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# The Management of Variety

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## 1. INTRODUCTION

For a long time, scientists and practitioners in the field of management and organization have focused on matters of efficiency in organizations. But efficiency is not sufficient for organizations to survive; flexibility and variety are necessary as well. Flexibility is necessary to cope with fluctuations in the environment. Variety is necessary to develop innovations that are necessary to survive in the long run.

From organizational theory and even from history, we know how the environment of organizations can be an inspiring source of innovations. When new technology becomes available in the form of tools and knowledge, it can be used to realize new organizational processes or products.

In 1625, Francis Bacon described how organizations employed so-called Merchants of Light that used the communication technology of those times (transportation of people and physical objects by ships) to bring books, abstracts, and patterns of experiments of all parts of the world to their home where the books were read, experiments were tried out and after deliberation, "(…) things of use and practice for man's life and knowledge" were implemented. In this way, dimensions of space and time shrinked and innovations from various communities could be absorbed into one's own community.

The introduction of telecommunication media in the twentieth century speeded up this process. Telephones, telexes and faxes have facilitated the exchange of ideas, and diffusion of innovations among known social relationships, thereby facilitating information exchange that used to be impossible because of geographical dislocation.

Today's new forms of information and communication technology not only shrink dimensions of space and time as 'historical' and 'traditional' communication technology have done, but also facilitate information- and knowledge exchange with partners outside traditional, known social relationships. Contemporary media like the Internet provide easily accessible cybercommunities of 'netizens' where information and knowledge can be exchanged relatively freely.

In order to survive, organizations have to absorb or generate variety. Variety absorption, however, is limited because organizations also have to maintain their efficiency. Scientific and technological information and knowledge is a source of variety that organizations can use to produce innovations. The Internet has decreased the efforts and costs associated with using this source of variety. The question is how organizations can use this source of variety in an optimal way, that is, without losing their efficiency. A passive use of the Internet will not lead to an optimal absorption of variety in organizations. New information technologies provide us with means to actively use the Internet and cybercommunities for deliberately obtaining variety in organizations.

In this paper, a model of the variety-absorbing organization is presented. Information management strategies that actively use the Internet are explained based on this organization model. Traditional information management strategies refer to the development of information systems that handle administrative processes more efficiently. Our focus on flexibility and variety in organizations requires a redefinition of the concept of information management strategy as *the management of variety*.

## 2. A CONCEPTUAL MODEL OF ORGANIZATION

Our conceptual model of organization is based on the idea that organizations are agent communities as well as systems.

As an agent community, an organization consists of agents. Agents are human or machine entities that are autonomous, and can apply and generate knowledge in order to fulfill tasks. Agent communities derive their behavior from the communication and cooperation of agents.

These agent communities can be seen as systems. Systems have properties like efficiency and variety. Systems can be subdivided in subsystems based on the tasks of agents. System properties like efficiency, flexibility and variety have to be seen as aggregates of agent properties or agent performance properties (Gazendam, 1993: 219).

Management is a task of one or more agents in an organization and includes, among others, organizing (defining agent tasks and organizational subsystems), planning (defining common plans and goals, and coordinating (evaluating agent performance and maintaining a balance between organizational interest and agent interest) (Fayol, 1916/1956; Gazendam; 1993: 226).

Systems theory states that open systems behave according to, among others, the following principles (Morgan, 1986: 46; Gazendam, 1993: 163):

- open systems use energy to maintain their form, thus counteracting the tendency of the second law of thermodynamics stating that all systems strive after a maximal entropy (negative entropy principle);
- the internal regulatory mechanisms of an open system must have a variety that matches the variety of possible disturbances from the environment (Ashby's law of requisite variety, Ashby, 1956: 105);
- open systems can change themselves gradually in order to cope better with the challenges and opportunities posed by the environment (evolution principle).

These principles are related to the system properties of efficiency and flexibility in the following way:

- *efficiency* is related to the negative entropy principle because, for the agents involved, the benefits of being organized must outweigh the costs of being organized (the coordination costs) in order to maintain an organizational form.
- *flexibility* is related to Ashby's law of requisite variety because flexibility means that quantitative fluctuations in the environment can be accommodated by a changed scheduling of agent efforts.

