

Intelligent Agents:

The Right Information at the Right Time

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Research Triangle Park, NC USA
May, 1997

ABSTRACT

Intelligent agents are an emerging technology that is making computer systems easier to use by allowing people to delegate work back to the computer. They help do things like find and filter information, customize views of information, and automate work. This paper examines some real agent-enhanced applications to explore the value of agents, summarizes the characteristics that differentiate agents from other software, and lists IBM intelligent agent technologies which can be used to add agents to new or existing applications.

1. Introduction

As computers, networks, and computer systems evolve, ease of use has not kept pace with the tremendous amount of advanced function now available. The result is that computers are becoming more and more daunting for beginning, and even veteran users. The information and processing which should be available is simply not accessible.

In our lives, when we find ourselves in a position where time and activities overtake us, we seek help in the form of assistants - people who take care of things we could do ourselves, but prefer not to. In the computer world, *intelligent agents* play the role of such assistants.

An Intelligent agent is software that assists people and acts on their behalf. Intelligent agents work by allowing people to **delegate** work that they could have done, to the agent software. Agents can, just as assistants can, automate repetitive tasks, remember things you forgot, intelligently summarize complex data, learn from you, and even make recommendations to you.

2. Problems Intelligent Agents Can Solve

To better understand intelligent agent technology, it is best to first examine some of the practical problems that intelligent agents can help solve. This list is not meant to be exhaustive, but rather illustrative. We will cover how agents work a little later.

Here is a typical problem: you don't know where the right information is, or how to find it. This can happen to you whether you are looking at corporate data or surfing the Internet. Intelligent agents can help solve this problem by **finding and filtering information**.

Another typical problem is that it takes time to wade through information in "the world's" order (which is how it is always presented!). This might be OK when there are only a few pieces of data, but as the amount of data grows, and as the rate of arrival of new data also grows, the order of the data is of paramount importance. Intelligent agents can help solve this problem by **customizing information**

to your preferences, thus saving you time in handling it.

Yet another typical problem is that events happen and no one takes action. These events could be real world events like competitive announcements or emergencies, or they could be computer events like a new version of a design document becoming ready. Intelligent agents can help solve this problem by **automating** the handling of things you don't want to take care of yourself.

All these problems can be solved in many different ways. You could just work a little harder and do it yourself. Someone could modify some corporate computer software. The **business value** of delegating intelligent agents to handle these three types of problems is that you get **the right information at the right time**, without having to do it all yourself or rewrite the base applications.

3. Scenarios of Intelligent Agent Use

Let's look in some detail at some real examples where intelligent agents are being applied to help solve problems that real people and real businesses have encountered.

3.1 Customer Help Desk

In a business whose job it is to field calls from customers and quickly find the answer to their problems, finding the right information at the right time is the name of the game! Years ago, such calls were handled manually, with trained professionals consulting hardcopy manuals, custom online databases, and sometimes having to consult by telephone with other help desk personnel. Computerization has improved things: many hardcopy manuals have been replaced with searchable CD-ROM collections, and some companies offer searches over the Internet.

However, applying intelligent agent technology to this problem helps even more. Imagine a help desk where an intelligent agent takes the problem as described by the customer, automatically searches the relevant databases (whether local, CD-ROM, or via the Internet), then presents a consolidated answer with the most likely information first!

Such a solution is being built today. This is a good example of using intelligent agents to **find and filter** information.

3.2 Web Browser Intelligence

On the Internet today, complexity is rampant. It is hard enough to find things you want, even with many sophisticated searching tools available, but when you do, you often find yourself retracing your steps to find it all over again, later. Why is this? Because you don't have a personal assistant watching what you do, and reminding you of things you forgot! IBM's Web Browser Intelligence (WBI, or "Webby") is an intelligent agent designed to help you out in situations like this!

