

Intelligent Agents on the Internet and Web

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ABSTRACT

An intelligent agent (IA) is a self-contained, autonomous software module that could perform certain tasks on behalf of its users. It could also interact with other intelligent agents and/or human in performing its task(s). There is now growing interest in using intelligent software agent for a variety of tasks in diverse range of applications: personal assistants, intelligent user interfaces, managing electronic mail, navigating and retrieving information from the Internet and databases, scheduling meetings and manufacturing operations, electronic business, online shopping, negotiating for resources, decision making, design and telecommunications. This paper gives a brief introduction to intelligent agents and their classification, outlines applications of intelligent agents on the Internet and Web and highlights their prospects.

1. INTRODUCTION

An intelligent agent (IA) is a self-contained, autonomous software module that could perform certain tasks on behalf of its users. It could also interact with other intelligent agents and/or human in performing its task(s). It is claimed as an important and exciting new paradigm in software to emerge in the 1990s and is currently a very popular area of investigation and development. The advent and widespread use of the Internet, Intranets and extranets and Web have opened vast opportunities for intelligent agents and, hence, industry, academia and media are now showing great interest in development and applications of intelligent agents.

Intelligent agents are currently used for a variety of tasks in diverse range of applications: personal assistants, intelligent user interfaces, managing electronic mail, navigating and retrieving information from the Internet and databases, scheduling meetings and manufacturing operations, electronic business, online shopping, negotiating for resources, decision making, design and telecommunications.

The following sections give a brief introduction to intelligent agents, outlines a range of applications of intelligent agents on the Internet and Web environments and highlights their prospects.

2. INTELLIGENT AGENTS

As Nwana (1996) notes software (intelligent) agent is now used as an umbrella term, meta-term or a class to represent a range of software with different characteristics and abilities. And hence, there are many definitions of an agent. They include:

- "Autonomous agents are computational systems that inhabit some complex dynamic environment, sense and act autonomously in this environment, and by doing so realize a set of goals or tasks for which they are designed" [Maes 1995, page 108].
- "Intelligent agents are software entities that carry out some set of operations on behalf of a user or another program with some degree of independence or autonomy, and in so doing, employ some knowledge or representation of the user's goals or desires. It can be described in terms of three dimensions of *agency* (degree of autonomy and authority), *intelligence* (degree of reasoning, and learned behaviour) and *mobility* (degree to which agents themselves travels through a network)"

IBM - <http://activist.gpl.ibm.com:81/WhitePaper/ptc2.htm>

- An agent is as an encapsulated problem solving entity , which exhibits the following properties [Wooldridge and Jennings 1995].

Autonomy: agents perform majority of their tasks without the direct intervention of humans or other agents, and they have control over their own actions and their own internal state.

Social ability: agents interact, when they deem appropriate, with other artificial agents and humans in order to accomplish their tasks and to help others. This requires that agents have, as a minimum, a means by which they can communicate their requirements to others and an internal mechanism for deciding what and when social interactions are appropriate, generating requests and judging incoming requests.

Proactiveness: agents take the initiative to do certain tasks where appropriate.

Responsiveness: agents perceive their environment and respond in a timely fashion to changes occurring in the environment.

2.1 Attributes of an Agent

The primary behavioural attributes of an agent are autonomy, cooperation and learning [Nwana 1996]. An agent possesses one or more of these attributes.

Autonomy: It "refers to the principle that agents can operate on their own without the need for human guidance. Agents have individual internal states and goals, and they act in such a manner as to meet its goals on behalf of its user. A key element of their autonomy is their proactiveness, i.e. their ability to 'take the initiative' rather than acting simply in response to their environment [Wooldridge and Jennings 1995]."

Cooperation: Cooperation with other agents is paramount: it is the reason for having multiple agents in the first place in contrast to having just one. In order to cooperate, agents need to possess social ability, i.e. "the ability to interact with other agents and possibly with humans via some communication language [Wooldridge and Jennings, 1995]."

