THE NECESSITY AND DEVELOPMENT OF USER MODELING FOR FUTURE MODELING AND SIMULATION SYSTEMS

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ABSTRACT

As modeling and simulation (M&S) applications and real-world systems become increasingly complex and automated, more reliance will be placed upon the computer system to assist and direct the human operator in the operation, use, and manipulation of the computer system. The ability of a computer system to guide and direct a human operator is based upon three main factors: prior or input information, current situational information, and operator goal information. The prior or input information includes information related to the individual operator, the objectives of the operator and system, and models of previous operations similar to the current one. The current situational information includes current operator status, current objective status, current systems status, and current environmental conditions. Operator goal information includes a variety of knowledge about operator past, present, and future uses of the system or direction of tasking for system components within the current environment and other relevant environments.

To acquire and utilize even the bare minimum of the information included in the previously mentioned factors surpasses current M&S system abilities and computing resources. One promising technology for addressing this shortfall within the M&S community is the employment of the research results from the behavioral and cognitive modeling, or user modeling, community. The need for user modeling is pervasive in many M&S application areas and, although not overtly present in many of these M&S systems, user modeling is a critical portion of most modeling and simulation systems for new development, especially intelligent agents. To realize future capabilities for M&S systems, they must incorporate the ability to effectively model the user and user needs within the environment. This paper will address this requirement by motivating the need for and describing the benefits of user modeling employment within M&S applications.

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INTRODUCTION

As modeling and simulation (M&S) applications and real-world systems become increasingly complex and automated, more reliance will be placed upon the computer system to assist and direct the human operator in the operation, use, and manipulation of the computer system. The ability of a computer system to guide and direct a human operator is based upon three main factors: prior (input) information, current situational information, and operator goal information. The prior (input) information includes information related to the individual operator, the objectives of the operator and system, and models of previous operations similar to the current one. The current situational information includes current operator status (workload, attention direction and focus, stress factors), current objective status (on-track, re-planning, aborting), current systems status (information display parameters and requirements, operational platform physical parameters, current operational tasking), and current environmental conditions (virtual environment portrayal). Operator goal information includes knowledge about operator past, present, and future uses of the system or direction of tasking for system components within the current environment along with other relevant environments.

To acquire and subsequently use even the bare minimum of the information included in the previously mentioned factors surpasses current M&S system abilities, development methodologies, and computing resources. One promising technology for addressing this shortfall within the M&S community is the employment of the research results stemming from the behavioral and cognitive modeling, or user modeling, community. The need for user modeling is pervasive in many M&S application areas: computer generated actors, intelligent tutoring and training, mission planning and rehearsal, training system operator assistance, simulation scenario generation, simulation environment assessment, user decision support, and intelligent agent systems. Although not overtly recognizable in many of these M&S systems, user modeling is a critical component and must play a significant role in new developments for modeling and simulation systems, especially intelligent agents.

To realize the needed future capabilities for modeling and simulation systems, these systems must incorporate the ability to effectively model the user and user needs within the environment. This paper will address this requirement by motivating the need for and employment of user modeling within M&S applications. The paper will discuss the information necessary to understand the area of user modeling, the major components of user modeling, and then motivate the need for a methodology to develop user models that encompasses work within cognitive task analysis. We present specifics on M&S applications where user modeling is vitally important and discuss the benefits to be reaped from incorporation of user modeling into current and future developments within these M&S applications. We conclude the paper by providing brief recommendations concerning the steps the M&S community should take to avail itself of user modeling methodologies for the development of future M&S capabilities.

USER MODELING FOR M&S APPLICATIONS

This section summarizes the area of user modeling, explains the types of user models, and describes the construction of user models primarily by the use of cognitive task analysis.

User Modeling Background

User models are knowledge representations that depict users' knowledge and interactions with a computer system. The main purpose of user modeling is to represent what the user intends to do within a system's environment for the purpose of assisting the user. In this context, human (user) intent may be defined as mental states that drive actions [21]. One approach to predicting user intent is to identify the salient characteristics of the domain environment and specifically determine the goals a user is trying to achieve [5]. This approach is based on the belief that what a user intends to do in an environment is the result of events occurring in the environment and the goals he/she is trying to obtain as a reaction to stimuli. These goals can be explicit or implicit, physical or cognitive. To achieve a goal, a user must perform certain actions. Furthermore, goals can be composed of multiple actions, with many pre- and post-conditions. Pre-conditions include directly observable events in the environment as well as indirectly observable events that cause a user to pursue a goal. User models are particularly useful in domains with a heterogeneous group of users and where the system may exhibit flexibility in its “response” to users [26].

Researchers from the fields of artificial intelligence (AI), human-computer interaction (HCI), psychology, education, and others have all investigated ways to construct, maintain, and exploit user models. This infusion of concepts and research results from many disparate research fields has allowed user modeling to advance rapidly by exploiting contributions from each of the separate research fields. For example, the user modeling community has been able to reap the benefits of AI research by using various AI knowledge representations such as logic-based techniques, abductive reasoning techniques, machine learning techniques, Bayesian methods, and neural networks. The HCI research field’s impact on user modeling can be seen in the use of user models to customize presentation of information to provide feedback to users about their knowledge in a domain and to help users locate useful information. Another HCI impact is to employ lessons learned from user modeling to impact the way we view interactive human-computer environments [32]. This approach proposes examining interactive HCI environments along three orthogonal dimensions: elements --- the goals, plans, resources, and actions composing the atomic entities an agent (human or otherwise) is concerned with, processes --- the types of processing (e.g., reaction, deciding, learning) that takes place in an agent, and relationships --- the way agents interact with one another. This approach makes explicit the reasoning about the purpose of adaptations (why adapt?), treats human and computer agents the same in the environment, takes into account user motivation, emotions, and moods, and presents a unified model of collaborative, cooperative, and adverse behavior. Additionally, user models have taken into account a user's psychological ability, such as working memory or cognitive load, to adapt a user interface and/or the information presented to the user [3][5][6][14].

