Future Capabilities

Intelligent C3 Architectures

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Panel 4: Intelligent C3 Architectures

Environmental Complexity

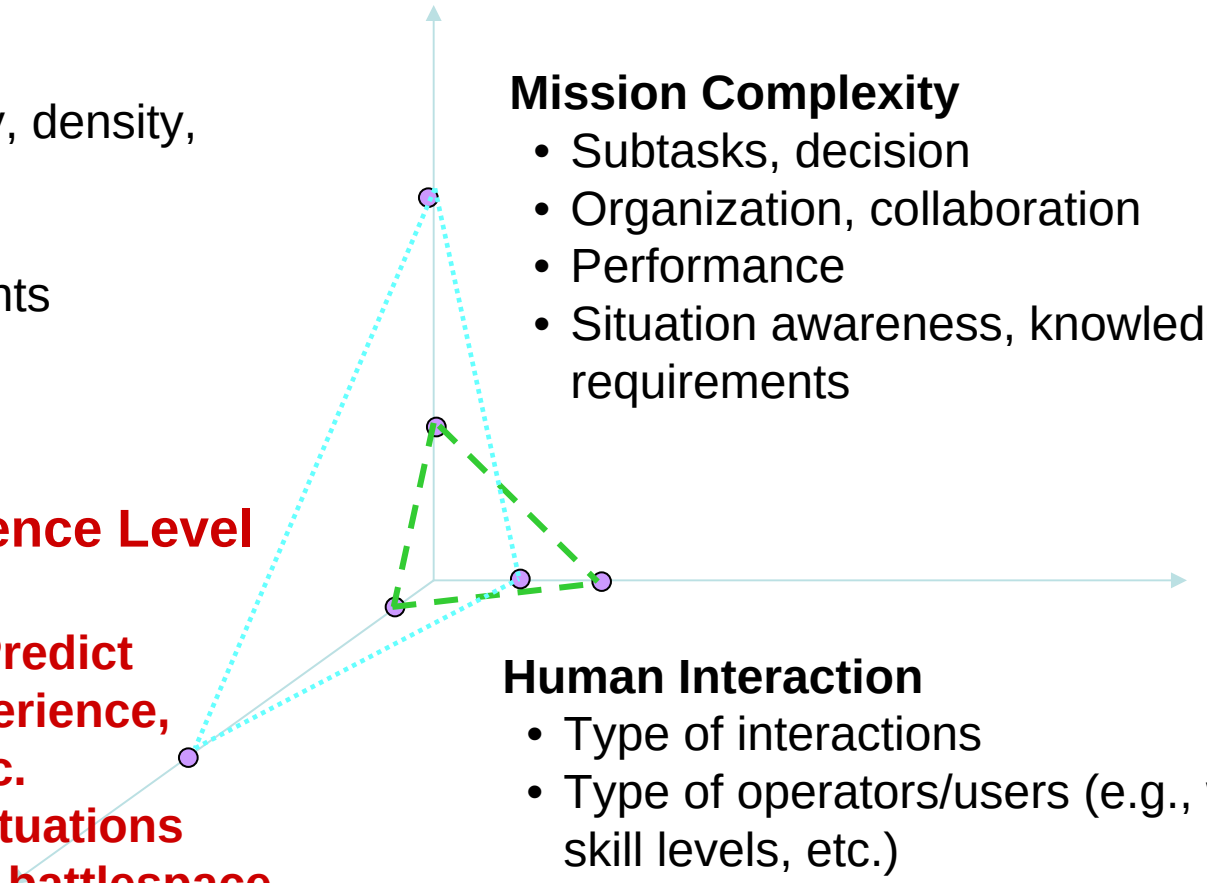
Solution ratios on:

- Terrain variation
- Object frequency, density, intent
- Weather
- Mobility constraints
- Communication dependencies

Machine Intelligence Level

Ability to:

- **Reason, Plan, Predict**
- **Learn from experience, instructions, etc.**
- **Adapt to new situations**
- **Understand the battlespace**
- **Interact with humans on a high level**



