Perspectives on and Prospects for Software Agent Systems

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Abstract

In this paper we propose a framework for analyzing the impacts of software agent system. The framework is applied to examine the impacts of an agent-based scanning and interpretation system on managers, as users, and on their scanning process and outcomes. Perspectives around the agent system are developed. Drawing on trends and developments in IT (Information Technology) and AI (Artificial Intelligence) fields, we also speculated on prospects for software agents.

Keywords: software agents, strategic scanning and interpretation system, impacts, prospects

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1. Introduction

Software agents are computational programs that attempt to model and simulate human mind and human behavior, to become substitutes for human agents. Agents act to accomplish delegated, specialized tasks on behalf of users (Maes, 1994; Wooldridge and Jennings, 1995). They participate actively in accomplishing specific missions by taking initiative autonomously and acting towards reaching certain user-specified or automatically generated goals.

Computing programs traditionally depend on users to use them. Software agents make it possible for the programs to work independent of users' presence and instructions, and to deliver only customized, user-wanted information and service. Conventional programs usually remain dormant until specifically called by user instructions, whereas agents are always "alive" and ready for action and do not rely on users' explicit action to be activated. They work in background and perform automatic actions at the user-level of abstraction (Maes, 1994; McKie, 1995).

Central to the notion of an agent is its autonomous and goal-directed behavior. However, automata are not new concepts. Intelligent machines have existed in fact or fiction for centuries. The interest in having an agent to do certain tasks for people has always been there, and it is in fact regarded as the primary driving force of the agent domain (Minsky, 1994; Norman, 1994). The reason why this field is revitalized today is to a large extent attributed to the development of information technology and the increase in computational power. In one aspect, applications thought to be impossible to automate in the past are rapidly becoming a possibility; in another aspect, today the widespread computer systems create new, extra tasks for people. Computers can do more to help people to exploit most from the computerized systems, and they are also expected to do so because people need help to deal with the ever-increasing information overload and work overload.

The concept of an agent has been used widely in the computer science literature, though not always as an entity directly at the user's service. Agents have great potentiality in a broad range of applications and people do seem to like to use the agent concept and technology in more and more contexts. Significant interest in agent research and development can be found scattered across different areas such as AI and mainstream computer science, robotics, software development, information access and management, network management, and many others (Riecken, 1994a, 1994b; Wooldridge and Jennings, 1995). In management studies, the agent concept has been utilized in designing agent-oriented organizations.

Accompanying its fast growing there also arose serious concerns about the impacts of software agents on people and the society. As Norman described (1994), agents occupy a strange place in the realm of technology - generating fear, fiction, and extravagant claims. "Agents may well have numerous positive contributions to our lives. They can simplify our use of computers, allowing us to move away from the complexity of common languages or the tedium of direct manipulation toward intelligent, agent-guided interaction". "Agents promise to hide complexity, to perform actions we could not or would prefer not do ourselves". However agent technology is not problem-free. "...along with the potential comes potential danger. ... Along with their benefits and capabilities comes the potential for social mischief, for systems that run amok, for a loss of privacy, and for further alienation of society from technology through increasing loss of the sense of control." (Norman, 1994). Agents (may) make people diminish themselves and start to think of themselves as being like the computer, as a consequence of unavoidable psychological algebra. *"They (will) start to limit themselves to the categories and procedures represented in the computer, without realizing what has been lost."* (Lanier, 1996).

The fact is that, agent technology and applications are still in the early stage of development and much of their effects and impacts remain to be explained. To address these concerns, in this paper we attempt to analyze the impacts of an agent-based environmental scanning system which we have developed to help managers in their environmental scanning activities. We shall first build a framework for analyzing the impacts of software agent system. We will then apply the framework to examine how the scanning agent system will affect managers, as users, and on their scanning process and outcomes. Perspectives around the agent system are developed. Drawing on trends and developments in IT and AI fields, we also speculated on prospects for software agents.

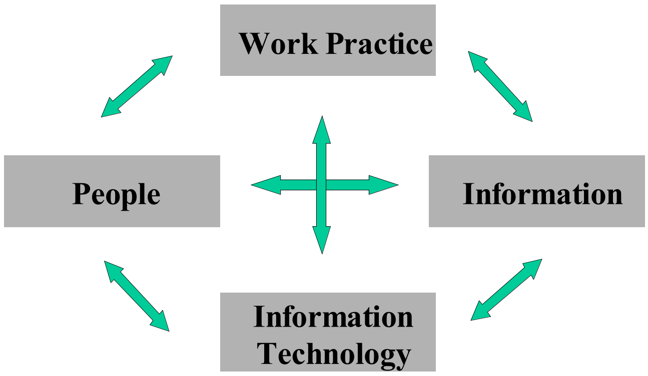
2. Conceptual Underpinnings

In information system studies, Leavitt's Task-People-Structure-Technology framework (Leavitt, 1965) has been frequently applied to analyze the role of information technology as an agent for organizational changes (Singh et al, 1994). Task, people and structure constitute the organizational context in which applications of technology happens. Tasks are the reason for an organization's existence. People are the organizational factors responsible for initiating and implementing changes. Structures are the organizational systems of authority, communication, and workflow. Technologies are problem solving tools. Task, people, structure and technology are highly interdependent; changes in any of them are usually accompanied by changes in one or more of others. The introduction and development of technologies in an organization may cause changes in its task, people and structure, or a combination of them (Leavitt, 1965).

