Intelligent Software Agents on the Internet: an inventory of currently offered functionality in the information society & a prediction of (near-)future developments

by Björn Hermans

"[...] Agents are here to stay, not least because of their diversity, their wide range of applicability and the broad spectrum of companies investing in them. As we move further and further into the information age, any information-based organisation which does not invest in agent technology may be committing commercial hara-kiri."

Hyacinth S. Nwana in [NWAN96]

Tilburg University, Tilburg, The Netherlands, the 9th of July 1996

http://www.hermans.org/agents
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1 Preamble

1.1 Abstract
Software agents are a rapidly developing area of research. However, to many it is unclear what agents are and what they can (and maybe cannot) do. In the first part, this thesis will provide an overview of these, and many other agent-related theoretical and practical aspects. Besides that, a model is presented which will enhance and extend agents' abilities, but will also improve the way the Internet can be used to obtain or offer information and services on it. The second part is all about trends and developments. On the basis of past and present developments of the most important, relevant and involved parties and factors, future trends and developments are extrapolated and predicted.

1.2 Introduction

“We are drowning in information but starved of knowledge”

John Naisbitt of Megatrends

Big changes are taking place in the area of information supply and demand. The first big change, which took place quite a while ago, is related to the form information is available in. In the past, paper was the most frequently used media for information, and it still is very popular right now. However, more and more information is available through electronic media. Other aspects of information that have changed rapidly in the last few years are the amount that it is available in, the number of sources and the ease with which it can be obtained. Expectations are that these developments will carry on into the future.

A third important change is related to the supply and demand of information. Until recently the market for information was driven by supply, and it was fuelled by a relatively small group of suppliers that were easily identifiable. At this moment this situation is changing into a market of a very large scale where it is becoming increasingly difficult to get a clear picture of all the suppliers.

All these changes have an enormous impact on the information market. One of the most important changes is the shift from it being supply-driven to it becoming demand-driven. The number of suppliers has become so high (and this number will get even higher in the future) that the question who is supplying the information has become less important: demand for information is becoming the most important aspect of the information chain. What's more, information is playing an increasingly important role in our lives, as we are moving towards an information society. Information has become an instrument, a tool that can be used to solve many problems.

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1 “Information society” or "Information Age” are both terms that are very often used nowadays. The terms are used to denote the period following the "Post-Industrial Age" we are living in right now.
1.2.1 Problems regarding the demand for information

Meeting information demand has become easier on one hand, but has also become more complicated and difficult on the other. Because of the emergence of information sources such as the world-wide computer network called the Internet\(^2\) (the source of information this thesis will focus on primarily) everyone - in principle - can have access to a sheer inexhaustible pool of information. Typically, one would expect that because of this satisfying information demand has become easier.

The sheer endlessness of the information available through the Internet, which at first glance looks like its major strength, is at the same time one of its major weaknesses. The amounts of information that are at your disposal are too vast: information that is being sought is (probably) available somewhere, but often only parts of it can be retrieved, or sometimes nothing can be found at all. To put it more figuratively: the number of needles that can be found has increased, but so has the size of the haystack they are hidden in. The inquirers for information are being confronted with an information overkill.

The current, conventional search methods do not seem to be able to tackle these problems. These methods are based on the principle that it is known which information is available (and which one is not) and where exactly it can be found. To make this possible, large information systems such as databases are supplied with (large) indexes to provide the user with this information. With the aid of such an index one can, at all times, look up whether certain information can or cannot be found in the database, and - if available - where it can be found.

On the Internet (but not just there\(^3\)) this strategy fails completely, the reasons for this being:

- **The dynamic nature of the Internet itself**: there is no central supervision on the growth and development of Internet. Anybody who wants to use it and/or offer information or services on it, is free to do so. This has created a situation where it has become very hard to get a clear picture of the size of the Internet, let alone to make an estimation of the amount of information that is available on or through it;

- **The dynamic nature of the information on Internet**: information that cannot be found today, may become available tomorrow. And the reverse happens too: information that was available, may suddenly disappear without further notice, for instance because an Internet service has stopped its activities, or because information has been moved to a different, unknown location;

- **The information and information services on the Internet are very heterogeneous**: information on the Internet is being offered in many different kinds of formats and in many different ways. This makes it very difficult to search for information automatically, because every information format and every type of information service requires a different approach.

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\(^2\) General, introductory information about the Internet and its services can be found in appendix two.

\(^3\) Articles in professional magazines indicate that these problems are not appearing on the Internet only: large companies that own databases with gigabytes of corporate information stored in them (so-called data warehouses), are faced with similar problems. Many managers cannot be sure anymore which information is, and which is not stored in these databases. Combining the stored data to extract valuable information from it (for instance, by discovering interesting patterns in it) is becoming a task that can no longer be carried out by humans alone.
1.2.2 Possible solutions: Search Engines and Agents

There are several ways to deal with the problems that have just been described. Most of the current solutions are of a strong ad hoc nature. By means of programs that roam the Internet (with flashy names like spider, worm or searchbot) meta-information is being gathered about everything that is available on it. The gathered information, characterised by a number of keywords (references) and perhaps some supplementary information, is then put into a large database. Anyone who is searching for some kind of information on the Internet can then try to localise relevant information by giving one or more query terms (keywords) to such a search engine.

Although search engines are a valuable service at this moment, they also have several disadvantages (which will become even more apparent in the future).

A totally different solution for the problem as described in section 1.2.1, is the use of so-called Intelligent Software Agents. An agent is (usually) a software program that supports a user with the accomplishment of some task or activity. In the future, it [agents] is going to be the only way to search the Internet, because no matter how much better the Internet may be organised, it can't keep pace with the growth in information...

Bob Johnson, analyst at Dataquest Inc.

Using agents when looking for information has certain advantages compared to current methods, such as using a search engine:

<table>
<thead>
<tr>
<th>Search Engine feature:</th>
<th>Improvement(s) Intelligent Software Agents can offer:</th>
</tr>
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<tbody>
<tr>
<td>1. An information search is done, based on one or more keywords given by a user. This presupposes that the user is capable of formulating the right set of keywords to retrieve the wanted information. Querying with the wrong, too many, or too little keywords will cause many irrelevant information (‘noise’) to be retrieved or will not retrieve (very) relevant information as it does not contain these exact keywords;</td>
<td>Agents are capable of searching information more intelligently, for instance because tools (such as a thesaurus) enable them to search on related terms as well, or even on concepts. Agents will also use these tools to fine-tune, or even correct user queries (on the basis of a user model, or other user information);</td>
</tr>
</tbody>
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4 For example, the gathering programs that collect information for the Lycos search engine, create document abstracts which consist of the document's title, headings and subheadings, the 100 most weighty words, the first 20 lines, its size in bytes and the number of words.

5 In appendix 1, a list of Internet search engines is given, to give an idea just what kind of search engines are currently being offered.

6 There are many different kinds of software agents, ranging from Interface agents to Retrieval agents. This thesis will be mainly about agents that are used for information tasks (such as offering, finding or editing all kinds of information). Many things that are said about agents in this thesis do, however, also apply to the other kinds of agents. However (for briefness' sake), we will only concern ourselves with information agents in this thesis.
2. Information mapping is done by gathering (meta-)information about information and documents that are available on the Internet. This is a very time-consuming method that causes a lot of data traffic, it lacks efficiency (there are a lot of parties that use this method of gathering information, but they usually do not co-operate with others which means that they are reinventing the wheel many times), and it does not account very well for the dynamic nature of the Internet and the information that can be found on it; Individual user agents can create their own knowledge base about available information sources on the Internet, which is updated and expanded after every search. When information (i.e. documents) have moved to another location, agents will be able to find them, and update their knowledge base accordingly. Furthermore, in the future agents will be able to communicate and co-operate with other agents (such as middle layer agents - see chapter 4). This will enable them to perform tasks, such as information searches, quicker and more efficient, reducing network traffic. They will also be able to perform tasks (e.g. searches) directly at the source/service, leading to a further decrease of network traffic;

3. The search for information is often limited to a few Internet services, such as the WWW. Finding information that is offered through other services (e.g. a 'Telnet-able' database), often means the user is left to his or her own devices; Agents can relief their human user of the need to worry about "clerical details", such as the way the various Internet service have to operated. Instead, he or she will only have to worry about the question what exactly is being sought (instead of worrying about where certain information may be found or how it should be obtained). The user's agent will worry about the rest;

4. Search engines cannot always be reached: the server that a service resides on may be 'down', or it may be too busy on the Internet to get a connection. Regular users of the service will then have to switch to some other search engine, which probably requires a different way to be operated and may offer different services; As a user agent resides on a user's computer, it is always available to the user. An agent can perform one or more tasks day and night, sometimes even in parallel. As looking for information on the Internet is such a time-consuming activity, having an agent do this job has many advantages, one of them being that an agent does not mind doing it continuously. A further advantage of agents is that they can detect and avoid peak-hours on the Internet;

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7 See appendix 2 for more information about Telnet.
5. Search engines are domain-independent in the way they treat gathered information and in the way they enable users to search in it. Terms in gathered documents are lifted out of their context, and are stored as a mere list of individual keywords. A term like "information broker" is most likely stored as the two separate terms "information" and "broker" in the meta-information of the document that contains them. Someone searching for documents about an "information broker" will therefore also get documents where the words "information" and "broker" are used, but only as separate terms (e.g. as in "an introductory information text about stock brokers");

6. The information on Internet is very dynamic: quite often search engines refer to information that has moved to another, unknown location, or has disappeared. Search engines do not learn from these searches, and they do not adjust themselves to their users. Moreover, a user cannot receive information updates upon one or more topics, i.e. perform certain searches automatically at regular intervals. Searching information this way, becomes a very time-consuming activity.

Software agents will be able to search information based on contexts. They will deduce this context from user information (i.e. a built-up user model) or by using other services, such as a thesaurus service. See chapter four and six for more detailed information about this.

User agents can adjust themselves to the preferences and wishes of individual users. Ideally this will lead to agents that will more and more adjust themselves to what a user wants and wishes, and what he or she is (usually) looking for, by learning from performed tasks (i.e. searches) and the way users react to the results of them. Furthermore, agents are able to continuously scan the Internet for (newly available) information about topics a user is interested in.

The precise characteristics of agents are treated in more detail in chapter two. Chapter three will focus on the practical possibilities of agents.

1.2.3 Agents as building blocks for a new Internet structure

The Internet keeps on growing, and judging by reports in the media the Internet will keep on growing. The big threat this poses is that the Internet will get too big and too diverse for humans to comprehend, let alone to be able to work on it properly. And very soon even (conventional) software programs will not be able to get a good grip on it.

More and more scientists, but also members of the business community, are saying that a new structure should be drawn up for the Internet which will make it more easily and conveniently to use, and which will make it possible to abstract from the various techniques that are hidden under its

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8 Users do not directly search the information on the Internet itself, but the meta-information that has been gathered about it. The result of such a search, is not the meta-information itself, but pointers to the document(s) it belongs to.

9 If a document is retrieved which turns out to be no longer available, the search engine does not learn anything of this happening: it will still be retrieved in future sessions. A search engine also does not store query results, so the same query will be repeated over and over again, starting from scratch.
surface. A kind of abstraction comparable to the way in which higher programming languages relieve programmers of the need to deal with the low-level hardware of a computer (such as registers and devices).

Because the thinking process with regard to these developments has started only recently, there is no clear sight yet on a generally accepted standard. However, an idea is emerging that looks very promising: a *three layer structure*\(^\text{10}\). There are quite a number of parties which, although sometimes implicitly, are studying and working on this concept. The main idea of this three layer model is to divide the structure of the Internet into three layers\(^\text{11}\) or concepts:

1. Users;
2. Suppliers; and
3. Intermediaries.

The function and added-value of the added middle layer, and the role(s) agents play in this matter, are explained in chapter four.

1.2.4 Thesis Constraints

There are agents in many shapes and sizes. As can be concluded from the preceding text, this thesis will deal mainly with one special type of intelligent software agents, namely those that are used in the process of information supply and demand. When, in the forthcoming sections of this thesis, the term "agent" is used, usually these "information agents" are meant. However, many things that are said, apply to the other types of agents as well.

1.3 Two statements

This thesis consists of two parts. For each of these two parts a separate statement will be formulated.

The first part of the thesis is an inventory of agent theory, agents in practise, and the three layer model. The *claim* for this part is:

"*Intelligent Software Agents make up a promising solution for the current (threat of an) information overkill on the Internet.*

*The functionality of agents can be maximally utilised when they are employed in the (future) three layer structure of the Internet.*"

The second part of the thesis will be about current, near-future and future agent developments. Questions such as "how will agents be used in the near future?", "who will be offering agents (and why)?", and "which problems/needs can be expected?" will be addressed here.

\(^{10}\) As opposed to the more or less two layer structure of the current Internet (one layer with users and another layer with suppliers).

\(^{11}\) The term "layers" is perhaps a bit misleading as it suggests a hierarchy that is not there: all three layers are of equal importance. Thinking of the layers in terms of concepts or entities may make things more clearer.
Because of the nature of this part, the second statement is a prediction:

"Agents will be a highly necessary tool in the process of information supply and demand. However, agents will not yet be able to replace skilled human information intermediaries. In the forthcoming years their role will be that of a valuable personal assistant that can support all kinds of people with their information activities."

1.4 Structure of the thesis
In the next chapter, the theoretical side of agents will be more deeply looked at: what are agents, what makes them different from other techniques and what is the functionality they (will) have to offer? After having looked at agents in theory in chapter two, chapter three will give an idea of the kind of practical applications that agents and the agent technique are already being used in. In chapter four a three layer model will be sketched, where the agent technique is combined with the functionality offered by the various Internet services. Together they can be used to come to a Internet that offers more functionality, is more surveyable, and has a cleaner logical structure than the current (two-layer) set-up.

The second part of this thesis, comprised by the chapters five and six, is entirely about past, present and future developments, prediction and expectations. The parties and factors that have, are, or will be influencing developments are looked at in more detail. In chapter seven, the thesis will be concluded with concluding remarks and a look at the accuracy of the two statements of section 1.3.
PART ONE - Theoretical and Practical Aspects of Agents and the Prospects of Agents in a Three Layer Model
2 Intelligent Software Agents Theory

2.1 Introduction

Intelligent software agents are a popular research object these days in such fields as psychology, sociology and computer science. Agents are most intensely studied in the discipline of Artificial Intelligence (AI). Strangely enough, it seems like the question what exactly an agent is, has only very recently been addressed seriously.

"It is in our best interests, as pioneers of this technology, to stratify the technology in such a way that it is readily marketable to consumers. If we utterly confuse consumers about what agent technology is (as is the case today) then we'll have a hard time fully developing the market potential."

J. Williams on the Software Agents Mailing List

Because of the fact that currently the term "agent" is used by many parties in many different ways, it has become difficult for users to make a good estimation of what the possibilities of the agent technology are. At this moment, there is every appearance that there are more definitions than there are working examples of systems that could be called agent-based.

Agent producers that make unjust use of the term agent to designate their product, cause users to draw the conclusion that agent technology as a whole has not much to offer. That is - obviously - a worrying development:

"In order to survive for the agent, there must be something that really distinguishes agents from other programs, otherwise agents will fail. Researchers, the public and companies will no longer accept things that are called agent and the market for agents will be very small or even not exist."

Wijnand van de Calseyde on the Software Agents Mailing List

On the other hand, the description of agent capabilities should not be too rose-coloured either.

Not everybody is that thrilled about agents. Especially from the field of computer science, a point of criticism often heard about agents is that they are not a new technique really, and that anything that can be done with agents "can just as well be done in C". According to these critics, agents are nothing but the latest hype.

The main points of criticism can be summarised as follows:

• Mainstream AI research (expert systems, neural networks) is not as successful as many people had hoped and the new paradigm of agents is the way to escape;
• Everything that has the label "agent" sells (this also counts in research). Like the words 'plus', 'super' and 'turbo', the term 'agent' sounds very attractive, even when most people do not know the

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12 For general information about AI, see this WWW page: http://wombat.doc.ic.ac.uk/?AI
13 This is a discussion list (using e-mail as the means of communication) about the subject of Software Agents. The list is used and read by both users as well as developers of such agents. For more information see http://www.ee.mcgill.ca/~belmarc/agent_faq.html.
14 C is a structured programming language developed by Dennis Ritchie at Bell Laboratories in 1972. C is a compiled language that contains a small set of built-in functions that are machine dependent. The rest of the C functions are machine independent and are contained in libraries that can be accessed from C programs.
exact meaning of 'plus', 'super', 'turbo' or 'agent'. Agents are nothing more but old wine in new bottles;

- Because of the fact that in most cases current software agents have neither a very sophisticated nor a very complicated architecture, some wonder what qualifies them as "intelligent".\(^{15}\)

Particularly by researchers in the field of AI, these points of criticism are refuted with the following arguments:

- What distinguishes multi-agent architectures from other architectures is that they provide acceptable solutions to certain problems at an affordable price. These are the kind of problems that cannot be solved with available resources in reasonable time with monolithic knowledge based systems.\(^{16}\)

  An example of this can be found in the field of *integrated decision making*, where systems are built where a single final diagnose is based on the diagnoses of individual *worker agents*.

  Moreover, there are some problems in the field of AI that cannot be solved satisfactorily unless a multi-agent architecture (i.e. an architecture where independent agents are working together to accomplish all kinds of tasks) is used;

- Agents make it possible to eradicate the differences between the different kinds of networks (WAN, LAN\(^{17}\), Internet) and to make the borders between them 'disappear'. Some researchers like to take this one step further by playing with the notion of agents that supersede AI.\(^{18}\)

  The response of (particularly) these researchers to the pronouncement quoted earlier, that what agents can do "can just as well be done in C", can be summarised in the following points:

  * It does not matter what the underlying technique of agents is. Whether that is a C program, a Perl script, or a LISP program: what it all boils down to is what the agent is and is not capable of doing. Or to be more precise: whether the agent is capable of displaying intelligent behaviour. And whether the basis for that behaviour is a C program, or whatever other programming language or technique, does not really matter;

  * It does not always apply that everything that can be done by multiple co-operative agents may "just as well be done in C" (not even in the object oriented variant of that programming language). There are several tasks and problems for which there is scientific proof that they cannot be accomplished or solved by one single program or person. These kind of problems call for a distribution of the task or problem over multiple entities (i.e. a multi-agent architecture) because this will lead to a solution in a much shorter time, and quite often to a solution of a higher quality because it is the result of a subtle combination of the partial results of each individual entity.

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\(^{15}\) Unfortunately that question opens up the old AI can-of-worms about definitions of intelligence. E.g., does an intelligent entity necessarily have to possess emotions, self-awareness, etcetera, or is it sufficient that it performs tasks for which we currently do not possess algorithmic solutions?

\(^{16}\) The 'opposite' can be said as well: in many cases the individual agents of a system aren't that intelligent at all, but the combination and co-operation of them leads to the intelligence and smartness of an agent system.

\(^{17}\) LAN stands for *Local Area Network* (as opposed to a WAN: a *Wide Area Network*). A LAN is a group of computers and other devices dispersed over a relatively limited area and connected by a communications link that enables any device to interact with any other on the network. LANs commonly include microcomputers and shared (often expensive) resources such as laser printers and large hard disks. Most (modern) LANs can support a wide variety of computers and other devices.

\(^{18}\) These researchers see a paradigm shift from those who build intelligent systems and consequently grapple with problems of knowledge representation and acquisition, to those who build distributed, not particularly, intelligent systems, and hope that intelligence will emerge in some sort of *Gestalt* fashion. The knowledge acquisition problem gets solved by being declared to be a 'non-problem'.
The 'pros' and 'cons' with regards to agents as they are mentioned here, are by no means complete, and should be seen as merely an illustration of the general discussions about agents. What it does show is why it is necessary (in several respects) to have a definition of the concept "intelligent software agent" that is as clear and as precise as possible. It also shows that there is probably a long way to go before we arrive at such a definition - if we can come to such a definition at all.

2.2 Definition

"An agent is a software thing that knows how to do things that you could probably do yourself if you had the time."

Ted Selker of the IBM Almaden Research Centre (quote taken from [JANC95])

In this section we will not come to a rock-solid formal definition of the concept "agent". Given the multiplicity of roles agents can play, this is quite impossible and even very impractical. On the Software Agents Mailing List, however, a possible informal definition of an intelligent software agent was given:

"A piece of software which performs a given task using information gleaned from its environment to act in a suitable manner so as to complete the task successfully. The software should be able to adapt itself based on changes occurring in its environment, so that a change in circumstances will still yield the intended result."

(with thanks to G.W. Lecky-Thompson for this definition)

Instead of the formal definition, a list of general characteristics of agents will be given. Together these characteristics give a global impression of what an agent "is".19

The first group of characteristics, which will be presented in section 2.2.1, are connected to the weak notion of the concept "agent". The fact that an agent should possess most, if not all of these characteristics, is something that most scientists have agreed upon at this moment. This is not the case, however, with the second group of characteristics, which are connected to the strong notion of the concept "agent". The characteristics that are presented in section 2.2.2 are not things that go without saying for everybody.

What "intelligence" is, and what the related term "agency" means, is explained in section 2.2.3.

2.2.1 The weak notion of the concept "agent"

Perhaps the most general way in which the term agent is used, is to denote a hardware or (more usually) software-based computer system that enjoys the following properties:

- **autonomy**: agents operate without the direct intervention of humans or others, and have some kind of control over their actions and internal state;20

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19 See [WOOL95] for a more elaborated overview of the theoretical and practical aspects of agents.

