Information System Metaphors

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Abstract

Nowadays, we are confronted with a *virtual domain* based on information technology artifacts and organize ourselves in *virtual organizations*. The limitations to the development of virtual organizations are those of the human imagination. Multiple ideas about what virtual organizations should be or should do are possible, and can be studied based on the metaphor concept. *Metaphors* are useful because they are efficient: they transfer a complex of meaning in a few words. Information systems are social constructs. Therefore, metaphors seem to be especially useful for explaining the space of possible meaning complexes or designs of information systems. Three information system metaphors and the associated meaning complexes are explained: the mill, the cell, and the mind. An information system as a *mill* is characterized by the efficient processing of large quantities of information. The processing has to be done using fixed, that is, *invariant*, rules en patterns that may be very complex. An information system as a *cell* is characterized by its fluent and adequate interaction with people. The information system consists of objects that take care of preserving their own integrity and that react on events. The cell metaphor is characterized by *interaction* and *integrity*. The information system as a *mind* appears as an intelligent assistant embodying that mind. An information system as a mind is characterized by capabilities like *knowledge use*, *autonomy* and *learning*. These three metaphors can be combined, and are combined, in real-life organizations.

1. Virtuality and Metaphors

1.1. Virtuality

What is virtual?

Virtual means in English: essential, real, what you do not see now, but what exists in practice. So there is an essence that you cannot perceive as such. You only can see manifestations of this essence. This definition seems to be inspired by philosophical traditions like essentialism or Platonic realism. On the other hand, virtual means in Dutch and also in physics: existent as image only, not real, what you see now, but what does not exist in practice. This definition is more in line with philosophical approaches like nominalism and Peircean realism (Hausman 1993). So, something virtual seems to be something intangible with a status between real and existing as image only. Let us use the following working definition. *Virtual* is something perceptible (e.g., visible), intangible and immaterial, that we can imagine based on perceived images or practical experiences, and with which we can interact using special artifacts. Via those artifacts, the virtual something can also influence or normal, nonvirtual world. In terms of Von Uexküll (Von Uexküll and Kriszat, 1936), the virtual something is a species with a very specialized semiotic Umwelt, based on

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the semiotic capabilities of those specialized artifacts. When people interact with this virtual species, their respective semiotic Umwelts are interconnected in a process of semiosis. In this semiosis process, people perceive images and symbol structures, experience practical effects, and influence or even instantiate the virtual species. Based on this process of semiosis, people imagine or mentally construct their interpretation of the virtual something.

A person talking to me at the other end of the telephone is not virtual, because she is supposed to be tangible and material, as one can find out when being in her vicinity (in this opinion I disagree with Tomas Dorta (1999), who thinks that such a person is virtual). This is a case of *distant reality*. A computer talking to me on the telephone in a voice response system is virtual because it will never be able to appear for me in tangible and material form. The internet shop of Amazon is virtual because I can see it and can interact with it, while, at the same time, I will never be able to walk physically into that shop. An organization like the university is a more complex case. At this moment, I assume that it is not virtual, because I cannot perceive it, but can only think about it and talk about it. I perceive the effects of the existence of the university in the form of receiving a salary every month. I interact with the university, but not directly, only through other persons or virtual actors that have some sort of mandate from the university to represent them. So the university is some kind of conceptual entity that exists and works based on the existence and work of people. This can be called *conceptual reality*. Another complex case is the doctor in Star Trek Voyager. Although he can be perceived by all senses, and you can interact with him, he is considered to be immaterial because he can be switched on and off. *Material presence* assumes *permanence*, not switchability. This criterion of permanence would be not applicable if the doctor could never be switched off. In this case, the concept of semiotic Umwelt says that you cannot distinguish between a real doctor and a virtual doctor. But there is a second criterion for material presence, namely *causation*. Material presence *causes* the phenomena that you perceive. This criterion is, however, disputable and sometimes difficult to apply. Your perception of the doctor in Star Trek Voyager is based on a stored program controlling some kind of emitter and not based on a material presence. Therefore, the doctor is virtual because he is immaterial. The last difficult case is Siegfried wearing the Tarnhelm making him invisible, and let us assume, also imperceptible by the other senses. This makes interaction difficult. You can only perceive the effects of his actions. Here you have someone that is not perceptible but at the same time material. So he is not virtual, but more something like *anti-virtual*.

The virtual domain

Nowadays, we are confronted with a *virtual domain* based on information technology artifacts that have a mediating role (Rheingold, 1991; Brooks, 1999). Computer screens and other media give us access to a virtual domain.

> "The screen is a window through which one sees a virtual world. The challenge is to make that world look real, act real, sound real, feel real. . . A display connected to a digital computer gives us a chance to gain familiarity with concepts not realizable in the physical world. It is a looking glass into a mathematical wonderland.... There is no reason why the objects displayed by a computer have to follow the ordinary rules of physical reality. . . The ultimate

> display would, of course, be a room within which the computer can control the existence of matter." (Sutherland, 1965)

According to Castells (1996, p. 327), there exists a culture of real virtuality. People experience intangible, nonmaterial images and symbols as real because they are accustomed to the use of television, computers, money in bank accounts, and organizations. The virtual domain fills a larger and larger part of our existence because of its attractiveness. Virtualization means that in work, leisure and organization, there is a primary role of the virtual domain. For human participants, physical places of exchange become virtual places of exchange. We wander around in this virtual domain when we play games, we buy books and music in the virtual shops at Internet, we meet other people in discussion groups and at game platforms, and so on. The virtual domain controls our nonvirtual, physical world. Information systems, which are entities that only exist in the virtual domain, work for us as virtual actors. For instance, information systems pay salaries. That is, they perform actions that change our material and conceptual world. National states do not have power over this virtual domain, because they have their roots in physical space. The virtual domain, on the other hand, is mainly composed of virtual actors, virtual objects, and virtual spaces. Virtual objects and virtual spaces are based on active representations that know how to react when interacting with people or virtual actors.

The experience of a virtual domain is not new; only the interpretation of it as virtuality is relatively new. For instance, in mediaeval times, theology studied an intangible, immaterial world that seemed to be more stable and therefore more real. Churches gave access to this world by offering sculptures and pictures[2]. Thomas Aquinas (1266-1273) invented the concept *information* for the immaterial mental constructs people use for denoting the likeliness of things. According to Thomas, the ability to know corresponds to the degree of immateriality. The degree of immateriality corresponds to the amount of information stored. The world of knowledge is an immaterial world.

Virtual organizations

In the context of organizations, Vincent Giuliano first used the concept of virtuality in 1982. Describing the office of the information age he stated:

> "There is no longer any need to assemble all workers at the same place and time. Computers and facilities for communication create a virtual office."

The virtual office breaks with the concept of an organization as a collective of people working together at a certain place and within a certain period of time. Of the unity of place, time and action, only coordinated action remains. Related to this concept of virtual office is the concept of a *network organization*, an organization consisting of persons that work at different places, while communicating and cooperating using computers and computer networks. Many scientific communities can be seen as such network organizations.

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[2] Because direct perception of, and interaction with, this intangible immaterial world is scarce (in the form of miracles), and at the same time you perceive the effects of its actions, this world does perhaps not qualify for virtuality in the sense as we understand it nowadays. It has more the character of an anti-virtual phenomenon, like Siegfried with the Tarnhelm, or a conceptual reality like the university.