While Leavitt's framework formulates a macro-context to understand the organizational impacts of information systems, Alter's information system model presents us a framework to study information technology in a micro-context (Figure 1) (Alter, Information Systems: A Managerial Perspective). According to Alter, work practice, people, information and information technology constitute an information system, which constantly evolves with the changes in its components or in the environment. Work practices must continually change to meet the challenges of the outside world. Work practices determines information needs; the availability of information determines which work practices are feasible. Work practices affect people in the organization, the characteristics of an organization's people will influence work practices.

Work practices determines requirements for technology support. People, information needs and information technology must adapt to new work practices. At the same time, the adoption of technology may change work practices, affect people and the way people conduct work practices. For instance, the application of information technology impose certain structures on the execution of tasks. It may automate a task and replace people to accomplish the work. It may simply formalize a task by establishing and enforcing methods and procedures that maintain uniformity and efficiency. Or it may only try to facilitate a task by providing tools an dinformation which can be used to perform the task more easily (Alter). The use of IT can also greatly speed up the pace of the work practice, which results in products being envisioned, developed and distributed much more quickly. As current technology becomes more powerful, it encourages the development of even more powerful technologies. These new technologies enable advances in work practices. On the other hand, information technology also brings potential threats and burdens to users, for example efforts on learning about new technology, getting used to working with computers, information and work overload, cognitive overload, loss of sense of control, loss of privacy, etc. (Alter, Ackoff, Norman).

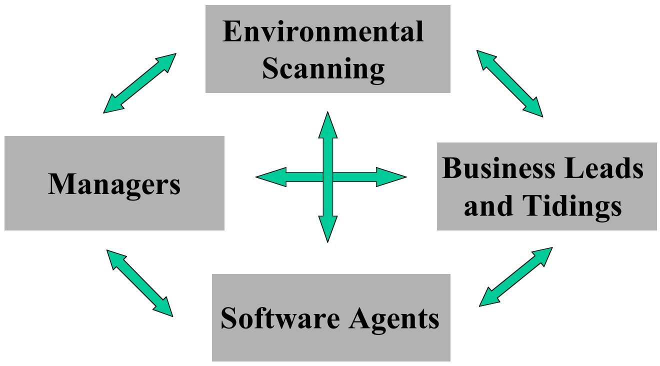
Figure 1. The Information System Model
(Source: Alter, 1996)
1996199619961980)



3. Agent-Based Environmental Scanning System

An environmental scanning system involves data acquisition and interpretation as work practice, managers as scanners and sensemakers, business leads and tidings as the central information content, and a computer system (here an agent system) as the technology tool, as is shown in Figure 2.

Figure 2. The Environmental Scanning System



Environmental scanning is the mechanism for an organization to be constantly alertful to threats and opportunities arising from various environmental forces. The view that sees external environment of an organization as one of the major determinants of its strategy is widely accepted. However the tools to monitor and grasp this important determinant are less developed than demanded. Traditionally the managerial understanding of a business environment has often been characterized by *intuitive and fragmented activities*. As the environment increases in scope, dynamics and complexity, the information to be digested explodes. The task of grasping environmental changes becomes increasingly demanding and threatens to exceed human capacity to bear it alone. Often data collected may contain rich information of strategic value while at the same time they may present incomplete, inaccurate and sometime conflicting signals that are subject to analysis and interpretation to figure out their real meanings and to understand their impacts on business. However the analysis and interpretation is greatly complicated by the enormous quantity of data. There is often the risk that there is too little time and too few skilled people for doing the detailed analysis of data and making sense out of the data, or it is often too costly to follow up the new information manually and to assure that the data are not outdated by the time someone gets around to analyze them (Bayer and Harter, 1991; Rangaswamy et al, 1991). The scanning and interpretation task becomes an extremely time-consuming, labor intensive and knowledge intensive process. The task of identifying all interesting events, giving explanations as to why those events occurred, grasping their interrelationships and understand their impacts on business, will be even more enormous.

All these changes in the business environment call for developments in the work practice of environmental scanning, which in turn calls for advances in the scanning technologies. Managers would need powerful information access and management tools to help them to get to the *limited, right* information, evaluate the accessed information and extract meaningful insights from it. In our case, the new technology tool we have developed is a software agent based computer system (Liu, 1998a, 1998b, 1998c; Olofsson, 1998).

