A G E N T   S T O R M

http://www.softagents.org

MURI: Integrating Intelligent Agents into Human Teams

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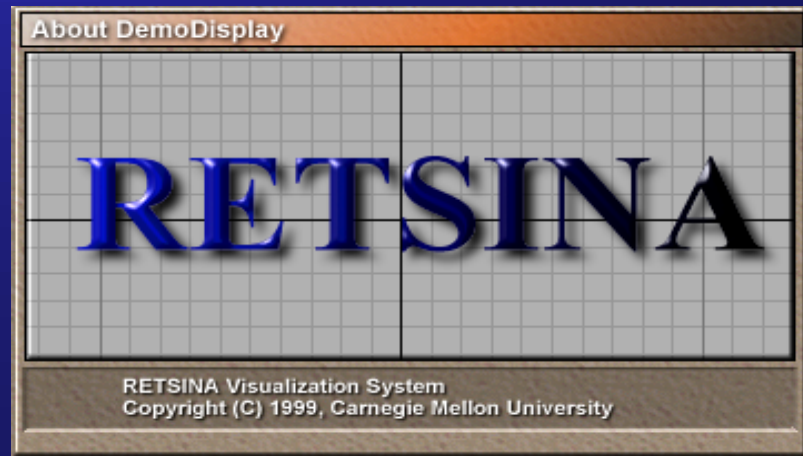 Joseph Giampapa   <garof+@cs.cmu.edu>   Tel: (412) 268-5245

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About DemoDisplay

RETSINA

RETSINA Visualization System
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Overall Research Goal

• Increase the effectiveness of joint Command and Control Teams through the incorporation of Agent Technology in environments that are:

- distributed
- time stressed
- uncertain
- open - where information sources, communication links and agents dynamically appear and disappear

•Team members are distributed in terms of:
- time and space
- expertise

Impacts for the DoD

- Reduce time for a C2 team to arrive at a decision

- Allow C2 teams to consider a broader range of alternatives

- Enable C2 teams to flexibly manage contingencies (re-plan, repair)

- Reduce time for a C2 team to form a shared model of the situation

- Reduce individual and team errors

- Support team cohesion and team work skills

- Increase overall team performance

Overall Approach

- Develop a collection of Intelligent Agents (the RETSINA infrastructure) that:
    - help humans organize data into useful information
    - help humans to better utilize results of improved information gathering
    - are adaptive and self-organizing
    - interact with humans and other agents
    - anticipate and satisfy human problem solving needs
    - integrate multimedia information management and decision support
    - are ubiquitous where they are useful
    - notify humans and agents of significant changes in the environment
    - adapt to user, task, and situation

- Develop model libraries of individual and team tasks that are reusable in novel contexts

- Develop human-agent interaction techniques whereby humans will be confident of agents' assistance

General Agent-based Team Aiding Strategies

- Support individual team members in completion of their own tasks

- Delegate subtasks to the agent as if it were another team member
    - track more information from more sources
    - manage more complex problems
    - the agent does the stove pipe integration for the human

- Support the team as a whole by:
    - agent-agent, agent-human interactions
    - role assignment and maintenance
    - relating and prioritizing sub-goals to mission goals

General Human-Agent Interactions

- Understand the nature of human team formation

- Model human team formation strategies as rules for agents

- Have agents reuse those team strategies in situations:
  - that are novel
  - that change constantly
  - involve interaction only with other agents
  - involve interaction also with humans

- Improve Human-Agent Trust

  develop presentation strategies by which humans can intuitively and reliably understand an agent's actions

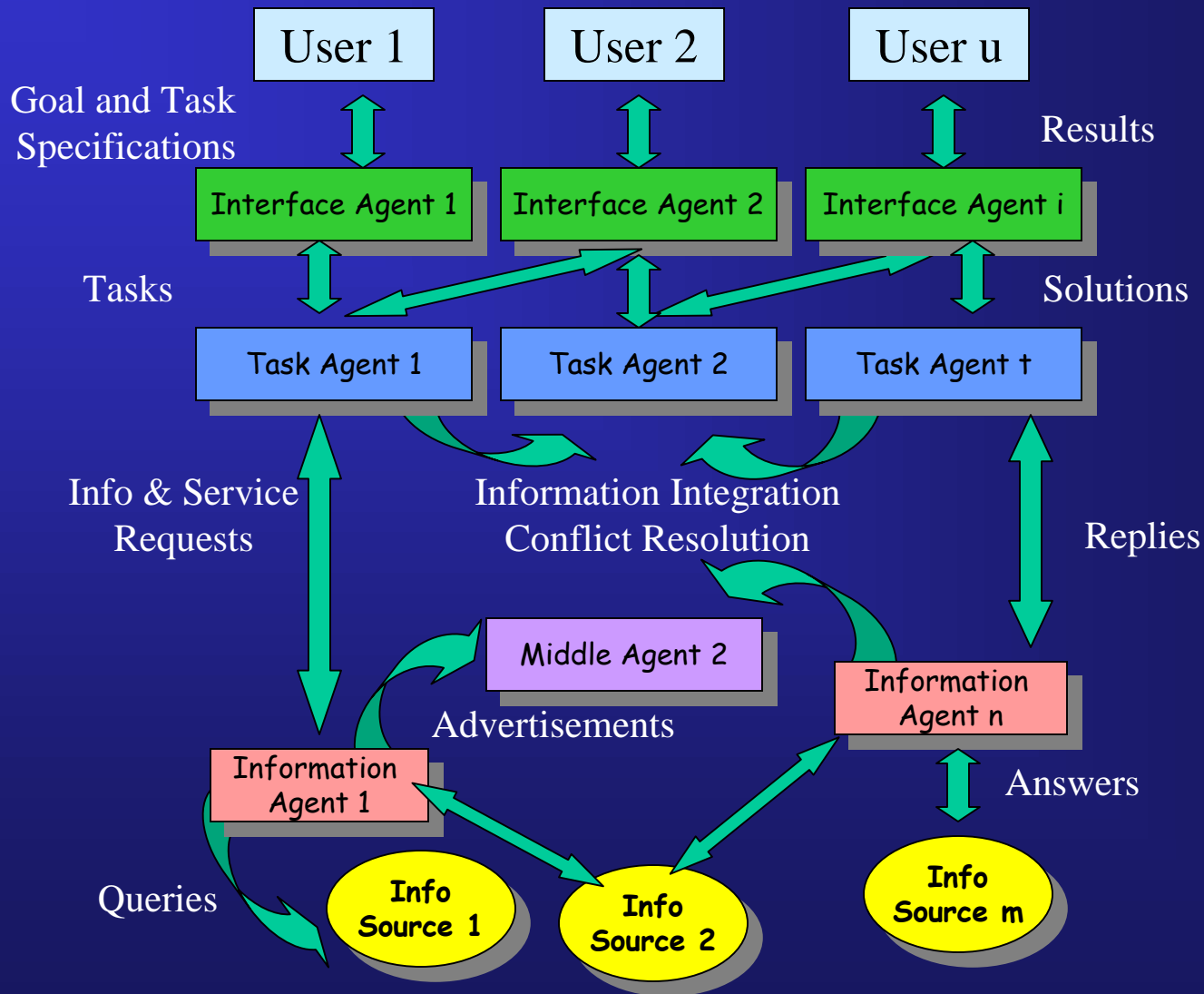RETSINA supports component reuse across application domains