Since the publication of Abbe Mowshowitz in 1994, concept of ‘virtual organization’ became more popular. Mowshowitz uses the metaphor of virtual memory. Virtual memory is a memory area that is not realized as a real memory space but as addresses referring to places on a hard disk where data can be stored. Only when these data are actually needed, they are loaded into a special real memory space. Therefore, this special real memory space switches its contents when needed, based on the virtual memory data stored on the hard disk. Mowshowitz’ virtual organization is based on this principle of switching. Management has to switch the allocation of concrete means in order to satisfy changing abstract requirements. Based on Mowshowitz’ work, in most publications the virtual organization is defined as an *organization network*:

> “A temporary network of autonomous organizations that cooperate based on complementary competencies and connect their information systems to those of their partners via networks aiming at developing, making, and distributing products in cooperation.” (Mowshowitz, 1994)

Central in Mowshowitz’ definition is the concept of a flexible organization network crossing the boundaries of organizations as defined by traditional economics. The discipline of economics has always put the property concept central, and even nowadays tends to see an organization as a mere plan. In this perspective, an organization’s boundaries correspond to the legal boundaries defined by the property concept and the contracts based on it. The modern concept of organization, as a social organism or work organization, as invented by Fayol (1918), does not have to follow these legal boundaries (Schmidt, 1991). For economists, there is a problem as soon as Fayol’s work organization does no longer coincide with the legal property boundaries. Therefore, Mowshowitz’ virtual organization concept had to be invented for denoting these work organizations (from Fayol’s perspective) consisting of flexible organization (from the perspective of traditional economics) networks.

So we have thus far two definitions of virtual organization: the virtual office or network organization, and Mowshowitz’ organization network. Both focus on breaking traditional organizational boundaries: in the case of the network organization the boundaries of place and time, and in the case of the organization network the property boundary. However, this discussion of the virtual organization as a network organization or organization network is unsatisfactory, because it misses the essential point of the existence of a virtual domain. We need a virtual organization concept that encompasses the virtual domain.

There are two approaches to defining virtual organizations based on the virtual domain: a subjective one and an objective one. In the *subjective approach*, one sees a virtual organization as a virtual reality one can see, feel, hear, and interact with. Central in this definition is the subjective experience of a virtual reality mediated by computer interfaces that more or less directly interact with the human senses. The senses are the portals to the mind. What we know about the virtual world is constructed by the human mind based on the affordances detected by active perception (Gibson, 1979: 127; Biocca, 1997).

In the *objective approach*, one sees a virtual organization as an organization (conceived as a social organism or work organization) extending into the virtual domain (Gazendam, 1999). The organization is seen as consisting of people and virtual actors. In this way, organization theory can be used and extended to the virtual domain, and information systems can be viewed as actors or organizational units with special capabilities. For the communication between human actors and virtual actors, the subjective approach to virtual organizations may be used as well as other approaches. This leads to the following definition of 'virtual organization'. A *virtual organization* is a multi-actor system consisting of human actors and virtual actors.

Multi-actor systems have to do with issues of communication, cooperation and coordination (Gazendam & Jorna 1993, 1998; Gazendam & Homburg 1996). They focus on the capabilities, interests, and interactions of actors, and study the phenomena that emerge from these interactions. Human beings as well as virtual beings can be seen as actors. With this perspective, human organizations, virtual organizations, and information systems can be understood by a common theory. This theory will be an innovative form of organization theory. An important topic of this theory will be the study of interaction patterns between actors. Recurrent interaction patterns can be seen as a form of negotiated order. They also can be seen as habits, Hägerstrand's (1975) and Giddens' (1984) paths in space and time, based on social norms (Stamper 1973), or interacting semiotic Umwelts (Von Uexküll & Kriszat 1936/ 1970).

An *information system* is a multi-actor system consisting of virtual actors. Information systems are parts of virtual organizations. Information systems are created by programs and data residing on computer hardware. In the virtual organization, information systems are active entities. As virtual agents, they are no longer rather passive representations of the nonvirtual reality, or very efficient helpers for doing invariant computing tasks. Information systems *represent* things and concepts in the world, but also *create* (determine) things, concepts, events etc. in the world by constructing *pre*presentations. They make new signs that have a value or meaning based on convention, like for instance when paying our salaries. Based on authorized actions and constructed *pre*presentations, they change the virtual domain as well as the nonvirtual world.

The perspective on the development of organizations and information systems has shifted from the application of information and communication technology in organizations to the perspective of social construction of virtuality. From the *technological perspective* on the development of organizations and information systems, a design problem has to be solved within the boundary conditions posed by information and communication technology and the inevitable laws of mathematics, computer science, and nature. Relative to organizations that do not use information technology, ITENOF, information technology enabled organizational forms, have to be optimized in a new way because computers and humans have different capabilities. From the *perspective of social construction of virtuality*, the limitations to the development of virtual organizations are those of the human imagination in a social context. For virtual organizations, we must not look at hardware, software and data, but look at the organization of the virtual domain. The virtual domain is created by imagination. Likewise, for understanding novels, we must not look at paper, pencil and printing, not look at grammar and words, but look at the story told, the imagination used (Gazendam, 1997). Multiple ideas about what virtual organizations should be or should do are possible, leading to alternative designs. From a semiotic point of view, these alternative designs can be studied based on the metaphor concept.

1.2. Metaphors

Metaphor: a way of imagination
A *metaphor* is an imaginative way of describing something by referring to something else that has the qualities that you are trying to express (Collins, 1987). Metaphors work because they transfer meaning by way of analogy. Metaphors are useful because they are efficient: they transfer a complex of meaning in a few words. For instance, if you say that "the camel is the ship of the desert", you do not only say that you need camels as means of transport to cross the desert, but also that the desert is like the sea because of its vastness, lack of drinking water, the danger of storms, and so on. For finding your way in the desert you need navigation like you would need at sea. Sitting on a camel may make you seasick. The horizon in the desert is like the horizon at sea. An oasis is like an island. The use of 'ship' as a metaphor opens up a meaning complex, a web of connected metaphors that add to the content of the analogy. Ship is related to ocean, islands, waves, storms, navigation, seasickness, and so on.

The use of metaphors has been studied extensively in semiotics (Stern, 2000). The use of metaphors is not without puzzling aspects. For instance, in most cases, the intention of the speaker using a metaphor is often clear, although the metaphor, if taken literally, would be not true.

> "A metaphor substitutes one expression for another in order to produce an expansion (or a "condensation") at the semantic level. . . . A metaphor is easily recognizable as such because, if it were taken literally, it would not tell the truth (since it is not true that Achilles was a lion)." (Eco, 1990: 138, 139).

However, there are also cases where a metaphor is true in both the metaphorical and the literal interpretations, for instance in Mao-Tse-Tung's comment "A revolution is not a matter of inviting people to dinner" (Stern, 2000: 4).

Social constructs
It is useful to see organizations and information systems as *social constructs*. This implies, according to Hacking (1999: 6, 12):

> "Social constructionists about X tend to hold that:
> (0) In the present state of affairs, X is taken for granted; X appears to be inevitable.
> (1) X need not have existed, or need not be at all as it is. X, or X as it is at present, is not determined by the nature of things, it is not inevitable.
>
> Very often they go further, and urge that:
> (2) X is quite bad as it is.
> (3) We would be much better off if X were done away with, or at least radically transformed."

Metaphors are useful for characterizing the meaning networks that can be associated with social constructs like organizations and information systems. In organization and management theory, metaphors have been used to explore the interpretation frames used by organization theories. The use of 'the machine' or 'the organism' as a metaphor for the organization is a convenient way to characterize the presuppositions of a certain organization theory in a short and condensed fashion. This facilitates the comparative investigation of organization theories, as Morgan (1986) has shown.