3.1 Environmental Scanning: the Process and Outcome

Environmental scanning is the acquisition of information about events, trends, and relationships in an organization's business environment, the knowledge of which will be of assistance to top executives in identifying and understanding strategic threats and opportunities (Aguilar, 1967). A complete process of environmental scanning encompasses a number of interconnected tasks including (1) look for information. (2) recognize only those that are relevant to own business, to classify the chaos of data into structures. (3) understand the identified events, to bring meaning out of observations. (3) discover plausible relationship and structures (e.g. cause-impact maps). (4) develop frames of references or models for understanding. The central information activity resolves the equivocality of environment information into meaning and action.

The scanning process is often evaluated by its efficiency, effectiveness and economics, characterized by a variety of attributes (Aguilar, 1967):

Table 1 Attributes of Scanning Process

Properties	. intuitive vs formalized, fragmented vs systematic, occasional vs continuous, rigid vs flexible (adapt to changing information needs) . personalizable . customizable
Rule of Efficiency	. instant feedback . time spent . good source accessibility . types and levels of scanning skills available in the organization
Rule of Effectiveness	. scope and magnitue . interests and values of the people who do the scanning . learning effects . results (good or poor): information quality
Rule of Economics	. cost: access to commercial information service, manpower expenses (cost must be weighted against benefits)

The direct outcome of the scanning process is information. Information quality is one of the indicators for the effectiveness of scanning activity. Information quality is always a multidimensional concept. It is often measured in terms of a set of characteristics (Alter; Singh et al, 1994; Wang et al, 1995; Watson et al, 1995):

Table 2 Information Quality Attributes
• *Value and Relevance:* related to the capacity of information for reducing uncertainty and resolving ambigurity.
• *Accuracy:* the degree to which the information portray what it is supposed to portray.
• *Reliability:* trustworth of the information, related with the credibility of its source.
• *Age (currentness), Timeliness* and *Time Span:* recent information is often more trusted and valued than older information (depends on what is the purpose for using the information).
• *Completeness* or *Sufficiency:* related with scope of coverage and level of detail or level of summarization. The scope and coverage of subject matter is important to data quality. A lack of understanding of the mental models of executives translates into inadequate information coverage, multiple cues,
• *Consistency:* conformity among information
• *Format:* media and layout, variety in presentation
• *Understandability:* information presented and known in context.
• *Precision:* the fitness of detail of the portray.

The quality of the acquired environmental information depends on the design and production process involved in generating the information. For example, the value, relevance, accuracy, reliability and consistency of information depends very much on the accessibility to good sources, availability of scanning skills, interests and values of the people who do the scanning.

The completeness or sufficiency, age (currentness), timeliness and time span of information are determined by the scope and magnitue of scanning, time spent on scanning, scanning speed, which have dependence on whether the process is intuitive or formalized, fragmented or systematic, occasional or continuous, rigid or flexible. The quality of information is also, of course, generally related to the cost of the scanning process. But high cost does not naturally guarantee good information quality.

3.2 Managers: Mental Models and Cognitive Capacity

Managers' mental models and cognitive efforts are indispensable inputs to the scanning process. How data are collected and interpreted, as well as the quality of interpretation and understandings always have a dependence on manager's interest, value, scanning skills and mental models as well as the time and effort managers would like to commit to scanning activities.

A mental model is the representation of belief and knowledge in the head, at conceptual level, as interconnected set of understandings and assumptions about the business elements and their effecting relationships. It reflects implicit views of what one's interests and concerns are, what is important, what demand action and what does not. Managers develop simplified mental models of reality using only a small part of the information available (approximate rationality), combined with prior knowledge, experience, intuition and judgement (Isenberg, 1985; Durand et al, 1996). Mental models are employed to synthesize data, make sense out of data. They enable individuals to make inferences and predictions, to understand phenomena, to decide what actions to take. New information is understood in the framework of existing mental beliefs and models. The key factors and links of the mental model affect the types of information to be watched, and the types of information used to evaluate the impacts or to interpret the information.

Mental models tend to be static during a certain period of time. However, over time with the accumulation of managerial experience as well as changes in business context it may call for changes in the models. Imposing new information leads, new understanding of the environment, engaging in the scanning process and learning in the process can trigger the change of existing mental models.

Cognitive effort refers to cognitive resource-expenditures, e.g. information processing effort, planning effort to determine what information to seek and watch, communicating effort, learning effort, etc. Cognitive capacity sets the bound or limit of cognitive effort. The cognitive effort expenditure in accomplishing tasks is also dependent on the approach used. For example, heuristics can save considerable effort relative to a normative approach while sacrificing little in terms of accuracy (Johnson and Payne, 1985; Payne et al, 1988; Thorngate, 1980).

