MULTI-AGENT SYSTEMS IN DEFENSE AND SECURITY

RESEARCH PROJECTS, SYSTEMS, AND TOOLS

The Control of Agent-Based Systems (CoABS) program

http://coabs.globalinfotek.com/

This is the technical coordination site for DARPA's project on software agents (http://www.darpa.mil/ito/research/coabs/index.html). It has pointers to the many MAS research projects it funds, as well as some publications and other information. CoABS is a program of the U.S. Defense Advanced Research Projects Agency (DARPA) to develop and demonstrate techniques to safely control, coordinate, and manage large systems of autonomous software agents. The Control of Agent-Based Systems (CoABS) program aims to develop and evaluate a wide variety of alternative agent control and coordination strategies to determine the most effective strategies for achieving the benefits of agent-based systems, while assuring that self-organizing agent systems will maintain acceptable performance and security protections. CoABS is investigating the use of agent technology to improve military command, control, communication, and intelligence gathering.

Integrated Marine Multi-Agent Command and Control System (IMMACCS)

http://www.cadrc.calpoly.edu/frame_text/text_projects_immaccs.html

Organization: Collaborative Agent Design Research Center (CADRC), California Polytechnic State University, San Luis Obispo, CA

The site contains research material (Brochure, Object Models and Immacs software) pertaining to IMMACCS, a Decision-Support System for the US Marine Corps Sea Dragon Program. IMMACCS was built by CDM Technologies at San Luis Obespo, CA under a contract from the Office of Naval Research. The Integrated Marine Multi-Agent Command and Control System (IMMACCS) provides an objectified picture of the battlespace to aid in exploiting opportunities and accelerating tempo. IMMACCS assists military commanders and crisis management teams under battle-like conditions when dynamic information changes, complex relationships, and time

pressures tend to stress the cognitive abilities of decision makers and their staff. As a trailblazing fires and maneuver system, IMMACCS disciplines the information environment and highlights factors affecting the commander's key concerns. In order to accomplish this support, IMMACCS incorporates agents that have reasoning and similarly intelligent capabilities. It is the core of the Capable Warrior C4I decision-support system (http://www.globalsecurity.org/military/ops/capable-warrior.htm), providing "near" real-time situation awareness (i.e., updated several times per second) at all C2 access nodes.

Reusable Environment for Task Structured Intelligent Network Agents (RETSINA)

http://www-2.cs.cmu.edu/~softagents/retsina.html

http://www.ri.cmu.edu/projects/project_76_text.html

Head: Katia Sycara, Robotics Institute, School of Computer Science, Carnegie Mellon University

These sites contain project and personnel information, publications and sub-projects. RETSINA is an open multi-agent system (MAS) that supports communities of heterogeneous agents. The RETSINA system has been implemented on the premise that agents in a system should form a community of peers that engage in peer to peer interactions. Any coordination structure in the community of agents should emerge from the relations between agents, rather than as a result of the imposed constraints of the infrastructure itself. In accordance with this premise, RETSINA does not employ centralized control within the MAS; rather, it implements distributed infrastructural services that facilitate the interactions between agents, as opposed to managing them. The RETSINA multiagent infrastructure consists of a system of reusable agent types that can be adapted to address a variety of different domain-specific problems. Each RETSINA agent draws upon a sophisticated reasoning architecture that consists of four reusable modules for communication, planning, scheduling and execution monitoring.

Agent Storm

http://www-2.cs.cmu.edu/~softagents/agent_storm.html

http://www.ri.cmu.edu/projects/project_442.html

Organization: Robotics Institute, School of Computer Science, Carnegie Mellon University

Agent Storm is a RETSINA agent scenario where agents autonomously coordinate their team-oriented roles and actions while executing a mission in the ModSAF

(Modular Semi-Automated Forces) simulation environment. The goal of Agent Storm is to increase the effectiveness of decision-making teams through the incorporation of agent technology in domains that are distributed, open and subject to time and other environmental contingencies. The AgentStorm system is composed of 25+ communicating software components developed with the RETSINA agent architecture. Agent Storm is one of seven winners of the "Innovative Enterprise Decision Support System" award in the Department of Navy Knowledge Fair 2000.

