Semantic Interoperability in Distributed Planning

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Outline

Introduction – Future C2 Requirements

Framework for Distributed Mixed-Initiative Planning

Leveraging Semantic Technologies

Conclusion
Future C2 Planning Requirements

• US forces being called on to support two types of conflicts:
  – Traditional force-on-force engagements
  – Smaller-scale conflicts characterized by insurgency tactics and time-sensitive targets of opportunity
    -> Requires a flexible C2 process that can adapt to the level of conflict
    -> Requires full-spectrum, joint warfighting capability (air, land, sea, & cyber)

• Air Force moving towards a model of continuous air operations not bounded by traditional 24-hour Air Tasking Order cycle
  -> Requires highly synchronized, distributed planning and replanning capabilities
  -> Requires transition from process of Observation and Reaction to Prediction and Preemption
Distributed Episodic Exploratory Planning (DEEP)
Challenges for the Future AOC

“AF C2 Enabling Concepts”
May 2006 Draft Document, AF/A5

• “... geographically separated but ... function as if collocated.”
  ➢ Distributed /Reachback planning

• “... maximize distributed network capabilities should engaged AOC encounter a catastrophic event ...”
  ➢ Redundant/Backup planning

• “... day-to-day, steady state C2 of continual lower-end contingencies.”
  ➢ Continuous planning

• “.. rapidly adapt to the level of conflict by connecting with worldwide capabilities, including joint and coalition forces.”
  ➢ Flexible, scalable, tailorable C2

“The AF will begin immediately to restructure JEFX-08 to focus on Joint C2 as one of its primary initiatives.”
CSAF Memorandum, 3 Aug 2005
Objectives of the DEEP project

• Develop in-house a prototype system for distributed, mixed-initiative operational-level planning that improves decision-making by applying analogical reasoning (i.e. the anticipation aspect of CPE) over an experience base

• Augment human intuition and creativity

• Specifically:
  – AI Blackboard for multi-agent, non-deterministic, opportunistic reasoning
  – Case Based Reasoning to capture experiences (successes and/or failures)
  – Episodic Memory for powerful analogical reasoning
  – Multi-Agent System for mixed initiative planning
  – ARPI Core Plan Representation for human-to-machine common dialog
  – Constructive Simulation for exploration of plausible future states

“Plans are worthless — but planning is everything.”
Dwight D. Eisenhower
DEEP Architecture

User Interface

Case Base  CBR System

Engaged CMDR: “I have a situation!”

JTF Agents (“CBR”)

Specialist Agents (“Critics”)

Adaptation Agents (“Repairers”)

Plan Execution

Simulated

Plan Execution

Selected:

Candidate Plans:

Objective 1

Objective 2

…”

Situation

Objectives

Situation

Selected:

Candidate Plans:

Objective 1

Objective 2

…”

Plan Execution

Simulated

Plan Execution

Adjusted

Plan Execution

Judged
Framework for Distributed Mixed-Initiative Planning

- **Core Plan Representation**
  - Object-oriented plan framework developed under ARPI
  - Motivation: Interoperability
  - Extended for DEEP (effects, outcome, costs,..)

- **Provides**
  - Human-machine dialog (mixed-initiative)
  - Recursive (multi-level)
  - Plan fragments (dist. C2)
  - Interoperable C2 (both integrated and joint)
DEEP adaptation of CPR

APRI-CPR model specification was too abstract to be used directly

Planning information within DEEP is structured (taxonomy based), making the free text used in APRI-CPR inadequate

DEEP uses a CBR system for plan selection and storage
Leveraging Semantic Technologies

Adjusted Specialist Agents

Objectives

Situation

Candidate Plans:
Selected:

User Interface

CBR System

Case Base

Suggeste d

Plan Execution

Suggested

Judged

Engaged

JTF Agents (CBR)

CMRD:

"I have a situation!"

Adjusted

Specialist Agents ("Critics")
Need for semantics

Hard coded and Implied Semantics

Difficult to extend
Defined terms have meaning only to people that developed them
Interpretation must be programmed into application

Semantic technologies enable us to say

I am talking about this specific “Thing”

This “Thing” has the following capabilities

Fly
Transport
Bombard
etc …
Why RDF in N3

Simple, provides a shorthand non-XML encoding of RDF

Designed with human-readability in mind

Extendible

Much more compact and readable than XML RDF encoding
  – XML RDF can be misleading to the human eye
    • RDF=Graph, while XML = Hierarchy tree

Has sentence like structure
DEEP-CPR Semantic extensions

DEEP-CPR Plan has a well defined object-oriented structure

These objects are expressed with taxonomy terms

DEEP-CPR taxonomies are encoded in RDF for capturing semantics
DEEP-CPR Semantic extensions

DEEP-CPR taxonomy concepts are grounded to a commonly accepted upper ontology models such as DC, FOAF, FRBR, etc…
Semantic Technology Benefits

Expressive, Descriptive
- Individual meaning and context can be represented and attached to information
- Each concept can be given any number of properties that provide both supplemental information as well as the relationship it has to other concepts

Abstraction
- Provides a structure that can be directly interpreted as layers of abstraction

Longevity
- Formal definitions of information semantics provide a structure that can be represented beyond a specific applications

Interoperability
- Provides a more formal basis for promoting predictable data transformation between information spaces
Building ontologies
  – Requires knowledge engineers
  – Effective within a small domain

Indexing ontologies
  – Currently no standard methods for indexing and allowing searches over ontological concepts and relationships

Ontology versioning
  – Ramifications on dependant ontologies when source ontology changes

Structure vs. Flexibility
  – Restrictions placed on a concept will be inherited by any instance of that concept type
Conclusion

DEEP project has successfully completed year one of four-year effort

Presented a number of extensions, both existing and planned to the CPR framework
Questions?
Objective of the DEEP Project

• To provide a mixed-initiative planning environment where a human experience is:
  – captured
  – developed
  – adapted

• Augment human intuition and creativity

• To support the distributed planners in multiple cooperating command centers to conduct distributed and collaborative planning
The original ARPI-CPR

• Motivation
  – Plan interoperability
  – Object-oriented plan framework based on UML

• Recursive nature of CPR supports planning at all levels:
  Strategic  Operational  Tactical

• Most commonly shared set of objects:
  Objective  Action
  Actor  Resource