D-AESOP: A Situation-Aware BDI Agent System for Disaster Situation Management

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Outline

• Problem statement
• Disaster Situation Management
  – How situation management addresses disaster recovery
  – A new approach to using BDI agents in situation management, and its benefits for DSM
• Example
  – From event processing to situation recognition
• D-AESOP architecture and implementation direction
  – Agent services and components
  – Benefits of FIPA-compliance MAS in DSM
  – Preliminary ontology
• Conclusions:
  – Main results
  – Future Work
Problem Statement

• Disaster situation management (DSM)
  – Effective organization, direction and utilization of counter-disaster resources
  – Coordination of a complex multi-dimensional process that involves large number of interoperating entities
  – Adaptive to different factors: social, medical, geographical, psychological, political & technological

• Multi-agent system (MAS) is appropriate architecture

MAS/BDI an effective solution?

• MAS Favorable Characteristics
  – Autonomous behavior – act independently
  – Rational behavior – goal-directed
  – Social behavior - cooperation
  – Spatial and Temporal behavior – space & time

• But DSM requires
  – Agent modeling at cognitive level – hence BDI agent
  – Comprehensive understanding of the overall disaster operation situation
    → Inter-organization versus intra-organization
  – Decisions making based on composite events and goals
Disaster Situation Management (DSM)

Situation(s) Meta Analysis

Disaster Situation Assessment
- Damage
- Casualties
- Medical
- Supplies
- Roads
- Communication
- Inter-situational Relations
- Side Effects (Epidemic, Weather, Panic, Law & Order)

Situation Model

Disaster Situation Model

Plan Reasoning / Selection

Relief Operations
- Decision Support
  - First aid delivery
  - Mobile ambulatories
  - Hospital selection
  - Hospital operations
  - Transportation selection
  - Dispatch of medical teams
  - Routing
  - Supplies planning
  - Backup scenarios

Plan Execution

Progress Reports

Operations Implementation
- Scheduling
- Monitoring

Medical Relief Operational Space

Disaster-related Information

Human Intelligence
- Building damage
- Casualties
- Supplies needed
- Reports from Police, Emergency Units, Authorities
- Eyewitness accounts

Signal Intelligence
- Embedded Sensors
- Satellite images
- Aerial Images (UAV, planes, etc)
- Distributed, chemical, biological
- Video, etc. sensors and Sensor networks

Disaster Data Collection

Information Correlation
- Temporal
- Spatial
- Structural
- Medical
- Environmental

Additional Adjusted Data Requests

Real-Time Operations Feedback

Situation Meta-Analysis

Situational Events
- Geographic & Weather

Events

Events Meta-Analysis

Situation(s)

Correlation Meta Data

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BDI Agent Paradigm

5 main notions: events, plans, intentions, beliefs & desires

Based on the dMARS formalism – a well recognized reference model for BDI agents

Situation-Aware BDI Agent Paradigm

**New Components:**
- Situation-Awareness

**Modified Components:**
- Situation-Driven
  - Reactive Situation Recognition
    - Driven by Event Correlation (EC)
  - Deliberative Plan Reasoning
    - Driven by Case-Based Reasoning

**Major Concept:**
- Event-Situation-Plan (ESP) Paradigm

**Diagram Elements:**
- External Events
- World Knowledge
- Situation Library
- Plan Library
- Plan Generation
- Belief Updates
- Plan Instantiation
- External Actions
- Intentions
- New Components: Situation-Awareness
- Modified Components: Situation-Driven
- Reactive Situation Recognition
  - Driven by Event Correlation (EC)
- Deliberative Plan Reasoning
  - Driven by Case-Based Reasoning
Components of a Situation Management System

- Situation Recognition
  - Reactive Situation Recognition Process
  - Spatial, Temporal, etc. Constraints
  - Event Correlation
  - Correlation Memory

- Plan Selection/Generation
  - Goals
  - Deliberative Plan Reasoning Process
  - Case-Based Reasoning
  - Case Memory
  - Plans
  - Sub-Plans

- Synthetic event


Example: DSM Situation Recognition

Event Correlation

Agent

Medical Emergency Vehicle (MEV1)

Medical Emergency Vehicle (MEV2)

Expected:

Event2 at 10:30am where Type(Event2) = B

Group

Correlation Memory

Correlation Rule 1

Correlation Rule 2

Correlation Rule N

Event1 at 10:30am where Type(Event1) = A
Example (cont’)

Correlation Rule 2: EXPECTED-EVENT-RULE

Conditions:

- MSG: EVENT-TYPE-A ?msg1
- TIME ?t1
- VEHICLE: VEHICLE-TYPE-MEV ?mev1
- Not MSG: EVENT-TYPE-B ?msg2
- TIME ?t2
- VEHICLE: VEHICLE-TYPE-MEV ?mev2
- GROUP: GROUP-TYPE-MEV ?mev1 ?mev2
- AFTER: ?t1 ?t2 600