See the ONR JoCCASTA video

Also view our CoABS TIE3 video

RETSINA Functional Architecture

User 1   User 2   User u

Goal and Task
Specifications

Results

Interface Agent 1   Interface Agent 2   Interface Agent i

Tasks

Solutions

Task Agent 1   Task Agent 2   Task Agent t

Info & Service
Requests

Information Integration
Conflict Resolution

Replies

Middle Agent 2

Information
Agent n

Advertisements

Information
Agent 1

Answers

Queries

Info
Source 1   Info
Source 2   Info
Source m

RETSINA Agent Architecture

Four parallel threads:
- Communicator
  - for conversing with other agents
- Planner
  - matches "sensory" input and "beliefs" to possible plan actions
- Scheduler
  - schedules "enabled" plans for execution
- Execution Monitor
  - executes scheduled plan
  - swaps-out plans for those with higher priorities

http://www.cs.cmu.edu/~softagents/retsina.html
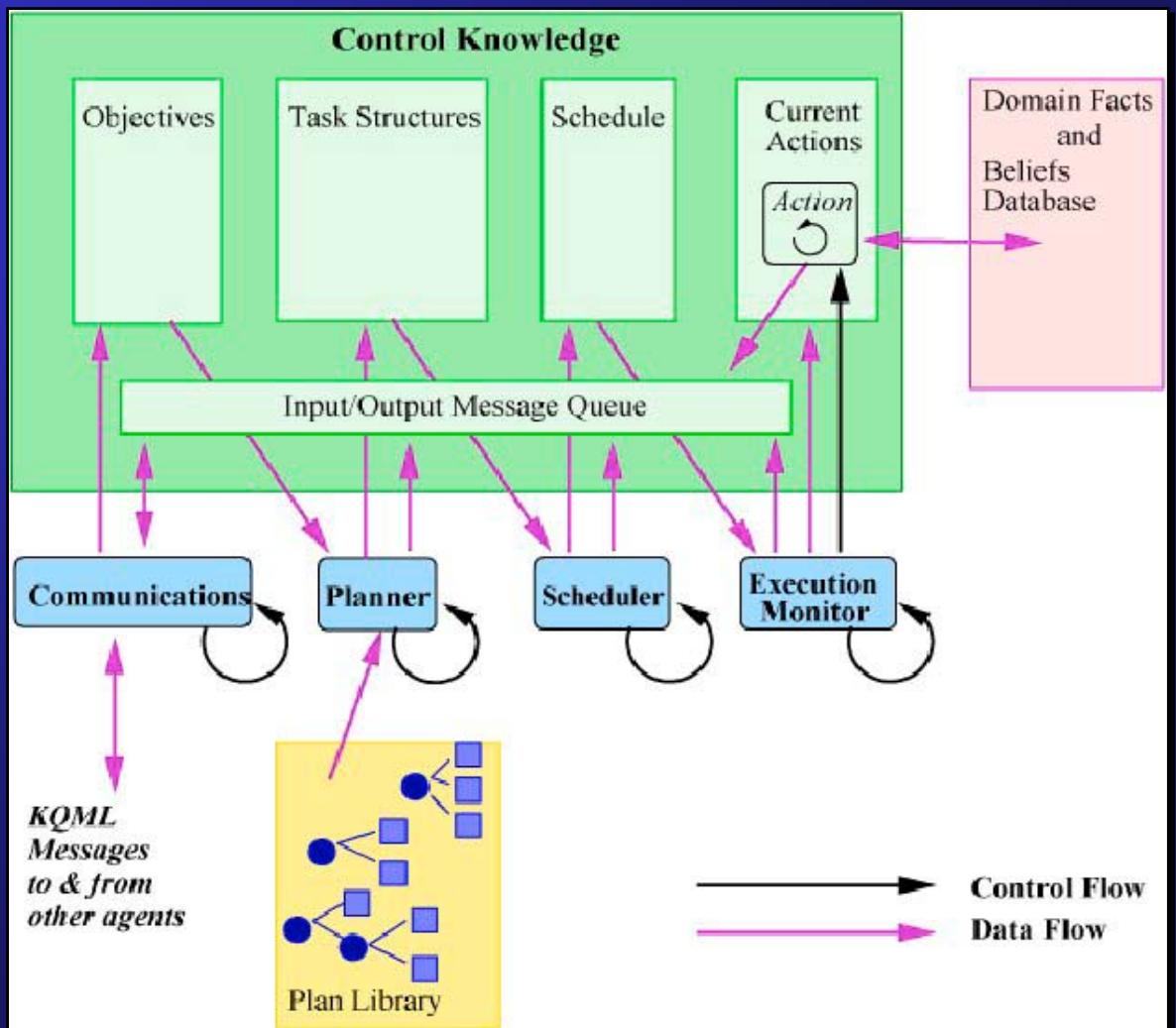
Agent Storm Scenario

- *Threat* forces are in retreat

- Three tank platoon commanders must patrol an area
  - Chase any *Threat* stragglers out of the area
  - May need to engage if necessary