1.3. Information systems and metaphors

Metaphors reveal information system design space
Information systems are social constructs, even more than organizations are, because human beings construct them consciously in steps of, amongst others, design and programming. An information system is not a neutral representation of an objectively given world. Conceptualization is needed when constructing an information system (Checkland and Holwell, 1998: 233). Therefore, metaphors seem to be especially useful for explaining the space of possible meaning complexes or designs of information systems. Doing so, metaphors explain that a certain way of designing information systems is not based on an inevitable law of nature, and that alternative designs are possible. Metaphors are also useful for stimulating the imagination when working on an information system design. When new concepts are created and explored, metaphors are often the best instrument for communicating what is meant.

Information system metaphors
A short search on Internet yields a variety of information system metaphors[3]. Metaphors express the nature of the design of the information system (island, architecture, zoning plan), its behavior (clock, apprentice, reporter), its use as a tool (spreadsheet, notepad, bulletin board, desktop, checklist), its character as a space or virtual world (library, superhighway, net, tree), and the nature of the interaction it requires (conversation, navigation). Several metaphors have been used for characterizing the process of information system development: game, machine, journey, jungle, family, zoo, society, war, organism (Kendall and Kendall; 1993).

Architecture is a metaphor that is often applied to the way of construction of socially constructed entities. Architecture can be applied to organizations, information systems, and virtual organizations. A new development in information system design (Gamma, Helm, Johnson, and Vlissides, 1995; Fowler, 1997; D'Souza and Wills, 1999) has been inspired by the use of *patterns* in architecture.

> "Each pattern describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice." (Alexander, Ishikawa, Silverstein, 1977: x)

Architecture is the way a system is composed of agents (subsystems) that each have a specific functionality or responsibility (a *design*), and the rules governing the behavior

[3] Sometimes, a specific information system architecture is also called a metaphor, although it is not a metaphor in the sense defined above. Examples are the model-view-controller metaphor, and the detector-selector-effector metaphor.

and cooperation of these agents (a *norm system*). Architecture normally is specified at several levels of functionality or granularity, in a consistent way. Architecture levels can be distinguished based on Stamper's (1973; 2001) semiotic ladder:

- social;
- pragmatic;
- semantic;
- syntactic;
- empiric;
- physical.

Virtual organization architecture has to do with the top three levels (social, pragmatic and semantic). At each level there will be a design and a norm system. Component architecture has to do with the syntactic and empiric levels. Technical infrastructure has to do with the physical level. In the description or the design of a virtual organization at the social level, it is important to design organization units based on capabilities and responsibilities. For the determination, or the imagination, of adequate capabilities of virtual actors (information systems) information system metaphors can be very useful.

A further explanation of information system metaphors can be done based on three basic metaphors: the *mill*, the *cell* and the *mind* (Gazendam, 1993: 282-293). Each of these basic metaphors leads to a meaning network composed of connected metaphors, associated theories, and associated design patterns.

2. The Mill Metaphor

2.1. The mill

Whole

A mill is a factory.

> "A mill is any machine, or building fitted with machinery, for manufacturing processes." (Oxford, 1977).

A mill is also a pumping-station, originally wind-driven, to remove redundant water from a polder, thus keeping Dutch feet dry.

Parts

The parts of a mill are cogs, wheels, and instruments attached to a machine that generates and distributes energy[4].

Environment

The environment of a mill consists out of a *network* of canals, roads, and railways for the transportation of raw materials and products.

[4] According to Castells (1996), the industrial age is characterized by the automatic generation and distribution of energy, while the information age is characterized by the automatic generation and distribution of information.

Process
So a mill processes *water*, pumping it into a channel, or it processes *raw material*, turning it into *products*.

Objectives
The quality of the mill is that, as a machine based on the generation and distribution of energy, it can process large volumes of material in an efficient, precise, reliable and rapid manner. The objectives of a mill are to work in this way, as planned.

Development
The realization of the mill is done by building it, fitting wheels and other machinery parts together, following a *design*, and using craftsmanship. The cohesion of the mill as a whole is a result from a top-down design process. In the design, best practices based in experience are used.

Connected metaphors
The mill is a large machine. Small machines can be used as *instrument* or *tool*. The emergence of effective windmills in the Netherlands in the seventeenth century coincided with a golden age in science and arts. Printers like Elsevier distributed scientific texts all over the world. This contributed to the development of the age of enlightenment, characterized, amongst others, by a drive to systematize knowledge in encyclopedia and libraries. In this way, the *book* and the *library* are connected to the mill.

2.2. The information system as a mill
An information system as a *mill* is characterized by the efficient processing of large quantities of information. The processing has to be done using fixed, that is, *invariant*, rules en patterns that may be very complex.

Process-oriented design: automata theory
The mill metaphor is consistent with a large part of traditional information systems theory, in which an information system is seen as an automaton processing data to render information. In computer science, the mill metaphor finds its fundaments in the concept of the *automaton*:

> "Thus, a finite automaton is a machine that can exist in a finite set of states, where the particular state it is in at any given moment depends on the inputs it has received and upon its previous states. The set of states in an automaton serves as its 'memory': the only information that an automaton has concerning its past operation is the current state it is in; at least, this is the only information it can use in deciding its next state and its next output when it is given an input symbol." (Jackson, 1985: 45).

The traditional way to design information systems is to analyze business processes, their relations with organization units, and their information input and output (Lundeberg, Goldkuhl, and Nilsson, 1982; IBM, 1984). In this analysis, business processes are decomposed, as well as input and output data sets. The input data and output data lead to a database design. The subprocesses to be automated are chosen and redesigned.

Data-oriented design: the library metaphor
The capabilities of the computer with respect to data storage and retrieval have led to an information system concept analogous to a library. The information system is seen as a large library in which information is stored in an orderly and systematic way. The use of the library consists of retrieving the information one needs in the form of books. This approach to information systems was as *data-oriented design* revolutionary in the 1980s (Martin, 1982; 1983). Processes are seen as operations on a database. The database is ordered according to object types and relationship types. In the database, stable states are distinguished. Transactions are the transitions of one stable state to another; program modules are based on transactions. Transactions can be thought as being composed of basic operations on attributes of object types; in object-oriented databases these basic operations are defined as methods. A special type of transaction is concerned with the derivation of attributes based on the values of other attributes; this derivation can be based on a special inference engine that uses inference rules.

The capabilities of the computer with respect to computation lead to efforts aiming at the design of the most efficient algorithms to perform a certain computational task. In the spirit of Taylor, one should redesign each computer task using the most efficient algorithms, thus specifying a method that minimizes the use of precious computer time. In this way, a library of algorithms or program modules can be formed that can be used to compose larger programs. The transactions and inference methods of the data-oriented design are examples of these larger programs.

Processing of data to get information
A mill processes water or other material. Data can be seen as raw material, while information is a product. An information system is often seen as an automaton that processes raw materials (data) in order to get products (information).

> "An information system is a set of organized procedures that, when executed, provides information to support decision-making and control in the organization." (Lucas, 1986: 10).
> "Computers have become an essential part of organizational information processing because of the power of the technology and the volume of the data to be processed" (Davis and Olson, 1985: 4).
> "Information is data that has been processed into a form that is meaningful to the recipient and is of real or perceived value in current or prospective action." (Davis and Olson, 1985: 200).

Information can also be seen as water flowing through a channel (Davis and Olson, 1985: 202).

Coherence by design
In a case that coherence only can be brought about by a top-down design, integration of information systems at design time is important. Such an integration of information systems has the following objectives (Theeuwes, 1986: 96):
- tuning of the information systems to the business processes;
- integration of information systems and data collections;
- development of new information systems by projects based on strategic data planning;

- planning and management of the technical infrastructure necessary for the integrated information systems;
- design an organization for the development and maintenance of information systems and data collections.

