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Defence Applications of Multi-Agent Systems

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Revised and Invited Papers

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Preface

The evolution of defense processes towards network-enabled systems and rapid deployment scenarios, as exemplified by the UK Network Enabled Capability (NEC) program or the US Network Centric Warfare (NCW) effort, is creating an urgent demand for highly adaptive and autonomous information support systems. These are large-scale organizational and technological transformational processes. There is therefore a requirement to create autonomous IT infrastructures with automated logistics and planning capability, all of which provides significant scope for an agent-based approach.

The emerging problem set in the defense ICT domain is also mirrored in the civil sector for enterprise scale systems, where cost reduction, legacy integration, scalability and security, are all significant problems to be addressed. To date, the civil sector has taken the lead on the application of agent systems, particularly in the manufacturing sector, (e.g., [Jennings & Bussmann 2003]). Recently, agent systems have become significant mainstream ICT technologies with the emergence of IBM's autonomic computing initiative and the integration of agent technology in various products for infrastructure management. Further information on civilian applications of agent technology can be found in the AAMAS industrial applications conference proceedings [Pechoucek et al. 2005].

Of course, the defense domain has the additional problems resulting from hostile actors and environments. However, it is precisely this aspect that makes a multi-agent system (MAS) approach attractive as it offers increased resilience, run-time flexibility, and embedded intelligence. In addition the key factors in the evolution of MAS have been the advent of service-oriented computing, high-power computing capability, and high-speed ubiquitous networks, which have finally created a suitably rich electronic environment for MAS to be deployed to full effect.

The defense domain therefore covers a broad spectrum of applications that will benefit from an agent approach, including:

ISTAR – sensing and information fusion management
C3 – agent-based command and control support and analysis
NEC/NCW – agent-based middleware and P2P networks
UAVs and Autonomous Robots
Self-Organizing Systems and networks
Simulation and Scenario Engines
Real-time Logistics and Planning support

As we enter the next phase of networked warfare up to 2020, the need for self-organizing, self-healing and intelligent ICT support systems and networks will become paramount. The roadmap to achieve this vision of NEC/NCW is heavily reliant on the fullest utilization of multi-agent systems.

This book is a post-proceedings for the Defence Applications of Multi-Agent Systems (DAMAS) workshop held at the Autonomous Agents and Multi-Agents System conference (AAMAS) in Utrecht in June 2005 (http://www.aamas2005.nl). It contains versions of selected papers presented at the workshop which have been updated and extended by the authors in the light of the comments and discussion of their work.

The workshop was cross-disciplinary in nature, bringing together researchers from academic, industrial, and defense teams. The goals of the workshop were to explore the value of agent technology in defense applications and to review example agent systems applied to defense applications. The book therefore represents a cross-section of the current state of the art in defense applications of agent systems.

The workshop featured several lively discussions on the presentations and the challenges that the defense domain held for agent technology. These are summarized in the first invited paper in this collection, by Beautement et al.

Part 1 contains several papers on decision support and simulation. This includes a contribution on maritime situation awareness by Hemaissa et al., which present an innovative approach based on multi-agent negotiation to fuse classifiers, using the flexibility and reliability of a multi-agent system to exploit distributed data across dispersed sources. The following paper by Louvieris et al outlines the application of Bayesian technologies to CSF (critical success factors) assessment for parsimonious military decision making using an agent-based decision support system. This paper illustrates the application of CSF-enabled Bayesian belief networks (BBN) technology through an agent-based paradigm for assessing the likelihood of success of military missions. A paper by Wise et al. considers whether an agent-based autonomic network control system can provide the flexibility needed to allow an agile mission group to reconfigure their network, while maintaining a high tempo, yet minimize their demands on signals staff. Their architecture describes services that configure a device, and a hierarchy of networks, in terms of the contribution that each makes to networks of which it is a member.

The next paper in this section by Parunak et al. considers the importance of modelling emotion within a simulated combat environment in order to provide a realistic simulation of the likely behavior of forces in battle. The models developed simulate the propagation of emotion in combat units using concepts from Agent technology such as pheromones in a computationally tractable and realistic training simulator.

Part 2 looks at UAVs and starts with a paper from Han et al. which discusses how three technologies can be combined to achieve the UAV functionality needed for coordinated autonomous operation, from building up accurate beliefs, efficiently gathering information, to acting rationally. It discusses how, in order to facilitate the target-tracking activity, a reliable information provisioning network can be constructed by selecting the most appropriate information sources and using trust evaluations to perform belief revision. Also, a macro-based action selection scheme is deployed for efficient coordination of target-tracking activity among agents.

This is followed by a paper from Dasgupta et al. on the interesting problem of automatic target recognition using a multi-agent swarm of unmanned aerial vehicles.

The aim being to avoid a centralized approach to UAV direction. The UAVs employ a swarming algorithm implemented through software agents to congregate at and identify targets.

Part 3 considers wider system management issues such as security and the logistics domain. The paper by Janicke et al. presents a security model that allows the expression of dynamic access control policies that can change on time and events. A simple agent system, simulating a platoon, is used to show the need and the advantages of our policy model. The paper finally describes how existing tool-support can be used for the analysis and verification.

A paper by Greene et al. covers the critical topic of intelligent logistics support using an agent approach. They present a novel cognitive agent architecture and demonstrate its effectiveness in the sense and respond logistics (SRL) domain. Effective applications to support SRL must anticipate and adapt to emerging situations and other dynamic military operations. SRL transforms the static, hierarchical architectures of traditional military models into re-configurable networks designed to encourage coordination among small peer units. This is followed by work from Carvalho et al., who present a mobile agent-based middleware that supports both point-to-point message and hierarchical data-stream communications in these environments. Two infrastructure technologies (Mockets and FlexFeed) are introduced as service providers for messaging and publish-subscriber models for data streaming. Opportunistic resource allocation and monitoring are handled by distributed coordination algorithms, implemented here through two complementary technologies (Stand-In Agents and Acquaintance models).

The final paper by Allsop is an invited contribution that considers the technical challenges that remain in realizing the potential of agent-based technologies in the defense arena.

Organizing the DAMAS workshop and producing this volume of proceedings was a difficult, time-consuming, but ultimately very rewarding exercise (or so we hope). It would have been far harder without the support, advice, and assistance of others. Most significantly no event of this type can occur without the support of the community in the form of contributed papers and presentations, and in the form of reviewing. All the presented papers at DAMAS were reviewed by at least two anonymous reviewers in the Program Committee, and we would like to take this opportunity to thank them for the quality of the reviews they produced and for the timely fashion in which they produced them. It is worth stressing that the nature of the DAMAS Program Committee makes this an even more noteworthy point than would normally be the case in a workshop. The DAMAS PC was made up of members that are all actively involved in defense projects and many of the members are senior people in major commercial organizations, and the demands made on their time make taking on a duty like reviewing for a workshop especially onerous.

In addition we would like to thank Nick Jennings and Mark Greaves for their assistance in organizing the workshop and acting as senior Program Committee members. Both of them were instrumental in making the event happen, and their advice and council did much to shape the workshops character and content. Andre Meyer

provided us with much-needed support in making the necessary local arrangements for the workshop and we would also like to thank him for his diligence and for the support he provided.

Finally we would like to thank the organizers of AAMAS 2005 for agreeing to host DAMAS, in particular Frank Dignum and Rino Falcone.

January 2006

Robert Ghanea-Hercock
Simon Thompson

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