- Agents help humans
  - Plan the mission
  - Gather and use intelligence to re-plan mission
  - Actively monitor patrol area during execution
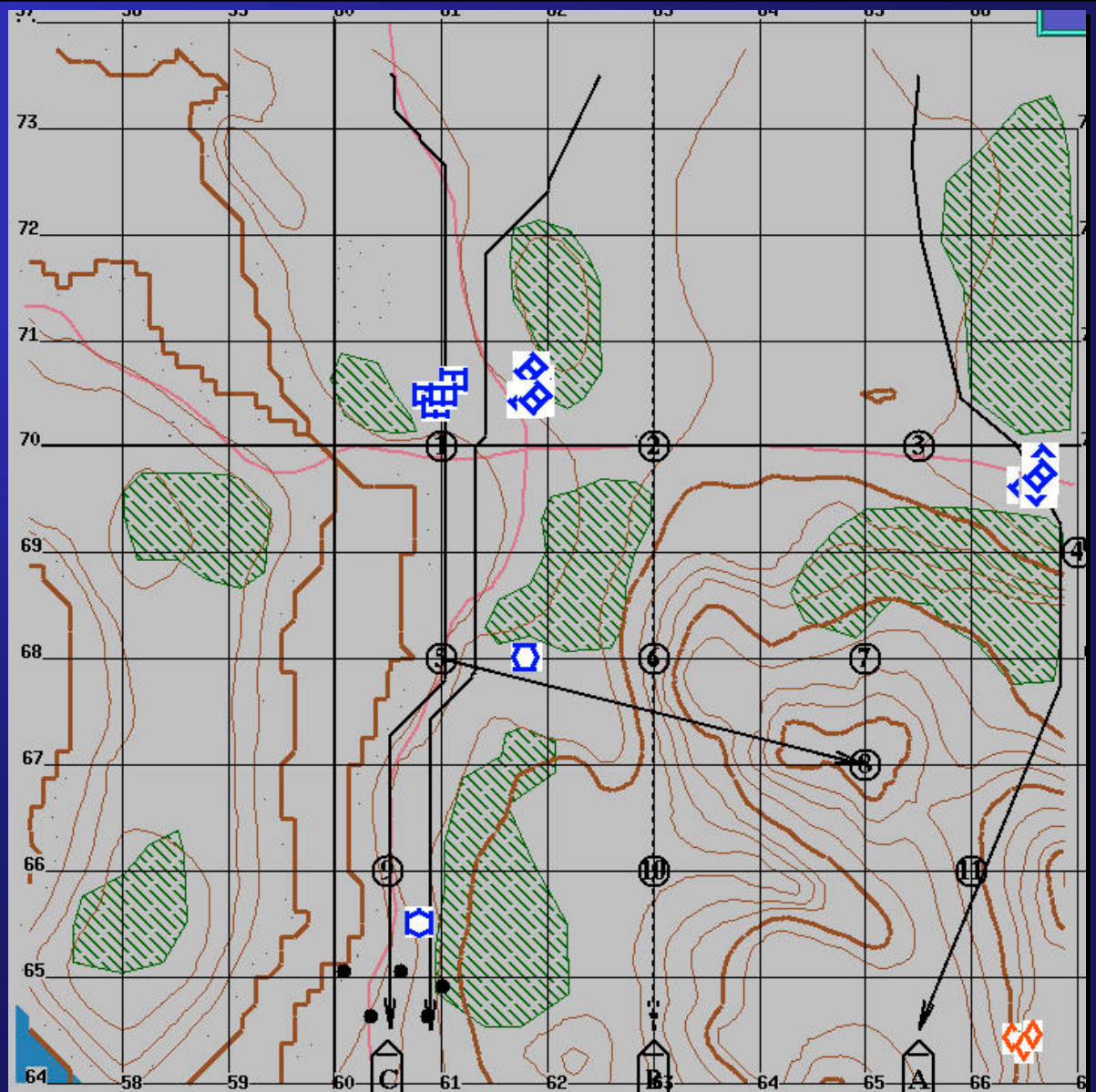 - De-mine an area

Agent Storm Simulated in *ModSAF*

Modular **S**emi-**A**utomated **F**orces

"Real world" events are simulated in *Agent Storm* by interaction with *ModSAF*
- minefield discovery
- encountering *Threat* platoon
- announcements of passed checkpoints

RETSINA *Mission Agents* control *ModSAF* platoon.
- route directions
- marching orders

RETSINA *Mission Agents*

- Propose mission plans to their commanders

- Execute mission upon commander approval

- Maintain situation awareness for humans

- Coordinate other agent activities for humans

- Automatically renegotiate their roles and plans when:
  - they conflict
  - they receive erroneous / conflicting intelligence reports
  - a teammate is "missing"
  - they discover an ambush

Shared Plan

A shared plan consists of:

- A route to follow

- A set of commitments that the agents should respect

- A set of checkpoints to monitor each other's progress

RETSINA *Mission Agents*
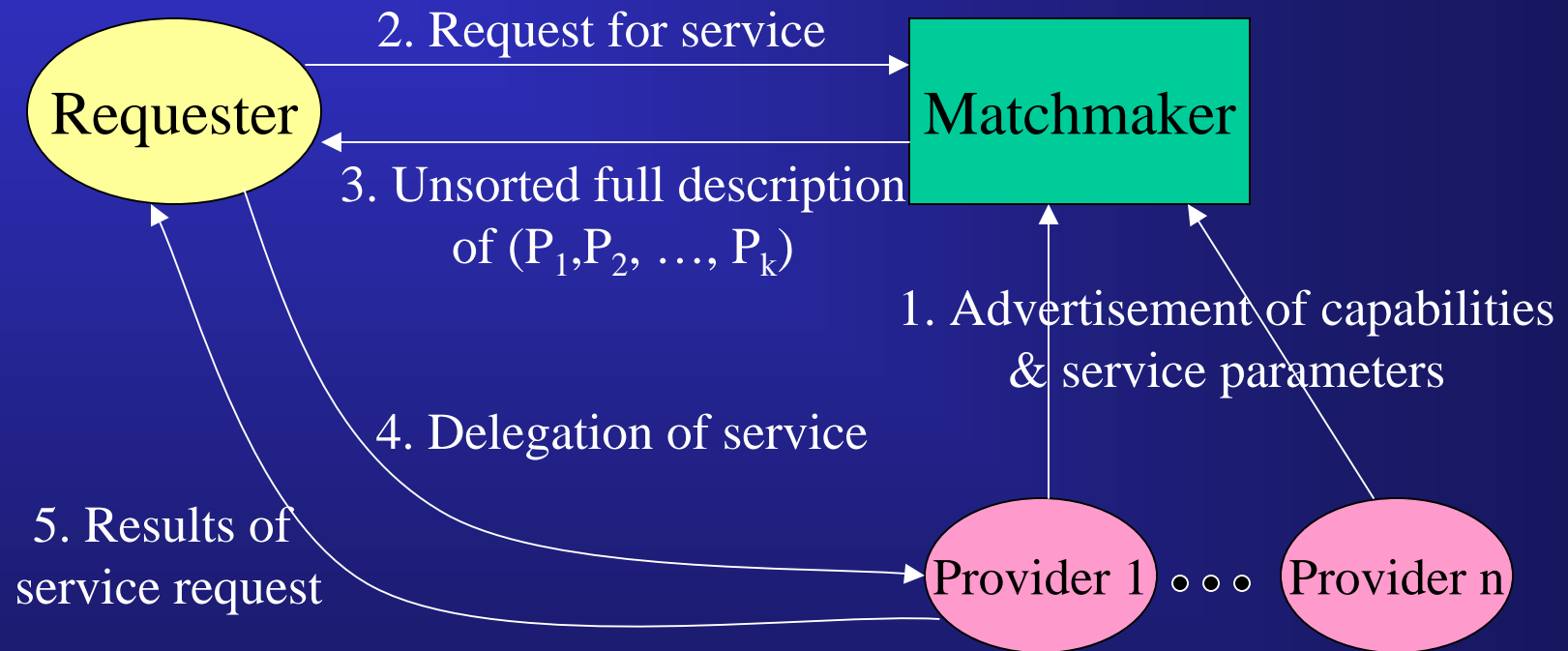
Mission Shared Execution

