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SOFTWARE AGENTS IN ELECTRONIC COMMERCE

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ABSTRACT

Software agents are computer programs that run in the background and perform tasks autonomously as delegated by the user. Although there has been much research on this topic recently, usable software agents are at an early stage of development, and are only now starting to appear in real applications. A fruitful application area for software agents is in the area of electronic commerce where agents can help buyers and sellers deal with the flood of information that can be exchanged and processed. Current developments in agent technology are reviewed, however this paper takes a product-focused approach to examine the functions that agents can perform in the commerce process. A model of decision support systems is used to classify agents as providing search support, choice support and interface support. In order to delegate activities to software agents, the user must trust that the agent will perform in a predictable and controllable manner. A framework based on marketing research is used to identify purchasing situations where this trust can develop and where agent technology is therefore likely to be adopted.

Key Words and Phrases: Software agents, decision support systems, buyer behaviour

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1. Introduction

This paper explores potential applications for the use of software agents in e-commerce (electronic commerce). E-commerce is the use of information and digital communications technologies to network economic activities and processes, in order to reduce information-related transaction costs or gain a strategic information advantage. It involves a family of innovations that began with the implementation of EDI (electronic data interchange) and electronic mail for commercial applications in the 1970s. At the current rate of growth, a substantial proportion of world business will be transacted by e-commerce by 2005. The use of software agents could be a major innovation in supporting computer applications in e-commerce, but this technology is currently at a very early stage of development, with few applications beyond the prototype stage. In this paper we attempt to identify where software agents might fill a genuine need in e-commerce, thereby being accepted by the community of participants.

Commerce is described as a process that includes activities such as marketing, sales, transactions and customer support. E-commerce is this same process, enabled by the use of communications and information technology. Moving these activities to an electronic platform such as the Internet will change this process in many ways. Much of the current literature does not make a clear distinction between business-to-consumer (B2C) and business-to-business (B2B) e-commerce. Significant differences exist, and these differences will mean that e-commerce and the use of agents will evolve differently in these two classifications. General issues in e-commerce, and issues specific to each of B2C and B2B commerce, will be discussed as they relate to agent development and design.

Current research and development on software agents are summarized in an overview of the subject. A DSS model is used to categorize software agents according to whether they support search, choice or interface activities. The buyer must be able to develop trust in the agent's behaviour before delegating activities. In order to develop trust, the buyer must be able to understand, control and predict the behaviour of agents. [Erickson, 1997; Malone et al, 1997] Frequency of purchase and perceived risks are two characteristics of a purchasing situation that will determine how this trust can develop. Marketing researchers have studied how both frequency of purchase and perceived risk influence the search and choice behaviours of buyers. This information is used to suggest ways to design agents that represent the purchasing problem in a form that is understandable and predictable for the buyer.

Much of the original work on agents arose from within the artificial intelligence (AI) field. AI encompasses many different fields of study including cognitive psychology, linguistics, mathematics, and computer science. This diversity of viewpoints contributes to a healthy

examination of where and when agents are useful, and how humans are likely to accept and use them. As an example, Lanier and Maes [1997] debate whether intelligent agents will augment human action, or whether humans will modify their behaviour to make the agent seem intelligent.

However, the AI community brings some "baggage" to the study of intelligent agents. The study of AI has been saddled, rightly or wrongly, with an image of over-promising and under-delivering. "Many of the same people who have made exaggerated promises for artificial intelligence, natural language processing, voice and handwriting recognition, and robots, are now pushing agents." [Schneiderman, 1997] Most AI applications have had very limited success in the real world. As a result, the arrival of intelligent agents is seen by some as a "renaissance" for AI. What can result is a tendency to develop "solutions looking for problems" as researchers latch on to their favourite AI tecnologies and build agents based on them. However, for any innovation to succeed, it must fill a genuine need. In this paper, a product-focused approach is used to build a framework that examines applicable domains and a classification system that concentrates on function, rather than technology.

2. E-Commerce

In order to examine potential applications for the use of agents in e-commerce, we need to understand the nature of e-commerce and its relevant characteristics. In the following discussion, commerce will be understood as "the process flow associated with a commercial relationship or transaction", including activities such as purchasing, marketing, sales, and customer support [Nissen, 1997]. E-commerce is then this same process, enabled by the use of communications and information technology.

At a minimum, the commerce process involves two participants, a buyer and a seller. Many descriptions of the commerce process take the view of only one of these participants. Marketing mix models examine the process from the seller's point of view, and buyer behaviour models examine the process from the buyer's point of view. Nissen [1997] proposes an integrated model of the commerce process showing what is exchanged between these two participants at each stage of

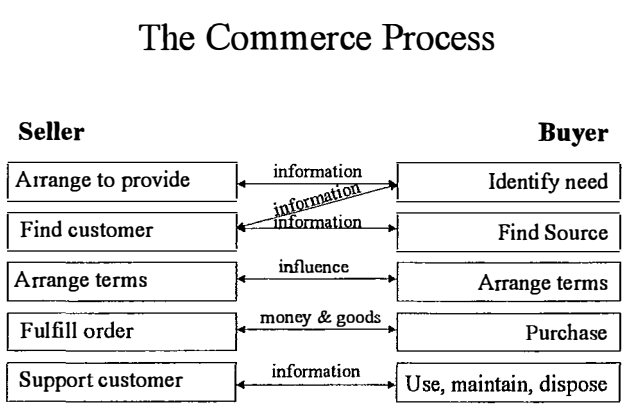

Figure 1 [from Nissen, 1997]

the process. (Figure 1)

There are significant differences in how the commerce process is conducted within the business-to-consumer (B2C) and the business-to-business (B2B) environments. As examples of these differences, in business-to-business marketing [Gross et al, 1993]:

- The buying unit is a group, not an individual
- Buyer-seller interaction is relationship-based, not transaction-based
- Personal selling is the predominant form of promotion as opposed to mass advertising
- Markets are more concentrated, and key accounts are important
- There is greater purchase involvement and purchase risks are higher
- Decision processes are complex and lengthy
- There are more pre- and post-transactional services than in business-consumer commerce
- Competitive bidding and price negotiation are common

The differences between business-to-consumer markets and business-to-business markets mean that while some of the effects of E-commerce will be common to both markets, many of these effects will vary in degree between the two markets, and still others will be present in only one type of market. Much of the current literature does not clearly address these differences. While there are significant additional challenges to implementing B2B e-commerce, it represents a much larger part of economic activity than B2C. In 1998, U.S. Internet B2B commerce was five times the value of B2C commerce, and is expected to grow to ten times the value by 2003.[1]

Products that have significant information content, or where information provides significant added value, will find e-commerce more valuable than commodity markets. [Bloch et al, 1996] Much of the additional pre and post-sale services in B2B marketing are information-related. An argument can also be made that e-commerce will result in the convergence of traditional consumer and business marketing. The need to engage in two-way "conversations" with customers, instead of just broadcasting messages, is similar to practices associated with personal selling. [Deighton, 1997]

B2C e-commerce, and many of the recent developments in B2B e-commerce are based on Web technologies. Nissen's model clearly shows that information exchange forms a large part of the commerce process. Because of the information-rich nature of the Web, we will focus our attention in these areas. The Web relies on a "pull" model of information flow so the buyer is expected to drive the adoption of new technologies such as software agents, however sellers and intermediaries can have facilitating roles in the exchange of information.

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[1] University of Texas survey, http://www.internetindicators.com

2.1 General Issues

Yuan, Archer and Bassett [1998] discuss the effects of E-commerce on the various elements of the marketing mix, including the traditional 4-P's (Product, Place, Price and Promotion), as well as Partners (alliances, intermediaries) and People (the target market). A summary of the changes expected to come about with the introduction of E-commerce is provided in Appendix A. Virtual communities, electronic markets, and the changing role of intermediaries are three areas of current e-commerce research that relate to the discussion of agent technology.

2.1.1 Virtual Communities

A virtual community is an online environment where people and business entities with common interests can share information. Virtual communities exist in both the B2C environment (e.g. usenet groups) and the B2B environment (e.g. Intranets, Extranets, and business networks). These communities are expected to become an important new source of information in the commerce process. On balance, virtual communities are expected to increase the power of customers in commercial transactions. Integrating content and communication adds value as members provide a fuller range of information and independent perspectives. Search costs are reduced, as product information is readily accessible. The distinctive focus of these communities can create niches of customers with very specific needs, reducing search costs for sellers who can meet those needs. Increased interaction with customers provides sellers the opportunity to improve products and increase their levels of customization. Market expansions (in both supply and demand) can result from lower costs. [Hagel & Armstrong, 1997]

2.1.2 Electronic Markets

The study of electronic markets examines e-commerce using micro-economic theory. Reduced search costs (both for the buyer to obtain product information and for the seller to communicate this information) make markets more efficient. The potential for price discrimination may be facilitated through customized products and better consumer profile information. Price discovery can be accomplished through on-line auctions and negotiations. Dynamic pricing and more efficient markets could potentially change the microstructure of markets. A number of researchers are studying "hypereconomy" or super-efficient markets, especially when enabled by agent technologies. [Chislenko, 1998; Kephartet et al, 1998]

Economic market theory also examines the question of the "optimal number of suppliers". [Bakos & Brynjolfsson, 1993] Conventional market theory says that "technological developments that lower the cost of acquiring information about prices and product

characteristics in a given market should increase the number of suppliers considered" [p.39]. On the other hand, the "increasing importance of non-contractible investments by suppliers, such as quality, information sharing and innovation" [p.42] increases the supplier's bargaining power and leads to a fewer number of suppliers.

A survey conducted by CommerceNet and the University of California at Berkeley found that large companies generally have closer relationships with suppliers, and see use of the Internet as increasing the number of suppliers they deal with. (It is acknowledged that closer relationships may be the result of using traditional EDI and the investment and commitment required by both parties to implement such a system.) Smaller companies, with more distant relationships, believe that use of the Internet will strengthen these relationships and reduce the number of suppliers they use. [Segev, et al, 1997]

2.1.3 Intermediaries

While many predict that the Internet will lead to disintermediation, Sarkar, et al [1995] consider important social and institutional factors, and allow for different types of transaction costs to change in differing manners. As a result, they conclude that intermediaries may be threatened in some areas, may be advantaged in others and a new form of intermediary - the cybermediary - will develop in still other situations. New ways of bundling products and services are facilitated by reduced transaction, distribution and "binding" costs, and new intermediaries are providing these bundles of services. [Bakos, 1998] An example is Auto-by-Tel, which combines consumer research, recommendations, price discovery, ordering, financing, and insurance services. Bakos notes that this is "everything but the test drive". Auto-by-Tel is currently "free-loading" this service from traditional dealers, but other arrangements will have to emerge, such as a fee back to the dealer, or to an alternative provider, such as a car rental company. The issue of "agent ownership", and the role of intermediaries in agent applications is discussed in Section 6.1.

2.2 Issues in Business-to-Consumer E-commerce

Examples of further research into the effects of e-commerce in business-to-consumer markets are plentiful. Two specific areas must be considered in the design of agent applications.

2.2.1. One-to-One Marketing

Hoffman and Novak [1996] describe how the traditional mass media communications model for consumer marketing is one-to-many, assuming a passive, homogenous audience. The Internet requires a new, many-to-many model, with two-way communications through a

computer-mediated environment. Customer power is increased through the possibility of relative anonymity, which "hinders personal selling at the same time as it encourages negative word-of-mouth activity." [p. 3] As a result of these observations, the authors argue that firms should be moving to a "market orientation" where the organization is focused on collecting information about current and future customer needs. This "new paradigm" will mean including the customer in the process of information sharing for both product and market development.

Bayers [1998] discusses how information gathering on the Web has not yet provided the promised level of service, or even matched that available from traditional sources. Successful (i.e. high-traffic) sites are growing so fast that they have not been able to assign resources to the information management problem, and the amount of data collected is so great that "the ability to warehouse, let alone mine" the information has been exceeded. He also believes that the traditional mass-market model is so entrenched that marketers cannot see past their old paradigm of demographic proxies for the ideal customer. Negroponte [1995] makes a distinction between narrowcasting (the targeting of small demographic groups) and the ultimate goal of individualization. Individualization uses information about the individual and events "that have no demographic or statistical meaning". [p.164] It is hoped that agent technology will allow this type of personalization to be built into e-commerce systems.

2.2.2 Privacy

Today, consumers "receive very little of the value their information and transaction histories represent... This will change as customers become more sophisticated capturers and managers of their own information". [Hagel & Rayport, 1997, p.8] Smart cards and financial-management software packages let consumers collect much more integrated information about themselves than was ever before possible. Consumers want this information to analyze spending and investment decisions. They may soon realize that it is also of value to businesses, and find ways to exchange it for something of value to them. This assumes that the issue for the consumer is not primarily one of privacy, but one of value in exchange. Once an exchange is negotiated, the only privacy issue remaining is secondary release of the information. [Hagel & Rayport, 1997]

2.3 Issues in Business-to-Business E-Commerce

Another set of issues become predominant when we look at what is changing in business-to-business e-commerce. With higher market concentration, both buyer and seller generally have a stronger commitment to the commercial relationship.

Sollish [1998] summarizes the state of e-commerce in business-to-business as: "consultants are proposing wildly insane growth numbers, the existing system is fragmented, costly and cumbersome, there are no standards, and effective leadership has just appeared." Preliminary results of a field study, conducted in cooperation with CommerceNet and the Journal of Internet Purchasing can be found in Segev, et al [1997]. In this study, the telephone, fax machine, and written documents were cited overwhelmingly as the prime technologies used in B2B procurement in all sizes of companies.

2.3.1 Process and Implementation Costs

B2B commerce involves integrating the buying and selling activities of the commerce process into the back-office processes of the respective organizations, primarily through the purchasing and sales organizations.

The University of California at Berkeley has studied how e-commerce is expected to affect the buying organization. Their description of the internal processes of the buying organization indicates the complexity that must be considered in this environment.

> "The workflow routines that companies install to handle procurement are frequently very complex, time consuming, error-prone and expensive. Accounting for the diversity and value of the items purchased as well as for situational requirements, they usually involve a large number of participants, such as end users, purchasing department, approval manager, receiving dock, and accounts payable." [Gebauer et al, 1998 (2), p.2)

Selling organizations have similar internal processes that must be considered in the introduction of e-commerce. The problems facing selling organizations are the subject of discussions by the Business Marketing Web Consortium of the Institute for the Study of Business Markets, lead by Pennsylvania State University.[2]

Because of the need to integrate commerce activities back into the seller's and the buyer's organizations, growth in electronic commerce in business-to-business activities is hampered by prohibitive costs, despite the imminent arrival of lower cost ways to transmit documents through the Internet.