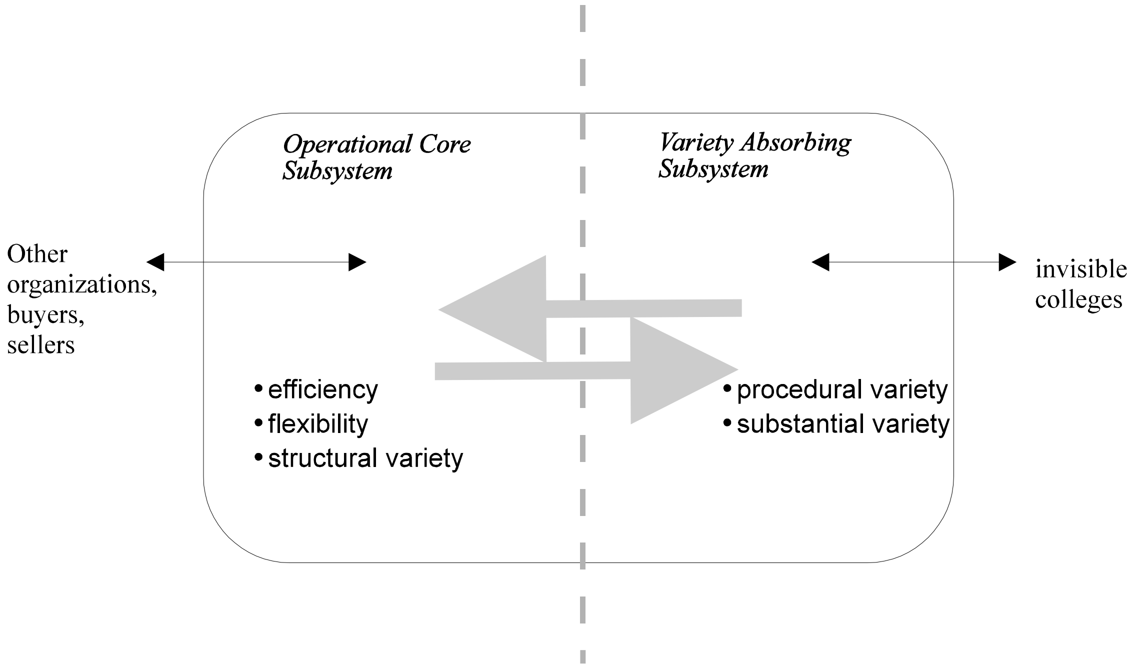
In order to relate variety to open system principles, we need to distinguish three types of variety, related to forms of organizational learning (Gazendam, 1993):

- *structural* variety: the (qualitative) variety of responses an organization can produce as a reaction to external disturbances. This type of variety is related to Ashby's law of requisite variety; an example is the assembly of customized products based on standard components or the adjustment of colors based on fashion.
- *procedural* variety: this refers to different, alternative strategies that can be used to perform tasks and to learn to apply the strategies that fit the task best. This type of variety is related to the evolution principle; an example is process innovation; another example is the variation of dominant coalitions in an agent community.
- *substantial* variety: this is the variety at a restructuring level and it refers to a repertoire of interpretation frames and design strategies to enable organizational restructuring. Substantial variety is related to the evolution principle; examples are product/market innovation and cultural change in an organization.

Procedural and substantial variety are necessary to develop the innovations that are necessary for an organization to survive in the long run. Variety absorption, however, is limited because organizations also have to maintain their efficiency and flexibility which are important to survive at short term. The maintenance of a balance between efficiency, flexibility, and variety is a central task for management. In organizing, it is important to find an organizational structure that enables an optimal mix of variety, efficiency and flexibility. In planning and coordinating, it is necessary to define information strategies that lead to efficient variety absorption and effective innovation processes.