• **social ability**: agents interact with other agents and (possibly) humans via some kind of agent communication language;\(^2^1\)

• **reactivity**: agents perceive their environment (which may be the physical world, a user via a graphical user interface, a collection of other agents, the Internet, or perhaps all of these combined), and respond in a timely fashion to changes that occur in it\(^2^2\). This may entail that an agent spends most of its time in a kind of sleep state\(^2^3\) from which it will awake if certain changes in its environment (like the arrival of new e-mail) give rise to it;

• **proactivity**: agents do not simply act in response to their environment, they are able to exhibit goal-directed behaviour by taking the initiative;

• **temporal continuity**: agents are continuously running processes (either running active in the foreground or sleeping/passive in the background), not once-only computations or scripts that map a single input to a single output and then terminate;

• **goal orientedness**: an agent is capable of handling complex, high-level tasks. The decision how such a task is best split up in smaller sub-tasks, and in which order and in which way these sub-tasks should be best performed, should be made by the agent itself.

Thus, a simple way of conceptualising an agent is as a kind of UNIX-like software process\(^2^4\), that exhibits the properties listed above. A clear example of an agent that meets the weak notion of an agent is the so-called *softbot* (‘software robot’). This is an agent that is active in a software environment (for instance the previously mentioned UNIX operating system).

### 2.2.2 The strong(er) notion of the concept "agent"

For some researchers - particularly those working in the field of AI - the term agent has a stronger and more specific meaning than that sketched out in the previous section. These researchers generally mean an agent to be a computer system that, in addition to having the properties as they were previously identified, is either conceptualised or implemented using concepts that are more usually applied to humans. For example, it is quite common in AI to characterise an agent using mentalistic notions, such as knowledge, belief, intention, and obligation\(^2^5\). Some AI researchers have gone further, and considered *emotional agents*\(^2^6\).

Another way of giving agents human-like attributes is to represent them visually by using techniques such as a cartoon-like graphical icon or an animated face\(^2^7\). Research into this matter\(^2^8\) has shown

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\(^{2^2}\) Note that the kind of reactivity that is displayed by agents, is beyond that of so-called (UNIX) *daemons*. Daemons are system processes that continuously monitor system resources and activities, and become active once certain conditions (e.g. thresholds) are met. As opposed to agents, daemons react in a very straightforward way, and they do not get better in reacting to certain conditions.

\(^{2^3}\) Analogous to the "sleep" state in a UNIX system (see the next footnote): a process that has no further tasks to be done, or has to wait for another process to finish, goes into a sleep state until another process wakes it up again.

\(^{2^4}\) UNIX is an operating system that is mostly used on large computer systems and workstations. The concept of process is the basic idea behind UNIX (a program running under UNIX consists of one or more independent processes which usually are operating in parallel).


that, although agents are pieces of software code, people like to deal with them as if they were dealing with other people (regardless of the type of agent interface that is being used).

Agents that fit the stronger notion of agent usually have one or more of the following characteristics:\(^\text{29}\):

- \textit{mobility}: the ability of an agent to move around an electronic network;\(^\text{30}\)
- \textit{benevolence}: is the assumption that agents do not have conflicting goals, and that every agent will therefore always try to do what is asked of it;\(^\text{31}\)
- \textit{rationality}: is (crudely) the assumption that an agent will act in order to achieve its goals and will not act in such a way as to prevent its goals being achieved - at least insofar as its beliefs permit;\(^\text{32}\)
- \textit{adaptivity}: an agent should be able to adjust itself to the habits, working methods and preferences of its user;
- \textit{collaboration}: an agent should not unthinkingly accept (and execute) instructions, but should take into account that the human user makes mistakes (e.g. give an order that contains conflicting goals), omits important information and/or provides ambiguous information. For instance, an agent should check things by asking questions to the user, or use a built-up user model to solve problems like these. An agent should even be allowed to refuse to execute certain tasks, because (for instance) they would put an unacceptable high load on the network resources or because it would cause damage to other users.\(^\text{33}\)

Although no single agent possesses all these abilities, there are several prototype agents that possess quite a lot of them (see section 3.2.2 for some examples). At this moment no consensus has yet been reached about the relative importance (weight) of each of these characteristics in the agent as a whole. What most scientists have come to a consensus about, is that it are these kinds of characteristics that distinguish agents from ordinary programs.

2.2.3 "Agency" and "Intelligence"

The degree of autonomy and authority vested in the agent, is called its \textit{agency}. It can be measured at least qualitatively by the nature of the interaction between the agent and other entities in the system in which it operates.

At a minimum, an agent must run a-synchronously. The degree of agency is enhanced if an agent represents a user in some way. This is one of the key values of agents. A more advanced agent can interact with other entities such as data, applications, or services. Further advanced agents collaborate and negotiate with other agents.

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\(^{29}\) This list is far from complete. There are many other characteristics of agents that could have been added to this list. The characteristics that are mentioned here are there for illustrative purposes and should not be interpreted as an ultimate enumeration.


What exactly makes an agent "intelligent" is something that is hard to define. It has been the subject of many discussions in the field of Artificial Intelligence, and a clear answer has yet to be found. Yet, a workable definition of what makes an agent intelligent is given in [IBM95]:

"Intelligence is the degree of reasoning and learned behaviour: the agent's ability to accept the user's statement of goals and carry out the task delegated to it. At a minimum, there can be some statement of preferences, perhaps in the form of rules, with an inference engine or some other reasoning mechanism to act on these preferences. Higher levels of intelligence include a user model or some other form of understanding and reasoning about what a user wants done, and planning the means to achieve this goal. Further out on the intelligence scale are systems that learn and adapt to their environment, both in terms of the user's objectives, and in terms of the resources available to the agent. Such a system might, like a human assistant, discover new relationships, connections, or concepts independently from the human user, and exploit these in anticipating and satisfying user needs."

2.3 The User's "definition" of agents

"User knowledge, rather than product capability, is the principal determinant of agent-enabled application usage today. [...] User need is the principal consideration in developing/executing business strategies for agent-enabled products."

from [JANC95]

Just like in the oncoming information society, the success and development of agents and the agent technique are driven by users really, instead of by producers or researchers. So, when considering just exactly what an agent is, and which aspects of it are very important and which are less important, the ever important user factor should not be overlooked. Users will not start to use agents because of their benevolence, proactivity or adaptivity, but because they like the way agents help and support them in doing all kinds of tasks; soon users will use all sorts of convenient (i.e. "intelligent") applications, without them realising they are using agents by doing so.

As was pointed out at the beginning of this chapter, there is one good reason why a fairly concise definition of an agent that can meet with general approval, should be drawn up as soon as possible: clarity towards the user. By all means it should be prevented that "agent" becomes a vague, meaningless and empty term, in the way a term such as "multi-media" has lost its meaning in the course of time. Agents will be perceived as nothing but the latest marketing hype:

"Just take your old program, and add an agent to the end of your product name. Voila! You have an Object Agent, Test Agent. [...]"

quote taken from [JANC95]

More about (professional) user’s views on agents, will follow in chapter five and six.

34 Users will not play that much of a very active steering-role, but user acceptance and adoption will be the ultimate test of agent’s success.
2.4 Summary

Today, agents are a popular research object in many scientific fields. An exact definition and exact set of characteristics (and their relative weight) are yet to be stated and chosen.

Ultimately, users of agents and agent-enabled programs will be the principal determinant of how agents will look, what they will be, and what things they should and should not be able to do.
3 Intelligent Software Agents in Practice

3.1 Applications of Intelligent Agents

The current applications of agents are of a rather experimental and ad hoc nature. Besides universities and research centres a considerable number of companies, like IBM and Microsoft, are doing research in the area of agents. To make sure their research projects will receive further financing, many researchers & developers of such companies (but this is also applicable on other parties, even non-commercial ones) are nowadays focusing on rather basic agent applications, as these lead to demonstrable results within a definite time.

Examples of this kind of agent applications are:

- Agents who partially or fully handle someone's e-mail;
- Agents who filter and/or search through (Usenet) news articles looking for information that may be interesting for a user;
- Agents that make arrangements for gatherings such as a meeting, for instance by means of lists provided by the persons attending or based on the information (appointments) in the electronic agenda of every single participant.

The current trend in agent developments is to develop modest, low-level applications. Yet, more advanced and complicated applications are more and more being developed as well. At this moment research is being done into separate agents, such as mail agents, news agents and search agents. These are the first step towards more integrated applications, where these single, basic agents are used as the building blocks. Expectations are that this will become the trend in the next two or three years to come. (Note that this does not mean that there will be no or little interesting developments and opportunities in the area of smaller, more low-level agent applications.)

In chapter four a model will be presented which supports this trend towards more complex, integrated systems. In this model basic agents can easily be combined to create complex structures which are able to perform high-level tasks for users, suppliers and intermediaries. The interface to this system (i.e. model) is through a single agent which delegates sub-tasks and queries to other agents.

In [IBM95] eight application areas are identified where now (or in the near-future) agent technology is (or will be) used.

These areas are:

1. **Systems and Network Management:**
   Systems and network management is one of the earliest application areas to be enhanced using intelligent agent technology. The movement to client/server computing has intensified the complexity of systems being managed, especially in the area of LANs, and as network centric computing becomes more prevalent, this complexity further escalates. Users in this area (primarily operators and system administrators) need greatly simplified management, in the face of rising complexity.

   Agent architectures have existed in the systems and network management area for some time, but these agents are generally “fixed function” rather than intelligent agents. However, intelligent agents can be used to enhance systems management software. For example, they can help filter and take automatic actions at a higher level of abstraction, and can even be used to detect and react to patterns in system behaviour. Further, they can be used to manage large configurations dynamically;
2. **Mobile Access / Management:**
As computing becomes more pervasive and network centric computing shifts the focus from the desktop to the network, users want to be more mobile. Not only do they want to access network resources from any location, they want to access those resources despite bandwidth limitations\(^{35}\) of mobile technology such as wireless communication, and despite network volatility.

Intelligent agents which (in this case) reside in the network rather than on the users’ personal computers, can address these needs by persistently carrying out user requests despite network disturbances. In addition, agents can process data at its source and ship only compressed answers to the user, rather than overwhelming the network with large amounts of unprocessed data;

3. **Mail and Messaging:**
Messaging software (such as software for e-mail) has existed for some time, and is also an area where intelligent agent function is currently being used. Users today want the ability to automatically prioritise and organise their e-mail, and in the future, they would like to do even more automatically, such as addressing mail by organisational function rather than by person.

Intelligent agents can facilitate all these functions by allowing mail handling rules to be specified ahead of time, and letting intelligent agents operate on behalf of the user according to those rules. Usually it is also possible (or at least it will be) to have agents deduce these rules by observing a user's behaviour and trying to find patterns in it;

4. **Information Access and Management:**
Information access and management is an area of great activity, given the rise in popularity of the Internet and the explosion of data available to users. It is the application area that this thesis will mainly focus on.

Here, intelligent agents are helping users not only with search and filtering, but also with categorisation, prioritisation, selective dissemination, annotation, and (collaborative) sharing of information and documents;

5. **Collaboration:**
Collaboration is a fast-growing area in which users work together on shared documents, using personal video-conferencing, or sharing additional resources through the network. One common denominator is shared resources; another is teamwork. Both of these are driven and supported by the move to network centric computing.

Not only do users in this area need an infrastructure that will allow robust, scaleable sharing of data and computing resources, they also need other functions to help them actually build and manage collaborative teams of people, and manage their work products.

One of the most popular and most heard-of examples of such an application is the groupware packet called *Lotus Notes*;

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\(^{35}\) Bandwidth is - in technical terms - the measure of information-carrying capability of a communication medium (such as optical fibre). An Internet service such as the World Wide Web, which makes use of graphical (and sometimes even audio or video) data, needs considerable amounts of bandwidth, whereas an Internet service such as e-mail needs only very small amounts.
6. **Workflow and Administrative Management:** Administrative management includes both workflow management and areas such as computer/telephony integration, where processes are defined and then automated. In these areas, users need not only to make processes more efficient, but also to reduce the cost of human agents. Much as in the messaging area (application area 3 in this list), intelligent agents can be used to ascertain, then automate user wishes or business processes;

7. **Electronic Commerce:**
Electronic commerce is a growing area fuelled by the popularity of the Internet. Buyers need to find sellers of products and services, they need to find product information (including technical specifications, viable configurations, etc.) that solve their problem, and they need to obtain expert advice both prior to the purchase and for service and support afterward. Sellers need to find buyers and they need to provide expert advice about their product or service as well as customer service and support. Both buyers and sellers need to automate handling of their "electronic financial affairs".

Intelligent agents can assist in electronic commerce in a number of ways. Agents can "go shopping" for a user, taking specifications and returning with recommendations of purchases which meet those specifications. They can act as "salespeople" for sellers by providing product or service sales advice, and they can help troubleshoot customer problems;

8. **Adaptive User Interfaces:**
Although the user interface was transformed by the advent of graphical user interfaces (GUIs), for many, computers remain difficult to learn and use. As capabilities and applications of computers improve, the user interface needs to accommodate the increase in complexity. As user populations grow and diversify, computer interfaces need to learn user habits and preferences and adapt to individuals.

Intelligent agents (called *interface agents*) can help with both these problems. Intelligent agent technology allows systems to monitor the user's actions, develop models of user abilities, and automatically help out when problems arise. When combined with speech technology, intelligent agents enable computer interfaces to become more human or more "social" when interacting with human users.

### 3.2 Examples of agent applications and entire agent systems

Because of the fact that a lot of research is being done in the field of agents, and because many like to field-test theories (i.e. implementations), a lot of agents are active on the Internet these days. Comparing them is not an easy task as their possibilities and degree of elaboration vary strongly. Add to this the fact that there still is no well-defined definition of what an agent is, and it is easy to see how difficult it is to judge whether or not a piece of software may be called an agent, and (if it is judged to be one) how good (or "intelligent") it is.

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36 A *workflow* is a system whose elements are activities, related to one another by a trigger relation and triggered by external events, which represents a business process starting with a commitment and ending with the termination of that commitment.

*Workflow Management* (WFM) is the computer assisted management of business processes through the execution of software whose order of execution is controlled by a computerised representation of the business processes.
Still, four examples from the broad variety of agent applications and agent systems have been selected to be given a closer look.

The two agent applications serve as examples of what is currently being done with agents in (relatively small) commercial applications. The agent systems are still more or less in the development (i.e. research) phase, but judging by what is said in their documentation, both are to be developed into full-fledged systems which may or may not become commercial products.

The chosen examples are to be seen as examples of what can be done with agents in actual practise. The choice for these specific agent implementations should not be seen as some kind of personal value judgement.

### 3.2.1 Two examples of agent applications

#### 3.2.1.1 Open Sesame!

Open Sesame! is a software agent that learns the way users work with their Macintosh applications. *"It streamlines everything you do on your desktop. It eliminates mundane, time-consuming tasks so that every minute you spend at your computer is productive".* Open Sesame! uses a learning agent which observes user's activities and learns which tasks are repeated again and again. It then offers to perform those repetitive tasks for the user automatically.

Open Sesame! can also automate crucial maintenance tasks the user may (easily) forget, such as rebuilding the desktop.

Some of the features of Open Sesame! are:

- It learns work patterns and generates instructions that automate tasks;
- It automatically performs tasks at specified times;
- It automatically performs two or more tasks that the user would otherwise have to perform separately;
- It gives the user shortcuts for opening or closing a related group of folders, applications and documents;
- It arranges windows of scriptable applications so the user can work with multiple applications more efficiently;
- It offers power users the option to expand Open Sesame! with AppleScript applets and macro utility mini-applications.

Open Sesame! uses Apple events to learn a user's patterns and to automate them. It is not a replacement for AppleScript: while the former provides a subset of the commands (such as opening documents and applications), it also provides functionality not available in the latter. However, sometimes it can be useful to use them together as AppleScript applets can be used as applications in Open Sesame! instructions.

One big advantage of Open Sesame! over tools such as Applescript is that it generalises the intent of a user's actions, and does not merely record every stroke and mouse click without any inference or generalisation.

Open Sesame! uses two types of triggers: time-based and event-based. Time-based triggers will execute certain instructions at a given time, whereas event-based triggers cause it to execute an instruction in response to a desktop action such as opening a folder, quitting an application, start-up, shutdown and so on.

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37 AppleScript allows a user to write small programs, or scripts, and uses Apple events to execute the program.
3.2.1.2 Hoover
The second example is SandPoint's Hoover, which "provides a single user interface to multiple information media, including real-time newswires, on-line databases, field intelligence, and corporate computing resources. Hoover automatically organises selected information according to the context of the user's need or function. Designed for groups of users, Hoover currently works with Lotus Notes. Support for other groupware solutions is under development."

Hoover's applications can be divided into five areas:

1. Current Awareness:
   Hoover has an information agent that delivers two types of current awareness: real-time news and full-text premier publications. For the first type of current awareness, Hoover can organise news in many different ways: by company, industry, government category, dateline, region, and more. Back issues of publications are stored on the Hoover server, enabling the user to review a past story or track of a certain development. The second type enables full-text word searching, enabling deep searches in news articles;

2. Research:
   Based on the type of information the user wants, such as information on companies, people, places, and markets, Hoover's research agent will search for information based on the appropriate context. Searching through news feeds and on-line databases in real-time is a further possibility. The thus retrieved information can be updated automatically as often as necessary;

3. Information Enabled Applications:
   Hoover offers so-called "information enabled applications" which "accelerate workflow and deliver specific information for decision making support";

4. Corporate Intelligence:
   Some of the most valuable sources of information for a company are the people working for it. With this part of Hoover, a place can be provided for team members to contribute what they've learned for knowledge-sharing. "Volumes of important ideas and observations - an essential part of the intellectual capital of a company - will be available for everyone. And neatly integrated with authoritative external sources";

5. Internal Databases:
   This part of Hoover unites internal and external information. It can draw from information in internal databases because of the open system architecture of the Hoover Scripting Language Tool Kit. "Now you can unite internal information with the Electronic Ocean outside [...]."

Hoover is able to meet about 75% of common information needs. Additions, such as a research centre, can be used for the more complex searches.

3.2.2 Two examples of entire agent systems

3.2.2.1 The Internet SoftBot
In [ETZI95] a list of currently available agents is given to show what is already being done with intelligent software agents. As a means of showing what the differences between the mentioned agents are, the (well-known) metaphor of the information highway is used. On this highway an intelligent agent may be a back-seat driver who makes suggestions at every turn (Tour Guides), a taxi driver who takes you to your destination (Indexing Agents or FAQ-Finders), or even a
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concierge whose knowledge and skills make it unnecessary for a person to approach the superhighway at all.

A draw-back of tour guides and indexing agents is that their actions and suggestions are based on a relatively weak model of what the user wants and what information is available at a suggested location. An attempt to change this is the Internet Softbot (developed by the University of Washington). The aim is to create an agent that attempts to determine what the user wants and understands the contents of information services.

The agents that were described in the metaphor, access unstructured or semistructured information (such as text files). The Internet Softbot tackles a different component of information on the Internet: structured information services such as stock quote servers or library databases.

Because the information is structured, the Softbot need not rely on natural language or information retrieval techniques to "understand" the information provided by a service. Instead, the Softbot relies on a model of the service for the precise semantics associated with information provided by the service. As a result, the Softbot can answer focused queries with relatively high reliability; the chances of finding relevant information are high and the amount of non-relevant information ('noise') is (relatively) low.

The key idea behind the Softbot is reflected in its name, which is derived from software robot. Its tools consist of UNIX commands such as ftp, print, and mail. Commands like list files and Internet services such as Finger and Netfind\(^\text{38}\) are used as a kind of sensors to find information. Internally, a least-commitment planner provides behavioural control of the Softbot. Several technical innovations were necessary, however, to make this approach successful in the complex world of the Internet.

The Internet Softbot is a prototype implementation of a high-level assistant, analogous to a hotel concierge. In contrast to systems for assisted browsing or information retrieval, the Softbot can accept high-level user goals and dynamically synthesise the appropriate sequence of Internet commands to satisfy those goals. The Softbot executes the sequence, gathering information to aid future decisions, recovering from errors, and retrying commands if necessary.

The Softbot eliminates a person's need to "drive" the information superhighway at all; the person (user) delegates that job to the Softbot. More general: the Softbot allows a user to specify what to accomplish, while it handles the decisions of how and where to accomplish it. This makes the Internet Softbot a good example of a goal-oriented agent.

The goal-orientedness of the Softbot is useful only if users find specifying requests to it easier than carrying out activities themselves. The agent has three properties which should make goal specification convenient for users:

1. **An expressive goal language**: the Softbot accepts goals containing complex combinations of conjunction, disjunction, negation, and nested universal and existential quantification. This allows specification of tasks such as "Get all of researcher Joe's technical reports that are not already stored locally";

2. **A convenient syntax and interface for formulating requests**: despite the expressive power of mathematical logic, many users are unable (or unwilling) to type long, complex, quantifier-laden sentences (something many Information Retrieval systems require). For this reason, the Softbot supplies a forms-based graphical user interface and automatically translates forms into the logical goal language. Natural language input, an alternative approach pursued by many researchers, is not yet incorporated in the Softbot;

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\(^{38}\) Netfind is a tool that can help to find a person's exact email address, given their name and a reasonably close guess about the Internet name of the computer they use.
3. **Mixed-initiative refinement dialogue**: even with a well-engineered interface, it is difficult to specify orders precisely. Human assistants solve this problem by asking questions to their client in order to be able to iteratively refine a given goal. The current Softbot has only limited support for in-between questions, but a new interface is being designed that will allow the Softbot to pose questions (while it continues to work) and allow the user to add information and constraints.

The Softbot possesses many, but not all of the desired characteristics as they were described in section 2.2. It is autonomous, goal-oriented, flexible and self-starting (i.e. it possesses "reactivity"). At this moment work is being done to extend the Softbot's collaborative, communicative, adaptive and personality-characteristics.

The Softbot is not mobile, but it does not really need to be that. What's more, it would entail all kinds of complicated security and privacy issues (with regard to its user).

### 3.2.2.2 The Info Agent

In [ALOI95] D'Aloisi and Giannini present a system that supports users in retrieving data in distributed and heterogeneous archives and repositories. The architecture is based on the metaphor of software agents and incorporates techniques from other research fields such as distributed architectures, relevance feedback and active interfaces.

When designing and developing the information agents for their system, the aim was to make the system suitable for different types of users with regard to local and external searches for information and data.

