Outline

- Program overview
- Rules analysis
- Inference engine
- Web service and client
- Future directions

The authors would like to thank the Test Resource Management Center (TRMC) Test and Evaluation / Science and Technology (T&E / S&T) Program for their support. This work was funded by the T&E/S&T Program through the Netcentric System Test (NST) focus area under contract with PEO STRI, Orlando, FL, contract N68936-09-C-0152.

Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Test Resource Management Center (TRMC) Test and Evaluation/Science & Technology (T&E/S&T) Program and/or the U.S. Army Program Executive Office for Simulation, Training & Instrumentation (PEO STRI).

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Program Overview (1 of 2)

- **Test & Evaluation Need**
  - Net-Centric Systems Test Science & Technology group identified a need to accurately evaluate systems for compliance with NR-KPP requirements.
  - Need included ability to assess tactical system Service Oriented Architecture and map the assessment findings to the NR-KPP requirements.

- **Science & Technology Challenge**
  - Conduct R&D for creation of tool and methodology for **automated** evaluation of mandatory NR-KPP compliance by assessing system’s architectural artifacts.
  - Output of resulting tool was to contain sufficient information to provide the user with explanations and alerts on **varying degrees** of NR-KPP compliance.
  - Prototype to determine NR-KPP compliance for a netted weapon system.

- **NetRAE Tool Development**
  - Three-phase program from 2008 through 2010
  - Final prototype included existence and relationship rules compliant with Joint Interoperability Test Command’s (JITC’s) rules, an Inference Engine, a web service and application, and rules database for a central repository.
Program Overview (2 of 2)

NetRAE NR-KPP Assessment Steps
1) Architecture created in Rhapsody
2) Artifacts imported into NetRAE tool
3) Check for existence and accuracy
4) Assess critical factors for degree of architecture end-to-end performance
5) Feedback to program

NetRAE

Import Mechanism
• Input as tagged data
• Impose some restrictions on form
• Present as a common form for views and data relationships

Initial Compliance Check
• Initial capability to take user through step-by-step check for required data
• Growth within scope to automate portions of script allowing, not requiring, user view

Critical Factor Assessment
• Initial capability to cue user on critical factors to pull out for Net Ready assessment
• Growth within scope to automate extraction of critical factors and system-specific risks

Compliance Report
• NCOW RM mapping exists to activities and technical standards
• Correct artifacts exist
• Data model provided
• Document gaps

Critical Factor Report
• Common critical Net Ready T&E factors
• System-specific risk and T&E drivers
• Document linked factors and program data for test plans

Architecture from Weapon System
• DoDAF Artifacts
• Populated architecture tools
• Tagged data files

Input Options

Feedback to Program

Input Options

Net Ready Requirements
**Rules Analysis (1 of 4)**

- **Requirement**
  - Metrics used assess information exchange end-to-end operational effectiveness for:
    - Net-centric data & services strategies
    - Applicable GIG Technical Guidance
    - DoD Information Assurance and Critical Infrastructure requirements
    - Supportability requirements
    - “Solution” architectures

[The required DoDAF artifacts for various DoD acquisition documents are shown in the diagram at right]

<table>
<thead>
<tr>
<th>ICD</th>
<th>CDD</th>
<th>CPD</th>
<th>ISP</th>
<th>TISP</th>
<th>ISP Annex (Svc/ Apps)</th>
</tr>
</thead>
<tbody>
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<td>X</td>
</tr>
</tbody>
</table>

**Note 1**: Required only when IT and NSS collects, processes, or uses any shared data or when IT and NSS exposes, consumes or implements shared services.

**Note 2**: The TV-1 and TV-2 are built using the DIStime and must be posted for compliance.

**Note 3**: The AV-1 must be uploaded onto DAR3 and must be registered in DAR3 for compliance.

**Note 4**: Only required for Milestone C, if applicable (see Note 1)

**Note 5**: The naming of the architecture views is expected to change with the release of DODAF v2.0 (e.g., StdV, SvcV, StdV, DIV). The requirements of this matrix will not change.

