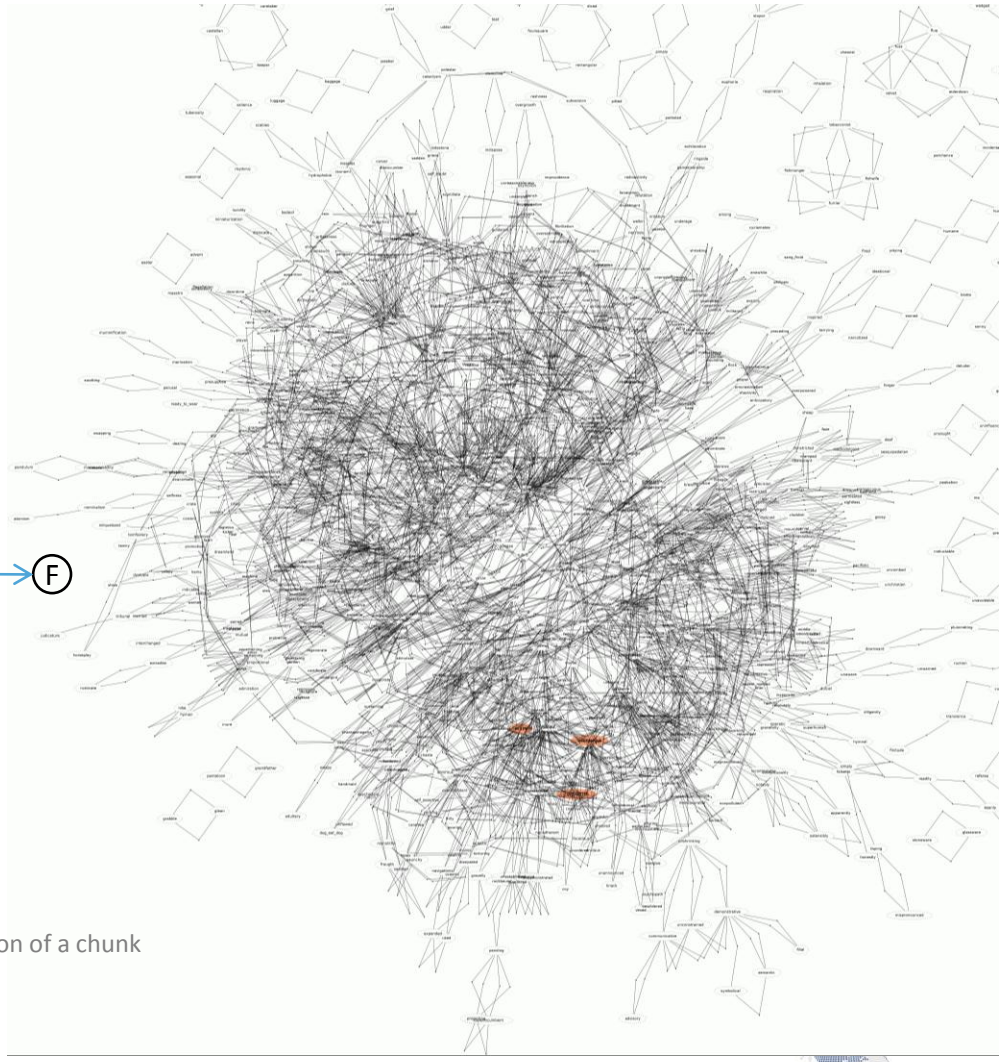
Common Name	Equation
Activation	$A_i = B_i + \sum_{j \in C} W_j S_{ji}$
Base-Level Learning	$B_i = \ln\left(\sum_{k=1}^{n} t_k^{-d}\right)$
Attention Weighting	$W_j = {}^{W}/_{n}$
Associative Strength	$S_{ji} = \ln(prob(i\|j)/prob(i))$
Retrieval Time	$Time = Fe^{-A_i}$
Retrieval Probability	$Prob = 1/(1 + e^{-(A_i - t)/s})$