Actions:

- AssertSituation: LOST-MEV-CONTACT-SITUATION
  - VEHICLE1 ?mev1
  - VEHICLE2 ?mev2
  - EVENT1 ?msg1
  - EVENT2 ?msg2
Example (cont’)

SituationName LOST-MEV-CONTACT-SITUATION
SituationClass MEV-SITUATION
Parameters
  VEHICLE1
  VEHICLE2
  EVENT1
  EVENT2
  ........
Actions
  PLAN SEND-EMERGENCY-HELICOPTER

Case Memory

Simple Deliberative Plan Reasoning

Plan
- Contact Helicopter Department
- Schedule a Helicopter
- Emergency Dispatch
- Investigate
- Search for Lost Vehicle
D-AESOP Agent Architecture

distributed multi-agent situation management platform

(Developed by Altusys Inc.)

Signal Intelligence

Human Intelligence

Disaster Information Access Agents

Sensor Management Agents
Reports Management Agents
Human Interface Agents
Vehicle/Team Communication Agents

Event Correlation
Situation Recognition
Plan Reasoning
Plan Execution

Event Correlation Agents
Situation Awareness Agents
Vehicle Routing Agents
Relief Planning Agents

Ontology Management Agents
Database Management Agents
Plans Management Agents
Rules Management Agents

DSM Belief Management Agents

Fast Events Transfer Channel
DSM Agents Specialists
Data & Knowledge Transfer Channel

Relief Teams Communication/Interface Agents

Event Notification Service
Knowledge Acquisition Service

World Knowledge
Situation Library
Plan Library
Ontology Library

AESOP Java Platform (J2EE)

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D-AESOP in Multi-Jurisdiction Operations

- Heterogeneous agent platforms are likely to be prevalent in DSM environments involving multiple administrative domains
  - FIPA provides interoperability between different APs
  - Shared ontology is also required

FIPA
Foundation for Intelligent Agents
D-AESOP: Example DSM Ontology
Conclusion: Main Results

- Multi-agent system (MAS) is appropriate architecture, but DSM requires
  - Agent modeling at cognitive level
    ⇒ We utilize the BDI (Belief-Desire-Intention) paradigm in the MAS architecture
  - Comprehensive understanding of the overall disaster operation situation
    ⇒ We integrate situation awareness into the BDI model
  - Decisions making based on composite events and goals
    ⇒ We replace the BDI Event-Plan (EP) with the Event-Situation-Plan (ESP) Paradigm
    ⇒ We replace Single Event/Goal Plan triggering with Situation Plan triggering
    ⇒ Broader view rather narrow view of the disaster situation
Conclusion: Future Work

• Future work
  – Optimal physical DSM agents to abstract MAS representations
    • Example: Physical Entity: Helicopter → How many MAS agents?
  – Embed situation recognition capabilities into agents
    • Example: Situation Predication
  – Exploration of MAS with self-adaptation, learning … etc
Thank You!
What is Situation?

• A snapshot of the world at some time instant
• Aggregated states of the entities and the relations between the entities observed at some particular discrete time interval

Notable Introduction:


Formal Theory:

Limitations of BDI approach to MAS DSM Solutions

• Lack of comprehensive understanding of the overall disaster operation situation
• Decisions making based on single event/single goal
Using BDI Agents in MAS DSM

Inter-agent collaboration (event-based coordination of goals, knowledge, plans)

High-Level Control Agent

BDI Agent

Team Control (Providing Knowledge, Goals, and Plans Timing, synchronization Constraints, resources, etc.)

Specialized and geographically Distributed teams of agents

Events

Plan Reasoning / Execution

Agent

“Sensing”

“Acting”

Agent

Agent

Agent

Agent

Agent

“Sensing”

“Acting”

“Sensing”

“Acting”

World

e.g. Disaster-related Data Collection
e.g. Plan executions, disaster relief operations

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Situation Recognition Driven by Event Correlation

- Situation Recognition driven by
  - Event Correlation: external/internal events correlated into synthetic events


Deliberative Plan Reasoning driven by Case-Based Reasoning

- Deliberative Plan Reasoning
  - Case-Based Reasoning
  - Case: a template of a generic situation
  - Learn from past experiences
  - Adapt standard situations to current situation

Implementation of DSM

- Instantiation of the abstract agent model
  - Concrete embodiment of the abstract features into different agents:
  - Agents-Specialists (e.g. event correlation, situation recognition, plan generation)
  - Information Access Agents (e.g. signal intelligence)
  - Interface Agents (e.g. human intelligence)
  - Belief System Management Agents (e.g. knowledge)
- Foundation: D-AESOP (Distributed Assistance with Events, Situations and Operations) service architecture

A distributed multi-agent situation management platform being developed by Altusys