HANDLING THE VARIABILITY OF INFORMATION PROCESSING IN COMPLEX SYSTEMS: AN INFORMATION SYSTEMS DESIGN PERSPECTIVE

Roberto R. Kampfner
Computer and Information Science Department
College of Computer and Information Science
The University of Michigan-Dearborn

Abstract

The variability of the dynamics of a system introduces variability in the way in which information needs to be processed. Complex adaptive systems such as modern organizations usually include computer-based processes as part of the information processing aspect of their dynamics. According to an adaptability-programmability tradeoff (Conrad, 1985), however, despite the tremendous speed, capacity, accuracy, and communication capabilities of digital computers digital computing faces important challenges, especially when it comes to the support of unstructured processes or of processes where the variability of information processing is high.

In this paper we discuss an approach to handling the variability of information processing in a system as goal of the design of computer-based information systems. We use the view of information processing as an aspect of the dynamics of systems as a means of identifying the requirements that the dynamics imposes on the way in which information needs to be processed. Our approach considers the analysis of the degree of structure of the processes that participate in the dynamics, the uncertainty of the changes occurring in these processes, and the computational and adaptability properties of the processors available in the system. Central to our approach is finding a combination of digital computing, human intelligence, and other forms of information processing on whose basis a computer-based information system that effective supports the functions of the system and contributes to its adaptability can be designed. A function support principle of design and the adaptability-programmability tradeoff provide the necessary guidance.

Keywords: computer-based information systems, variability of information processing, dynamics of systems, human intelligence, biological information processing, uncertainty of behavior.

INTRODUCTION

Information processing can be considered an aspect of the dynamics of systems (Kampfner, 1998). Any system needs to process information in order to perform its functions and thus achieve its goals and accomplish its mission. The information processing aspect of the dynamics of a system can be considered the particular way in which the processes that perform its functions process the information they need. In biological systems information processing has evolved as an integral part of the dynamics underlying their functions. The biological evolutionary process has indeed made biological information processing highly compatible with the processes with which jointly performs these functions. The compatibility of biological information processing with the functions it supports is, in my opinion, what makes it so effective. In systems such as modern organizations, on the other hand, information is processed in a manner that is greatly influenced by human design. This is especially true in the case of computer-based information processing. A consequence of this is that the effectiveness of the support that computer-based information systems provides to the functions of a system cannot be taken for granted. Rather, it must be the result of careful design. In this paper we focus on principles and criteria that help the designers of computer-based information systems to handle properly the variability of information processing that exists in the system being supported.

One of the problems that must be properly handled by the designers of computer-based information systems in order to achieve the compatibility that is needed for the effective support of function is the variability of information processing that usually exists in complex systems such as modern organizations. In this paper we discuss the challenge that the variability of information processing represents to the design of computer-based information systems that provide effective function support and contribute to adaptability. We show that taking into account the variability of information processing is crucial to many important design decisions including the allocation of information processing functions to computers and to people, architecture design, process design, and the design of the user interface. We discuss and extend previously stated principles for the design of computer-based information systems that help to make such decisions in a manner consistent with the effective support of function and the adaptability of the system as a whole.

The way in which a system processes the information it needs is necessarily influenced by the dynamics of which information processing forms a part. In Section 2 I briefly discuss the idea of information processing as an aspect of the dynamics of systems and the framework that it provides for the analysis and design of computer-based information systems. In Section 3 I discuss the variability of information processing in complex systems. This characteristic of the dynamics of a system may have a significant effect on the way in which it processes information. As the variability of information processing increases in a system, the number of ways in which the information needs to be processed increases as well and so do the cost and complexity of information processing. By the variability of information processing we mean here the frequency, magnitude, and uncertainty of the changes that occur in the way in which the system processes information. The uncertainty of the changes in the way in which information needs to be processed imposes demands on the adaptability of the system. Essentially, to be adaptable a system needs to have a potential uncertainty of behavior at least as large as the potential uncertainty of behavior of its environment. Because information processing is an aspect of the behavior (i.e. dynamics) of a system, it must meet the requirements imposed by the variability of this dynamics. This is necessary in order for the information processing capabilities of the system to be sufficient for the effective support of its functions and its adaptability.

