Reasoning About Change in Knowledgeable Office Systems

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ABSTRACT

Managing of and reasoning about dynamic processes is a central aspect of much activity in the office. We present a brief description of our view of office systems and why change is of central importance in the office. A description system used to describe the structure of the office and office activity is discussed. A viewpoint mechanism within the description system is presented and we discuss how this mechanism is used to describe and reason about change in the office.

A general scenario is described in which viewpoints are illustrated as a means of describing change. Previous technologies for accommadating change in knowledge embedding languages are characterized. We contrast the approach using viewpoints with previous technologies where change is propagated by pushing and pulling information between slots of data structures.

I. Introduction

The computer has been used in the office environment for many years with its application mainly limited to highly structured and repetitive tasks in a non-interactive mode. With the ever-decreasing cost of hardware computers can be potentially used in the future to aid office workers in a wider variety of tasks. Indeed, the computer based office system is today seen as both a motivation for achieving a new understanding of office work and as a medium within which to integrate new tools and knowledge into a coherent system. This has led to the realization that there is enormous potential in the use of the computer in the office in novel and as yet unforeseen ways. These new uses will impact the way office work is done in fundamental ways demanding new ideas about how to manage information in an office and a new conceptualization of what office work is in the presence of powerful computational capabilities.

As a step toward developing computer systems that may effectively support office workers in their tasks we employ two paradigms from Artificial Intelligence, those of knowledge embedding and problem solving. We are developing a descriptions system called OMEGA [Hewitt 80] to be used to embed knowledge about the structure of the office and office work in an office system. One of our objectives is to support the problem solving activities of individuals in an office. Much of the problem solving activity within an office concerns reasoning about change. We have developed mechanisms in OMEGA to describe changing situations. In the following section we present a short description of our model of the office. Following this we discuss the importance of change in the office and the mechanism within OMEGA to deal with change. The approach we take is compared with other approaches to the problem of accommodating and managing change.

II. The Knowledgeable Office System

We view an office system in terms of the two dominant structures in the office, the *application structure* and the *organizational structure*. The application structure of an office system concerns the subject domain of the office. It includes the rules and objects that compose the intrinsic functions of a particular office system. As an example, in an office concerned with loans the application structure includes such entities as loan applications, credit ratings and such rules as criteria for accepting or rejecting loans. In an insurance company the application structure is concerned with insurance policies, claims and actuarial tables. The application structure explains the scope of the functionality an office system has on a subject domain as well as providing a model by which those functions are characterized. Overtly, the application structure is the primary reason for the existence of the office system.

In contrast to the application structure is the social structure of the office system as an organization [Katz 78]. Our concern with this aspect of an office system stems from the fact that the activity in the application domain of an office system is realized by people cooperating in a social system. The structure of this social system involves such aspects of an organization as the roles of the individual participants, the interaction of roles, the social norms of the office and the various subsystems that make up the organization. We view the office system as a functioning organism in an environment from which it extracts resources of various kinds and to which it delivers the products of its mechanisms.

OMEGA's descriptions are the fundamental entities upon which the Knowledgeable Office System is based. The emphasis of our approach is on a description manipulation system for embedding knowledge as opposed to a forms manipulation system. Descriptions are used to express the relationships between objects in the Knowledgeable Office System. Descriptions are more fundamental than electronic forms, in particular, electronic forms are a way of viewing descriptions, a visual manifestations of descriptions.

One of the goals of our work is to support office workers in their problem solving activity. Problem solving is a pervasive aspect of office work that has been neglected until recently [Wynn 79, Suchman 79]. Office work is naturally characterized as goal oriented activity. The office procedure is merely a suggested way by which to accomplish a particular goal. We believe that this is one reason why it has proved to be difficult to describe office work from a procedural point of view.

The formalism we are developing allows us to describe and reason about the application and organizational structures of office systems as well as the interaction between these structures. The major benefits of OMEGA with relevance to our discussion here are that a computational system can support problem solving in dynamic environments that are weakly structured, and knowledge rich. OMEGA also provides a precise language within which to characterize the static and dynamic aspects of office systems.

A central problem in an office system is reasoning about and managing change. This is a recurrent theme at several levels of abstractions. Viewing the organization in relation to its environment, the organization must evolve in order to adapt to the changing environment. For example, an accounting office must adapt to new tax laws or an office must adapt to new technology. Viewing the organization as producer of some product, the organization must adjust its production output to the demand for the product which it produces in light of the resources available to the organization and the constraints under which it must operate. The individuals that make up an organization are faced with such tasks as reasoning about processes that have produced anomalous results, maintaining system constraints as the state of the constrained parts change and analyzing the implications of hypothesized processes.

OMEGA has a *viewpoint* mechanism that is used to describe and reason about change. The viewpoint mechanism provides a means to present time varying processes to office workers for analysis, be these processes historical, in progress or postulated. Changing environmental dependencies and changing aspects of the organization can be captured in descriptions using the viewpoint mechanism. In the remainder of this paper we describe OMEGA and its viewpoint mechanism.