The informational aspect system
The integration idea leads, in its most extreme form, to the concept of *one information system for one organization* (the total information system). A related idea is the integration of information systems from the viewpoint of the informational aspect system of the organization. This idea is related again to the idea of control by aspect systems: financial control, human resource control, material resource control, and so on. With respect to this control, a neat planning and control hierarchy based on Anthony's (1965) theory is strived after. It is consistent with this concept to consider 'the' information system as an aspect system of the organization, comprising:

> “- the organizational subsystem made up of people and procedures;
> - technical appliances;
> - programs
> - data” (Boersma, 1989: 6).

The organization's information system has to be managed as a whole by an information manager and a data administrator. This abstract information system is often subdivided in integrated aspect-oriented information systems for finance, marketing, personnel, materials management, and so on. Information is seen as a resource to be managed centrally. Data are processed by transaction processing systems and by management information systems that produce information necessary for decision-making. Standardization of financial procedures, intensifying financial control, integration of the components of the organization's information system, and centralization of data administration are seen as important topics for information management. Because of the uniqueness of the organization's information system, software has to be tailor-made.

The resulting planning and control design leads, however, to problems. It is an example of controlling organizational activity by planning and control organized by aspect systems. Kastelein's (1985: 204) view on this type of control is:

> “There is an unstoppable process of interweaving and stitching through of the organizational web in which the organizational units are embedded, resulting in the increasing restriction of substantial change possibilities, and the suffocating of already going change processes.”

Another result of thinking in terms of an informational aspect system is the resulting passivity of managers and users, who leave the design and building of information systems to the computer specialists.

Design of architectures and building activities
A central role in the design of integrated information systems is played by the architectures distinguished in the strategic data planning approach to information planning (Martin, 1983, 1984; IBM, 1984). To optimize an information system, the principle of minimizing information exchange between subsystems is used. This

principle is based on Simon's (1962) 'nearly decomposable system' concept. Simon argues, that processes that are subdivided in hierarchically organized subprocesses are more efficient than non-subdivided processes. This is a result of the localization of the effects of external disturbances during execution.

After planning, determining requirements and design, the information system has to be built. This is traditionally accomplished through structured programming techniques (Lundeberg, Goldkuhl, and Nilsson, 1982; Jackson, 1983). In short, for designing and building information systems based on the mill metaphor, a well-developed toolkit exists.

Internet
The environment of a mill metaphor information system is a network. Like its name says, Internet is a global network of communication channels. Channel capacity is important. Internet is also an information superhighway, on which traffic has to be regulated. It can also be seen as a global library.

2.3. People, organization and the mill

Business process redesign and job redesign
The design of a mill focuses on finding the best method of accomplishing a certain job. Efficiency, precision, reliability, and speed are important criteria. Thus, the major objective of computerization is -according to the mill metaphor- the best way of organizing business processes. Together, information systems and humans can do many jobs much better than a human can do it alone. Thus, jobs and business processes have to be redesigned in cases where the computer is used. In this redesign, one tries to make an optimal use of the capabilities of the computer in the field of data storage, data retrieval, and computation. The character of mill metaphor information systems is especially clear in the design of the human-computer interaction. Here, the user is guided along the path that is considered the most efficient one, and no discretion is left to the user regarding leaving that path and choosing his or her own one.

People become wheels in the mill
Garson (1988: 10) uses the mill metaphor --she calls it the factory of the past-- to describe the process of computerizing white-collar work. People become wheels in the mill.

> “In the modern factory, parts move continuously along an assembly line that human beings feed and tend as necessary. Everything seems bent on production.... Soon, when you walk into the fully automated office, it will seem equally ordained and complete.” (Garson: 1988: 261).

Work is degradated, like blue-collar work in the industrial revolution:

> “Both these systems were designed to capture the skill of the individual griddleman or broker and transfer them to a program. Thereafter, the job can be done by workers with less skill and knowledge.” (Garson, 1988: 11).

People and information systems are not equal partners. Most people are 'slaves' of the information system, which is controlled by a happy few:

> "In almost all cases we'll be looking at, the effect is to centralize control and move decision making higher up in the organization." (Garson, 1988: 11).

Attached to a mill metaphor information system, people can be monitored. Examples of monitoring are reading Email, automatic registration of time spent on tasks via applications used, automatic registration of Internet use in the office and sometimes even at home. Monitoring, however, is a moral problem. People don't like to be monitored; they don't like to be in a situation where *"Big Brother is watching you"*.

McDonaldization
Ritzer (1996: 1) describes McDonaldization as

> "the process by which the principles of the fast-food restaurant are coming to dominate more and more sectors of American society as well as of the rest of the world"

McDonaldization is an organization form based on efficiency, calculability, predictability, and control. McDonalds is an example of the process organization, which is characterized by the following principles:
- strong standardization;
- what can be automated, is automated;
- flat organization resulting from the fact that the logistic information system takes over middle management functions;
- the principle of the working customer (where IKEA is the paradigmatic example);
- registration of customer data (based on credit cards or customer cards) for customer oriented marketing and sales.

McDonaldization and the redesign leading to process organizations can be seen as examples of business process redesign, which is associated with the application of the mill metaphor to information systems.

Criticism of the mill metaphor
Garson criticizes the mill metaphor information system because of its degradation of work. Ritzer criticizes McDonaldization because of its dehumanization and its illusions of low cost, fun, and reality. The question is whether these criticisms are not too severe. They may be inspired by an anti-machine nostalgic romanticism. Of course, there are examples of mill metaphor computerization that have gone on the wrong, dehumanizing track. But there are also examples of process organizations that combine efficiency with a social orientation. Valens (1994) remarks that many people are happy to work in a well-organized process organization like Albert Heijn.

3. The Cell Metaphor

3.1. The cell

Whole
The cell is something that lives. It can be autonomous, or part of a larger living being.

> "A cell is the smallest part of an animal or plant that is able to exist by itself." (Collins, 1987).

> "A cell is a small usually microscopic mass of protoplasm bounded externally by a semi permeable membrane, usually including one or more nuclei and various nonliving products, capable alone or interacting with other cells of performing all the fundamental functions of life, and forming the least structural unit of living matter capable of functioning independently." (Webster, 1980:177)

All organisms are composed of cells, or consist of one cell.

Parts
A cell is made up of a cell wall and cell contents. Protoplasm is the material bearer of life. Cells can multiply themselves, forming cell clusters. In cell clusters, cells can differentiate related to their function; this process is called morphogenesis (creation of forms). The cell contents consist of a transparent material (protoplasm) carrying several organelles, bodies with a specific function (Koningsberger, 1962). Of these organelles the kernel, which carries the inherited genetic information, catches the eye. Grown above a certain size, the cell divides itself. Individual cells have a limited lifetime. although the cell cluster or organism they are parts of may live a lot longer.

Environment
Organisms live in a spatial-temporal environment in which they wander and coexist with other organisms. These other organisms will be of a great variety. Organisms generally need to interact, rely on each other, for example for food, and form in this way an ecosystem. In a spatial environment where dangers can await you, you have to be cautious. For traveling long distances, you need navigation.

Process
Cells communicate and interact by sending and receiving streams of material through their walls. The structure of the walls and the laws of osmosis regulate these streams. Cells need food in order to survive, to grow and adapt. In an organism, special cell types process raw material to material that cells can digest. Organisms are very busy with preserving their *integrity* (feed themselves, repair themselves), and with *interaction* with the environment.

Objectives
Organisms want to survive. They have a variety of biological needs like eating and sleeping. They also strive after mating and reproduction in order to preserve their genetic information. Their behavior is structured around biological rhythms, habits, moods, daily paths through time and space, handling impulses. There is no global rationality; there are only local needs, local perceptions, local actions (*principle of localization*).