The theory of bounded rationality and the cost-benefit view of cognition suggest that the joint objectives of a decision maker are to maximize accuracy (or decision quality) and minimize effort expenditures (Simon, 1965; Payne, 1982). As these objectives often conflict, tradeoffs are made between the two. The tradeoff between effort and accuracy is likely to be highly dependent on characteristics of the task. A decision maker who emphasizes accuracy would be performing a task using all available cognitive resources. Give two strategies that produce equivalent outcomes, the one that is expected to require less effort will be preferred. Other things being equal, decision makers will try to minimize effort (Beach and Mitchell, 1978; March, 1978; Todd and Benbast, 1992). However, often the cost and benefit are not so easily and accurately determined, or better outcome does require more effort expenditure and "real" tradeoffs have to be made. The research of Todd and Benbast (1992) suggests that decision makers appear to weight effort considerations heavily, attend more to effort reduction than to accuracy maximization. They tend to place a high value on effort minimization because feedback on effort is both an immediate and tangible feedback on accuracy (Todd and Benbast, 1992). In scanning activities, managers need to tradeoff cognitive expenditures with information quality.

Table 3 Cognitive Elements

Cognitive Structure	. mental models . learning effects
Cognitive Efforts	. effort expenditure: information processing effort, communicating effort, learning effort . cognitive capacity

3.3 The Technology: DSS and Software Agent System

Support tools (DSS) are invented to help people to improve decision quality and save decision effort. More generally, management methods are computerized as technology means via DSS to help managers accomplish their management tasks and enhance productivity in work performance. The technology means may automate some of the tasks previously handled by people, structure and formalize methods and procedures for accomplishing tasks, or supply tools that will facilitate the execution of tasks. In taking different approaches, work practices get structured and influenced to a varying extent. People are also impacted differently.

Although DSSs are purported to improve decision quality and save decision effort, they can not guarantee that decisions be made at a lower level of cognitive cost than they would have without the DSSs. In fact, when assisted with a DSS, users' cognitive effort expenditure often get expanded because it consists of not only the effort to process information generated by the system but also effort to learn about the system and to use the system. Sometimes, the effort associated with using the tool might overburden the user and inhibit their additional information processing (Todd and Benbast, 1992), such as in the case where a DSS is designed only to provide user a basket of tools and the user is left to decide if and how system capabilities should be employed. When a user is immersed in an information-rich or knowledge-rich environment, he may also be overloaded with heavy cognitive activity.

The use of support tools will also have influence on users' cognitive structures of understanding, i.e. the mental models. Rochart and DeLong speculated that, in the long run, the enhanced mental models of the system users may be the most significant effect of computer support to managers (Rochart and DeLong, 1988). Mental models can be significantly enhanced by looking at the same information from different perspectives, looking at a piece of information in a general picture, validate and test assumptions in new situations, exploring new cause-effect relationships, and help to clarify ambigurity relationships (Rochart and DeLong, 1988). Support tools are especially valuable when managers are facing large-size problems. The negative impact of support tools on human cognition may come from underlying psychological effects. That is, support tools may make people diminish themselves and start to think of themselves as being like the computer (Lanier, 1996). They (will) start to limit themselves to the categories and procedures represented in the computer, thus lose their vision and creativity.

While the traditional DSS literature has emphasized the importance of decision quality (Keen and Scott Morton, 1978), literature in behavioral decision theory has indicated that effort may be a more important overall consideration in many problem contexts. In settings where the decision makers must live with the consequences of the decision, it may be that the decision quality becomes a primary concern and increased effort expenditures will result from support tool use. In many other cases, managers will tend to play high priority on effort saving (Todd ans Benbast, 1992). The software agent approach, as a way of building support constructs, emphazises effort saving, flexibility and customizability. Software agents make it the principal idea behind DSS to look for the best synergy of human skills, experience, creativity and judgement with computerized analytical and inference instruments.

Agents are purpose or goal-directed. The agent approach suggests task and responsibility delegation. In accomplishing their assigned tasks, agents take initiative autonomously and decide own course of actions dynamically while responding to their environment. Such an approach simplifies the use of computers, allows users to move away from computing details and to focus on more conceptual constructs. Agents promise to hide complexity and to increase efficiency in information processing. The delegation of functions supports user mobility [Etzioni and Weld, 1995, 1996; Maes, 1994; Norman, 1994].

An agent system can make things happen proactively as it can operate without depending on initiative from user. However, the user does have the power and is given the mechanisms to exert control and interference to agent's performing process. Users can define their personalized profiles or the agent can implicitly learn about users' needs and preferences, to customize its support service to changing requirements. Agent systems are easy to use and are often endowed with powerful computing and information processing capability. The disadvantages are that the risks are higher for a loss of privacy, for systems that run amok, and for further alienation of society from technology through increasing loss of sense of control.