An organization has to protect its operational core by shielding it off from the environment of the organization that could cause disturbances or that could try to gather important competitive information (Thompson, 1967). In systems theory, it is advocated to localize disturbances from the environment in a separate subsystem. Given the task to design an organizational structure that enables an optimal absorption of variety while maintaining the efficiency and flexibility of the operational core, we therefore propose the following organizational model. In an organization, two subsystems can be distinguished: an *operational core subsystem* and a *variety absorbing subsystem* (see figure 1). It is important to note that these subsystems are organizationally separated. They consist of agent communities that have their own tasks and responsibilities. These agent communities are relatively autonomous, engaging in conversations (with requests, answers, and so on) about various subjects.

**Figure 1: conceptual model of an organization**




The operational core subsystem is a system encompassing the primary processes on which the organization is existence-dependent. It has to produce and sell goods or services. The transformation and transaction processes can be based on matter or on information. An example of the latter transformation processes can be found in banks, insurance companies and government agencies. The transaction processes of buying, selling, hiring, paying personnel and so on, can be supported by EDI. The management of the operational core aims at an optimal mix of structural variety, efficiency and flexibility by using management control systems for an efficient financial management and management tools like business process redesign and contracting-out for an optimal structural variety and flexibility.

The variety absorbing subsystem is organizationally separated from the operational core in order to seal off this core from disturbances. The variety absorbing subsystem handles the events that the operational core would see as disturbances. Its aim is to enhance the organization's procedural and substantial variety.
The variety absorbing subsystem has three main tasks:

- the gathering and production of a variety of information and knowledge that is relevant for the organization,

- the development of innovations,
- the implementation of innovations in cooperation with the operational core subsystem.

The agents that work in the variety absorbing subsystem have the role of gatekeepers (Allen, 1969), professionals that use their networks of professional contacts (sometimes called invisible colleges, de Solla Price, 1963) for identifying important developments and gathering relevant information. Communication media like the Internet can facilitate these ‘invisible colleges’ and inspire the creative activity the development of innovations is.

In a world of variety absorption and invisible colleges, interorganizational communication plays an important role. In interorganizational communication, four types or fields can be distinguished using the dimensions commercial/ not commercial and private/ public:

**Table 1: interorganizational links**

| | *public* | *private* |
|---|---|---|
| *non commercial* | scientific communication in invisible colleges; public information services; | (electronic) mail |
| *commercial* | electronic markets | electronic data interchange (EDI) |

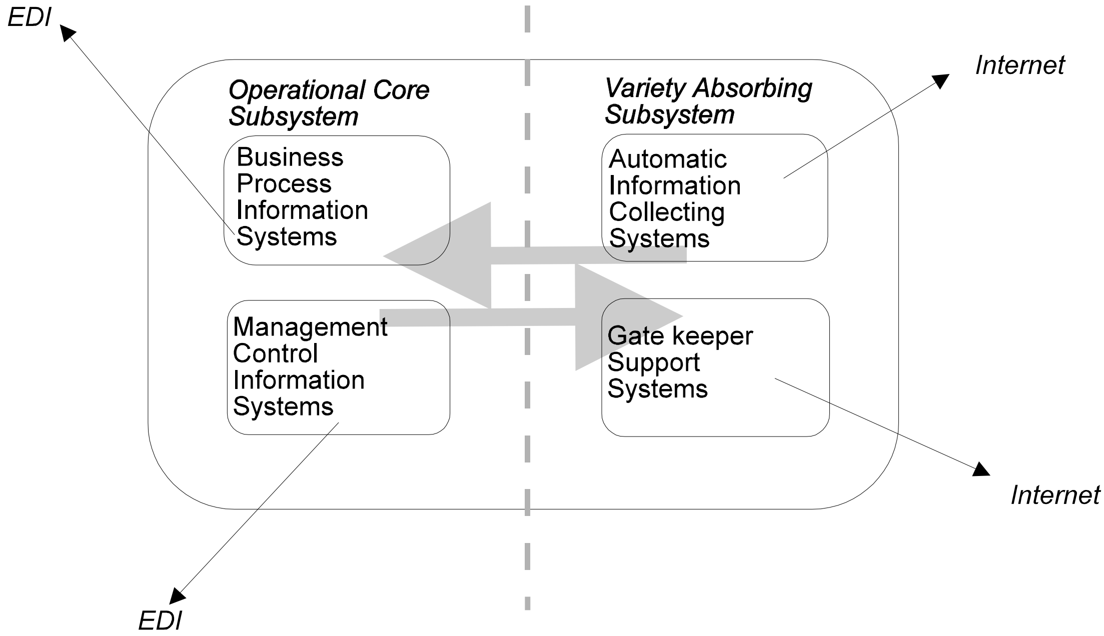
For the purpose of variety absorption, it is recommendable to have a well-functioning system of invisible colleges that can use a non-commercial and public communication facility with its associated behavior rules. Therefore, we think that it is important to keep an instrument like World Wide Web in its original category ‘non-commercial and public’, and to distinguish a separate ‘businessnet’ for electronic markets, where business oriented rules apply.