> "Even with current Internet technology, the cost to put a medium sized business and all of its vendors on line, using standardized vendor catalogues, common interfaces, including applications for receiving, billing, back ordering and returning goods, appears to be absolutely preposterous. Most US companies have yet to implement enterprise software, which by best estimates can run $2 to $3 million a pop. But the cost of ERP implementation pales compared to the scope of EC. One EC vendor estimates it will cost about $6 million, when the last 't' is crossed." [Sollish, 1998]

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[2] ISBM Business Marketing Web Consortium, http://www.smeal.psu/isbm (Viewed July 15, 1998)

2.4 E-commerce Standards

A low cost, easy to implement solution for e-commerce is required before small and medium business will be able to enter the e-commerce arena. While Electronic Data Interchange (EDI) and its standards have been adopted by many large businesses, the high cost to implement traditional EDI has been a barrier to smaller businesses.

2.4.1 Extensible Markup Language (XML)

Perhaps the most anticipated new standard for the WWW is "eXtensible Markup Language (XML). The Standard Generalized Markup Language (SGML) is a meta-language for defining markup languages. SGML considers documents to be composed of a series of entities (or objects) that contain elements. The elements can be assigned attributes (or properties) that describe how it can be processed. A Document Type Definition (DTD) outlines rules about the types of entities, elements, attributes, and notations allowed in a particular type of document. HTML 2.0 and HTML 3.2 are DTD's and are therefore considered to be applications of SGML.

However, HTML is very limited in its description of the structure of a document. This is adequate for the unstructured, free text information that composes much of the Web's content. However, semi-structured information, such as catalogue records, financial transactions, or even books and technical manuals would benefit from additional structural tagging. [Light, 1997] As well, in the interest of robustness, most current Web browsers ignore the HTML DTD, meaning that the information that it conveys cannot be used to assist in searches. It also allows new document elements such as frames to be adopted without a formal DTD. (HTML 4.0 provides a DTD that includes frames, but the standard was developed long after the use of frames became common.) [Light, 1997]

The World Wide Web Consortium (W3C) teamed up with a group of SGML experts to develop a new markup language that would incorporate some of the power of SGML yet be simple enough for widespread implementation on the Web. The result of this collaboration was the initial specifications for XML, approved in November 1996. The XML 1.0 recommendation was adopted in February 1998.

XML is a simplified subset of SGML, formally known as an SGML profile. By defining DTD's within this subset, developers can create XML applications. Unlike HTML, XML does not allow "minimization" where end tags can be omitted. This allows for cleaner processing of the structural information contained in the tags. XML documents are "well-formed" when their structure conforms to the XML standard. XML documents can also be validated against their specified DTD. [Light, 1997]

W3C is redeveloping HTML to conform as an XML application. Figure 2 shows other XML applications being developed. The Resource Description Framework (RDF) uses XML to code meta-data about a document. RDF has applications in indexing, querying, censoring/filtering, and privacy protection. [W3C-(1); Jenkins et al, 1999; Decker (S.) et al; Duetsch et al, 1999]

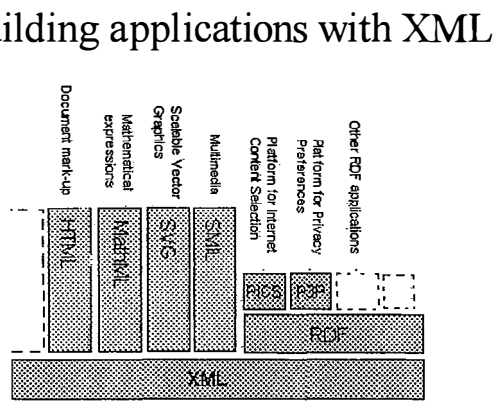


Figure 2 (from http://www.w3.org/XML/Activity)

A key feature of XML is the ability to create user-defined tags to describe elements within the document. The definitions for these elements can be declared within the tag itself through an internal reference within the document, or a reference can be made to an external resource that contains the declaration. These external references will allow communities of interest to create a set of elements for use within the community. An example of this can be found at http://www.xmlnews.org/intro.html where a set of XML standards have been developed to define the content of news stories, making it easier for news providers and news consumers to share and process information.

HTML also has other limitations. Only one type of simple link is defined. The presentation of the document cannot easily be adjusted by the user (i.e. for special requirements) or by the author (i.e. to adapt the output for different terminal devices such as handheld computers or low resolution TV screens). [Light, 1997; Halfhill, 1999] The W3C is coordinating further work in these and many other XML-related areas, including:

- namespaces (the external resources that define sets of elements for a particular domain),
- XML linking (using XML elements to define different types of links),
- XML Processors (allowing existing software such as word processors or OODBs to interpret XML documents)
- XML style sheets (to be specified in the document or declared by the user).

The status of the W3C's XML activities can be found at http://www.w3.org/XML/Activity.

2.4.2 XML/EDI

The speed at which the Internet community adopts XML is expected to have a significant impact on the growth of business-to-business e-commerce. The XML/EDI Group is an ad hoc group formed in 1997, providing a forum for the development of XML/EDI standards.

Traditional EDI provides standardized message formats and a dictionary of data elements. Much of the cost of implementing traditional EDI results from the need to translate information contained in the user's system into the format required by EDI standards and to translate EDI messages into the format required for processing and presentation by the recipient. XML/EDI standards will incorporate EDI data element definitions and message formats by defining corresponding elements for use in XML documents and providing templates, including DTD's, for EDI message formats. XML/EDI will therefore be backward compatible with traditional EDI.

However, XML/EDI will allow users to define their own business documents and processes, and use "repositories" to reference these documents to external dictionaries, DTDs, business objects and trading partners if required. In this way, the XML/EDI group intends that their framework will be open and dynamic so new processes, technologies and parties can be introduced easily. Users will also have the flexibility to implement part or all of the functionality that the framework provides. [XML/EDI, 1998]

2.4.3 Ontology

While XML tags such as <Order-No> or <author> may be meaningful to a human reader, they do not carry any semantic value when the message is received by a machine. Cover [1998] explains that XML "formally governs syntax only – not semantics" and that "shared ontologies are not the domain of XML". While providing "descriptive markup" this "does not in itself enable blind interchange or information reuse." Cover elaborates that "(p)articipants in a partner or network relationship need assurance that transactions will be negotiated meaningfully and correctly because all participants mean the same thing in the use of ... markup constructs."

Ontology.Org is a research forum addressing ontologies required for electronic commerce. It notes that:

> "The terms in an ontology are selected with great care, ensuring that the most basic (abstract) foundational concepts and distinctions are defined and specified. The terms chosen form a complete set, whose relationship one to another is defined using formal techniques. It is these formally defined relationships that provide the semantic basis for the terminology chosen." [Smith]

The need for agents to be autonomous and adaptable will require them to operate at a high level of abstraction. For this reason, Ontology.Org believes that "shared foundational ontologies" will be necessary for agent-mediated electronic markets. [Smith] These detailed unambiguous semantic models need to be developed for vertical use within industries and for horizontal use across industries where common processes can be found.

3. Software Agents

3.1 What is a software agent?

The introduction to almost every paper on software agents starts out with this question. Software agents are still in the early stages of their evolution. Some of the first articles on the subject (circa 1994) describe as agents, application software features that are no longer considered to be agents. Even today, Java applets, software daemons, wizards, cookies, Internet search engines, and viruses, could all be considered as software agents under the multiplicity of definitions available, yet few authors consider these entities to be agents. Bradshaw [1997] argues that there are two approaches to defining an agent: 1) as a description, and 2) as an ascription.

Most of the definitions proposed in the literature are of Bradshaw's "agent as a description" form. In these definitions, various attributes are listed to describe what is meant by the term "agent", often including some or all of: autonomous, persistent, mobile, intelligent, learning, responsive, pro-active, communicating, social, and rational. These characteristics are useful in defining sub-categories of software agents, such as mobile agents, intelligent agents, and "multi-agent societies" of social and communicating agents.

An agent is defined "as an ascription" through an attribution by the user; if the user <u>believes</u> that that he or she has delegated a task to the software entity, it is an agent. In this case, an agent is seen as a black box, where the user does not know (or want to know) how the agent is performing a task, only its outcome. While the user will often choose to view the agent as a black box, it is argued that an agent should be designed as a glass box, where the user can see, understand and modify how the agent is completing its task when desired. See Section 4 on Agents and Decision Support for more on this topic. Using a similar approach, Lieberman suggests that an agent is seen as a "helper" whereas an application is seen as a "tool".

The "definition as an ascription" approach to defining agents allows for the user's understanding of the term to evolve as the development of agents evolves. This approach is compatible with the evolving nature of what is considered to be artificial intelligence. "Throughout its history, artificial intelligence has focused on problems which lie just beyond the

reach of what state-of-the-art computers could do at that time. As computer science and computer systems have evolved into higher levels of functionality, the areas which fall into the domain of AI research have also changed". [Bigus & Bigus, 1998, p.xxiv] A similar pattern is seen in the development of software agents.

This paper will not attempt to add to the accumulation of definitions. For our purposes, Bradshaw's definition by ascription will suffice. If the user believes that he/she is using an agent, then an agent it is.

3.2 Are all agents intelligent?

The concept of agency is often assumed to imply some sort of knowledge base and intelligence. As such, the term "intelligent agent" is often considered to be interchangeable with the term "software agent". However, we can have agents with limited intelligence, and intelligent programs that are not agents. IBM's model of intelligence, agency and mobility is useful to clarify this distinction, where agency refers to the agent's degree of autonomy and authority. Using only the agency and intelligence dimensions, the model distinguishes between a conventional expert system, non-intelligent or fixed-function agents, and intelligent agents as shown in Figure 3. [IBM Open Blueprint]

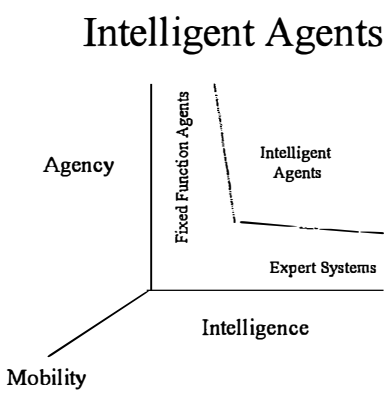


Figure 3 (from IBM Open Blueprint)

Artificial intelligence consists of a knowledge base and an intelligent processing system. Techniques from the field of knowledge representation, including the use of predicate logic, frames, semantic nets, or Bayesian networks, are used to build a knowledge base. Problem solving through search strategies, reasoning systems using rules or cases, and learning systems using neural networks or genetic algorithms can all be used to provide intelligence. The level of intelligence required in the agent is related to its degree of autonomy and its mobility. If an agent will encounter a variety of situations it will require a larger knowledge base and a more flexible reasoning system. Mobility however requires compact code that may limit these features. [Bigus & Bigus, 1998]

Agents are likely to evolve from using basic intelligence techniques, to more powerful techniques as users become accustomed to the concept. Rules may not be the most sophisticated

reasoning system, but IBM research has shown that rules are understandable even to non-technical users and rule systems can be adapted for user editing. "Pure" (yes/no) rule-based systems are predictable and explainable, which will encourage user acceptance. Learning systems and the introduction of "probabilistic-flavor knowledge" should be considered as future enhancements. [Grosof, et al, 1995] It is noted that the "current crop of agents are 99% computer science and only 1% artificial intelligence" [Etzioni, 1997] and many researchers believe that less intelligent agents, or agents with severely limited intelligence may be the most acceptable and useful.

Etzioni [1997] explains that the emergence of the World Wide Web provides an opportunity of immense proportions for the study and development of working AI applications in the form of agents. He warns, however, that AI researchers must recognize that the WWW is a very demanding environment. Its users insist on robustness, speed, and added value to a degree unheard of in the traditional research environment. He suggests a "useful first" approach. Traditionally, the study of AI has tried to model human intelligence and promised that useful applications would follow. To take advantage of the opportunity afforded by the WWW, researchers should be designing agent applications that are useful now, and promise to add more intelligence in the future.

An important carry-over from the field of artificial intelligence lies in the distinction between deliberative and reactive agents. While classical AI concentrates on representing an explicit model of the world within an intelligent system (the "top-down" approach), researchers in robotics and distributed AI propose building a model of the world in a "bottom-up" fashion, or purely from sensory input.

A deliberative agent follows the classical "top-down" AI tradition and contains a model of its environment that it uses for planning and decision-making. Deliberative agents are also commonly referred to as Belief, Desire, and Intention (BDI) agents. Brenner et al [1998] point out that deliberative agents reflect many of the problems that classical AI has encountered. Deliberative agents must be designed for a specific problem area, and are difficult to employ in dynamic, rapidly changing environments.

A reactive agent is a task-specific stimulus/response system, following the "bottom-up" AI approach. A reactive agent relies on its interaction with the environment and the coordination of numerous agents (or "competence modules") to produce intelligent behavior. Reactive agent architectures allow for quick response in dynamic environments, and are more fault-tolerant and robust than deliberative agent architectures. Reactive agents, however, cannot formulate plans or

produce optimal solutions to problems. [Brenner et al, 1998] The distinction between deliberative and reactive agents reappears in the discussion of agent architectures in Section 3.8.2.

3.3 What do agents do?

As expected, there are almost as many classification systems for agents as there are definitions. Franklin and Graesser [1996] suggest a taxonomy for autonomous agents. Bird [1993] has worked on a taxonomy of multi-agent systems.

The distinction between simple agents and multi-agent systems is important. Simple agents have developed out of the traditional areas of artificial intelligence and computer science. They must interact with their human "user" and with traditional software components such as operating systems and databases. Multi-agent systems have evolved from the study of distributed intelligence and distributed programming. Brenner et al [1998] propose a classification system similar to the IBM Open Blueprint model, but substitute a simple versus multi-agent dimension for the autonomy scale. This is shown in Figure 4.

Bigus and Bigus [1998] suggest three ways to classify agents:

- by their capabilities (i.e. intelligence, agency, mobility, as in the IBM model),
- by their processing strategies (e.g. reactive agents, goal-directed agents, collaborative agents)
- by their processing functions (e.g. interface agents, information agents)

Classification matrix for agent systems

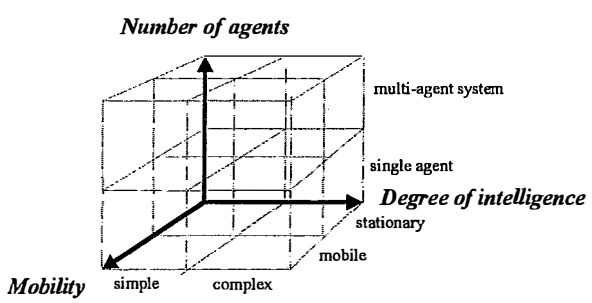


Figure 4 (from Brenner et al, 1998)

Brenner et al [1998] also classify agents by processing function, as information agents, cooperation agents, and transaction agents. They emphasize that a specific agent may fall into more than one category.

From the buyer's point of view, the commerce process is a decision-making process. Taking a "process" point of view it will be helpful to use a classification system that ties in with the "definition by ascription" concept, where the user sees the agent as doing something on his or her behalf. We want the classification system to answer the question "What does the user see the agent as doing on his or her behalf?" as opposed to how the agent is actually performing this function. In Section 5, we propose a classification system, by processing function, and based on the DSS model.