Mission Complexity

- Subtasks, decision
- Organization, collaboration
- Performance
- Situation awareness, knowledge requirements

Human Interaction

- Type of interactions
- Type of operators/users (e.g., workload, skill levels, etc.)
- Frequency, duration, robot initiated interactions

Panel 4: Intelligent C3 Architectures

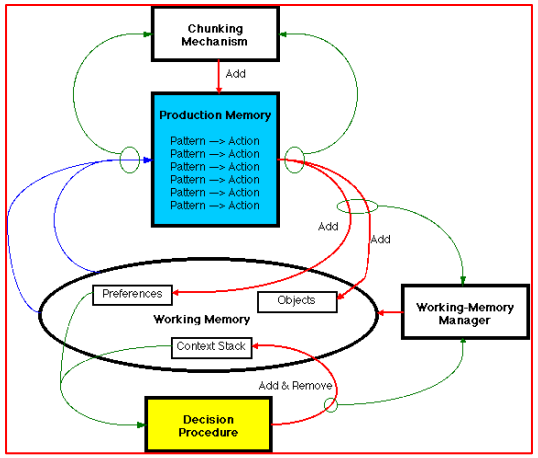
- Intelligence is key to autonomy and an enabler of other areas
  - Perception / Scene understanding
  - Collaboration with humans
  - Autonomous operations by teams of agents

- The Goal is to develop human-level intelligence for agents (cyber & physical), and teams of agents, so that they can
  - Perform in uncontrolled environments without constant human supervision
  - Interact with humans at a high level in ways that are natural to us

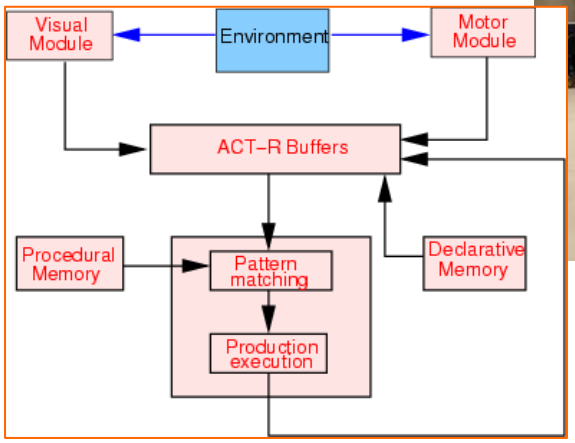
  - Characteristics of Uncontrolled Environments:
    - Uncertain Information: Imprecise, incomplete, contradictory, irrelevant
    - Open World:
      - Numbers and types of objects, agents, people are unrestricted
      - Incompleteness → Cannot infer the truth-value of all statements
    - Unpredictable: Agents/people may be non-cooperative or hostile with unpredictable adversarial behaviors

Topics and Issues

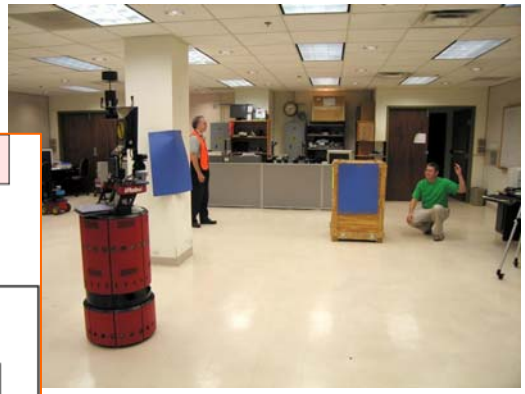
- **Intelligent and Cognitive Architectures**
  - **Basic capabilities:** Perception & recognition; reasoning, problem solving, planning & prediction; decision making; action/execution; and learning & adapting
  - **Knowledge:** Representation, organization, utilization, & acquisition/refinement
  - **Examples:** SOAR, Act-R, Polyscheme, Icarus, Prodigy, 4D/RCS, …



SOAR



ACT-R



Spatial reasoning for human-robot collaboration (NRL)