In complex systems such as modern organizations computer-based information processing becomes part of the information processing aspect of the dynamics. For this reason, a computer-based information system must be designed taking into account the role it plays in the dynamics as well its contribution to meeting its information processing requirements, including those imposed by the variability of information processing. Section 4 focuses on design principles and criteria that help to handle the variability of information processing of the system in a manner consistent with the effective support of function and its adaptability. The function support design principle calls for the compatibility needed for the effective support of function and adaptability. Conrad's adaptability-programmability tradeoff helps to capitalize on the tremendous speed and accuracy of digital computing in a manner consistent with the adaptability of the system as a whole. Section 5 discusses the application of the function support design principle and the adaptability-programmability tradeoff to the design of computer-based information systems. The focus is on design decisions that are particularly relevant from the standpoint of handling the variability of information processing such as those involving the allocation of information processing functions to digital computers and to humans and other types of information processors available in the system; other relevant design decisions involve the design of computer-based processes, and the design of the user interface. Section 6 presents a summary and some conclusions.

INFORMATION PROCESSING AND THE DYNAMICS OF SYSTEMS

By the dynamics of a system we mean the processes that perform its functions. As an aspect of its dynamics, information processing represents the ability of a system to provide the processes that perform its functions with the information they need. The idea is that any process that achieves a specific purpose needs to have an information processing aspect that allows it to perform and coordinate its parts or component processes in order to achieve such purpose. This notion of information processing is indeed very broad. It applies not only to the processing of information that is done consciously by the human brain. It encompasses also the information processing that in done by any system, natural or artificial, as part of its dynamics, including the information processing done by biological systems as part of their dynamics, by digital computers following pre-specified algorithms, and by analog computers based on the properties of electrical circuits. As an aspect of the dynamics, information processing is concomitant with the processes that perform the functions of a system. In order to perform its functions correctly, however, a system must process information in an appropriate manner. Biological information processing, in particular, is a very effective form of information processing. It supports the functions of biological systems in a highly effective manner. The effectiveness of biological information processing is in my opinion possible because it is highly compatible with the processes that perform the functions it supports (Kampfner, 1997, 2002). In fact, a basic, biologically motivated design principle stated earlier (Kampfner, 1997, 2002) asserts that in order for the support it provides to be effective, a computer-based information system must be compatible with the dynamics of the system it supports and with its adaptability. In this paper we review the essentials of this principle, referred to here as the function support principle, and discuss its application as a guide for handling the variability of information processing. The compatibility of biological information processing with the functions it supports becomes clearly apparent when we see the effectiveness with which biological systems perform all of their functions. This includes regulatory, genetic, metabolic, and communication functions at the cell, organ, and organism levels, as well as functions at the population and ecosystem levels. Clearly, none of these functions could be performed effectively without the appropriate kind of information processing.

The view of information processing as an aspect of the dynamics of systems allows us to study it in the context of the dynamics in which it occurs. This view helps us to understand better how the processes that perform the functions of a system use and produce information and interact and communicate with each other in a manner that allows for the control and coordination of the functions they perform. As an aspect of its dynamics, information processing is the specific way in which such a particular system processes the information it needs in order to perform its functions. A basic assumption of this notion of information processing is that any system must be able to receive, store, transform, and communicate the information it needs in order perform its functions. In other words, the assumption is that the basic information processing capabilities mentioned above (i.e. to receive, store, transform, and communicate information) must be an integral part of the processes that perform the functions of any dynamic system. These information processing capabilities allow for these processes to be performed and to communicate and interact with other processes. This in turn allows the system as a whole to execute, control, and coordinate the processes that perform its functions, and to communicate and interact with other systems.

Handling the Variability of Information Processing

Biological systems are able to perform their functions and persist on the face of an uncertain environment. In other words, they are adaptive. The adaptability of biological systems exists at all levels, including the level of the global ecosystem. In the adaptive processes that underlie biological evolution the changes occurring in individual organisms give rise to new species or significantly modify the capabilities of existing ones. At each level of biological organization, including the levels of cells, organisms, populations, and communities, biological systems adapt to the uncertainty of the environment. This is also true for biological information processing which, as an aspect of their dynamics, has evolved with the functions it supports. Biological information processing is clearly compatible with the other processes with which it jointly performs the functions it supports. In other words, it is compatible with the dynamics underlying these functions. This compatibility has in fact helped biological systems to pass the test of natural selection,