Development
Cells are created by cell division. Later they grow and adapt. Organisms are created by sexual procreation. They grow by cell division, and adapt to the circumstances in their environment. The coherence of an organism is based on gene-directed growth. They learn habits. Individuals can be seen as bearers of genes and memes. Memes are packages of cultural information, sign complexes.

> "Examples of memes are tunes, ideas, catch-phrases, clothes fashions, and ways of making pots or building arches." (Dawkins, 1976/ 1989: 192).

Genes and memes strive after survival, and strive to spread themselves over the world. Species adapt by mutation and selection (biological evolution).

3.2. The information system as a cell or organism

The behavior and structure of cell metaphor information systems
An information system as a *cell* is characterized by its fluent and adequate interaction with people. The information system consists of objects that take care of preserving their own integrity and that react on events. The cell metaphor is characterized by *interaction* and *integrity*. If we see an organization as an organism, an information system is a specialized cell or organ. An information system encapsulates itself within a kind of cell wall, thus maintaining its own integrity. An information system consists of smaller bodies (objects) with a specialized function, of which the bearer of inherited, type-determining information is the most noticeable. An information system can also be seen as a larger cluster of cells (objects), of which each cell maintains its own integrity, while these cells communicate by sending and receiving messages through their cell walls. Communication is regulated by the cell wall encapsulating private material and behaving according to its structure, only permitting access to recognized material. An information system is grown, not built. Grown above a certain size, an information system tends to divide itself or to disintegrate. Information systems have a limited lifetime, but their type-determining information may be copied by new information systems. Information systems need information (food) to grow and to live, and can process raw material into food for themselves and other components of the organism.

Object-oriented analysis, design, and programming
The cell metaphor finds its computer science foundation in the object concept. Several aspects of this cell metaphor can be recognized in the object-oriented analysis, design and programming paradigm (Goldberg and Robson, 1983; Coad and Yourdon, 1991a; 1991b). This paradigm also contains principles --such as simulating the real world by a world model—that fit into the mind metaphor. An *object* is a virtual entity realized on a running computer system. An information system can be described as a system of objects serving an organization module. A cell is represented by either an object or an information system. An object has a life cycle, a behavior determined by methods, and a memory based on private data. The encapsulation and message passing principles are obvious. In object-oriented information systems, integrity maintenance is more natural than in imperatively built information systems. The class as a kernel containing the inherited type-determining information is apparent. The principle of reusing information systems by copying its class definitions and altering them is well known.

Locality
An important aspect of information systems seen as cell clusters, in which the cells are the objects, is that the activity of the information system in fact consists of the object activities, and that these object activities are purely local in this sense that an object only can execute its inherited methods, and only can process material which is available within the object.

Growing information systems
The objectives of the cell metaphor information system are first and foremost the survival of the organization, and secondly the survival of the information system during its natural life cycle. The development of information systems is primarily seen as an evolutionary process, in which competition between information systems and incremental change play roles.

The principle of growing is recognizable because object-oriented systems are grown by feeding them -as running symbol systems- with information.

> "When my program is running, I am typing in some new statements, and then he is actually eating it and growing by it." (Wouter Gazendam, 11 years old, 1990).

According to the cell metaphor, information systems must be grown. There is empirical evidence for the success of such an approach (De Jong and Gazendam, 1991:

> “Group by group tasks have been computerized using microcomputers. Most computerized systems were database applications that could be realized in a short period of time using a fourth generation language; a result with which the users were pleased. These modular systems, developed according to the zoning plan, were disseminated throughout the whole organization, where they were subsequently incrementally changed and used... the developed systems were step by step integrated...leading to a decrease in the abundant streams of forms... one of the consequences was the possibility to work client-oriented... There is empirical evidence that the zoning plan approach is substantially more efficient than the blueprint approach . . .”

Genetic algorithms (Holland, Holyoak, Nisbett, and Thagard, 1986; Goldberg 1989) can be used for creating descendant objects from parent objects, and provides also selection mechanisms for the survival of the fittest. Artificial life consists of very simple beings that develop and reproduce in a virtual environment (Holland, 1995; Ward, 1999).

The methodology of planning, designing, and developing object-oriented information systems has developed rapidly in the last decennium. Experiences have been documented as patterns (Gamma, Helm, Johnson, and Vlissides, 1995; Fowler, 1997; D’Souza and Wills, 1999). A universal language for analysis and design, UML, has been developed (Rumbaugh, Jacobson, and Booch, 1999; Booch, Rumbaugh, and Jacobson, 1999; Jacobson, Booch, and Rumbaugh, 1999).

Event-oriented design
The capabilities of the computer with respect to the graphical presentation of objects and interaction with the user, and with respect to communication with other computer systems, lead to event-oriented design. In *event-oriented-design*, the events that are relevant for the computer system are identified. These can be events caused by the human user, or time events resulting from the computer clock, or events in the sphere of communication with other computers. For each event type, an appropriate reaction of the computer system has to be designed. In object-oriented analysis and design, methods for the analysis of interactions have been developed based on use cases

(Jacobson, Ericsson, and Jacobson, 1994) and standard communication patterns (Dietz, 1992; 1996).

The world-wide web
The environment of a cell metaphor information system is a virtual spatial and temporal environment, a web of daily paths through time and space (Giddens, 1984: 116) in which meeting places exist. Information systems that have the form of autonomous agents wander around in this environment, and communicate by sending and receiving signs. In the ecology of the information system, the human organization is very important. A cell metaphor information system needs human attention; otherwise it will die.

3.3. People, organization and cell metaphor information systems

The congruence hypothesis
In the organism metaphor of organizations, organization modules are seen as the organisms controlling themselves. Each module has to survive in an environment that consists mainly of other organization modules, sometimes entangled in an organizational web. The exchange of persons, things, materials, and information with the environment is determining for the structure as well as for the survival of the organization module. An information system is part of such an organization module, or perhaps a special organism for communication between organization modules, but is never shared by two or more modules: you cannot share each others organs. This has as a result that information systems tend to grow in a way that, in the long run, is congruent witch organization modules (the *congruence hypothesis*).

Interorganizational information systems
Kastelein (1985: 70) distinguishes four organizational levels: the group, the organization module, the supersystem, and the organizational net. If there is something such as a centralized electronic data processing department, it will have to operate successfully on the market formed by the other organization modules in its environment to survive. The level of the individual and the group is seen as dependent on the organizational module level. In such a situation, information system planning and control is naturally done on the organization module level, and control by aspect systems of the supersystem is avoided. Planning and control activities at the organizational net and the supersystem level can only succeed insofar as they are restricted to common interests (Homburg, 1999). These common interests lie mainly in the fields of technical infrastructure and timetables specifying information exchange.

People and information systems as partners
As seen by the cell metaphor, people are fellow organisms, having the ability to form dynamic self organized systems. They are the growers of information systems. In fact, the information systems develop and grow by using them, incorporating information and adapting to their users. People are not slaves of the information system, such as in the mill metaphor. People and information systems are equivalent components of a wider ecological environment, to which both are subjected. There is no separate role for information system builders here, only for people who help self organized groups by offering their experience.

4. The Mind Metaphor

4.1. The mind

Whole
The mind is the faculty of thinking as well as the domain where thoughts are.

> "Your mind is where your thoughts are." (Collins, 1987).
> "Mind is the faculty of thinking, reasoning, and acquiring and applying knowledge." (Microsoft Word for Windows Thesaurus).

The concept of mind is often used for an entity functionally embodying the unity of human cognition (Anderson, 1983: 1):

> "The most deeply rooted preconception guiding my theorizing is a belief in the unity of human cognition, that is, that all the higher cognitive processes, such as memory, language, problem solving, imagery, deduction, and induction, are different manifestations of the same underlying system.... The view that the mind is unitary is certainly not universally held; it may not even be a majority opinion."