First, WBI helps you find things you forgot on the Web, because it is always watching and learning from you. It **customizes** your view of the Web by automatically keeping a bookmark list, ordered by how often and how recently you've gone to a site. It allows you to search for any words you've seen in your Web travels (even on a page you didn't look at too carefully!) and then takes you back to that site, allowing you to **find & filter** quickly. It even helps you find where you were by showing you all the different "trails" you took starting at the current page, showing you another **customized** view of the Web.

Next, WBI can **automate** your Web browsing by notifying you when sites you like are updated. It can even automatically download pages for you to browse later, offline.

And, before you waste minutes waiting for a site to respond, or before you click on the slowest download site of all, WBI **automates** your Web access by showing "traffic lights" next to each url reference, indicating the relative speed of the server that contains the page.

Finally, WBI **customizes** the Web even further by noticing if you follow a fixed pattern of browsing - if you do, it puts up "quantum links" that take you directly where you want to go, without any backtracking!

A no-cost version of WBI is available for you to download and try out - just visit the IBM Intelligent Agents Home Page at <http://www.networking.ibm.com/iag/iaghome.html>.

3.3 Personal Shopping Assistant

Whether you are an Internet shopper or the owner of a store on the Internet, you'd like to avoid page after page of the wrong merchandise, and get right to items that interest you most. IBM's Personal Shopping Assistant, and experimental part of IBM's complete line of electronic commerce offerings, uses intelligent agent technology to help you out.

Personal Shopping Assistant can **customize** both stores and merchandise. For each shopper, it learns their preferences, and whenever enter a mall of stores, or looking at specific merchandise, it can rearrange merchandise so that the items you like the most are the first ones you see.

In addition, it can correlate buying patterns of whole groups of shoppers, **finding and filtering** where there are items that are often purchased together, for example. So when you buy shoes, there will be socks for you to look at, as well!

Finally, Personal Shopping Assistant **automates** your shopping experience by reminding you of times you might want to go shopping, such as birthdays, anniversaries, or when items in which you are interested go on sale.

There are certainly many other examples of intelligent agent usage in the marketplace today. These just discussed are just a few, but they illustrate some of the important ways intelligent agents can help solve real problems, and make today's computer systems easier to use. We hope that these examples will start you thinking about how intelligent agents can help improve your own experiences with computer systems!

4. Characteristics of Intelligent Agents

Having examined some of the ways intelligent agents can help make life easier, let's look more at what makes intelligent agent software different from any other software. First, our definition again: *An Intelligent agent is software that assists people and acts on their behalf.* This definition focuses on the delegation (1) aspect of intelligent agents, which is certainly one thing that sets agents apart, since agents are built to help people, just like human assistants.

However, some agents may be invisible to the user, because they represent a second level of delegation by the user's agent, or even because they are a part of the way the system itself is structured. Perhaps the best way to show what agent software is is to enumerate the characteristics (2,3) of agent software.

All agents are **autonomous**. That is, an agent has control over its own actions. This is good, because when you delegate something to your agent, you expect it to have the independence to work on your

request no matter what happens around it.

All agents are also **goal-driven**. Agents have a purpose, and act in accordance with that purpose. There are several ways of making goals known to an agent, however:

- A rudimentary agent could be driven by a **script**, which pre-defines its actions. The script would then define the agent's goals.
- An agent could also be a **program**, as long as the program is driven by goals, and shares the other characteristics of agents.
- An agent could also be driven by **rules**, which is a more general way of defining the agent's goals.
- There are even more sophisticated ways of embedding agent goals, such as "planning" methodologies (5), and in some cases, the agent may even have the flexibility to change its own goals over time.

All agents are also **reactive**. That is, an agent senses changes in its environment and responds in a timely fashion to these changes. This characteristic of agents is also at the core of delegation and automation. Just as you tell your assistant, "When x happens, do y " an agent is always waiting for x to happen! Finally, in order to carry out the wishes of the user, all agents **continue to run**, even when the user is gone. This implies that an agent may run on a server, but in fact some agents run on user systems.