- At execution time they monitor each other's progress

- Exchange information on possible problems that can affect the success of the mission

- Renegotiate commitments to react to unpredictable situations: an agent cannot break a commitment without the agreement of the teammates

RETSIINA Matchmakers

- Enable an agent to find another agent:
    - by functionality, capability, availability, time to completion, etc.
    - without knowing who or where the provider agent might be

- Enables multi-agent systems [MASs]:
    - to dynamically reconfigure themselves to suite a need
    - reduce agent systems administration overhead
    - to scale in the number of agents that are distributed in a computer network

- RETSINA has two main types of Matchmakers:
    - *RETSINA Matchmaker*
        - http://www.cs.cmu.edu/~softagents/matchmaker.html
        - Please try it: http://www.cs.cmu.edu/~softagents/a-match/index.html
    - *LARKS Matchmaker*
        - **L**anguage for **A**dvertisement and **R**equest for **K**nowledge **S**haring
        - http://www.cs.cmu.edu/~softagents/larks.html

RETSINA Matchmaking

2. Request for service

Requester

Matchmaker

3. Unsorted full description
of $(P_1, P_2, \ldots, P_k)$

1. Advertisement of capabilities
& service parameters

4. Delegation of service

5. Results of
service request

Provider 1 ○ ○ ○ Provider n

RETSINA *Briefing Agent*

- Eavesdrops on the Captain's brief to platoon Lieutenants

- Dialogues with Navy's *NaCoDAE* to access plan templates

- Extracts information for plans from the briefing:
  - location of maneuvers
  - intelligence resources available (scouts, satellites, etc.)
  - *Threat* force composition and defenses

- Queries other agents when appropriate:
  - RETSINA Matchmakers (*LARKs* and *Matchmaker*)
  - Weather agents for atmospheric conditions

- Merges data gathered from humans and agents into plans
  - Plans used by *Mission Agents* to learn their assignments

- Saves humans the task of explicitly "configuring" agents

RETSINA *Briefing Agent* & NaCoDAE

Integrates both human and agent input.

Supports:
- Caching of environmental information.

- Up-to-date situation evaluation.

- An increase in the relevance and quality of decision making.
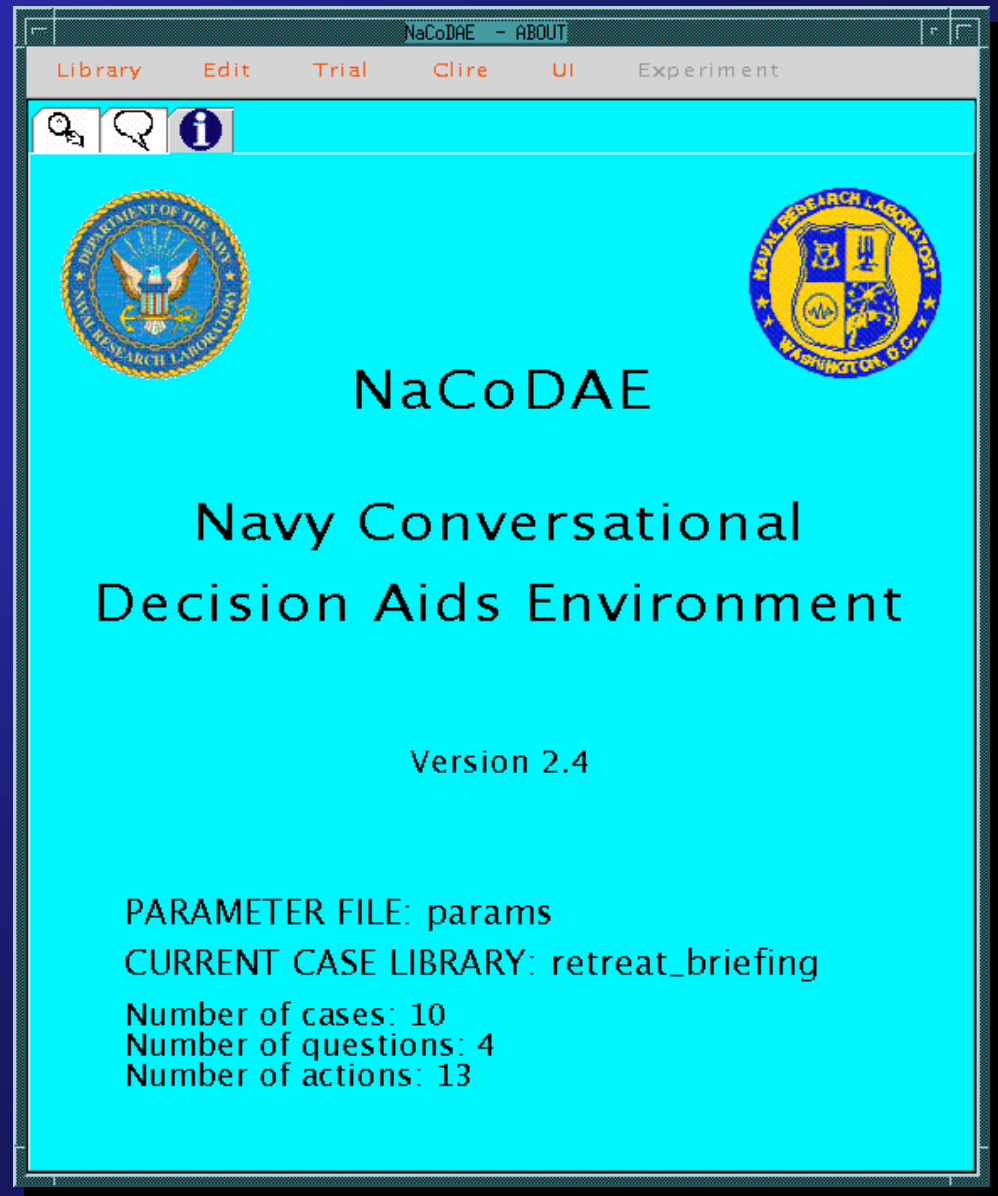
RETSINA *MokSAF* Interface Agent

