Modeling Command and Control in Multi-Agent Systems*

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C2 in Agent-Based Systems

• What is C2?
  – accomplishing goals/mission in a competitive environment with distributed resources (sensors, effectors)

• Applications:
  – combat simulations, fire fighting, ATC, urban disaster rescue operations, training systems

• Existing multi-agent systems
  – SOAR/STEAM, RETSINA, PRS/dMARS
  – good for distributed problem-solving, e.g. coordinating maneuver of entities on battlefield
• Tactical behavior is more than just coordinating maneuver of entities
  – it involves a decision making process, collaborative information gathering and fusion

• Example: staff operations in a battalion TOC
  – an S2 agent can be told to automatically forward a situation report, but shouldn’t it already know?

• Importance of emulating human tactical decision-making
  – human behavior representation
  – information gathering activities, assessing relevance
  – understanding & interacting with humans
Cognitive Aspects of C2

- Naturalistic Decision Making
- Situation Awareness
- Recognition-Primed Decision Making (RPD)
- Strategies for Dealing with Uncertainty
- Meta-cognition
- Teamwork
Basic Activities to Integrate

mission objectives

information gathering, situation assessment

tactical decision making

implicit goals:
- maintain security
- maintain communications
- maintain supplies

emergency procedures, handling threats
Overview of Approach

• Implement RPD loop:
  - represent situations, features, weights in KB
  - find-out procedures
    - e.g. use radar, UAV, scouts, RFI to Bde, phone, email, web site, lab test...
  - challenges:
    - information management (selection, tracking, uncertainty, timeouts)
    - priority management among activities
• **C2/CAST**: declarative and procedural KB’s (rules and plans)
Model of Situation Assessment

- situations: \( S_1 \ldots S_n \)
  
  e.g. being flanked, ambushed, bypassed, diverted, enveloped, suppressed, directly assaulted

- features associated with each sit.: \( F_{i1} \ldots F_{im} \)

- RPD predicts DM looks for these features

- weights: based on relevance of feature (+/-)

- evidence(\( S_i \)) = \( \sum_{j=1}^{m} w_{ij} \cdot F_{ij} > \theta_i \)

- unknowns: assume most probable value:

  \( F_i = \text{true} \) if \( P[F_i=\text{true}] > 0.5 \), else \( F_i = \text{false} \)
Situation Awareness Algorithm

• (see paper for details)

• basic loop:
  while situation is not determined (i.e. no situation has evidence>threshold),
    pick a relevant feature whose value is unknown
    select a find-out procedure, initiate it

• information management issues
  – ask most informative question first (cost? time?)
  – asynchronous, remember answers pending
  – some information may go stale over time (revert to unknown, re-involve find-out)
RPD “wrapper” task

(task RPD ()
    (method (parallel
        (do (mission))
        (do (maintenance_tasks))
        (do (situation_awareness))))

(start (response-action handle-threat))
Priorities

Model: current “alert” level suspends lower-level activities

5 - handling high-level threats
4 - situation awareness
3 - handling low-level threats
2 - maintenance tasks for implicit goals
1 - pursuing targets of opportunity
0 - executing the mission

high-level threat occurs, suspend mission
resume mission when threat handled
Directions for Future Work

- on-going situation assessment (monitoring)
  - change thresholds? confirmation bias, etc.?
- mental simulation, response adaptation, dynamic re-planning
- team-based C2
  - write RPD as *team plan* in multi-agent language
  - joint commitment to goal (SA) drives collaboration and information flow
  - shared mental model of goal, plan, facts