One single agent, called the **Info Agent**, is used as the interface between the system and the user. The Info Agent, in its turn, uses a so called **Interface Agent** for handling the communication with the user. This agent is like a personal assistant who is responsible for handling user needs, and for the connection of the user with the agent(s) that will help him solve his problem. The number of types of agents the Interface Agent has to deal with, depends on the aims of the system. As a result of the distributed and agent-based architecture of the system the whole structure of it can be easily changed or updated by adjusting the Interface Agent only.

The Interface Agent is able to reason about the user's requests and to understand what type of need he is expressing: it singles out which of the two other agents in the system is able to solve the current problem and sends to it its interpretation of the query (using KQML - the Knowledge Query and Manipulation Language\(^39\)). These other two agents are the **Internal Services Agent** and the **External Retrieval Agent**.

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The Internal Services Agent knows the structure of the archives available in a given organisation: it is in charge of retrieving scientific and administrative data, performing some classes of actions (such as finding available printers) and supporting the user in compiling internal forms.

The External Retrieval Agent is in charge of retrieving documents on the network. It can work in two modalities: retrieval (or query) mode and surfing mode. In the first case, it searches for a specific document following a query asked by the user: this service is activated by a direct user request. In the second case, the agent navigates the network searching for documents that, in its opinion, could interest the user. The search is driven by a user’s profile built and maintained by the Interface Agent. Refinement of this profile takes place according to how the user manages the data that the agent finds for and/or proposes him. Using the user’s profile, the Interface Agent charges specialised agents to navigate through the network hunting for information that could be of some interest for the user. In this way, the user can be alerted when new data that can concern his interest area(s) appear.

Currently, both the External Retrieval Agent as well as the Internal Services Agent utilise the same software tool to perform their search: it is a public-domain software called Harvest, which is “an integrated set of tools to gather, extract, organise, search, cache and replicate relevant information across the Internet”\textsuperscript{40}. Nevertheless it is also possible to provide the system with other search methods or systems to be used alone or along with Harvest: that is an advantage due to the modular and distributed architecture of the whole framework. The number of agents co-ordinated by the Interface Agent is also a part of the system that can quite easily be changed.

In a nutshell the Interface Agent has the following crucial system tasks:

- **Assisting the user in performing requests and compiling his profile.**
  The user does not need to be aware of what is available on the network, how this information is structured and organised, where the repositories are localised, or what retrieval services are at disposal. This is the responsibility of the Interface Agent;

• **Deducing the user's information needs by both communicating with him and observing his "behaviour".**
  The agent observes the user's behaviour and the current state of the world to deduce what actions are to be performed and how to modify the current user's profile;

• **Translating the requests of the user and selecting the agent(s) able to solve his problem(s).**
  This allows the user to completely ignore the structure of the system he is interacting with. Moreover he can also ignore how the system works. The user interacts with a personalised interface that knows how to satisfy his requests without bothering him with all sorts of details;

• **Presenting and storing the retrieved data.**
  This avoids the user to know the different formats (such as WordPerfect, Postscript or LaTeX format) and how to manage a document to have a printable or showable version. The Info Agent deals with each retrieved document according to its format and transforms it into a form the user can utilise (e.g. convert a LaTeX document into WordPerfect format).

The Info Agent resembles, in a number of ways, the Softbot (which we saw in section 3.2.2.1). One of the differences between these two agents is that the Info Agent focuses mainly on the user, whereas the Softbot focuses mainly on the requests of the user. Another difference is that the Info Agent searches in both structured as well as unstructured information (documents), whereas the Softbot "limits" itself to structured information only.

### 3.3 Summary
Currently available agent-systems and agent-enabled applications are of a rather basic and ad hoc nature. However, more complex and elaborated systems are in the making.

In this chapter, eight application areas of the agent-technology have been identified. From those areas, *Information Access and Management, Collaboration* and *Electronic Commerce* are the ones that are most intensely studied at this moment (note that this is research that is not only into agents and agent-enabled applications, but into many other subjects as well).

To give an idea of what is already possible with agents, i.e. what is already being done with the agent technology, four examples of agent-systems and agent-enabled applications were described.

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41 For more information about collaboration projects on the Internet, see this WWW page: http://union.ncsa.uiuc.edu/HyperNews/get/www/collaboration.html.

More information about (research into) Electronic Commerce can be found on this WWW page about "Electronic Commerce Web Resources": http://www.sics.se/ps/commerce/survey.html.
4 The Three Layer Model

4.1 Introduction

"The information superhighway directly connects millions of people, each both a consumer of information and a potential provider. If their exchanges are to be efficient, yet protected on matters of privacy, sophisticated mediators will be required. Electronic brokers can play this important role by organizing markets that promote the efficient production and consumption of information."

from [RESN95]

Although the Internet provides access to huge amounts of information, the information sources, at this moment, are too diverse and too complex for most users to use them to their full extent. "Currently, the World Wide Web (WWW) is the most successful effort in attempting to knit all these different information resources into a cohesive whole that can be interfaced through special documents (called Web pages or hyper/HTML documents). The activity best-supported by this structure is (human) browsing through these resources by following references (so-called hyperlinks) in the documents."42 However, as is pointed out in [DAIG95a], "the WWW & the Internet do not adequately address more abstract activities such as information management, information representation, or other processing of (raw) information".

In order to support these activities with increasingly complex information resources (such as multimedia objects, structured documents, and specialised databases), the next generation of network services infrastructure will have to be interoperable at a higher level of information activity abstraction.

This may be fairly evident in terms of developing information servers and indexes that can interact with one another, or that provide a uniform face to the viewing public (e.g., through the World Wide Web). However, an information activity is composed of both information resources and needs. It is therefore not enough to make resources more sophisticated and interoperable; we need to be able to specify more complex, independent client information processing tasks.43

In [DAIG95b] an experimental architecture is described that can satisfy both needs as were just described. In this architecture the information search process is divided into three layers: one layer for the client side of information (information searchers), one for the supply or server side of information (information providers), and one layer between these two layers to connect them in the best possible way(s) (the middle layer).44

Leslie Daigle is not alone in her ideas: several other parties are doing research into this concept or concepts very similar to it.45 Fact is that more and more persons are beginning to realise that the current structure of the Internet, which is more or less divided into two layers or parties (being users and suppliers) is more and more failing to be satisfactory.

42 Quote taken from [DAIG95a].
43 Note that this client may be a human user, or another software program.
44 Other names that are used to name this layer are information intermediaries, information brokers, but also a term such as (intelligent) middleware. Throughout this thesis these terms will be used interchangeably.
45 For instance, IBM is doing research into this subject in their InfoMarket project.


4.2 Definition

Currently, when someone is looking for certain information on the Internet, there are many possible ways to do that. One of the possibilities that we have seen earlier, are search engines. The problem with these is that:

♦ They require a user to know how to best operate every individual search engine;
♦ A user should know exactly what information he is looking for;
♦ The user should be capable of expressing his information need clearly (with the right keywords).

However, many users do neither know exactly what they are looking for, nor do they have a clear picture of which information can and which cannot be found on the Internet, nor do they know what the best ways are to find and retrieve it.

A supplier of services and/or information is facing similar or even bigger problems. Technically speaking, millions of Internet users have access to his service and/or information. In the real world however, things are a little more complicated. Services can be announced by posting messages on Usenet, but this is a 'tricky business' as most Usenet (but also Internet) users do not like to get unwanted, unsolicited messages of this kind (especially if they announce or recommend commercial products or services). Another possibility to draw attention to a service is buying advertising space on popular sites (or pages) on the World Wide Web. Even if thousands of users see such a message, it still remains to be seen whether or not these users will actually use the service or browse the information that is being offered. Even worse: many persons that would be genuinely interested in the services or information offered (and may even be searching for it), are reached insufficiently or not reached at all.

In the current Internet environment, the bulk of the processing associated with satisfying a particular need is embedded in software applications (such as WWW browsers). It would be much better if the whole process could be elevated to higher levels of sophistication and abstraction.

Several researchers have addressed this problem. One of the most promising proposals is a model where activities on the Internet are split up into three layers: one layer per activity.

![Figure 2 - Overview of the Three Layer Model](image)

Per individual layer the focus is on one specific part of the activity (in case of this thesis and of figure 2: an information search activity), which is supported by matching types of software agents. These agents will relieve us of many tedious, administrative tasks, which in many cases can be taken over very well, or even better, by a computer program (i.e. software agents). What's more, the agents will enable a human user to perform complex tasks better and faster.
The three layers are:

1. **The demand side** (of information), i.e. the information searcher or user; here, agents’ tasks are to find out exactly what users are looking for, what they want, if they have any preferences with regard to the information needed, etcetera;

2. **The supply side** (of information), i.e. the individual information sources and suppliers; here, an agent’s tasks are to make an exact inventory of (the kinds of) services and information that are being offered by its supplier, to keep track of newly added information, etcetera;

3. **Intermediaries**; here agents mediate between agents (of the other two layers), i.e. act as (information) intermediaries between (human or electronic) users and suppliers.

When constructing agents for use in this model, is it absolutely necessary to do this according to generally agreed upon standards: it is unfeasible to make the model account for any possible type of agent. Therefore, all agents should respond & react in the same way (regardless of their internal structure) by using some standardised set of codes. To make this possible, the standards should be flexible enough to provide for the construction of agents for tasks that are unforeseen at present time.

The three layer model has several (major) plus points:

1. **Each of the three layers only has to concern itself with doing what it is best at.**
   Parties (i.e. members of one of the layers) do no longer have to act as some kind of "jack-of-all-trades";

2. **The model itself** (but the same goes for the agents that are used in it) **does not enforce a specific type of software or hardware.**
   The only thing that has to be complied to are the standards that were mentioned earlier. This means that everybody is free to chose whatever underlying technique they want to use (such as the programming language) to create an agent: as long as it responds and behaves according to the specifications laid down in the standards, everything is okay. A first step in this direction has been made with the development of agent communication and programming languages such as **KQML** and **Telescript**\(^{46}\).
   Yet, a lot of work has to be done in this area as most of the current agent systems do not yet comply to the latter demand: if you want to bring them into action at some Internet service, this service needs to have specific software running that is able to communicate and interact with that specific type of agent. And because many of the current agent systems are not compatible with other systems, this would lead to a situation where an Internet service would have to possess software for every possible type of agent that may be using the service: a most undesirable situation;

3. **By using this model the need for users disappears to learn the way in which the individual Internet services have to be operated;**
   the Internet and all of its services will 'disappear' and become one cohesive whole;

4. **It is easy to create new information structures or to modify existing ones without endangering the open (flexible) nature of the whole system.**
   The ways in which agents can be combined become seemingly endless;

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5. To implement the three layer model no interim period is needed to do so, nor does the fact that it needs to be backward-compatible with the current (two layer) structure of the Internet have any negative influences on it. People (both users and suppliers) who chose not to use the newly added intermediary or middle layer, are free to do so. However, they will soon discover that using the middle layer in many cases leads to quicker and better results in less time and with less effort. (More about this will follow in the next sections.)

The "only" current deficiency of this model is the lack of generally agreed upon standards, such as one for the used agent communication language. Such standards are a major issue for the three layer model, as they ensure that (agents in) the individual layers can easily interface with (agents in) the other ones. Organisations such as the Internet Engineering Task Force (IETF) and its work groups have been, and still are, addressing this issue.

4.3 The functions of the middle layer

Recently, a lot of work has been done to develop good user interfaces to the various services on the Internet, and to enhance existing ones. However, the big problem with most of the services is that they are too strongly aimed at catering for the broadest possible range of users. This approach goes all wrong as services become either too complicated for novice users, or too tedious and limited for expert users. Sometimes the compromises that have been made are so big, that a service is not really suitable for either of them.

The Internet services of the future should aim at exactly the opposite with tailor-made services (and interfaces) for every individual user as the ultimate target. Neither the suppliers nor the users of these services should be responsible for accomplishing this, as this would - once again - lead to many different techniques and many different approaches, and would lead to parties (users and suppliers) trying to solve problems they should not be dealing with in the first place. Instead, software agents will perform these tasks and address these problems.

In this section it will be explained why the middle layer will become an inevitable, necessary addition to the current two layer Internet, and an example will be given to give an impression of the new forms of functionality it can offer.

4.3.1 Middle layer (agent) functions

"The fall in the cost of gathering and transmitting information will boost productivity in the economy as a whole, pushing wages up and thus making people's time increasingly valuable. No one will be interested in browsing for a long while in the Net trying in whatever site whatever information! He wants just to access the appropriate sites for getting good information."

from "Linguistic-based IR tools for W3 users" by Basili and Pazienza
The main functions of the middle layer are:

1. **Dynamically matching user demand and provider’s supply in the best possible way.**
   Suppliers and users (i.e. their agents) can continuously issue and retract information needs and capabilities. Information does not become stale and the flow of information is flexible and dynamic. This is particularly useful in situations where sources and information change rapidly, such as in areas like commerce, product development and crisis management.

2. **Unifying and possibly processing suppliers' responses to queries to produce an appropriate result.**
   The content of user requests and supplier 'advertisements' may not align perfectly. So, satisfying a user's request may involve aggregating, joining or abstracting the information to produce an appropriate result. However, it should be noted that normally intermediary agents should not be processing queries, unless this is explicitly requested in a query. Processing could also take place when the result of a query consists of a large number of items. Sending all these items over the network to a user (agent), would lead to undesirable waste of bandwidth, as it is very unlikely that a user (agent) would want to receive that many items. The intermediary agent might then ask the user (agent) to make refinements or add some constraints to the initial query.

3. **Current Awareness, i.e. actively notificate users of information changes.**
   Users will be able to request (agents in) the middle layer to notificate them regularly, or maybe even instantly, when new information about certain topics has become available or when a supplier has sent an advertisement stating he offers information or services matching certain keywords or topics.
   There is quite some controversy about the question whether or not a supplier should be able to receive a similar service as well, i.e. that suppliers could request to be notified when users have stated queries, or have asked to receive notifications, which match information or services that are provided by this particular supplier. Although there may be users who find this convenient, as they can get in touch with suppliers who can offer the information they are looking for, there are many other users which would not be very pleased with this invasion on their privacy. Therefore, a lot of thought should be given to this dilemma and a lot of things will need to be settled, before such a service should be offered to suppliers as well.

4. **Bring users and suppliers together.**
   This activity is more or less an extension of the first function. It means that a user may ask an intermediary agent to recommend/name a supplier that is likely to satisfy some request without giving a specific query. The actual queries then take place directly between the supplier and the user.
   Or a user might ask an intermediary agent to forward a request to a capable supplier with the stipulation that subsequent replies are to be sent directly to the user himself.

These functions (with exception of the second one) bring us to an important issue: the question whether or not a user should be told where and from whom requested information has been retrieved.

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47 i.e. the list of offered services and information individual suppliers provide to the middle layer/middle layer agents.
48 Responses are joined when individual sources come up with the same item or answer. Of course, somewhere in the query results it should be indicated that some items (or answers) have been joined.
49 For instance, when information about second-hand cars is requested, by stating that only the ten cheapest cars or the ten cars best fitting the query, should be returned.
In case of, say, product information, a user would certainly want to know this. Whereas with, say, a request for bibliographical information, the user would probably not be very interested in the specific, individual sources that have been used to satisfy the query. Suppliers will probably like to have direct contact with users (that submit queries) and would like to by-pass the middle layer (i.e. intermediary agent). Unless a user specifically request to do so (as is the case with the fourth function), it would probably not be such a good idea to fulfil this supplier's wish. It would also undo one of the major advantages of the usage of the middle layer: eliminating the need to interface with every individual supplier yourself.

At this moment, many users use search engines to fulfil their information need. There are many search engines available, and quite a lot of them are tailored to finding specific kinds of information or services, or are aimed at a specific audience (e.g. at academic researchers). Suppliers use search engines as well. They can, for instance, "report" the information and/or services they offer to such an engine by sending the URL of it to the search engine. Or suppliers can start up a search engine (i.e. information service) of their own, which will probably draw quite some attention to their organisation (and its products, services, etcetera), and may also enable them to test certain software or hardware techniques.

Yet, although search engines are a useful tool at this moment, their current deficiencies will show that they are a mere precursor for true middle layer applications. In section 1.2.2, we saw a list of the general deficiencies of search engines (compared to software agents). But what are the specific advantages of usage of the middle layer over search engines, and how does the former take the latter's limitations away (completely or partially)?

- **Middle layer agents and applications will be capable of handling, and searching in, information in a domain dependent way.**
  Search engines treat information domain-independently (they do not store any meta-information about the context information has been taken from), whereas most supplier services, such as databases, offer (heavily) domain-dependent information. Advertisements that are sent to middle layer agents, as well as any other (meta-)information middle layer agents gather, will preserve the context of information (terms) and make it possible to use the appropriate context in such tasks as information searches (see next point).

- **Middle layer agents do not (like search engines) contain domain specific knowledge, but obtain this from other agents or services, and employ it in various sorts of ways.**
  Search engines do not contain domain specific knowledge, nor do they use it in their searches. Middle layer agents will not possess any domain specific knowledge either: they will delegate this task to specialised agents and services. If they receive a query containing a term that matches no advertisement (i.e. supplier description) in their knowledge base, but the query does mention which context this term should be interpreted in, they can farm out the request to a supplier that indicated he offers information on this more general concept (as it is likely to have information about the narrow term as well)\(^{50}\). If a query term does not match any advertisement, specialised services (e.g. a thesaurus service, offered by a library) can be employed to get related terms and/or possible contexts. Or the user agent could be contacted with a request to give (more) related terms and/or a term's context.

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\(^{50}\) This can be very handy in areas where a lot of very specific jargon is used, such as in medicine or computer science. A query (of either a user of intermediary agent) could then use common terms, such as "LAN" and "IBM", whereas the agent of a database about computer networks would automatically translate this to a term such as "Coaxial IBM Token-ring network with ring topology".
• **Middle layer agents and applications are better capable of dealing with the dynamic nature of the Internet, and the information and services that are offered on it.**

Search engines hardly ever update the (meta-)information that has been gathered about information and service suppliers and sources. The middle layer (and its agents), on the other hand, will be well capable of keeping information up-to-date. Suppliers can update their advertisements whenever and as often as they want. Intermediary agents can update their databases as well, for instance by removing entries that are no longer at their original location (it may be expected that future services will try to correct/update such entries, if possible). They may even send out special agents to find new suppliers/sources to add to the knowledge base. Furthermore, this information gathering process can be better co-ordinated (compared to the way search engines operate) in that a list is maintained of domains/sites/servers information has been gathered about (which avoids double work from being done).

• **Middle layer agents will be able to co-operate and co-ordinate efforts better than search engines do now.**

The individual search engines do not co-operate. As a result of this, a lot of time, bandwidth and energy is being wasted by search engines working in isolation. Middle layer agents will try to avoid doing so, by co-operating with other agents (in both the middle as well as the supplier layer) and by sharing knowledge and gathered information (such as advertisements). One possibility to achieve this could be the construction of a few "master" middle layer agents, which receive all the queries and advertisements from all over the world and act as a single interface towards both users and suppliers. The information in advertisements and user queries is distributed or farmed out to specialised middle layer agents. These "master" middle layer agents could also contact supporting agents/services (such as the earlier mentioned thesaurus service), and would only handle those requests and advertisements that no specialised agent has (yet) been constructed for. In fairness it should be remarked that expected market forces will make it hard to reach this goal. In section 4.4.2 we will come back to this.

• **Middle layer agents are able to offer current awareness services.**

Search engines do not offer such services as current awareness. Middle layer agents and applications will be able to inform users (and possibly suppliers) regularly about information changes regarding certain topics.

• **Middle layer agents are not impeded in their (gathering) activities by (suppliers’) security barriers.**

Many services do not give a search engine's gathering agents access to (certain parts of) their service, or do - in case of a total security barrier such as a firewall\(^5\) - not give them access at all. As a result of this, a lot of potentially useful information is not known to the search engine (i.e. no information about it is stored in its knowledge base), and thus the information will not appear in query results.

In the three layer model, suppliers can provide the middle layer with precise information about offered services and/or information. No gathering agent will need to enter their service at all, and thus no security problems will arise on this point.

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51 A firewall is a system or group of systems that enforces an access control policy between two networks. Generally, firewalls are configured to protect against unauthenticated interactive logins from the “outside” world. This, more than anything, helps prevent outsiders (i.e. "vandals") from logging into machines on a corporate/organisational network. More elaborate firewalls block traffic from the outside to the inside, but permit users on the inside to communicate freely with the outside.
4.3.2 An example of a future middle layer query
To give an idea of how the middle layer can contribute to (better) solve queries, we will have a look at a fictitious example.

Mister Jones wants to buy another car, as his old one has not been performing very well lately. The old car is a Ford, and as Mr. Jones has been very pleased with it, the new car will have to be a Ford as well. However, as he turns to his personal software agent for information, he (unintendedly) does not ask for information about "Fords" that are for sale, but about "cars". So the user agent sends out a query to an intermediary agent for information about cars which are for sale.

The intermediary agent checks its database for advertisements that mention information about "cars", "sale" and "for sale". It sends out requests to suppliers offering this information. The individual supplier's responses are unified into a single package, and maybe the entries are sorted according to some criteria. Then they are sent to the user agent.

The user agent receives the response ("answer") from the intermediary agent, and presents the information to mister Jones. The user agent soon discovers that he only looks at those entries that are about Fords, so it concludes that he is interested in "Fords", rather than in "cars" in general. As a result of this, it sends out a new query, specifically asking for information about "Fords".

The intermediary agent receives the query, and finds that it has no advertisements in its database yet, that mention Fords. The intermediary agent may now be able to resolve this query because the query of the user agents mentions that one of the attributes of a "Ford" is that it is a kind of automobile, or - if this is not the case - it could send out a query to a thesaurus service asking for more general terms that are related to the word "Ford" (and get terms such as "car" and "automobile" as a result of this query). The agent can then send a query to one or more suppliers which say they offer information about "cars" and/or "automobiles", specifying it wants specific information about Fords. Supplier agents that receive this query, and which indeed have information about Fords, will then send back the requested information. Furthermore, the supplier's agent can now decide to send a message (i.e. 'advertisement') to the intermediary agent, telling it that it offers information on Fords as well. The intermediary agent, again, unifies all responses into a single package, and sends it to the user agent, which will present it to the user.

