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Agent Technologies for Sensor Networks

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The development of agent technologies for sensor networks has received increasing research attention within both the sensor network and multi-agent systems research communities. The International Workshops on Agent Technologies for Sensor Networks (ATSN) held in 2007, 2008 and 2009 sought to bring these communities together, and this special issue of The Computer Journal presents extended versions of some of the papers that appeared at these workshops, along with new submissions specifically for this journal.

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Sensor networks increasingly facilitate wide-area monitoring and surveillance within environmental, security and military applications. Such networks consist of multiple sensors, deployed over a wide area, connected through a communication network. To ensure minimal human intervention, sensors within these networks should be able to self-organize, autonomously manage their own resources and coordinate to achieve system-wide goals. As such, the distributed nature of these networks, and the autonomous behaviour expected of them, naturally suggest the application of techniques from the research literature of multi-agent systems.

However, the mapping from sensor to agent is not straightforward. Research in the multi-agent systems domain typically does not address the constrained computational and communication resources of low-powered sensor nodes. Moreover, research often fails to consider that communication might be slow and intermittent, hardware might be unreliable and failure-prone and environments might be highly dynamic. As such, although existing agent technologies are extremely valuable, they cannot be used directly. Rather, to address the specific constraints and challenges posed by this application setting, we need a new synthesis that adapts and extends these traditional technologies to this new domain.

Addressing this challenge has been the focus of three international workshops on Agent Technologies for Sensor Networks (ATSN) which co-located with the International Conference on Autonomous Agent and Multiagent Systems (AAMAS) in 2007, 2008 and 2009. This special issue of The Computer Journal presents extended versions of some of the papers that appeared at these workshops, along with new submissions specifically for this journal.

In more detail, Vinyals *et al.* [1] present a survey of existing sensor network research from the perspective of multi-agent systems. A number of authors present coordination mechanisms for sensor networks. In particular, Waldock and Nicholson [2] propose and evaluate a framework for cooperative control, Kho *et al.* [3] use dynamic programming to coordinate wireless visual sensor nodes and Tynan *et al.* [4] apply multi-agent systems approaches to coordinate the hibernation of nodes within a sensor network.

Similarly, Markham and Trigoni [5] use a biologically inspired approach to tune the parameters (such as sampling rate) of a wireless sensor network. While Turgut and Boloni [6] consider heuristic approaches for a setting in which there are mobile sinks that can collect data from sensors by moving to their vicinity, Suenaga *et al.* [7] extend this notion of mobility to agents that move from sensor to sensor within the network, and consider the group migration srategies of mobile agents in such a network.

Further work considers middleware for sensor networks with Bade [8] describing an agent-based event-processing middleware, Aiello *et al.* [9] presenting a Java-based agent platform for programming sensor networks and Freitas *et al.* [10] developing a multi-agent middleware for mission-driven heterogeneous sensor networks. Similarly, Abdelhak *et al.* [11] describe how computation can be divided across the nodes of a sensor network, and Şensoy *et al.* [12] use semantic descriptions and reasoning mechanisms to efficiently allocate sensor resources to tasks. Zafar and Corkill [13] show how online model development time can be reduced by using constraints between sensor observations, and Mukherjee and

Sen [14] compare reputation schemes that can detect malicious nodes within the network.

Finally, we have works that consider the real-world deployment of these approaches with Corkill [15] describing the challenges of deploying power-aware, wireless sensor agents in the wild, and Ferranti and Trigoni [16] exploring the practical issues of deploying mobile agents in sensor-instrumented environments.

When taken together, these papers show that much progress has already been made in this domain. However, as new low-cost processing and sensing hardware is developed, and energy harvesting becomes more practical, we can expect to see sensor networks composed of more sensors, with more sophisticated capabilities, being deployed over larger areas for greater periods of time. This will present new challenges, and it is hoped that the work presented here will act as a point of departure for future developments in the use of agent technologies which will lead to sensor networks that exhibit unprecedented levels of flexibility, robustness and autonomy.

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REFERENCES

[1] Vinyals, M., Aguilar, J.A.R. and Cerquides, J. (2011) A survey on sensor networks from a multi-agent perspective. *Comput. J.*, **54**, 455–470.

[2] Waldock, A. and Nicholson, D. (2011) A framework for cooperative control applied to a distributed sensor network. *Comput. J.*, **54**, 471–481.

[3] Kho, J., Tran-Thanh, L., Rogers, A. and Jennings, N.R. (2010) A distributed coordination mechanism for wireless visual sensor nodes using dynamic programming. *Comput. J.*, **53**, 1277–1290.

[4] Tynan, R., Muldoon, C., O'Hare, G. and O'Grady, M. (2011) Coordinated intelligent power management and the heterogeneous sensing coverage problem. *Comput. J.*, **54**, 490–502.

[5] Markham, A. and Trigoni, N. (2011) The automatic evolution of distributed controllers to configure sensor network operation. *Comput. J.*, **54**, 451–438.

[6] Turgut, D. and Bönöni, L. (2011) Heuristic approaches for transmission scheduling in sensor networks with multiple mobile sinks. *Comput. J.*, **54**, 322–344.

[7] Suenaga, S., Yoshioka, N. and Honiden, S. (2010) Group migration by mobile agents in wireless sensor networks. *Comput. J.*, **54**, 345–355.

[8] Bade, D. (2011) An agent-based event processing middleware for sensor networks and RFID systems. *Comput. J.*, **54**, 321–331.

[9] Aiello, F., Fortino, G., Gravina, R. and Guerrieri, A. (2010) A Java-based agent platform for programming wireless sensor networks. *Comput. J.*, **54**, 439–454.

[10] Freitas, E.P., Heimfarth, T., Pereira, C.E., Ferreira, A.M., Wagner, F.R. and Larsson, T. (2011) Multi-agent support in a middleware for mission-driven heterogeneous sensor networks. *Comput. J.*, **54**, 406–420.

[11] Abdelhak, S., Chaudhuri, R.S., Gurram, C.S., Ghosh, S. and Bayoumin, M. (2011) Energy-aware distributed QR decomposition on wireless sensor networks. *Comput. J.*, **54**, 373–391.

[12] Şensoy, M., Le, T., Vasconcelos, W.W., Norman, T.J. and Preece, A.D. (2011) Resource determination and allocation in sensor networks: a hybrid approach. *Comput. J.*, **54**, 356–372.

[13] Zafar, H. and Corkill, D. (2010) Reducing online model development time by agents using constraints between shared observations. *Comput. J.*, **53**, 1302–1314.

[14] Mukherjee, P. and Sen, S. (2011) Comparing reputation schemes for detecting malicious nodes in sensor networks. *Comput. J.*, **54**, 482–489.

[15] Corkill, D. (2010) Deploying power-aware, wireless sensor agents. *Comput. J.*, **54**, 382–405.

[16] Ferranti, E. and Trigoni, N. (2011) Practical issues in deploying mobile agents to explore a sensor-instrumented environment. *Comput. J.*, **54**, 309–320.