- Interface Agent for the platoon leaders (Lieutenants)

- Capabilities
  - Displays the suggested route for a given platoon
  - Allows platoon leaders to see theirs and others' routes on same map
  - A visual interface to the *Mission Agent*
  - Commander can confirm suggested route or plot a new or modified route

- Other Agent Systems
  - *MokSAF* Environment: Test bed used to explore agent integration and coordination within human teams.

RETSINA *MokSAF* Interface Agent

Charlie's Shared Route
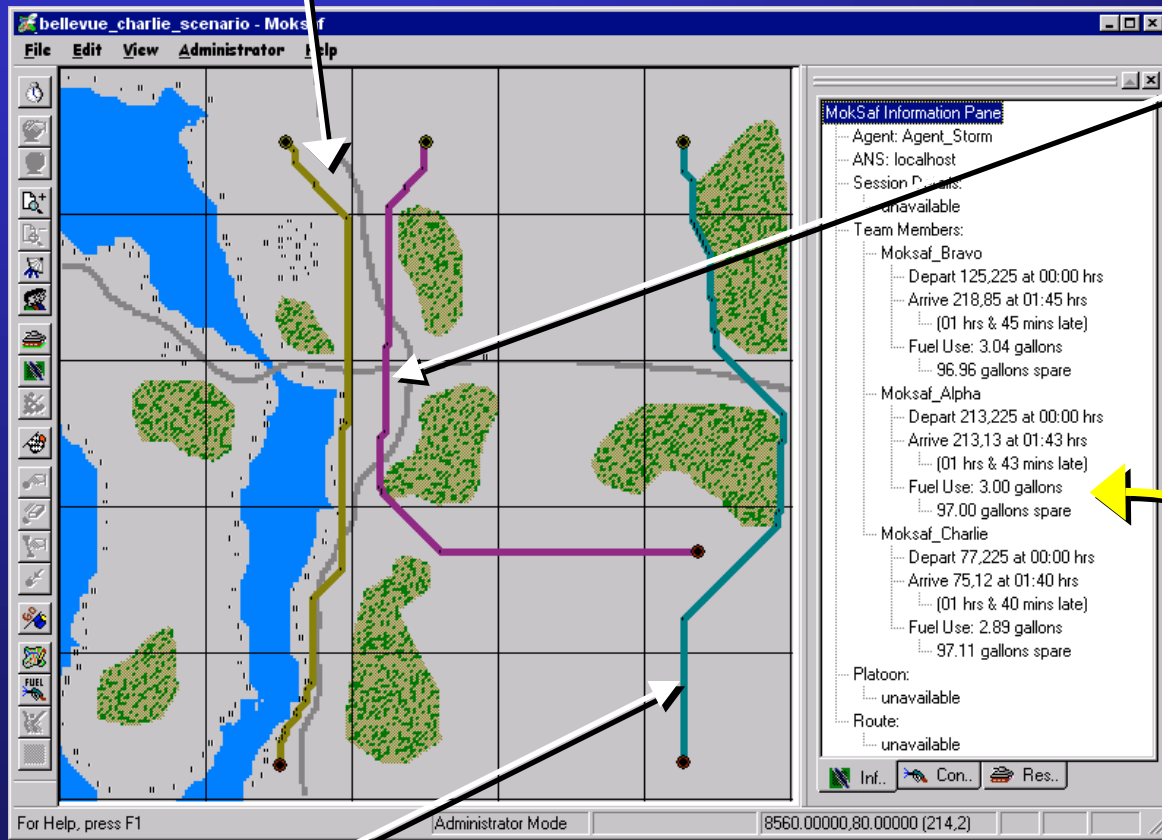
Bravo's Shared Route.

Note that this route initially support's *Charlie's* route, then crosses to intercept *Alpha's* route.

Alpha's Shared Route

Information about shared routes...

RETSINA *PalmSAF* Interface Agent

- Miniaturized form of *MokSAF* for hand-held computers

- Full RETSINA multi-agent system available to *PalmSAF* user

- Technical challenges:
    - little memory
    - very few communication ports
    - intermittent communication connections

RETSINA *Route Planning Agent*

- Capabilities
    - Two forms of path planning used within *Agent Storm*:
        - Autonomous RPA
        - Supporting RPA
    - Avoids geographic & intangible constraints (e.g. forests, water, etc, & doctrinal or human defined constraints).

- Use and Reuse
    - Human teamwork experiments (60+ subjects)
    - *MokSAF* environment
   - *CoABS* TIE1 (flight paths) & TIE 3 (evacuation routes)

RETSINA *Route Planning Agent*

Autonomous RPA

- *Autonomous RPA* generates lowest cost (i.e. *fastest*) route between start and end points

- Factors considered when generating route:
  - The platoon characteristics w.r.t. type of terrain.
  - Location of intangible constraints.

- Input parameters:

  - Start and end points of a route.

- Output parameters:

  - A route between these points (as a sequence of points).

Used to generate fastest (optimal) route...
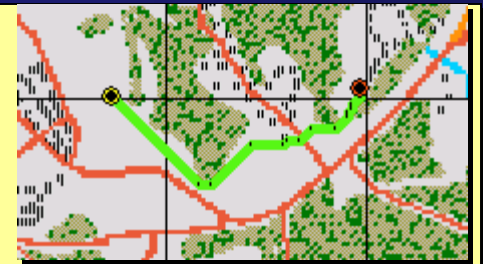
RETSINA *Route Planning Agent*

Supporting RPA

- Generate shortest path from x to checkpoint c;

- From checkpoint c, flank the route r to endpoint y whilst remaining in a corridor no closer than d_1 and no further than d_2 from r.

- Factors considered when generating route:
    - The platoon characteristics w.r.t. type of terrain.
    - Location of intangible constraints.