This is just one way in which such a query might be handled. There are many alternative paths that could have been followed. For instance, the user agent might have stored in the user model of mister Jones that he owns a Ford, or that he has quite often searched for information about Fords. So in its first query it would not only have requested information about "cars", but about "Fords" that are for sale as well.

What this example shows us, is how agents and the middle layer/three layer model can conceivably contribute to make all kinds of tasks more efficient, quicker, etcetera.

4.4 Computer and human Intermediaries

52 This will happen only if this has been explicitly requested by the user agent, as normally this is a task for the user agent.
4.4.1 Introduction

"Electronic brokers will be required to permit even reasonably efficient levels and patterns of exchanges. Their ability to handle complex, albeit mechanical, transactions, to process millions of bits of information per second, and to act in a demonstrably even-handed fashion will be critical as this information market develops."

from [RESN95]

When necessary, human information searchers usually seek help from information intermediaries such as a librarian. More wealthy or more hasty information searchers, e.g. large companies and institutions (for which "time is money"), call in information brokers. Both types of information searchers realise it is much better to farm out this task to intermediaries as they possess the required (domain-specific) knowledge, are better equipped to do the task, or because it simply is not their core business. It is only logical to follow this same line of thought when information on the Internet is needed.

The availability of safe payment methods on the Internet (which make it possible to charge users of an information service for each piece of information they download) will be a big incentive to make use of electronic intermediaries (and agents in general too) as searching for information and/or services in an “unintelligent” way will then not only cost time, it will also cost money. Moreover, weighing the pros and cons of several information providers becomes a very complicated task if you have to take their prices into account as well: (intermediary) agents are (very soon) much better at doing this compared to their human user, especially as they can take the various user preferences into account as well when deciding which provider is most suitable, and they are better able to keep an overview of all the possible suppliers (and their prices).

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53 Human information intermediaries are persons or organisations that can effectively and efficiently meet information needs or demands. The difference between information intermediaries and information brokers, is that the former (usually) only asks for a reimbursement of any expenses that were made to fulfil a certain information need/demand (which may include a modest hourly fee for the person working on the task). Information brokers are more expensive (their hourly fees usually start at a few hundred guilders), but they will usually be able to deliver results in a much shorter span of time. They can also offer many additional services, such as delivering the requested information as a complete report (with a nice lay-out, additional graphs, etcetera), or current awareness services.
In [RESN95], five important limitations of privately negotiated transactions are given which intermediaries, whether human or electronic, can redress:\(^5\)

- **Search costs.**
  It may be expensive for suppliers and users to find each other. On the Internet, for example, thousands of products are exchanged among millions of people. Brokers can maintain databases of user preferences and supplier (i.e. provider) advertisements, and reduce search costs by selectively routing information from suppliers to users. Furthermore, suppliers may have trouble accurately gauging user demands for new products; many desirable items or services may never be offered (i.e. produced) simply because no one recognises the demand for them. Brokers with access to user preference data can predict demand.

- **Lack of privacy.**
  Either the “buyer” or “seller” may wish to remain anonymous, or at least to protect some information relevant to an exchange. Brokers can relay messages without revealing the identity of one or both parties. A broker can also make pricing and allocation decisions based on information provided by two or more parties, without revealing the information of any individual party.

- **Incomplete information.**
  The user may need more information than the supplier is able or willing to provide, such as information about product quality or customer satisfaction. A broker can gather product information from sources other than the product or service provider, including independent evaluators and other users.

- **Contracting risk.**
  A consumer (user) may refuse to pay after receiving a product, or a supplier may give inadequate post-purchase service. Brokers have a number of tools to reduce risk:
  1. The broker can disseminate information about the behaviour of providers and consumers. "The threat of publicising bad behaviour or removing some seal of approval may encourage both producers and consumers to meet the broker's standard for fair dealing";  
  2. If publicity is insufficient, the broker may accept responsibility for the behaviour of parties in transactions it arranges, and act as a policeman on his own;  
  3. The broker can provide insurance against bad behaviour. (The credit card industry already uses all three tools to reduce providers' and consumers' exposure to risk.)

- **Pricing Inefficiencies.**
  By jockeying to secure a desirable price for a product, providers and consumers may miss opportunities for mutually desirable exchanges. "This is particularly likely in negotiations over unique or custom products, such as houses, and markets for information products and other public goods, where free-riding is a problem. Brokers can use pricing mechanisms that induce just the appropriate exchanges."\(^5\)

The Internet offers new opportunities for such intermediary/brokering services. Both human as well as electronic brokers are especially valuable when the number of participants is enormous (as with the stock market) or when information products are exchanged.

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\(^5\) Two comments should be made by this list. The first is that they are about a special class of intermediaries: brokers. The second comment relates to this speciality: the given limitations are strongly focused on information and services that have to be paid for and/or that call for some form of negotiation, while in this thesis this aspect of information and services is left aside (i.e. "ignored") most of the time;

\(^5\) One intriguing class of mechanisms requires a broker because the budget balances only on average: the amount the producer receives in any single transaction may be more or less than the amount paid by the customer, and the broker pays or receives the difference.
Electronic brokers can offer two further opportunities over human ones. Firstly, many brokering services require information processing; electronic versions of these services can offer more sophisticated features at a lower cost than is possible with human labour. Secondly, for delicate negotiations, a computer mediator may be more predictable, and hence more trustworthy, than a human one.\textsuperscript{56}

### 4.4.2 Intermediary/Broker Issues

Intermediary agents (i.e. brokers) force us to address some important policy questions.\textsuperscript{57}

→ **How do we weigh privacy and censorship concerns against the provision of information in a manageable form?**

Whenever information products are brokered, privacy and censorship issues come to the fore. An electronic intermediary or agent can be of great help here, as it can more easily perform potentially troubling operations involving large amounts of data processing:

→ **Should intermediaries be allowed to ask a fee for their services?**

Should providers or intermediary services be permitted to charge fees, even if the information providers may not or do not? "Much of the information now exchanged on the Internet is provided free of charge and a spirit of altruism pervades the Internet community. At first glance, it seems unfair that an intermediary should make a profit by identifying information that is available for free, and some Internet user groups would likely agitate for policies to prevent for-profit brokering." But so long as the use of brokering services is voluntary, it helps some information seekers without hurting any others: anyone who does not wish to pay can still find the same information through other means, at no charge. Moreover: one pays for finding, not for the information itself. This is a well known problem also in the traditional/paper world.

→ **Should intermediary activities be organised as a monopoly (for the sake of effectiveness) or should competitive parties provide them?**

With intermediary, but especially with brokerage services, there is a tension between the advantages of competition and those of monopoly provision.

Firstly, a competitive market with many brokers will permit the easy introduction of innovations and the rapid spread of useful ones. Because of the rapid spread, however, the original innovator may gain little market advantage and so may have little reason to innovate in the first place. Patents or other methods of ensuring a period of exclusive use for innovations may be necessary.

Secondly, some services may be a natural monopoly (because of the nature of the services or information they deal with). Similarly, auction and other pricing services may be most effective if all buyers and sellers participate in the same market. One solution might be for all evaluations to be collected in one place, with brokers competing to sell different ways to aggregate them. More generally: some aspects of brokering may be best organised as monopolies; others should be competitive.

\textsuperscript{56} For example, suppose a mediator's role is to inform a buyer and a seller whether a deal should go through, without revealing either's reservation price to the other, since such a revelation would influence subsequent price negotiations. An independent auditor can verify that a software mediator will reveal only the information it is supposed to; a human mediator's fairness is less easily verified.

\textsuperscript{57} See [RESN95].
4.4.3 Human versus Electronic Intermediaries

Some think that computer (i.e. agent) intermediaries will replace human intermediaries. This is rather unlikely, as they have quite different qualities and abilities. It is far more likely that they will co-operate closely, and that there will be a shift in the tasks (i.e. queries) that both types handle. Computer agents (in the short and medium term) will handle standard tasks and all those tasks that a computer program (i.e. an agent) can do faster or better than a human can. Human intermediaries will handle the (very) complicated problems, and will divide these tasks into sub-tasks that can (but not necessarily have to) be handled by intermediary agents.

It may also be expected that many commercial parties (e.g. human information brokers, publishers, etcetera) will want to offer middle layer services. Although the most ideal situation would be one where the middle layer has one single contacting point for parties and agents from the other two layers, it is very unlikely that this will happen. However, this is not such a big problem as it looks, as it will also keep the levels of competition high (which very likely leads to better and more services being offered to both suppliers and users). Also, having more than one service provider in the middle layer does not mean that efforts will not be co-ordinated and that parties will not co-operate, as doing so not only enables them to offer better services, they will also be able to cut back on certain costs.

It lies outside the scope of this thesis to treat this subject in more detail. Further research is needed into this area, among others to make more reliable predictions about future developments with regard to these (“intermediary”) issues.

4.5 An example of a middle layer application: Matchmaking

In [KUOK92] Daniel Kuokka and Larry Harada describe an agent application whereby potential producers and consumers of information send messages describing their information capabilities and needs to an intermediary called a *matchmaker*. These descriptions are unified by the matchmaker to identify potential matches. Based on the matches, a variety of information brokering services are performed. Kuokka and Harada argue that matchmaking permits large numbers of dynamic consumers and providers, operating on rapidly-changing data, to share information more effectively than via traditional methods.

Unlike the traditional model of information pull, Matchmaking is based on a co-operative partnership between information providers and consumers, assisted by an intelligent facilitator (the matchmaker). Information providers and consumers update the matchmaker (or network of matchmakers) with their needs and capabilities. The matchmaker, in turn, notifies consumers or producers of promising "partners". Matchmaking is an automated process depending on machine-readable communication among the consumers, providers, and the matchmakers. Thus, communication must occur via rich, formal knowledge sharing languages\(^{58}\).

The main advantage of this approach is that the providers and consumers can continuously issue and retract information needs and capabilities, so information does not tend to become stale and the flow of information is flexible and dynamic. This is particularly critical in situations where sources and information change rapidly.

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There are two distinct levels of communication with a matchmaker: the message type (sometimes called the *speech act*) and the content. The former denotes the intent of the message (e.g., query or assertion) while the latter denotes the information being exchanged (e.g., what information is being queried or asserted).

There is a variety of message types. For example, information providers can take an active role in finding specific consumers by *advertising* their information capabilities to a matchmaker. Conversely, consumers send *requests* for desired information to the matchmaker. As variations on this general theme, the consumer might simply ask the matchmaker to recommend a provider that can likely satisfy the request. The actual queries then take place directly between the provider and consumer. The consumer might ask the matchmaker to forward the request to a capable provider with the stipulation that subsequent replies are to be sent directly to the consumer. Or, the consumer might ask the matchmaker to act as an intermediary, forwarding the request to the producer and forwarding the reply to the consumer.\(^59\)

Since the content of requests and advertisements may not align perfectly, satisfying a request might involve aggregating or abstracting the information to produce an appropriate result. For example, if a source advertises information about automobiles while a consumer requests information about Fords, some knowledge and inference is required to deduce that a Ford is an automobile. Such transformation of data is an important capability, but its addition to a matchmaker must be carefully weighed. If knowledge about automobiles were added to a matchmaker, similar knowledge could be added about every other possible topic. Obviously, this would quickly lead to an impractically large matchmaker. Therefore, a matchmaker as such does not strictly contain any domain knowledge. However, a matchmaker is free to use other mediators and data sources in determining partners. Thus, it could farm out the automobile/Ford example to an automobile knowledge base to determine if a match exists.

To evaluate and test the matchmaking approach, two prototype matchmakers have been built. The first matchmaker was designed and prototyped as part of the SHADE system\(^60\), a testbed for integrating heterogeneous tools in large-scale engineering projects. It operates over formal, logic-based representations, and is designed to support many different types of requests and advertisements.

A second matchmaker was created as an element of the COINS system (Common Interest Seeker). The emphasis of this matchmaker is on matching free text rather than formal representations.

Both matchmakers run as processes accepting and responding to advertisements and requests from other processes. Communication occurs via KQML, which defines specific message types (historically known as *performatives*) and semantics for advertising and requesting information. KQML message types include simple queries and assertions (e.g., *ask*, *stream*, and *tell*), routing and flow instructions (e.g., *forward* and *broadcast*), persistent queries (e.g., *subscribe* and *monitor*),

\(^59\) As pointed out previously, one of the benefits of matchmaking is that it allows providers to take a more active role in information retrieval. Thus, just as requests can be viewed as an effort to locate an information provider, an advertisement can be viewed as an effort to locate a consumer's interests. This raises serious privacy considerations (imagine a consumer asking for a list of automobile dealerships only to be bombarded by sales offers from all of the dealerships). Fortunately, the various modes of matchmaking can include exchanges that preserve either party's anonymity.

and information brokering requests (e.g., advertise, recommend, recruit, and broker), which allow information consumers to ask a facilitator (Matchmaker) to find relevant information producers.

These two types of matchmakers were developed separately due to the differences between their content languages (logic vs. free text), and the resulting radical impact on the matching algorithms. They could, in principle, be integrated, but just as a matchmaker uses other agents for domain-specific inference, it is preferable to keep them separated, rather than creating one huge matchmaker. If desired, a single multi-language matchmaker may be implemented via a simple dispatching agent that farms out requests to the appropriate matchmaker. This approach allows many matchmakers, each created by researchers with specific technical expertise, to be specialised for specific classes of languages.

Experiments with matchmakers have shown matchmaking to be most useful in two different ways:
1. Locating information sources or services that appear dynamically; and
2. Notification of information changes.

A third benefit, that of allowing producers of information to actively seek potential consumers, has only been partially demonstrated. Nevertheless, provided that user (but also producer) privacy can be guaranteed, this capability can attract the attention of many information providers. Yet, even though matchmaking has proven very useful in the above applications, several important shortcomings have been uncovered. Whereas queries can be expressed succinctly, expressing the content of a knowledge base (as in an advertisement) is a much harder problem. Current formal content languages are adequate for the simple examples shown above, but to go beyond advertising simple attributes quickly strains what can be represented. Additional research is required on ever more powerful content languages. The COINS matchmaker is, of course, not limited by representation. Here, the efficiency and efficacy of free-text matching becomes a limiting factor.

It should be noted that Matchmaking is a special type of middle layer application as it does not use any domain-specific knowledge. It also is not an agent application really: it farms out tasks/queries to specialised, or otherwise most suitable agents for that specific problem (i.e. query). Matchmakers could, however, play an important role as a sort of universal interface to the middle layer for both user as well as supplier agents or agent applications as they do not have to figure out which middle layer agents are best to be contacted.

4.6 Summary

The current two layer structure of the Internet (one layer for the demand side/users, and one layer for the supply side/suppliers) is getting more and more dissatisfactory. For tasks, such as an information search, tools like search engines have been created to circumvent many of the problems (and inefficiencies) that arise from this structure. However, search engines will only do as a short-term compromise. In the medium and long term, they will become increasingly insufficient and incapable to deal with future user and supplier needs and demands.

So, to "actively seek" does not mean that producers will be able to find out just exactly which users are looking for which information. In [KUOK92] it is explicitly stated that their matchmaker will never offer this "service" to producers. More than that, they will not even allow producers to find out what exactly other producers are offering (i.e. they are not allowed to view an entire description of what other producers are offering), nor are they able to find out which producers are also active as searchers of information (i.e. are both offering as well as asking certain information and/or services from the Matchmaker).
A very promising solution for the whole situation is to add a third, intermediary layer to the structure of the Internet. This will enhance and improve the functionality of the Internet in many ways. Per layer, agents can be employed that can offer just the functionality that each layer needs. The main task of the middle layer is to make sure that agents and persons from different layers can communicate and co-operate without any problems.

It is not clear at this moment how many parties will be offering these services, and who exactly those parties will be. It may be expected that there will be quite a lot of parties (such as publishers and commercial information brokers) that will want to offer these services. (Internet) Users will not think too deeply about these two questions: they will want a service that delivers the best and quickest results, against the lowest possible costs. The one that is best at matching these needs, will be the one they use.

The three layer model is a very powerful and versatile application for the agent-technique; although individual agents can offer many things, they can offer and do so much more when employed/combined in this way. However, before we can really use the model, quite some things will need to be settled, decided and developed: a number of standards, a solid (universal) agent communication language, etcetera.
PART TWO - Current & Expected Near-Future and Future Agent Developments, Possibilities and Challenges
5 Past and Current Agent Trends & Developments

5.1 Introduction
To be able to make predictions about the next step(s) in the development of agents and the agent technique, several factors have to be considered. In this chapter the past and present of agents is given a closer look. There are several parties and factors that are related to these, and they will be looked at in the next sections.
The first factor, which will be looked at rather briefly in section 5.2, is about links between developments in the area of computers (in general) and agent technology.
Secondly, we will have a closer look at the human factor in agent developments: agent users (section 5.3), the suppliers & developers of agents (section 5.4), and the government (section 5.5). In these sections it will be clarified why there is not such a thing as the user or the supplier, and what benefits governments can get from the agent technology.
Lastly (in section 5.6), past and current developments on and around the Internet will be subject to a more detailed scrutiny.
Each section will start with the state of affairs and general remarks with regard to that its subject and will then move on to indicate the links between this factor or party and the agent-technique.

Most of the information in this chapter, is of a rather general nature, and could just as well have been put in the next chapter. However, this would have resulted in one, huge chapter, which does not make it all very comprehensible or readable. Instead of that, it has been chosen to structure it the way it is now: divided over two chapters, where chapter five built a basis for, and raises questions about, issues that are discussed in chapter six.  

5.2 Computers and the agent-technique
The developments on and around the Internet are bearing a strong resemblance to the development of computers and their interfaces. In the very beginning, computers were hardly user-friendly, they were commandline-driven and had no form of on-line help whatsoever. Slowly this changed when the first help functions were added. One of the most important changes has been the introduction of the Graphical User Interface (GUI), which enabled a much more abstract view on the operation of a computer. The popularity of computers, particularly that of home computers or PCs, is largely due to the introduction and further developments of the GUI.

The Internet developments have followed this pattern in many ways. At first there were not many people using it, and most of them were highly educated users who were well capable of working on it without much support or nice interfaces. With the introduction of the Internet's own "graphical user interface" - the World Wide Web in combination with its graphical browsers - this changed drastically. From that moment, even novice users are able to use the various Internet services without having to know how each individual service should be used.

After the introduction of GUIs on computers followed a massive production of all kinds of applications and programs, most of which exploited GUI capabilities as much as possible. The same is bound to happen on the Internet too. The major difference between these applications and the applications that have been written for PCs and the like, is that the former will have to be more flexible and robust. To

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62 So "Agent Trends & Developments - General remarks" may have been a good name for this chapter as well.
put it more boldly: they will have to be more intelligent to be able to function properly in the dynamic and uncertain environment the Internet is known to be. Agents are meant to do precisely that.

At this moment, agents are offering this functionality in a very simple form. The chosen form is usually that of a forms-based interface, or that of a so-called wizard. These latter wizards, which are basically small background processes, may be considered as simple predecessors of real agents, as they are very straight-forward (they are usually driven by a set of if-then rules) and are neither very intelligent nor are they autonomous.

How this is all (expected or predicted) to change, will be described in chapter six.

5.3 The User
At this moment, most users of the agent technique are researchers and a small part of the WWW user population. But who will be the users of the future, and what will their needs and demands be? This is an important question, as user-acceptance of agents (leading to user-demand) is one of the key factors for agent success.

SRI International has conducted a psychographic research into the users of the World Wide Web. The effort of this research was to augment standard demographics (such as age, income and gender) with a psychographic analysis of the WWW users. They have used their own psychographic system (VALS 2) to explore the psychology of people's choices and behaviour on the WWW.

What makes the results of their research interesting, apart from the unusual (psychological) approach, is their finding that the Web has two very different audiences:

"The first is the group that drives most of the media coverage and stereotypes of Web users, the "upstream" audience. Comprising 50% of the current Web population, this well-documented group are the upscale, technically oriented academics and professionals that ride on a variety of institutional subsidies. Yet because this group comprises only 10% of the US population [...], their behaviours and characteristics are of limited usefulness in understanding the future Web.

The second Web audience comprises a diverse set of groups that SRI calls the Web's "other half." Accounting for the other 90% of US society, these groups are where Internet growth will increasingly need to take place if the medium is to go mainstream."

Although this research comprises US users only, it still indicates that it would be a bad policy to talk and predict about the needs, preferences and motivations of the WWW/Internet user, as there is a broad variety of (types of) users. It is therefore important to find out which of these groups will be the most dominant and most important ones. This could even mean that groups of users have to be accounted for in the future, that are not using the WWW and the Internet right now:

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63. This group is comprised of mostly experienced, academic users, who like to experiment with and try out early (test)versions of agents or agent-based applications.
64. See [SRI95].
65. but the findings and conclusions of their research can very well be extended to all Internet users.
"Many information-intensive consumers in the US population are in the other-half population rather than the upstream population. These particular other-half consumers report the highest degree of frustration with the Web of any population segment. Although they drive much of the consumer-information industry in other media, they as a group have yet to find the Web particularly valuable."

The "information have-nots" (a term coined by SRI) are not able to use the Internet and its services as result of a low income, but because of limited education. Tackling this problem requires an approach that is completely different from the one that is used at this moment to ensure that everybody can use the "information highway".

Agent technology can be brought into action here. Not that agents can solve the entire problem as described, but they can do their bit by making usage of the Internet (and computers as well) more user-friendly and easier. At this moment a lot of research is done in the area of so-called interface agents. These are agents whose main purpose is to provide an easy-to-use interface to complex systems such as the Internet, but also to computers in general. By means of such things as animated characters, computers and all kinds of other systems are given a more human appearance. This will make it easier for both novices and experts to operate them.