Computer-based information systems in modern organizations can also be understood as an aspect of their dynamics. The dynamics of modern organizations, however, is a complex mix of natural and artificial processes. The natural part is biological in nature and its most important manifestation is human intelligence. Because of its adaptive nature, human intelligence is capable of adapting to changes in the information processing requirements of the functions it supports whenever this is within its range of adaptability. It does so through an adaptive process that makes use of its capabilities of learning, training, problem solving and creativity. The artificial part of the information processing aspect of organizations, on the other hand, mostly provided by digital computers, is inherently programmable and, for this reason, it is not adaptable (Conrad, 1985). A consequence of the programmability of digital computing is that the computer programs that support functions with variability of information processing need to be changed as the information processing required for the support of the functions changes. The number, magnitude, and uncertainty of the changes that a computer-based information system needs to undergo tend to increase with the variability of information processing. Because of their inherent programmability (and the lack of adaptability that it implies) the potential contribution of a computer-based information system to the adaptability of the system it supports is more difficult to achieve as the variability of information processing in this system increases. The function support design principle guides us toward the achievement of the compatibility of information processing with the dynamics that is needed for the effective support of function. In the remainder of this paper, we will discuss in more detail the application of the design principle as a means of handling the variability of information processing.

As an aspect of its dynamics, information processing represents the way in which a system obtains, produces, and transforms information and makes it available to the processes that perform its functions. Notice that the processes that obtain, produce, and transform information in a system are not necessarily distinct from the processes that use the information. In some cases, however, some processes can be said to provide other processes with some of the information they need. Notice also that the information processing aspect of the dynamics of a system is necessarily influenced by the characteristics of the dynamics of which it forms a part.

THE NEED TO COPE WITH THE VARIABILITY OF INFORMATION PROCESSING

A characteristic of the dynamics that exerts a great influence on its information processing aspect is its variability. The variability of a dynamics imposes demands on its information processing aspect because the latter must be capable of supporting this variability in an effective manner. In this section we will consider the variability of the dynamics of a system and the effect it has on the variability of information processing. We consider the variety of the changes that may occur in this dynamics, the frequency with which they occur, and the predictability of these changes. All of them contribute to the variability of information processing. The variability of information processing in modern organizations and how the function support principle of information systems design helps tackle it is of special interest to us. Before dealing with that, however, let us briefly consider the variability of the dynamics of biological systems and how biological information processing handles it.

Biological information processing takes advantage of the specificity, variability and conformational capabilities of macromolecular structures such as nucleic acids and protein enzymes. These properties of the macromolecular basis of biological information processing are critical to its ability to provide the variability needed by biological systems in order to cope with the uncertainty of the environment. The immune system of organisms, for example, depends highly on the variability of biological information processing in order to cope with an enormous and highly uncertain variety of viruses and bacteria in a highly effective manner. Clearly, the macromolecular basis of biological information processing allows for the variability that it needs in order to support effectively the functions of the immune system. The ability of biological information processing to support the functions that biological organisms perform as they grow, develop, reproduce, and survive in highly uncertain environments can be illustrated in a variety of situations. High-level organisms such as humans need to cope with environmental changes that occur very frequently. This is the case when they need to interact with other organisms in a very dynamic fashion. In addition to that, biological organisms usually need to cope with highly uncertain environments. This happens, for example, when they are exposed to not previously experienced diseases or other unexpected environmental conditions. Biological information processing clearly helps biological systems to cope with the uncertainty of the environment they face.

A discussion of the foundations of biological information processing and of its ability to support the variability of the dynamics of biological systems is beyond the scope of this paper. We will, however, refer to some characteristics of biological information processing that are essential to its ability to provide effective support to biological function and adaptability. Two of these characteristics are subsumed in the biologically motivated design principle mentioned earlier: the first one is the compatibility of information processing with the functions it supports; the second one is its contribution to the adaptability of the system as a whole. These characteristics of biological information processing, especially in its manifestation in the form of human intelligence, are essential to the ability of complex systems such as modern organizations to handle the variability of information processing that is needed for the effective support of function and adaptability. A suitable combination of human intelligence and digital computing is clearly needed in order to handle the variability of information processing in a manner consistent with the effective support of function and adaptability. Our biologically motivated principle for the design of computer-based information systems helps us to achieve that.

