Cognitive Modeling and its Application for the Development of Socially Adept Technologies

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ABSTRACT
In this paper we would like to propose that the methodology of cognitive modeling can provide an approach to the implementation of socially adept technologies and the evaluation of its usability. We base this approach on the assumption that representations play an essential role in mediating social relations. Cognitive representations and their causal link to the social and physical environments have been recognized as an essential element for understanding social relations. The challenge is to port cognitive modeling methodology into the realm of socially adept technologies. The first section briefly presents the state of development of a modeling environment aimed at supporting usability testing of socio-technical systems. The second section will give an overview of an application intended to support social and personal awareness in a web-based learning environment. This application maps users identity, users behavior, and shared information content into a model of human memory.

Keywords
User modeling, adaptive web interface, usability, socio-technical systems.

INTRODUCTION

In this paper we would like to propose that the methodology of cognitive modeling can provide an approach to the implementation of socially adept technologies and the evaluation of its usability. We base this approach on the assumption that representations play an essential role in mediating social relations. Cognitive representations and their causal link to the social and physical environments have been recognized as an essential element for understanding social relations. In fact, according to one well-known sociologist (Sperber, 1999), it is impossible to identify socio-cultural phenomena without relying on the mental representations of social agents.

The challenge is to port cognitive modeling methodology into the realm of socially adept technologies. The purpose of designing socially adept technologies is to create a human-machine interaction that is sensitive to human dimensions such as emotions, values, social and cultural contexts (Marsh, et al, 2002). We suggest that one could make the assumption that cognitive models, which take the form of computer programs, provide, at a certain level of abstraction, an explanation of the causal links between perception and representations, and representations and overt behavior.

The task of building socially adaptive technology requires advancements on a variety of issues such as the explicit representation of cultural knowledge, individual personalities and preferences that can be used to allow machine adaptation to the user s individual and social characteristics. From a methodological point the view, the development of socially adept technologies also requires a reduction of the gap between social requirements and technical feasibility (Ackerman, 2000). We suggest that cognitive modeling could help in reducing this gap.

Cognitive modeling has been applied to many areas of individual cognition (Anderson, & Lebiere, 1998) An interesting benefit of cognitive modeling is that the same models that are build to explain cognitive phenomena can also be used as building blocks for implementing adaptive software agents. Cognitive modeling is in fact an iterative methodology similar to the learning cycle in CHI research (Olson, & Olson 1997) that goes through successive cycles of theory building, computational artifact construction, and empirical evaluation.

The first section briefly presents the state of development of a modeling environment aimed at supporting usability testing of socio-technical systems. The second section will give an overview of an application intended to support social and personal awareness in a web-based learning environment. This application maps users identity, users behavior, and shared information content into a model of human memory.

COGNITIVE MODELS AS USERS

Cognitive models are computer programs that simulate human performance of cognitive skills. These models have been successfully applied:˚as a way to evaluate the efficacy of different user-interface design by making predictions on task performance,˚as a means to provide help in the form of cognitive tutors, and˚as substitutes for users when interacting with real systems (Ritter, 2000).

According to Ritter (2000), three artifacts are needed for modeling human-computer interaction tasks: (1)˚a cognitive model that simulates the cognitive performance of a human performing a task, (2)˚a task simulation that provides the task as well as the interface that will be used by the cognitive model, and (3)˚a linkage mechanism that simulates human perception and action so that the cognitive model can communicate with the task simulation.

SOS (Simple Operating System) is an application that we have developed to implement both the task simulation and the linkage mechanism (West & Emond, 2001). SOS objects contain general perceptual properties and can be accessed through motor controls, representing hand movements, triggered by a cognitive model. The SOS simulation is independent of the cognitive model it is linked to. In order for the two to interact, SOS commands need to be inserted into a cognitive model. SOS works in conjunction with cognitive models written in ACT-R 5.0 (Anderson, 2001), which is a cognitive architecture that has been shown to accurately model human cognition across a wide variety of tasks (Anderson, & Lebiere 1998). ACT-R provides both a symbolic and a subsymbolic system for knowledge representation and learning.