- Input parameters:
    - Start & End Points x & y
    - Checkpoint c
    - Route r
    - Min & Max Distances d_1 & d_2

Generates a route within a corridor supporting path r from checkpoint c...

- Output parameters:
    - The fastest route constrained by the supporting corridor (as a sequence of points).

RETSINA *Visual Recognition Agent*

- Reconnaissance Satellite Agent
  - triggers on asynchronous events
  - recognizes *Threat* tanks
  - agents autonomously locate it via a *Matchmaker*
  - agents subscribe to it via the RETSINA *Passive Monitor Query*

- RETSINA Information Agent
  demonstrates that the information agent protocol model is applicable to both data and event sources

- Used / Reused in Many Projects
  - MURI '98 Joccasta
  - CoABS '99 NEO TIE
  - MURI '00 Agent Storm

http://www.cs.cmu.edu/~softagents/visrec.html
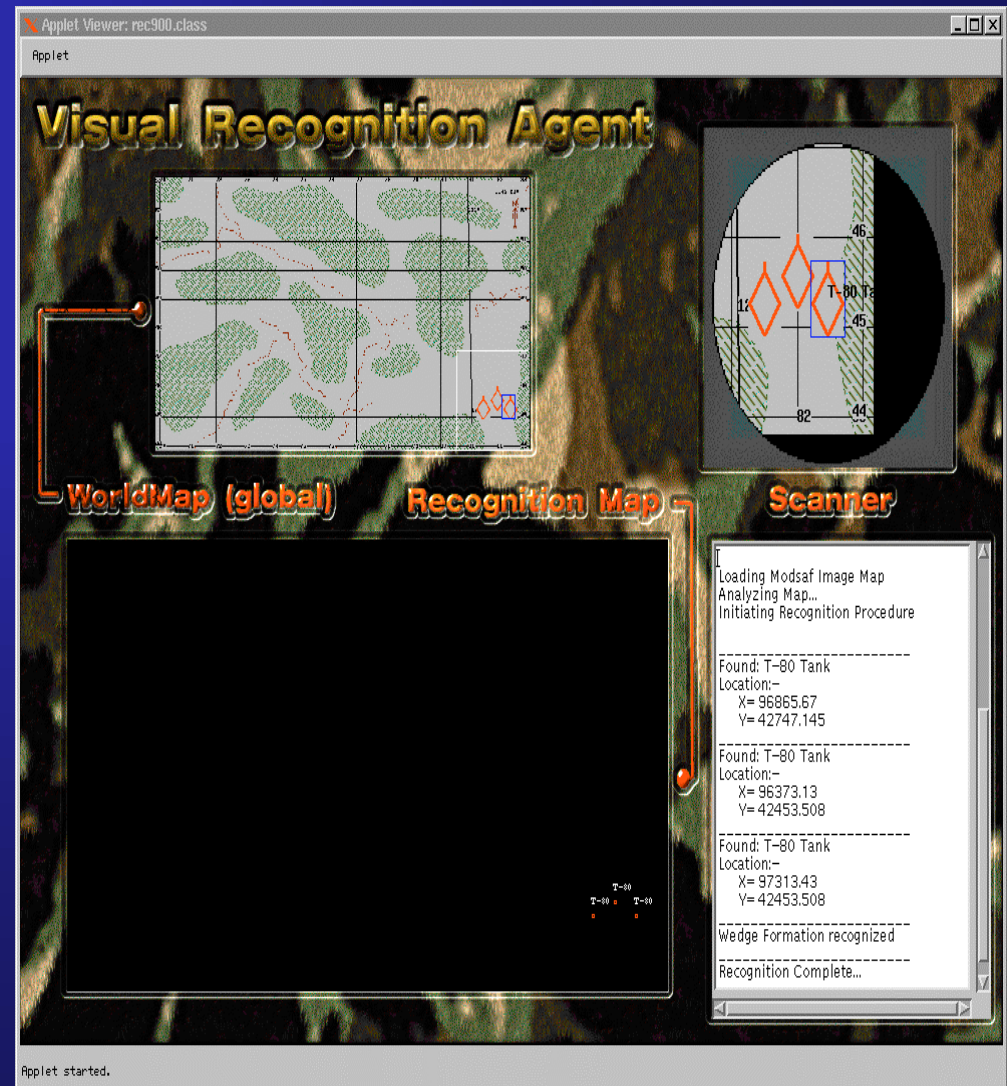
RETSINA *Voice Agent*
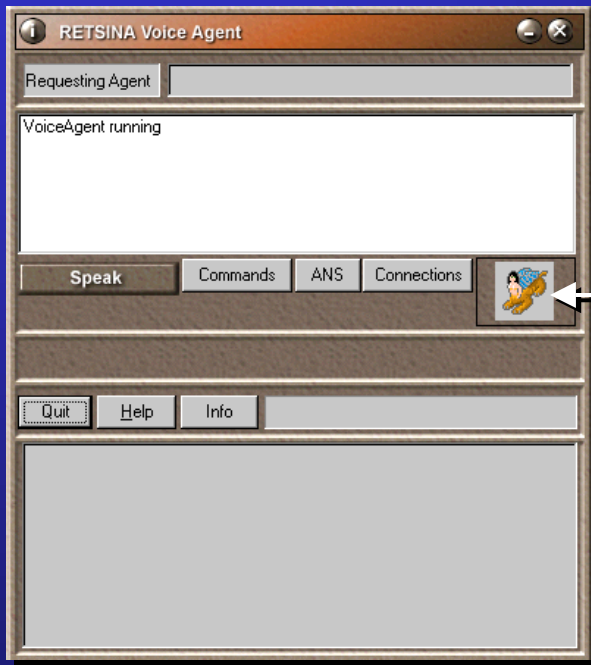
The VoiceAgent is a RETSINA Interface Agent.

It uses the CMU Sphinx engine for its speech recognition. More info is available at:

http://www.speech.cs.cmu.edu/sphinx/Sphinx.html

The VoiceAgent is a plug and play interface agent that can be added to any of our current agent configurations. The agent is triggered by pre-determined combinations of keywords. When it finds one such sequence it sends it to any agent that has indicated interest in speech input.