The four characteristics above are always true of intelligent agents. There are four more characteristics which are useful, and in fact are often true of agents, but may not *always* be true.

Some agents are **social**. That is, they interact, or communicate with other agents. This communication could be by proprietary means, or it could be by a standard way such as KQML (Knowledge Query and Manipulation Language) (4). Some systems are even built entirely of communicating, cooperating agents, called *Multi-Agent Systems* (5).

Some agents are **customized** or **adaptive**. That is, they **learn**, or change their behavior based on previous experience. This characteristic is prominent in each of the examples of agent usage previously shown, and is key to agent ease of use.

Some agents are **mobile**, and move from machine to machine (6). In so doing, agents can be closer to data they may need to process and do so without network delays.

Finally, some agents strive to be **believable**, in that they are represented as an entity **visible** or **audible** to the user, and may even have aspects of emotion or personality.

5. IBM Intelligent Agent Technologies

A number of individual technologies may be necessary to implement intelligent agents that have the characteristics outlined above. IBM offers a full range of technologies, as well as services to put the technologies together in the form of custom solutions to individual problems. In addition, many IBM products and service offerings utilize intelligent agent technology to make them easier to use. The various technologies and offerings will be described briefly here to better explain how intelligent agents work, and to further illustrate the value of adding intelligent agents to applications.

5.1 Agent Building Environment

Typically, for early adopter agent-enabled applications, agents are built into the application from the

beginning, as other parts of the system are being developed. To facilitate quicker and easier agent-enablement for both new and existing systems, IBM offers the **Agent Building Environment (ABE)**, which can be downloaded from the Internet on <http://www.networking.ibm.com/iag/iaghome.html>.

Architecture is necessary to form an open environment in which agents can be added to existing applications, and agent parts, once developed, can be reused across many applications. ABE is based on such an architecture, shown in Figure 1. Its key parts include:

- **Engine** - the agent's "brains" - typically a rule engine controlling the overall operation of the agent.
- **Knowledge** - what the agent knows, believes, and thinks, stored persistently in the **Library**.
- **Adapters** - the "eyes, ears and hands" of an agent which allow it to see events from any outside domain, and take action in any domain.
- **Views** - the human interface to the agent, to instruct it what to do, for example.

The Agent Building Environment, as currently available, offers the following functions:

- A forward chaining inference engine, most widely used and required, to allow an agent to be rule-driven
- Knowledge stored in KIF (Knowledge Interchange Format) (9), an emerging standard. This allows, for example, more than one view component to input rules to the inference engine, as long as they are generated in standard KIF.
- KIF rule editor. Rules are stored in the Library.
- A set of adapters which allow common Internet applications to be built. Adapters include **Time** (sets alarms to trigger rules), **File** (observes and manipulates files), **HTTP** (casts the Internet HTTP domain in event - condition - action format), **NNTP** (allows monitoring and manipulation of USENET newsgroups) and **SMTP** (allows sending SMTP mail messages), as well as others.
- A set of demonstration intelligent agents, including news filtering, stock quote monitoring and others.

5.2 Web Browser Intelligence

The functions of IBM's **WBI** have been described above, in section 3.2

Because of its tight connection to the user and the immediate presentation of results and changes onscreen, WBI is implemented on the client system rather than on the server, as with many other intelligent agents. WBI is built as a generalized proxy server, but with "plug-in intelligence" and is suited as a general base for Internet applications. It is powered by intelligent agent user modeling technology from IBM's Almaden Research Lab, and is available for download at IBM's intelligent agent home page, <http://www.networking.ibm.com/iag/iaghome.html>.

5.3 Knowledge Utility

Knowledge Utility (KnU) is a general purpose hypermedia system offering intelligent information retrieval and management. KnU allows groups of users to weave together all forms of data, connecting knowledge into meaningful patterns which aid users in retrieving appropriate information.