# 3. INFORMATION MANAGEMENT STRATEGIES

Information management strategies (or information strategies) deal with goals, prioritization, development and use of information systems in organizations. Just like general management, information management strategies need to strike a balance between efficiency, flexibility and variety.

In section two, the decomposition of organizations in two conceptual agent communities revealed that the operational core activities are governed by completely different principles than the variety absorbing activities and that various types of information systems could be thought of that supported the organizational subsystems (see section two and figure two). These various types of information systems each have an own balance between efficiency, flexibility and variety and therefore, different information management strategies have to be used. Below, the information management strategies for the organizational subsystems will be discussed.

**Figure 2: conceptual model of information systems**




## 3.1 Information strategy in the operational core subsystem

In the operational core subsystem, information management strategies have to support the efficiency and flexibility as well as the structural variety of products and services. The primary processes that produce these goods and services can be based on information or matter.

In traditional information management, in the mix of variety, flexibility and efficiency the structural variety component has often been ignored. Information management strategies in the field of information-bound business processes (supported by *transaction processing systems*) often aimed at enhancing efficiency, ignoring flexibility and structural variety. In the case of material-bound processes, flexibility as well as efficiency has been given attention in the form of planning and scheduling applications, but again, structural variety has been ignored until recently. .

A phenomenon that has gained considerable attention recently is *business process redesign*, the reshuffling of business processes in order to meet customers' requirements in a more flexible way, thereby drawing attention to matters of efficiency and flexibility but also to structural variety.

Telecommunication technology that has affected the above processes predominantly resulted in transaction-related links to buyers, customers, et cetera. These interorganizational relations are supported by *electronic data interchange applications*.

The above processes all take place in the operational core, and information systems that support these processes can be subsumed under business process information systems.

The primary processes are subject to planning and control. Especially in the late 1970s and early 1980s, it was claimed that *management information systems* could produce management information for mid- to long term forecasts based upon data from transaction processing systems and management control systems. This claim has not been justified in practice. In the late 1980s, a more modest claim has become dominant, namely that management control information systems contribute to a better financial management. Information management strategies in this field often aim at offering financial models that enable financial flows to be traced and allocation of scarce resources to be evaluated, referring to respectively efficiency and flexibility.

Traditional information management has been occupied with planning the development of the systems mentioned above, often by decomposing a complete system specification of a company database into information systems areas in which concrete applications were planned and built.

This approach towards information management is more or less outdated because of the development of an industry chain in the software industry. Because of that, the effort to build an information system has been reduced by an order of magnitude (Gazendam, 1993). Expensive information planning projects are no longer worthwhile. Information management is no longer only looking inward for controlling costs and effectiveness of computerization, but also looking outwards to markets, products and strategic partnerships. Developing information systems consists of the definition of applications using visual development environments in which general types of building blocks are available rather than coding programs in third generation programming languages. Information management contributes to system development by selection of standards and developing a house-style for consistent interfaces.
Today's information strategies in the operational core subsystem can be characterized by using the software industry chain to a maximum, aiming at applications that offer efficiency, variety at a structural level and flexibility.

