Intelligent Agents — Where AI meets Information Technology

Prof. James A. Hendler
Dept. of Computer Science
University of Maryland
College Park, MD 20742, USA
hendler@cs.umd.edu

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In the following short article, I seek to explore the issue of why so much attention is starting to focus on the potential for AI in the area of information technology, with a special emphasis on the use of “intelligent agents” as the technological device that will get us there. To summarize some of the key points, it is my contention that we are currently in the early days of intelligent agents, analogous perhaps to the late 1970s viz. the emergence of rule-based expert systems. This is because AI, and intelligent agency in particular, is a crucial tool in coping with the complexities of the information rich problems imposed by the explosion of data residing on the current and future internet.

The Emergence of Intelligent Agency

During the mid-1980s a funny thing happened to some of us in the AI planning community. Discouraged by the lack of progress in thirty years of generative planning systems, we began to explore new approaches in which the AI systems were situated in a changing world. We began to explore domains in which “goal satisfaction” had to compete with reacting to change or to take a second place to protecting the planner’s survival. My own research group’s work in this area, for example, ranged from simple “reactive” mechanisms aimed at coping with responding to rapid change in the world through to software architectures for integrating these reactions with more deliberative, traditional goal-based planning.1

As successes started to be reached with these technologies, some members of the planning community turned to robotics as the proving grounds for the ideas.2 Rather than looking at simulated, symbolic change in artificial worlds, we began to explore the complexities of interacting with a physical world as perceived through robotic sensors. Others, deterred by the then high-cost of robots and the vagaries of limited sensors and mechanical actuators, turned to softbots3 (a variant on the earlier database-oriented Knowbots4) which would

1See http://www.cs.umd.edu/projects/plus/
2See http://www.cs.cmu.edu/afs/cs.cmu.edu/user/jkr/www/robotics.html
4See http://204-148.98.169/select/wp.11.html
try to similarly react to an uncontrolled environment the information environment of computer systems, and later, the internet. The general term “intelligent agency” started to be heard at AI conferences, with a growing research community exploring those issues of agents which had goals and which also had to function in an environment not completely theirs to control.

At about the same time, a separate community was forming also using the term “agents,” sometimes in a similar way. This was the software agents community, which was exploring how smaller and more self-reliant pieces of code could be developed. The idea of programs which could run somewhat separate from a host environment, moving across networks to deliver information, or more often entertainment value, grew. Languages like Java and ActiveX, in which software could be developed in one place and run portably and relocatably in another, became a new focus of excitement.

Unfortunately, the blend of software- and intelligent-agents into “intelligent software agents” has not always been easy. Confusion between the use of the terms in the different communities has reigned, and the marriage of the two technologies has often been a marriage of convenience, and at that, an uneasy one. Currently, these two active and highly visible communities are beginning to compete and/or converge, and this has become one of those “hot” areas in which the smoke often obscures the real results being made by those in the forefront of the research.

In this article, and the special issue it’s included in, the focus is on intelligent agents as the term was used in the AI community, but with an emphasis on those agents functioning in information rich worlds, rather than the physical worlds of autonomous robots. While there are many similarities between robots and softbots, the difference in emphasis is clear. The point I try to make in this article, and in my choice of the articles included in this issue, is that the marriage of AI techniques and information technology is not one of convenience but one of necessity, with great benefits that can accrue to both communities.

What are “intelligent agents”?

Put simply, the goal of AI researchers working on intelligent agents is to create advanced artificial intelligence programs that can function usefully in environmental niches of importance to humans. For physical agents, these environments include ones in which it is difficult to place humans, such as outer space or deep sea beds, or dangerous, as in the core of a nuclear reactor. For information agents, the domains are “virtual” - worlds that don’t exist in our sensory universe, such as the information rich world of the internet or the interactive cyberspace worlds being talked about in the virtual reality community. Although some systems have stumbled into some simpler problems which can admit to solution using simple techniques (for example performing Internet searches using keyword-based Information Retrieval techniques), the real payoff is to create systems that can amplify human problem-solving abilities and/or function autonomously in complex worlds (where the complexity is measured by the information complexity of the environment).

As well as the oft-discussed role of so-called softbots for internet applications, the poten-

tial use of more significant "intelligent agents" is both diverse and economically important. Current applications being explored include the management of air traffic and other transport services; aircraft flight control and mission analysis; the control of telecommunications, power, and computer networks; transaction management in banks and insurance companies; the monitoring and control of industrial processes; on-line fault diagnosis and malfunction handling; the supervision and control of manufacturing operations; the provision and monitoring of medical care; and the control of industrial robots. In addition, wearing a more "theoretical" AI hat, what we learn from this endeavour is sure to have significant implications on how we view the nature of intelligence and how we describe intelligent behaviors.

To appreciate the problems inherent in designing such intelligent agents, one need only consider the difficulty of operating in complex and diverse environments such as those mentioned above. To be effective, or to survive at all, these agents must be able to accommodate conflicting goals, to choose among them, and to reason about how best to accomplish those that are chosen. This choice, and the means chosen to realize these ends, will depend upon the beliefs the agent has about present and future situations, and upon any commitments or intentions that may have been earlier decided upon. Often it will be necessary to obtain more information about the tasks to be performed, either prior to choosing a plan of action or during its execution. Furthermore, knowledge of the world itself is frequently incomplete, making it necessary for these agents to have some means of forming reasonable assumptions about the possible occurrence of important events or the behaviors of other agents.