3.4 Why are agents useful?

Jennings and Wooldrich [1998] give three reasons why agents are considered an important development in today's information systems environment:

> **Open systems** – Open systems such as the Internet are a dynamic, unpredictable environment. This requires flexible software that can adapt to changes, and negotiate and cooperate with other applications in the environment.
>
> **Complex systems** – In complex systems, modularity allows specialized components to be designed more easily. Agents are a useful abstraction to design and manage these modular components.
>
> **Ubiquitous systems** – As information systems are used in more and more applications, the need to "delegate, not manipulate" [Negroponte, 1995] becomes critical to utilize the full power of current and future applications. The human-computer interface is still a bottleneck for both experienced and naïve users.

Bradshaw [1997] echoes these points, by explaining that agents help to reduce the complexity of distributed systems (open systems and complex systems) and improve the user interface (ubiquitous systems).

The convergence of computer and communications systems has also led to an increase in "mobile computing". IBM's Open Blueprint suggests that mobile computing has created a need for "surrogates within the network, that represent mobile users...even when the mobile user is disconnected" or operating "over a variety of media, with different bandwidth, reliability, and security characteristics".

Brenner et al [1998] state that "agents should perform certain tasks for their users that they cannot undertake themselves because of insufficient time or lack of knowledge." [p.20] This may be a useful distinction in later discussions outlining the requirements for different agent applications. An agent that is employed to save its user time is likely to be very different from an agent that is employed to supplement the user's knowledge.

It has been predicted that, by 2006, agent-related products and services will bring global revenues of $4.7 billion to basic software developers, agent technology developers, and downstream product developers and service providers. This would be an increase from $19 million in 1996. [Stark, 1997]

3.5 When should agents be used?

We start by identifying significant conditions that will be necessary for the adoption of software agents. Jennings and Wooldrich [1998] suggest that agents are appropriate when there are widely distributed resources. The nature of information on the Internet certainly fulfills this

condition. They also suggest that agents will be more easily accepted when there is a natural metaphor for their use. The presence of human agents in traditional commerce provides a wide variety of metaphors for agent applications.

A third condition for agent application is that the user is able to develop trust in the agent's abilities before comfortably delegating tasks. This requires that the delegated activity be repeated often enough that the user can verify that the agent is making reasonable and acceptable decisions. [Jennings & Wooldrich, 1997] Repetitive activity is also required for agents that must "learn" from their users' actions. [Maes, 1997]

Whether a user is willing to delegate an activity to an agent will also depend on the risks involved and the consequences of errors. In analyzing their GroupLens agent, Konstan, et al [1997] looked at the consequences of recommendation errors in different Usenet subject groups. A sample item can be desirable or undesirable, and the agent can predict it to be good or bad. When the agent predicts a desirable item to be good, the result is a hit. Predicting an undesirable item to be bad is a correct rejection. Errors occur when an undesirable item is predicted to be good (a false positive), or when a desirable item is predicted to be bad (a miss). The consequences of each type of error will vary with the domain. A recommendation for a restaurant that turns out to be undesirable (a false positive) is costly in time and money, whereas the time that it takes for the user to reject a recommendation of an undesirable research article (another false positive) is minimal. Similarly, missing a legal citation could have serious consequences, whereas missing a recommendation for a good music CD is less important. The framework for this predictive utility analysis is shown in Figure 5.

Predictive Utility Framework

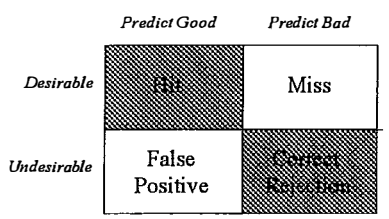


Figure 5 (from Kostens et al, 1997)

3.6 Security

The issue of trust has been discussed above, as far as transparency in design and allowing the user time to see that the agent is doing reasonable things. In the design of agents, requirements testing and the predictability of agent actions raises important issues not only for the user, but also for "host" systems managers.

The premise of "ethical agents" started with the original "spiders" sent out to search the early WWW and collect data for search engines. Koster [1993, 1994] developed Guidelines for Robot Writers and the Robot Exclusion Standard. While recognizing the need for automated collection of data in order to manage the resources of the WWW, these guidelines were necessary to protect web servers from debilitating visits from spiders. In this and other guidelines and proposed standards, it is suggested that agents be designed with qualities such as safety, tidiness, thrift, vigilance, openness, appropriateness, and respect. [Eichmann, 1994]

Many of the security measures being developed for the Internet (such as encryption, message authorization codes, digital signatures, and certificates) can be used to ensure that messages from stationary agents are not intercepted or interfered with. When mobile agents are deployed, the host computer must be able to identify both the agent and its owner and be able to validate the internal structure of the agent and its authorizations in order to grant it access rights. The host may also be required to monitor the activities of the agent to ensure that it does not change its procedures during its visit. The agent must also be able to verify the identity of its host. [Brenner et al, 1998]

Research into artificial life and multi-agent societies, although generally conducted in closed systems, has investigated various social mechanisms for controlling inefficient or malicious agents. Rasmusson and Jansson [1996] propose that "social control" is the natural process for policing open systems such as the Internet. They argue that social or soft control is more robust than hard control, where access is controlled centrally. With the commercialization of the WWW, social control is evident in electronic versions of the Better Business Bureau (e.g. www.bizrate.com), and the policies posted on commercial auction sites. As an example, the eBay auction site (http://www.ebay.com) has buyers submit references on sellers they have dealt with.

3.7 Agent Standards

Standards will address some security issues. In this early stage in the development of agent technology, neither formal nor de facto standards exist. Agents represent a major innovation in distributed computing systems. As a result, new models, architectures, protocols, languages and ontologies will be required. If the Internet is expected to be the domain where agents will be employed, the need for open standards is critical.

Three organizations that are dealing with the early stages of standards requirements for agents (and notes from their recent meetings and workshops) can be found at:

- The Agent Society (http://www.agent.org/society/meetings/workshop9702/report.html),
- The Foundation for Intelligent Physical Agents (FIPA) (http://drogo.cselt.stet.it/fipa/yorktown/nystditems.htm),

- The Agent Mediated Electronic Commerce Special Interest Group of the EU supported AgentLink (http://www.iiiia.csic.es/AMEC/BrusselsSummary.html and http://www.iiia.csic.es/AMEC/LondonSummary.html)

The history of information systems tells us that standards only develop when something is tried and works. If successful, then it (or modifications to it) are adopted and become a standard. Some examples of promising research and areas of current development follow.

3.8 Agent Development

3.8.1 Agent Models

Erickson [1997] argues that software that learns and adapts its behaviour to the situation could be portrayed as a "smart object". However, he advocates a clear distinction between object and agent models. Users' expectations of an object (that it is visible, passive, has a location, and can contain things) allow them to manipulate and investigate even unfamiliar objects. He proposes a similar model for agents, where it is understood that an agent can notice things, know things, take actions, and go places. Users should then be able to look at an unfamiliar agent and find out what things it will notice, what things it knows, what actions it can take and where it can go, using similarly general mechanisms for access and control.

Brenner et al [1998] state that the analysis and design of "(a)gent systems, from their nature, can be assigned to the object-oriented systems. Their objects, the agents, consist of attributes and methods, and communicate with each other by invoking methods or by sending messages, and use classical OO concepts, such as inheritance, data encapsulation or aggregation." [p.154]

The general model of object-oriented (OO) methods includes:

- a base model describing the objects and their classes, attributes and methods,
- a static model representing relationships such as inheritance, aggregation, association, and subsystems, and
- a dynamic model representing the processes and flow of information between objects (messages and interaction) and within objects (internal structure and procedures).

Brenner et al [1998] describe work by other researchers, proposing agent-oriented models that consider the more complex internal structures of agents and their behaviour patterns. For example, while an object is passive, and its methods are activated only on receipt of a message, agents may be proactive and will react differently to the same message at different times. The communication between agents is also different from the communication between objects.

Typical agent communications involve the exchange of more content (i.e. knowledge, intentions, goals), and use "complex communications protocols and dialogue structures." [p. 158]

Burmeister's framework for agent-oriented design proposes three models, similar to those of OO-methods [Brenner et al, 1998]:

- The Agent model describes the agents and their internal structures (combining the OO base model and the internal portion of the OO dynamic model).
- The Organizational model describes the static relationships between agents and agent classes (similar to the static model of the OO methods).
- A Cooperation model describes all of the interaction and cooperation processes between agents.

3.8.2 Agent Architectures

Brenner et al [1998] describes a number of architectures that have been developed for agents and agent systems. The type of agent (reactive or deliberative) is a major determinant of the architecture to be used when designing individual agent applications.

Architecture of a deliberative agent

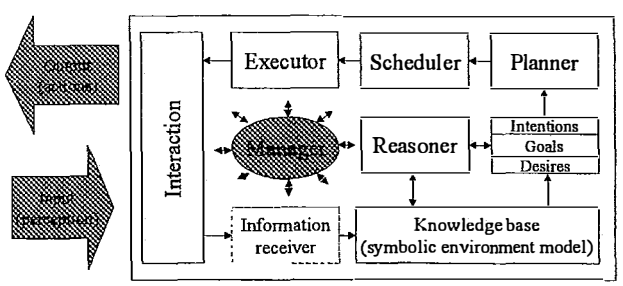


Figure 6 (from Brenner et al, 1998)

Deliberative agent architectures must include a knowledge base that forms the beliefs of the agent and a reasoning/planning component that is able to derive desires, goals and intentions from the agent's beliefs and formulate plans. The central components of a deliberative agent architecture are shown in Figure 6.

Reactive agent architectures consist of a number of task-specific competence modules that receive input from the environment through sensors, and use actuators to perform their derived actions. Competence modules can communicate with each other directly or through actions in the environment. This is a decentralized structure, allowing only for one-to-one communication between components. See Figure 7.

The advantages and disadvantages of deliberative and reactive architectures have led to the development of a number of hybrid architectures. These generally consist of reactive components at lower layers, and deliberative components at higher layers. The Interrap architecture, developed by Muller, is shown in Figure 8, and adds a communication and coordination layer at the highest level. A problem is passed up through successive layers based on

Architecture of reactive agents
(based on Brooks, 1986)

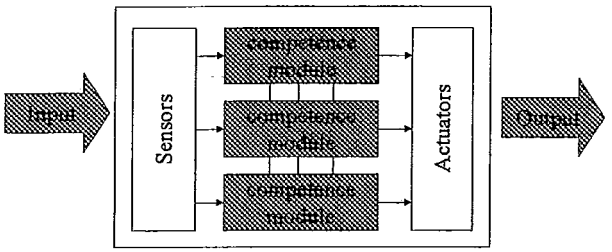


Figure 7 (from Brenner et al, 1998)

need. "(A) layer receives control over a process only when (the process) exceeds the capabilities of the layer below." [Brenner et al, 1998, p.76]

3.8.3 Agent Environments

While the above architectures describe the components of individual agents, multi-agent systems and mobile agents require new architectures for the systems in which they reside. Brenner [1998] discusses how object-oriented standards for distributed client/server systems, such as the Common Object Request Broker Architecture (CORBA) may play an important role in the development of agent standards. CORBA components are designed to provide objects with access to common services and facilities. Incorporation of agent interfaces into a CORBA architecture can provide the basis for distributed agent systems. [Brenner et al, 1998] The Object Management Group, a consortium of interested commercial and research parties are developing CORBA. Other platforms for distributed object-oriented development include Microsoft's "Distributed Component Object Model" (DCOM) and JavaSoft's "Java/Remote Method Invocation" (Java/RMI). [Raj]

Interrap agent architecture [Muller 1996]

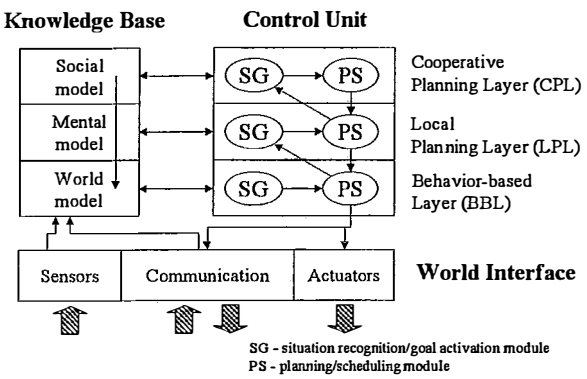


Figure 8 (from Brenner et al, 1998)

In parallel with developments in distributed object environments, a number of agent development toolkits contain infrastructure or environment components. Examples include the "Java Agent Template, Lite" (JAT*Lite*) from Stanford University, which includes an agent message router.

Mobile agents require additional considerations in the design of system architecture. Stationary agents use remote procedure calls (RPC) similar to those used by traditional client-server software programs. In contrast, mobile agents use remote programming (RP) where the procedure itself is transferred to the remote site and executed there. Implementing an architecture that facilitates RP requires additional security and communications components. Brenner et al [1998] propose a base software layer that sits between the agents and the operating system and applications in the host computer. This base software, in turn, contains: 1) an agent layer that monitors and executes all active agents, 2) a security layer that controls the secure transfer of messages and information within the system, and 3) a communications layer that provides basic services such as RPC, RP, and object serialization. (Object serialization permits the deconstruction of an agent-object into a serial data stream for migration and its reconstruction at the receiving site.) Examples of mobile agent environments under development are "Java Aglets" and the "Agent Transfer Protocol" from IBM, and "Java-to-go" from University of California at Berkeley.

"Telescript", developed by the General Magic consortium, defined a platform for the development of mobile agents, including an architecture, an agent language and communications protocols. [White, 1997; Brenner et al, 1998] However, the proprietary nature of Telescript's development environment was seen by some as limiting its adoption. IBM's "Agent Building Environment" (ABE) and "Reusable Agent Intelligent Software Environment" (RAISE) are no longer under development. IBM has integrated agent research into its other research areas.

3.8.4 Agent Programming Languages

Brenner et al [1998] summarize the requirements for an agent programming language as:

- Object-orientedness
- Platform independence
- Communications capability
- Security
- Code manipulation

Reactivity, multitasking, persistent data storage and extensibility are identified as additional desirable qualities. [p. 163-164]

The Java language, developed by Sun Microsystems, would seem to meet many of these requirements. Java is object-oriented and platform independent. It can be used to implement any of the standard AI algorithms. For mobile agents, Java supports both remote method invocation (RMI) and object serialization. The security requirements for Java applets are similar to those

required in a mobile agent system. The Java Beans model allows for component-based development. [Brenner et al, 1998; Bigus & Bigus, 1998]

While Java combines aspects of both a programming and a script language, many developers of scripting languages are adding mobility and security features. The "Tool Command Language" (Tcl), a script language and an interpreter originally developed for UNIX systems, is another agent programming option. Although Tcl is not object-oriented, extensions such as Safe-Tcl and Agent Tcl have been developed to address the issues of security and mobility. [Brenner et al, 1998] "Penguin" (perl5), "Python", and "NetREXX" are other examples of scripting languages that have been adapted for mobile applications. [W3C-(2)]

A list of agent construction tools that includes both commercial products and academic projects can be found at http://www.agentbuilder.com/AgentTools/index.html. While Java is the predominant development language, examples of agent construction in C, C++, LISP, and lesser-known languages can also be found.