Topics and Issues

- **Command, Control, and Communications Issues**
  - C3 Architectures
    - Common/Interoperable architectures & components across diverse application domains
    - Intelligent C3 needs
    - Why and when cognitive architectures are useful for C3 tasks
  - Embedding in the physical world
  - Integration of AI/Intelligent Agent Approaches with Control
  - Human interaction
    - Control: Mixed-initiative decision making
    - Communication: Multi-modal dialogue (NL understanding, gesture recognition, …)
  - Intelligent Communications/Networking
    - Provide right information to the right people at the right time
    - Robustness with respect to data latency, dropped packets
    - Robust and adaptive network protocols and communications
  - Bio-inspired designs/approaches

Hard Problems

- **Integrated Architectures**
  - Integration of algorithms for perception, reasoning, learning, control, interaction, etc. is required to build autonomous systems that operate in real-time. Ad-hoc integration isn't sufficient because these algorithms are mutually constraining.
  - Must address practical concerns about the representations
    - Combine "probabilistic graphical models" and "logic-based representations"

- **Building Blocks of Intelligent Systems**
  - Reasoning
    - Common-sense reasoning with uncertain, incomplete, contradictory, information
    - Meta-Reasoning
  - Planning
    - Anytime planning, partially known environment, multiple goals, partially modeled
    - Plan/intention recognition: Knowledge-intensive requires rich inferencing in real time
    - Planning with unpredictable adversaries/coalitions: Requires plan/intention recognition, social/metacognition
  - Learning
    - Learning complex concepts/tasks, group behaviors, etc.
    - Life-long learning (unsupervised with embedded reasoning, hybrid)
  - Knowledge
    - Knowledge representation and acquisition from many sources. Some recent advances in handling contradictory information, but work is in its early stages
    - Updating knowledge bases, model of the world, beliefs

Hard Problems

- **Social Cognition and Metacognition**
  - Endowing cognitive architectures with explicit “mental models” of other agents to allow for collaboration, dialogue participation, quick strategy adaptation, socially-guided acquisition of knowledge, etc.

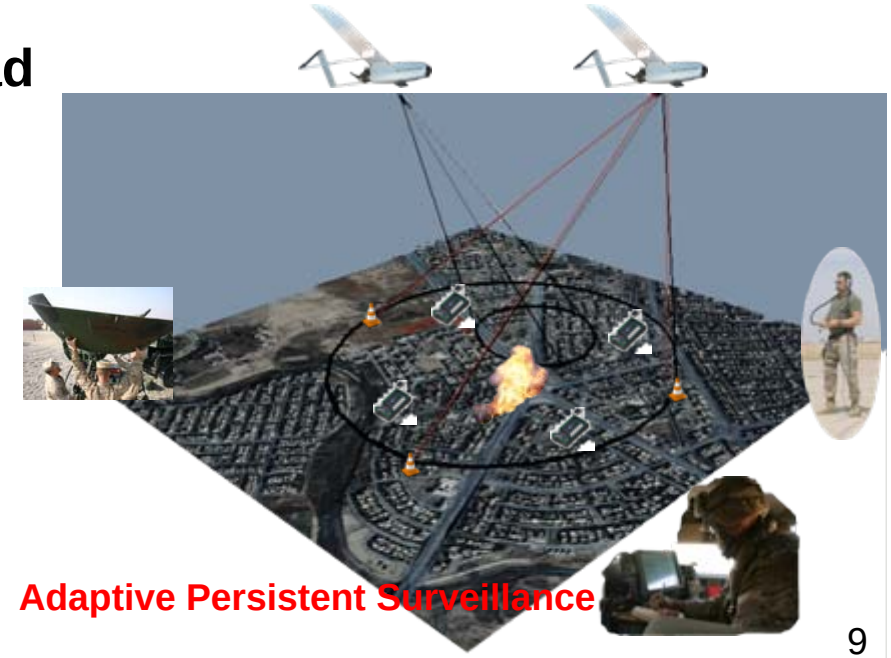
- **Intelligence for Decentralized Systems**
  - When we have Teams of Agents, these problems (e.g., decentralized planning) become even harder