KnU allows an individual to identify interconnections among pieces of knowledge from different disciplines, and leaves a tangible and persistent record of that process of research and exploration. To accomplish this, KnU keeps user-specified relationships between data objects, allowing the users to

receive information which is tailored to their interest pattern. Data returned to each user is automatically prioritized based on the preferences *learned* from that user, using Bayesian Networks (7).

The World Wide Web provides connections from within the Internet and remains largely read-only, so no additional connections can easily be made. KnU can provide connections into and out of the Internet. Using KnU, users can connect from Internet objects to their own private data and back again, building an important knowledge base.

The *preference profiling* offered by KnU helps agents customize information. KnU is the technology used, for example, in the Personal Shopping Assistant described in section 3.3 above. The **Aquí** prototype, another example, personalizes Internet information connections and is also built on KnU. Aquí can be found at <http://knu aqui.stllab.ibm.com> or on the IBM intelligent agent home page.

5.4 Intelligent Miner

Intelligent Miner is an intelligent agent based system which utilizes a number of presentation and modeling techniques, including neural networks, to interactively perform pattern analysis on large amounts of data, and highlight patterns and features of interest. Further, user segmentation discovered using Intelligent Miner can be used for "social learning" where information learned from users is applied to other users in the same segment., as well as associated buying.

The neural network feature in Intelligent Miner allows a combination of neural networks, fuzzy rule systems, and data filtering/translation to be graphically connected and then embedded into applications. It supports on-line learning, controlled by scripts or application programs. It is also extendible through the addition of custom neural network models and custom data filters.

Intelligent Miner is used in the Personal Shopping Assistant described above in section 3.3.

5.5 SmartGuide

SmartGuide is a wizard-style help system that builds panels that leads user through the steps of accomplishing a task. SmartGuides are scripted based on data from a HTML-like tag set.

The SmartGuide Viewers make it easier for an application to provide wizard-style helps. The Viewers free developers from the headaches of screen management, navigation, and data management that normally have to be dealt with when building wizards with traditional programming languages. The Viewers give developers the added advantage of allowing customers to further customize wizards to meet their specific needs.

5.6 Lotus Notes Agents

Notes Agents in **Lotus Notes** Version 4 allow automation of many tasks within Notes. They operate in the background to perform routine tasks automatically for the user such as filing documents, sending e-mail, looking for particular topics or archiving older documents. They can be created by designers as part of an application to automate routine tasks such as progress tracking, reminders of overdue items, or perform more powerful functions, such as manipulating field values and bringing data in from other applications.

Agents can either be private agents created by the user and used only by the user, or shared agents created by a designer and used by anybody who has access to the application or database. Both private and shared agents are design elements that are stored with the database for which they are

created. They can be run manually by the user, automatically when certain events occur such as mail arriving, or scheduled to run at certain intervals. They can contain Notes simple actions, @function formulas, or a LotusScript program.

5.7 COACH

The **COACH** (COgnitive Adaptive Computer Help) (8) system, developed by Ted Selker of IBM Research, models user behavior and uses an inference engine to provide proactive and adaptive assistance. COACH has been applied to both application-specific environments and general-purpose system interfaces, and is included as a standard part of IBM's OS/2 Warp operating system, called *WarpGuide*.

5.8 Aglets

Java is a popular language for use in the Internet environment, not only because it is platform independent, but also because it allows use of *applets*. Applets are small programs that are automatically downloaded and run as a part of accessing a Web page. IBM's Tokyo Research Lab has extended the applet concept into mobile agents in a project called **Aglets** (Agent Applets).

Based on Aglets, the *Aglets Workbench* (AWB) is a first-of-its-kind visual environment for building network-based applications that use mobile agents to search for, access, and manage corporate data and other information. AWB consists of the following components:

- Aglets, Java class libraries and tools to enable objects to move
- Jodax, a high level Java library to IBM's DB2 database
- JDBC, an ODBC-style library to RDBs
- Tazza, a visual GUI builder for Java

In addition, a related experimental package called Java KQML (**JKQML**) has been made to allow agent interaction in the Aglets environment. Two preliminary *ontologies* (vocabularies of common terms) are also supported. One is the *Agent Life Cycle Ontology* for management of agent creation, destruction, transportation and name resolution, the other is the *Yellow Page Service Ontology*, and like the telephone book provides a search facility for the addresses of the desired services.