5.4 The Suppliers & the Developers

As much as there is not such a thing as the user, there also is not such a thing as the developer or the supplier. Until recently, developers of Internet applications and techniques were mostly (academic) researchers. With the emergence of the Internet as a commercial market, many other parties are starting to do research and develop techniques and applications for the Internet:

"The emergence of the Internet and the World Wide Web has created a heightened demand for intelligent software agency. From a functional perspective, utilisation of the Web is moving from a scattered browsing model to an efficient point-to-point information transfer medium. This trend has (and is) driving the intelligent agent development from academic research environments and proprietary corporate uses to mass commercial usage."

from "Intelligent Agents: a Technology and Business Applications analysis" by Mark Nissen

Moreover, many suppliers of information and/or services play a double role as they are (becoming) developers as well.

This has its effects on developments in the agent technique. Aspects that were of minor importance in the past, such as profitability of a technique and whether or not it meets a certain market or user demand (and how well this demand has been met), are becoming major issues now. Companies use the Internet and agent-based applications as a means to draw attention to other products they sell (e.g. like Sun Microsystems who use the JAVA technique to sell more Internet servers 66) or as a profitable extension of existing products (e.g. like IBM who are developing agents to extend their groupware and network software packages).

66 JAVA itself is not an agent-application. Yet, the Java Agent Template is available which "provides basic agent functionality packaged as a Java application. This agent can be executed as a stand alone application or as an applet via a WWW browser".
So, predicting tomorrow's developments depends strongly on who is leading developments today. A commercial 'leader' will want agents to have quite different characteristics compared to, say, academic researchers. An overview of these differing aims is given in the following table:

<table>
<thead>
<tr>
<th>Commercial developers' aims:</th>
<th>Non-commercial developers' aims:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The aim usually is to move on to the practical implementation as soon as the related theory has been sufficiently worked out (i.e. theoretical research should be sufficiently elaborated, but does not need to be exhaustive, at least not immediately);</td>
<td>Non-commercial developers will (most probably) first do extensive research into a complete (and well-defined) concept or application, before moving on to sub concepts and the practical implementation (if they move on to this stage at all);</td>
</tr>
<tr>
<td>2. Agents should be profitable - somehow - within a foreseeable period of time;</td>
<td>Agents may turn out to be profitable (or have potential to be so), but this is not an explicit aim;</td>
</tr>
<tr>
<td>3. User/market demand(s) plays a very important role in the development process. Because of this importance however, unforeseen applications or demands may be overlooked;</td>
<td>Theoretical soundness, robustness and completeness are most likely to be important factors in the development process. User/market demands usually do not come into play until the practical implementation stage is reached (and may not be always that well known). Research may also tend to stay in the theoretical stage too long;</td>
</tr>
<tr>
<td>4. Commercial developers will probably not be extremely interested in developing generally agreed upon, open standards (unless this standard is the one they have invented themselves).</td>
<td>The aim (although not always explicitly) is to come to general/open standards, or at least reach a consensus on vital issues, as this makes it easy to work together with other groups and share results (preventing duplicate work/research from being done).</td>
</tr>
</tbody>
</table>

Neither of these two "extremes" is very desirable: agents should not remain "an interesting research object" until eternity, but neither should research be aimed at merely scoring quick results.

A lot of attention should be paid to the demands of users (and other parties) in 'the real world'. However, care should be taken that not only the needs of the largest or the most profitable user groups are catered for, but also those of smaller groups and even of user communities that have yet to be discovered.

In [JANC95] developers find that the development and support costs of agents are about the same as with other forms of development. Most developers create applications for a single domain. Because they control the domain, they can manage the costs of development and support. In the report, developers predict an increase in cost once agents become mobile, irrespective of whether one single agent model (i.e. all agents use the same language, such as Telescript) or several models are used.

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67 i.e. they know exactly what domain they will be used in.
68 more about this will follow in section 6.2.
Furthermore, most vendors indicated that agent-empowerment will make a difference, but they are (still) struggling to help their user community (existing and prospective) understand what the agent-enabled applications could do. In some markets, such as network management, "agents" are a required item to sell (even though experience-to-date shows limited user adoption of the agent capabilities)."

5.5 The Government

It is currently impossible extract one single governmental policy or vision with regard to the Internet from all the individual policies: there are as many visions of the information future as there are sectors of the economy helping to create them.

What can be more or less concluded is that at this moment, governments\(^{69}\) and politicians are not interested in agent technology per se. However, most of them state in their future plans for the Internet (or National Information Infrastructure (NII)\(^{70}\) in case of the United States) that both individuals (or civilians) as well as companies and institutions should be able to make maximum use of it: users of the Internet should have free access to a broad variety of information (such as information from the government) and be able to choose from an equally broad variety of services. Services and information which every company or institution should be enabled to offer freely (with as little restrictions as possible).

But what use is all this information when users (i.e. civilians) are not able to find it, or are not able to access the Internet at all? How do users find out if (and which) services are being offered, and - if they find them - will they be able to use them (properly)?

To all appearances it seems that, although governments and politicians do not say it in so many words, agent technology - preferably combined with the three layer model as seen in chapter four - is a powerful and versatile tool that could be used to achieve this aim. Many application areas (and applications) are sketched in the various policy plans, each of them presupposing there to be a powerful, "intelligent" technology that makes it all possible: agent technology may very well be what they are looking for (but it is - for the time-being - unknown to them).

For instance, in [IITA93] it is stated that the development of applications for the "National Information Infrastructure" will be predicated on two other developments. The first is "creating the underlying scaleable computing technologies for advanced communication services over diverse bitways, effective partitioning of applications across elements of the infrastructure, and other applications support services that can adapt to the capabilities of the available infrastructure". The second one is much more interesting with regard to agents (and more clearly linked to it), and is almost identical to the aims and (future) possibilities of agent technology and the three layer model:

\(^{69}\) When, in this and the next chapter, something is being said about "the government" or "governments", the governments of the United States, various individual European countries and the European Union (as a whole) are meant. It were their policies that have been used for section 5.5 and 6.5.

For further and more detailed information, check the list of Information Policy Resources available at the http://www.nlc-bnc.ca/ifila/II/infopol.htm

\(^{70}\) Throughout this thesis the National Information Infrastructure (NII) will be treated as being equal to the Internet, or rather: equal to the American part of the Internet. However, in policy plans of the United States, the NII is much more than the Internet alone. For simplicity's sake we will ignore that difference.

See box 1.1 ("The NII: What is in a Name? A Range of Reactions") in The Unpredictable Certainty: Information Infrastructure Through 2000, which can be found in [NRC94].
"[...] creating and inserting an intelligent service layer that will significantly broaden the base of computer information providers, developers, and consumers while reducing the existing barriers to accessing, developing, and using advanced computer services and applications. In parallel with these activities, a more effective software development paradigm and technology base will be developed. This will be founded on the principles of composition rather than construction, solid architectures rather than ad hoc styles, and more direct user involvement in all stages of the software life cycle."

As we saw earlier, it is not low income that has kept, and is keeping, certain communities from using the "Information Superhighway", but a lack of (certain) education or skills. Agents could be used in an attempt to bridge this gap, and to prevent the government from only addressing the needs of a small part of the civilians of the information society:

"[...] Actualizers (highly educated persons who work in academic or technical fields) [...] are what all the excitement is about when "the consumer Internet" is invoked. The problem is that the fast-growing consumer Internet that most observers anticipate will saturate the Actualizer population relatively quickly, leaving the question of who drives continued growth."

from [SRI95]

Moreover, the fact that the government in most countries is both one of the biggest suppliers as well as one of the biggest consumers of information stresses the need even more for governments to address this problem. Currently, they are usually doing this rather passively by financing projects of large companies, hoping that they will come up with the techniques and applications to handle the situation. In the future, it may be better if governments started to play a more active role, just like the active role they are pursuing with regard to (general) Internet developments.

5.6 The Internet & the World Wide Web
Which important Internet developments can currently be observed?
1. **The number of people using the Internet is growing rapidly:** in the early years of Internet (the eighties and the very beginning of the nineties) most of its users were researchers and (American) public servants. These users were highly educated, were familiar with computers and/or networks, and knew how to use the various Internet services.
   However, most of the users that step onto the Internet today are computer novices, they do not necessarily have a very high level of education, and are only partially familiar with the possibilities and techniques of networks in general and the Internet and its services in particular;
2. **The number of parties offering services and information on the Internet has grown rapidly:** an increasing number of companies, but also other parties such as the government, are starting to offer services on the Internet (usually through the World Wide Web). The amounts of money that is invested in 'Internet presence' and the like have been increasing since 1993 (when businesses and media start to take notice of the Internet); to get an idea of just how rapid the number of hosts on the Internet is growing: in January 1996, compared to January 1995, the number of hosts had doubled to a staggering number of over 9 million Internet hosts. See appendix 3 and [ZAKK96] for further and more detailed information;

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71 A host is a service which offers information and/or Internet services such as an FTP archive or WWW-pages.
3. **The growth in the number of people using the Internet is outrunning the increase of available bandwidth**: although large investments are being made in faster connections (for instance by replacing coaxial or copper wires by optical fibre) and more powerful backbones, the demand for bandwidth is outrunning the supply by miles. User, especially those Internet users that have been working on the Internet since the early days, are complaining about the overcrowdedness of the Internet, which leads to moments where it is nearly impossible to connect to servers or where transferring data takes ages. Internet users will have to live with this 'inconvenience', as it seems most unlikely that the growth of bandwidth will catch up soon with user growth;

4. **Since 1995 the World Wide Web is the most popular Internet service**: up till 1995 e-mail used to be the most used service on the Internet. However, because it is user-friendly, easy to use, and looks "cool" and attractive, the World Wide Web has taken over first place (in [ZAKK96], the WWW is declared as one of the two technologies of 1995). Moreover, the WWW can serve as a sort of "umbrella" to put over other Internet services such as FTP or Gopher. Interfacing with a software archive through the WWW is much easier than using FTP itself: the user can usually do most (if not all) of the work with only a mouse and does not need to know the various commands to move around the archive and download (i.e. get) software from it. The same goes for most of the other Internet services.

5. **The emerging technologies of 1995 are mobile code (such as JAVA), Virtual environments (VRML) and collaborative tools**.

What influence do these developments have on agent technology and/or how are they linked to it? One of the most remarkable developments is the high popularity of the World Wide Web. This popularity seems to indicate the need of users for a single, user-friendly interface that hides most (or even all) of the different techniques (actually: services) that are needed to perform certain tasks on the Internet:

> "The Web appears to provide what PC owners have always wanted: the capability to point, click, and get what they want no matter where it is. Whereas earlier manifestations of the information revolution bypassed many people who were uncomfortable with computing"

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72 Backbones are large-capacity circuits at the heart of a network (in this case the Internet), carrying aggregated traffic over (relatively) long distances.

73 Sun's JAVA technology was the other one. JAVA is a programming language that makes it possible to make mobile code (applets) which can perform various tasks at the user's computer.

74 It should be noted that the user-friendliness is strongly dependent on the program that is used to navigate the Internet: the so-called browser. The functionality of the various browsers can vary considerably. However, most WWW-users (about 80% at the beginning of 1996) use the popular Netscape browser which offers all of the functionality as is described above.

75 "VRML" stands for Virtual Reality Modelling Language, a programming language that can be used to extend HTML documents. VRML makes it possible to create virtual three dimensional environments that the users can move around in. For instance, a service offering all sorts of corporate information, can then be presented by
technology, it appears that the Web is now attracting a large cross section of people, making the universality of information infrastructure a more realistic prospect. If the Web is a first wave (or a second, if the Internet alone is a first), it is likely that further advances in utility and application will follow."

from [NRC94]

Developers of browser software are jumping onto this trend by creating increasingly versatile software packages. For instance, the newest version of Netscape - the most popular browser at this moment - can be used as an WWW browser, but also as a newsreader (for using Usenet) and a mail program (to send and receive e-mail). In fact, the booming popularity of the WWW is largely due to the versatile browsers that have been written for it. Agents can offer this functionality as well. Better still: they can do it better with improvements such as greater software and hardware independence, extended functionality and flexibility. And they can easily be combined with open standards (such as the three layer model).
The World Wide Web may very well be considered as the first step or stepping-stone towards using more sophisticated technologies (e.g. intelligent software agents) and developing open standards for the Internet.

A growing problem on the Internet at this moment, is the availability of bandwidth. A salient detail in this matter is the fact that currently agents are partly the cause of this. A specific class of agents - information gathering agents, called worms and spiders, which are used to gather information about the contents of the Internet for use in search engines - are consuming quite a lot of bandwidth with their activities. The major reason for this is the fact that for every individual search engine a whole bunch of such agents is gathering information. The gathered information is not shared with other search engines, which wastes considerable amounts of bandwidth.  

However, as agent technology evolves this will change. Agents can then be brought into action to help reduce the waste of bandwidth. This reduction is achieved by such things as:

• **Executing tasks, such as searches, locally (on the remote service) as much as possible.**
  The agent only sends the **result** of a search over the Internet to its user;

• **Using results and experiences of earlier performed tasks to make future executions of the same task more efficient, or even unnecessary.**
  Serious attempts are being made where agents share gained experience and useful information with others. Many user queries can then be fulfilled without the need to consult (i.e. use) remote services such as search engines;

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means of a virtual copy of the/an office building. A user will start in the lobby (where general information is provided) and can then go to other "rooms", i.e. other pieces of information.

76 See section 1.2.2 and 4.3.1.

77 Agents will help reduce the **waste** of bandwidth: they will not decrease the need for bandwidth.
• Using the "intelligence" of agents to perform tasks outside peak-hours, and to spread the load on the Internet more evenly.
  Furthermore, agents are better at pinpointing on which hours of the day there is (too) much activity on the Internet, especially since this varies between the days of the week as well.

More on this subject will follow in the next chapter.

5.7 Summary
This chapter has made general remarks to issues, parties and factors that are involved in the development of agents and agent-enabled applications. This has been done by looking at events from the (recent) past & present, which give us an insight into what has already been accomplished. Using the information from chapter five, we can now move on to chapter six to see what all is (most likely) going to be accomplished in the future and near-future.
6 Future and Near-Future Agent Trends & Developments

6.1 Introduction

"[...] it often is impossible to identify the effects of a technology. Consider the now ubiquitous computer. In the mid-1940s, when digital computers were first built, leading pioneers presumed that the entire country might need only a dozen or so. In the mid-1970s, few expected that within a decade the PC would become the most essential occupational tool in the world. Even fewer people realised that the PC was not a stand-alone technology, but the hub of a complex technological system that contained elements as diverse as on-line publishing, e-mail, computer games and electronic gambling." 

from "Cyber-Seers: Through A Glass, Darkly" by G. Pascal Zachary

In this chapter we will take a cautious look into the future of agents and the agent-technique. To do so, in each section one important aspect related to, or one party involved in it, will be looked at more closely. First general remarks will be made about it. Next, where possible, a rough chronology of expected and announced events and developments is sketched to give an idea of what may be expected with respect to this party. The given chronologies are divided into three periods:

- "short term", relating to the period one to two years from now (i.e. from now up to and including 1997);
- "medium term", relating to the period three to five years from now (i.e. from 1998 until the year 2000);
- "long term", relating to the period from six years from now and beyond (i.e. the period beyond the year 2000).

This partition is rather arbitrary, but it is the most practical and workable compromise.

Another thing that may look rather arbitrary is the list of parties that have been selected for a further examination. It - indeed - could have been much longer, but we have chosen to look only at those parties and techniques of which it is (almost) certain that they will be involved in, or have influence on, future agent developments.

The depth of the examination may also appear rather superficial. However, it seemed more sensible to "just" describe those factors and issues that will influence developments (and to clarify and illustrate them wherever possible), than to make bold predictions (implicating that the future is straightforward and easy to predict) which are very hard to found with facts;

"Depending on the addressed area, carrying out [such an] analysis may be more or less easy: policy and regulatory trends for instance are quite easy to identify and understand. Business strategy too can be more or less easily deciphered. Yet this may already be a lot more complex since there is often a part of guessing or gambling behind corporate moves. Consumers' interest can also be guessed, for instance in the light of the skyrocketing popularity of the Internet or the multiplication of commercial on-line PC services.

78 Note that whenever in this chapter things are being said about "agents", the words "agent-based applications" should be thought off as well wherever possible and applicable.

79 It is probably needless to say that all of the expectations in the chronologies, are rather good guesses than hard facts.
The most difficult part of the exercise may in fact be to gauge the economic, social and cultural impact of new applications [such as agents]. Indeed, their visibility is still limited, making it all the more difficult to assess their penetration in the social fabric and in public interest areas."

from "An Overview of 1995's Main Trends and Key Events"
in Information Society Trends, special issue

Yet another compromise is the distribution of information over the various sections and the remarks that are made about it: there is quite some overlap in both of these. The reason for this is twofold. Firstly, there is quite a lot of information and remarks that fit into more than one section. The section it has been put in now is the one that it is thought to fit in best, or the one where it was the most practical to put it in. Secondly, some of the mentioned parties (such as suppliers) can play more than one role and are linked to other parties. These links and roles are given in the various sections, but information about the involved parties is given only once.

6.2 The Agent-technique

This section is about expected or announced developments in the agent technique itself in the forthcoming years.

6.2.1 General remarks

Agents will have a great impact, as was seen in the previous chapter. Some, mostly researchers, say they will appear in everyday products as an evolutionary process. Others, such as large companies, are convinced it will be a revolutionary process. The latter does not seem very likely as many parties are not (yet) familiar with agents, especially the future users of them. The most probable evolution will be that agents, initially, leverage simpler technologies available in most applications (e.g. word processors, spreadsheets or knowledge-based systems). After this stage, agents will gradually evolve into more complicated applications.

Developments that may be expected, and technical matters that will need to be given a lot of thought, are:

⇒ The chosen agent architecture / standards:
This is a very important issue. On a few important points consensus already seems to have been reached: ACL (Agent Communication Language) is adopted and used by many parties as their agent communication language. ACL uses KIF (Knowledge Interchange Format) and KQML to communicate knowledge and queries to others. KIF and KQML are also used by many parties, for instance by the Matchmaker project we saw in chapter four, and is currently being further extended. In general, standards are slow to emerge, but examples such as HTML have shown that a major standard can emerge in two to three years when it is good enough and meets the needs of large numbers of people.

Another, related and equally important issue, is the agent architecture that will be pursued and will become the standard. No consensus has been reached about this yet. There are two possible architectures that can be pursued, each of which has strong influences on such aspects as required investments and agent system complexity. 80:

80 But also on such aspects as marketing, development and investments. See, for instance, [JANC95].
Future and Near-Future Agent Trends & Developments

- **Homogeneous Architecture:**
  here there is a single, all-encompassing system which handles all transactions\textsuperscript{81} and functions\textsuperscript{82}. Most of the current agent-enabled applications use this model, because the application can, itself, provide the entire agent system needed to make a complete, comprehensive system;\textsuperscript{83}

- **Heterogeneous Architecture:**
  here there is a community within which agents interact with other agents. This community model assumes agents can have different users, skills, and costs.

There are various factors that influence which path the developments will follow, i.e. which of these two types of architectures will become predominant:\textsuperscript{84}

1. **The producer of the agent technique** (i.e. used agent language) **that has been chosen to be used in a homogeneous model:** this producer will have to be willing to give out its source code so others are able to write applications and use it as the basis for further research.
   If this producer is not willing to do so, other parties (such as universities) will experiment with and start to develop other languages. If the producer \textit{does} share the source code with others, researchers, but also competitors, will be able to further elaborate the technique and develop applications of their own with it. It is for this last consequence, that most producers in this situation, at least all the commercial ones, will chose to keep the source code to themselves, as they would not want to destroy this very profitable monopoly.
   In the end, this 'protectionism' of this producer, combined with findings of (university) research and market competition, will result in multiple alternative techniques being developed (i.e. lead to a heterogeneous architecture);

2. **Interoperability requirements,** i.e. the growing need to co-operate/interact with other parties in activities such as information searches (because doing it all by yourself will soon lead to unworkable situations). Here, a homogeneous architecture would clearly make things much easier compared to a heterogeneous architecture as one then does not need to worry about which agent language or system others may be using.
   However, multi-agent systems - especially those involved in information access, selection, and processing - will depend upon access to existing facilities (so-called \textit{legacy} systems). Application developers will be disinclined to rewrite these just to meet some standard. A form of translation will have to be developed to allow these applications to participate. In the final analysis it is clear that this can only be done when using a heterogeneous agent model.\textsuperscript{85}
   Furthermore, agent systems will be developed in many places, at different times, with differing needs or constraints. It is highly unlikely that a single design will work for all;

3. Ultimately, the most important factor will be \textit{"user demand created by user perceived or real value"}. People will use applications that they like for some reason(s). The architecture that is used by (or best supports) these applications will become the prevailing architecture, and will set the standard for future developments and applications.

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\textsuperscript{81} i.e. correspondence between one or more agents (or users).
\textsuperscript{82} i.e. tasks that are performed by an agent.
\textsuperscript{83} General Magic’s \textit{Telescript} expands this premise into multi-agent systems. As long as all agents in the system use Telescript conventions, they are part of a single, all-encompassing system. Such a system can support multiple users, each (in theory) using a different application.
\textsuperscript{84} See chapter five of [JANC95].
\textsuperscript{85} Either that, or by means of a very complicated and extensive homogeneous architecture (as it has to be able to accommodate every possible legacy system).
Although a homogeneous architecture has its advantages, it is very unlikely that all the problems that are linked to it can be solved. So, although the agent architecture of the future may be expected to be a heterogeneous one, this will not be because of its merits, but rather because of the demerits of a homogeneous one.