DESIGN PRINCIPLES AND CRITERIA THAT HELP TO COPE WITH THE VARIABILITY OF INFORMATION PROCESSING

Michael Conrad's adaptability-programmability tradeoff provides a basis on which the challenge of coping with the variability of information processing can be met. The adaptability-programmability tradeoff means that the adaptability and computational efficiency of information processing are always obtained at the expense of structural programmability, and vice versa (Conrad, 1985). It is easy to see that biological information processing (including the use of human intelligence) is in the adaptability and computational efficiency side of this tradeoff; digital computing, on the other hand, is clearly in the programmability side. Taking into account the adaptability-programmability tradeoff clearly helps us to find a combination of biological information processing and digital computing capable of handling the variability of information processing in a manner consistent with the adaptability of the system a whole. Doing so in the context of the design principle mentioned above (see also Kampfner, 1987, 1997) further allows us to cope with the variability of information processing in a manner consistent with the effective support of function and adaptability. More specifically, in the context of the design principle the adaptability-programmability tradeoff helps us to find a combination of biological information processing and digital computing that allows us to handle the variability of information processing in a manner consistent with the adaptability of the system. It should be noticed however that although biological information processing includes human intelligence, which is by far its most important manifestation in modern organizations, it also may include other forms of biological computing.

According to the function support design principle the compatibility of a computer-based information system with the dynamics of the functions it supports and with the adaptability of the system as a whole is essential to its effectiveness. In complex systems such as modern organizations, the variability of the dynamics that is needed in order to cope with the complexity and the uncertainty of the environment is frequently high. This entails a correspondingly high variability of the information processing aspect of this dynamics. Any computer-based information system that supports the functions of a system becomes an integral part of the information processing aspect of its dynamics. As we know, in order to provide effective function support its design must be compatible with all the aspects of the dynamics of which it forms a part, including the information processing aspect. Achieving this compatibility amounts to obtaining a combination of digital computing, human intelligence, and possibly other forms of biological information processing that allows for the effective support of function and adaptability. Such a combination of digital and biological computing must also be able to handle effectively the variability of information processing, which in turn requires that the information processing tasks be allocated to computers, to human intelligence, and to other biological processors taking into account the adaptability, programmability, speed and capacity of each of these types of information processors. As explained below, the adaptability-programmability tradeoff clearly provides a solid basis on which such a suitable combination of digital and biological computing can be found.

The enormous speed and capacity of digital computers make them an incredibly powerful tool for handling information processing tasks that are sufficiently structured to be specified in the form of computer programs. In addition to that, the astounding advances in information technology continue to expand the ways in which computer-based information systems can be distributed, embedded into a variety of other systems, communicate between them, and exchange information between them and their users. A consequence of this is that computer-based information systems can be used in the support of an increasing variety of functions in complex systems such as modern organizations. An important caveat is that because of the adaptability-programmability tradeoff, the programmability of digital computing makes them less adaptable and, consequently, less capable of contributing by themselves to the adaptability of the systems they support.

The inability to contribute to adaptability that the programmability of digital computing causes becomes more apparent when the variability of information processing increases.

Handling the Variability of Information Processing

The effective support of function and the contribution to adaptability that the design principle demands, however, can still be achieved in these situations. What we need to do is to apply the design principle in a manner that takes advantage of the adaptability-programmability tradeoff. In the face of high variability of information processing, the allocation of information processing tasks to digital and to biological computing becomes a critical design decision, one that must result in a suitable combination of digital and biological computing. We can apply the design principle in a manner that takes advantage of the adaptability-programmability tradeoff by combining digital computing, biological computing (which includes human intelligence as its most important manifestation), and other forms of information processing available in the system in a synergistic manner.

Because of the adaptability-programmability tradeoff, the information processing tasks that have greater variability of information processing should be assigned to human intelligence and possibly to other forms of biological information processing, as appropriate. The more structured, less changing information processing tasks, on the other hand, should be assigned to the computer-based information system. The allocation of information processing tasks to human intelligence, digital computers, and to other kinds of processors available, however, should be done in a manner in which both a good contribution to the adaptability of the system as a whole and the effective support of function are achieved. As the function support design principle asserts, this requires the compatibility of the computer-based information system with the dynamics of the functions it supports and with the adaptability of the system as a whole.

Essentially, a computer-based information system is compatible with the dynamics of the functions it supports if it provides these functions with information they need in order to achieve their goals. But since the computer-based information system is just a part of the information processing aspect of the dynamics, this must be done in a manner consistent with the whole of the dynamics. More precisely, since the dynamics of a system is made by the processes that perform its functions, we can see that the compatibility of the computer-based information system with the functions it supports is in fact the compatibility between the processes that the computer-based information system provides and all the other processes that perform these functions, including of course other processes that participate in the information processing aspect. We can also say, in a simple, informal way, that a computer-based information system is compatible with the functions it supports if it provides the other processes that perform these functions with the information they need, at the time they need it and in the form they need it. According to the function support design principle, this has to be done in a manner that is compatible with the adaptability of the system as a whole.

