ARTES First Year Report
Project: 0005-22, Real-time Autonomous Agents

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This project focuses on Autonomous Agents in Real-time environments. It is in the ARTES area "How to specify and design a heterogeneous real-time system." The original project plan was to support the final stages of a Ph.D. dissertation and prepare a new graduate student to continue research in the area. The grant was approved for the finishing student.

More specifically this research investigates how to design the action selection mechanism of an agent to make its behavior easy to understand and change at runtime. The capability of modifying the autonomy and control of agent behavior on-line is called Adjustable Autonomy. Adjustable autonomy is an important aspect (although not the only aspect) of designing agents for real-time environments. In particular, adjustable autonomy allows online control of agents by human users. This supports incrememtal development and reduces the need for developers to be certain of all agent actions before the agent is tested. For example, when using agents for controlling long term manned space missions it is highly important that nothing goes wrong. Adjustable autonomy provides a mechanism that allows the behavior of the agents to be modified online to avert potential errors or allow the agent to better exploit unexpected opportunities. This research attempts to address the problem "How to specify and design agents for a heterogeneous real-time system, where adjustable autonomy is important."

The dissertation focus is to extract a set of guidelines for the design of intelligent agents that makes adjustable autonomy straightforward to implement. The aim of the guidelines is to encourage agent designers to design agents for which adjustable autonomy is the most straightforward to implement. We found that some agent "features" make adjustable autonomy difficult to implement, while other features lead to the straightforward implementation of adjustable autonomy. The utility of the guidelines is evaluated by analyzing their impact on the design of two systems with adjustable autonomy. Specifically, the agent features that result from adherence to or divergence from the guidelines are analyzed with respect to their impact on the subsequent adjustable autonomy implementations. Paul Scerri's Ph.D. thesis (see the next section for more information) is expected to be completed by the end of 2001.

During this project, we have developed a prototype agent development and run-time environment called EASE (End-User Actor Specification Environment). EASE is being applied to real-time domains, including the control of aircraft in Saab's combat simulator TACSI. The work is ongoing with presentations at international workshops and conferences. A list of project publications can be found in the last section of this report.

Designing Agents for Systems with Adjustable Autonomy

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Ph.D. Dissertation
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Projected completion: 2001

Abstract

Agents are an artificial intelligence technique of encapsulating a piece of pro-active, autonomous, intelligent software in a module that senses and acts in its environment. As the technology underlying sophisticated multi-agent systems improves, such systems are being deployed in ever more complex domains and are being given ever more responsibility for more critical tasks. However, multi-agent technology brings with it not only the potential for better, more efficient systems requiring less human involvement but also the potential to cause harm to the system's human users. One way of mitigating the potential harm an intelligent multi-agent system can do is via the use of *adjustable autonomy*. Adjustable autonomy is the idea of dynamically changing the autonomy of agents in a multi-agent system depending on the circumstances. Decision making control is transferred from agents to users when the potential for costly agent errors is large.

We believe that the design of the agents in a multi-agent system impacts the difficulty with which the system's adjustable autonomy mechanisms are implemented. Some features of an agent will make the implementation of adjustable autonomy easier, while others will make it more difficult. The central contribution of this thesis is a set of guidelines for the design of agents which, if followed, lead to agents which make adjustable autonomy straightforward to implement. In addition, the guidelines lead to agents from which it is straightforward to extract useful information and whose autonomy may be changed in a straightforward manner.

The usefulness of the guidelines is shown in the design of the agents for two systems with adjustable autonomy. The first system is EASE, which is used for creating intelligent actors for interactive simulation environments. The second system is the Electric Elves which is a multi-agent system streamlining the everyday coordination tasks of a human organization. An analytic evaluation demonstrates that following the guidelines leads to agents that make effective adjustable autonomy mechanisms easier to implement.

1 Project Publications:

1. Paul Scerri and Nancy E. Reed. 1999. An Approach to Directing Intelligent Agents in Real-time. March 1999. *Proceedings of the AAAI Spring Symposium on Agents with Adjustable Autonomy*, pages 114–115, Stanford University.

2. Nancy E. Reed and Paul Scerri. 1999. Adjustable Autonomy in Simulated Pilots, August. *Proceedings of the Workshop on Adjustable Autonomy Systems,* Sixteenth International Joint Conference on Artificial Intelligence (IJCAI99) pages 56-59, August 1, Stockholm, Sweden.

3. Paul Scerri and Nancy E. Reed. Engineering characteristics of autonomous agent architectures. *Journal of Experimental and Theoretical Artificial Intelligence*, 12:191–212, April 2000.

4. Paul Scerri and Nancy E. Reed. Creating complex actors with ease. In Carles Sierra, Maria Gini, and Jeffrey S. Rosenschein, editors, *Fourth International Conference on Autonomous Agents (Agents 2000)*, pages 142–143. ACM Press, June 2000.

5. Paul Scerri and Nancy E. Reed. Real-time control of intelligent agents. In Josep Puyol-Gruart, editor, *Technical Summaries of the Software Demonstration Sessions, Fourth International Conference on Autonomous Agents (Agents 2000)*, pages 28–29, June 2000.

6. Paul Scerri and Nancy E. Reed. On-line control of actors using ease. In Nancy E. Reed, editor, *Workshop on Teams with Adjustable Autonomy, Pacific Rim International Conference on Artificial Intelligence (PRICAI 2000)*, pages 25–34, August 2000.

7. Paul Scerri and Nancy E. Reed. Designing agents for systems with adjustable autonomy. In *Workshop on Autonomy, Delegation and Control: Interacting with Autonomous Agents, Seventeenth International Joint Conference on Artificial Intelligence (IJCAI 2001)*, to appear, August 2001.

8. Nancy Reed. Adjustable Autonomy and Teamwork in Autonomous Agents, Introduction. In Ryszard Kowalczyk, Seng Wai Loke, Nancy Reed, and Graham Williams, editors, *Lecture Notes in Artificial Intelligence*, volume 2112, to appear. Springer Verlag, Berlin, 2001.

9. Paul Scerri and Nancy Reed. Making Adjustable Autonomy Easier with Teamwork. In Ryszard Kowalczyk, Seng Wai Loke, Nancy Reed, and Graham Williams, editors, *Lecture Notes in Artificial Intelligence*, volume 2112, to appear. Springer Verlag, Berlin, 2001.

10. K. Suzanne Barber, Cheryl E. Martin, Nancy E. Reed, and David Kortenkamp. Dimensions of Adjustable Autonomy. In Ryszard Kowalczyk, Seng Wai Loke, Nancy Reed, and Graham Williams, editors, *Lecture Notes in Artificial Intelligence*, volume 2112, to appear. Springer Verlag, Berlin, 2001.

11. Paul Scerri. Designing Agents for Systems with Adjustable Autonomy. Ph.D. dissertation, Institutionen för datavetenskap, Linköpings universitet, Expected completion Dec. 2001.