3.8.5 Agent Communication Methods

There are two basic models for agent communications. The "blackboard model" provides a common work area where agents can read and write information, data and knowledge. Blackboard systems can be enhanced through partitioning or the use of a dispatcher. Distributed problem-solving may involve use of both a domain blackboard and a control blackboard where information about the progress of solutions to sub-problems is maintained.

A dialogue/message model can be used for direct agent-to-agent communications. This is a much more flexible structure but requires that each agent understand the semantics of the communication, which includes not only the transfer of information, but the intent of the message and its effect on the agent's internal state and the environment. [Brenner et al, 1998]

3.8.6 Agent Communications Protocols and Languages

A protocol defines the rules and procedures for communications between two parties. Protocols are required for software agents to communicate with traditional communications systems, their human users, and other agents.

The Knowledge Query and Manipulation Language (KQML) was developed at the University of Maryland (Baltimore) as part of the Knowledge Sharing Effort (KSE) project. It defines communications protocols and a communications language to facilitate communications between agents and between agents and applications such as databases. It has been used in a number of early implementations of multi-agent systems. KQML consists of three layers. The

communications layer describes low level communications parameters, such as the identity of the sender, the identity of the receiver, and a communication identifier.

The message layer is the core of the program, specifying the protocol (including whether the communication will be synchronous or asynchronous) and a "performative that identifies the intent of the message. Performatives are based on speech-act theory. Examples of basic performatives include ask-about, ask-if, tell, achieve, reply, and sorry (indicating that a request cannot be filled). KQML defines such basic performatives, but is extensible in order that specific requirements can be added for different system needs. [Finin et al, 1994] An example of extending KQML is contained in He et al [1997] where new performatives are identified to enable an agent-based Public Key Infrastructure for secure communications over the Internet.

KQML's third layer is the message content. KQML is designed to be independent of the knowledge representation language used in any particular system, so its message layer merely identifies the boundaries of the content and the language in which it is represented. KQML messages can specify content that is written in KIF (a knowledge representation language that was also developed by the KSE), Prolog, LISP, or simple ASCII or binary notations. The message layer can also specify an ontology that it assumes the recipient will recognize. This allows for the proper routing of a KQML message, without analyzing its content. [Finin et al, 1994]

Some critiques of KQML [Bradshaw et al, 1997; Cohen & Levesque, 1997] have been addressed in a newer version. Covington [1998] provides a summary of these changes, and makes additional suggestions for future improvement.

The Agent Communication Language (ACL), also developed by the KSE, combines the KQML communications language with the KIF message language. Its developers argue that message handling cannot always be content independent. ACL incorporates the use of facilitators to both interpret and route messages from their agents to the appropriate recipient. [Genseretb, 1997]

In developing the Knowledgeable Agent-oriented System (KaoS) architecture, Bradshaw et al [1997] argue that communications between agents would be facilitated by the use of "conversation suites" consisting of a predefined series of performatives. Core conversation suites consist of Inform, Offer, Request, Conversation for Action, and Query. As an example, the Inform conversation consists of an Inform performative from agent A to agent B, and either an Acknowledge performative from B to A, or silence from B, depending on whether A requests a response through the parameters attached to the initial inform message. [Bradshaw et al, 1997]

3.8.7 Agent Ontologies

Once agents start to communicate, an ontology or common vocabulary will be required. In the context of knowledge sharing and reuse, an ontology describes the concepts and relationships within a domain of knowledge. Gruber provides a short answer to this question as "An ontology is a specification of a conceptualization." An agent "commits" to an ontology by agreeing to use it consistently, if not completely.

> "Pragmatically, a common ontology defines the vocabulary with which queries and assertions are exchanged among agents. Ontological commitments are agreements to use the shared vocabulary in a coherent and consistent manner. The agents sharing a vocabulary need not share a knowledge base; each knows things that the other does not, and an agent that commits to an ontology is not required to answer all queries that can be formulated in the shared vocabulary." [Gruber]

An ontology is required to specify concepts within the agent environment as well as within an application domain. At the environment level we can find developments such as IBM's Agent Life Cycle Ontology to create, name, transport, and destruct agents, and its Yellow Page Service Ontology so that agents can locate common services. [Gilbert, 1997] KIF contains basic ontologies such as sets, sequences, numbers and arithmetic, and relations as described at http://www-ksl.stanford.edu/knowledge-sharing/kif/.

Within application domains, development of ontology is expected to be the responsibility of industry groups or standard setting bodies. Structured information such as New York Stock Exchange (NYSE) ticker information is easily described. The Knowledge Sharing Effort reports on early work in areas such as concurrent engineering, product development, military logistics, engineering mathematics, and bibliographic data. [KSE, 1999]

The "Cyc" project (short for "encyclopedia") which has been underway in the AI community since the mid-1980's, attempts to encode semantic information about the world at large. Sub-sets of Cyc's ontology are being made available for applications that require natural language understanding and semantic information retrieval. Mayfield et al [1995] describe a project where agents containing subsets of the Cyc knowledge base interact to solve a problem. Wordnet, developed at Princeton University, is a collection of semantic relationships that is available for agent developers at http://www.cogsci.princeton.edu/~wn/.

There is a lot of interest in Web-related ontologies, including Simple HTML Ontology Extensions and Apple's Meta-Content Format. [UMBC AgentWeb] Future web developments such as the widespread introduction of Extensible Markup Language (XML) are expected to play an important role in this area.

3.8.8 Agent Cooperation Protocols

In a classical distributed problem-solving system, central design of the agents (or modules) ensures the "benevolent agent assumption". In multi-agent systems, agents can have conflicting goals and employ different coordination strategies. In either case, problems or sub-problems must be assigned to agents capable of finding a solution. This process is called the "connection problem". Brenner et al [1998] describes two coordination protocols for addressing the "connection problem":

- In a **Contract Net** system, pending tasks are offered in a marketplace and agents "bid" for the tasks. A central "manager" evaluates the bids, offers contracts, receives confirmation of the contracts and receives the task results.

- **Partial Global Planning** gives agents the ability to observe and collect information from other agents that are also working on the problem. Partial Global Planning allows for agents to modify their plans when tasks are interdependent, or when the environment changes.

3.8.9 Matchmaking and Brokering

Multi-agent systems generally require the services of facilitators to solve the "connection problem". Two specific types of facilitators are matchmakers and brokers. Both are supported by special KQML performatives.

A matchmaker maintains a database of the capabilities of servers who have "advertised" their services. A server may be another agent or an agent-friendly database. At the request of an agent, the matchmaker searches its database and returns the name and address of a server capable of fulfilling the requested task. The requesting agent then contacts the server directly to request its service. In contrast, a broker remains as an intermediary throughout the process, relaying requests and replies between the requester and the server. Brokers can therefore maintain confidentiality for the parties, and can control the use of resources.

Decker (K) et al [1997] identify additional types of "middle agents" by looking at the "preferences" of requester agents and the "capabilities" of provider agents, and classifying middle agents according to how they manage the privacy of this information. In this way they describe 9 alternative types of middle agents that may all be useful in different situations. They also provide experimental results comparing the efficiency, robustness, and adaptiveness of matchmaker and brokered systems.

3.8.10 Negotiation Strategies and Protocols

A negotiation protocol defines the rules for an economic mechanism and the form of communications between agents, or agents and other systems. [Brenner et al, 1998] Using auctions as an example, negotiation protocol specifies the rules and the form of communication

for each type of auction. Other economic mechanisms can be defined with different negotiation protocols.

While a protocol is defined for a particular environment, individual agents within that environment can have different negotiation strategies. The agent designer must however ensure that the chosen strategy is effective with the given protocol. [Brenner et al, 1998] Some researchers believe that agents will need a set of strategies (i.e. benevolent, self-interest, inpatient), and may want to switch strategies between negotiations, or even within a negotiation. [Moon et al] Whether the agent's strategy can be determined or inferred from its actions will affect the effectiveness of its negotiations, although large systems of agents with fairly rudimentary negotiating strategies appear to reach fairly sophisticated negotiation results. Much of the study of negotiation strategies builds on game theory. Genetic algorithms and Bayesian probability have both been used as learning techniques. [Beam & Segev, 1997] Dworman et al [1996] conducted a study of genetic algorithm learning in an asymmetric game where three agents attempt to find a two-agent coalition. Their experiment shows results that are reasonably close to both theoretical outcomes and human performance.

4. Agents and Decision Support

The commerce process consists of a series of complex problem-solving and decision-making tasks. We want to look at how agents can support these tasks. Important design issues are related to the user's ability to understand, control and predict the behaviours of agents. [Erickson, 1997] Malone, Grant, and Lai [1997] describe two principles that have evolved from their work on interface agents.

> **The principle of semi-formal systems:** "Don't build agents that try to solve complex problems all by themselves... Build systems where the boundary between what the agents do and what the humans do is a flexible one."
>
> **The principle of radical tailorability:** "Don't build agents that try to figure out for themselves things that humans could easily tell them...Build systems that make it as easy as possible for humans to see and modify the information and reasoning processes their agents are using"

With these principles, Malone, Grant, and Lai [1997] describe a much more interactive experience for the user than that usually associated with a "black box" model. In fact, there are many similarities between the above principles and those used to design decision support systems (DSS).

Finding a commonly accepted definition for a decision support system is just as difficult as finding a commonly accepted definition of a software agent. However, the DSS field has

evolved to include the incorporation of AI technologies such as expert systems into management decision-making situations. It is expected that many of the insights from DSS research will be applicable to agent design.

4.1 Decision Support Systems

Decision support systems (DSS) are an area of information systems that attempt to support humans in solving complex and ill structured (or semi-structured) problems. A DSS does this by structuring parts of a larger unstructured problem. Humans interact with the system, using their own knowledge and intuition to "join" these structured parts together and develop a complete solution to the problem. DSS have been built to support both one-time and repetitive problem situations and to support various stages in the decision-making process. DSS are primarily concerned with improving the effectiveness of decision-making. [Stabell, 1986]

Widing and Talarzyk [1993] argue that the goals of decision making research should be to improve decision quality, reduce the effort and time to make decisions, and "(enhance) decision maker satisfaction with the decision process" [p. 125]. Marketing opportunism and market inefficiencies result when consumers do not make use of all of the available information,. The goals of consumer policy should be to increase the accessibility and processability of information. New electronic information sources are starting to assist in these goals. This new media can "lower the cost of search and thinking thresholds, thereby enhancing the likelihood that the information will be used". [p. 126]

4.2 Agents and Decision Support Systems

Current research in DSS is incorporating artificial intelligence techniques to add structure to larger and more complex areas of the decision-making process. AI applications can help decision-makers use more exhaustive and complex information sources. [Siskos & Spyridalos, 1999] Research is also exploring how these applications can enhance learning and creativity. [Sauter, 1999; Williams et al, 1992]

Expert systems have been the most successful commercial application of AI technology to decision problems. An important difference between expert systems and traditional DSS is that an expert system "replaces" the decision-maker. This is similar to the way that we envision tasks being delegated to an agent. An agent-enabled DSS can incorporate artificial intelligence so that the system can learn and adapt to individual preferences or capture an experienced buyer's expertise, adding structure to additional non-routine portions of the decision problem.

Turban [1998] suggests that AI can be embedded into DSS to support the model, data and dialogue subsystems, the complete system, or the user (Figure 9). This provides an appropriate way of looking at how intelligent agents with different functionality can be built into a cooperative DSS system. Search support is associated with the data subsystem. Choice support is associated with the model subsystem and interface support is associated with the dialogue subsystem. A "generic" e-commerce shopping agent would require an agent to coordinate the activities of these three agents by recognizing the problem situation and calling on agents with the appropriate capabilities to respond to that situation.

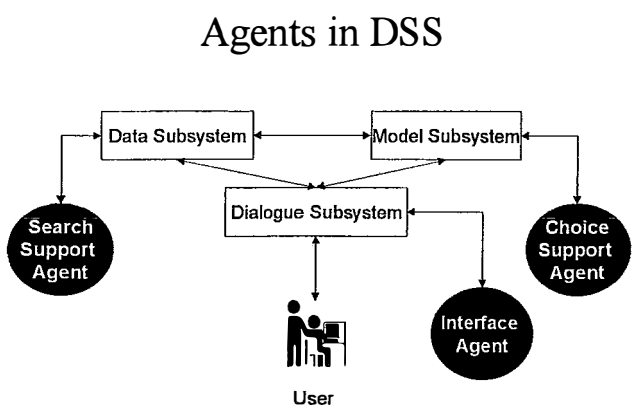


Figure 9 (adapted from Turban, 1988)

Appropriate measures for search support systems would include standard information retrieval methods such as precision and recall, as well as search cost/benefit analysis. While weighted average strategies are generally assumed to produce higher quality decisions, and are often used as the benchmark for evaluating decision quality, this has been questioned in some research. [Widing & Talarzyk, 1993] Other measures used in the evaluation of DSS, such as user satisfaction, ability to justify decisions and number of alternatives considered, may be applicable to measuring agent choice support. The field of human computer interaction has a number of measures that may be adopted to evaluate the usefulness and usability of agent systems.

In "An agent-based framework for building decision support systems", Bui and Lee [1999] describe " development of agent-based DSS as being a process of putting together a coordinated workflow of collaborating agents that is able to support a problem-solving process." [p. 225] The development process involves deconstructing the overall problem-solving process into primitive tasks, specifying the required functionality and behaviour of agents for these tasks, and then specifying the coordination and collaborative strategies and mechanisms so that these individual agents can integrate their activities into an overall workflow. [Bui and Lee, 1999]

At the micro-level, agent attributes (intelligence, mobility, lifetime, interaction, task specificity, initiative) are specified for each primitive task. The benefits and costs of using an agent are then examined to decide if an agent is justified. System design at the macro level addresses the need to coordinate the creation and integration of results from each agent. [Bui and

Lee, 1999] This approach is well-suited to the use of single-task reactive agents, employing the limited capabilities of current AI technologies.

5. Marketing Models

Commerce involves a complex and dynamic set of problem-solving and decision-making tasks. By understanding how customers approach and complete these tasks, marketing managers hope to be able to interpret information about their customers, develop effective marketing strategies, design effective packages of information for their customers, and predict market response to these strategies. [Webster & Wind, 1972]

Economic models of decision-making describe a "rational" decision-maker, employing concepts such as marginal utility, expected utility, and multi-criteria decision analysis. However, observations of human behaviour show that humans are not always "rational" in this manner. The behavioural sciences bring psychological and sociological concepts to the study of decision-making in an attempt to explain and understand this observed behaviour. Marketing models "emerge from a compromise between the differing points of view that economics and behaviour sciences offer on this topic" [Nicosia, 1966, p. 38].