Learning - For agent systems to be truly 'smart', they would have to learn as they react and/or interact with their external environment and interface with users. A key attribute of an intelligent system is its ability to learn to understand the user's preferences and behaviour, to cope with new situations it may face and to improve its performance over time.

For further discussion on agent properties see Franklin and Graesser (1996).

2.2 Classification of Intelligent Agents

Agents could be classified in a variety of ways: by their characteristics, by the underlying technology, by the function they perform (what they do), or a combination of them. Agent classification is not unique, as some of the features of agents used for classification are not mutually exclusive.

Static and Mobile Agents

Based on mobility of the agents, agents could be classified as static (stationary) agents, or mobile agents. A stationary agent resides in one computer system and executes its functions/tasks and interacts with the outside world by exchanging messages in a manner similar to the conventional software. A mobile agent can physically move through the network to other computer systems, execute the designated functions and process required information at a different computer and return to the home computer with acquired/processed information. Rather than transmitting messages to receive information required, they *visit* other computer systems on a network to gather information (see Morreale 1998, Ohsuga 1997).

Interface Agents

Interface agents which mainly assists the users:

- reduce the interface complexity and enhance the ease of use in the presence of greater functionality.
- provide "smart" user interfaces that can detect when a user is having difficulty and "coach" the user around the problem.
- observe and learn the user's preferences and habits, and try to perform automatically what the user routinely does.

An interface agent can observe the actions taken by the user, learn new capabilities dynamically, suggest a course of action to the user, provide context-sensitive help, adapt the interface automatically to the user's personalised requirements, or automate tasks which would otherwise require tedious sequences of manual operations. To do these, it may use learning and reasoning techniques developed in other areas of artificial intelligence and may adopt the principles of good human-computer interaction.

Collaborative Agents and Multi-Agent System (MAS)

A collaborative agent interacts and cooperates with other agents (and/or humans) to perform the tasks on behalf of a user. A multi-agent system (MAS) consists of two or more semi-autonomous agents that interact, collaborate and work together to perform a set of tasks or goals. These agents have, among others, problem solving, communication, and coordination abilities. Collaborative agents may be a homogeneous or heterogeneous group of agents and they may have similar or differing goals, and knowledge representation facilities. They heavily draw upon on the principles of artificial intelligence, sociology, organisational theory, animal behaviour, economics, and distributed systems. Agents in a MAS have ability to solve problems, and to communicate, coordinate and negotiate with other agents. For further information on MAS see Sycara (1998).

Information/Internet Agents

In the networked world, an enormous amount of information is available from a wide variety of sources. Information/Internet agents can filter inexhaustible amount of information available on the Internet, passing on to the user only those information which the user is interested in. They can seek for and retrieve information required and process the information obtained. They aid in the tedious task of retrieving the relevant information from networked resources.

Learning Agents

A learning agent uses machine learning techniques to 'learn' as they react and/or interact with external environments and users. It tries to improve its performance with time and to learn its users' preferences and interests to better assist them. It could learn: 1) by observing and imitating the user, 2) from (corrective) feedback from the users, 3) by following explicit instructions from the user, and/or 4) by asking other agents for advice.

Emotional Agents

These agents can depict emotions and convey their internal state to the user. Emotions can help animate faceless software agents to cartoon-like characters, making them more live like "*servicing with smile*." They provide an illusion of life in convincing ways to make audience believe the agent is real. They are also known as believable agents, synthetic characters (Elliot and Brzezinski, 1998) and anthropoids. Examples of emotional agents include: *Creatures* (www.cyberlife.co.uk) (*Grand and Cliff, 1998*), real-time, interactive, self-animating creatures called *Woggles* (Oz Project at Carnegie-Melon University, USA.)

The Persona project at Microsoft is developing the technologies required to produce conversational assistants - life like animated characters that interact with user in a natural spoken dialogue.

