The Application of a Course-of-Action Ontology to Support OPFOR COA Selection and Assessment

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Outline

• Introduction
• Application Overview – Empire Challenge 10 / Green Devil II Exercise
• Utility Theory Overview
• Ontology Overview
• EC 10 Application
• Conclusion
Introduction – Problem Context

COA Selection and Assessment

Ontology

Contour Map

Preference Model

Possible COAs

COA Selection and Assessment Algorithms

COA Ranking

Contour Map Generator

IO Vector Calculator

COA Ranking Algorithm

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Establish COAs (generally 3) that will successfully transition from the current state to the desired final state.

The End-Phase Outcome is defined by the commander strategic objective. This is the overall goal that is to be achieved by the COA.
Application Overview

• Empire Challenge 10 / Green Devil II Exercise

• Problem
  – Determine why an OPFOR insurgent group was pursuing a given course of action
  – Predict the next course of action that the insurgent group would pursue

• The OPFOR has the following goals
  – Short Term – inflict damage
  – Medium Term – discourage confidence in host nation government
  – Long Term – impose cultural and religious control
Utility Theory Overview

- The COA selection / assessment decision problem as a utility-theoretic multi-attribute decision problem
- Utility theory was originally developed in economics to measure the desirability of a good or alternative from the perspective of an agent
- A utility function is given by:
  \[ u : O \rightarrow \mathbb{R} \]
  - \( O \) are the possible alternatives
  - \( \mathbb{R} \) is a real-valued number
- A common form of utility function is a weighted sum of attribute values:
  \[ u(o_i) = \sum_k w_k \cdot a_k[o_i] \]
  - \( w_k \) is an attribute weight
  - \( \sum_k w_k = 1, w_k \geq 0.0 \)
- The set of attribute value scores \( a_k[o_i] \) is the IO vector
- A preference is a relation between alternatives such that \( u(o_i) \geq u(o_j) \)
Ontology Overview – Core

- The core ontology defines the basic concepts, relations and rules for modeling decision problems.
- Concepts include: attributes, alternatives and preferences
- Rules include: dominance, value functions and level calculators
Alternatives, Attributes, Preferences

Alternatives are defined in terms of a collection of attributes.

Attributes have raw levels (the measured or observed values), values (a normalized value), and weights.

Preferences implicitly represent the trade-offs among attributes from the perspective of a decision maker.
Ontology Overview – Course of Action

- The course of action ontology defines the basic concepts and relations for modeling COA selection decision problems
- Concepts include: COAs, phases, lines of effort, measures of effectiveness
Outcomes and MOEs

Measures-of-Effectiveness are a type of attribute used to describe the outcome of an action.

An action outcome is an alternative that represents the result of a COA. Preferences are asserted over action outcomes.

Instances of action outcomes are the specific result of a COA, described by MOEs. MOEs have subjective levels (red, amber, green), numeric level and normalized value.
Ontology Overview – COIN

- The COIN ontology defines the basic concepts and relations for modeling COIN domain knowledge.
- Concepts include: specific COIN and insurgency activities and measures of effectiveness.
EC 10 Application – Example

• Using SPIN / SPARQL rule-based inference, a preference graph is generated by the following steps
  – Create an IO vector by inferring a qualitative value, followed by a utility-theoretic value for a collection of possible and actual COA outcomes
  – Elicit a preference model from an SME over a collection of possible COA outcomes (independent of how those outcomes are achieved)
  – Infer a preference graph over a collection of possible COAs that is consistent with the preference model
Each event or action is defined using multiple MOEs.
Each MOE is described in terms of the source numeric level and a subjective green / amber / red level.
Rules transform the number level into the subjective level.
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Each MOE is described in terms of the source numeric level and a subjective green / amber / red level
Rules transform the number level into the subjective level
The result of the transformation of a numeric level to a subjective level can be displayed as a COA effect prediction table
Each row is a COA; the columns represent the subjective levels that are the predicted effect of executing the event

<table>
<thead>
<tr>
<th>Course of Action</th>
<th>Discourage confidence in host nation government</th>
<th>Impose religious and cultural control</th>
<th>Inflict destruction on COIN forces</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle borne IED attack</td>
<td>green</td>
<td>amber</td>
<td>amber</td>
</tr>
<tr>
<td>Attack against CF FOB or PB</td>
<td>amber</td>
<td>amber</td>
<td>amber</td>
</tr>
<tr>
<td>Attack against civilian NAI</td>
<td>green</td>
<td>green</td>
<td>red</td>
</tr>
<tr>
<td>Sniper attack against CF PB</td>
<td>amber</td>
<td>amber</td>
<td>amber</td>
</tr>
<tr>
<td>Sniper attack against local official</td>
<td>green</td>
<td>amber</td>
<td>red</td>
</tr>
<tr>
<td>Deliberate ambush on CF patrol</td>
<td>green</td>
<td>amber</td>
<td>green</td>
</tr>
<tr>
<td>Hit and run against CF convoy</td>
<td>amber</td>
<td>amber</td>
<td>amber</td>
</tr>
<tr>
<td>Roadside IED attack in village A</td>
<td>red</td>
<td>red</td>
<td>green</td>
</tr>
<tr>
<td>Roadside IED attack in village B</td>
<td>green</td>
<td>green</td>
<td>amber</td>
</tr>
</tbody>
</table>
IO Vector Calculation – Step 2

- The IO vector results from applying a value function to each attribute
- This value function converts the subjective level to a numeric (utility-theoretic) value
The IO vector results from applying a value function to each attribute. This value function converts the subjective level to a numeric (utility-theoretic) value. The IO vector for each COA is displayed in tabular form. Each row is a COA; the columns represent the (utility-theoretic) values that are the predicted effect of executing the event.
Preference Modeling

• Preferences are asserted over a collection of possible outcomes (independent of how those outcomes are achieved)

• For example, an SME playing the role of an insurgent leader might have the following preferences:
  – Outcomes with the best values for the feature “inflict destruction on COIN forces” are most preferred
  – For outcomes with the same value for the feature “inflict destruction on COIN forces”, prefer outcomes with the best values for the feature “discourage confidence in host nation government”
  – For outcomes with same value for the feature “inflict destruction on COIN forces”, and “discourage confidence in host nation government”, prefer outcomes with the best values for the feature “impose religious and cultural control”
Preference Modeling

According to the preference model just outlined, the most preferred COA in the table above is #47; followed by #16.
Preference Graph

Using a method whose details are out of scope for this paper, a preference graph is inferred.

- The nodes are the possible COAs and the edges represent the preference relation.
- Nodes with a green title bar are the most preferred. Nodes with a red title bar are the least preferred. Nodes with an amber title bar lie somewhere in between.

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Most preferred COAs are those that inflict damage on the coalition forces in an area that is more supportive of the CF.

Least preferred COAs are those that inflict damage on civilians / non-combatants.
Conclusion

• Initial results from the EC 10 demo showed promise for this approach
• Relatively broad and deep model of the COA domain
  – IO feature vectors for describing COA effects, utility-theoretic preference models
• Visualization of the COA preference space clearly showing the most- and least-preferred COAs
• Extensive use of inference to support a “code-free” processing chain