Parts
Another opinion is that the mind is no unity, but a society of semi-autonomous subsystems (Minsky, 1985). Although it is not uncommon to see an organization as a multi-actor system, to see a mind in such a multi-actor way is still uncommon. Viewing the mind as a multi-actor system would provide for an explanation of the massive parallel processing that takes place in the human mind.

Explaining the structure of the mind as a metaphor for an information system is a kind of bootstrapping because the computerized information system has been used as a metaphor for the mind. An example is Anderson (1983: 19) who uses the decision support systems architecture --consisting of data base, model base, and active interface-- for his ACT* cognitive architecture. The major components of the cognitive system are the background memory (the world model), the structure of problem spaces (the views), the working memory (the controller), the sensors, and the effectors.

Environment
The environment of a mind consists of the world that can be perceived (the spatial, temporal, ecological *environment* like in the cell metaphor), and of other actors that have minds. Actors are organized in *families*, *organizations* and *societies*. These collections of organized actors can be seen as multi-actor systems (Gazendam and Jorna, 1993). Because minds create and process knowledge, the books and other media that provide knowledge and entertainment are appreciated. So the world is also some kind of *library* for the knowledge-seeking mind.

Process
The mind processes information in a way that we call intelligent. Information comes in various kinds and structures, ranging from the direct representations that are received in perception, via language expressions that are used in communication and

thought, to conceptual representations that form networks of concepts used in language processing and thought.

Objectives
Because of its roots in a biological organism, the mind wants to survive, and help to fulfill the basic needs of its organism. Because of this, it is coupled to biological rhythms (e.g. sleep), and the associated moods, habits, and so on. But it has also its own dynamics as a mind, it wants to experience new things, to learn, to be creative, to process information, to be entertained.

Development
The mind develops by learning. There are different kinds of learning, for instance learning by imitation, rote learning, learning by experience (building a world model), and learning by creation and assessment of new ideas. Logically, learning can be described as a combination of processes of induction, abduction, and deduction. Coherence of the mind is brought about by its growth as a biological organ, and by processes of information processing and learning that are more or less coherent. Coherence of the multi-actor system is brought about by social structure and culture, based on interactions, mutual learning, contracts, and power structures.

4.2. The information system as a mind simulator

The information system as an assistant or virtual actor
The information system as a *mind* appears as an intelligent assistant embodying that mind. An information system as a mind is characterized by capabilities like *knowledge use*, *autonomy* and *learning*. Such an information system corresponds with the idea that information systems are actors. Information systems are *virtual actors* that

- are semi-autonomous units,
- have some semi-intelligent capabilities, and
- have responsibilities and follow social norms.

This virtual actor is an active assistant of people that realizes its responsibilities in a rather intelligent and autonomous way. The information system as a mind is characterized by responsibility and autonomy. The main objective of the virtual actor is increasing the productivity and creativity of the supported people (Sprague and McNurlin, 1986). An example is: an official normally takes care of the funding of 10 schools; because of a supporting information system he will be able to take care of 50 schools and to participate in policy formulation (Gazendam, 1993).

Symbol systems theory
The theoretical basis for the mind metaphor is the artificial intelligence theory about symbol systems (Newell and Simon, 1972; Anderson, 1983; Newell, 1990). A running information system, as well as the human mind, can be seen as a *symbol system*, thus enabling the simulation of the human mind by computers. An information system can be perceived as a symbol system simulating human intelligence partially, comprising human knowledge, and assisting people within organizations.
Symbol systems theory (Newell, 1990) distinguishes the following components:

- the problem spaces,
- search control,
- the background memory or knowledge base,

- the sensor and the effector.

These components, together, can simulate an intelligent agent. The actor communicates with the user by its sensor/effector interface, reading and generating messages or actions. If we take the virtual actor interpretation literally, the components of the cognitive architecture of the virtual actor --e.g. the problem spaces-- are cognitively impenetrable by the user; only the messages and actions generated by the virtual actor can be perceived. Most expert systems work in this way. However, for the virtual actor designer, its components have to be cognitively penetrable.

The semiotic Umwelt

The virtual actors, or intelligent assistants, have to get some place in the human semiotic Umwelt in order to be useful. The semiotic Umwelt (Von Uexküll and Kriszat, 1936/ 1970) is an environment around a human being or animal consisting of the signs and symbols that it creates and perceives. The types of signs and symbols that can be created and perceived depend on the biological species. Humans like to have an Umwelt filled with books, paper, pencils, writings, drawings, television, computers and other artifacts that contain symbol structures (information and knowledge in the form of pictures, stories, and so on) they have created themselves or that stem from other sources. Knowledge workers like to have a semiotic Umwelt that stimulates their creativity, quality, accuracy, and so on, in writing and other design tasks or information processing tasks.

The semiotic Umwelt and virtual actors

As a virtual actor that assists people in performing their tasks, a mind metaphor information system has to function in a semiotic Umwelt. We imagine that such a semiotic Umwelt presents itself as a working environment in which the user has the initiative, in which programmable documents (spreadsheets, hypertext documents, animations) -or other virtual objects behaving in a way that is familiar to the user- represent the products of user thought, and in which tools are present for the creation and manipulation of these objects (Gazendam, Jorna and Blochowiak, 1991). Such an environment can be visible as a kind of desktop on which the documents mentioned above lie (the desktop metaphor), or as another simulated reality (the virtual reality architecture). Young (1987) has described such a working environment aimed at decision support as well as creativity support.

The desktop metaphor

In the *desktop metaphor,* the user elaborates his or her ideas by manipulating the programmable active documents on his or her desktop, and asks for help from the virtual actor by using a tool or special document. The virtual actor responds by doing a certain task in the field of document manipulation, or starts a conversation with the user using a special document.

Virtual reality architecture

In the *virtual reality architecture,* the user explores a virtual reality consisting of simulated objects and actors. Virtual actors communicate by means of putting messages on several documents or blackboards and reading these messages from these documents or blackboards. The user participates in this multi-actor organization. The user has tools for moving around in the virtual reality, for inspecting and manipulating objects, and for communicating with the actors. The virtual reality architecture fits in a larger architecture consisting of communicating actors of different kinds: human beings, simulated intelligent actors, and virtual actors that are guides to semi-intelligent databases or object bases.

Meaning of the Internet in the mind metaphor
The Internet is a library consisting of documents in that store knowledge, and try to communicate knowledge. Furthermore, Internet is a society in which you can meet other actors, real or virtual. Internet is organized based on families that each have a site where they live, a site where their home is.

4.3. People, organization and mind metaphor information systems

Assisting or replacing people?
The information system that is a virtual actor assisting people within organizations will be termed the *mind-1 metaphor*, because another alternative is possible. Instead of writing 'assisting', 'replacing' could have been written. The view corresponding to 'replacing' will be termed the *mind-2 metaphor*. With its position, the mind-1 metaphor opposes the mill metaphor, which makes people slaves of the system. The mind-1 metaphor puts the information system in the role of an semi-intelligent *assistant* of people, consequently having to adapt itself to the characteristics of human cognition. The mind-2 metaphor is compatible with the mill metaphor with respect to its aim to replace people by computerized information systems. Expert systems are examples of the mind-2 metaphor. Knowledge engineering aiming at expert systems tries to absorb the knowledge of experts in computer systems, for the rest following the approach of the mill metaphor. Decision support systems, including KB-DSS (Klein and Methlie, 1990) and thought support systems are examples of the mind-1 metaphor.