MokSAF

http://www-2.cs.cmu.edu/~softagents/moksaf.html

Organization: Robotics Institute, School of Computer Science, Carnegie Mellon University

MokSAF is a software system that supports mission critical team decision-making, and provides a virtual environment for route planning and team coordination. It allows commanders to register new agent teams and design new scenarios, plan individual routes to a common rendevous point, communicate synchronously across great distances, negotiate the selection of platoon units, and plan joint missions via a shared virtual environment

TIE-3 Demo: Interoperability of Multi-agent Systems to Support an Escalating Noncombatant Evacuation Operation (NEO)

http://www-2.cs.cmu.edu/~softagents/tie3.html

Organization: Robotics Institute, School of Computer Science, Carnegie Mellon University

The NEO Tie-3 Demo is a demonstration of agent technology in a Noncombatant Evacuation Operation (NEO). In TIE-3, RETSINA and Open Agent Architecture (OAA) agent systems are coordinated and their agents are used to evaluate a crisis situation, form an evacuation plan, follow an evolving context, monitor activity, and dynamically re-plan. TIE-3 demonstrates the interoperability and use of two disparate agent systems for aiding humans (officers and Ambassador) to effectively monitor the scenario, retrieve and fuse information for immediate use, and to plan and re-plan an emergency evacuation.

The Aircraft Maintenance System

http://www-2.cs.cmu.edu/~softagents/aircraft.html

Organization: Robotics Institute, School of Computer Science, Carnegie Mellon University

The Aircraft Maintenance System is wearable software that uses RETSINA agents to assist in the process of documenting and making repairs to aircraft.

RETSINA Demining

http://www-2.cs.cmu.edu/~softagents/demining.html

Organization: Robotics Institute, School of Computer Science, Carnegie Mellon University

This is a robotic demining system, part of AgentStorm. The robotic demining agents cooperatively clear paths, enabling simulated forces to breach minefields. Within the demining domain, the researchers explore different multi-robot cooperation and communication strategies.

SEAWAY: Joint Decsion-Support System for Sea Base Logistics Planning and Coordination

http://www.cadrc.calpoly.edu/frameset_info/info_projects_seaway.html

Organization: Collaborative Agent Design Research Center (CADRC), California Polytechnic State University, San Luis Obispo, CA

The site contains information on SEAWAY, a decision-support system designed to satisfy the focused logistic demand of Joint Vision 2020 (U.S. Department of Defense). The SEAWAY's approach to system design incorporates collaborative agents with knowledge in specific domains such as cargo visibility, cargo operations, mission planning, mission tracking, and mission execution. These agents create a partnership and collaborate with expert human staff members during the various stages of the logistic process. SEAWAY is expected to play an integral part in the naval and joint sea base logistic program. SEAWAY is an agent-based system that assists sea base operations by providing total theater visibility of all shipborne asset items en route to onshore objectives.

LOGGY: Joint Decision-Support System for Tactical Logistic Planning and Coordination

http://www.cadrc.calpoly.edu/frameset_info/info_projects_loggy.html

Organization: Collaborative Agent Design Research Center (CADRC), California Polytechnic State University, San Luis Obispo, CA.

LOGGY is a decision-support system designed to satisfy the focused tactical logistic demands of Joint Vision 2020 (U.S. Department of Defense). LOGGY demonstrates how agent-based tools can assist commanders in rapidly developing schemes of

maneuver and the correlating logistic requirements that support the warfighter in the field.