The allocation of information processing tasks to the various types of processors available in the system is a fundamental design decision that determines basic characteristics of the computer-based information system such as its boundaries, the information that will be exchanged through the user interface, the processes that will interact through this interface and the nature of the interactions involved. The characteristics of the computer-based information system that this decision determines are essential to its ability to handle the variability of information processing in a manner consistent with the effective support of function and adaptability. In order for these goals to be ultimately achieved, however, the rest of the design must be completed. This includes the design and implementation of an architecture that properly incorporates the allocated processes, their interfaces and interactions, as well as the detailed design and implementation of the processes and the user interface.

IMPLICATIONS FOR THE DESIGN OF COMPUTER-BASED INFORMATION SYSTEMS

In previous sections we discussed the problem of handling the variability of information processing in complex systems such as modern organizations and the challenges it represents for the designers of computer-based information systems. We found that in order to meet this challenge the designers of the computer-based information system must allocate the information processing tasks to humans and to machines in a manner that takes advantage of the computational capabilities and adaptability properties of each of these computing domains. In this section we consider in more detail this decision in the context of information systems design. The function support principle sets the achievement of effective function support and adaptability as the basic, underlying goal of information systems design. The allocation of information processing tasks to humans and machines in a manner consistent with this goal can then be accomplished taking into account the adaptability-programmability tradeoff.

More specifically, the function support principle calls for the compatibility of the computer-based information system with the structure and the dynamics of the system it supports in order for the support it provides to be effective. Briefly, the compatibility with the structure requires for the support of each function to be appropriate to its type and to its level in the function hierarchy. The compatibility with the dynamics, on the other hand, requires for the processes that the computer-based information system performs to provide the other processes that perform the functions with the information they need. It must be noticed that the compatibility of the information system with the structure of the system it supports and its compatibility with the dynamics are closely interrelated with each other. We distinguish between these two kinds of compatibility because the influence that the structure of a system always has on its dynamics becomes more apparent with this distinction.

The compatibility of a proposed design with the structure and the dynamics of the system being supported cannot be assessed without an adequate representation of such a structure and dynamics. The organizational control systems modeling formalism, or OCSM, (Kampfner, 1987, 2002) provides a means for such a representation. We also need a method that allows us assess the compatibility and contribution to adaptability of a proposed design as the information system design process proceeds. The abstraction-synthesis methodology (ASM) of information system development (Kampfner, 1987, 1997) provides such a method. The ASM uses the OCSM for the representation of the structure and dynamics of the system to be supported by the information system. In the remainder of this section we will describe some essential features of the OCSM representation, then we will describe the contribution that the ASM as a means of capitalizing on the view of information processing as an aspect of the dynamics of systems and on the description of the structure and the dynamics of the system that the OCSM provides.

The OCSM allows us to represent the structure and dynamics of adaptive systems in a manner that helps to determine and analyze the information needs of their functions. Because of the hierarchical, compartmental form of the representation it provides, the OCSM also helps to analyze the adaptability of the system it models. The OCSM models the structure of an adaptive system in terms of the functions it performs, some of which are adaptive, and the relationship that exists between them. A simplified system S with a control subsystem S_0 and two functional subsystems, S_1 and S_2 is shown in Figure 1. Because of the hierarchical nature of systems, the structure of a particular function includes the relationships between the smaller functions that it contains. Notice also that in the OCSM a function represents the functional subsystem that achieves the same goals as the function does. This applies both to adaptive and non-adaptive functions (or subsystems). We define an adaptive function (or subsystem) as one that achieves its goals while facing an uncertain environment. In order to succeed in an uncertain environment, and adaptive function (or functional subsystem) must have some degree of self-control. The self-control capabilities of a functional subsystem are represented in the OCSM by its control subsystem. The control subsystem of a functional subsystem is responsible for monitoring the performance of its operational siblings, that is, the operational subsystems of its parent system, and coordinating their actions so that they together achieve the goals of their common parent, that is, the functional subsystem that has self-control capabilities. The highest-level function of an adaptive system, which must be an adaptive function, is the function that the whole system performs. The other functions may or may not be adaptive. The functions that are not adaptive occur usually at the lowest levels of the function hierarchy. Clearly, the non-adaptive functions of a system do not have a control subsystem and therefore, they do not have self-control capabilities; they cannot change in response to changes occurring in their environment. In an adaptive system, these non-adaptive functions will be used by other, higher-level adaptive functions but only when the specific goals that they achieve need to achieved as sub goals of the system as a whole.

