Rapid Synthesis of Multi-Model Simulations for Computation Experiments in C2

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Critical Issues in C4I
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Outline

- Program Background
- A typical C2 Architecture, Issues to study
- Multi-modeling integration challenges
- Our approach: The C2 Wind Tunnel (C2WT)
- C2WT capabilities
- Recent C2 scenario demonstrated with C2WT
- C2WT current status
Program Background

**AFOSR:** Partnership for Research Excellence and Transition (PRET) in Human System Interaction Program

**Project:** Human Centric Design Environments for Command and Control Systems: The C2 Wind Tunnel

**Program manager:**
Dr. John Tangney and Dr. David Luginbuhl

**PRET Team:**
- Vanderbilt University: Institute for Software Integrated Systems (ISIS)
- George Mason University: System Architectures Laboratory (SAL)
- UC Berkeley
Typical C2 Architecture

C2 issues to be studied experimentally:

- **Distributed Mission Operation**
  - Synchronization and coordination
  - Distributed dynamic decision making
  - Network effects

- **Increased Information Sharing**
  - Shared situation awareness
  - Common Operation Picture (COP)
  - Network effects

- **Seamless Integration of Manned/Unmanned Assets**
  - Mixed-Initiative Teams

- **System Level Impact Analysis**
  - Cyber attacks
  - Resilience solution
  - Strategy/gaming
How can we integrate the simulated heterogeneous system components?
How can we integrate the simulation engines?
How can we rapidly synthesize and deploy integrated simulations?
Multi-Model Integration Challenges

Integrating models

- Heterogeneous models for different domains: human organizations, communication networks, C2 software systems, vehicle simulations, etc. These models need to talk to each other somehow.
- Needed: an overarching integration model that connects and relates these heterogeneous domain models in a logically coherent framework.

Integrating the system

- Heterogeneous simulators and emulators for different domains: Colored Petri Nets, OMNET++, DEVS, Simulink/Stateflow, Delta3D, etc.
- Needed: an underlying software infrastructure that connects and relates the heterogeneous simulators in a logically and temporally coherent framework.

Key idea: Integration is about messages and shared data across system components. Why don’t we model these messages and shared data elements and use these models to facilitate model and system integration?
C2WT Metamodel

 Defines language for integrating models in scenarios

- Graphical representation of definition of the Model Integration Language (MIL)
- Compatible with OMG’s Unified Modeling Language (UML) standard
- Defines the syntactic, semantic, and presentation information of a domain

Note: Only a part of the metamodel is shown here.
Example: A specific data-model used in a complex C2 scenario

Inheritance
Example: Integration model of a specific C2 scenario

Federates (component simulators) publish and subscribe to various types of interactions. (—)
Specific dataflows across networks are specified via ported federates and dataflow connections (-----)
Simulation models

Domain specific models
-- abstract simulation models

• Data models
  -- interaction & data models
• Integration models
  -- data-flow, timing, & parameters

Configuration

Domain specific federates

<table>
<thead>
<tr>
<th>OMNeT++ federate</th>
<th>CPN federate</th>
<th>Devs Java federate</th>
<th>Simulink federate</th>
<th>Physics federate</th>
<th>Sensor simulation federate</th>
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HLA RTI (Portico)
Example: Simulink Model Integration (Vehicle dynamics)

Original Simulink model (X4 simulator)

Modified model

Add input-output bindings

Input binding

Output binding

Signal flow

Signal flow

HLA Run-Time Infrastructure (RTI)

GME integration model

Generated .m Receiver and Sender S-function code + .java code for representing Simulink federate

Code generation

RTI runtime communication
Three levels of modeling & customization:

- **Modeling the modeling tools - Infrastructure**
  - Performed “one-time” when a new simulation platform (model type) is integrated [usually by developers]

- **Modeling the integration of the models – Scenarios**
  - Performed when a new scenario has to be experimented [usually by subject matter experts who can describe scenarios]
  - Requires:
    - Models of model tools used (‘federates’)
    - Data models
    - Integration models: Interactions among the models

- **Modeling the situations – Experiments**
  - Execution platform, experiment setup, deployment [usually by experimenters who can parameterize experiments and analyse experimental results]
C2WT Capabilities

- Provides a rapid system integration technology
  - For empirical studies in human system interaction paradigms in dynamic C2 architectures.