RETSINA *Speech System*

The *Speech Agents* in combination with the *Speech Broker* provide:

• Audible feedback from otherwise abstract planning agents

• Coordination feedback through the use of a narrator agent

• Non-intrusive real-time background explanation of an evolving plan

• The transformation of parallel and asynchronous events to serial narration

RETSINA *Speech System*
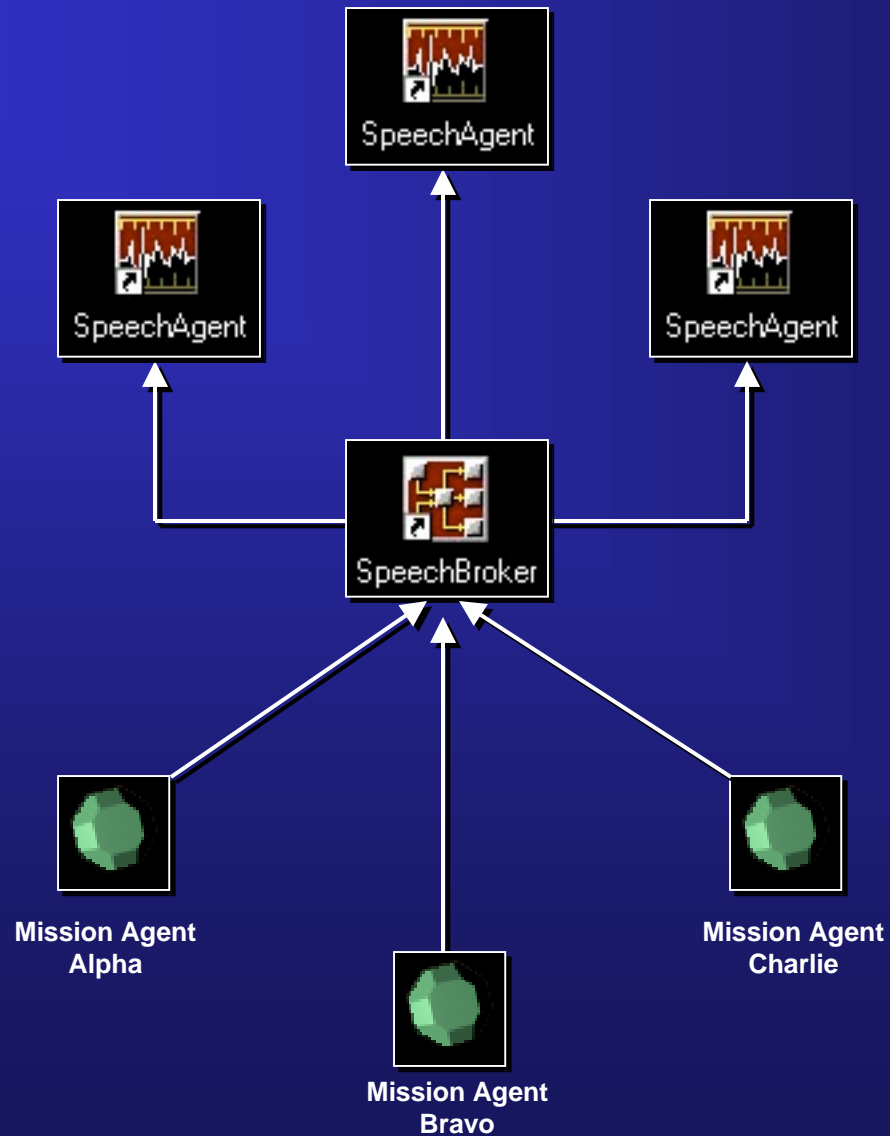
RETSINA *De-mining System*

- Robotic De-mining System

- Receives simulated "real world" input from ModSAF

- Robots communicate:
    - sharing data with Robot Manager
    - location of mines
    - if mines are active, being diffused, or diffused

- *Agent Storm* mission:
    - 3 de-mining robots
    - coordinate to clear one path
   - for platoon through minefield
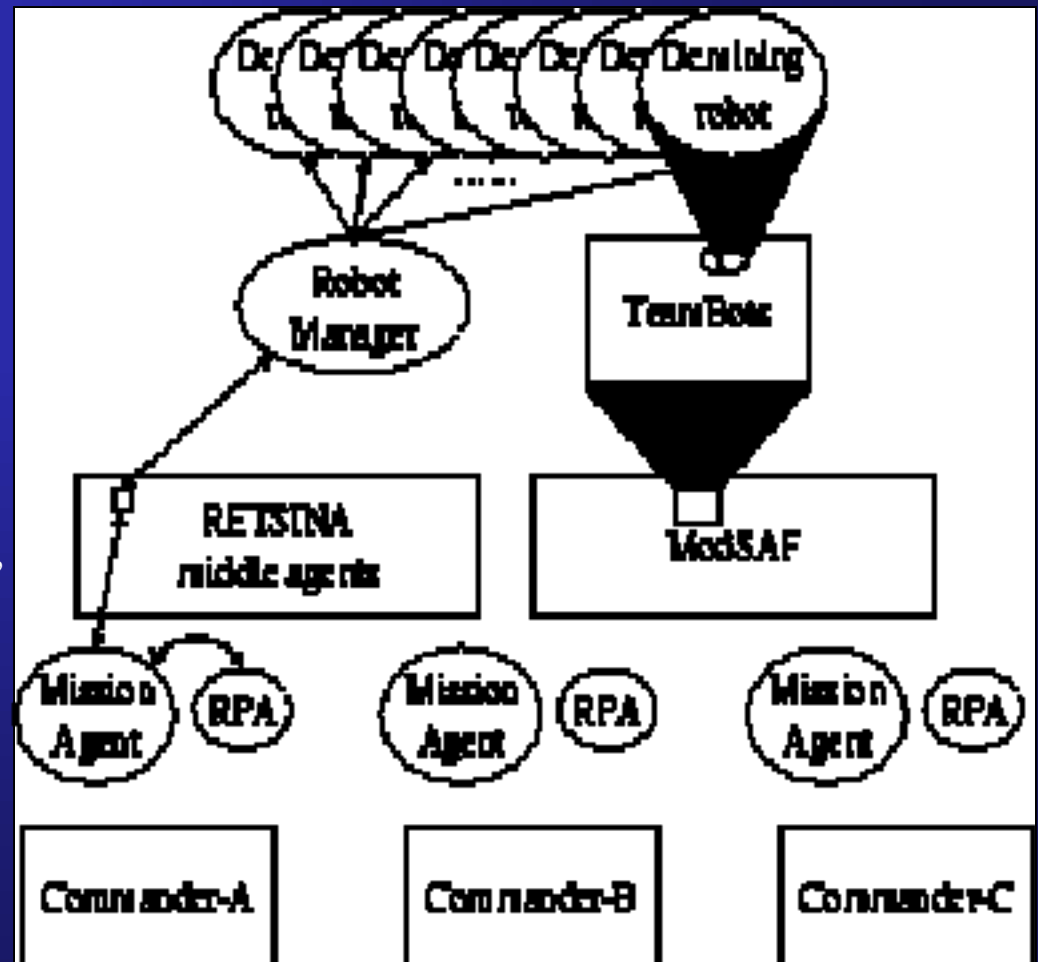
RETSINA *De-mining System*