The relationships between variables in a commerce process are complex and as researchers define the behaviour spaces and behaviour fields they are studying, only a small cross-section of the process is examined. [Nicosia, 1966] Johnston and Lewin [1994] identify thirteen major constructs as determinants of organizational buying behaviour. Each of these constructs (i.e. purchase, organizational, seller, etc.) includes a number of different characteristics that have been used as variables in research projects. Their examination of twenty-five years of organizational buying behaviour research found that some constructs were used primarily as independent variables, others primarily as dependent variables, but many were used as both. [Johnston & Lewin, 1994]

Product characteristics are important variables in determining behaviour. There are various models that attempt to classify products according to characteristics such as whether the value proposition is intangible or tangible, or whether the product is a luxury or a necessity. These characteristics can define classes of products where similar search and decision strategies are chosen.

Product categories are specific groups of comparable products (or brands) that satisfy a particular need for the buyer. Product categories define a very specific domain, where experience and knowledge affect the search strategy and choice criteria.

Marketing models of buyer behaviour can be used to describe the decision-making process, the purchasing situation, and the decision mechanisms employed.

- **Purchasing Process Models** In Section 2.0, commerce was defined as a process. Process models describe the participants and the activities undertaken at different stages in the commerce process.
- **Purchasing Situation Models** Purchasing Situation models describe the product, market and buyer characteristics that are present for a specific purchase.
- **Purchasing Decision Models** The buyer must "decide how to decide" between alternatives. Purchasing decision models describe how the buyer arrives at a decision, and include both the buyer's information search behaviour and the buyer's choice processes. These models can be used to represent the problem space in a form that is similar to the way that the buyer processes information and makes a decision.

  Kotler and Turner [1994] suggest that there are five purchase sub-decisions: brand decision, vendor decision, quantity decision, timing decision, and payment-method decision. People and corporations use budgets to manage the complexity of their overall purchasing requirements. [Edwards, 1990] A budget may limit the number of alternatives to be considered in quantity, timing and/or payment method decisions. Budgeting and quantity decisions usually precede brand and vendor choice [Baltas, 1998].

  Search behaviour describes the type of search that the buyer conducts prior to evaluation and choice. Search-costs and search-benefits, the types of sources used in the search, and the extent and duration of the search will by affected by the purchasing situation, the product category and the decision-maker's perception and attitude towards the product. Search can include information on both products and suppliers.

  Choice behaviour describes how a buyer makes a choice between alternatives. Most marketing research into choice behaviour examines the task of choosing between brands within a product category. These models examine the relationship between the consumer and the collection of attributes that describe a product and how consumers process this information and arrive at a decision. Multi-Attribute Attitude Theories (MAAT) assume that the behaviour of a consumer is determined by the consumer's attitude toward a small number of the attributes associated with the product. [Grunert, 1989] Means-end theories attempt to link the consumer's product knowledge (about product attributes) to the consumer's self-knowledge (about values and goals) through a hierarchical model of cognitive structure. [Olson, 1995]

Samples of marketing research are used in the following sections, with emphasis on characteristics that may become salient in the e-commerce arena.

5.1 Business to Consumer Models

5.1.1 Purchasing Process Models

In describing traditional Consumer Buyer Behaviour (CBB) models, Nicosia [1966] observes that "(t)he structure of the process is rather simple in its overall conception, and ill-defined in its details." [p. 44] Examples of this "simple" structure of the process can be found in many different CBB models.

Nicosia's extended view of consumer behaviour describes a much more complex process. He argues that the process is not a simple one-way flow, but rather a network of relations between variables that forms an adaptive, dynamic system. Buyer behaviour is a dynamic system because buyers learn from previous purchase experiences. This enables them to generalize from one experience to the next and to routinize certain behaviours. Buyers also learn from information in their commercial and social environments. [Howard & Sheth, 1969] and develop relationships based on trust or reciprocity. [George, 1998] For these reasons, the behaviour of a buyer will not be consistent over time.

As an example of research that uses a process model, Liang and Huang [1998] conduct an experiment to test how product characteristics influence a consumer's willingness to purchase the product in an electronic market. Two product characteristics were selected for the study: uncertainty and asset specificity. It was believed that these characteristics would influence the perceived transaction costs for different product categories. Transaction cost components were assigned to each stage of the CBB process model. Electronic commerce was seen to lower the search costs. Comparison costs were seen to be lower for only some products. Examination, payment and post-service costs were higher in electronic commerce. Reducing uncertainty, by providing more information prior to purchase, will encourage purchases by both experienced and inexperienced electronic consumers. [Liang & Huang 1998]

5.1.2 Purchasing Situation Models

Most marketing textbooks use a model similar to the one shown in Table 1 to illustrate differences in consumer involvement and levels of product differentiation.

Table 1 - Consumer Buying Situations
[from Kotler & Turner 1995]

	High Involvement	**Low Involvement**
Significant differences between brands	COMPLEX BUYING BEHAVIOUR	VARIETY-SEEKING BUYING BEHAVIOUR
Few differences between brands	DISSONANCE-REDUCING BUYING BEHAVIOUR	HABITUAL BUYING BEHAVIOUR

High involvement occurs when " the product is expensive, bought infrequently, ...and highly self-expressive." [Kotler & Turner 1995, pg. 184] When there are significant differences between brands, the consumer sees a high risk that he or she will not make a good decision. This situation corresponds with high pre-sale information needs. When there is high involvement, but little perceived differences between brands, the consumer will often conduct only a cursory search for information and make a decision quickly, based on price or convenience. Because of the shallowness of pre-purchase research, consumers often have post-purchase doubts and sellers compensate with extensive post-purchase information.

Low involvement describes low-cost purchases that are made frequently. When there is little difference between brands, the purchaser behaves habitually, and is more influenced by brand recognition, than by brand loyalty. When there are significant differences between brands, the consumer will readily switch brands to try something new. Marketers may therefore try to introduce differentiation into a product to move consumers from a habitual buying situation to a variety-seeking one. [Kotler & Turner 1995]

In e-commerce, an important consideration is whether the product or service is information-based or tangible. Peterson et al. [1997] consider whether the "value proposition" of the product is tangible (physical) or intangible (informational) and incorporate this concept into the purchasing situation matrix to define eight classes of products as shown in Table 2.

The purchasing situation models discussed above assume that there is a correlation between frequency of purchase and outlay. While this may be true for most products, there are some infrequently purchased products that involve only a small outlay. Spices or kitchen utensils would be examples. There may also be some frequently purchased services that could be considered high outlay, depending on how these two dimensions are measured. Mortgages and insurance are often renewed annually, so the buyer accumulates significant experience with these decisions.

Table 2 – Product and Service Classification Grid
[Peterson et al, 1997]

Frequency of Purchase	*Value Proposition*	*Differentiation Potential*	*Examples of Products and Services*
Low outlay, frequently purchased goods	**tangible**	**High**	Wines, soft drinks, cigarettes
		Low	Milk, eggs
	intangible	**High**	Newspapers, magazines
		Low	Stock market quotes
High outlay, infrequently purchased goods	**tangible**	**High**	Stereo systems, automobiles
		Low	Precious metal ingot of known weight and purity
	intangible	**High**	Software packages
		Low	Automobile financing, insurance

5.1.3 Purchasing Decision Models

5.1.3 a) Search Behaviour

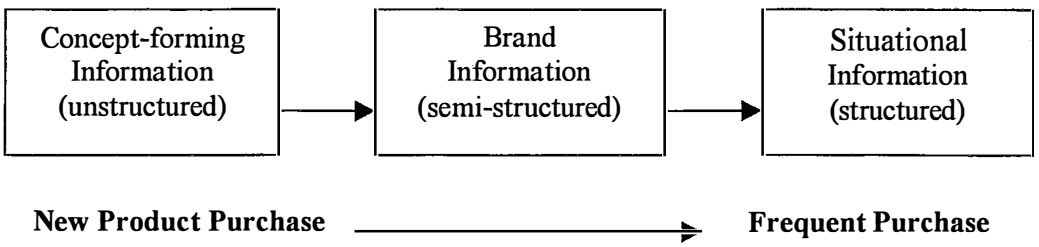
By reducing search costs, the Internet is expected to increase the extent of search activities over all types of purchasing situations. The Internet has also changed the mix of sources available to buyers. It provides a number of ways for buyers to share their experiences with products and new information-bundling intermediaries are aggregating different types of sources in one location. Marketing research has examined how buyers use different types of information sources and how buyers allocate search effort among sources, but we do not yet understand how buyers will value these new sources or how the new mix of sources will be used. [Klein, 1998; Hauser et al, 1993]

A buyer who is unfamiliar with a product needs "concept-forming" information, to learn about the relevant attributes of the product category and determine the appropriate choice criteria. Once the choice criteria are formed, the buyer collects brand-specific information to compare the important attributes to these criteria.[3] Through this process, the original set of alternatives is limited to a manageable set of potential brands. A buyer familiar with a product category, but

[3] The choice criteria may influence whether a supplier is chosen before a brand, or vice versa. If supplier-related attributes such as product support are important, a set of suppliers may be chosen before a set of brands.

buying infrequently, will continue to use previously developed choice criteria, but needs new information about relevant brand attributes. With frequent purchases, the buyer's information needs are reduced to a small set of situational attributes, such as price or availability, to compare between acceptable brands. [Kaas, 1982] Thus, the information requirements change from unstructured to structured as the buyer accumulates knowledge about the product category.

Figure 10 – Information Requirements and Frequency of Purchasing
[adapted from Kaas, 1982]



In the 1970's, Nelson proposed the classification of products into search goods and experience goods. The total cost of the product is the sum of both search and product costs.

> "Search goods are defined as those dominated by product attributes for which full information can be acquired prior to purchase; experience goods are dominated by attributes that cannot be known until purchase and use of the product or for which information search is more costly and/or difficult than direct product experience." [Klein, 1998, p. 196]

Economic theory argues that a consumer will search out information until the perceived marginal costs of additional search are greater than the perceived benefits. Search costs include time (opportunity cost), travel, media access and effort. Search benefits include cost savings, increased product quality, reduced risk, satisfaction through the search process, and social recognition.

The Web has the potential to change how consumers perceive experience goods. Some experience goods will become search goods because the cost of search on dominant attributes can be reduced to a point where the consumer will search rather than experience through purchase. Samples of products that can be digitized, such as music clips or software demonstrations are available through the new media, providing direct experience without the cost of purchase. The consumer can also gather "indirect user experience" through communication with other users of the product. Other research has shown that perceived risk will lead to more extensive search, and that the higher the perceived risk, the more weight consumers will place on experience. Further

research is required to determine whether consumers will place the same value on virtual experience. [Klein 1998]

Search behaviour is described by components such as extent, duration, types of sources, number of sources, depth within sources, order of sources, and time distribution between sources. Klein [1998] classifies sources as retail, media, interpersonal and neutral and argues that interactive media such as the WWW tend to blur the distinctions between these types of sources.

Little empirical research has been conducted on how the mix of sources affects search behaviour or how the patterns of search and interrelationship of variables affect the value consumers assign to the information received. Klein [1998] concludes that "...the impact of consumer use of interactive media on information search processes and purchase behaviour will not be the same across all consumers or all product categories". By studying how search/experience attributes relate to search behaviour "we may be able to understand better how the value of information is affected by the context in which it is presented and by the interaction effects between the individual and the situation." [p. 199]

Peterson et al [1997] consider the Internet as an alternative to traditional information sources and develop a series of three possible consumer decision sequences. These sequences differ in whether consumers use one or both of traditional and Internet information sources, and how early a brand is chosen during the search. For example, Figure 11 shows potential search sequences if brand choice is made at the beginning of the process. The authors then examine the nature of these product classes to predict "likely" decision sequences for each class of product. If we interpret the results in terms of the traditional CBB purchasing situation model, they suggest that for Variety-Seeking and Habitual Behaviour, information search and purchase will remain in traditional channels for tangible products, but both search and purchase will switch to the Internet for intangible products. In Complex and Dissonance Reducing Behaviours, the authors suggest that users will use both channels for searching out information, and that purchase may occur in either channel, regardless of whether the product is tangible or intangible. [Peterson et al. 1997]

Search and Decision Sequence

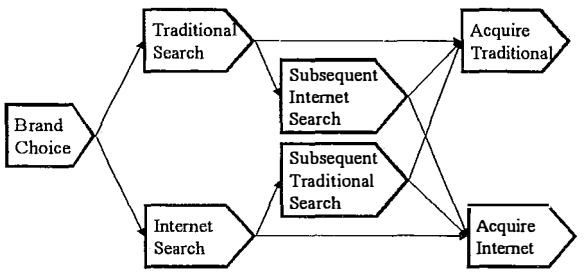


Figure 11 (from Peterson et al, 1997)

5.1.3 b) Choice Behaviour

The decision task facing a consumer consists of a set of alternatives, each described by a series of attributes. These attributes can vary in desirability, consequences and the consumer's willingness to trade-off one attribute for another. Uncertainty is introduced when the consumer does not have all information about some attributes. The difficulty of a decision is a function of the number of alternatives, the number of attributes, uncertainty, and the presence of difficult trade-offs. [Bettman et al. 1998] A number of other researchers have proposed that task difficulty results in declining information search, reduced choice accuracy, and heavier reliance on personal sources of information. [Feick et al. 1993]

Bettman et al. [1998] present an extensive review of consumer decision research. Two approaches to studying consumer decision-making have been the Rational Choice Theory (RCT) and the Information Processing (IP) or Bounded Rationality approach. RCT assumes that the consumer considers a "choice set", assigns a utility value to each option in the set, and selects the option that maximizes utility. The IP approach assumes that humans have limited processing capabilities with respect to working memory and the ability to do calculations. Human perception also affects what information is used. Using the IP approach, characteristics of the task situation as well as the capabilities of the human information processing system must be examined in order to understand behaviour. The IP approach helps to explain observations that consumers do not simply retrieve known preferences, but rather "construct" them when required. "Thus, consumer preference formation may be more like architecture, building some defensible set of values, rather than like archeology, uncovering values that are already there" [p. 188]

Decision strategies can be characterized according whether information is processed consistently or selectively (how much of the available information is used), whether information is processed by alternative or by attribute (the pattern of processing), and whether the strategy is compensatory (requiring trade-offs) or non-compensatory (not requiring trade-offs). [Bettman et al. 1998]

Bettman et al. [1998] describe eight decision strategies that have been observed and/or studied in consumer research. These strategies are detailed in Appendix B. Consumers often use a staged approach to decision-making. An initial strategy will be used to limit the number of alternatives to a manageable number A strategy that involves more extensive information processing can then be applied to the remaining alternatives.

Bettman et al [1998] discuss how a consumer's goals will affect the strategy that is chosen. They suggest a framework consisting of four (potentially conflicting) goals:

- Maximizing the accuracy of the decision
- Minimizing the cognitive effort involved in the decision
- Minimizing negative emotion
- Ease of justification

The accuracy goal accommodates the Rational Choice Theory. Minimizing cognitive effort encompasses the Information Processing approach. The last two goals consider the emotional and social aspects of decision-making. Each of the strategies described in Appendix B has different advantages and disadvantages with respect to these goals. If decision situations can be described in terms of dominant goals, we can determine which strategies are most likely to be chosen for a given situation.