IV. The Viewpoint Mechanism

OMEGA is a system with which a structure of descriptions is built. The system is designed to be incremental; new knowledge can be incorporated into the system as it is discovered or as the need for it arises. There is no minimal amount of information needed before the system is usable. The system is monotonic in the sense that nothing is lost when new information is added. As is explained in the following paragraphs, knowledge is relativized to viewpoints, information that is inconsistent with information in a particular viewpoint can be placed in a different viewpoint. This accommodates aspects of non-monotonic systems [McDermott 79]--where new information may invalidate previously held beliefs--without the need for a notion of global consistency.

OMEGA's fundamental rule of inference is *merging*; new descriptions are merged with previous descriptions. Any new deductions as a result of the new information are carried out during the merging operation.

OMEGA is used to build, maintain and reason over a lattice of descriptions. Descriptions are related via an inheritance relation called the **is** relation. The **is** relation is relativized to a viewpoint that indicates the conditions under which the **is** relation holds. Intuitively a viewpoint represents the conditions under which the inheritance relation holds. In this respect it is reminiscent of McCarthy's situational calculus [McCarthy 69] and the contexts of QA4 [Rulifson 72].

A major difference between these approaches and viewpoints is that viewpoints are descriptions and thus are subject to the full descriptive power of OMEGA. Viewpoints may be embedded in structures expressing complex inheritance relationships relating viewpoints to one another. Other aspects of OMEGA include higher order capabilities such as the ability to describe properties like transitivity for relations in the system and meta-description capabilities to talk about the parts of descriptions.

III. Dealing With Change

A key property of viewpoints is that information is only added to them and is never changed. Consider, for example, a description which is the underlying representation of a form. The description is relativized to a viewpoint and information is added to this description increasing its specificity. Descriptions may contain constraints between attributes, as information is added further information may be deduced. Should the information in a field of a form be changed then the following scenario might occur:

1. A new viewpoint is created and described as being a successor to the old viewpoint.

2. All information that was not derived from the changed information is copied to the new viewpoint.

3. The new information is added in the new viewpoint, any deductions resulting from this information are made.

4. The description in the new viewpoint represent the most recent contents of the form.

In this case the new viewpoint inherits all but the changed information and the information deduced from the changed information from the old viewpoint. What actions are taken when information in a viewpoint is changed is specified via meta-descriptions.

Previous approaches to the problem of accommodating changing information have been to perform updates to the data structures in question. System based on property lists such as LISP have used *put* and *get* operations to update and read database information. These have the disadvantage that deductions based on updated information must be handled explicitly leading to unacceptable complexity and modularity problems. Languages like FRL [Goldstein 77] use triggers on data structure slots to propagate changes. The disadvantage here is that there is no support for keeping track of what was deduced and why. This makes changes difficult because information dependencies are not recorded.

The language KRL has been used to implement a knowledge-based personal assistant called ODYSSEY [Fikes 80]. ODYSSEY aids a user in the planning of trips. In this system *pushers* and *pullers* are used to propagate deductions as a result of updates and to make deductions on reads. A simple dependency mechanism is used to record information dependencies. In this case it is necessary to be very careful about the order in which triggers fire for as updates are made there is both new and old information in the database making it difficult to prevent anamolous results due to inconsistencies.

OMEGA separates new and old information into different viewpoints. Information consistency is maintained within viewpoints. The propagation of information between viewpoints is controlled via meta-description. An advantage of the approach using viewpoints is that the system has a historical character. This is an important step toward our goal of aiding office workers in problem solving about dynamic processes. Viewpoints can be used as historical records of past processes, as an aid in tracking ongoing processes and as an aid to determine the implications of postulated actions.

VI. Conclusion

We have presented the viewpoint mechanism of the descriptions system OMEGA along with some examples of its use to describe a changing form in an accounting office. The viewpoint mechanism has proved useful in describing objects whose properties vary with time as well as a means with which to interpret statements about the system's description structure. The viewpoint mechanism presented here is related to that in ETHER [Kornfeld 79] and to the layers of the PIE system [Goldstein 80]. Viewpoints are a powerful unifying mechanism which combine aspects of McCarthy's situational tags [McCarthy 69] and the contexts of QA4 [Rulifson 72]. They serve as a replacement for update and pusher-puller mechanisms.

Omega is *monotonic* using *merging* of descriptions as a fundamental rule of inference. It uses *viewpoints* to keep track of different possibilities. This aspect causes it to differ substantially from systems based on property lists [IPL, Lisp, etc.] which are based on operations to *put* and *get* attributions in data structures. These differences carry over to more recent systems [SIR, SIMULA, FRL, KRL, etc.] based on record structures with attached procedures that execute when a *put* (*update*) or *get* (*read*) operation is performed.

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