⇒ **Legal and ethical issues (related to the technical aspects of agents):**
   This relates to such issues as:
   ◇ **Authentication**: how can be ensured that an agent is who it says it is, and that it is representing who it claims to be representing?
   ◇ **Secrecy**: how can be ensured that an agent maintain a user's privacy? How do you ensure that third parties cannot read some user's agent and execute it for their own gains?
   ◇ **Privacy**: how can be ensured that agents maintain a user's much needed privacy when acting on his behalf?
   ◇ **Responsibility which goes with relinquished authority**: when a user relinquishes some of his responsibility to one or more software agents (as he would implicitly), he should be (explicitly) aware of the authority that is being transferred to it/them;
   ◇ **Ethical issues, such as tidiness** (an agent should leave the world as it found it), **thrift** (an agent should limit its consumption of scarce resources) and **vigilance** (an agent should not allow client actions with unanticipated results).

⇒ **Enabling, facilitating and managing agent collaboration/multi-agent systems:**
   A lot of research has to be done into the various aspects of collaborating agents, such as:
   ◆ **Interoperability/communication/brokering services**: how can brokering/directory type services for locating engines and/or specific services, such as we have seen them in chapter four, be provided?
   ◆ **Inter-Agent co-ordination**: this is a major issue in the design of these systems. Co-ordination is essential to enabling groups of agents to solve problems effectively. Co-ordination is also required due to the constraints of resource boundedness and time;
   ◆ **Stability, scalability and performance issues**: these issues have yet to be acknowledged, yet alone tackled in collaborative agent systems. Although these issues are non-functional, they are crucial nonetheless;
   ◆ **Evaluation of collaborative agent systems**: this problem is still outstanding. Methods and tests need to be developed to verify and validate the systems, so it can be ensured that they meet their functional specifications, and to check if such things as unanticipated events are handled properly.
Issues related to the User Interface:
Major (research) issues here are:\n◊ Determining which learning techniques are preferable for what domains and why.
  This can be achieved by carrying out many experiments using various machine learning
  techniques over several domains;
◊ Extending the range of applications of interface agents into other innovative areas
  (such as entertainment);
◊ Demonstrating that the knowledge learned with interface agents can be truly used
  to reduce users’ workload, and that users, indeed, want them;
◊ Extending interface agents to be able to negotiate with other peer agents.

Miscellaneous technical issues:
There are many other technical issues which will need to be resolved, such as:
♦ Legacy systems: techniques and methodologies need to be established for integrating
  agents and legacy systems;
♦ Cash handling: how will the agent pay for services? How can a user ensure that it does
  not run amok and run up an outrageous bill on the user’s behalf?
♦ Improving/extending Agent intelligence: the intelligence of agents will continuously
  need to be improved/extended in all sorts of ways;
♦ Improving and extending agent learning techniques: can agent learning lead to
  instability of its system? How can be ensured that an agent does not spend (too) much of its
  time learning, instead of participating in its set-up?
♦ Performance issues: what will be the effect of having hundreds, thousands or millions of
  agents on a network such as the Internet (or a large WAN)?

6.2.2 Chronological overview of expected/predicted developments

6.2.2.1 The short term: basic agent-based applications
In the short term, basic agent-based software may be expected to emerge from research, e.g. basic
interface agents such as mail filtering or calendar scheduling agents. Basic mobile agent services will
also be provided now.

A "threat" in especially this period is that many software producers will claim that their products are
agents or agent-based, whereas in reality they are not. In fact, the first manifestations of this are
already becoming visible:

"[...] we are already hearing of ‘compression agents’ and ‘system agents’ when ‘disk
compressors’ and ‘operating systems’ would do respectively, and have done in the past."

quote taken from [NWAN96]

On the other hand, mainly from the domain of academic research, an opposite trend is starting to
become visible as well, namely that of a further diversification and elaboration of (sub-)agent
concepts. The origins of this lie in the constant expansion of the agent concept: it already is starting to
get too broad to be used in any meaningful way. Therefore logical and workable sub-classes of

\[86\] See (also) section 5.2 of [NWAN96].
agents, such as information agents and interface agents, are being stipulated and defined by researchers.

Available (i.e. offered by a significant number of producers/vendors) agent-applications will allow users to specify a query/request by means of written sentences (which may not be ambiguous). Agents will then search for information with the aid of indices available at the source(s) (irrespective of application developing the index). Searches can be based on keywords, but concepts may be conveniently used as well. The first mobile agents will too become available now.

Agents that are really used (by a significant number of users) are the well-known wizards. Wizards can be used to guide a user through some procedure (which may be creating a table in a word processor, but they can also be used to launch or set-up agents), and can pop-up when needed to give a user some advice or hints. Also used in this period are agents that can be used for information retrieval (where the user is helped by one or more agents, which communicate with the user by means of a personalised user interface).

In this period, setting up agent-based applications is that difficult, that only skilled users (such as researchers or software developers) are able to do this. It may be expected that a special branch of companies or organisations will emerge in this period which consist of professionals that set-up agents for others. As time goes by, and agents get more user-friendly to install (or agents will even be able to install their software themselves), the need for this profession should disappear again: toward 1998 it is expected that agent-based applications become available that can be set-up by end users themselves.

6.2.2.2 The medium term: further elaboration and enhancements
In this period more elaborated agent applications are available and used, as more mobile and information agent applications and languages will become available. It is also by this time that the outlines of the most important agent-related standards should become clear. The different agent sub-types of the short term, will now start to mature, and will be the subject of specialised research and conferences.

The first multi-agent systems, which may be using both mobile and non-mobile agents, and most probably are using a heterogeneous architecture, will be entering the market somewhere around 1998 or 1999. Significant usage of these systems may be expected at the turn of the century. It is also at this time that agents that are able to interact with other agents managed by other applications, are becoming available. Because of their increased usage, agents will probably by this time generate more traffic on the Internet than people do.

Around 1998-1999, agent applications can and will be set-up by significant numbers of end-users themselves. Expectations are that a few years later, agents that are able to do this themselves (i.e., a user agent "sees" a need, and "proposes" a solution to its user in the form of a new agent) will become available.
Agent-empowered software that is as effective as a research librarian for content search will be available in 1998\textsuperscript{87}, and may be expected to be used by a significant number of users near the year 2000.

Agents that can understand a non-ambiguous, written request will be used in 1998 as well, just like indices that are based on a concept search (such as Oracle's Context). It will probably not be until the year 2000, before the first agent applications are available that can understand any written request, made using normal natural language (interaction with the user is used to resolve ambiguities in these requests).

**6.2.2.3 The long term: agents grow to maturity**

Beyond the year 2000, it is very hard to predict well what might happen:

> "We may expect to see agents which approximate true 'smartness' in that they can collaborate and learn, in addition to being autonomous in their settings. They [...] possess rich negotiation skills and some may demonstrate what may be referred to, arguably, as 'emotions'. [...] It is also at this stage society would need to begin to confront some of the legal and ethical issues which are bound to follow the large scale fielding of agent technology."

from [NWAN96]

End users may be expected to really start using anthropomorphic user interfaces. Agents will more and more be interacting with agents of other applications, will more or less set themselves up without the help of their user, and will get more powerful and more intelligent.

Users can state requests in normal language, where agents will resolve such problems as ambiguity by making use of user preferences and the user model (the expected date for such agent functionality to be available will at the earliest be in 2005).

**6.3 The User**

**6.3.1 General remarks**

> "Agent-enablement will become a significant programming paradigm, ranking greater in importance than client/server or object orientation. The big difference will lie in increased user focus. Successful implementors will view their products in the context of personal aids, such as assistant, guide, wizard."

from [JANC95]

Users are one of the most - if not the most - influential party involved in the developments around agents. However, it may be expected that most users will adopt a rather passive attitude with regard to agents: research and past experiences with other technologies have learned us that substantial user demand of new technologies is always lagging a few years behind the availability of it.

\textsuperscript{87} Already, the first user-operated search engines which support conceptual searches are becoming available. The *Infoseek Guide* as offered by Infoseek Corporation (http://www.infoseek.com) is an example of such a search engine.
So users may be called "passive" in a sense that they will only gradually start to use applications that employ the agent-technique. Moreover, they will not do this because of the fact that these applications use the agent technique, but simply because they find these application more efficient, convenient, faster, more user-friendly, etcetera. They may even find them "smarter", even though they have never heard of such things as intelligent software agents.

Not until applications using agents are sweeping the market and users are more familiar with the concept of agents, will the role of users become more active in the sense that they knowingly favour agent-enabled applications over applications that do not use the agent-technique.

### 6.3.1.1 Ease of Use

"Software is too hard to use for the majority of people. Until computers become a more natural medium for people... something they can interact with in a more social way, the vast majority of features and technologies will be inaccessible and not widely used. [Our industry] has historically proven more finesse at delivering difficult and challenging technologies, than it has providing these in an approachable way."

-- a Delphi Process respondent in [JANC95]

In general, "ease of use" (or the lack of it) will be one of the most important issue in the agent-user area. If users do not feel comfortable working with agents, if they find them insecure or unreliable, or if they have to deal with hardware or software problems, agents will never be able to enter the mainstream.

The issue of ease of use can be split up into a number of important sub issues:

**The User Interface (broadly speaking)**

The interface between the user and agents (i.e. agent applications) is a very important factor for success. Future agent user interfaces will have to bridge two gaps: the first is the gap between the user and the computer (in general) and the second is the gap between the computer user and agents:

"*the end user first must feel comfortable with computers in general before attempting to get value from an agent-enabled application.*"

-- a remark made by a respondent in [JANC95]

Special interface agents will have to be used to ensure that computer novices, or even users who have never worked with a computer at all, will be able to operate it and feel comfortable doing so:

"*People don’t understand what a computer is, and you ask them to work with a state of the art tool. First we must make them feel comfortable with computers.*"

-- a remark made by a respondent in [JANC95]

A good agent/computer user interface will have to look friendly to the novice user. There are strong debates over the question whether or not anthropomorphic interfaces (i.e. interfaces who use techniques such as animated characters) are a good way of achieving this goal. Some say people like to treat computers as if they were humans, so providing an interface which gives a computer a more human appearance would fit perfectly to this attitude. Others think users may get fed up by anthropomorphic interfaces (e.g. find them too round-about, or too childish), or they may be disappointed by the level of intelligence (i.e. by the perceived limitations) of such interfaces.
Therefore, user interfaces will not only have to look good (e.g. more "human"), but they will also need to be "intelligent". Intelligence in this context relates to such abilities as being able to understand commands given in normal (i.e. natural) language (preferably with the additional ability to understand ambiguous sentences) or the ability to take the context into consideration in which commands are given and by whom this is done.

### Security / Reliability

"Users must be comfortable trusting their intelligent agents. It is essential that people feel in control of their lives and surroundings. They must be comfortable with the actions performed for them by autonomous agents, in part through a feeling of understanding, and in part through confidence in the systems. Furthermore, people expect their safety and security to be guaranteed by intelligent agents."

from "Intelligent Agents: a Technology and Business Applications analysis"

The security and reliability (i.e. predictability) will be an important issue for many users. The rise of multi-agent systems complicates things even further, as it becomes very hard to keep a good overview on a situation where several layers of agents and all types of agents are involved: how can one be sure that nothing is lost, changed or treated wrong, in a system where multiple kinds of agents need to work together to fulfil a request?

One possibility to offer a secure agent system is to use one common language, such as Telescript. But as has been pointed out in section 6.2.1, it is very unlikely that all agents will use the same language.

Another complicating factor is the fact that agents are programmed a-synchronously; agents are built at different moments in time, so each agent will have its own agenda and skills, which may not be easily compatible with (those of) other agents.

In [JANC95] respondents were asked when agents will be relied on for complete personal information security (by users). The given answers (i.e. opinions) varied strongly. Some thought that complete security could never be accomplished. New and better security techniques will be invented, but so are new "other" techniques which give rise to new security problems.

Others thought it would be possible within ten to twenty-five years. Additional remarks made by these respondents were the expectation that it will take quite some time before people really have trust in agents. But, on the other hand people (i.e. users) will have to trust agent security as "more and more information is imposed on us, we will not be able to manage all this by ourselves. We need to define templates and rules for different events, etc., and therefore pass the responsibility at least partially to an agent."

To one of the respondents agent security was sort of a non-issue, as he found that it is something an agent should not be concerned with in the same way an agent should not be concerned about the

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88 i.e. what one person means to say may be different from what another person means to say, even though they both use identical words. Furthermore, a person may wish a different outcome over time, even though the same expression is used.

A related challenge is in setting appropriate thresholds to trigger intervention: novice users will be glad when an agent helps him without an explicit call for help, whereas a power user will soon get very annoyed when he is constantly being "helped" (i.e. interrupted) by agent(s). (See [JANC95] for more detailed information.)

89 See Appendix III of this report, page A3-33.
operating system a user is using: 'If the question is "When will agents make my personal data secure?" my answer would be never - the technology would be misapplied, since secure communications technology covers this issue fairly completely now, and is constantly being improved with public encryption, authentication services.'

Hardware Issues
The current PC operating system environment, as used by many users, makes it difficult-to-impossible to capture the type of information needed to measure a user's actions. Without these signals, user interface agents cannot determine when to intervene. A related problem is the non-standard environment. Every PC can be just a little bit different, making standard interface development a challenge.

6.3.1.2 Available applications
"Ease of use" is tightly coupled to another factor in user accepation and adoption of agents: the availability of agent applications that the user finds useful, convenient, etcetera. User adoption of agents will not be driven by the agent technique's (cap)abilities, but by agent applications:

"The catalyst will be a few good agent applications controlling data that is important to users. The bar needs to be set and then customers will demand agents."

respondent reaction, taken from [JANC95]

Generally seen, the following major user agent applications (related to user information needs) can be distinguished, each of which have been realised already, or can be realised within a few years\(^90\):

- **Personal assistants**: here the agent system treats each user as an individual. As the system gets more and more experience, it will look more and more like a personal assistant.
  Examples of such personal assistants are *Open Sesame!* and Microsoft's *Bob*;

- **Information management**: this relates to search engine improvements. One improvement would be the ability to go beyond the regular search environment. Another improvement would have an agent pre-determine which data sources it would check. A further improvement is the ability to do searches based on context rather than a search based on keywords, and to select data sources based on this context. An example of such an agent is Oracle's *ConText* which is a natural language processing technology capable of compressing and summarising documents. The way data is compressed may depend on personal taste: the type of data, day of the week, etc. Intelligence may be required to determine how to present such data;

- **Personal newspaper**: a daily personal newspaper is presented to a user. This newspaper includes headlines and summaries of articles for maximum ease of use. The application will scan which information the user reads first, and adjust future presentations to match this reading pattern.
  Examples of personal newspapers that are currently being offered are those of *The Wall Street Journal*, *The Times* and IBM's *InfoSage*;

- **Personal research assistant**: here there is an agent (the assistant) which has knowledge of a user's preferences, as well as his or her standing requests for information on certain topics. It periodically scans appropriate databases, and delivers summaries on a scheduled or on-request basis. Eventually, the assistant will both understand - and communicate using - natural language.

\(^90\) See [JANC95].
6.3.2 Chronological overview of expected/predicted developments

6.3.2.1 The short term: first agent encounters
By the end of this year, expectations\(^91\) are that end users have somehow heard of, and therefore recognise, the term “agent(s)”, even though they may not be able to give a (very rough) definition or description of it.

One year later, in 1997, it is expected that about a quarter of the then current PC/workstation user base consider "agents" to be personally helpful (although they may be referring to simple wizard-like agent-applications) and will say they (themselves) are using, or have once used, a product or service incorporating agents.

Agent-applications that are available are user-invoked interfaces that enable a dialogue with an agent, and agents that can produce reports that are generated by the agent itself at regular intervals or whenever necessary.

Agent-applications that are really used are those that can act as a personal assistant: they can effectively sort incoming mail and filter (electronically available) news articles that match a user's areas of interest.

6.3.2.2 The medium term: increased user confidence and agent usage
Useful, but still rather limited, interface agents will be available which perform such roles as that of an eager assistant, a WWW guide, memory aid, WWW filter/critic, and which can deliver entertainment.

User communication will be by such means as anthropomorphic agent user interfaces (which are expected to become available somewhere around 1998-1999), as

> "people love having a social entity to help them with a task. People are willing to pay a premium today for something as simple as the social entities in Bob. People use computers to do many of the things above, and will feel much, much more comfortable with a social entity or character."

quote taken from [JANC95]

One out of every four users, by this time, will be so confident about agents, that he trusts his agent to navigate the network (Internet) to find candidate products for some purchase. In [JANC95] it is predicted by Delphi Process respondents that by the year 2000, these users may even trust their agent to make a purchase (although this probably won't go for such purchases as a new car or a new home). However, some of the respondents in this report were sure that users will never let an agent buy goods for them at all.

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\(^91\) Which can be found in [JANC95].
In the same report, it is predicted/expected that by the year 1999-2000, about 10% of the then current
PC/workstation users will consider the following agent aspects to be "solved problems":
- Ease of use;
- Security;
- Privacy;
- Training and support;
- Continuity (i.e. an initiator knows his agent traversed the network, and can rely on the reports of
results).

About one year later, agent overload (i.e. an agent handles overload by modifying requests and/or
ignoring some), will be added to this list.

By the same time, agents that can produce reports that are generated by the agent itself at regular
intervals, or whenever needed\(^{92}\), are really used. Also used a lot then (i.e. somewhere around the year
2000) is agent-empowered software that is as effective as a newspaper, in the ability to headline/set
document length based on the expected article importance for the user.

6.3.2.3 The long term: further agent confidence and task delegation?
How developments will continue in this period is rather uncertain, and because of that is hard to
predict precisely.

What may be expected is a further increase of user's confidence in agents. In [JANC95], for
instance, it is predicted that over ten years, a quarter of the then current PC/workstation user base
will allow an/its agent to anticipate its needs/desires, find candidate products, and to make the
purchase.

Agent-applications that will start to be used by large numbers of users, are anthropomorphic user
interfaces (this is predicted to happen somewhere near the year 2001).

6.4 The Suppliers & the Developers
This section is about suppliers and developers of agents and agent-based applications. However, in
many places in this section, both these parties can be interpreted in a (much) broader sense: i.e.,
"suppliers" can also relate to suppliers of (information) services on the Internet using agents in some
way for their service\(^ {93}\), and "developers" can also be related to researchers investigating the agent
technique and related areas (such as that of Artificial Intelligence).

Two very important questions with regard to suppliers are who is going to offer agents and why/with
what reasons they are doing this. For developers/researchers a very important question is what
(functionality) agents will be offering. However, things will get very complicated in the future as both
suppliers and developers can play the other's role as well; e.g. a supplier of agent software can do
research into agents as well, which it can then use in all sorts of agent applications. And: suppliers and
developers can be users of agents too!

It is probably not surprising that this makes it (very) difficult to predict how in the future these
separate roles and aims might be intertwined.

\(^{92}\) For instance, by reporting automatically about certain events (e.g. a report about monthly sales figures).
\(^{93}\) e.g. to deliver better services, to collect all sorts of (user) information, or to communicate with other/middle
layer agents.
6.4.1 Who will be developing agents, and how will they be offered?

At this moment, many suppliers/producers use the one-way (business) model of Netscape/JAVA to reach consumers/users. Especially manufacturing and distribution companies, which produce a tangible product, are more likely to use this producer/distribution model.

At the same time, there is a trend for organisations whose main product is to provide service(s), i.e. where value is added through transaction processing (such as information (service) providers who are active on the Internet), to change their role of that of a rather passive supplier to a more active and more elaborated role. These organisations are switching from the production/distribution model to a consumer/push-pull model, and are very interested in applications and techniques that enable them to reach all those users whose needs they can cater for, and improve and enhance the ways in which they offer their services.

Concepts such as the three layer model (as seen in chapter four) and software agents, can help to offer/enable all of this. Non-commercial intermediaries, such as libraries or the government (and all its services and organisations), could use them to extend their services by providing these to a much larger user group (that of the Internet or an Intranet94) and by tapping into all the information sources the Internet provides access to. They can also help users selecting the right sources to match their needs (in a same way as these intermediaries have been doing for conventional media such as books and articles). Commercial intermediaries (or information brokers), can offer these services to this audience too, but more elaborated and with various forms of support. See section 4.3.1 for more detailed information about this.

As said, the producer/distribution model is currently the vogue among many organisations "doing business on the Internet". One of the most important motives for them to do so, is probably the fact that this allows producers to use the same techniques and the same materials (such as advertisements) on the Internet, as they use, and have used, for other media (such as newspapers or television channels). The problem with using this simple model is that the user (i.e. consumer) must track down and access the content (i.e. a provider's Internet service). And it may be expected that future Internet users are unlikely to spend much time on doing this.

Although, consumer/push-pull strategies have not yet proven successful on the Internet, they might be turned into profitable, successful strategies if certain principles are followed. In [LEWI95] such a model - called the software economy - is sketched. In this "economy", the basic economic unit is a transaction, which is of a special kind: barter. Thus, the basic mechanism for making money becomes the transaction fee or commission. Another major difference between this model and the previous (current) one, is that business is initiated predominantly by users/consumers:

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94 Intranets, which runs on open TCP/IP networks, enable (large) organisations/companies to employ the same types of servers and browsers used for the World Wide Web for internal applications distributed over the corporate LAN. Because intranets are based on the same independent standard Internet protocols and technologies, they are accessible to every member within an organisation, regardless of their choice of hardware platform. Intranet servers enable business functionality such as publishing information, processing data and databased applications, and collaboration among employees, vendors, and customers. Driven by the powerful combination of openness and security, intuitive access to detailed information, extreme cost-effectiveness, and flexibility for customisation in increasingly competitive times, Intranets are a getting very popular nowadays.
“Someone somewhere wants to buy information, service, or a product. They enter into a community of buyers and sellers, e.g. a market, and obtain the service or product by electronic bartering. The intriguing prospect in this model, however, is the idea of a software agent - a program that roams the telesphere (cyberspace) looking for buyers and sellers (who are also software agents). Whenever two or more software agents meet in the telesphere, they barter for services and products, and then report back to their human owners.”

from "Stepping Out" in [LEWI95]

Various (electronic) publishers, but also others, are doing a lot research into all (new) sorts of electronic publishing, which make use of the previously described principle. An example of this is the InfoMarket project of IBM, where one of the concepts that research is done into, is that of superdistribution. This technique makes it possible to package documents in such a way that they can be transported from, say the author, or the publisher, to an (in theory) infinite number of users, without getting any copyright infringements. In fact, the more the document gets handed out to others (i.e. friends, colleagues, peers), the more the author or the publisher can earn with it.