To sum up, support tools can be described in terms of such attributes as: structures imposed on tasks, degree of ease of use (related with demanded cognitive effort and learning effort from users), feedback and follow up capability, information processing capability, target problem size, etc.

Table 4 DSS and Software Agent System
. structures imposed on work practice . degree of ease of use (related with demanded cognitive effort and learning effort from users) . operating and maintenance cost . feedback and follow up speed . information processing capability . problem size . privacy concerns . user's control over the system . constraints on users

4. Impacts of An Agent Based Scanning and Interpretation System on Managers and Their Strategic Scanning Activities

The discussions in the previous sections on work practice (environmental scanning), people (managers) and technology (DSS and software agents) present a framework (summarized in Table 5) for us to analyze agent-system impacts.

As is illustrated in the table, the impacts of an agent-based scanning and interpretation system can be examined in terms of its influence on the scanning process, on information quality, on managers' cognitive effort devoted to scanning, their cognitive structure, their sense of control over the system and their privacy concerns.

By definition, software agent systems tend to acquire more autonomy from users in accomplishing the tasks. The basic idea behind agent systems determines that they are easy to use, require minimal user training, require reduced cost in system operation and maintenance. Agents bring speed, productivity, customized service and proactive support to information handling and service (Maes, 1994; King and Jones, 1995; King and O'Leary, 1996; Turban and Aronson, 1998).

Table 5 Impact Analysis Framework of Agent Based Scanning System

The Technology	**The Work Practice And People**	**Agent Based Scanning System - the Impacts**
Decision Support Systems . structure imposed on work practice . degree of ease of use (related with demanded cognitive effort and learning effort from users) . flexibility . feedback and follow up capability . information processing capability . problem size . division of labour between people and the systems . cost for system development, operation and maintenance *Software Agents* . initiative and autonomy (impose high structure on work practice) . easy to learn and use (little user training) . reduced operating and maintenance cost . personalizable and customizable (user profile) . adaptability to changing information needs . proactive support . large-size, repetitive tasks . fast feedback and easy follow up	*Scanning Process* . intuitive vs formalized . fragmented vs systematic . occasional vs continuous . rigid vs flexible . feedback speed . personalizabity and customizability . types and levels of scanning skills available in the organization . interests and values of the people who do the scanning . time spent, speed . follow-up . information recall . scope and magnitue of scanning . good source accessibility . learning effects **. cost**: access to commercial information service, manpower expenses *Information Quality* . value and relevance . accuracy . reliability . age, timeliness, time span . completeness or sufficiency . consistency . format . understandability . precision	*Scanning Process with Agents* . formalized . systematic . continuous . flexible . instant feedback . easily personalizable and customizable . consistency and gradually improving scanning skills . always perform at best possible level . can incorporate changing interests and values of people . faster than human process alone . follow up much easier . information recall accurate and easy . broad coverage in scanning . does not guarantee good source accessibility, but can access to more sources . fast process and fast feedback result in more frequent learning effect, but there is the risk of incorrect learning. . reduced manpower expenses . when access to same sources as huamn process, it may not guarantee the same quality on value and relevance, accuracy, reliability, consistency, understandability. But it can out-perform human in timeliness, age, time span, completeness, and format of information.

	Managers *Cognitive Effort* . effort expenditures . cognitive capacity	. The system reduces greatly managers' effort expenditures in scanning by offering a single integrated information channel, and do scanning for managers.. But the data it presents to managers need to be carefully controlled so that it will not use up managers' coognitive capacity. . Agent teaching effort is very limited.
	Cognitive Structure . mental models . learning effects	. enhanced, augmented mental models . explicit representation of mental models inside the agent . accumulative laerning from scanning process and outcome . does not exclude communication channels from managers so preserves their creativity
	Sense of Control, Privacy Concerns	. security mechanisms needs to be carefully designed to protect privacy . leave important control power to user

An agent based environmental scanning system tends to automate the scanning activities and ask for little real time user interference. While doing so, because of its capability to incorporate users' perspectives into the system, it would not have to sacrifice flexibility of the process, in terms of sources to be consulted, changing interests and concerns, and the natural mixture of searching, analysis and signal tracking procedures. The scanning process is more formalized and is much faster than the human process. As repetitive work by the system does not require much extra cost, constant and systematic search and monitoring effort as well as information recall would be easily conducted, which ensures that managers get their knowledge about the environment refreshed as frequently as needed. Due to the computing efficiency an agent system can have (Gaulbert and Wilson, 1970; Winograd and Flores, 1986), the speed of getting access to the limited, right information gets increased, and the range of environmental elements covered in scanning can be greatly widened while manpower is saved. The benefits of agent system would become more significant as the number of data sources increases and as the scope of scanning expands.