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Rules Analysis (2 of 4)

Example Architecture Developed

OV-1
Simple Architecture

- Weapon
- Control
- Sensor

Integrated Air Defense

Three Operational Nodes
- Weapon Node
- Control Node
- Sensor Node

Three Activity Diagrams
- Look for Target (Critical Activity)
- Conduct Attack (Critical Activity)
- Assess Weapon Readiness

Four System Nodes
- Sensor System
- Weapon System
- C2 Engagement
- C2 Inventory

Two Interfaces
- Sensor System to C2
- C2 to Weapon System

Includes Models:
- OV-1 Graphic, Mission Concept (*Rhapsody specific)
- OV-2, OV-3, OV-4, OV-5, OV-6c, OV-7
- SV-1, SV-2, SV-3, SV-4, SV-5, SV-6, SV-10c

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Rules Analysis (3 of 4)

NetRAE v1.1 Rule Types

• Existence-type examples
  • Rule: “Is the OV-4 present?”
    • NetRAE v1.1: “OV-4 Organizational Relationship Chart exists.”
  • Rule: “Is the OV-7 present?”
    • NetRAE v1.1: “OV-7 Logical Data Model exists.”

• Relationship-type examples
  • Rule: “Is the OV-5 linkage to OV-6c clear?”
    • NetRAE v1.1: “Each OV-5 maps to one or more OV-6cs.”
  • Rule: “Does the OV-5 include required operational nodes/activities?”
    • NetRAE v1.1: “Each OV-1 mission objective/node maps to an identical OV-5 activity/node.”

Compliance Enables the Evaluator to UNDERSTAND the Architecture

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Are the capabilities of this network adequate?

Test: Are all the NODES traceable

WARNING: Possible Interface Missing

Test: Are all the Critical Interfaces Managed

VALID/INVALID: Critical Interface

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### Conclusions from comparing reasoning methodologies:

1. **Possibility Theory (Fuzzy Logic)** most straightforward approach to meet NetRAE’s rule needs
2. Decision Trees second as viable option (depending mostly on input data and required rule set)

### Inference Engine Overview

<table>
<thead>
<tr>
<th>Metrics vs. Methods</th>
<th>Possibility Theory (Fuzzy logic)</th>
<th>Bayesian</th>
<th>Certainty Theory</th>
<th>Dempster-Shafer</th>
<th>Decision Trees</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lit search of “Compliance Auditing” using this method</td>
<td>Many</td>
<td>Some</td>
<td>None</td>
<td>None</td>
<td>Some</td>
</tr>
<tr>
<td>Academic community using methodology (over last 10 yrs)</td>
<td>Many</td>
<td>Many</td>
<td>Little</td>
<td>Some</td>
<td>Many</td>
</tr>
<tr>
<td>NetRAE assumed inputs fit model's inputs and assumptions</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Most</td>
</tr>
<tr>
<td>Straight forward; easy to understand</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

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Rule-Based Design Definition

- User queries input data source (through inference engine) which searches testable data and produces results on the input data source
- Knowledge base is represented in the form of sets of rules (with varying levels of uncertainty) and includes semantic context of the input objects
- Attributes & relationships between objects of interest are detailed in the semantic network

**Example of a production rule form (in the context of NetRAE)**

IF <condition (or evidence)> THEN <conclusion (or hypothesis)>

where <condition> and <conclusion> are variants:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>View A is Found</td>
<td>Rule is Valid</td>
</tr>
<tr>
<td>View A Element 1 is Not Found</td>
<td>Rule is Invalid</td>
</tr>
<tr>
<td>View A is Found &amp; View A Element 1 is Not Found</td>
<td>Rule is Invalid</td>
</tr>
<tr>
<td>Relationship link 1 between views Found &amp; Relationship link N between view Found</td>
<td>Rule is Valid</td>
</tr>
<tr>
<td>Etc … (any other variations of items using AND, OR, and NOT)</td>
<td>Etc …</td>
</tr>
</tbody>
</table>

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## Inference Engine (3 of 4)