## 3.2 Information strategy in the variety absorbing subsystem

The information management strategy in the variety absorbing subsystem differs quite radically from the information management in the operational core subsystem. In the variety producing subsystem, especially procedural and structural variety are enhanced, by respectively developing new strategies or modes of operation for the operational core subsystem and providing frameworks, strategic changes of business, and organizational configurations for the operational core. The emphasis is on augmenting creativity and much less on efficiency. It therefore lacks the control-oriented approach of the operational core information strategy. The aim is to absorb information from the data landscape as the Internet can metaphorically be described, to localize and filter procedural and substantial variety and to transfer this variety to the operational core subsystem. The information gathering by the variety absorbing subsystem takes place in two ways: by automated systems and by human gatekeepers (Allen, 1969). Gatekeepers can be thought of as human agents that browse information sources such as the Internet and act as 'trendwatchers'. They surf the net, searching for innovations, like the Merchants of Light traveled the seas looking for innovations.

Gatekeepers are agents that use tools such as Internet browsers, *gatekeeper support systems*, (the World Wide Web Worm, *http://www.cs.colorado.edu/home/mcbryan/WWWW.html*, Lycos, *http://lycos.cs.cmu.edu*). These tools are not sufficient though, to support their task of browsing the web and finding information. To be able to report their findings to the operational core, browsing applications and search engines have to be augmented with the possibilities to summarize findings using interpretation frameworks that can be understood by the organization as a whole[1]. This interpretation framework is a representation of the profile of an organization and its business strategy so that initial search profiles for information (thematic maps) can be composed. These search profiles or thematic maps have a structure deriving from the world view of an organization. These world views will develop based on the training that results from the use of profiles by human agents. The resulting collection of facts, relations, maps and models is a dynamic world atlas tailored to the organization's interests. From this dynamic world atlas, innovation projects that enhance procedural or substantial variety can be proposed to management agents.

Tools that support gatekeepers could include (not currently available) utilities to model functional aspects of the world that are relevant. The gatekeeper's task can be described as seeking and developing frameworks, filling them with knowledge and information relevant to the organization, and communicating the results of these activities.

Apart from the human gatekeeper agents and their computer support systems, one can think of machine agents in the form of automatic information collecting systems. In a functional sense, these systems can be thought of as agents that have been positioned somewhere and that take care of providing information from Internet newsgroups and Internet mailinglists. Doing this by hand results in overwhelming amounts of information. It has been tried to use simple keyword-matching organization's profiles to filter messages, but effective filtering requires more

[1] A method for the analysis and specification of world views derived from organizational theories has been explained elsewhere (Gazendam, 1993).

complex, rule based profiles to be designed by an organization, and most organizations are not able or willing to build sufficiently complex ones. Therefore, intelligent filtering agents can be put to use that actively learn an organizations profile and to help the gatekeeper with the composing and maintaining of an organization's profile that filters variety from the environment.

The information strategy of this part of the variety absorbing subsystem can be described as the positioning of agents in a strategic way, and to store, maintain and learn the organization a world view or profile of things the organization is interested in. Software agents can be helpful in this strategy as they can support the building of such a world view or profile. In section four, some real-world examples of automated support for variety absorption will be discussed.

### 3.3 The transfer of variety

Organizational prosperity derives not so much from innovation *per se* as from speedy and effective diffusion of innovation. Adoption of new technology is never a goal in itself; its goal is to yield improved processes or products (Nooteboom *et al*, 1995). Therefore, not only the absorption of variety and acquisition of knowledge about certain innovations need attention, but also the transfer of variety from variety absorbing subsystem to the operational core and concrete implementation of innovations have to be stressed. In this section, the role of Internet in this diffusion process is described.

Rogers defines the innovation decision process as the process through which an individual passes from first knowledge of an innovation, to forming an attitude toward the innovation, to a decision to adopt (or to reject), to implementation of the new idea, and to confirmation of his decision (Nooteboom *et al*, 1995). According to Gatignon & Robertson, in the early stages of adoption (awareness, interest) one can rely more on impersonal communication at a distance, through mass-media.

