# Multiagent Coordination in Distributed Interactive Battlefield Simulations*

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The goal of our research is to understand the cognitive capabilities required in fully autonomous intelligent systems. The specific application we are studying is real-time distributed battlefield simulations that include humans (in simulators and specially instrumented vehicles) and computer generated forces, interacting in real-time, unscripted, realistic engagements. The Soar/IFOR consortium, involving the University of Michigan, Information Sciences Institute of the University of Southern California, and Carnegie Mellon University, is developing simulated computer forces for all military air missions (Laird *et al.* 1995; Tambe *et al.* 1995).

Computer forces must have many of the cognitive capabilities of people, including real-time reactivity, goal-directed problem solving, and large bodies of knowledge. In addition, one of the most important determiners of success is the ability to coordinate their behavior with other friendly forces. Previous work in computer-generated forces has not extensively modeled the coordination of individual forces, using either an omniscient human or computer agent to provide the appearance of coordination through low-level monitoring and controlling of individual agents.

In Distributed Artificial Intelligence, most of the techniques put a premium on architectural mechanisms for general, but knowledge-lean approaches to coordination. The approaches are based on explicit runtime reasoning and communication about the coordination problem itself, requiring complex models of agents, negotiation, etc. These techniques may be necessary for coordination "in general"; however, for modeling military organizations, where there are established methods and procedures, it is possible to "compile out" general reasoning and communication about coordination and use domain specific knowledge of how and when to coordinate.

Thus, our approach is straightforward. We model the command and control methods currently in use by military organizations so that our agents must coordinate their behavior just as humans do, through shared knowledge and various forms of communication. One advantage of this approach is that our agents can coordinate not only among themselves, but also with humans. Thus, we can have missions, such as an air-to-ground attack by a division of four aircraft where there is a mixture of human and computer agents participating. The human can use the same methods for coordination with the IFOR as would be used with with other humans (although not in full natural language).

Using this approach, agents (be they human or computer) coordinate their behavior based on the extensive shared background knowledge of common doctrine and tactics, explicit communication during a mission briefing, the observed behavior of other agents, and explicit communication between agents during execution of the mission. Currently, our agents have between 1800 and 2700 rules, have approximately 40 different mission parameters, and send and receive approximately 80 different message types. Our approach puts a premium on knowledge. Knowledge about common doctrine and tactics, knowledge about missions, knowledge about interpreting behavior, and knowledge about interpreting communication. Our hypothesis (borne out in our implementations of ten different types of agents) is that an architecture designed to support general intelligent agents — such as Soar (Rosenbloom, Laird, & Newell 1993) — is appropriate for these types of complex coordination.

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