Capabilities

- **Advances in solving Hard Problems in "Intelligent C3 Architectures" do not generally by themselves lead to stand-alone capabilities. They contribute to and enable the following capabilities discussed by Panels 1-3:**
  - **Human-Machine Interactions**
    - Hard Problems: Reasoning, plan recognition, knowledge, learning, social cognition, and cognitive architecture
  - **Coordinated Operations by Teams of Autonomous Systems**
    - Hard Problems: Decentralized reasoning, planning and plan recognition, knowledge management, learning, and intelligent architectures (for individual agents and teams of agents)
  - **Scene Understanding**
    - Hard Problems: Learning, knowledge acquisition, reasoning (about sensor data and the scene), planning (to obtain additional information), plan recognition, and architecture
- **Additional Capabilities**
  - **Rapid Deployment of Autonomous Systems**
  - **Training**
  - **Intelligent Assistant**
  - **Detect, Prevent, Mitigate Cyber Attacks**

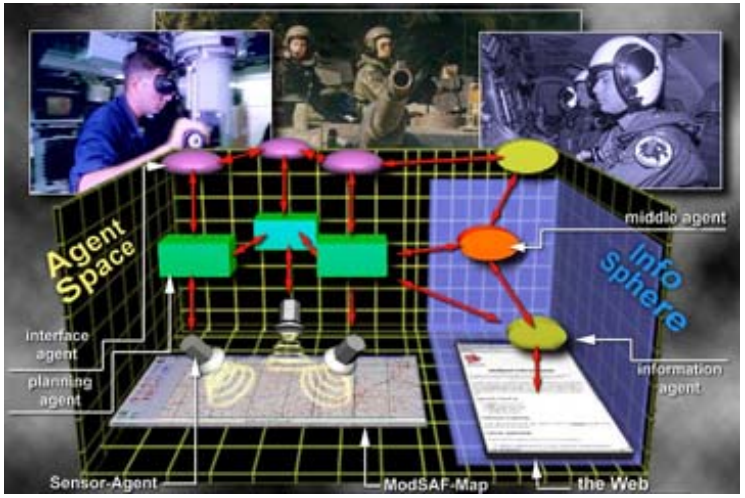
Capabilities

- **Rapid Deployment of Autonomous Assets**
  - **An autonomous system's ability to reason, plan, learn, and coordinate with other systems enables it to adapt to unforeseen situations. It reduces the need for time-consuming, pre-mission, detailed modeling, planning and tasking.**
  - **Plug-and-play new assets/payload**
  - **Post-deployment adaptability, with minimal warfighter intervention, is particularly important for long-duration missions, where planning becomes impossible (e.g. persistent surveillance).**



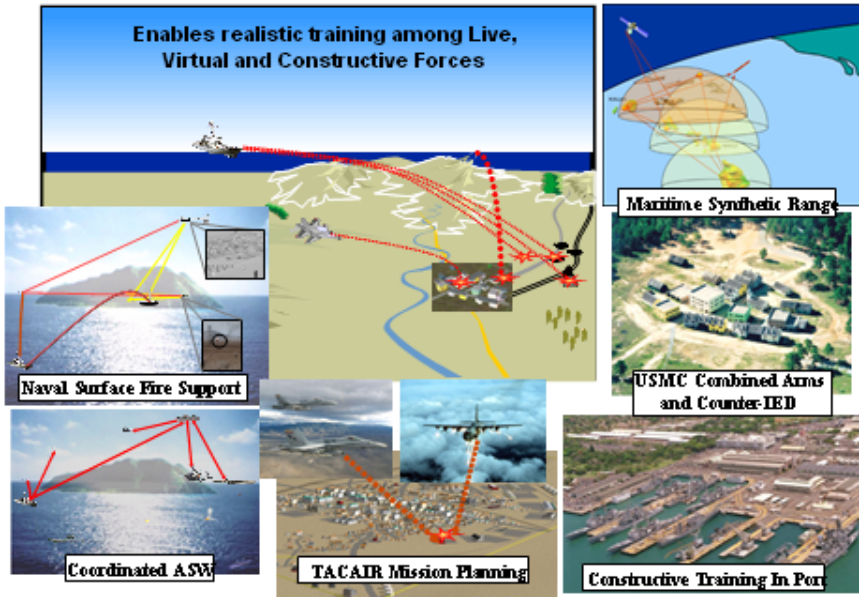
Capabilities

- **Training**
  - **Simulated environments with intelligent agents for realistic warfighter training**