As a personal representative, the agent system forms a medium for direct and flexible communication between managers and data sources, cuts down the need for many intermediaries acting as information filters (while it does not exclude human communication channels from managers) and reduces the flow of documents in the organization. Because of the inherent limitation of computer systems (Gaulbert and Wilson, 1970; Winograd and Flores, 1986), when having access to the same data sources as people do, an agent system may not guarantee the same quality on value and relevance, accuracy, reliability, consistency and understandability, especially when it is at the beginning of its operation. However, it could out-perform human in timeliness, age, time span, completeness, and format of information. As the agent fulfills its responsibilities again and again, and it learns from its own running process and learns about the human scanning process, the information quality could be improved in terms of value and relevance, accuracy, reliability, consistency and understandability.

Although it has always been a hard job to try to implement the human thinking process, especially personal, ad-hoc, creative thinking process, in computer systems, with current technology advances it is quite possible to incorporate people's knowledge and perspectives into the working process of the system so their creativity is preserved. An agent based scanning system may not have a value system and a thinking mechanism exactly like its human counterpart, but managers who work with the agent system can define their personalized profiles, provide knowledge support to the agent and inject creativity into the agent's scanning process from time to time. The agent is able to assist users in compiling their profiles (Olofsson, 1998). It can even be able to induce user profiles by keeping track of the evolution of his interests and preferences in accomplishing tasks and to maintain a dynamic user model (Etzioni and Weld , 1996; Krulwich and Burkey, 1997).

The division of labour between the agent system and managers are different from interactive systems in that, with agent systems it is as if users are providing support to the system rather than the system is supporting users. The agent system reduces greatly manager's effort expenditures in the scanning process when it automates the automatable part of the task. Managers can simply concentrate on attending to the information brought to them by the agent, supplying the needed knowledge to the agent and giving orders to it. The risk of a possible increase in effort expenditures may come from the agent's ability to quickly bring a lot of information to the manager's attention if it has not been carefully controlled. Fortunately, managers themselves can have control over the amount of information they want to attend to. They would not forced to handling all the information the agent presents. They could choose not to, without affecting much of the system's performance.

Managers' mental models are explicated inside the agent. The explication is guided by templates provided by the agent so that it would not result in a heavy demand on the user's cognitive effort. When frequently accessing new information leads, developing new understanding of the environment, learning about new business rules and relationships, the management assumptions, or mental models would get augmented or enhanced (Rockart and DeLong, 1988).

In the environmental scanning system, a user's sense of control over the scanning process would seem to be an issue of less concern than privacy issue, as the agent operates as a personal representative of a manager and contains private information property and sensitive business information, whereas its activity is not under close scrutiny and control by the manager. So security mechanisms would need to be carefully deployed.

5. Prospects for Software Agents

In this Section we speculate on plausible trends for the development of software agents in ten years. We first look at developing trends in the underlying technologies (IT, AI) and application fields. We then discuss the likely nature of their impact on agent development.

5.1 Trends in IT

5.1.1 Hardware, Software, Digitizing, Coordinating, Informating and Interfacing

In foreseeing the future of information technology, Grover and Segars (1996) emphasized four important trends: (1) hardware is evolving in the direction of smaller and more powerful machines; (2) software is evolving in the direction of user-friendly, modular and flexible platforms; (3) cost of digitizing is approaching 0; (4) cost of coordinating, which refers to all costs involved in acquiring and evaluating information, is also approaching 0.

Cost of digitizing approaching 0 means that every single piece of information interpreted by our brain through our five senses can be represented in digital form at no cost. The cost of coordinating approaching 0 means that there will be a lot of opportunity for innovation in companies and for securing better services by customers (Grover and Segars, 1996). These will cause further changes in the way of supplying information (informating) and interfacing of software systems. Information supply will be very different from the current "react to needs and provide" cycle. Smaller but powerful processing technologies that allow information consumers to access, manipulate and communicate different forms of information will be needed (Grover and Segars, 1996). At the same time, it is also likely that information itself will contain processing capabilities and become smart data that can recognize complementary form of data which can be used to form larger information constructs useful to information consumer (Grover and Segars, 1996).

5.1.2 IT Management - Information Focused Culture

Markus (1996) developed insights into the future of IT management through a hypothetical case in which IT recession happened. He speculated that "perhaps the most common new IT management role in the organizations of the future will be IT-use facilitators who work closely with people to help them learn new tools and discover new work methods". Then, when users became familiar with technology, spent less time dealing with technology problems, had reliable system and infrastructure, the focus will move from understanding about technology to the effective use of information. Computers came to be viewed as information appliances. In many ways IT in the early 21st century became like automobiles - simply ways to get things done. Later on in the 21st century (2020) IT will entirely be taken for granted as does electricity today (Markus, 1996). Organizations will develop information-focused culture. The attention of IT management will be paid to information consumers on how to identify users' information needs, how information could be sought, acquired and used to improve business decisions.