The process of acquiring knowledge of innovations and forming an attitude towards it using traditional communication is very time-consuming. The time that elapses between an initial scientific idea and publication of the idea in a journal is about three years (Garvey, 1979). Before official publication, a scientist often uses pre-prints or informal reports to present her or his ideas to a small audience. In the past, efforts to institutionalize pre-prints have been blocked by publishers of scientific journals.

The discovery of innovations from science typically take place in the variety absorbing subsystem. The use of the Internet is useful here because it is an institutionalized source of 'invisible colleges' (De Solla Price, 1963), Internet is a rich source of scientific 'preprints' of articles and papers[2] and organizations can therefore much earlier begin considering adopting an innovation than in the case where only official scientific media were used.

Later stages of the innovation decision process (trial, evaluation, adoption) require closer, more personal and oral contact between variety absorbing subsystem and operational core subsystem and in these stages, the conceptual separation of these subsystem needs to be relaxed. In these processes, information systems and computer agents play a less prominent role.

## 4. AGENT TECHNOLOGY

### 4.1 Software agents

In the previous section, an outlook on the practical use of automatic information collecting systems has been given. In this section, automatic information collecting will be further explained and some real-world systems will be described.

Software agents or agent-based systems are machine agents, computer systems with properties of autonomy, social ability, reactivity and proactiveness (Jennings & Wooldridge, 1995) that have mentalistic notions such as knowledge, belief, intentions and obligations. These computer

[2] See for example http://www.bdk.rug.nl/mais/papers.html

agents can therefore by considered as members of organizations, learning and applying knowledge to fulfill tasks.
Maes (1994) describes agents as active computer entities that can sense the environment and perform actions for users in a semi-intelligent way, that is, the software agent knows (or: learns) the user's or the organization's goals, habits, et cetera. An example of a (very primitive, not actively learning) software agent is the Bargain Finder (http://bf.cstar.ac.com/bf/), an Internet agent that is able to scan catalogs of eight online music stores and finds the best price of a CD of your choice. An example of a system that actively learns (and therefore can be truly called an 'agent') is *firefly* from MIT (http://www.agents-inc.com), Firefly is capable of recommending music that it knows the user will enjoy by using and learning the tastes, opinions, preferences and idiosyncrasies of those most similar to you (your "nearest neighbors") in order to suggest new music that the user might like too. The more *firefly* is trained, the more useful and accurate it gets. The more other people use the system, the smarter the firefly community of users becomes.

## 4.2 Filtering agents

In the context of the conceptual organization model of section two, and our vision of information strategy in section three, one can envisage software agents that filter variety from mailinglists, Newsnet and the World Wide Web, in order to search innovations that could be used in the organization.
A central theme in information filtering is the 'recall and precision' issue (Loosjes, 1973). *Recall* is the number of relevant documents retrieved expressed as a percentage of the total number of relevant documents present in cyberspace. *Precision* is the number of relevant documents expressed as a percentage of the total number of retrieved documents, including the noise. There is a tradeoff between searching through fewer articles and finding more information. With simple subscription to mailinglists or access to newsgroups without any intelligent filtering or processing capabilities, an acceptable balance will not be easy to find. Much work is being done to develop agents that, technically speaking, deserve that denotation, i.e. learn an organization's profile and could be described as 'intelligent' (Huang, Jennings and Fox, 1994). This research is aimed at developing mail agents as well as Newsnet agents as well as WWW-agents. The latter categories have been emphasized as these areas continue to multiply.
In the following table, examples of filtering agents and their URL's on the Internet are stated. In sections 4.2.1 and 4.2.2, two examples will be described.