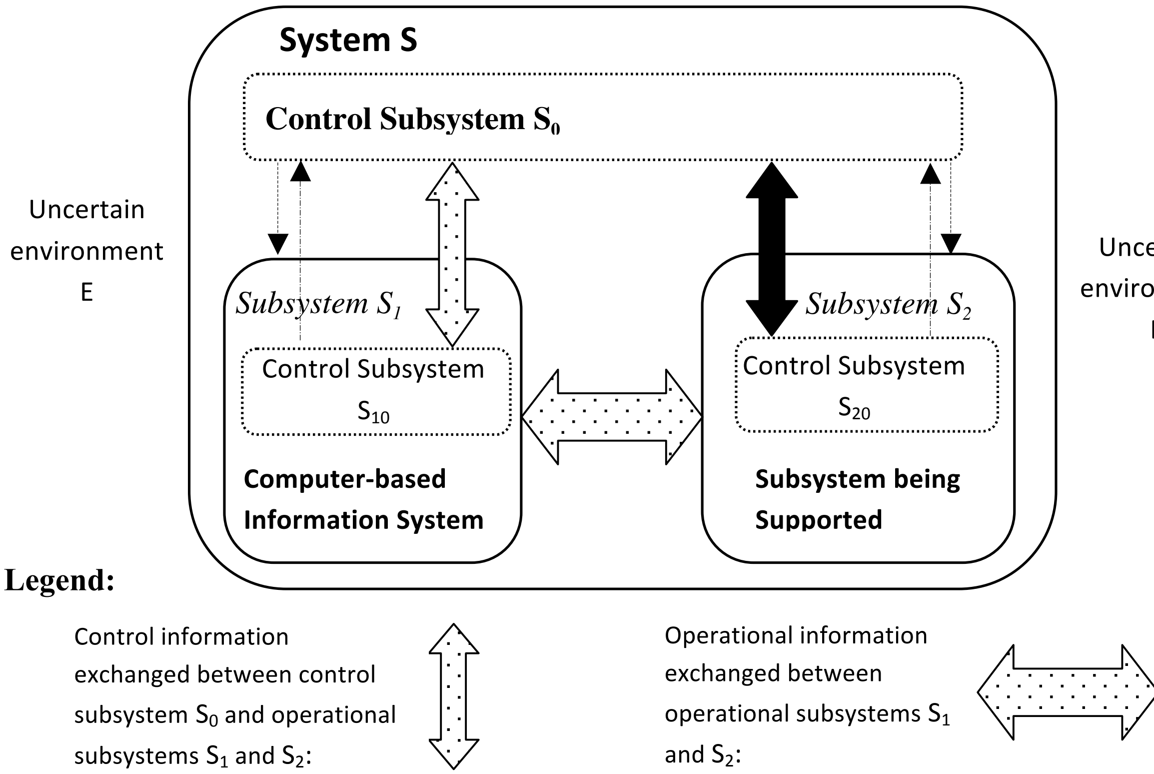

Figure 1 A hierarchy diagram that shows the structure and dynamics of a simplified system **S** that contains 3 subsystems: S_0, S_1, and S_2. The diagram follows the OCSM modeling formalism (Kampfner, 1987). Subsystem S_0 is a control subsystem that monitors the performance of the operational subsystems S_1 and S_2 towards the achievement of the goals of their parent system **S**. The operational subsystems may be adaptive and consequently they may have a control subsystem. The dynamics, implied by the structure, is described more explicitly using the informational interaction diagrams. Only a general view of the information processing aspect of the dynamics is shown here.

The OCSM models the dynamics of a system in terms of the processes that perform its functions. This dynamics is manifested through the execution of these processes and the interactions that they have with each other and with the external environment. The dynamics of adaptive systems can be considered as having some degree of self-control. This means that some of the changes that need to occur in the processes that perform the functions of an adaptive system originate within the changing processes themselves. Many of the changes occurring in the processes that perform the functions of an adaptive system may be imposed on them by external agents. A function, or functional subsystem, of a system, however, can be considered as having self-controlling capabilities whenever the changes that occur in the processes that perform such function are produced by processes that belong to the set of processes in which the change occurs. Notice that the changes that occur in the processes that perform the functions of a system can be considered part of the dynamics (albeit a slower part of the dynamics) in which these processes participate. An adaptable, slower part of the dynamics is clearly essential for the evolution and adaptability of systems.