The ability to quickly evolve down the data-information-knowledge-wisdom-action cycle will be the most important asset for organizations. On one hand, companies may engage in large scale data warehousing and data mining of warehouses combining internal and external data. On the other hand, many entrepreneurial investor resources are being devoted to creating and consolidating external DBs and content archives. They have strong incentives to try to draw user organizations away from computing and managing their own DBs. Third, advances in communications and processing technologies may render collective storage obsolete. Information may be coded to remain with its source, only to be accessed or aggregated when needed (Markus, 1996).

Interestingly, Davenport (1996) also described a future environment for information systems in which information replaces technology as the primary focus of a firm's efforts. Swan and Galliers (1996) then described the future role of information professionals as a technical knowledge and business information broker who knows where to look for information, how to screen it and interpret it, how to utilize it internally for specific purpose to create knowledge and expertise within their organization.

5.1.3 Personalized Service

The development in information and communication technology also incur changes in the way of service supplying. Watson et al (1996) believed that the information age will cause a dramatic change in the form, extent and delivery of service. IT will create a society in which services are tailored to the personal tastes of customers. Similar to the agricultural technology revolution which brought plentiful and inexpensive food, and the industrial technology revolution which brought plentiful and inexpensive goods, information technology revolution will bring many highly personalized services. "It will enable the great majority of citizens to receive a level of customized service now enjoyed only by the effluent" (Watson et al, 1996).

5.2 Trends in Artificial Intelligence Applications

Artificial Intelligence (AI) is concerned with programs that respond flexibly in situations that were not specifically anticipated by the programmer. To make computers/programs smarter and smarter and come closer and closer to imitating, or ultimately surpassing, complex human thought processes, we need to draw upon advances in artificial intelligence.

Robotics has always been a branch of AI research and application. Robots were originally conceived to do tediously repetitive assembly-line tasks. Over the years, however, it has become apparent that in addition to never getting bored, never getting sick and never going on strike, robots can be designed to work far more rapidly and precisely than human alone. Nevertheless, it has been a challenge to equip them with enough sensory perception, computing power and real-time response capability to adapt to such situation as having a part presented slightly askew on an assembly line. As computer components have gotten exponentially smaller and algorithms have gotten exponentially more clever, robots have become more and more capable and flexible in their behavior. In the centuries to come, robots will play crucial roles in exploring the space. Software agents are soft robots, or softbots. They represent one integral part of AI too. Their development naturally takes great advantage of advances in other AI branches, while they at the same time motivate and justify that research.

As Esther Dyson predicted long time ago that AI would not become truly important commercially until AI becomes embedded in main-stream, strategically important systems like raisins in a loaf of raisin bread (referred in Winston et al, 1997), time has proven

Dyson's prediction correct. AI as a field is becoming more important as emphasis shifts away from replacing expensive human experts with stand-alone expert systems toward enabling or enhancing main-stream computing systems that create strategic advantage. Accordingly, many of today's AI systems are connected to large data bases, deal with legacy data, talk to networks, handle noise and data corruption with style and grace, implemented in popular languages, and run on standard operating systems (Winston et al, 1997). AI will certainly be an essential part, although often a small part, of the total solution to customers' problems. AI technology will go beyond expert systems, where computers could do what human experts could do, only less expensively. The emphasis will move from doing what people do to exploiting opportunities to do tasks that people cannot do alone. The commercial value of AI will lie in the direction of new revenue building rather than replacing people.

AI will play significant roles in offering new capabilities and creating new revenue streams in areas such as operating systems, interfaces and information access, indicated by AI enabled information access, AI enabled human-computer interaction, and AI driven advances in computing infrastructure. Through truly gigantic high-resolution displays that are coming, more natural and familiar modes of communication that may soon make the keyboard obsolete, all rely on AI technology. To provide help to WWW-users in information access, the creators of aggregation tools must take advantage of AI work. AI research has developed new ways of analyzing heaps of data that complement traditional statistical methods. AI technology can take us a great leap forward from systems limited to key word analysis (in Winston et al, 1997).

Software agents, like Bayes nets, neural nets and genetic algorithms, is regarded as newer technical ideas in the field of AI. All of them are important; but none, by itself, is the answer. When combined with older ideas such as rule chaining, they will form a powerful unit. In fact, the power of software agents lie exactly in their synthesized use of multiple AI techniques and integration with mainstream business applications.

Kendall (1996) described the development of AI systems as will follow four paradigms: (i) *cognitivist* (based on symbolic techniques, with applications such as expert systems, knowledge based systems). (ii) *connectionist* (neural nets). (iii) *action-selection* paradigm (represented by autonomous agents selecting actions that emerge from the interaction of multiple, diverse, relatively independent modules), and (iv) *evolutionary paradigm* (genetic algorithm, evolving systems that can access the merits of inconsistent motives, can store and compare motives, change upon self-evaluation, and adapt to approval or disapproval of external agents) (Kendall, 1996).