- Supports Scenario driven experimentation
  - Extensible infrastructure supported by metamodeling.
  - Rich suite of modeling languages already covering C2 team/organizational modeling aspects.
  - Model-based simulation integration exploring metamodeling and model transformation.

- Provides infrastructure for detailed instrumentation & analysis
  - Foundation for driving operational tools and cognitive performance monitoring tools.
  - Detailed simulation logging at various levels (status, scenario, debugging).
  - WebTAS (Web-enabled Temporal Analysis System) integration.

- Parameterizable models and scalable distributed infrastructure
  - Parameterized scenario specifications.
  - Experiment control and human in the loop simulation.
  - Automated federation deployment, batch execution of scenarios, experimentation, and analysis.

- High quality, open source tools and components
  - Most of the tools used are in use worldwide by the research community and industry (MIC Tools, Omnet++, Portico, Devs, Delta3D, CPN, OGRE).

- Very low cost, open-source infrastructure
  - Distributable to the research community and government industry users
The OpenC2WT community website

- The OpenC2WT community website is:
  - [http://wiki.isis.vanderbilt.edu/OpenC2WT](http://wiki.isis.vanderbilt.edu/OpenC2WT)

- A website for C2WT community, for end users, contributors, and developers.

- Provides access to the C2WT installation release

- Provides all “relevant” documentation and example cyber scenarios demonstrated with C2WT

- Provides re-usable simulation “component libraries”

- Serves as a primary means for C2WT dissemination and collaboration
The scenario was defined by Prof. Alex Levis’ team at GMU

- Demonstrates integration of loosely coupled models in support of operations of Central Command and Control (Blue team)
- Focusses on finding, tracking, and acting on time-critical adversary targets (Red team)
- Includes human organization models involving tactical and operational decision making
- Exemplifies Command and Control resilience in the presence of cyber attacks
- Demonstrates time-sensitive and reactive (adaptive) modeling of Red and Blue actions.
- Demonstrates two-sided action in an urban environment
Blue team:

- CAOC
  - Commander
  - Dynamic Targeting Cell (DTC)
  - ISR Division (ISRD)
- Cyber Cell

Red Team: Red Leader, WMD and VBIED trucks, truck drivers, Bomb factory

- SIGINT
- UAV Operators/Controllers
- Land Component (LCC)
Intel learns that a delivery of bomb making materials is to be made to the bomb making facility. The exact location of the loading point of the delivery truck is not known, but the expected route and key identifying features (e.g. type and color) of the delivery truck is provided.

Two UAVs (UAV 1 and 2) are in the vicinity of the expected truck route and the neighborhood where the bomb making facility may be located. A third UAV (3) is within range if needed.

- Red truck with bomb materials travels from supply location to the IED factory
- Red Cell Leader calls IED factory to report pending delivery of bomb making materials
- Bomb materials truck arrives at IED factory

- Vehicle with IED leaves factory and travels to pre arranged bombing location
- Vehicle driver arms IED
- Vehicle driver leaves vehicle and calls lookout facility saying the IED is armed
Experimentation:
Providing answers to Command and Control questions

Key Events/Messages
Blue’s View

Cell Phone Intercept
UAV 1 Tracking Vehicle
UAV 1 locates building

ORA Social Network
C2WT Current Status

- The C2WT is a prototype of an operational system

- The C2WT has been installed at AFRL/RI – Rome Research site and is operational

- The C2WT is being prepared by AFRL/RI for transition to AFIOC

- The C2WT has been implemented and is operational at Vanderbilt, George Mason and Carnegie Mellon Universities with the models shown in the demonstration

- The C2WT is being used by research communities like at Sandia and BAE systems
Thank you!

- Questions?

- Contact:
  - Himanshu Neema
    - Email: himanshu@isis.vanderbilt.edu

- The OpenC2WT community website
  - [http://wiki.isis.vanderbilt.edu/OpenC2WT](http://wiki.isis.vanderbilt.edu/OpenC2WT)