Socionics is a new term that combines the disciplines of sociology and informatics. One of the aims of research work in this area is to develop intelligent computer technologies by using /adopting paradigms from sociology. It is envisaged that advances in socionics might lead to more human like agent environment and formation of better and more capable multi-agent societies. For more information on a new interdisciplinary work has that begun recently in this area in Germany see:

http://www.tu-harburg.de/tbg/SPP/Start_Spp.html

For a detailed overview on intelligent agents see Bradshaw 1997, Chorafas 1997, Cockayne and Zyda 1997, Comm ACM 1994, Harrison and Caglayan 1997, Nwana 1996, Nwana and Azarmi 1997, Green, and Jennings and Wooldridge 1998.

3. APPLICATIONS OF INTELLIGENT AGENTS ON THE INTERNET AND WEB

There is enormous interest in deploying intelligent agents on the Internet, intranets and extranets and Web for a variety of applications ranging from personal to entrepreneurial: intelligent personal assistant, mail management, information retrieval and presentation, planning and scheduling, personal service, electronic commerce and on-line shopping, collaborative decision making, enterprise management (*AI Magazine* 1997, *IEEE Internet Computing* 1998).

3.1 Agent-Based Information Retrieval

Information Explosion: In the last few years, there has been a major revolution in information generation and dissemination, resulting in information explosion. Inexhaustible amount of information is now available from an increasing number of heterogeneous, distributed information sources. Information can now be made available on the Internet very easily and at a very low cost with minimal effort. Further, most of the information is dynamic - it may updated or modified at anytime. In addition, many persons encounter a large volume of email. As observed by John Naisbit, "we are drowning in information, but starved of knowledge."

Growing problems of using the Internet and Web to retrieve information of interest to a user include:

- Inexhaustible pool of information
 - Difficulty of retrieving relevant information
 - More time spent on searching for information.
 - Information overkill – *infostrress*
- Dynamic nature of the information on the Internet
 - Sudden appearance and disappearance of information.
- Distributed, heterogeneous nature of information and information services.

To manage these problems, we need tools to search, retrieve, filter and present relevant information, reactively and proactively. Intelligent software agents offer promising solutions to the current (threat of) information overkill on the Internet and the problem of information retrieval (IR). They have potential to mitigate the complexity of information retrieval and management by providing locus of intelligence.

Agents could provide intelligent IR interfaces, or perform mediated searching and brokering, clustering and categorisation, summarisation and presentation. Agent based approaches make IR systems more scalable, flexible, extensible and interoperable.

Interfaces: An intelligent agent-based interface to an information retrieval system provides an easy-to-use, personalised, adaptive interface. It can act as an agent for a user, and learn about its users and their preferences.

Mediated Searches and Information Brokers: Currently many search tools/engines are available for searching information available on the Internet and Web. However, each has its own query structure, interface and nomenclature. Gathering relevant information from multiple, distributed, heterogeneous information sources on the Internet and Web poses difficult problems, which include:

- Finding appropriate sources of information relevant to the query and suitable search tool(s).
- Formulating queries in the 'terms' that the information sources can understand
- Interpreting retrieved information
- Collating the information received from several sources into a coherent, concise information.

Information brokering and mediated search agents can provide a uniform interface for general queries and send requests to the most appropriate resource(s) and search tool(s) -- Examples: *Ahoy* and *Metacrawler*.

Information Filtering Agents: They find information of specific interest to a user from different information sources [Belkin and Croft 1992]. Unlike the Web search engines that provide URLs of information sources, information filtering agents:

- gather recent articles about a chosen topic from various sources (eg. Web pages, news feeds, etc.),
- filter this information based on the personal preferences of the user, and
- present the filtered information to the user.

Examples of information filtering agents:

- NewsHound: the personal news service by San Jose Mercury News
- ZDNet Personal View: the personalized computing news by Ziff-Davis
- NewsPage Direct: the personal newspaper

Categorization and Presentation: It would be better if agents analyse the information, and then structure it in a manner more useful and convenient to a user. Further, it could also derive '*metadata from information*'.

