Flexible Group Behavior

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The Need: Advanced SF Representation

3.1 Distributed collaborative decision making
   ➡ Collaboration at the entity and unit level

3.2 Decisions loosely constrained by doctrine
   ➡ Generating appropriate sequences of actions in complex and unanticipated situations

3.3 Increased variability & realism of responses
   3.3.2 Plausible representation of battlefield stress
      ➡ Emotional responses to battlefield situations
The Need (continued)

3.3.4 Adaptive behaviors (learning)
➲ Learning to improve models of (other groups) of entities

3.3.5 Goal-based reasoning for executing forces
➲ Collaborative planning
➲ Goal-oriented execution by individual entities

3.3.7 Modeling commander’s intent
➲ Understanding and representing intent

3.3.8 Group behavior
➲ Modeling coordination, communication, commitments, recovery, heterogeneity, etc.
The Approach: Flexible Group Behavior

- Develop an integrated model of:
  - Group understanding
  - Group planning
  - Group execution
  - Group learning
  - Group emotions

- Explore in context of RWA Attack Battalion
  - Soar/RWA/IFOR drives entity-level behavior
  - Soar/RWA/CFOR drives command-level behavior
Soar: Artificial and Human Cognition

- Interact with external environments
- React quickly in a context-sensitive manner
- Represent knowledge in a parallel-associative memory of rules
- Integrate knowledge in decision making
- Hierarchically decompose complex tasks
- Reflect on problems
- Learn from experience
- Use natural language
Soar in a Nutshell

I/O

Reaction

Deliberation

Reflection

Learning

Faster

Smarter
Soar/RWA

- Three kinds of missions with up to 24 helos
  - Army deep attack; Marine transport and escort
- To be deployed in STOW ‘97
Soar/RWA/IFOR: Entity Level

- Accept CCSIL orders from commanders
- Hierarchically instantiate behavioral plans
- Understand (groups of) other entities
- Group execution via a model of teamwork
- React quickly and appropriately
- Deployed in all 3 missions for 3 types of helos

![Diagram showing the process of understanding and executing tasks]

- Understand
- Execute
Soar/RWA/CFOR: Command Level

- Accept CCSIL orders and adapt to local unit
- Transmit adapted plans to subunits
- Monitor execution and generate reports
- Deployed in Army attack at company level
Towards Flexible Group Behavior

**Battalion**

Understand → Plan → Execute

**Company**

Understand → Plan → Execute

**Entity**

Understand → Execute

Emote

Learn
Group Understanding

- **Issue**: Understanding groups of entities
  - Goals, intentions, behavior, coordination, etc.
- **SOA**: Small homogeneous groups (RESC)
  - Use self as model of others
  - When there is a choice, select worst case
  - Use model selectivity and sharing for efficiency
  - Only works at the entity level
Group Understanding 2

◆ Goal: Larger heterogeneous groups
  – Use models of dissimilar others
    » e.g., ground forces
  – Model functional aggregates of entities
    » e.g., a company consisting of light and heavy teams
  – Use focused group perception
    » Mostly see groups rather than individuals
  – Incorporate into command level for planning use
    » Requires extending control structure of commander
    » Requires extending algorithm to full plan representation
Group Understanding: Progress

- Extended group understanding model
  - Model dissimilar others by “thinking like them”
  - Exhaustive search of model space when have time (rather than always selecting worst-case)
  - Track groups of entities rather than individuals
    » Based on bottom-up, cluster-based, group perception

- Implemented prototype of extended model
  - Developed high-level model of (ground) OPFOR
    » Focuses on whether are attacking, defending, or moving
  - Embodied models as part of RWA scouts
    » Scouts run internal models of OPFOR behavior
  - Scouts reach right conclusion
Group Understanding: Progress 2

- Developed dynamic group perception
  - In addition to seeing individual entities, already perceive sets of entities as “group objects”
    » Maintains summary information about whole group
  - Now only perceive individual entities for one group
    » See closest group with live entities
    » Used for engaging, suppressing, etc.
**Group Understanding: Issues**

- **Extended understanding model**
  - Not yet extended to command entities
  - Doesn’t yet cope with functional aggregates

- **Implemented prototype**
  - Can’t concurrently model self and others
  - Can’t change conclusion if behavior changes
  - Only works in scouts, not attack helos

- **Dynamic group perception**
  - Not smart about which group to break out
  - Must still see all of certain entities (e.g., ADA)
Group Planning

- **Issue**: Plan creation for a group by a group
- **SOA**: Centralized planning by commander
  - No model of superior and minimal model of group

![Diagram showing the flow of plan creation and feedback between the commander and pilot agents.](image-url)
Group Planning 2