The changes that affect the dynamics of a system necessarily change its information processing aspect, that is, the way in which it processes information. The OCSM allows for the representation of the relationship between the functions of a system and the processes that perform them. This relationship also applies to the information processing aspect of the dynamics in which these processes participate. When a computer-based information system is introduced in an organization, the computer-based processes that it provides become part of the processes that perform the functions of the system. This means that the processes that the computer-based information system provides become part of the processes that perform the functions they support and, consequently, that the relationship between the functions of a system and the processes that perform them that the OCSM representation makes explicit applies also to the functions being supported and processes that a computer-based information system provides for their support. Moreover, the relationship between the functions of a system and the computer-based processes that participate in their performance that the OCSM description makes explicit can be easily extended to a similar relationship between these functions and the modules and computer programs that specify the processes and the functions that these processes support.

By allowing for the representation of the relationship between the functions of a system, and the information processing processes that perform these functions, the OCSM representation facilitates the design of computer-based processes that are compatible with the structure and the dynamics underlying the functions they support. The view of information processing as an aspect of the dynamics of systems is extremely helpful in this respect. The reason is that it allows us to describe information processing in terms akin to the processes in which it occurs, which further helps us to understand the information processing needs and capabilities of these processes and the impact that the computer-based processes would have on the adaptability of the system. The abstraction-synthesis methodology (ASM) capitalizes on the advantages that the OCSM representation and the view of information processing as an aspect of the dynamics provide for the analysis and design of computer-based information systems. The ASM provides guidelines for the analysis of the information needs of functions, the requirements fo the computer-based information system, and the design of the architecture, the computer-based processes, and the interactions between them and with the other processes that perform the functions they support. The ASM, on the basis of the OCSM description of a system and with the view of information processing as an aspect of the dynamics guides us in the achievement of the compatibility of information processing that is needed for the effective support of function and adaptability. Moreover, this can be done in a manner that helps the designers of computer-based information systems to cope with the variability of information processing.

SUMMARY AND CONCLUSIONS

The variability of the dynamics of a system, that is, the existence of frequent and unpredictable changes in the processes that perform its functions, makes the information processing aspect of this dynamics variable as well. Complex adaptive systems such as modern organizations increasingly include computer-based processes as part of the information processing aspect of their dynamics. According to the adaptability-programmability tradeoff, however, digital computing faces important challenges despite the tremendous speed, capacity, accuracy, and communication capabilities of digital computers. This challenge is greater when it comes to the support of processes where the variability of information processing is high, which normally happens when the processes of the system are unstructured and face uncertain environments.

In this paper we discussed an approach to handle the variability of information processing in a system as goal for the design of its computer-based support. Central to this approach is finding a combination of digital computing, human intelligence, and other forms of information processing as a basis for the design of a computer-based information system that provides effective support the functions of the system and contributes to its adaptability.

We found the view of information processing as an aspect of the dynamics of systems extremely valuable for the study of the information processing needed by the dynamics. Also of great value is the guidance provided by the function support design principle and by M. Conrad's adaptability-programmability tradeoff.

REFERENCES

Conrad, M. *Adaptability*, New York: Plenum Press, 1983.

Conrad, M. "On design principles for a molecular computer," in Communications of the ACM, 28, 464-480, 1985.

Gorry, G. A., and M. S. Scott Morton. "A Famework for Management Information Systems." Sloan Management Review 13(1):49-62. 1989.

Kampfner, R. A hierarchical model of organizational control for the analysis of information systems requirements, Inf. Syst. 3(3): 243-254. 1987.

Kampfner, R. "Function Support as an Information Systems Development Paradigm," World Futures, Vol. 50, pp. 689-702, 1997.

Kampfner, R. “Dynamics and Information Processing in Adaptive Systems,” BioSystems, Vol. 46, pp. 153-162, 1998.

Kampfner, R. “Digital and biological computing in organizations,” BioSystems, Vol. 64, pp.179-188, 2002.

Simon, H. A. The New Science of Management Decision. New York: Harper & Row. 1960.