**Table 2: list of Internet filtering agents**

| | | |
|---|---|---|
| SIFT | The Stanford Information Filtering Tool | http://sift.stanford.edu/ |
| NewsWeeder | neural network based USENET News filtering service (Carnegie Mellon University) | http://anther.learning.cs.cmu.edu/ifhome.html |
| NewsClip | language designed for filtering USENET News that is capable of binary filtering when used with any newsreader | http://www.clarinet.com/newsclip.html |
| MAXIMS | Collaborative electronic mail filtering system (MIT Media Lab Autonomous Agents Group). | ftp://media.mit.edu/pub/agents/interface-agents/MAXIMS/ |
| WebWatcher | (Carnegie Mellon University) | http://webwatcher.learning.cs.cmu.edu:8080/cgi-bin/agent-welcome.pl?http://www.ai.univie.ac.at/oefai/ml/ml-ressources.html |
| Webhound / WebHunter | A collaborative World Wide Web filtering system (MIT Media Lab Autonomous Agents Group). | http://webhound.www.media.mit.edu/projects/webhound/ |

### 4.2.1 Intelligent Usenet agent: NewsWeeder

NewsWeeder is an example of an intelligent filtering agent. It uses both content based filtering (matching documents and texts against a user's profile) as well as collaborative filtering (using rates of earlier readers of an article to predict an article's importance).
NewsWeeder begins with presenting all articles of a certain newsgroup and asks for a user's rating of articles. Each night, the system uses the collected rating information to learn[3] a new model of an organization's interests and can, after a while, present virtual newsgroups, personalized lists according to learned preferences for an organization (Lang, 1995).

### 4.2.2 Intelligent WWW agent: WebWatcher

An example of an intelligent software agents that advises users to search in hypertext documents and that can also search autonomously, is WebWatcher (Armstrong *et al*, 1995). As a user surfs the net, searching for information, WebWatcher uses its learned profiles to recommend especially promising hyperlinks to the user by highlighting these links on the user's display. The user gives feedback by clicking 'I found it' or 'I give up', thereby generating knowledge that WebWatcher uses on coming net searches.
The working of this agent (its learning mechanisms) are comparable to that of NewsWeeder, but the representation of the underlying data landscape is something more complicated (with hyperlinks and so on) and WebWatcher guides the user less deliberately (the user can more easily ignore WebWatcher's advises).

## 5. SUMMARY AND CONCLUSIONS

Traditionally, management emphasizes efficiency as a critical success factor. Flexibility and variety are also necessary to survive in the long run, in order to be able to pick up innovations from the environment and to be able to use new technology.
The Internet provides organizations with a very rich source of variety. However, there's a limit to which efficient organizations can absorb variety. In order to absorb external variety optimally, organizations must have a variety absorbing subsystem apart from the operational core in which goods and services are produced. These subsystems require different management strategies:

- a strategy seeking an optimal mix of efficiency, flexibility and structural variety and
- a strategy aiming at optimal variety absorption and variety transfer.

An explicit management of variety in organizations is necessary because of the opportunities arising from new information and communication technology.

In the operational core subsystem, the emphasis is on efficiency. Information systems are used to support scheduling activities and management control systems facilitate financial management. New communication technology is used to speed up external transactions with suppliers, consumers and banks. The emergence of an industry chain in the software industry has had an important influence on information management strategies. Nowadays, information management strategies use this industry chain to a maximum.

In the variety absorbing subsystem, information and knowledge is absorbed from for example the Internet by human gatekeepers that use browsing tools and build models of organizational reality, and by software agents that actively learn a profile of interorganizational interests and present all kinds of documents that are interesting to an organization. In this way, scientific innovations can be found much earlier than using official scientific publications. The information strategy of this organizational subsystem consists of the strategic positioning of software agents on the Internet and of developing, storing and maintaining an organization's world view or profile of things an organization is interested in. This process can be supported

[3] NewsWeeder makes use of term-frequency / inverse-document frequency weighting and a technique that is based on the minimum-description length. For the sake of brevity, these techniques will not be presented here but the interested readers are referred to the original article of Lang (1995).

by intelligent browsers, intelligent filtering agents and all kinds of tools that can be used to model an organization's profile and to document innovation projects.

The resulting information strategies invite us to position new telecommunication technology such as electronic data interchange applications on one hand and (intelligent) Internet browsing agents on the other hand as completely different developments that require different information management strategies. The latter, intelligent Internet filtering agents draw attention to possible strategic use of the Internet.
In this paper, we have presented elements of the management of variety. Using these techniques, we think we have supplied the gardeners of the data landscape with strategies to harvest fruitfully.

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