In situations where there is little emotional involvement and little need to justify the decision, the strategy chosen by the consumer will depend on a "preference function" between effort and accuracy. Factors outside of this model, such as time pressure, can also have an effect on the preference function.

Negative emotion arises when consumers are asked to make difficult trade-offs or there are serious potential consequences that may arise from a decision. Examples could be trading off a safety attribute against other attributes in an automobile purchase decision, or environmental considerations in the purchase of a pesticide. It is suggested that consumers cope with negative emotion in two ways. Problem-focused coping leads to more extensive processing and an emphasis on increased accuracy. Emotion-focused coping avoids the need to make trade-offs by choosing non-compensatory or attribute based strategies. The need to justify a decision may lead to accuracy goals becoming dominant. [Bettman et al. 1998]

5.2 Business to Business Models

5.2.1 Purchasing Process Models

The stages in industrial buying are often described according to the Buy Grid model. The Buy Grid model was developed out of an extensive empirical study conducted by the Marketing Science Institute. This study identified a sequence of eight "buyphases" that describe the purchasing process. Three "buyclasses" describing purchase situations are described in the next section. [Robinson et al, 1967]

The eight "buyphases" of the Buy Grid model are:

1. Anticipation or Recognition of a Problem (Need)
2. Determination of Characteristics and Quantity of Needed Item
3. Description of Characteristics and Quantity of Needed Item
4. Search for and Qualification of Potential Sources
5. Acquisition and Analysis of Proposals
6. Evaluation of Proposals and Selection of Supplier(s)
7. Selection of an Order Routine
8. Performance Feedback and Evaluation

Business to business commerce often involves a number of participants from the buying organization. "As any buying process unfolds...the significance of any individuals or functions involved in the process changes." [Robinson et al, 1967, p. 21] During the early stages of the process, participants may include designers and product planners, among others. As detailed specifications become clear, purchasing and operations supervisors may become more involved. Purchasing will generally conduct negotiations and finalize order and contract arrangements. Shipping, receiving and inspection personnel can be involved in the fulfillment process and end users provide performance feedback. [Robinson et al, 1967]

While the Buyphases model is similar to some of the B2C models, there is a more explicit process for determining the product requirements. This is consistent with the need to involve more than one participant in this stage of the process. The common practice of competitive bidding is incorporated in steps four through six. Step seven provides for the development of a transaction process that can be used for repeat purchases.

Robinson et al [1967] emphasize that this model is a simplification of an often complex process. For any single purchase, some stages may be combined, some stages may be skipped, and some stages may be of greater relative importance. When a problem cannot be solved at one stage, the process may become iterative or may be aborted. They also discuss the idea of "creeping commitment", where decision-making is viewed as a series of incremental decision points, with the number of remaining alternatives reduced at each of these points.

5.2.2 Purchasing Situation Models

In B2B commerce, important differences can also be found in buying situations. Empirical research leading to the Buy Grid model identified three distinct "buyclasses": the straight rebuy, the modified rebuy, and the new task. These buying situations are defined by three factors as shown in Table 3. Although other factors such as product usage were studied, the researchers found that the buying situation was the most important determinant of purchase behaviour. Appendix A provides further descriptions of the Buy Grid model's buyclasses.

Table 3 – Distinguishing Characteristics of Buying Situations
[from Robinson et al, 1967]

TYPE OF BUYING SITUATION (Buyclass)	Newness of the Problem	Information Requirements	Consideration of New Alternatives
New Task	High	Maximum	Important
Modified Rebuy	Medium	Moderate	Limited
Straight Rebuy	Low	Minimal	None

The overall Buy Grid model combines the Buyphases (process) and Buyclasses (situation) models in a matrix that can be used to predict buyer behaviour and select marketing strategies appropriate to the buying situation at any stage of the purchasing process. For example, in a new task situation, the earlier stages of the process are considered critical to the purchase success. (Robinson et al refer to this as the "centre of gravity" of the process.) In this situation there is much active search for information. Problem solving is often collaborative between the buying and selling organization. In straight rebuy situations, later stages of the process receive the most attention.

B2B transactions are also commonly classified according to the use of the products or services within the organization. Frequency of purchase is one of the characteristics used to describe these categories of products and search and choice behaviour has also been studied according to these categories. [Gebauer et al., 1998 (1)]

Raw materials and production goods and services
- large quantities, high frequency, unique specifications, often just-in-time delivery)

Maintenance, repair, and operating supplies and services (MRO)
- Low unit cost, low volume, off-the-shelf, relatively high frequency

Capital goods and ad hoc procurement for functions such as new product development
- Often outside the normal procurement process because of convenience, speed, and unique specifications

5.2.3 Purchasing Decision Models

Many of the concepts involved in B2C commerce are applicable to individual decision-making within an organization. However, the B2B purchasing process often involves more than one individual and both individual and organizational needs contribute to the motivation behind B2B purchases. As well, organizational factors such as information flows and control structures must be considered in any examination of B2B purchasing.

"(T)he organizational decision process is likely to be more *explicit*, as a reflection of the need for the several members of the buying center to coordinate their activities and to obey the policies and control procedures of the organization. This observation is consistent with the observation that the organizational decision process is a *rational* one..." [Webster & Wind, 1972, p. 128]

5.2.3 a) Search Behaviour

In B2B commerce, search processes are often highly structured. The stronger relationships between participants reduce the number of sources by establishing lists of approved or preferred suppliers. Suppliers provide catalogues of available products, containing rich information about product attributes. Large organizations may even create their own purchasing catalogues, integrating information about products from a number of approved sources. Tendering can also be considered as a form of search strategy. Request for proposals (RFPs), and request for quotes (RFQs) are structured ways of searching for information to determine product requirements and potential sources. Suppliers' sales personnel are supplemental resources and often act as search facilitators.

> "The organizational buyer learns to depend on certain information sources...'In' suppliers may be favored not only because of their previous performance in providing products and services but also because they have become trusted and valuable sources of information about other products as needs have arisen." [Webster & Wind, 1972, p. 99]

The credibility of sources has two dimensions: trustworthiness and expertise. Trustworthiness contributes to the "confidence value" of information while expertise increases the "predictive value" of information. Industrial sales personnel are viewed as credible because of their expertise. Both the trustworthiness and expertise of sources will act to reduce the uncertainty in the purchasing decision. Research has also shown that highly credible sources secure more opinion change, and the value of information from these sources increases with higher risk. This is known as the "source effect". However, research has also shown a "sleeper effect", where the value of information from credible sources diminishes over time and the value of information from less credible sources increases over time. [Levitt, 1967; Webster & Wind, 1972] It has also been shown that information from sources that are both credible and trustworthy is not retained as well as information from sources that are credible, but not necessarily trustworthy. [Bauer, 1967]

Honeycutt, et al [1998] believe that the process of information gathering on the Web is similar to personal selling in the importance placed on the quality of information and the credibility of the information provider. The predominance of personal selling in business-to-business promotion also leads to application of the 20-80 rule in most sales organizations. With

20% of the customers generating 80% of revenues, 80% of customer information needs are under-served. These "forgotten customers" are an opportunity that can be met by Internet-based information services. [Honeycutt et al, 1998]

In the article "Value of Supplier Information in the Decision Process", Monczka et al [1992] look at the relationship between product classifications and the type of supplier information that decision-makers found valuable. Their results are shown in Table 4. The importance of customer ratings of supplier quality and delivery performance indicates that virtual communities of buyers may be a valued source of information across all product types.

Table 4 - Value of Supplier Information
[adapted from Monczka et al, 1992]

Information items considered important for all product types:

- Customer ratings of supplier quality performance
- Customer ratings of supplier delivery performance
- Total lead time
- Past price paid
- Engineering support

Other information items considered important by product type:

Raw Materials	**Engineered Components (Unique)**	**Engineered Components (Standard)**	**MRO Supplies**	**Capital Equipment**
Buyer's prior sales volume with supplier; Price trend data	Type of equipment used by supplier; Supplier's long-term plans	Cost structure in the supplier's industry	Supplier's shipping location	Pending legal actions; Industry that the seller serves

5.2.3 b) Choice Behaviour

While it is generally argued that B2B decision strategies are more "rational" than those observed in B2C purchases, the presence of more than one decision-maker and various organizational influences can complicate the choice of and implementation of decision strategies.

Webster and Wind [1972] classify models of organizational buying behaviour as "task models" and "non-task models". Task models reflect the rational aspects of decision-making and include concepts such as minimizing costs, maximizing profits, reciprocity and source loyalty. Non-task models introduce personal and organizational influences such as the buyer's self-image, the relationship between the buyer and salesperson, interactions among members of the buying group, and perceived risk.

Two types of decision models are used to describe the decision-making behaviour of organizational buyers: dominant dimension models and multi-attribute models. [Webster & Wind, 1972] The perceived risk model is a dominant dimension model. Perceived risk and the minimization of potential problems are believed to be a strong goals in organizational buying. Perceived risk is a function of the uncertainty that an individual has about the outcome of a decision and the consequences (both performance and psychosocial) associated with various outcomes. In an organization, an individual may also be uncertain about the goals and the extent to which an action will satisfy the goals. Webster and Wind [1972] suggest that the importance of the consequences is related to both the importance of the goal and the "investment" involved in the decision process. Perceived risk can be reduced by:

- Information acquisition and processing (to reduce both performance and psychosocial risk)
- Goal reduction (specifications may be relaxed or constraints removed.)
- Loyalty (reduces goals to the current level)
- Investment reduction (leasing rather than buying, or a decision to award on a low-bid basis) [Webster & Wind, 1972]

Some research has classified products according to the type of problem that might arise from their adoption (i.e. procedural problems, performance problems,. or political problems). Wilson and Woodside [1995] examine the relationships between these problem-related product classifications and the choice criteria used to select a supplier (price, quality, delivery and service). The purchasing situation (modified rebuy or new task) and purchaser role (buyer, user, engineer) were also used as variables in the study.

Webster and Wind [1972] list four types of multi-attribute models:

- **Conjunctive** – meets a minimum standard on each of the attributes (multiple cutoff criteria)
- **Disjunctive** – requires a certain minimum on some attributes (either substantial cost savings or exceptional service)
- **Lexicographic** – a hierarchy of importance of attributes
- **Compensatory** – a surplus on one attribute compensates for shortage on another.

Operations researchers have developed sophisticated models that can be used to optimize purchasing decisions. These models adjust quantity and price variables, to accommodate uncertain market conditions. Morris [1977] proposes a model for competitive bidding that optimizes the expected return using historical data on actual versus estimated costs, and the bidding history of competitors.

Marketing researchers have investigated the use of other decision-making models, such as Analytical Hierarchy Process (AHP) which combines quantitative (i.e. price, delivery) and qualitative (quality, service) criteria. [Saaty, 1980] AHP can also be applied in a group decision-making process. [Nydic & Hill, 1992]

6. Use of Agents in E-commerce

6.1 Agent Ownership

Before we discuss agent design in more detail, the fundamental question of "agency" must be addressed. While human agents are considered to work for the benefit of their "employers" or "clients" we acknowledge that they also have self-interests. An agent is trusted only when the goals of the employer/client and the agent converge. The issue of who designs and "owns" the software agent and for whom the agent "works" must be clearly addressed in e-commerce applications. Business models for agent applications that address this issue are still evolving.[4] A product-focused approach to agent development must consider appropriate agent "ownership" as a critical factor in user acceptance. Sellers may have to provide systems to accommodate the requirements of different agents acting for buyers with different needs.

Jennings and Wooldrich [1998] proposed that the presence of a natural metaphor would help users accept and adopt software agents. Human agents can act as the buyer (a purchasing agent), the seller (a sales agent or distributor) or as an intermediary (i.e. a real estate agent, insurance agent, or travel agent). The roles played by "human agents" in traditional commerce can provide clues as to what types of agents are applicable and what they should do. Because e-commerce is expected to change the roles of intermediaries, it is possible that new roles for both agents and intermediaries will evolve.

6.1.1 Selling Agents

Information from sales agents is valued because of the source's expertise, even if conflicting goals may mean that the agent is not completely trustworthy. [Bauer; Cox; Levitt; 1967] Buyers might therefore use software agents "owned" by sellers and intermediaries for their expertise in search support, even if they are not perceived as trustworthy.

In fact, sellers may be in the best position to gather the knowledge bases required for some search and choice support functions. What is an infrequent purchase for the buyer, is often a frequent occurrence for the seller. Sellers can use this accumulated knowledge to develop search and choice support agents (software sales agents) to deal with human buyers. Intermediaries may

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[4] *Jango*, a "search and compare" agent (or shopbot) developed at the University of Washington was purchased by Excite, a popular web search engine. *Firefly*, a recommending agent developed at the Massachusetts Institute of Technology, was first commercialized as a new independent intermediary service. It was later purchased by the Microsoft Network (MSN). E-Bay, a popular consumer auction site is currently being investigated for anti-trust activities related to legal actions that E-Bay has taken against "aggregators" using shop-bots.

also be in a position to accumulate similar knowledge bases and may be seen as more trustworthy.

Bakos [1998] identifies that "a key variable (in a differentiated market) is the cost of product information *relative to the cost of price information*." He argues that the electronic marketplace can be designed to promote competition based on product features or to promote price-shopping. This may suggest that sellers should design sites that are "agent-friendly", with product information that is structured to be easily accessible by search agents. Many industries are moving in this direction with the development of XML-based ontologies and classification systems.

It is believed that collaborative recommendations can increase the size of the market and sellers are expected to support their use. [Bailey & Bakos, 1997] Information from interpersonal sources, such as a recommendation from another buyer, is often given credibility because the source is trusted, regardless of expertise. It is suggested that sellers can reduce perceived risk by "providing trained and licensed raters to personally inspect and evaluate products; (and) word-of-mouth endorsements from other similar customers". [Burke, 1997, p. 358] It is not known how "virtual" recommenders will be perceived. Repeated use of information from the same source, with positive results, would likely be required before trust is established. Whether a recommendation that originates from a seller's site would garner the same level of trust as one from an intermediary site is open to question.

6.1.2 Intermediary Agents

Bailey and Bakos [1997] pointed out that standards reduce the need for a facilitator. Lower search costs also reduce the need for intermediaries, but abundance of information requires intermediaries for efficient matching.

On-line directories reduce information overload by concentrating relevant information in one location. The arrival of shopbots poses a challenge for directories. If the need for one-stop shopping is reduced by an agent's ability to "shop around", what new value will directories provide? Information service bundles, including recommendations, complementary products, and transaction facilities may be required to entice users.

Our discussion of agent architectures identified important roles for matchmakers and brokers in multi-agent systems. "Middle agents" can also be used to manage the confidentiality of information provided by both buyers and sellers, and thereby encourage adoption. [Decker (K) et al, 1997] Intermediaries would be expected to provide these middle agent functions.

To delegate a purchase decision, the agent must be completely trustworthy. However, development costs will require that agents be shared between many users. Thus, choice support is likely to be developed and provided by intermediaries – either a new kind of intermediary or as part of a "bundle" of services supplied by existing Internet intermediaries.