6.4.2 What kinds of agents will be offered?

"Success in the Info Age95 means learning to use technology to individualise and personalise services and products. In other words, technology which increases the human touch will succeed. Technology which plunges humankind deeper into machine-like efficiency will fail."

from "Living in real time ..." in [LEWI95]

Information service providers (but the same goes for just about any company or organisation offering services on the Internet) will soon have to adjust to the change as described in the previous paragraph. Soon a situation will emerge where there are so many suppliers offering seemingly identical products and/or services, that users (i.e. buyers, consumers, etc.) will need to be attracted by other means than sharp prices or nice advertisements. It has every appearance that delivered services (such as product information, user support, the availability of some kind of help desk, etcetera) will be that decisive factor.

Agents can be used to offer individualised services/information (i.e. in the form that is suitable for a specific user), but also to provide these at any time that is suitable for the user (regardless of his location). They can be used for such uses as have been described in section 6.2 and 6.3, and for various functions in middle layer activities.

Here are a few examples of such possible future services:

* Agents can be used to deliver tailor-made (personalised) services, e.g. (in case of the government) help a person to find the right juridical information about some juridical problem he or she has, and present it in the most comprehensive way (based on information provided by the user agent);

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95 i.e. in the information society. The "Info Age" denotes the period following the current "Post-Industrial Age", and will be a period where information is the most important good.
* Publishers can use agents as a tool to pre-select information (such as news articles) for users. Because of their experience and authority, groups of users will keep on relying on publishers to pre-select information, just like they do now for the publication of magazines and professional literature (probably even regardless of whether or not a model like the three layer model is used on the Internet);

* Small/individual suppliers (such as a real-estate agent) can use agents to provide personalised information about their service(s) or product(s), and can save money as they do not have to send out printed brochures which can only provide generic information.

No matter what will be offered in the future, it is vitally important that - especially developers of agents and agent-based applications - be real "ambassadors" for agents, in that they give good, reliable information about agents: they should give a realistic representation of the possibilities of the agent-technique to prevent overoptimistic expectations of (potential) users of agents. Neither users, nor suppliers, nor developers would have any avail of that.

### 6.4.3 Why/with what reasons will agents be developed and/or offered?

The reasons why organisations or companies develop agents can be very diverse. However, they all have their (minor or major) influences on agents, and the functionality they have to offer.

For commercial developers, there are probably three important reasons to develop agents:
1. First and foremost, agents are developed because they can and will be profitable. Judging by their necessity as we saw in chapter one and four, and adding to this the functionality they can offer (as we saw in chapter two, three and four), it may be safely concluded that money can be made with them. And if you, as a company, do not develop them or do research into applications for them, then your rivals surely will. And just as it has been said about the Internet: it is better not to wait to long with doing so;

2. Suppliers and intermediaries/brokers can use agents to more effectively (i.e. better) reach their target groups (perhaps even target groups that until now could not, or not well enough be reached with the aid of traditional media). So, they have every reason to develop good (user, intermediary and supplier) agents that are able to do this;

3. The Internet makes it possible to reach a huge public against relatively small risks and costs. Agents can extend this advantage, by making it possible to provide customised services all night and day. Money can be saved in various way, for instance because a software agent is much cheaper than a human agent.

An important, rather general reason to develop agents, for any kind of developer, is that they are able to perform many tasks. Better still, they can perform them more intelligently than conventional programs can, and much more. This saves time and money, provides better results, etcetera. Many parties can profit from this: not only IT-freaks, but many other groups as well, e.g. students, managers, and the average civilian.\(^{96}\)

Apart from reasons to develop and/or offer agents, there are also good reasons - for some - not to do so. Usage of the three layer model, and of agents, leads to a very transparent market, as users - by means of the middle layer and/or agents, can get a detailed overview of all (or at least many) of the

\(^{96}\) The specific benefits agents can offer governments, are discussed in the next section (6.5).
suppliers in a specific market, of their prices, the service they offer, etcetera. Therefore, a very justified question to ask, is whether suppliers want such a transparent market, as market obscurity can be an advantage to them (it makes it hard(er) for users to get an idea of whether or not there are better or cheaper alternatives). So, besides the reasons why agents are developed and/or offered, the reasons why some will not want them to be developed or offered will play a role as well. The influence of it, however, will not be that big, as it is very unlikely that parties adhering to this opinion will be able to exert a strong influence.

6.5 The Government

The influence of governments, their departments, and various services on the developments, at least in the foreseeable future, may be expected to be of a rather indirect nature in most cases (as will be seen in this section). In some cases, e.g. where juridical aspects of agents need to be addressed, this influence will have to be more than just superficial. Besides, there are quite some important Internet-related governmental issues, that can greatly benefit from the functionality offered by agents: the three layer model we saw in chapter four, is an example of such a thing that can very well be used in government policies or plans regarding "The Information Super-Highway".

We will step through the list of important governmental Internet-issues, and indicate in which way(s) agents and/or the three layer model can contribute to solving these.

1. **The government**, maybe through one of its departments, **should ensure that developments regarding agents and the Internet go in the right direction.** What that right direction should be, is not very easy to determine. In fact, in the United States the government is more and more delegating this kind of decision making to third parties (e.g. groups of large IT-companies) as they think these are better up to the task and/or because this saves the government lots of money. However, it can be said for sure that the right developments are not very likely to emerge from the action of market forces alone as the largest en most powerful companies would dominate the others:

   "The key issue for the emergence of new markets is the need for a new regulatory environment allowing full competition. This will be a prerequisite for mobilising the private capital necessary for innovation, growth and development.

   In order to function properly, the new market requires that all actors are equipped to participate successfully, or at least that they do not start with significant handicaps. All should be able to operate according to clear rules, within a single, fair and competitive framework."

   from [BANG94]

   Issues, such as **the development of open standards for agents** (or for Internet services), are of such great importance, that governments should (at least) supervise the whole process:
"In an efficient and expanding information infrastructure, [...] components should work together. Assembling the various pieces of this complex system to meet the challenge of interoperability would be impossible without clear conventions. Standards are such conventions."

from [BANG94]

Thus, it should not be a supervision on the specific ins and outs of a standard. The government should engage in a steering role to ensure that standards are and remain really open, and not become a standard that is exacted or enforced by one party (leading to a stifling monopoly):

"Most people can agree that an ideal information infrastructure should have such qualities as extended interoperability, broad accessibility, and support for broad participation. [...] Progress toward that ideal is more likely if the government can set an example with its own services and help enable a consensus on a vision of the future by removing barriers to its realisation. [...] However, the government's role is as a partner and participant with the private sector, exercising its regulatory authority with restraint."

from [NRC94]

2. The previous quote mentions another reason why the government should be actively using the Internet, related services and techniques: governments can set an example towards others and encourage them (other parties or even to complete sectors) to follow it:

"Initiatives taking the form of experimental applications are the most effective means of addressing the slow take-off of demand and supply. They have a demonstration function which would help to promote their wider use; they provide an early test bed for suppliers to fine-tune applications to customer requirements, and they can stimulate advanced users [...]"

from [BANG94]

In fact (as we saw in section 6.4.3) agents can be of general use to (the) government(s). Governments can set an example by offering useful and convenient services on the Internet. They can do this by employing agents (we have seen many of such possibilities in the previous sections) and by adopting, actively using and maybe even promoting some form of the three layer model. After all, governments are active in all three layers/roles: as suppliers (of many services and all kinds of information), as intermediaries and as a user of services and information (e.g. reports) of others.

3. Governments are already addressing various juridical aspects of the Internet in general (such as copyright), but specific ones related to agents will need to be addressed as well. For instance, who is responsible for the actions of an agent? The user, one might say, but it is almost impossible for the average user to follow the actions of an agent all the time that it is active on his behalf. If it isn't the user, who is? These matters will become pressing in about five years. And as it always takes quite a while before laws/rules are passed and ready to be used in legal practise, it may be a good idea for governments to address this problem as soon as possible. For instance by asking advice from all sorts of experts and institutions that operate in this field.
Issues related to this, and that of point 1, are the need for security and encryption techniques to make sure that agents and the Internet can be used without endangering the secrecy of data or endangering people's privacy.

4. **Not only**, as seen in point 2, **can agents & the Internet be of great use for the government, it is** (not surprisingly) **of great use to many others too.** This makes agents & the Internet in general, something the government should be interested in. The Internet "industry", already, is a growing economic sector, providing work to many. It may be expected that the agent industry (although on a smaller scale compared to the Internet) will too be a sector with many (economic) opportunities:

> "nothing will happen automatically. We have to act to ensure that these jobs are created [...], and soon."

from [BANG94]

5. **Agents and the three layer model can be introduced as a logical continuation of current Internet policies.** The first aim of the government was to get people, companies and organisations to discover, make use of and perform research on the Internet. A second aim now should be to make use of the Internet easier, more efficient, more user-friendly, more profitable, etcetera:

> 
> "[...] Once people are comfortable finding information on the Internet, they will discover that they want much more: they will want help in locating reliable, useful information; they will want to discuss it with others, [...] generate it, and so on."

from [NRC94]

These are all things software agents (preferably combined with a three layer structure) can help to offer.

6. **The Internet can be used for educational purposes (in a broad sense):** "It is no longer a question of "whether" it will happen - it is a question of 'how soon'”. In chapter five it has been described why education will play in increasingly important role with regard to the aim that everyone (i.e. every civilian) should be able to use the Internet/NII/"Information Super-Highway". The exact future applications of agents in education are not easy to foresee at this moment. But the functionality that can be offered at this moment, already looks very promising. For instance, agents can be used in education to gather all sorts of information, and to offer customised teaching programmes to scholars and students. They also can reduce costs, save time and improve the learning process:

> "The Hudson Institute, headquartered in Indianapolis, Indiana, reviewed 20 years of research on computer-based instruction and found that students learn 30 percent more in 40 percent less time and at 30 percent less cost when using computer-aided instruction. Who says automated delivery isn't as good as delivery in the flesh?"

from "Living in real time" in [LEWI95]
6.6 The Internet & the World Wide Web

As the most important application environment, the Internet and its services, need to be taken into account as well when making predictions. Furthermore, more and more people are getting familiar with the Internet (in general), and more and more are making their first trips on it:

"Whether they have actually logged on to the Internet or not, Americans are optimistic about the new medium [...]. Eighty percent of those on-line, and 54 percent of those not on-line (59 percent of all respondents), say they believe the information on the Internet is useful."

from Business Wire

However, after the initial period of introduction, many new users run into several problems. One of the most important is having difficulties finding (specific) information:

"[...] there is a big difference between Americans' ideas about the value of information in Cyberspace, and their abilities to access that information: 54 percent of those on-line report they spend most of their time searching for information rather than finding it. And of those not on-line, 46 percent believe that if they were on-line, they'd spend more time in search of information than actually finding it."

from Business Wire

Contrary to what may be expected, this does not have a negative influence on the perception of the usefulness of the Internet as a source of information:

"[...] Whether they are on-line or not, the Americans surveyed do not view the Internet as something that would complicate their lives. Further, they report that the new electronic medium with its oceans of information will neither complicate their lives nor does the prospect of going on-line make them feel they would be isolated from others. Of all survey respondents, 63 percent say the Internet does not complicate life for them. (87 percent of those on-line, and 57 percent of those not on-line agreed.) In fact, 58 percent of all those surveyed actually thought the Internet would simplify their lives."

from Business Wire

Agents can be of great help to users that are searching for (specific) information. In fact, from the preceding it can be concluded that it is of vital importance that this functionality is offered. Moreover, agents can not only be used as information gatherers, but to provide suitable (and customised) interfaces to computers and the Internet as well.

Another pressing problem, which will at least exist in the forthcoming few years (i.e. short term), are resource strains. The increased use of the Internet (i.e. the demand for bandwidth) is outrunning its capacity. It is hard to predict whether this is only a "temporary" problem (i.e. it will end within a few years). It all depends on whether or not certain parties are willing to invest in more and faster network connections.\(^{97}\)

\(^{97}\) As long as most of the Internet services are free (largely due to the fact that there are not yet safe methods to make many small payments on the Internet - see next footnote), commercial parties will be very inclined to do so.
Agents play a strange role here. On one hand, they can help to reduce the waste of bandwidth (e.g. by performing searchers more efficiently), on the other hand they will increase the usage of bandwidth as the user-friendliness and convenience (e.g. efficiency, speed) they can offer, will attract more users and lead to an increased use of the Internet as an information tool. This latter development is likely to eclipse the former. However, agents cannot be blamed for that.

Probably within a year, safe payment methods will be available which make it possible to easily make many small payments\(^9^8\) on the Internet. This will strongly stimulate the demand for agents and agent-enabled applications, as performing information searches inefficiently, does not only cost you time but also money. Weighing the (value of) offered services and information of the numerous suppliers against the money that has to be paid for (retrieving) it, will be a task that is too complicated for humans to do all by themselves. Instead, in the medium term, they will farm out this task to agents. (See chapter four for more about this.)

Another medium term development may be a further rise of the number of Intranets. Intranets are well manageable (also financially), they are well suited for multi-media applications, can act as a gateway to the Internet, and are basically secure (compared to the rather insecure Internet). For the rest, they have all the good qualities of the Internet (e.g. openness, robustness). Intranets enable Internet providers to offer more differentiated Internet services. For instance, they can then offer cheap, but slow(er) services to those who favour low prices over fast connections, and offer more expensive, but also faster and more elaborated services at higher rates. And they offer many large organisations and companies to means to connect their various offices and employees.\(^9^9\) Fortunately, agents can be active on both Intranets as on the Internet. And again, agents will then probably be needed to weigh which connections to use: cheaper and slower, or more expensive but faster ones. This can all depend on the nature and the urgency of the task that has to be performed, the time of the day it is performed on, etcetera. Soon, this may be expected to become a task that is too complicated for humans to do themselves.

Non-commercial parties (such as the various governments) do not have sufficient funds to fully meet the increased demand for bandwidth.

\(^9^8\) In the near-future it is very likely that very small amounts of money will need to be paid for each page of information that is retrieved. The exact amount does not have to be more than a few cents, as information pages (especially popular ones) get retrieved so often, that only small charges will be sufficient to cover the costs that have to be made to put the information on-line.

To make this system work (i.e. interesting for Internet users), there should preferably be no, or virtually none (i.e. not more than a few cents), overhead costs per payment.

\(^9^9\) It is predicted that Intranets will, within a few years, become much cheaper alternatives for expensive groupware packages such as Lotus Notes. Some even argue that "Internet technologies are much more relevant and exploitable within a local LAN [i.e. an Intranet], right now, than over much slower, dial-up access routes associated with typical home-access to the Internet" (from "The Intranet - a Corporate Revolution" by JSB Computer Systems Ltd).
6.7 Summary

Predicting how agents will develop into the future is not an easy task at all. Not only because the agent-technique is still in its early years, but also because most of the factors and parties that are involved in the developments around it influence each other mutually. This makes it quite impossible to predict now how the state of affairs will be over - say - five years, and how the "environment" (e.g. users, suppliers, Internet, computer technology) will have responded to the agent-technique and many other developments (including its own).

The ultimate test of agent's success will be the acceptance and (mass) usage of them by users. The road to this success is most likely to be laid by developers and suppliers. Apart from them, it may be expected that many commercial companies and organisations will join in on this as well, as there are many interesting opportunities for them. Agents will enable all to offer personalised and "smart" services, delivered around the clock and (probably) at low(er) prices.

However, there are a few important points that need to be settled before this can really be done well. Solid standards need to be established for such things as the used agent communication language, some sort of list of standard agent queries and responses needs to be drawn up, etcetera. Furthermore, rules and possibly even laws are needed to regulate (unwanted) agent behaviour and to be able to deal with various (future) legal issues (e.g. who is responsible for an agent's actions?). Seeing that these standards emerge and that the juridical issues are dealt with, is mainly a task for the most important "players" in the agent area (e.g. companies, researchers). The role of the government in all of this will be mostly supportive, but - because of the fact that the government is also a party that can greatly benefit from agents in many ways - it can be an active one as well.
7 Concluding remarks, statement reviews and acknowledgements

7.1 Concluding remarks

Intelligent Software agents have been around now since a few years. But even although this technique is still young, it looks promising already. Promising, but also rather vague and a bit obscure to many. This thesis' aim was - and is - to provide an overview of what agents are offering now and are expected to offer in the future. For that purpose, practical examples have been given to indicate what already has been accomplished. A model was outlined which can be used to extend, enhance and amplify the functionality (individual) agents can offer. And trends and developments from past and present have been described, and future developments have been outlined.

One of the conclusions that can be drawn from these trends and developments, is that users will be the ultimate test of agents' success. Users will also (albeit indirectly) drive agents' development; that is something that seems to be certain. What is uncertain is whether users will discover, use and adopt agents all by themselves, or whether they will just start to use them because they are (getting) incorporated into a majority of applications. Users may discover more or less on their own how handy, user-friendly and convenient agents are (or how they are not), just like many users have discovered or are discovering the pros and cons of the Internet and the World Wide Web. But it may just as well go like as in the case of Operating Systems and GUIs, where companies with the biggest market share have more or less imposed the usage of certain systems and software.

From the current situation it cannot be easily deduced which path future developments will follow. There is no massive supply of agents or agent-based applications yet, but what can be seen is that large software and hardware companies, such as IBM, Microsoft and Sun Microsystems, are busy studying and developing agents (or agent-like techniques) and applications. Initial user reactions to the first agent applications (not necessarily provided by these large companies) may be called promising: such applications as wizards (although these aren't true agents, but a good predecessor of them) and search-engines (which heavily employ all sorts of search agents, or agent-like variants of these) are eagerly used by users and viewed as (very) positive, sometimes even as a real relief. Also strongly gaining in popularity are personalised newspapers and search agents that continuously scan Usenet articles (sometimes even the entire Internet or the WWW) looking for information that matches certain keywords or topics.\(^\text{100}\)

And this only seems to be the beginning, as the agent-technique can be used in many more ways. The growing popularity of the Internet, but also the problems many people encounter when searching for or when offering information or services on it, will only increase the possible number of applications or application areas: the Internet is an ideal environment for agents as they are (or can be) well adapted to its uncertainty, and are better\(^\text{101}\) at dealing with the Internet's complexity and extensiveness. In the future, agents should also be able to relief humans of many other tasks, both mundane as well as more complicated ones (i.e. which require more "intelligence").

To get to this stage, however, some important obstacles need to be tackled first. For example: one of the interesting and powerful aspects of agents will be their ability to communicate with other agents, other applications and - of course - with humans. To do this, good and powerful interfaces and communication languages (i.e. protocols) have to be developed. Standards could be of great help here, but it also takes quite some time (at least some years) before these are drawn up. As much as they

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\(^\text{100}\) Examples of such services are the Sift service of Stanford University and IBM's InfoSage.

\(^\text{101}\) better than many conventional programs.
Conclusions and acknowledgements

will help speed up developments from that moment on, the lack of them is likely to slow down developments up till then.

Other important issues that have not, or only partially been addressed and tackled, are such things as security, (user) privacy, means to accomplish real intelligent agent behaviour, and many ethical and juridical issues.

My expectations are that, within foreseeable time (i.e. within five years), enough of these issues will have been sufficiently dealt with\textsuperscript{102}. The situation for agents can, in a way, be compared to that in the area of Artificial Intelligence in general: critics have been, and still are saying that it is unclear what AI exactly is, what its aims are, and that AI researchers are not able to come up with many concrete techniques or practical (usually meaning: profitable) applications. These critics seem to pass over the fact that, although there may be a number of concepts that still are rather vague or that lack a clear definition, and that there are a lot of pieces missing in its puzzle, AI has managed to make impressive achievements: concepts and techniques like fuzzy logic and neural networks have been used and incorporated into many applications.

At this moment, agents seem to have become the critics' latest "moving target". Agents are being incorporated into future doom scenarios, where they are used (for instance by "Big Brother") to spy on Internet users, and where they turn people into solitary creatures, that live their life inside their own little virtual reality. Agents (in their view) are the latest hype, and - as a technique - have not much to offer.

As was said at the beginning: the agent-technique is still very young. It 'growing up' takes time, and it will take a lot of trial and error, and a lot of experimenting to make it mature. This is exactly the stage where we are at now, so you can't expect agents to already be advanced and (nearly) perfect. This thesis has described just how advanced and "perfect" agents are at this moment, and how they are expected to mature in the future. Developments may not have come "there" at this moment, but they certainly have made enough progress to make them more than just a hype.

7.2 Statement conclusions

In chapter one, two statements have been formulated. Let us see now how these statements - a claim and a prediction - have turned out.\textsuperscript{103}

7.2.1 The claim

The claim that was made with regard to the first part of this thesis consisted of two parts. The first part was:

\textit{"Intelligent Software Agents make up a promising solution for the current (threat of an) information overkill on the Internet."}

Judging from the information that we have seen in chapters two and three, and also judging from published research reports, new product announcements and articles in the media, it seems safe to conclude that agents are starting to lift off, and are judged by many as valuable, promising and useful. Numerous agent-like as well as real agent-enabled applications are available on the Internet (albeit often as test or beta versions). These are already able to offer a broad range of functions, which

\textsuperscript{102} which does not mean that they have been completely solved, but to such a degree that they do not interfere (much) with further developments.

\textsuperscript{103} about six months after they have been formulated.
make it possible to perform all sorts of tasks on the Internet (some of which were not feasible in the past), and/or support users while doing them.

There are only a few objections that can be raised against the claim that agents "make up a promising solution" for the information overkill on the Internet. Objections that can be made, concern the lack of standards with regard to vital agent aspects (such as the communication language and the architecture that will be used) and about the vagueness of some of the agent's aspects (as seen in section 2.2). While these are indeed valid objections, none of them really are insurmountable obstacles for further development of the agent-technique as a whole, and of agent-enabled applications in particular.