- **SOA 2**: Hierarchical partial-order planning
  - Model tasks as preconditions and effects
  - Decompose complex tasks into sets of simpler ones
  - Add ordering constraints among tasks as required
    - For example, when the effect of one task can clobber the precondition of another
  - Track dependencies of planning decisions
Example Plan Fragment

- Attack
  - Destroyed (E)
    - Move (HA)
      - @(HA)
    - Move (BP)
      - @(BP)
    - Engage (E)
      - Move (LD)
        - @(LD)
      - Passage of Lines
        - Move (HA)
          - @(HA)
Group Planning 3

Goal:
- **Collaborate during planning**
  - Accept feedback on plans and modify accordingly
  - Generate feedback to superior and subordinates on plans
- **Exploit group/superior understanding in planning**
  - Violate received plan if necessary, while staying within intent
  - Use differential capabilities of subgroups in allocating tasks
- **Replan when necessary during execution**
  - Replan when current plan becomes infeasible
  - Use dependencies to guide replanning
- **Time, conditionality and information gathering**
Group Planning: Progress

- Developed meta-planning capability
  - Support for replanning and collaborative planning
  - Define meta-literals
    » “these tasks are a plan”, “this plan is shared knowledge”, etc.
  - Define meta-operators
    » “create a plan”, “transmit a plan”, etc.

- Implemented replanning
  - Commander replans when threats to plan exist
    » Retract and add tasks and constraints
  - Meta-information determines if changes are part of shared knowledge, and thus must be transmitted
Group Planning: Progress 2

- Implemented battalion commander stub
  - [Ultimately to perform collaborative planning with company commanders]
  - Sends out battalion order (doesn’t plan)
  - Receives and consolidates status reports
  - Tracks companies’ locations
Group Planning: Issues

- Replanning
  - Need to be able to send plan changes (i.e. Frag Orders) rather than whole plans

- Battalion commander
  - Generalize planner’s domain theory to groups
  - Planning and collaborative planning
Group Execution

- **Issue**: Coordinated behavior in groups
  - Maintain even when faced with unexpected

- **SOA**: Goal-oriented teamwork (STEAM)
  - Model goals, actions, roles, and commitments
    » Model for both individuals and groups
  - Use models (and situation) to drive action selection, communication, role assumption, etc.
  - Only works at the entity level

- **Goal**: Teamwork at command level
  - Replanning must take into account current group composition and capabilities
Group Learning

- **Issue:** Improve understanding from experience
  - Only one small piece of overall group learning

- **SOA:** Inductively propose model changes
  - Compare successful and failed predictions
  - Use self-explanation to focus on relevant features
  - Only for one kind of change, in one situation, with domain-dependent knowledge

- **Goal:** Broader classes of changes and situations in a domain-independent manner
Group Emotions

- **Issue**: Exhibit emotional behavior
  - Only interpersonal emotions such as *fear*
- **SOA**: Nothing implemented
- **Goal**: Initial model of emotion for SF
  - Arise by understanding others and relations to self
  - Affect (at least) both understanding and execution
    » Focus on source of emotion
    » Understand subsequent actions in terms of emotion
    » Adjust kinds of actions selected based on emotion
Milestone 1: 9/97

Technology POP Demonstration 1
  – RWA attack company
  – Demonstrate limited group understanding
    » Model dissimilar groups of entities
    » Some ability to scale up to larger groups
  – Demonstrate limited group planning
    » Replanning
  – Deliver software and domain independent descriptions of new capabilities
Architecture as of Milestone 1

Company

Entity

Plan → Execute

Understand → Execute
Milestone 2: 12/97

Design Review 1

– Approach to scaling up group understanding
– Approach to temporal, conditional and information-gathering planning
– Approach to teamwork and group understanding in commander
Milestone 3: 9/98

Technology POP Demonstration 2

- RWA Attack Battalion
- Demonstrate advanced group understanding
  - Scale up to larger groups of entities
- Demonstrate advanced group planning
  - Temporal, conditional and information-gathering planning
  - Group understanding
- Demonstrate advanced group execution
  - Commander utilizes teamwork model
- Deliver software and domain independent descriptions of new capabilities
Architecture as of Milestone 3

Understand → Plan → Execute

Battalion

Company

Understand → Plan → Execute

Entity

Understand → Execute
Milestone 4: 12/98

Design Review 2

– Approach to learning improved group models
– Approach to group emotions
– Approach to collaborative planning
Milestone 5: 9/99

Technology POP Demonstration 3

- RWA Attack Battalion
- Demonstrate advanced group understanding
- Demonstrate more advanced group planning
  » Collaborative planning
- Demonstrate advanced group execution
- Demonstrate group learning
  » Improve group models through experience
- Demonstrate group emotions
  » Fear
- Deliver software and domain independent descriptions of new capabilities
Architecture as of Milestone 5