One crucial problem of Java-based mobile agent systems is that mobile agents cannot hold their process state while moving across the network. That is, it is difficult to build a mobile agent that can perform successive jobs in series or parallel at different places. In **JMT** (*Java-based Moderator Templates*), a *plan*, common in the field of workflow applications, defines the sequence of activities to be performed. In JMT, this plan moves along with a mobile agent across the network.

5.9 Agent Characteristics vs. Technologies

Figure 2 below shows a summary of agent characteristics versus IBM agent technologies.

6. Market State & The Future

"Agents will be the most important computing paradigm in the next ten years. . . By the year 2000, every significant application will have some form of agent-enablement" (2)

There are several reasons for this conclusion:

1. Desktop applications are becoming so "feature rich" that users can master only a small part of

their capabilities. Agents mask the complexity and help the user do what he/she wants.

2. Sources of information are increasing, and their content is also increasing. Agents help do the data mining—as well as help locate the most productive mines.
3. Greater bandwidth means more data can get to you more quickly—but the user still has only 16 hours in the day available to work. Agents help manage the flow, by sending only the information *the user* considers essential.
4. Desktops and servers now are getting enough power to easily help users and processes.
5. Rapidly increasing use of the Internet and World Wide Web is creating a much more complex computing environment. Many people are beginning to refer to this as "network computing." This implies that we are moving from simple connections (i.e., a terminal-to-a-host, or a client-to-a-server) into the complex world of multiple servers and services interconnected like a highway network: Everything is available, but services change by the second, and the user has to figure out how to find them. Agents make a cohesive whole out of this stochastic world.
6. University and industrial research has now passed the point of mere theory, and experimental systems are freely available and in-use on the Internet.
7. Early adopters of commercial systems are giving a practical base for future application and commercial development.
8. Large custom applications are becoming agent-enabled, further broadening the experience base.

There are at least 50 vendors currently supplying agent-enabled software and services. They are spread across virtually every application area, including Internet applications. Customers fit into the market category called "early adopters": they take a niche, often technology-centric application, and figure out how to adapt it to their use. The challenge is to make it easy to add intelligent agents to *any* application, new or existing. A recent market study (2) predicted when many people would be using agents, and when agent-enabled applications would be in widespread use. These predictions have been born out by the flood of agent-enabled applications announced in 1996; 1997 is moving at an even faster pace.

Application Area	Many Use	Mainstream Use
Administrative Mgt	1997	1999
Collaborative	1997	1998
Commerce	1997	2000
Desktop Applications	1995	1998
Information Access / Management	1997	1999
Messaging (e-mail)	1996	1998
Mobile Access / Mgt	1996	1998
Network Management	1994	1996
User Interface	1997	1999

7. Summary

Intelligent agents are in use today, helping make applications easier to use, and their usage is increasing rapidly. Agents are especially good at finding and filtering information, customizing information, and automating tasks --- "Finding the right information at the right time." While we have shown several examples of agent usage, there are many more.

IBM offers a full line of intelligent agent technology which can be used to add agents to new or existing applications. These are available in various forms, or as a part of custom services designed to

deliver an agent-enhanced solution.

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Web sites with more information

[IBM Intelligent Agents](http://www.networking.ibm.com/iag/iaghome.html) - <http://www.networking.ibm.com/iag/iaghome.html>

[IBM Technology and Research](http://www.ibm.com/technology) - <http://www.ibm.com/technology>

[Lotus](http://www.lotus.com) - <http://www.lotus.com>

[Knowledge Utility \(KnU\)](http://knuaiqui.stllab.ibm.com) - <http://knuaiqui.stllab.ibm.com>