The second part of the claim elaborated on the first part:

"The functionality of agents can be maximally utilised when they are employed in the (future) three layer structure of the Internet."

The current structure of the Internet seems to be missing something. Users complain that they are increasingly unable to find the information or services they are looking for. Suppliers are complaining that it gets increasingly difficult to reach users, let alone reach the right ones. Both seem to find "it's a jungle out there". A worrying development, also for governments and many others who want the Internet (and all the information and services that are available through it) to be easily accessible and operable for all. What many seem to be wanting, either implicitly (e.g. by stating that some sort of intermediary services are needed) or explicitly, is that a third party\textsuperscript{104} or layer be added to the Internet. This layer or party will try to bring supply (i.e. suppliers) and demand (i.e. users) together in the best possible way. The three layer model, as seen in chapter four, is a way in which this can be accomplished.

So, adding a third layer or party to the Internet seems to be very promising and a way of offering new and powerful services to all on the Internet. But does it lead to agents being "maximally utilised"? First and foremost: it does not mean that agents have little to offer if they are not employed in a three layer structure for the Internet. Individual agents (or agent systems) are capable of doing many things, even when not employed in a three layer structure. But some of the offered functionality can be done more efficiently, and probably quicker or at lesser costs, when the three layer structure is used (as was shown in chapter four). Moreover, the structure will enable tasks that a single agent is incapable of doing (well, or not at all), such as finding information within a foreseeable period of time on (ideally) the whole Internet.

Adding the conclusions and remarks about the two sub-statements together, it can be safely concluded that agents, either individually or (preferably) employed in the three layer structure, have the potential to become a valuable tool in the (Internet's) information society.

\textsuperscript{104} users and suppliers being the first and second one.
7.2.2 The prediction

With regard to the trends and developments of the second part of this thesis, the following prediction was stated:

"Agents will be a highly necessary tool in the process of information supply and demand. However, agents will not yet be able to replace skilled human information intermediaries. In the forthcoming years their role will be that of a valuable personal assistant that can support all kinds of people with their information activities."

In the previous section it has been shown that agents are able to contribute in many ways to improve "the process of information supply and demand" (e.g. as intermediary agents). The question now is: are they better at doing this than, say, a human information broker?

When I started writing this thesis, i.e. when I formulated this prediction, I assumed agents are not - and would not - be able to replace human intermediaries (at least not in the next three to five years). Now, lots of information, six chapters, and five months later, I would say that this assumption was more or less correct. "More or less" because it paints the future situation with a dither brush than necessary: agents will not (yet) be able to replace skilled human information intermediaries in all areas. There are tasks that are so complicated (in the broadest sense) that they cannot be done by agents (yet, or maybe never at all). But there still are numerous other tasks that agents are very well capable of doing. What's more, there are tasks that (soon) agents will be better at than their human counterparts (such as performing massive information searches on the Internet, which agents can do faster and twenty-four hours a day).

So, agents will be 'nothing more' than "a valuable personal assistant" in some cases, but they will also be (or become) invaluable in other ones. And there will be cases where humans and agents are (more or less) equally good at. For instance, in case there has to be chosen between a human or an electronic intermediary, the decision which of these two to approach (i.e. 'use') will then depend on such factors as costs/prices and additional services that can be delivered.

More generally, it may probably be the choice between doing it yourself (which leaves you in control, but may lead to a task being done inefficiently, incompletely or more expensively) or trusting agents to do it for you (with all the (dis)advantages as we have seen them in this thesis).

7.3 Acknowledgements

There are many persons that have contributed to the realisation of my thesis, and I am very grateful to all those who did.

There are a few persons that I would especially like to thank: Jan de Vuijst (for advising me, and for supporting me with the realisation of this thesis), Peter Janca, Leslie Daigle and Dan Kuokka (for the valuable information they sent me), and Jeff Bezemer (for his many valuable remarks).
8 Used information sources

8.1 Literature


8.2 Information sources on the Internet

The @gency (http://www.info.unicaen.fr/~serge/sma.html):
A WWW page by Serge Stinckwich, with some agent definitions, a list of agent projects and laboratories, and links to agent pages and other agent-related Internet resources.

Agent Info (http://www.cs.bham.ac.uk:80/~amw/agents/):
A WWW page containing a substantial bibliography on and Web Links related to Interface Agents. It does provide some information on agents in general as well.

Agent Oriented Bibliography (http://www.hec.unil.ch/people/tsteiner):
Note that as this project is at beta stage, response times might be slow and the output is not yet perfect. Any new submissions are warmly welcomed.

Mark Kantrowitz' Artificial Intelligence Frequently Asked Questions contains information about AI resources on the Internet, AI Associations and Journals, answers to some of the most frequently asked questions about AI, and much more.

A WWW page by Eric Vereerstraeten about "assistants or agents [that] are appearing in new programs, [and that] are now wandering around the web to get you informed of what is going on in the world". It tries to give an impression of what the next steps in the development of these agents will be.
**Intelligent Software Agents** ([http://pelican.cl.cam.ac.uk/people/rwab1/agents.html](http://pelican.cl.cam.ac.uk/people/rwab1/agents.html)):
These pages, by Ralph Becket, are intended as a repository for information about research into fields of AI concerning intelligent software agents.

**Intelligent Software Agents** ([http://www.sics.se/isl/abc/survey.html](http://www.sics.se/isl/abc/survey.html)):
This is an extensive list that subdivides the various types of intelligent software agents into a number of comprehensive categories. Per category, organisations, groups, projects and (miscellaneous) resources are listed. The information is maintained by Sverker Janson.

**Personal agents: A walk on the client side** ([http://www.sharp.co.uk/pk/unicom/Unicom.htm](http://www.sharp.co.uk/pk/unicom/Unicom.htm)):
A research paper by Sharp Laboratories. It outlines "the role of agent software in personal electronics in mediating between the individual user and the available services" and it projects "a likely sequence in which personal agent-based products will be successful". Other subjects that are discussed are "various standardisation and interoperability issues affecting the practicality of agents in this role".

**Project Aristotle: Automated Categorization of Web Resources** ([http://www.public.iastate.edu/~CYBERSTACKS/Aristotle.htm](http://www.public.iastate.edu/~CYBERSTACKS/Aristotle.htm)):
This is "a clearinghouse of projects, research, products and services that are investigating or which demonstrate the automated categorization, classification or organization of Web resources. A working bibliography of key and significant reports, papers and articles, is also provided. Projects and associated publications have been arranged by the name of the university, corporation, or other organization, with which the principal investigator of a project is affiliated". It is compiled and maintained by Gerry McKiernan.

SIFT is an abbreviation of "Stanford Information Filtering Tool", and it is a personalised Net information filtering service. "Everyday SIFT gathers tens of thousands of new articles appearing in USENET News groups, filters them against topics specified by you, and prepares all hits into a single web page for you." SIFT is a free service, provided as a part of the Stanford Digital Library Project.

A WWW page, maintained by Marc Belgrave, containing Frequently Asked Questions about this mailing list. Questions such as "how do I join the mailing list?", but also "what is a software agent?" and "where can I find technical papers and proceedings about agents?" are answered in this document.

An information service of the UMBC's Laboratory for Advanced Information Technology, maintained by Tim Finin. It contains information and resources about intelligent information agents, intentional agents, software agents, softbots, knowbots, infobots, etcetera.
9 Appendices

Appendix 1 - A list of World Wide Web Search Engines

There are many Search Engines on-line on the Internet. These search engines allow a user to search for information in many different ways, and are highly recommended web search tools for the time being. The following list\(^\text{105}\) will give an idea of the kind of the search engines that are currently available. Between brackets the URL of the service (which is needed to find and use it) is given.

- **Achoo!** ([http://www.achoo.com/](http://www.achoo.com/)):
  Achoo! is a new Internet Health Care Directory, modeled after Yahoo (see later on in this list), it is one of the most comprehensive search sites for medical information. Containing over 5,000 sites, users can browse by subject categories with this quick search vehicle;

- **Affinicast Agent** ([http://www.affinicast.com](http://www.affinicast.com)):
  A new way to locate Web sites geared towards your personal preferences. After administering a short questionnaire about your preferences for Internet content and activities, Affinicast provides a set of specific suggestions;

- **AliWeb** ([http://web.nexor.co.uk/aliweb/doc/aliweb.html](http://web.nexor.co.uk/aliweb/doc/aliweb.html)):
  The Archie-Like Indexing for the Web is part of the Web at Nexor, in the United Kingdom. Their database is a collection of document summaries written by their publishers and regularly collected by ALIWEB;

- **Alta Vista** ([http://altavista.digital.com/](http://altavista.digital.com/)):
  This is the first search engine created by Digital Equipment Corporation (DEC). Alta Vista is a quick, responsive, and easy to use search engine indexing over 8 billion words found in over 16 million Web pages and over 13,000 news groups updated in real-time;

- **Bess** ([http://www.bess.net/](http://www.bess.net/)):
  Bess, the Internet Retriever for kids, families and schools is a new breed of Internet service provider specifically designed to protect children and others from the sexually explicit and adult-oriented material proliferating on the Internet. At the same time, Bess provides Internet users with a simple point-and-click environment to facilitate exploration of the thousands of educationally valuable and entertaining sites of the Internet;

- **B.E.S.T** ([http://eyecatchers.com/eyecat/BEST/](http://eyecatchers.com/eyecat/BEST/)):
  Best Education Sites Today is a search engine dedicated to education. With over 10,000 URLs in its database, it is the most comprehensive source for education links on the Internet. Users can Search by keyword, or by the Topic List, or browse the Awards for extensive reviews of the hottest education sites of the month;

- **Clearinghouse for Subject-Oriented Internet Resource Guides** ([http://www.lib.umich.edu/chhome.html](http://www.lib.umich.edu/chhome.html)):

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\(^{105}\) The information in this list has been largely derived from C. Steele's Web page about WWW search engines ([http://www.interlog.com/~csteele/newbie3.html](http://www.interlog.com/~csteele/newbie3.html)). See this page for a very comprehensive and up-to-date list of search engines.
Here you'll find Web links arranged mainly in educational categories, such as the humanities, social sciences, and science;

- **Computer ESP Internet Search** ([http://www.uvision.com/search.html](http://www.uvision.com/search.html)):
  This site contains one of the most comprehensive, organized, up-to-date collection of search forms to Internet store catalogs, business directories, magazine indices, newsgroup indices, and Web indices related to the computer industry. Easily search dozens of stores for price and terms;

  DejaNews is a tool for searching Usenet articles. Allows searches through mountains of Usenet archives in seconds to find the information you need. Fill-out forms and "how-to" guides help you target your search to get what you want;

- **Electronic Library** ([http://www.elibrary.com/](http://www.elibrary.com/)):
  Launch comprehensive searches across this deep database of more than 1000 full text newspapers, magazines, and academic journals; plus images; reference books; literature; and art. Just type a query or keyword in plain English and The Electric Library will quickly and simultaneously search 150 newspapers and newswires, nearly 800 magazines and journals, 3,000 reference works, and many important works of literature and art. And every article, story and reference work is full-text. This is a pay per use service, but at this moment there is (still) the possibility for a free trial;

- **EXPOguide** ([http://www.expoguide.com/](http://www.expoguide.com/)):
  EXPOguide is a database of over 5,000 trade shows and conferences worldwide. Users can locate shows utilizing our concept search engine, or via location, date and alphabetical indexes. EXPOguide also contains listings of vendors providing services to the trade show industry;

- **Find Newsgroups** ([http://www.cen.uiuc.edu/cgi-bin/find-news](http://www.cen.uiuc.edu/cgi-bin/find-news)):
  This is a simple tool for discovering Usenet newsgroups of interest. Just enter a single string and a menu of newsgroups whose names or brief descriptions (not articles) match the search string will be returned;

- **Findex** ([http://www.findex.com/search.htm](http://www.findex.com/search.htm)):
  Fidex is the definitive global directory of financial institutions and services. Highlights include a searchable index of worldwide banks, security firms, stock exchanges, venture capitalists and all financial media on the WWW;

- **FTP Search 95 v3.0** ([http://ftpsearch.unit.no/ftpsearch](http://ftpsearch.unit.no/ftpsearch)):
  FTP Search is an excellent search engine for locating what files reside on which server. Users type in keywords or the name of the file they wish to find, there are even several configuration options (such as the operating system that you use) which can be toggled before an search is initiated. The result is a quick list of FTP servers, with the path of the directory, and location of the file, designed as a quick link that can be access at the press of a button;

- **HYTelnet v6.8** ([http://galaxy.einet.net/hytelnet/START.TXT.html](http://galaxy.einet.net/hytelnet/START.TXT.html)):
  HYTelnet is designed to assist users in reaching all of the Internet accessible libraries, Free-nets, BBs, & other information sites by Telnet, specifically those users who access Telnet via a modem or the ethernet from an IBM compatible personal computer;
- **Image Finder** (http://wuecon.wustl.edu/other-www/wuarchimage.html): The Image Finder, a thematic index for a vast image archive at the University of Washington, makes it possible to search for certain images on the Internet. Users simply type in a query or browse through the available list of categories.

- **INFOSEARCH Broadcasting Links(c)** (http://www.xmission.com/~insearch/links.html): INFOSEARCH Broadcasting Links(c) is a comprehensive hypertext directory of broadcasting related sites on the World Wide Web.

- **Internet Business Directory** (http://www.ibdi.com): The IBD is a new search tool allows users to find local, regional, national, or international companies by name, city, state, zip, area code or type of business. With over 20 million listings, this service provides free searches and listings for businesses.

- **ListWebber II** (http://www.lib.ncsu.edu/staff/morgan/about-listwebber2.html): Using a forms-capable World Wide Web browser, you can use ListWebber to search the archives of LISTSERV or ListProcessor lists and extract only the information you want. ListWebber provides the means for searching LISTSERV and ListProcessor lists while reducing the need to know their searching syntax.

- **MediaFinder** (http://www.mediafinder.com): Request free information from a searchable database of newsletters, magazines, journals, and catalogs. More than 5000 listings in 265 subject categories.

- **NetGuide's Calendar of Events** (http://techweb.cmp.com/net/calendar/cal.htm): This service provides an online calendar covering current electronic events. Areas covered include Online services, Internet-Related Conferences, WWW Events, and other Event Calendars.

- **Notable Citizens of Planet Earth: Biographical Dictionary** (http://www.tiac.net/users/parallax/): An online searchable dictionary reference which contains biographical information on over 18,000 people from ancient times to the present day. Information contained in the dictionary includes birth and death years, professions, positions held, literary and artistic works, awards, and other achievements.

- **OKRA: Net Citizens Directory Service** (http://okra.ucr.edu/okra/): Contains over 800,000 e-mail addresses, and is constantly growing. Allows users to search its index for registered users, and allows users to submit their own database.

- **Purely Academic** (http://apollo.maths.tcd.ie/PA): Purely Academic is a database recently launched on the Web by a group of Students in Trinity College Dublin. It is a searchable database of Academic links, and links that are of interest to people involved in research.

- **SavvySearch** (http://guaraldi.cs.colostate.edu:2000/): SavvySearch is an experimental search system designed to query multiple internet search engines simultaneously. With help of a Search Form users can indicate whether they'd like to search for all or any of the query terms, and indicate the number of results desired from each search engine.
When a user submits a query, a Search Plan is created wherein the nineteen search engines are ranked and divided into groups;

  SIFT allows users to conduct searches and submit key words which skims thousands of Usenet news messages to find stories of interest. This free service will also notify you via e-mail once the articles you've requested are available;

  A collection of pointers to national and regional telephone directories on the Internet. Includes links to various US Yellow Pages, as well as a few directories for other countries such as Australia and France;

- **The WWW Virtual Library** ([http://info.cern.ch/hypertext/DataSources/bySubject/Overview.html](http://info.cern.ch/hypertext/DataSources/bySubject/Overview.html)):
  Another good place to start exploring if you have a particular topic in mind, the Virtual Library includes topical and geographical indexes to Web pages;

- **Whoopie!: Index of Audio and Video on the Internet** ([http://www.whoopie.com](http://www.whoopie.com)):
  A comprehensive audio and video search engine on the Internet. Live daily program guide of streamed audio and video. Allows a user to search both directories at once, individually, or browse through a number of categories including news, sports, medical, miscellaneous clips and educational documentary;

- **Yahoo!** ([http://www.yahoo.com/yahoo/](http://www.yahoo.com/yahoo/)):
  Created by David Filo and Jerry Yang from Stanford University in March 1994. Organized and structured using menus, instead of user prompts. Very easy to use, and quick response time, this site is the prime and most favourable location for web links for many users;

- **Yellow Pages & Web Page Search** ([http://superpages.gte.net](http://superpages.gte.net)):
  An online Yellow Page site which has a good search capability for 10 million yellow page listings and 50,000 Web sites.
Appendix 2 - General, introductory information about the Internet

Introduction

The Internet is the biggest computer network in the world. It consists of a large collection of computer networks of differing kinds which link the most varied sorts of machines with each other - from PCs to mainframes.

The Internet is an extraordinary network because it belongs to no-one and there is no central management. The individual networks which comprise the Internet are maintained and developed further on a local level (with, for example, the support of the government). There are, however, a number of organizations that monitor certain aspects or sections of the Internet but there is no central organization behind them.

Thus, there is an organization which looks at the direction in which the Internet should be heading: the Internet Society (ISOC). This organization consists purely of volunteers whose single aim is to promote the free exchange of global information by means of Internet technology.

The technical aspects of the Internet are regulated by the Internet Architecture Board (IAB). They design and approve new network protocols and applications which can be used on the Internet on a large scale.

Finally, the body which is responsible for the registration of all computers and networks that are linked to the Internet, as well as offering special consulting services to the participating networks, is called InterNIC.

The Internet has been around for more than 25 years. However, its incredible rise in popularity is a very recent phenomenon (of the last two to three years). The most important driving force behind this rising popularity is the WWW, which - when combined with a user-friendly and easy-to-use browser such as Netscape or Mosaic - is a very attractive medium to use.

The money being invested in the Internet by both the various governments and also businesses, could comfortably be called substantial (particularly in The United States). This is an indication that governments and companies are taking the Internet seriously and that it is going to play an important role in future (international) developments in all kinds of fields.

Internet Services offered

The Internet provides access to an unprecedented amount of information about the most various of subjects, as well as to a great quantity of software for the most various of applications. Moreover, there are several services on the Internet which can considerably facilitate finding this information and/or files. Besides this, there are all sorts of worldwide forms of communication possible, such as electronic post and keeping up with newsgroups. At the moment, the Internet's information and services are still mostly free to obtain and use but the chance is high that, in the near future, payment will have to be made for access and use. When this will actually happen depends on such things as how long it will take before payments can be made on the Internet in a safe way. There are facilities existing at the present time but these are not yet reliable and safe enough to allow intensive use.

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106 This information has been largely obtained from the NBBI WWW-service: http://www.nbbi.nl
In the following overview you will find a short account of the Internet’s most important features. We shall begin with the possibilities for (finding) information and files:

- **FTP:**
  FTP is an abbreviation of *File Transfer Protocol*. This protocol is a sort of language which enables machines to communicate with each other and makes it possible to connect to an external computer and then have files sent from this computer to your own machine (or vice versa). FTP makes it possible to exchange all sorts of files with every sort of machine - as long as the other machine also uses this protocol;

- **Telnet:**
  Telnet is a communications protocol which can make a connection to a computer elsewhere, after which it is possible to work on this external computer;

- **Gopher:**
  Gopher is a system for searching for information via the Internet. Gopher works with a simple menu screen for finding information and thus shields the user from the underlying search mechanisms. The information offered may be anywhere in the world but, in principle, the user will not notice this and therefore need not concern himself about where in the world the particular information he is looking for is located.
  As far as presentation is concerned, Gopher is simpler and more sober than a service such as the World Wide Web but, on the other hand, Gopher enables a relatively quicker search in most cases;

- **World Wide Web:**
  The World Wide Web (WWW for short) is a worldwide information system which can be approached via the Internet and which is based on Hypertext. A hypertext document is a text which includes so-called links which connect to other texts or text fragments, video or audio (extracts) or graphic objects such as pictures. Links are recognizable because they are displayed in a different way to ‘normal’ text - for example, underlined or in bold type - but a link can also be hidden behind a picture. WWW pages can be called up/found by using a so-called *Universal Resource Locator* (or URL for short).

As far as the communication possibilities are concerned, the following facilities are available:

- **Electronic mail:**
  Electronic mail (or e-mail for short) is a simple way of exchanging electronic messages between two people (or more). The only thing you need to know about the recipient of your message is his (worldwide, unique) e-mail address. Up till 1995, E-mail was far and away the most frequently used Internet service, but has been surpassed by the World Wide Web.
  Sending a message goes in much the same way as sending a ‘normal’ message by post, only much quicker. Another advantage of e-mail is that it is not bound to certain times: you can send a message whenever you want and the recipient can read it whenever it best suits them.
  So-called ‘mailing lists’ constitute a special use of e-mail. These are forums in which discussions on a specific subject are held via e-mail;

- **Usenet News:**
  Usenet News is a worldwide conferencing system that comprises thousands of discussion lists about specific subjects called newsgroups. There is a news group for just about every conceivable subject. This might be a serious subject (such as science) but it could also be a much more light-hearted one (such as food and drink). The newsgroups are arranged in a hierarchy, based on the newsgroup’s subject (computers, alternative, business etc.);

- **Internet Relay Chat:**
  Internet Relay Chat (or IRC for short) offers the facility of ‘chatting’ worldwide and with more than one user at a time. The ‘chatting’ takes place by typing in messages which the other participants see on their screens.
# Appendix 3 - Internet Growth Figures

These growth figures have been taken from [ZAKK96]. See this document for further and more detailed information. On the next page a column chart is included of the number of hosts from January 1989 up till January 1996.

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Figure 3 - Number of Internet hosts