Intermediaries can also provide marketplaces where negotiating agents acting for buyers and sellers can interact. New multi-issue matching algorithms are being explored to eliminate the price-only focus of the standard auction format. [Teich et al, 1999]

6.1.3 Buying Agents

The introduction of shopping agents (shopbots) has been controversial. Bargainfinder, an early prototype from Anderson Consulting, was blocked by some retailers who objected to a price-only comparison. [Bailey & Bakos, 1997] To frustrate blocking, subsequent shopbots, such as Jango, were designed so that the agent was seen to originate from the user's computer, rather than a central site.

Without extensive profile information Lanier warns of the lowest common denominator problem, where "An agent's model of what you are interested in will be a cartoon model, and you will see a cartoon version of the world through the agent's eyes."[5] Hagel and Rayport [1997] believe that buyer's profiles can be made "richer" by utilizing the information that an individual collects about themselves through other applications. They suggest that negotiating agents may be employed to exchange this information for value in return. Agent residency in the buyer's system may alleviate some privacy and security concerns when user profiles are used to search and filter information. Lanier, however, envisions the following scenario. "If info-consumers see the world through agent's eyes, then advertising will transform into the art of controlling agents, through bribing, hacking, whatever. You can imagine an 'arms race' between armor-plated agents and hacker-laden ad agencies."

6.2 Agents and the Purchasing Process

Some attempts have been made to classify agent applications in e-commerce according to purchasing process models. Guttman et al. [1998] use a six-stage process model adapted from various consumer buyer behaviour (CBB) models used in traditional marketing theory. The same model is used in a more recent paper by the same authors. [Maes et al, 1999] These stages and examples of agents are shown in Table 5.

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[5] This was the author's impression after using Lifestyle Finder, a recommendation service that uses demographic profiling..

Table 5 - The online shopping framework with representative examples of agent mediation
[from Maes et al. 1999]

Examples of Agents **Stage**	Persona Logic	Firefly	Bargain Finder	Jango	Kasbah	Auction Bot	Tete-a-Tete
Need Identification							
Product Brokering	X	X					X
Merchant Brokering			X	X			X
Negotiation					X	X	X
Purchase and Delivery							
Product service & Evaluation							

Terpsidis et al. [1997] outline a proposed multi-agent electronic marketplace, using a different CBB model as a reference. This model does not make a distinction between product and merchant brokering, instead dividing the brokering function into two stages - *Information Search* and *Evaluation of Alternatives*, which includes negotiations if applicable.

Table 6 - Proposed Agent Architecture and CBB Stages
[adapted from Terpsidis et al. 1997]

Class of Agent	**CBB Stage(s) agent is active**
Shopping Recommender: Uses consumer's profile and collaborative filtering to provide recommendations from electronic catalogs	Problem Recognition, Information Search
On-Line Sales Negotiator: Finds, negotiates and purchases products based on user-specified constraints	Information Search, Evaluation of Alternatives, Purchase Decision, Purchase
Observer Wizard: Collects consumer behaviour (navigation) data for the seller	Problem Recognition
Help Desk Operator: Provides product data during purchase and collects feedback	Purchase Decision, Post Purchase Evaluation
Personalized Retail Store Visualizer: Highlights or displays only those products of interest to the consumer, based on profile information	Evaluation of Alternatives, Purchase Decision

The proposed multi-agent architecture is described as follows:

> "The buying agent collects information about a number of products and presents its conclusions to the buyer. If the buyer is interested in purchasing the product the buying agent contacts the selling agent and starts the negotiating process. During negotiations the agents are able to react to new feedback and go back to collect information about different products and services." [Terpsidis et al. 1997]

The agents making up this architecture are described in Table 6 along with the CBB stages in which they are active. The authors acknowledge that consumer behaviour on the Internet may not follow traditional patterns. "Thus, in order for the deployed architecture to reach an optimal equilibrium point for the retailer and the consumer it must be tested and fine-tuned over not just one but a series of consumer behaviour models". [Terpsidis et al. 1997]

Archer and Yuan [1999] offer a process model for B2B commerce (the Customer Relationship Life Cycle) and identify technologies that can be used to support the relationship between buyers and sellers at each stage. Many of these technologies (i.e. on-line information, catalogues, negotiation support, and auctions) could include artificial intelligence capabilities and/or agent support as shown in Table 7.

Table 7 – B2B Process Stages and Type of Support
[from Archer & Yuan, 1999]

Stage	Vendor Tools	Type of Support
Information Gathering	Transaction and interactive marketing, Bid preparation, Web sites, E-mail	Search Support
Supplier Contact	Interactive Marketing, Bid Preparation, Web sites, E-mail	Search Support
Background Review	Interactive Marketing, Bid Preparation, Web sites, E-mail	Choice Support
Negotiation	Negotiation Support, Groupware, Web auctions	Choice Support
Fulfillment	Scheduling, Tracking, EDI, IOS	Interface Support
Consumption, Maintenance, Disposal	On-line information services, Interactive and network marketing,	Search Support
Renewal	Interactive and network marketing	Choice Support

A rudimentary business-to-business information search agent (or shopbot) was the subject of an experiment by Khoo, et al [1998]. In this application, an mobile agent visits a pre-selected list of suppliers, collects product information, makes comparisons based on how closely the products meet the specifications and uses weightings assigned to each attribute to rank the suppliers' offers. They recommend further research to include more sophisticated negotiation

processes, including the use of short-lists and revisiting, offering incentives, and machine learning.

Nissen [1999] has developed a prototype system of agents to automate the procurement of products such as computer software and office supplies. A process model is used to identify the participants (user, purchasing department, and supplier) and the tasks required. Pilot tests have shown that the agent system can conduct a market survey, issue requests for quote, analyze responses, select a supplier and issue a purchase order within one minute.

6.3 Agents and the Purchasing Situation

The purchasing situation is believed to be an important determinant of buyer behaviour. As the starting point for an agent development framework, the purchasing situation can indicate domains where agents are most applicable. Since repetitive activity is essential for the successful application of agents, frequency of purchase should be one dimension of this model.

The risks associated with a purchase are linked to frequency of purchase, in that uncertainty is generally reduced through repeated transactions. However, there are other factors that will contribute to the amount of perceived risk, such as the amount invested, the importance of the goal, and perceived psychosocial risks. Thus perceived risk is a second dimension in the situation model.

As described in previous sections, marketing research has explored how both frequency of purchase and perceived risk affect the search and choice behaviours of the buyer. The following sections show how this information can be used to design agents to support search and choice activities in different purchasing situations.

6.3.1 Search Support

Because of the extent of the information required, the duration of the search is longer for a new purchase. Search duration may also be extended as a risk-reduction measure, as the buyer tries to reduce the amount at stake by deferring the purchase. [Taylor, 1974] Storage, memory aids, and the continued timeliness of the information will be important considerations in these situations.

Marketing research tells us that acquiring and processing additional information is also a common strategy that buyers use to reduce perceived risk. [Cox, 1967; Taylor, 1974; Webster & Wind, 1972] In a high-risk situation, the buyer wants in-depth information about potential outcomes and consequences so that the uncertainty associated with these factors can be reduced. In contrast, low risk situations are characterized by shallow search behaviour.

We have seen that the credibility of a source is related to both its expertise and its trustworthiness. [Levitt, 1967; Webster & Wind, 1972] Trustworthiness will become less important as the buyer accumulates knowledge and develops the ability to select or reject new information. The type of sources used will therefore change with the buyer's familiarity with the product category. The type of risk also affects the sources used. When performance risk is perceived, buyers place a higher value on information from neutral sources. When psychosocial risk is perceived, buyers will seek out interpersonal sources of information. [Cox, 1967; Klein, 1998; Bettman et al, 1998; Webster & Wind, 1972] Table 8 summarizes these general characteristics of search behaviour as they relate to the purchasing situation.

Table 8 – The Purchasing Situation and Search Behaviour

	NEW PURCHASE	FREQUENT PURCHASE
HIGH RISK	• Extensive search • Trustworthy sources (neutral or interpersonal)	• Directed search • Sources with expertise (neutral or supplier-controlled)
LOW RISK	• Shallow search • Low cost sources	• Directed search • Low cost sources

Agent development must recognize that individual buyers have varying levels of familiarity with a product category and different perceptions of the risks involved in a purchase. Frequent buyers of a product have structured, situational information requirements. Simple "shopping agents" can search a limited set of suppliers and return comparative information on a limited set of situational attributes. Agents can also address the dynamic nature of information content on the Internet by continually monitoring remote sites for relevant changes where market conditions and other environmental variables change frequently. This would be especially valuable in B2B commerce, where raw materials and production goods and services are bought frequently, yet represent large outlays.

More complex content-filtering agents can be used for infrequent but repeat purchases, where the buyer has determined choice criteria but lacks current information about alternatives. These agents can be personalized so that the content of the information selected and presented is closely matched to the user's criteria. Since different types of sources have different values according to the buyer's experience and risk profile, allowing the buyer to select or rank the types of sources would be a useful feature.

The choice criteria may dictate the use of a heterogeneous mix of attribute information from full-text documents, semi-structured sources such as catalogues, or traditional databases. The content-filtering agent must be able to assemble this information using different query techniques. This is an area where cooperating agents may best facilitate information retrieval. The buyer agent would maintain the buyer's individual profile, while the seller agent or an intermediary would hold the knowledge base that "translates" the buyer's request into the necessary queries. Risks in information retrieval can be related to two possible types of errors – a relevant document may not be retrieved (a "miss"), or a non-relevant document may be retrieved (a "false positive"). The possibility of a miss will contribute to uncertainty when using an agent to find information. False positives will reduce the performance and value of the agent. The type of error and its consequences must be considered when designing agents for a specific domain. [Konstan et al, 1997] By using semantic knowledge about the specific domain, the seller or intermediary agent could improve the recall of the result, reducing the possibility of a "miss". The buyer agent would ensure precision, and avoid "false positives" by only including information relevant to the chosen criteria in the final response to the buyer.

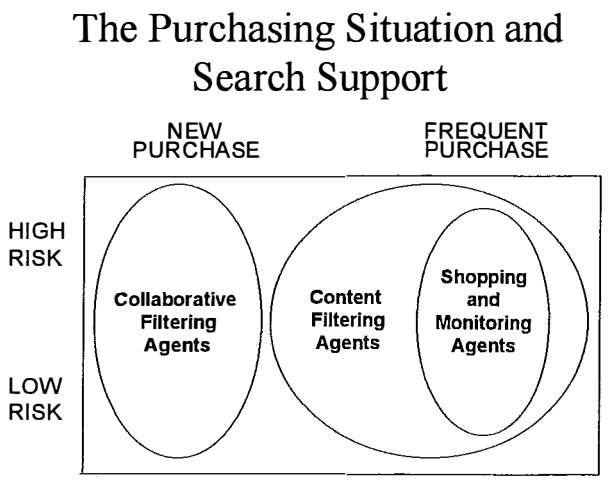

Figure 12

Collaborative information filtering uses the experience of more than one information-seeker to broaden the search. This is especially valuable when the user has little experience on which to evaluate content. It may therefore be effective in establishing choice criteria for new purchases. Collaborative filtering has primarily been applied in B2C situations such as music CD's and movie rentals, where the risk of a poor recommendation is relatively low. For other purchasing situations, including those in B2B commerce, the idea of using an agent-based system to collect information from "expert recommenders" holds promise. [Ackerman et al, 1997]

6.3.3 Choice Support

In a repetitive purchasing situation, there is little uncertainty. Buyers know the attributes that are important, and have limited the alternatives to those products with the necessary values in these attributes. The decision problem is highly structured. In a new purchase, unstructured and

constructive choice processes are observed. Buyers often use a staged approach where a constraint-based approach is used initially to limit the number of alternatives. A strategy employing more extensive information processing can then be applied to this limited set of alternatives. [Bettman et al, 1998]

While choice behaviour that involves extensive information processing is a recognized risk-reduction strategy, less rational strategies such as loyalty to current suppliers and investment reduction are also commonly observed. [Webster & Wind, 1972] Important characteristics of choice behaviour, according to the framework are shown in Table 9.

Table 9 – The Purchasing Situation and Choice Behaviour

	NEW PURCHASE	FREQUENT PURCHASE

HIGH RISK	• Unstructured processes (staged, constructive)
	• Risk reduction through
	  • Extensive information processing
	  • Trade-off avoidance
		• Structured processes
		• Risk reduction through
		  • Use of familiar suppliers/brands
		  • Investment reduction

LOW RISK	• Unstructured processes (stage, constructive) • Minimal information processing	• Structured processes

Highly repetitive, low risk buying situations will be the most appropriate domain for delegation of the choice process to an agent. In B2B commerce, the straight rebuy occurs with the most frequency and is the most structured and routine of purchasing situations. Information systems have already been developed to support much of this activity. For this reason, agents are likely to supplement existing information support systems. Agents, with their ability to decrease processing costs, may be employed to increase the number of "approved" sources considered for each purchase.

In electronic marketplaces, buying and selling agents can be programmed with simple negotiating strategies. [Chavez & Maes, 1996] Researchers are also looking at the potential of Bayesian networks and genetic algorithms as mechanisms for agents to learn more complex and effective negotiating strategies. [Maes et al, 1999; Beam & Segev, 1997; Dworman et al, 1996] such systems could be effective in highly repetitive, low risk situations. It should be noted that some of the risk inherent in frequent decisions is masked by risk reduction techniques. The ability to use low cost agent decision support may reintroduce some elements of risk (balanced by related opportunities) in these situations.

While increasing risk in the purchasing situation will encourage the use of agents for search support, it must be seen as a barrier for choice support. It is highly unlikely that buyers will delegate risky decisions to an agent. Nevertheless, intelligent components of a DSS can still be employed to generate and evaluate alternatives and assist buyers in employing strategies that require more extensive processing. Expert systems have been used in some purchasing applications where frequent application can justify the high cost of development. [Cook, 1992] In B2B commerce a modified rebuy has similarities to a straight rebuy situation by definition. This suggests that case-based learning and reasoning capabilities may be applicable. [Cook, 1997]

In a new purchasing situation, model-based DSS using multi-attribute, constraint-based, or combinations of decision models, can be employed to process alternatives based on the user's preferences and accommodate both staged and constructive choice processes. Marketing and IS researchers have identified areas where buyers are likely to choose dominated alternatives, miss "just discernable differences", or eliminate otherwise attractive options using constraint-based strategies. [Bettman et al, 1998; Widing & Talarzyk, 1993; Arthur, 1991; Davis & Olson, 1985; Holsapple & Whinston, 1996] Intelligent components of a DSS could increase the quality of decisions by alerting the buyer to these situations.