### NetRAE Fuzzy Rules Example

<table>
<thead>
<tr>
<th>Rule Identifier</th>
<th>View</th>
<th>Element</th>
<th>Rule</th>
<th>Found Results</th>
<th>Not Found Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>OpNodes_1</td>
<td>OV-2, OV-1</td>
<td>Operational Nodes</td>
<td>For a Node in OV-2, there is a representative Node in the OV-1.</td>
<td>Valid</td>
<td>Invalid</td>
</tr>
<tr>
<td>OpNodes_3</td>
<td>OV-2, OV-5</td>
<td>Operational Nodes Mapped to Operational Activities</td>
<td>For a Node in OV-2 there is at least one OV-5</td>
<td>Valid</td>
<td>Invalid</td>
</tr>
<tr>
<td>OpNodes_4</td>
<td>OV-2, OV-6c</td>
<td>Operational Nodes Mapped to Event Sequence Life Lines</td>
<td>For a Node in OV-2 there is at least one instance of a Liveline in at least one OV-6c</td>
<td>Valid</td>
<td>Invalid</td>
</tr>
<tr>
<td>OpNodes_2</td>
<td>OV-2, OV-4</td>
<td>Operational Nodes &amp; Organization Nodes</td>
<td>For a Node in OV-2, there is a representative Node in the OV-4.</td>
<td>Valid</td>
<td>Warning</td>
</tr>
<tr>
<td>Op_Nodes_0</td>
<td>OV-1, OV-2, OV-3, OV-4, OV-5, OV-6c</td>
<td>For each Operational Node in OV-2</td>
<td>Provide results of OpNode_1 thru OpNode_4</td>
<td>Warning</td>
<td>Warning</td>
</tr>
</tbody>
</table>

**Binary Results (0/1)**

**Non-Binary Results (0-1)**
Inference Engine (4 of 4)

Rules for OpNodes_2 (Non-Binary Results Desired)
- OpNodes_2: For a Node in OV-2, there is a representative Node in the OV-4

Rule Form

IF (RatioOfAllNodes-OV2-OV4 is X4) THEN (OpNodes_2 is Z)

\[
\text{RatioOfAllNodes - OV2 - OV4} = \frac{\text{# of links found}}{\text{total OV2 nodes found}}
\]

Definition of Non-Binary Input Variable:

<table>
<thead>
<tr>
<th>Membership Sets</th>
<th>Relationship Mapping Table</th>
<th>Example (0.67)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Invalid</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cond #</th>
<th>X4</th>
<th>Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>High</td>
<td>Valid</td>
</tr>
<tr>
<td>2</td>
<td>Low</td>
<td>Invalid</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Invalid()</th>
<th>Valid()</th>
</tr>
</thead>
<tbody>
<tr>
<td>n/a</td>
<td>0.67</td>
<td>n/a</td>
</tr>
</tbody>
</table>

Centroid of rule results

Output: 0, 0.67, 1.0
Web Service and Client

- **Stated Need**
  - Provide a connection to non-Rhapsody architecting tools
  - Provide a capability for users without Rhapsody knowledge
  - Reduce the number of Rhapsody licenses to be acquired

- **Web Service**
  - Supports local or remote (via network/internet) input of architecture and rules
  - Allows evaluation results to be returned via download

- **Web Client**
  - Client enables automation of architecture submission process
  - Client software needed due to complex data types required by Service
  - Client can be used to submit files and receive analysis report
  - Allows evaluations to be requested by person or automated by software
Future Directions

- **Research**
  - Natural language input
  - Develop method to evaluate artifacts provided by non-architecting tools
  - Explanation facility for possibility output
  - Learning algorithm for advanced inference engine

- **Development**
  - Incorporate DoDAF Metamodel (DM2) capability
  - Develop interface to other UML architecture tools (e.g. System Architect)
  - Secure user authorization for service

- **Prototype for Demonstration Testing**
  - Demonstrate implementation in tool of Possibility Theory algorithms
  - Leverage developed architecture prototypes
  - Provide JITC near term tool to assist existing architecture evaluations

- **Research funded by US Army BAA**
  - Organization: PEO / STRI (Simulation, Training and Instrumentation)
  - Title: “Network Systems Test Science & Technology (NST S&T)”
  - Timeframe: April 2008-2013, covering six annual multi-year efforts
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