Thought support
The decision support systems movement has been emphasizing the support of individual people by information systems for decades (Sprague and Carlson, 1982). Thought support is essentially different from task automation (Young, 1987):

> "One can automate doing, one can only support thinking."

The goal of thought support is not 'controlling thought processes' or 'automating ways of doing', but 'stimulating and supporting creativity'. An important point in thought support is that the user is at the *driving wheel*, not the computer program. The user develops ideas or decisions by a unique combination of mental objects and a self-chosen chain of cognitive tasks. In group decision-making, idea representation and manipulation is necessary for group learning processes and getting consensus about certain idea's or items. This means, that thought support systems are essentially different from expert systems where the solution generating process is automated, and controlled by the computer.

5. Discussion
The foregoing explanation of information system metaphors tries to make visible the design space that organizations and individual designers have in describing or designing an information system. The explanation of these metaphors also tries to stimulate the imagination, and to facilitate new directions in information system research. Two questions that remain are:

- how do the three metaphors (or metaphoric meaning complexes) relate to each other?
- can these three metaphors be combined in a single organization?

Of the three metaphors, the cell metaphor seems to be the most general. It has a time scale that encompasses life and death of information systems, and transfer of genetic information. It also has a spatial scale in which an organization or information system with integrated rationality is only a local region, bubble, or niche. The mind metaphor is clearly derived from the cell metaphor. It depends on the biological characteristics of the cell metaphor and could be seen as a specialization of the cell metaphor, a species of organism specializing in intelligence, language and symbol structure use. The mill metaphor relates to the mind metaphor as follows. A mill is a machine, an instrument, or tool, made and used by an intelligent being (a biological species of the mind metaphor type). Social structure in the multi-actor society of mind metaphor beings leads to a possible misuse of these mills.

The three metaphors can be combined, and are combined, in real-life organizations. Hagel and Singer (1999) describe such a composite organization. They think that organizations will unbundle their core processes, leading to specialized parts for:

- customer relationship management that identifies, attracts new customers, and builds relationships with customers;
- infrastructure management that builds and manages facilities for high-volume, repetitive operational tasks; and
- product innovation that creates attractive new products and services and commercializes them. (Hagel and Singer, 1999: 135)

We see that organizations can be composed of subsystems that specialize in a certain direction. For instance, an innovation-oriented subsystem can use mind metaphor information systems, an efficient processing subsystem can be based on mill metaphor information systems, and a subsystem giving attention to people can be helped by cell metaphor information systems.

Bibliography

Alexander, Christopher, Sara Ishikawa, Murray Silverstein, e.a.
1977 *A Pattern Language: Towns, Buildings, Construction.* New York: Oxford University Press.
Anderson, J.R.
1983 *The Architecture of Cognition*. Cambridge, MA: Harvard University Press.
Anthony, Robert N.
1965 *Planning and Control Systems: A Framework for Analysis.* Boston, MA: Division of Research, Harvard University Graduate School of Business Administration.
Aquinas, Thomas
1266-1273 *Summa Theologiae*, I, Pt. 1, qu. 14, a. 1. Quoted in: A.J.Ayer and Jane O'Grady. A Dictionary of Philosophical Quotations. Blackwell, Oxford, 1992: 13.
Biocca, Frank
1997 'The Cyborg's Dilemma: Progressive Embodiment in Virtual Environments', Journal of Computer-Mediated Communication, vol 3, no 2, September 1997, http://www.ascusc.org/jcmc/
Boersma, S.K.Th.
1989 *Beslissingsondersteunende systemen: Een praktijkgerichte ontwikkelingsmethode*. (Decision support systems: A practice-oriented development method.) Ph.D. Thesis, University of Groningen, Schoonhoven: Academic Service.
Booch, Grady, James Rumbaugh, and Ivar Jacobson
1999 *The Unified Modeling Language Guide*. Reading, MA: Addison-Wesley.
Brooks, Frederick P.
1999 'What's Real About Virtual Reality?', *IEEE Computer Graphics and Applications*, November/December 1999: 16-27.

Castells, Manuel
1996 *The Rise of the Network Society*.Oxford: Blackwell.
Checkland, Peter, and Sue Holwell
1998 *Information, Systems, and Information Systems*. Chichester: Wiley.
Coad, P., and E.Yourdon
1991a *Object-oriented analysis.* Englewood Cliffs, NJ: Prentice-Hall.
1991b *Object-oriented design*. Englewood Cliffs: Prentice-Hall.
Collins
1987 *Collins COBUILD English Language Dictionary.* London: Collins.
Davis, Gordon B., and Margrethe H. Olson.
1985 *Management Information Systems: Conceptual Foundations, Structure, and Development: Second Edition.* New York: McGrawHill.
Dietz, J.L.G.
1992 *Leerboek Informatiekundige Analyse*. Deventer: Kluwer Bedrijfswetenschappen.
1996 *Introductie tot DEMO: Van informatietechnologie naar organisatietechnologie*. Alphen a/d Rijn: Samsom.
Dawkins, Richard
1976 *The Selfish Gene*. Oxford: Oxford University Press. (Edition 1989)
Dorta, Tomas V.
1999 'Entendiento la realidad virtual.', *Arquitectura Digital*, no 7, Septiembre de 1999, pp. 50-53.
D'Souza, Desmond F., and Alan Cameron Wills.
1999 *Objects, Components, and Frameworks with UML: The Catalysis Approach*. Reading, MA: Addison-Wesley.
Eco, Umberto
1990 *The Limits of Interpretation*. Bloomington: Indiana University Press.
Fayol, Henri
1916/1956 'Administration, industrielle et générale.', Extrait du *Bulletin de la Société de l'Industie Minérale*, 3e livraison de 1916. Quarantième Mille, Dunod, Paris, 1956.
Fowler, Martin
1997 *Analysis Patterns: Reusable Object Models*. Menlo Park, CA: Addison-Wesley.
Gamma, Erich, Richard Helm, Ralph Johnsson, and John Vlissides
1995 *Design Patterns: Elements of Reusable Object-Oriented Software*. Reading, MA: Addison-Wesley.
Garson, Barbara
1988 *The Electronic Sweatshop: How Computers Are Transforming the Office of the Future into the Factory of the Past.* New York: Simon and Schuster.
Gazendam, Henk W.M.
1993 *Variety Controls Variety: On the Use of Organization Theories in Information Management*. Groningen: Wolters-Noordhoff.
1997 *Voorbij de dwang van de techniek: Naar een pluriforme bestuurlijke informatiekunde*, Rede uitgesproken bij de aanvaarding van het ambt van hoogleraar Bestuurlijke Informatiekunde voor de Publieke Sector, in het bijzonder Financiële Informatiesystemen, 16 oktober 1997. Universiteit Twente, Enschede.
1999 'Types of Virtual Organization.', *Conference at the Faculty of Economics, University of Buenos Aires, Argentina, 1 November, 1999*. Buenos Aires: Instituto de Investigaciones Administrativas. 5 pp.
Gazendam, H.W.M., and V.M.F. Homburg
1996 'Emergence of Multi-Actor Systems: Aspects of Coordination, Legitimacy and Information Management.', *Proceedings of the COST A3 Conference 'Management and New Technologies', Madrid, June 12-14, 1996*. Office for Official Publications of the European Communities, Luxembourg: 323-327.
Gazendam, Henk W.M., and René J.Jorna
1993 'Theories about architecture and performance of multi-agent systems.', *Paper presented at the III European Congress of Psychology,* Tampere, Finland, July 4-9.
1998 'Semiotics, multi-agent systems and organizations*.', Proceedings of the Joint Conference on the Science and Technology of Intelligent Systems, September 14-17, 1998, Gaithersburg, MD, USA*. IEEE, Piscataway NJ: 84-89.
Gazendam, Henk W.M., René J.Jorna, and Kenneth R. Blochowiak