According to Kendall (1996), the evolutionary paradigm will be in store for AI for a future of perhaps 50 years. In ten years, however, our focus will be on autonomous agents of the action-selection paradigm. *Autonomous agents* will evolve from being just capable of autonomous, purposeful actions that responds to external stimuli, *to intelligent, adaptive agents* that are capable of performing actions they were not capable of previously by acquiring knowledge and building on earlier actions (Kendall, 1996).

5.3 Software Agents in 10 Years

The benefits of using software agents include speed, productivity, customized service, new way of information and support supplying, among others. In this section we relate the future of software agents to the above-mentioned developing trends in IT and AI.

5.3.1 The Needs

Changes in the way of information supplying (i.e. re-informating) call for software agent applications. Software agents do not follow only the "react to needs and provide" cycle. They can actively push the required information to users. They can also bring a more rich and novel information environment to users. The needs for smaller but powerful processing technologies to allow consumers of information to access, manipulate and communicate information, actually proposes a heavy processing load for computer programs. They must have agent-units embedded in or have multiple agents to collaborate on. Finally, data itself becoming smart also relies on the embedding of agent-like processing constructs.

Information focused culture will lay great emphasis on organizations' competence in quickly discovering knowledge from large volumes of data sets. Knowledge discovery from electronic data in multiple formats is already, and will still be, an important area of intelligent agent applications. In cases where advances in communications and processing technologies may result in collective storage becoming obsolete and data will remain with their sources, agents will be needed to visit dispersed sources, to extract needed information, to synthesize and analyze the data and to add value.

A society offering highly customized services would create a huge demand for service staff. Service providers or companies would try to employ technology and systems instead of just throwing more service at a problem, This, however, will lay the burden on customers. Software agents can be generated to serve the customers. Agents as service providers take the human element out of service thereby eliminating variability. They enable customization by allowing IT to create and deliver the precise service that the customer desires. Software agents actually translate a service delivery strategy into an effective IT infrastructure (Watson et al, 1996).

To summarize, agent technology can make computer applications more efficient and effective. They bring competitive benefits to software systems (McKie, 1995) and further, in business operations. The software agent marketplace is far from mature, and it is set for rapid growth and owns a huge potential.

5.3.2 The Possibilities

As speed and flexibility are essential to support systems, embedded agent-functions will be popularly seen in various main-stream applications.

Hardware evolving towards smaller and powerful machines makes it possible for software agents to be simpler and smaller in structure. Wall-size displays plus costless digitizing bring more friendly user interfaces (visual, voice) into software systems. Software agents will make their performance transparent to users at an appropriate level fitting to the user's skills and knowledge level. Users can expect to have easy control over their agents and easy communication with their agents.

Cost of coordinating approaching 0 may indicate a cost-benefit for multi-agent systems.

Like robots, software agents will benefit greatly as computing algorithms got exponentially more clever. Autonomous agents that fulfill the action-selection paradigm will develop towards adaptive, intelligent agents, capable of performing actions they were not previously capable of performing by acquiring knowledge and building on earlier actions. However, evolutionary agents as a new development of autonomous agents will not be able to come in 10 years.

Software agents seem to have not been developing fast enough. Trends from IT and AI seem to converge to a stage that call for and facilitate the development of software agents in large volume. Software agents bring competitive benefits to software systems. They represent a technology that may soon underpin all mission-critical business applications. Advances in IT and AI will grant software agents with more and more computing power. In the market there will be increasing ranges of application for agents, popularly in the form of merger and penetration of software agents with all kinds of business applications. Software agents will evolve towards intelligent, adaptive system constructs.

The development of autonomous agents may have profound implications for the future. As it is true that the ultimate success of new technologies will be in the way they favorably interact with humans, business, social structures, markets, culture, society, government and other entities. So do software agents. Social and community norms and cultures affect technology choice. The acceptance of agents by people and society may take a while, which is related with the resolving of problems such as potential social mischief, loss of privacy, loss of control. Issues of user control, trustworthiness, security and privacy, customization and repair, and how to make sure agents aid rather than hinder group work and information filtering are important issues which frequently call for attention from researchers and developers.

6. Conclusions

In trying to predict the impact of agents systems, this paper analyzed the task, people, and technology elements in a software agent based environmental scanning system and proposed an analysis framework. The impacts of the agent system on managers, as users, and on their scanning process and outcomes are perceived. The next step in this research process would include empirical studies following system implementations.

Drawing on trends and developments in IT (Information Technology) and AI (Artificial Intelligence) fields, we also speculated on prospects for software agents. It is shown that, compared with market needs, software agents have not been developing fast enough. Having benefited from advances in IT and AI, software agents will soon evolve towards intelligent, adaptive constructs that make integrated use of a group of techniques, rather than rely on one single technology. The potential for software agents is vast in both range and power. In ten years, there will be mergers and a penetration of software agents with almost all kinds of business applications.

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