An Example: VAST (Virtual At Sea Training) - Harold Hawkins

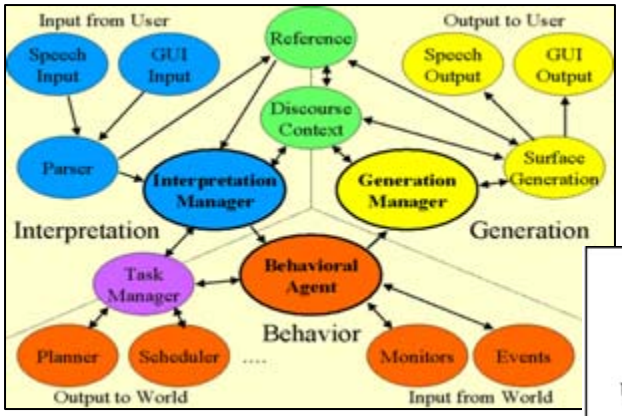
Training systems exploiting mixes of live, virtual and constructive simulation to provide combat teams the use of live or constructive fire against simulated adversaries in synthetic environments for realistic, affordable deployable training any time or place



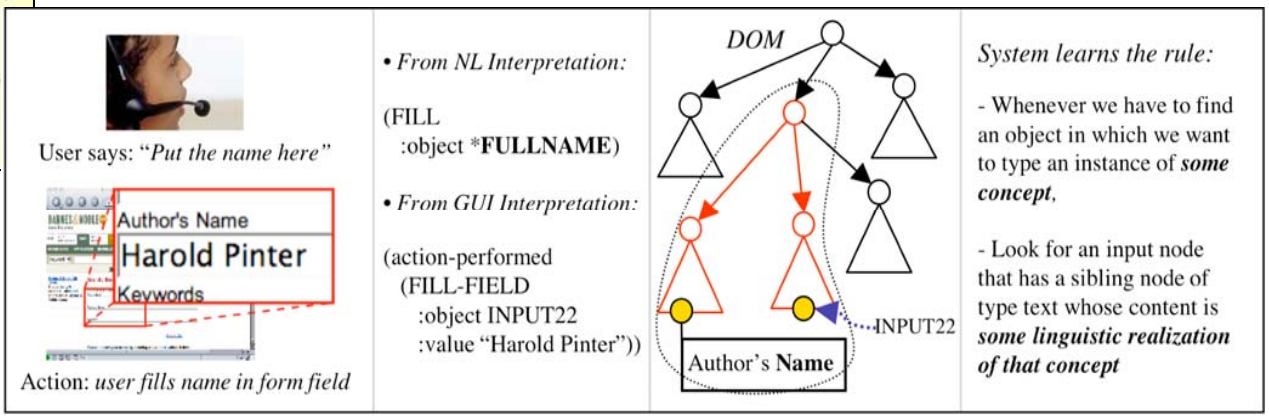
Capabilities

- **Intelligent Assistants**
  - **Software Agents that learn what the user does through instructions and observations**
  - **Reduce the cognitive load, perform repetitive and tedious tasks**

Example: Project CALO



Dialogue System Architecture



Example: Finds/fills the "author field" on a book-seller's website after only one session with a trainer!

Capabilities

- **Detect, Prevent, Mitigate Cyber Attacks**
  - **Large numbers of cyber agents observing and learning internet activities can provide warfighters real-time automated capabilities to**
    - **Detect abnormal activities**
    - **Prevent potential attacks (e.g. denial of service, virus propagation)**
    - **Plan to mitigate the effects of such attacks when they occur**