FALCON: Future Army Leaders Command Operations Network

http://www.cadrc.calpoly.edu/frameset_info/info_projects_falcon.html

Organization: Collaborative Agent Design Research Center (CADRC), California Polytechnic State University, San Luis Obispo, CA

The project FALCON is designed to provide an expandable intelligent agent tool kit as a client to the DaVinci system currently under development by the US Army Communications and Electronics Command (CECOM), under the Command Post XXI Advanced Technology Demonstration (ATD) program, at Fort Monmouth, New Jersey. FALCON utilizes CDM's Integrated Cooperative Decision Making framework and includes agents to address the following military command and control objectives: execution monitoring, scaled distributed situation awareness, inferences and implications, focused overwatch, and allocation of both combat and combat service-support assets.

ISAAC/EINSTein: An Artificial-Life Approach to Land Combat

http://www.cna.org/isaac/

http://www.cna.org/isaac/einstein_test_version.htm

The site contains research material (papers, briefs and beta-test software) pertaining to an ongoing project that involves applying complexity theory to land warfare. ISAAC and EINSTein are "toy model" agent-based models of combat. ISAAC is a simple multiagent-based model of land combat that was developed to illustrate how certain aspects of land combat can be viewed as emergent phenomena resulting from the collective, nonlinear, decentralized interactions among notional combatants. ISAAC takes a bottom-up, synthesist approach to the modeling of combat and represents a first step toward developing a complex systems theoretic analyst's toolbox for identifying, exploring, and possibly exploiting emergent collective patterns of behavior on the battlefield. Originally developed for the US Marine Corps, EINSTein's continued development is sponsored, in part, by the Office of Naval Research.

The CoAX Project (Coalition Agents eXperiment)

http://www.aiai.ed.ac.uk/project/coax/

This is an international collaborative effort that aims to demonstrate that the agent-based computing paradigm is a promising new approach to dealing with the technical

issues of establishing coherent command and control (C2) in a coalition organization. This effort is a Technology Integration Experiment under the auspices of DARPA's Control of Agent Based Systems (CoABS) program.

The ActComm Project

http://actcomm.thayer.dartmouth.edu/

Project Personnel: George Cybenko, Bob Gray, David Kotz, and Daniela Rus at Dartmouth College, H. T. Kung and Brad Karp at Harvard University, Ken Vastola and Major Lisa Shay at Rensselaer Polytechnic Institute, P. R. Kumar, Tamer Basar and Gul Agha at the University of Illinois, Ken Whitebread and Sue McGrath at Lockheed Martin, and Eileen Entin at ALPHATECH. Contact information of all the participants can be found at the project's site.

This project focuses on transportable agents and wireless networks. The project's goal is to develop technologies that will maximize the usability of complex, global computer and communications networks for modern command-and-control applications. The concept of an *active communications system* is major technical innovation of the project. Active elements will be coordinated by a novel architecture that uses advanced agents to manage network, computer and information assets delivering high confidence communications and computing.The ActComm project is funded by the Air Force Office Of Scientific Research through a Department of Defense Multidisciplinary University Research Initiative (MURI) grant.

Decision-Theoretic Multi-Agent Sensor Planning

http://www-cse.uta.edu/~holder/research/ugv.html

Investigators: Diane J. Cook, Piotr Gmytrasiewicz and Lawrence B. Holder, University of Texas at Arlington, Department of Computer Science and Engineering

The project focuses on a decision-theoretic approach to cooperative sensor planning between multiple autonomous vehicles with specific applications for executing military missions. During the deployment of autonomous vehicles, intelligent cooperative reasoning must be used to select optimal vehicle viewing locations and select optimal camera pan and tilt angles throughout the mission. Decisions can be made in order to maximize the value of information gained by the sensors while maintaining vehicle stealth. Changes in the battlefield over time can be used to learn patterns of enemy movement and improve estimation of future utility for sensor placement alternatives. Because military missions involve multiple vehicles, cooperation can be used to balance the work load and to increase information gain. The approach is being applied within DARPA's Unmanned Ground Vehicle program.