3.2 Recommender Systems

To cope with an insurmountably large array of choices people have in making a selection, such as buying a CD, a book, or an airline ticket, people turn into some kind of automatic recommendation services, which over time adapts to its user's interests and preferences. There is now a growing potential for on-line automatic recommender services.

Recommendation services falls into three classes: 1) *content-based* – those that recommend items based on some analysis of their content, 2) *collaborative* – those that recommend

items based on recommendations of other users, exploiting similarities between the users' interests, and 3) a hybrid approach that make use of both the content-based and collaborative approaches, thereby taking advantages of shared interest among users without losing the benefits of representation provided by content analysis.

3.3 Agents in Electronic Commerce

One of the objectives of agent-mediated electronic commerce is to help users in all aspects of online shopping: Software agents on the Internet could help users in a number of ways [Doorenbos 97, Andreoli 1997, Gutman, et al., 1998]:

- Helping the user decide which products to buy (e.g.: by listing what products of a certain type are available).
- Finding specifications and reviews of them.
- Making recommendations
- Comparison shopping to find the best price for the desired product.
- Watching for and intimating user about special offers and discounts.

Already a few comparison-shopping agents are in use. Examples include *BargainFinder* and *ShopBot* (www.cs.washington.edu/research/shopbot <http://bf.cstar.ac.com/>). They scour the Internet on the user's behalf, visiting all the on-line 'virtual' shops and give the lowest price, an ordered list of prices and the vendors, and other related information on the products that the user is interested.

BargainFinder is a virtual shopping agent for the Web developed by Anderson Consulting to query pricing and availability of user specified music CDs. It uses the parallel search architecture used in meta search engines such as *MetaCrawler*. It submits user's product query in parallel to a group of on-line vendors by filling out the form at each site. It parses the query results after filtering out the header, trailer, and advertisements to find each vendor's price for the required product and prepares a summary to the user combining the filtered results from each vendor.

Comparison shopping agents offer a number of advantages:

- They provide a unified interface for dealing with cyberstores.
- There is no need for the user to navigate to different stores, and to deal with separate user interfaces
- They find the best price and availability through comparison shopping, thus relieving the user to search for a product at each online store.
- Further, they eventually trigger a price war among sellers potentially making prices almost same everywhere.

Comparison shopping agents do, however, have limitations:

- Currently, most agents ignore other factors such as service, quality.
- It is harder for agents to compare products with varied configurations such as computer, travel packages, etc. However, they can work well for standard goods such as books, CDs and airfares.

The roles of agents have expanded beyond tasks such as comparison-shopping – agents on the Internet can interact with each other and take part in procurement activities. The agents may issue request for goods, bid to supply the required goods, evaluate the bids, place an order and, after receipt of

goods, make payments. Many multiagent applications in electronic business are emerging (see Guttman et al 1998).

3.4 Agent Services

Service agents provide a specified service to a user based on information made available to them. They include:

- *Announcement Agents*: Remind users of important occasions (eg. birthday, anniversary, Valentines Day and the like) that are customised for personal needs.
- *Book Agents*: Track newly released books to notify users books that match each user's reading interests.
- *Business Information Monitoring Agents*: Monitor the exchange of information on the Internet relating to services, products, industry and companies, and reports findings as a report.
- *Classified Agents*: Search a database of classifieds daily to find a user-specified item, and notify the user via email. An example of classified agent is *AdHound*. It searches databases of classifieds in areas specified by the user and it finds a match, it sends an email giving the relevant classified ads.
- *Job Agents*: Serve as virtual recruiters to find employees who match with the employer job profiles.
- *Direct Mail Agents*: Enable personalised direct mail advertising that matches the user's stated personal background, activities, lifestyle and liking.
- *Financial Service Agents*: Deliver email messages containing prices and financial news for a personalised portfolio of securities and mutual funds.
- *Food and Wine Agents*: Remember each user's previous purchases and tasting notes and make customised presentations of the inventory during the next visit.
- *Entertainment Agents*: Find communities with similar interests to those of the user, and recommend albums, movies, etc. based on group evaluations.

