Integrity ★ Service ★ Excellence

Systems and Software

06 March 2013

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AFOSR
Air Force Research Laboratory
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Form Approved
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Standard Form 298 (Rev. 8-98)  
Prescribed by ANSI Std Z39-18
NAME: Systems and Software

BRIEF DESCRIPTION OF PORTFOLIO:

• Enable quantifiable performance evaluation of critical systems
• Manage environments in order to preserve vital mission functions
• Comprehensively understand distributed effects in large infrastructures to predict global system failures

LIST SUB-AREAS IN PORTFOLIO:

• Composeable Dynamic Models
• Formal Analysis and Verification
• Assessment/Repair of Failure
Current Program Scope

• Composeable Dynamic Models
  – New programming languages or language constructs reduce errors at run-time
  – Domain-specific languages enhance capabilities for code generation

• Dynamic Formal Analysis and Verification
  – Verification of system properties based on formal specifications

• Assessment/Repair of Failure
  – Abstract models of systems and their interactions facilitate automated generation of code

DISTRIBUTION A: Approved for public release; distribution is unlimited.
Scalable Model Checking
C. Tinelli, U. Iowa, C. Barret, NYU

Approach: Formal verification suffers from state space explosion.
Compactly represent logical symbols in scalable nested satisﬁability modulo theory (SMT)

Payoff: More scalable verification to handle large heterogeneous systems

Compact SMT Language

- **Valid:**
  - satisfied by all states in Q

- **Inductive:**
  - \( I(s_0) \models P(s_0) \),
  - \( P(s_n), T(s_n, s_{n+1}) \models P(s_{n+1}) \)

- **k-inductive:**
  - \( I(s_0), T(s_0, s_1), ..., T(s_{k-1}, s_k) \models P(s_0), ..., P(s_k) \),
  - \( T(s_n, s_{n+1}), ..., T(s_{n+k-1}, s_{n+k}), P(s_n), ..., P(s_{n+k}) \models P(s_{n+k+1}) \)

- **Invariant:**
  - satisfied by all reachable states of S
Approach: Heterogeneous and uncertain states characterize system performance across multiple levels of software. Using stochastic models can enable robust characterization for system performance verification.

Payoff: Computationally tractable ways of system performance verification at multiple layers of software including human interaction.

System Performance Model

- Task characteristics
- Communication characteristics
- Cognitive traits

Task Performance Prediction Model

- Metric 1
- Metric N

System Performance Model

- TL = Task load (# enemies)
- MQ = Message quality (% relevant messages)
- WM = Working memory (OSPAN)
- Gaussian noise (fixed std dev)

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Mission Verification
Elbaum, Dwyer U. Neb., Rosenblum

Approach: Develop a language to represent mission scenarios tied to integrated distributed software architecture.

Payoff: Verify global mission properties as function of lower level software constructs for quantifiable fault tolerance in achieving mission objectives
Systems and Software
AFRL Tech Directorate Interest/Coordination

• Information Directorate
  – Systems and Software Producibility
  – Multi-core Computing

• Air Vehicles
  – Flight-critical systems and software
  – Mixed-criticality architectures

• Human Effectiveness
  – Modeling of human-machine systems
  – Meta-information portrayal STTR
  – Robust Decision Making
  – Large Scale Cognitive Modeling/C2WT

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Increased Scale/Integration via DSMLs Anchored in DEVS
(Douglass, 711th HPW/RH)

DEVS (discrete event system specification)
- Formal rigor
- Model reusability
- Interoperability

A discrete event system specification (DEVS) is a mathematical structure (7-tuple)

\[ M = \langle X, S, Y, \delta_{\text{int}}, \delta_{\text{ext}}, \lambda, tA \rangle \]

where
- \( X \) is the set of input values
- \( S \) is a set of states
- \( Y \) is the set of output values
- \( \delta_{\text{int}} : S \rightarrow S \) is the internal transition function
- \( \delta_{\text{ext}} : 2^X \times X \rightarrow S \) is the external transition function
- \( \lambda : S \rightarrow Y \) is the output function
- \( tA : S \rightarrow \mathbb{R}_{\geq 0} \) is the time advance function

Domain-Specific Languages
- Tailored for cognitive modeling
- Semantically anchored in DEVS

High-Performance Computing
- Scalable simulation infrastructure
- Exploiting 25 years of DEVS

Navigator
Plans routes from targets to targets under constraints

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Approach: Use parallel processing resources and network infrastructure as means of emulating and detecting system faults
Payoff: Far fewer defects and more detailed assessment of integrated system performance
Collaborations at AFOSR

- **Information Operations and Security**
  - Fundamental software constructs for system security
- **Information Fusion**
  - Signal and sensor processing for integration of large data into systems architectures
- **Complex Networks**
  - Mathematical and statistical methods for network and networked systems
- **Foundations of Information Systems**
  - Measurement and statistical verification for software, network, and hardware
- **Computational Mathematics**
  - Methods of computational modeling of large complex physical processes
- **Dynamic Data Driven Applications Systems**
  - Strategies for real time feedback of data into distributed computational processes
- **Optimization and Discrete Mathematics**
  - Optimization strategies and algorithms for discrete computational processes
- **Dynamics and Control**
  - Dynamical systems theory for assessment of performance of control architectures

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Agency Interactions:

- **OSTP/NITRD Coordinating Group**
  - High Confidence Systems and Software (HCSS)
- **ASDR&E**
  - Software Producibility Initiative
- **NSF**
  - Cyber Physical Systems
- **NASA**
  - V&V of Flight Critical Systems
  - Ames Research Laboratory

Other Funding Agencies

- **ARO**
- **ONR**
- **DARPA**