Littoral Warfare Modeling and Simulation

http://www.ncsc.navy.mil/Capabilities_and_Facilities/Capabilities/Littoral_Warfare_Modeling_and_Simulation.htm

Organization: Coastal Systems Station

The Coastal Warfare Evaluation Systems (CWES) office provides end-to-end simulation support to meet analysis, training, and acquisition needs for the littoral warfare (LITWAR) community, including mine countermeasures (MCM), minefield operations and planning, amphibious assaults, naval fires support, and naval special warfare.

Robust Agent-based Systems Incorporating Teams of Communicating Agents

http://www.cse.ogi.edu/CHCC/Agents/main.html

Organization: Center for Human-Computer Communication (CHCC) in the Department of Computer Science & Engineering within the OGI School of Science & Engineering at the Oregon Health & Science University

This is another project sponsored by the Defense Advanced Research Projects Agency under the CoABS (Control of Agent Based Systems) Program. The concept of *teamwork* is central to this project and the goal is to support robust teams of humans and robots in the long run. The project is comprised of the following three research areas and deliverables:

- Adaptive Agent Architecture (AAA): Based on the theory of teamwork, the researchers have built a fault tolerant multi-agent system, AAA, and deployed it in support of TIE1 (helicopter evacuation). The research has also contributed a theory of persistent teams and maintenance goals, and a formal representation of fault-tolerant behavior in logic. The AAA library is developed in Java and is available for download by the DARPA CoABS and the research community.
- Agent-Talk: This research investigates the design of an agent communication language with well-founded communicative acts and provably correct dialogue protocols. The researchers at CHCC have proposed a framework for group communication semantics that meets a broad range of desired requirements.
- STAPLE: This research aims to design, specify and implement an agent oriented programming language called STAPLE (Social & Team Agents Programming Language) by building upon a formal theory of multi-agent systems (Belief, Desire, Intention, Teamwork, Persistent Teams, Maintenance Goals), a formal agent communication language based on

speech act theory with provably correct semantics (Agent-Talk), and agent architectures that use some incarnation of BDI logic as formal specification of their behavior.

VIPAR Multi-Agent Intelligence Analysis System

http://www.csm.ornl.gov/~v8q/Homepage/Projects/projects.htm

Contact: Dr. Thomas E. Potok, Group Leader - Collaborative Technologies, Computer Science & Mathematics Division, Oak Ridge National Laboratory

The goal of VIPAR (Virtual Information Process Research Agent) has been to develop intelligent software agents that address challenges facing the intelligence community in quickly gathering and organizing massive amounts of information, then distill that information into a form directly and explicitly amenable for use by an intelligence analyst in his decision making process. The Oak Ridge National Laboratory has successfully implemented this technology for the US Pacific Command.

SURGE - Spare Part Grouping

http://www.csm.ornl.gov/~v8q/Homepage/Projects/projects.htm

Contact: Dr. Thomas E. Potok, Group Leader - Collaborative Technologies, Computer Science & Mathematics Division, Oak Ridge National Laboratory

The goal of SURGE (Supplier Utilization through Responsive Grouped Enterprises) has been to develop an agent based manufacturing system that groups aircraft parts into families so that efficiencies can be gained. The system has been successfully developed for the Defense Logistics Administration.

TeamLeader: An Approach to Mixed-Initiative Agent Team Management and Evaluation

http://openmap.bbn.com/~burstein/coabs/

Investigators: Dr. Mark H. Burstein, Principal Investigator, BBN Technologies (Cambridge), and Prof. Drew V. McDermott, Department of Computer Science,Yale University

This is a project within the Control of Agent Based Systems Program of DARPA supported by the Air Force Research Laboratory at Rome, NY. The TeamLeader project is taking an experimental, prototype driven approach to developing strategies and mechanisms for humans to control and manage collections of software agents acting as teams within mixed human/agent organizations. A major focus and driving force for the research in this project has been the role of BBN Technologies as lead

for a collaborative effort to develop a large scale demonstration of command and control in mixed human/agent organizations. The Mixed-initiative Agent Team Administration (MIATA) system has demonstrated how six people representing various military officers could control over 100 agents as they executed, in simulation, a recreation of the U.S. relief effort in response to the Hurricane Mitch disaster.