The immediate purpose of SOS is to provide support in a rapid prototyping environment (West, & Emond, 2001). SOS interacts with a formal specification of the interface created within the SOS system (i.e., a model of the actual interface). This allows interface designs to be tested against individual SOS/ACT-R agents. However, we are currently developing a multi-agent version of SOS, which is a generalization of the previous version. In the multi-agent version, the SOS simulation will consist of a shared space with private views to reflect the difference in user specific interfaces. The intention is to develop cognitive models of computer mediated collaboration between simulated agents as a means to both evaluate the usability of such systems, and to develop cognitive models of the relevant social dimensions in the interaction processes. Current applications of SOS-agents include game playing and web adaptive interfaces. The following section will address this last issue (the full application of SOS-agents for the simulation of users for this project is currently under development and will not be discussed in detail).

USER INTERFACES AS USER MODELS

Typically, an application that represents user characteristics in a meaningful way would either proceed by explicitly asking users to name or give values to some of these characteristics, or by learning them by observing users behavior. The last approach has some obvious advantages over the first as it is not intrusive, it adapts to change and evolves over time. Preferences and interests are often the result of exploration and/or discovery and therefore are constantly evolving. Adaptive hypertext and hypermedia as well as web based educational systems (Brusilovski, 1999) both require a user model as a fundamental source for interface adaptation.

The main objective of these type of adaptive systems is to tailor a user information and communication space in such a way as to bring up front the most relevant information, taking into account the user's goal, tasks, interests, and preferences (Brusilovsky, Kobsa, Vassileva, 1998). In the domain of socially adept technologies, this also implies adapting to users common ground, context, trust, time zone and culture (Olson, & Olson, 2000)

There has been a wide range of proposals regarding the nature of these user models. The standard practice in artificial intelligence applied to education has been to represent a user's performance in terms of some target model specified as a model of expert performance or other typical classes of user model. This approach is suitable for domains where the knowledge is relatively well specified as a set of pre-determined symbolic knowledge representations to be acquired. Although in the context of large distributed and unstructured information repositories or open and self-developing learning communities, the possibility of using very detailed user models based on a predetermined symbolic knowledge representation is certainly challenged.

Our proposal is to use both symbolic and sub-symbolic levels of representation for the users identity, behavior, and information content. This dual representation schema has its origin in mixed cognitive architectures and models of human memory (Anderson, 1993; Just, & Carpenter, 1992). Models of human memory have been successfully applied to predict document access in large multimedia repositories (Recker, Pitkow, 1996) and in the context of web information foraging as a model of users' exploration of large document collections to support adaptive browsing (Pirolli, 1998; Pirolli, & Card, in press).

The notion that user interfaces can be organized in a similar manner as human memory has been a central idea behind the development of hypertext and hypermedia learning environments. The perceived benefits of hypertext technology is to match as closely as possible the learners mental representation of the domain described by a set of hypertext documents and navigation links (Dee-Lucas, 1996). The idea is supported by the fact that human memory, conceived as a network of entities, is a central and well founded theoretical construct in psychology and neuroscience, even if one can find disagreements about the nature of these entities and their relationships (Baddeley, 1990; Anderson, 2000). The notion of hypertext and hypermedia as a mean to facilitate an individual acquisition of knowledge was rapidly extended, with the growing presence of the web, to the notion that the web actually represented something like a collective intelligence (Smith, 1994; Heylighen, 1999). The current proposal makes a similar transition by applying cognitive architecture concepts, which have been used as basis for models of individual cognition, to the collective representation of a group of users. The idea that a society can be represented as an individual is quite old (e.g., see Hobbes, 1651) but, to the best of our knowledge, has not been applied in this context. This transition also follows the paradigm of distributed cognition where cognition is understood as encompassing interactions between people, and with resources and materials in the environment (Hutchins, 1995; Hollan, Hutchins, Kirsh, 2000).