De-mining *Robot Manager*

• Acts as the bridge between RETSINA and the de-mining robots

• Deploys the de-mining robots

• Maintains internal map of global minefield for de-mining robots

• Supports RETSINA Information Agent queries:
  • Single Shot Query
  • Active Monitor Query
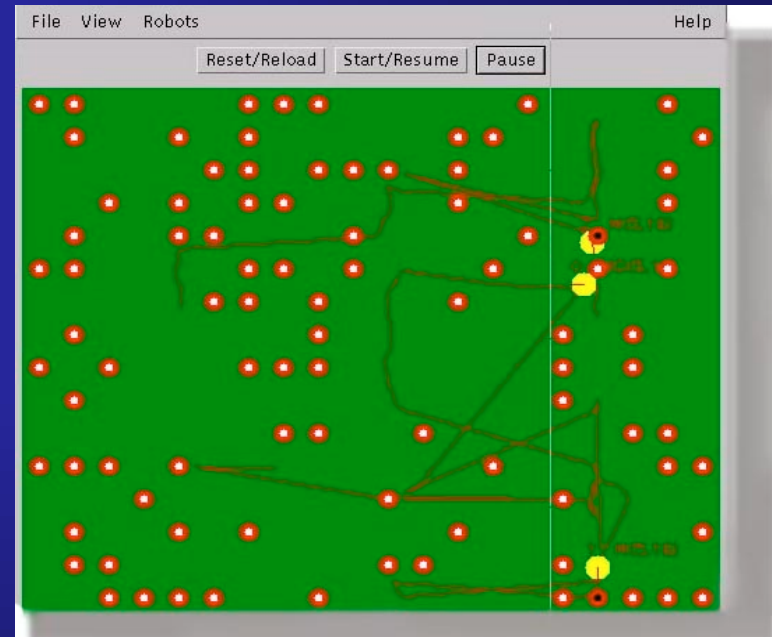 • about the status of the minefield and de-mining activity

402810: robot #1
403110: robot #0
408610: robot #2

Update robots
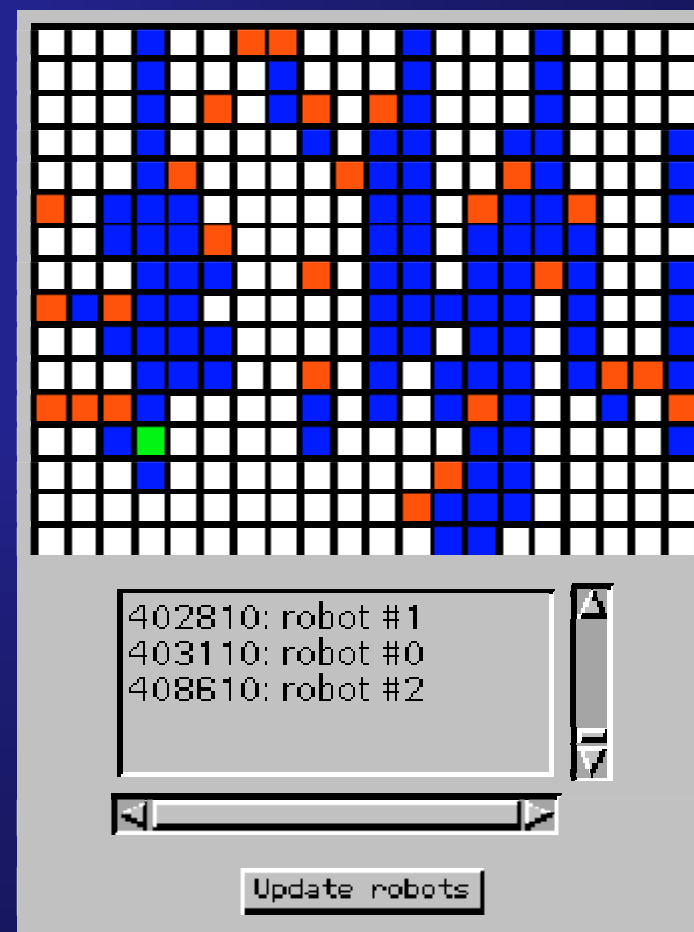
RETSINA *De-mining System*

Without Team-Aware Coordination

With Team-Aware Coordination
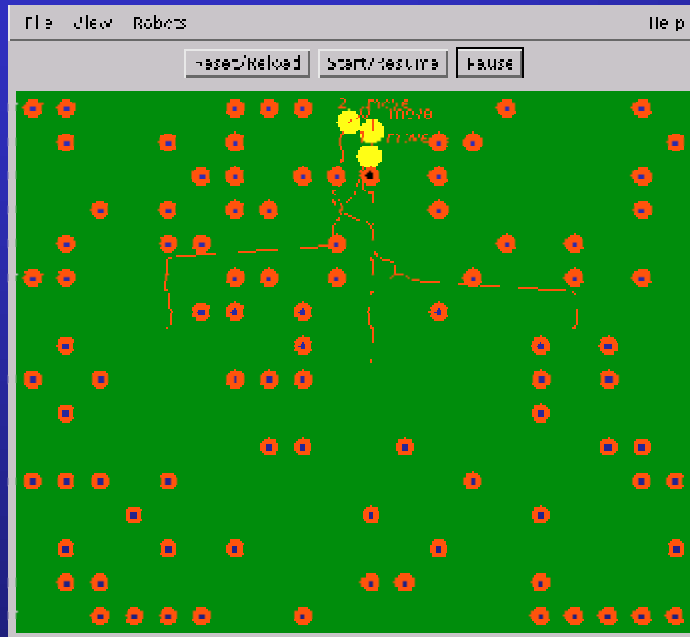
- Using simple homogenous strategy
- Robots interfere with each other
- Robots attempt to de-mine same mine

- Using simple homogenous strategy and rule that they cannot diffuse the same mine
- Robots do not interfere with each other
- A path is more rapidly cleared

http://www.cs.cmu.edu/~softagents/demining.html