3.5 Agents for Business Operations

Intelligent agents also find applications in Intranets of organisations and business enterprises. They include:

- Collaborative customization agents: intranet agents that automate workflow processes in business units.
- Process automation agents: Intranet agents that automate industrial processes.
- Database agents: Intranet agents that provide agent services for users of enterprise databases.
- Resource brooking agents: Agents that perform resource allocation in client/server architectures.

3.6 Entertainment Software Agents

Autonomous software agents have significant potential in areas such as entertainment and in online chat. Interactive entertainment products based on anthropoids or synthetic characters are emerging. These agents can depict emotions and convey their internal state to the user. These cartoon-like characters provide an illusion of life in convincing ways to make audience believe the agent is real.

Some of the examples include: *Creatures* (www.cyberlife.co.uk) (Grand and Cliff, 1998), real-time, interactive, self-animating creatures called *Woggles*. (Oz Project at Carnegie-Melon University, USA)

There is growing interest in incorporating agents in interfaces to make interactions more natural and easier. Examples include: Extempo's Web-situated virtual bar based on Barbara Hayes-Roth's work at Stanford University on virtual bartender (www.extempo.com/webBar/) and virtual personalities (www.vperson.com/). Another example is the agent Jullia who participates on online chat rooms, providing directions to users and taking part in online discussions. Agents have potential to play influencing roles in marketing, education and training (see PPP and Lewis 1998).

4. FURTHER WORK

Though in the last three years agent-based systems have advanced and there have many successful agent-based applications, agent technology is still young and many problems and research challenges still remain. Further, as we move to deploy agents on the Internet for critical applications, and as our dependence on agents continue to grow, issues and requirements such as reliability, real-time performance, openness, security and trust become paramount importance. To fully benefit from agent technologies, further developments are needed in the following major areas:

- Information access, filtering, etc.
- Learning
- Multiagent cooperation, coordination and negotiation
- Real-time performance issues and considerations
- Testing, verification and validation
- Trustworthiness, security
- Ethical issues and considerations
- Mobile agents - execution considerations in remote host(s)
- Integration of agent-based systems with other systems

For further information a roadmap on agent research and development see Jennings, Sycara and Wollidridge (1998).

5. CONCLUSION

Intelligent agents on the Internet and Web will grow dramatically in the next few years and they would be put into use in a variety of new applications and services. The following quotes aptly highlight the prospects of intelligent agents.

"Agents are here to stay... because of their diversity, their wide range of applicability and the broad spectrum of companies investing in them."

- Nawana, 1996

"One of the most interesting entrepreneurial activity for the next several years is likely to be discovering new and unique ways of using the Internet [and Intelligent Agents] for business [and personal] advantage."

- Yourdon, 1997

"Agents will be the most important computing paradigm in the next 10 years. By the year 2000, every significant application will have some form of agent enablement."

- BIS Strategic Decisions

"In the future, it [agent] is going to be the only way to search the Internet, because no matter how much better the Internet is going to be organised, it can't keep pace with information."

- Bob Johnson of Dataquest

As we move further into the information age and start using the Internet, Intranet, extranets, and the Web for a wide range of simple to complex applications, there will be a steady growth in agent applications and in the agent market. Realising this many organisations are investing in agent technology and many players - computer manufacturers, software houses and many start-up companies - have entered into this highly competitive field. The stakes are high and the future belongs to those who are prepared. The winners would be those who have vision, are innovative and are prepared to realise those visions. Perhaps now is the time to act. *Now* never waits.

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URLs of Some Useful Web Pages

Multiagent Systems: WWW.cs.wustl.edu/~mas/links.htm

The Agent Society: www.agent.org

Agents List and Archive: <http://www.cs.umbs.edu/agentslist/>

AgentWeb: <http://www.cs.umbc.edu/agents/>

Agent: <http://www.opensesame.com/agents/agenttop.html>

FIPA (Foundation for Intelligent Physical Agents): <http://drogo.cscit.stet.it/fipa>