1991 'The Mind Metaphor for Decision Support Systems.' In: A.A.Verrijn-Stuart, H.G.Sol, and P.Hammersley (eds.). *Support Functionality in the Office Environment.* Amsterdam: Elsevier (North -Holland) / IFIP: 203-223.
Gibson, James Jerome
1979 *The Ecological Approach to Visual Perception*. Boston: Houghton Mifflin.
Giddens, Anthony
1984 *The Constitution of Society*. Berkeley, CA: University of California Press.
Giuliano, V.E.
1982 'The Mechanization of Office Work.', *Scientific American*, 247, no. 3, September 1982: 125-134.
Goldberg, Adele, and David Robson
1983 *Smalltalk-80: TheLanguage and its Implementation.* Reading, MA: Addison-Wesley.
Goldberg, D.E.
1989 *Genetic Algorithms in Search, Optimization, and Machine Learning.* Reading, MA: Addison-Wesley.
Hacking, Ian
1999 *The Social Construction of What?* Cambridge, MA: Harvard University Press.
Hägerstrand, T.
1975 'Space, time, and human conditions.', in: Karlqvist, A., *Dynamic Allocation in Urban Space*. Saxon House, Farnborough.
Hagel, John, and Marc Singer
1999 'Unbundling the Corporation', *Harvard Business Review*, March-April 1999: 133-141.
Hausman, C.R.
1993 *Charles S. Peirce's Evolutionary Philosophy*, Cambridge University Press, Cambridge.
Holland, John H.
1995 *Hidden Order: How Adaptation Builds Complexity*. Reading, MA: Addison-Wesley.
Holland, J.H., K.J.Holyoak, R.E.Nisbett, and P.R.Thagard.
1986 *Induction: Processes of inference, learning, and discovery.* Cambridge, MA: The MIT Press.
Homburg, Vincent M.F.
1999 *The Political Economy of Information Management: A Theoretical and Empirical Analysis of Decision Making regarding Interorganizational Information Systems*. Capelle a/d IJssel: Labyrinth.
IBM
1984 'Business Systems Planning.', *Unpublished Method Handbook.*
Jackson, Michael
1983 *System Development.* Englewood Cliffs, NJ: Prentice-Hall.
Jackson, Philip C.
1985 *Introduction to Artificial Intelligence.* New York: Dover Publications.
Jacobson, Ivar, Grady Booch, and James Rumbaugh
1999 *The Unified Software Development Process*. Reading, MA: Addison-Wesley.
Jacobson, Ivar, Maria Ericsson, Agneta Jacobson.
1994 *The Object Advantage: Business Process Reengineering with Object Technology*. Wokingham, England: Addison-Wesley.
Jong, W.M. de, and H.W.M.Gazendam
1991 'Blauwdruk of bestemmingsplan: Hoe ver moet informatieplanning reiken?', *Informatie*, 33 (1991): 141-220.
Kastelein, J.
1985 *Modulair organiseren doorgelicht.* (A review of modular organization.) Groningen: Wolters-Noordhoff.
Kendall, Julie E., and Kenneth E. Kendall
1993 'Metaphors and Methodologies: Living Beyond the Systems Machine.', *MIS Quarterly*, June 1993: 149-171.
Klein, Michel, and Leif B. Methlie
1990 *Expert Systems: A Decision Support Approach: With Applications in management and finance.* Wokingham: Addison-Wesley.
Koningsberger, V.J.
1962 *Inleiding tot de plantenphysiologie.* (Introduction to plant physiology.) Amsterdam: Scheltema en Holkema.
Lucas, Henry C.
1986 *Information Systems Concepts for Management: Third Edition.* New York: McGrawHill.

Lundeberg, M., G.Goldkühl en A.Nilsson
1982 *De ISAC-methodiek: Systeemontwikkeling volgens ISAC.* (The ISAC method: System development according to ISAC.) Alphen a/d Rijn: Samsom.
Martin, James
1982 *Strategic Data Planning Methodologies.* Englewood Cliffs, NJ: Prentice Hall.
1983 *Managing the Data Base Environment.* Englewood Cliffs, NJ: Prentice Hall.
Minsky, Marvin
1985 *The Society of Mind.* New York: Simon and Schuster.
Morgan, Gareth
1986 *Images of Organization.* Beverly Hills: SAGE.
Mowshowitz, A.
1994 'Virtual Organization: A vision of management in the information age.', *The Information Society*, vol. 10, no. 4: 267-288.
Newell, Allen
1990 *Unified Theories of Cognition: The William James Lectures, 1987.* Cambridge, MA: Harvard University Press.
Newell, Allen., and Herbert .A.Simon.
1972 *Human Problem Solving*. Englewood Cliffs, NJ: Prentice-Hall.
Oxford
1977 *The Concise Oxford Dictionary of Current English: Sixth Edition.* London: Book Club Associates.
Rheingold, Howard
1991 *Virtual Reality*. London: Mandarin.
Ritzer, George
1996 *The McDonaldization of Society: An Investigation into the Changing Character of Contemporary Social Life: Revised Edition*. Thousand Oaks, CA: Pine Forge Press.
Rumbaugh, James, Grady Booch, and Ivar Jacobson
1999 *The Unified Modeling Language Reference Manual*. Reading, MA: Addison-Wesley.
Schmidt, K.
1991 'Cooperative Work: A Conceptual Framework.', In: Rasmussen, J., Brehmer, B., Leplat, J. (eds.), *Distributed Decision Making: Cognitive Models for Cooperative Work*, John Wiley and Sons, Chicester: 75-110.
Sprague, Ralph H., and E.D.Carlson.
1982 *Building effective decision support systems.* Englewood Cliffs, NJ: Prentice Hall.
Sprague, Ralph H., and Barbara C. McNurlin.
1986 *Information Systems Management in Practice.* Englewood Cliffs: Prentice Hall.
Stamper, Ronald
1973 *Information in Business and Administrative Systems.* New York: Wiley.
2001 'Organisational Semiotics: Informatics without the computer', In: In: Kecheng Liu. Rodney J. Clarke, Peter Bøgh Andersen, and Ronald K. Stamper (eds.). *Information, Organisation and Technology: Studies in Organisational Semiotics.* Boston: Kluwer Academic Publishers: 115-171.
Stern, Josef
2000 *Metaphor in Context*. Cambridge, MA: The MIT Press.
Sutherland, Ivan E.
1965 'The Ultimate Display', In: W.A. Kalenich (ed.), *Information Processing 1965: Proceedings IFIP Congress 1965, Vol. 2,* Spartan Books, Washington, D.C., and Macmillan, New York: 506-508.
Theeuwes, J.A.M.
1986 'Voorzien van informatie: Modellen voor informatiebeleidsvorming en informatieplanning.' (Providing information: Models for information policy development and information planning.), *Unpublished PhD Thesis*, Eindhoven: Technische Hogeschool Eindhoven.
Uexküll, Jakob von, und Georg Kriszat
1936 *Streifzüge durch die Umwelten von Tieren und Menschen*. Berlin: Springer. Neuausgabe Frankfurt;: Fischer, 1970.
Valens, J.
1994 'Organisatica', *Syllabus Faculteit Bedrijfskunde*. Groningen: Faculteit Bedrijfskunde Rijksuniversiteit Groningen.
Ward, Mark
1999 *Virtual Organisms*. London: Macmillan.

Young, Lawrence F.
1987 ‘The metaphor machine: A database method for creativity support.’, *Decision Support Systems*, 3: 309-317.

Webster
1980 *Webster's New Collegiate Dictionary.* Springfield, MA: Merriam-Webster.