Agent-Based Modeling and Behavioral Representation

http://www.afrlhorizons.com/Briefs/0006/HE0009.html

Organization: AFRL's Human Effectiveness Directorate, Deployment and Sustainment Division, Sustainment Logistics Branch, Wright-Patterson AFB OH

To satisfy the needs for more sophisticated modeling approaches that will enhance the modeling and simulation capability of the Air Force, scientists at the Human Effectiveness Directorate are conducting research to discover efficient ways to simulate intelligent behavior in existing and new models. In particular, they are developing and demonstrating agent-based approaches to emulate intelligence. The first technology demonstration project has been to create an agent-based intelligent mission controller node (IMCN) to link the Theater Battle Management Core System (TBMCS) to several Air Force simulations, including the current simulation used to support CPXs (Air War Simulation) and the new simulation environment under development (National Air and Space Model). The second demonstration focuses on improving the behavior of some of the autonomous models that make up a CPX, for example, individual aircraft that fly missions under the control of role players. A role-playing intelligent controller node (RPICN) is being created, which will be an autonomous agent-based model capable of "seeing" changes to the battlefield and reporting them back to the role player.

Enabling agent perception in multi-agent air mission simulation

http://www.cs.mu.oz.au/~pearce/

http://www.cs.mu.oz.au/~pearce/research.html

Co-Chief Investigators: Dr A Pearce & Prof T Caelli. DSTO: Dr. S. Goss1996-7: 2 year Postdoc (Dr. A. Pearce), Air Operations Division (AOD) 1998-9: Contract Research Grant for deliverable (2) with Prof S.Venkatesh.

This project has developed in collaboration with Air Operations Division, DSTO, (http://www.dsto.defence.gov.au/) real-time matching and learning techniques that enable agents to recognize aeroplane manoeuvres during operational flight simulation. Outcomes: used for integrating valid pilot competencies into computer

controlled agents, earmarked for future use in answering specific questions about expensive equipment requisitions, component capabilities and rehearsing dangerous tactical operations.

Situation description language (SDL) and situation assessment processor (SAP)

http://www.cs.mu.oz.au/~pearce/

Co-Chief Investigators: Dr A Pearce & Prof S Venkatesh. DSTO: Dr. C. Davies 1998-2001 3 year Postdoc (Dr S Greenhill), Maritime Operations Division (MOD)

The project involves development of methods for acquiring and describing plans and mission details for submariners. In collaboration with Maritime Operations Division, DSTO (http://www.dsto.defence.gov.au/).The project addresses a basic deficiency in maritime simulations, in that there has been no explicit way of representing the kind of situational assessments (tactical or operational) that experts think in terms of when describing responses to situations. The project utilizes temporal and interval logic, spatial analysis, procedural and multi-agent reasoning and Bayesian uncertainty techniques. The technology has value in the area of improving the quality and efficiency of multi-agent simulations of procedural and tactical operations. Natural language situation descriptions improve the credibility of simulations by allowing stakeholders to easily appreciate the logic controlling the action in a simulation.

C2: Agent-oriented software engineering

http://www.cs.mu.oz.au/~pearce/

Principle Investigator: Dr A Pearce. ADI Limited: Dr N. Lewins

This project aims to apply agent-oriented software engineering methods by transferring agents, normally used in operational simulations, for visualization in desktop command & control systems. In collaboration with ADI Limited (http://www.adi-limited.com.au/).