Our intention is to use the interface as a representation of the state of memory of user's personal and social characteristics. These characteristics being the expression of individual, group and community interests, and preferences extracted from the interactions with an adaptive system. The central idea is to present to users alternative views so as to support the exploration of different perspectives. For example, in the context of large information repositories or self-developing communities, a user has to frequently browse through large amounts of data or unstructured discussion threads. An adaptive social interface in this context could offer alternative sort options reflecting one s own pattern of exploration or those of groups of individuals. This type of interface could help to foster reflexive thinking by reification (Collins, Brown, 1988) of the implicit individual and collective memory assessed through behavior patterns. The emphasis on providing control and explicit representation of the learners' model is congruent with the shift from teacher/tutor centric to learner centric adaptive educational systems (Kay, 2001).

Two concepts are central for that purpose: (1)°activation, and (2)°spreading activation. The notion of activation is an important component of the rational analysis of cognition and is also central to the ACT-R architecture (Anderson , Lebiere, 1998). Activation is a subsymbolic process, that mitigates the process of symbolic processing. It represents a measure of the degree that past experiences indicate that they will be useful at a particular moment in time. The base-level activation of a memory chunk represents how recently and frequently it is accessed. The base-level activation therefore takes into account both the number of times a memory chunk is accessed as well as the time related to the past references to the chunk. This is an important feature of activation because its value is not constantly growing as the number of references increases, but is subject to decay as determined by a logarithmic function. The role of decay rate and interference are both important factors in models of human memory (Altmann, & Schunn, 2000). Closely related to the concept of activation is the concept of spreading activation. Spreading activation refers to the notion that activation from one unit flows or spreads to neighborhood units to increase their own activation levels. Spreading activation is also widely used in neural networks as a learning mechanism, and has been applied to information retrieval applications (Crestani, 1997; Crestani, & Lee, 2000).

To integrate the ACT-R activation system into web-based communication environments the system should maintain a set of symbolic activation units parallel to the units used in the users mind to represent elements in the interface. This set of units would consist of the cross product of the information content elements (e.g., problem statements, plans, observations, and reflections), the user units (individual users, and groups), and user activity types (e.g., resource exploration, annotation, and resource creation). These symbolic units are in fact discrete data structures that can easily be implemented either in a relational or object oriented database format. Attached to the activation units are activation levels that have continuously varying values. Provided the activation units are correctly specified, using the ACT-R activation algorithms to process these values should create an activation network that parallels that of the user or, if the group data is used, of the collective.

We propose to use a path based constrained spreading activation method to organize the activation system. According to this method, the time of reference is propagated along a predefined path of activation units from specific activation units towards more abstract units. The purpose of this propagation schema is to collect the activation levels of lower units. Thus the root unit, which is at the top of the hierarchy, provides a base upon which to compare all activation levels of lower units in the hierarchy. The automatic recording and propagation of references to objects not only traces learners activity patterns across time, but a learner could also see various activation levels attached to an object. This allows for some powerful sorting options of the information space by a learner to reflect his/her immediate goals. For example, objects could be sorted as to their levels of activation, by focusing on either knowledge exploration by the learner himself, knowledge exploration by the group, knowledge construction by the learner himself, or knowledge construction by the group.

CONCLUSIONS

This work and the multi-agent SOS work inform and support each other. Because both systems use the ACT-R architecture there a level of convergence can be attained that is not possible with systems that all use different cognitive algorithms. Thus, information concerning how people use and explore new interfaces can be ported directly from SOS to the socially adaptive web interface, and activation values for social information can be ported directly to SOS, where it can be used to create realistic models of how humans operate in a computer supported social environment. This illustrates our claim at the beginning that cognitive modeling, particularly a commitment to a specific architecture, can be used both in the design and testing of CSCW interfaces. We believe that through this interactive cycle we will begin to see the creation of social aware agents that have the ability to truly understand the needs of the user and to evolve that understanding as the needs of the user evolve.

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