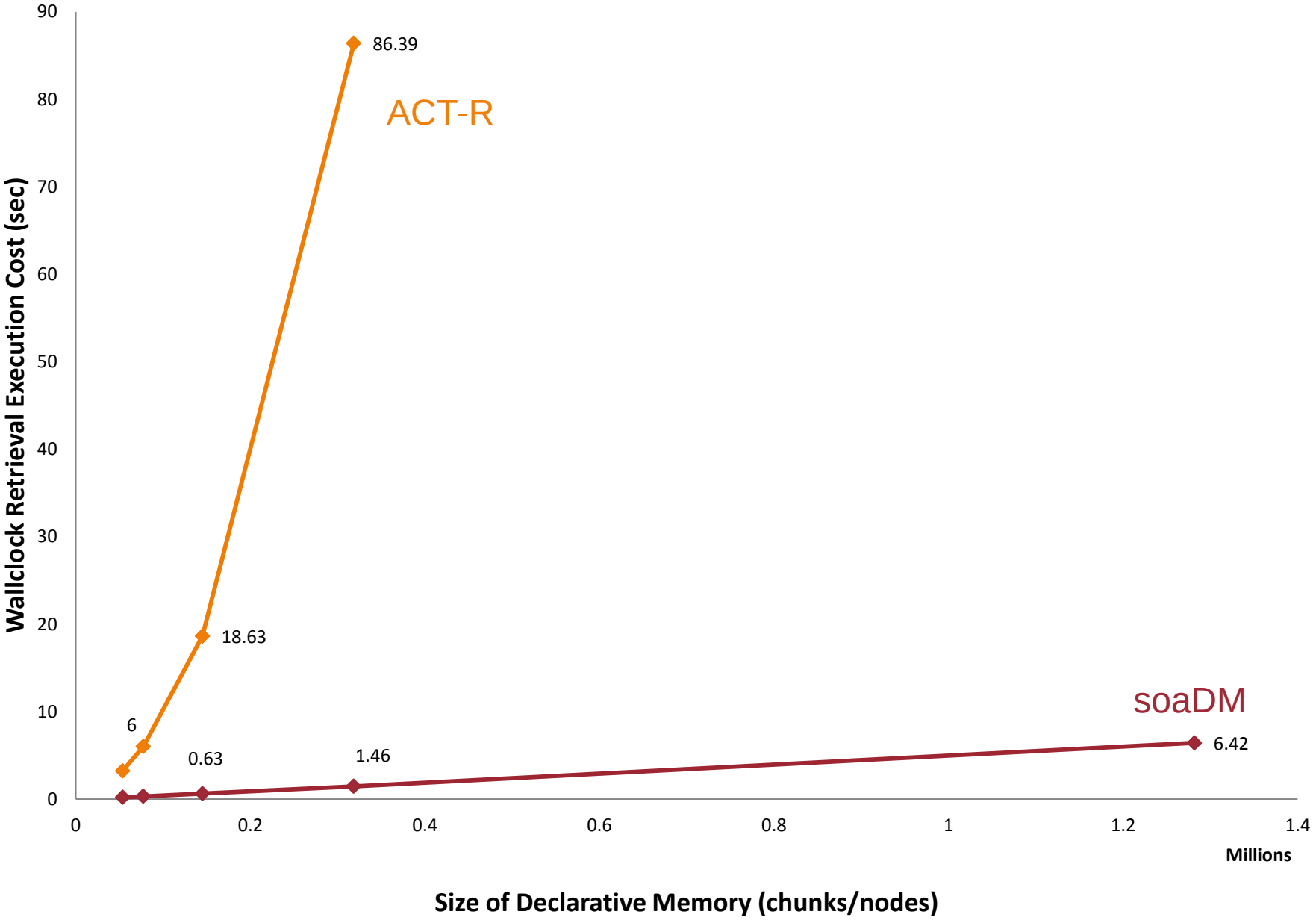
ACT-R

soaDM

S Start
F Finish
t Time to compute activation of a chunk



Scalability of Associative Memory Appliance



Year 2 Progress

6. Integrated Cognitive Modeling Framework

- **DSL use and transformation**
  - **Abstract Syntax Trees**
  - **Cascading automated transformations**
- **Control of modeling and simulation process**
- **Model behavior visualization and analysis**
  - Bogart, C., Burnett, M., Douglass, S. A., Piorkowski, D. & Shinsel, A.. (2010). *Does my model work? Evaluation abstractions of cognitive modelers*
  - Bogart, C., White, R., Adams, H., & Douglass, S., A. (submitted). *Designing a Debugging Language for Cognitive Modelers with Natural Programming Plus*