To make matters worse, all this has to be accomplished in a complex and dynamic world typically populated with many other agents. These other agents may be other computer programs of varying complexities, or even human beings working interactively in the same environment. The agent planning or deciding upon possible courses of action can choose from an enormous repertoire of actions, and these in turn can influence the world in very complicated ways. Moreover, because of the presence of other agents, and the many environmental "processes" that occur every day, the world is changing continuously–even as the agent deliberates on how best to achieve its goals. In short, the system must deal with an overwhelming amount of complex knowledge about an ever-changing world while at the same time navigating its way towards its possibly changing goals.

The challenge of information technology: When too much is worse than none at all.

One problem that is beginning to claim the attention of a great many AI scientists is that of scaling AI to much larger information domains. In particular, the "holy grail" for the "information technologist" is clearly the internet – not just searching the pages World Wide Web, but also taking advantage of the numerous databases and other information repositories available on the "information superhighway." In fact, the analogy to the development of the interstate highway system makes clear a basic underlying assumption – that rapid access to large amounts of information will be as crucial in the 21st century's data rich society as transportation needs were to the citizenry in the 20th. However, means for navigating this new resource are still a puzzle – how is the user to find appropriate knowledge given that so much is out there?
Consider the situation of a medical professional in the next decade. A health care worker is sitting at a terminal connected to the global information network. The amount of information available to help in aiding a patient is staggering. The online information includes patient records and the full history of all doctors, hospitalizations, tests, etc. concerning the patient. Data is also available for thousands of other patients being treated worldwide. Added to this are medical libraries, including all the most recent journal articles on little known diseases (some written in languages other than the professional's own), current data about drugs and their interactions, information about past therapy plans and their results (including contraindications), and thousands of bytes more of multimedia information relating not only to conditions the patient might have, but to a vast array of medical conditions which are not relevant to the current patient.

To put it mildly, the medical practitioner (or, in fact, any other user) is faced with a new and daunting problem — how to find that information which is relevant to their problem, and how to use that information to solve it. The information available via the network will be overwhelming, and it is the ability to appropriately access, scan, process, modify and use the relevant data that will be crucial in the future. Taking appropriate action will require the ability to manage not just information, but also to apply knowledge about the underlying networks, the organization of the data, and the particular problem being solved.

Information technology poses many exciting challenges to the AI researcher. New inference classes and access mechanisms must be developed for efficiently exploring the ever larger knowledge repositories available to users. New techniques must also be found for “mining” the data stored in scientific and medical databases, and reasoning mechanisms must be developed for extending software agents technology, tailoring it to the creation and use of large knowledge-based memories. As these techniques become more commercially viable, we can expect to see the next great stride in the use of AI technology in industrial, government, and scientific applications.

Information Complexity: Why Information Technology needs AI

Given my earlier “definition” of intelligent agents, with the particular emphasis on information complexity as the measure of the complexity of the tasks to be performed, it is not surprising that information technology problems have an appeal for AI researchers. But more importantly, it should be noted that this same complexity is exactly the reason why AI is so important to the future of information-based applications. To simplify the issue drastically, searching for relevant information is exactly a search problem, and what’s more the use of knowledge to direct this search is necessary for the searches to be successful. In short, the same things that made rule-based expert systems attractive to those with limited-domain decision-making problems, make AI technology attractive to problems concerned with finding and using relevant information in information space.

In fact, information technology problems have parallels, on a smaller scale, in the expert systems domain. Developing knowledge-based expert systems requires a vocabulary for talking about and managing information. Expert systems developers, who realize that much information can be used in multiple applications, have begun talking about “knowledge
sharing" - mechanisms and infrastructure for finding and filtering appropriate knowledge in distributed networks. In addition, the need for common "ontologies," shared representations of the crucial information and relations in a domain, has led to the development of tools and languages aimed at handling communication about information itself (not just its content).

The question obviously arises, however, as to which AI technologies might be most appropriate for attacking information technology problems. The answer is that we need an approach which can handle the features of these information problems: domains with high information complexity, domains in which there is constant change, and domains in which many players may interact in solving a problem. In fact, however, these are exactly the kinds of problems that intelligent agent techniques were designed to attack! Thus, it is not surprising that many of the most successful attacks on complex information problems are being led by this segment of the AI community.

A cautionary note, however. To date, while agent-based tools and techniques are very promising, they still require the sorts of drastic domain limitations that were the hallmark of the early successes in expert systems. For example, agents can be fairly complex but limited in their domains of discourse, such as the Firefly agent which allows one to interact with other agents for domain-limited items such as music and movies\(^6\) or the University of Washington Internet softbot \(^7\), which helps users with a set of Unix-based internet commands. Conversely, the agents may be simpler but allow one to interact in a more complex domain, such as the agents for electronic commerce currently under development\(^8\). However, much current research is looking at how to scale these solutions to the much larger sizes and less well-defined domains inherent in the internet and other large information spaces.

Thus, my contention in the introduction that the current world of agents has some of the feel of the early days of rule-based expert systems. We're starting to see a promising technology transitioning out of the laboratories in a limited way. The first companies marketing agents are starting up, and the economic potential is promising, but not yet realized. The future looks good (although, if we learned anything from the old expert systems days, we'd better be careful not to oversell the technology)! In short, the use of intelligent agents for information technology tasks is an important area of investigation and development. In addition, the excitement of the intelligent agents field may be just what the doctor ordered to get a somewhat moribund AI field back on its feet.

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\(^6\)http://www.firefly.com/
\(^7\)http://www.cs.washington.edu/projects/software/www/softbots.html
\(^8\)http://www.eitech.edu/