Future Combat System - Joint Vision Battlelab Generative Analysis Project

http://www.lanl.gov/orgs/d/d5/projects/FCSJVBGAn/FCSJVBGAn.htm

Organization: Military Systems Analysis and Simulations Group (D-5) at Los Alamos National Laboratory

Generative Analysis (GAn) is the use of evolutionary and other heuristic learning algorithms to search and assess technology, force structure, and doctrinal spaces of a new or future system using simulations that portray the system in the environments that it is expected to operate.

SOFTWARE TOOLS

The Darpa Agent Markup Language (DAML)

http://www.daml.org/

This is the DARPA Agent Markup Language program homepage. The goal of the DAML effort is to develop a language and tools to facilitate the concept of the semantic web. It is a language for writing ontologies. They also now offer DAML-S, a language for describing web services.

The CoABS Grid

http://coabs.globalinfotek.com/

The CoABS Grid is an important output from DARPA's CoABS — a middleware layer based on Java / Jini technology that provides the computing infrastructure to enable the dynamic interoperability of distributed, heterogeneous, objects, services, and multi-agent systems. It is being used to produce militarily relevant technical integration experiments where legacy systems and multi-agent systems developed by CoABS researchers are integrated to solve real-world problems. The CoABS Grid features flexible run-time communications and dynamic registration and discovery of relevant participants. It is adaptive and robust, with the system evolving to meet changing requirements without reconfiguring the network.

D'Agents

http://www.cs.dartmouth.edu/~agent

Organization: Dartmouth College

D'Agents is a mobile-agent system. The ultimate goal of D'Agents is to support applications that require the retrieval, organization and presentation of distributed information in arbitrary networks. D'Agents focuses on support for multiple languages, security, fault tolerance, performance, and the ability to operate effectively in volatile, wireless networks. It will be the middle layer of the ActComm infrastructure, sitting on top of the network services but below the planning, learning, resource discovery, and information-retrieval services.

Generative Analysis Project - Integrated Virtual Environment for Simulation (IVES)

http://www.lanl.gov/orgs/d/d5/projects/IVES/GAnIVES.htm#IVES

Organization: Military Systems Analysis and Simulations Group (D-5) at Los Alamos National Laboratory

The Integrated Virtual Environment for Simulation (IVES) is a Java implementation of simulation concepts developed by personnel within the Military Systems Analysis and Simulations Group (D-5) at Los Alamos National Laboratory. IVES is a composition-centered framework to develop discrete event simulations based on a regulated aggregate-component view of simulation. A simulation is viewed as a top-level aggregate comprised of a collection of components, i.e., simulation entities, that interact with each other and an optional simulation environment. A component can be realized as an actor, an agent, or any entity that can generate events that affect itself, other components, or the state of the system.

The Swarm Simulation System:A Toolkit for Building Multi-agent Simulations

http://www.santafe.edu/projects/swarm/

http://www.swarm.org/index.html

Authors: Nelson Minar, Roger Burkhart, Chris Langton, Manor Askenazi

Swarm is a multi-agent software platform for the simulation of complex adaptive systems. In the Swarm system the basic unit of simulation is the swarm, a collection of agents executing a schedule of actions. Swarm supports hierarchical modeling approaches whereby agents can be composed of swarms of other agents in nested structures. Swarm provides object oriented libraries of reusable components for building models and analyzing, displaying, and controlling experiments on those models. Swarm is currently available as a beta version in full, free source code form. It requires the GNU C Compiler, Unix, and X Windows. For more Swarm information, software, user community information and publications, visit: http://www.swarm.org/index.html

The Agent-Based Configurable (ABC) Testbed

http://www.bbn.com/mst/abc.html

Authors: The BBN Technologies

The ABC Testbed combines modeling and simulation with innovative visualization, providing a simulation and analysis environment for understanding large distributed heterogeneous systems. It allows researchers to: model system components at suitable levels of fidelity, to execute those models in a controlled environment and to analyze the resulting data set.