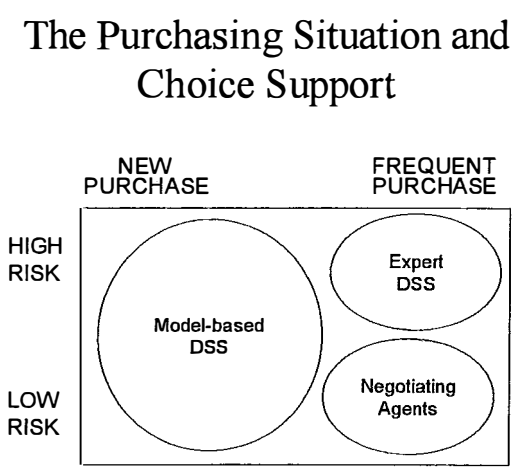

Figure 13

Finally, while the objective of IS should be to assist the buyer in overcoming cognitive limitations and make better decisions, but we must remember that only the buyer will judge the quality of the decisions. Information systems can not ignore the emotional and social factors that limit "rational" behaviour. Forcing a buyer to examine trade-offs may be necessary to increase the accuracy of the decision, but may not be accepted when the buyer's preference is for emotional-focused coping.

6.3.5 Interface Support

Much of the current research on agents has focused on the user interface. Lanier and Schneiderman both believe that agents are just an excuse for sloppy interface design. Schneiderman [1997] argues for direct manipulation, and believes that "the effective paradigm for now and the future is comprehensible, predictable, and controllable interfaces that give users

the sense of power, mastery, control and accomplishment." [p.100] Lanier takes a more confrontational stance, suggesting that an agent be defined as "(a) network/database query program whose user interface is so obscure that the user must think of it as a quirky but powerful person in order to accept it."

The appropriate use of anthropomorphism is the subject of heated debate in the agent research community. Advances in natural language processing (NLP) and the multimedia capabilities of today's systems mean that the presentation of agents to the user can range anywhere between a text dialogue box to a "full-blown simulated personality". [Laurel, 1997] Anthropomorphism requires sophisticated NLP capabilities. For an interesting comparison of past and present attempts to simulate full human conversation, see the Chatterbots on Botspot, http://www.botspot.com.

Both General Magic and Microsoft seem to have completely integrated their concepts of agent technology with NLP. General Magic was one of the early developers of agents and agent systems. As of June 1999, its Web site (http://www.generalmagic.com) is completely devoted to NLP systems. A search for the keyword "agents" on the Microsoft Web site finds a reference to instructions on how to build one of three animated characters in Visual Basic. These characters will respond to voice commands and "read" documents to the user. [Microsoft, 1999] A bias towards anthropomorphism is not surprising considering Microsoft's previous attempt to introduce an interface agent named "Bob" and its current version of the "Office Assistant".

Arguments in favour of the use of human-like character traits in agent interfaces are that these traits "function as stereotypic 'shorthand' for understanding and predicting character behaviour" [Laurel, 1997, p.75]. While humans naturally use metaphors based on humans or animals to describe behaviour, the question is how selectively these metaphors are applied. Laurel argues for the use of dramatic characters, "selecting and representing only those traits which are appropriate to a particular set of actions and situations" and suggests that an agent should pass an anti-Turing test, where the user is assured that the behaviour of the agent will be more predictable than that of a human. The Turing test, originally proposed by Alan Turing in 1950, describes an observer using a terminal to interact with both a human and a computer by asking questions and receiving answers. Turing proposed that a computer could be considered intelligent if this observer could not tell which correspondent was the human and which was the computer. [Turing, 1950]

Erickson [1997] considers the question of selective representation by asking how we should portray "semi-intelligence". Bradshaw [1997] uses the example of a "digital dog" sent to the newsstand for the NY Times; If the stand is out of the NY times, the "digital dog" will return

without a paper, whereas a "digital butler" would choose another paper that it knew the user would like. Laurel [1997] explains how a "digital dog" would be expected to deliver the newspaper, but would not be expected to interpret it.

Experiments have shown, however, that the use of metaphors is so natural that even very small cues are enough for users to apply "social rules" to the behaviour of machines. As a result, the user's characterization of the agent as a living being may be unavoidable. [Erickson, 1997] Arguments against anthropomorphism are that it falsely raises expectations. If a user sees some language understanding, he or she expects full understanding. [Norman, 1997] Users may also avoid accepting responsibility for results, and continue a tendency to "blame the machine". [Schneiderman, 1997; Lanier]

Koda and Maes [1996] study the effect of using faces and facial expressions to represent an agent in an entertainment domain. The results showed that personification was welcome, overall, in this domain. However, they conclude that a significant group of users are not in favour of personification in general and the interface design should be flexible in light of this dichotomy. From a practical point of view, history tells us that "anthropomorphic terms and concepts have continually been rejected by consumers". [Schneiderman, 1997] Additional research into the reactions of users is required before appropriate agent design can be approached, with special attention to simple choices for users among agent display and action (e.g. personification, less obtrusive appearance, or just plain disabling the agent).

A user's experience level and frequency of use has been recognized as an important determinant of dialogue preferences. While NLP is an active area of agent development and may play an important role in facilitating the dialogue between buyers and agents, its capabilities are still limited. The risks and frustrations associated with miscommunication using imperfect NLP technologies may hamper the development of trust in the agent. NLP is expected to be of more value when agents are employed in infrequent or one-time buying situations. NLP may not be necessary, and may even be detrimental, when an application is used frequently.

Decision-makers with experience in a domain have shown different display preferences (text, tabular, graphical) than those without experience. [Montazemi, 1991] The choice strategy must be also be considered when determining how information should be displayed (i.e. by attribute or by alternative) so that appropriate comparisons can be made. Search, choice and dialogue support must be integrated to ensure that information is displayed appropriately.

After a choice strategy is chosen, data may need to be restructured through transformation, editing and inference operations. Restructuring has also been seen as a constructive process where patterns and regularities in the data may suggest the use of an

appropriate choice strategy. Constructive restructuring is most commonly observed with inexperienced buyers. [Coupey, 1994] Intelligent interface support could assist buyers in restructuring operations. Agents could assist constructive restructuring by eliminating redundant or irrelevant information and identifying patterns that suggest the use of a particular choice strategy.

Table 10 - A Typology of Restructuring Operations

[from Coupey 1994]

Editing	• Round values • Eliminate redundant attribute information • Eliminate non-diagnostic information
Transforming	• Standardize attribute values • Re-label attribute weights or values (e.g. by ranking) • Combine information (e.g. group similar options) • Segregate information (e.g. good and bad options) • Rearrange information (e.g. create a matrix)
Inferring	• Infer attributes • Infer attribute values

(Note: Source references for individual operations have not been shown. See Coupey 1994 for this information)

6.4 Agent Knowledge Bases

We have looked at some search and decision tasks that we want agents to support. We have also looked at how the purchasing situation may influence the buyer's search and choice behaviour while performing these tasks. This section summarizes the knowledge bases that can be built into agent-enabled systems, according to three major types of knowledge: procedural, factual, and semantic. Procedural knowledge is commonly represented in the form of rules and processed through inference engines. Factual knowledge can be represented in forms as diverse as structured databases, semi-structured forms such as indexing systems and XML tagging, and unstructured full text documents. Semantic knowledge is derived from ontology and represented in semantic nets.

Table 11 shows the knowledge bases required for search support, choice support and interface support, with references to useful sources of information about these topics.

Table 11 – Agent Knowledge Bases

Search Support		
FACTUAL KNOWLEDGE	PROCEDURAL KNOWLEDGE	SEMANTIC KNOWLEDGE
Directories to identify sources of information on products, sellers, and other users	Query formation using rule-based and/or learning systems [Etzioni, 1997]	Ontology, semantic nets [Mayfield et al, 1995; Widmeyer & Lee, 1986]
Product and seller information in databases, indices, catalogues and documents	Search heuristics	
User profiles [Lieberman; Ackerman et al, 1997; Pazzani, 1999]	Matching algorithms for information retrieval, filtering, and monitoring [Belkin & Croft, 1992]	
	Clustering and other statistical techniques	

Choice Support		
FACTUAL KNOWLEDGE	PROCEDURAL KNOWLEDGE	SEMANTIC KNOWLEDGE
Product attributes	Decision models and algorithms (including group decision-making processes)	Transaction protocols [Covington, 1998]
Seller attributes	Process and workflow knowledge [Bui & Lee, 1999]	Negotiation protocols
User profiles	Negotiating strategies, using rule-based or learning systems [Beam & Segev, 1997; Perkins, 1996]	
Case-based systems [Cook, 1997]		

Interface Support		
FACTUAL KNOWLEDGE	PROCEDURAL KNOWLEDGE	SEMANTIC KNOWLEDGE
User profiles	Restructuring operations [Coupey, 1994]	Natural language processing systems

7. Conclusions

This paper has provided an overview of the field of software agents and their potential applications in e-commerce. The rate of innovation in e-commerce and the Web means that developers need to be able to move quickly from research to commercially viable products. Related developments in e-commerce, such as Extensible Mark-up Language (XML), and efforts to migrate traditional Electronic Data Interchange (EDI) transactions to more flexible platforms will remove some of the remaining technical and process barriers to agent-enabled e-commerce. As agent developers move past a technology focus to a product focus, we will see the adoption of agent technologies into e-commerce processes. The product-focused approach taken in this paper has identified functions that agents can perform for their users and issues surrounding agent ownership.

Using the DSS model, the functions that agents perform can be categorized as search support, choice support, and dialogue/interface support. Despite what may be a prevalent development focus on the interface, agents can play a role in all three components of a traditional DSS. Intelligent and personalized support for information retrieval and management can assist buyers and sellers with the complex information exchanges required in the commerce process. Intelligent and personalized support can also be applied to the selection and deployment of choice strategies.

Marketing research has identified characteristics of the purchasing situation and buyer behaviour that may help guide agent development. Frequency of purchase and perceived risk provide a framework that can help match agent functions to buyer's needs. When buyers purchase a product frequently they develop structured information requirements and choice processes. Simple agent components can provide both search support and choice support in these situations. In other situations, the purchasing situation model identifies important differences in the type of information required, the extent and duration of search behaviour, and the choice processes likely to be used. Because the value of information increases with perceived risk, buyers would be expected to find agents that support search efforts helpful across all purchasing situations, but these agents will have to be designed to meet the different information needs that arise in these different situations. It is unlikely that buyers will delegate high-risk decisions to agents, but intelligent components of a DSS system can be used to help the buyer process more information and use it more effectively.

In frequent and/or low risk situations, supplier-controlled sources of information are valued and supplier-provided components for search support are likely to be acceptable in these

situations. The supplier's expertise can be exploited in frequent, high-risk purchasing situations. Interpersonal and neutral sources will be preferred in high risk, new purchase situations and information bundling intermediaries may be in the best position to provide agent support in these situations. Lowering the cost of search through ease of use will be an important factor in low risk purchase situations.

Our framework is based on marketing research that was developed to describe traditional commerce. A better understanding of how buyers and sellers find interpret, value and use information in the e-commerce environment would help to expand this framework. Klein [1998] suggests that the new interactive media may provoke a return to marketing research based on the theories of information economics, and away from the product and consumer segmentation models that have dominated marketing research for the last few decades. Renewed interest in these areas should provide opportunities for interdisciplinary collaboration between information systems and marketing researchers. By matching the capabilities of agent technology to the needs of buyers and sellers, collaborative efforts could accelerate the development of agents that users will trust to help them cope with the complex decision-making tasks posed by e-commerce.

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Appendix A - The 6-P Model

[from Yuan, Archer, and Bassett, 1998]

People	• Restrict, extend, and redefine prospective customers • Demographic identification of market niches • Enrich information gathering to identify customer preferences and buying behaviour • Encourage higher expectations of wider selection, lower prices, better service • Change perceptions and trust of virtual / physical institutions
Product	• Enrich information content of existing products and services • Enable new forms of information products and services • Enable mass customization of products and services • Increased attention to copyright protection issues
Place	• Movement from physical space to virtual cyberspace • On-line delivery of information goods and services • Support outsourcing, electronic coordination of in- and outbound logistics • Promote globalization of the marketplace
Price	• New forms of pricing and payment methods • Development of more efficient markets, more competitive prices • Raise new taxation issues
Promotion	• Enable new options for push and pull technologies • Encourage, facilitate customer initiated information search • Attract customer attention with free information services • Extensive tailored product and service information • Development of virtual communities • Flexible promotion strategies easily implemented
Partners	• Eliminate or adapt existing intermediaries • Create new digital intermediaries, including web-base search-engines, directories, auctions • Coordinate partners via virtual links • Search engines, directories support customer shopping

Appendix B - Decision Strategies

[adapted from Bettman et al. 1998]

Weighted Adding: The consumer assigns importance weights to each attribute being compared. Each alternative is then evaluated in turn, with a subjective value assigned to each attribute according to its relative performance in meeting the consumer's objectives.
Lexicographic: Using a lexicographic strategy, the consumer decides which is the most important attribute, and determines which alternative has the best value on this attribute. This alternative is selected.
Satisficing: Alternatives are considered in sequence, with the value of each attribute compared to a minimum cut-off level that has been determined for that attribute. The first alternative that passes the cutoff level on all attributes is selected.
Elimination by Aspects: this is a combination of the Lexocographic and Satificing strategies. Alternatives are eliminated if they do not meet a minimum cutoff level on the most important attribute. The process is then repeated for the second most important attribute, and so on, until only one alternative remains.
Equal Weight Strategy: Similar to weighted adding, the equal weight strategy assigns values to each attribute in each alternative, however all attributes are considered of equal importance.
Majority of Confirming Dimensions: In this strategy, the consumer considers a pair of alternatives by comparing the values of the attributes. The poorer alternative is discarded and the better alternative is then compared to the next alternative. The process is continued until only one alternative remains.
Frequency of Good/Bad Features: If the consumer decides to focus on good features, a count of the attributes rated as good is conducted for each alternative. Similarly, the consumer could decide to focus on bad features and count the number of bad features.
Componential Context Model: This model combines a perceptual approach and relational heuristics. It can include searching for patterns of dominance among pairs of alternatives, consideration of relative trade-offs and compromise effects. Studies of this approach have so far been limited to fairly simple decision tasks.

Appendix C- Types of Buying Situations ("Buyclasses")

[from Robinson et al, 1967]

I NEW TASK

- A requirement or problem that has not arisen before
- Little or no relevant past buying experience to draw upon
- A great deal of information is needed
- Must seek out alternative ways of solving the problem and alternative suppliers
- Occurs infrequently – but very important to marketers as it sets the pattern for the more routine purchases that will follow
- May be anticipated and developed by creative marketing

II. STRAIGHT REBUY

- Continuing or recurring requirement, handled on a routine basis
- Usually the decision on each separate transaction is made in the purchasing department
- Formally or informally, a "list" of acceptable suppliers exists
- No supplier not on the "list" is considered
- Buyers have much relevant buying experience, and hence little new information is needed
- Appears to represent the bulk of the individual purchases within companies
- Item purchased, price paid, delivery time, etc., may vary from transaction to transaction, so long as these variations do not cause a new source of supply to be considered

III MODIFIED REBUY

- May develop from either new task or straight rebuy situations
- The requirement is continuing or recurring or it may be expanded to a significantly larger level of operations
- The buying alternatives are known, but they are CHANGED
- Some additional information is needed before the decisions are made
- May arise because of outside events, such as an emergency or by the actions of a marketer
- May arise internally because of new buying influences, or for potential cost reductions, potential quality improvements or potential service benefits

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