“Mixed-Initiative Planning in a Distributed Case-Based Reasoning System”

C2 Architectures and Technologies

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Overview

• Future C2 Challenges and Vision
• Related Work & MI Challenges
• Approach Overview
• Architecture & Supporting Technologies
• User Interface Mockup
• Future Work / Research Areas
• Conclusion
Future C2 Challenges

• 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 any 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 Air Tasking Order plan-execute cycle
  ➢ Requires highly synchronized, distributed planning and replanning capabilities
  ➢ Requires transition from process of Observation and Reaction \(\rightarrow\) to Prediction and Preemption
Distributed Episodic Exploratory Planning (DEEP) Overview

• Research platform for distributed, mixed-initiative planning

• Objectives:
  – Provide a **mixed-initiative planning environment** where human expertise is captured and developed, then adapted and provided by a machine to augment human intuition and creativity.
  – Support **distributed planners** in multiple cooperating command centers to conduct distributed and collaborative planning.

• Technologies:
  – Experience-Based Reasoning
  – Multi-Agent Systems
  – Distributed Blackboards
  – Exploratory Simulation
Related Work

• DARPA Program - *Mixed Initiative Control of Automa-teams* (MICA) (Final Tech Report 2004)

• *Expectation Failure as a Basis for Agent-Based Model Diagnosis and Mixed Initiative Model Adaptation during Anomalous Plan Execution* (Mulvehill 2007)

• *A Model of Types and Levels of Human Interaction with Automation* (Sheridan 2000)
Challenges

• Mixed-Initiative Interaction Challenges (Horvitz 07):
  – Recognition of relevant problems
  – Decomposition of the problems into subproblems
  – Identification of subproblems that might be best solved through automation
  – Solution of the subproblems
  – Integration of human and machine contributions
  – Communication and coordination about this reasoning and problem solving

Objective

- Agile C2 requires a “rich and continuous set of interactions between and among participants…and with the broadest distribution of decision rights.” Alberts (2007)
- The current DEEP implementation lacks this “continuous set of interactions”
- This approach supports more agile C2
Approach Overview

Human Contribution
• Template Development
• Library Usage
• Constraint

Computer Feedback
• Critic Agent Analysis
• Experience-Based Suggestions
• Exploratory Analysis
• Warnings / Alerts

Evolving Plan
User Interactions

- Library
  - Template Specification
  - Instance Specification
- Drag and Drop
- Positive/Negative Constraints
Feedback

- Critic Agent Analysis
- Experience-Based Suggestions
- Exploratory Analysis
- Warnings & Alerts
Architecture & Supporting Technologies

- **DEEP components:**
  - **Distributed AI Blackboard** for multi-agent, non-deterministic, opportunistic reasoning
  - **Experience-Based Reasoning** to capture and retrieve experiences
  - **Episodic Memory** for powerful analogical reasoning
  - **Multi-Agent System** for mixed-initiative planning
  - **Plan Representation** for human-to-machine dialog
  - **Simulations** for exploration of plausible future states
Distributed Episodic Exploratory Planning (DEEP)

Distributed Blackboard

- Distributed Shared Data Structure
  - Provides
    - Multi-agent, non-deterministic, opportunistic reasoning
    - Persistent storage
    - System messaging
  - Components
    - Core Data Store
    - Knowledge Sources
    - Control
Distributed Episodic Exploratory Planning (DEEP)

Multi-Agent System

Planning Agents

Suggested

Situation

Selected:

Objective 1

Candidate Plans:

Objective 2

Adjusted

Adaptation Agents

(“Repairers”)

Critic Agents

(“Evaluators”)

Judged
Distributed Episodic Exploratory Planning (DEEP)

Critic Agents

- **Adaptation Critic Agents**
  - Plan repair
    - Example – Capabilities Agent checks actor roles and makes sure the present actors are capable of performing their assigned roles

- **Scoring Critic Agents**
  - Plan evaluation
    - Example – Weather Agent uses weather knowledge and data to evaluate plan actions

- **Execution Selection Critic Agents**
  - Determines top rated plans
  - Mixed-initiative decision point
Bringing it all together…
User Interface Mockup
User Interface Mockup
Future Work

• Plan Visualizations
• Adjustable Autonomy
• Commanders Intent
• Tailored Information
• Other Human Entry Points
Conclusion

• This approach has promise to enhance DEEP’s agility by providing users a functional way to interact with an adjustably-autonomous system providing the following capabilities:
  – Level-Independent Mixed-Initiative Planning
  – Asynchronous Mixed-Initiative Planning
  – Plan Oriented Machine Interaction
Questions?

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Backups
Distributed Episodic Exploratory Planning (DEEP)
The Importance of Experience in Planning

- “Most of the time spent in orient phase reducing the fog of war”
- “Orientation relies on an experience base”
- “Experience is the basis for the increasing requirement of creativity in plans” --John Boyd

Harness an experience base to rapidly
- Rapidly recognize the situation
- Plan better by recalling prior successes and/or failures
- Creatively explore what the plan may accomplish
Distributed Episodic Exploratory Planning (DEEP)
Building Block for MIP/Distributed C2

• **Core Plan Representation (CPR)**
  - Object-oriented plan framework developed under ARPI (Air Force Research Laboratory Planning Initiative)
  - 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)
Distributed Episodic Exploratory Planning (DEEP)

Architecture Diagram

1. Engaged CMDR: “I have a situation!”
2. Planning Agents
3. Case Base
4. CBR System
5. Suggested
6. Adjusted
7. Judged
8. Execution Selection Critic Agent
9. Simulated
10. User Interface

Adaptation Agents ("Repairers")

Critic Agents ("Evaluators")

Plan Execution

Simulated

Selected:

Candidate Plans:

Situation

Objectives

Objective 1

Objective 2

...
Distributed Episodic Exploratory Planning (DEEP)

Distributed Blackboard Architecture

Knowledge Sources

- RSS Data
- Case Base

Critic Agents
Adaptation Agents
Planning Agents

Proxy / API / Interface

Control

BB Data Structure

Remote Blackboard
Remote Knowledge Sources
Remote Data

Remote Blackboard
Remote Knowledge Sources
Remote Data

Remote Machines

Java Distributed Blackboard
Objective
Better, faster, more creative planning

Current AOC Planning

BOGSAT
• Bunch of Guys/Gals Sitting Around a Table

Constrains planning
• Quality
  – Finite experience
• Speed
  – Limited automation
• Creativity
  – Finite diversity

Gráfico de "AF C2 Enabling Concepts"
May 2006 AF/A5

• Experienced-based
  – Orient and decide faster than adversaries with better plans
• Mixed-initiative
  – Syntheses of the strengths of both human and machine
• Net-centric
  – Expert team formation with greater diversity and creativity

Improve planning quality, speed, and creativity
Distributed Episodic Exploratory Planning (DEEP)

Planning Agent

- Interact with case-base reasoning system
- Mechanism for mixed-initiative interaction