Types of User Models

Many types of user models have been developed for a variety of purposes. Each type of model represents specific attributes of the user of a computer system, and each type of model is useful in applications for which it was designed. However, no model represents everything; therefore, investigators with one set of aims may find models useless that were devised for other purposes. For user models, there is a distinction between competence models (which determine what a user could do) and performance models (which determine what a user is likely to do). The remaining paragraphs summarize a few types of user models with an emphasis on two types of models, the behavioral and cognitive models.

One type of user model, often used in the field of human-computer interaction, is a physical model. Physical models are based on empirical knowledge of the human motor system, and focus on task execution. Fitts’ law, a model for the prediction of user hand movement time, is an excellent example of a physical user model [9]. Physical models are competence models, as they assist interface designers in developing interfaces that are easier to use. Another user model, the neurological model, maps user actions or thoughts onto specific regions of the brain. This model has not been used extensively in the design of intelligent systems. However, as our understanding of the human brain increases, the neurological model could play an important role in the development of user interfaces. Other user modeling research factors the model into demographic factors (age, gender), professional factors (expertise level), physiological factors (reaction, workability), and psychological factors (understanding, memory) [10].

The two user models of primary interest, behavioral and cognitive models, are both performance models in that they are used to determine a user’s future actions. The primary difference between the two models lies in the level to which the user is modeled. Both models observe the user’s execution of actions; however, cognitive models attempt to determine the user’s goals, whereas the behavioral model directly forecasts user activity. Because of their predictive nature, both models have been applied within M&S applications.

Human cognitive models have been studied by researchers in the field of psychology for many years. Cognitive psychology is concerned with understanding tasks in which a stimulus is processed in some way before a response is chosen. Humans form cognitive models of their environment to make sense of and organize the information they observe. Similarly, a computer system may also use a cognitive model of its environment and its user as it determines how to assist the user. Cognitive models represent aspects of users' understanding, knowledge, intentions and processing, and tend to have a computational flavor. Stokes emphasizes that to be adaptive, the system requires a model of the cognitive state of the human operator that will infer both the present level of operator performance and the current state of mental workload and resource allocation [28]. Put simply, a cognitive model represents the human user as a collection of goals and a set of actions to accomplish the goals.

The behavioral model is the other performance type of user model and attempts to address some of the difficulties encountered when using a cognitive user model. In a behavioral model, the behavior of a system is manifested in input-output relationships; the user's behavior can be defined as a succession of states. Put another way, a behavioral model represents the human user as a collection of sequences of actions that the user performs. This model observes and predicts the actions of the user. The system does not attempt to determine the user's goal, as done with a cognitive model, but directly predicts future user actions based on the status of the environment and past user actions.

User Model Construction

The first step in the development of a user model involves examining the tasks users perform and the knowledge they use to perform these tasks. One approach, cognitive task analysis (CTA), centers on informing the design process through the application of cognitive theories. A task is defined as what the person or other intelligent agent has to do (or believes is necessary) to accomplish a goal by use of some device [25]. A task is accomplished by performing actions (or simple tasks) in some order. CTA recognizes that these actions include both physical and mental activities. Whereas hierarchical task analysis is concerned with establishing an accurate description of the steps that are required to complete a task, the focus of CTA is on techniques that capture some representation of the knowledge that people have, or that they need to have, to complete the task [25]. The underlying assumption of much of cognitive psychology is that a human perceives the world and produces some representation of it in his or her mind, called the "problem space". This representation is what we would usually call "knowledge." This knowledge may be described in terms of the concepts that we possess, the relationships between those concepts and our capacity to make use of those concepts. The human then manipulates that representation and produces some output, or behavior, that can be observed. CTA seeks to model the internal representation and processing that occurs for the purpose of designing tasks that can be undertaken more effectively by humans. This basic characterization of human actions in terms of perceiving the world, representing it internally, manipulating it, and expressing it underlies Norman's model [20] and other cognitive theories.

There are a number of CTA techniques, some examples follow in the next paragraph, that focus on different aspects of the cognitive processing assumed to be necessary for a person to complete a task. In addition to the levels of description, most of these techniques focus attention on the mappings between levels, or how a description of one level is translated into a description at another level. For example, two principle levels of cognitive activity that must be undertaken within a user centered design framework are the task-action representations and mappings and the goal-task representations and mappings.

Of the various cognitive models, the most important historically is the model human processor (MHP) [8], which presents a psychological model as consisting of three interacting systems: the perceptual, motor, and cognitive systems, each of which has its own memory (maintains an internal representation or knowledge) and processor. This model led to the GOMS (Goals, Operations, Methods, and Selection rules) [16] method of CTA. Johnson's theory of Task Knowledge Structures (TKS) [12] assumes that as people learn and perform tasks, they develop knowledge structures. His method, known as Knowledge Analysis of Tasks (KAT), identifies the elements of knowledge represented in a task knowledge structure. Other cognitive task analysis techniques that focus on different aspects of the general information processing model include Task Action Grammar (TAG) [23], which is concerned with an evaluation of the learnability of systems; and Moran's External Task Internal Task (ETIT) [19] and Payne's Yoked State Space (YSS) [22], which are concerned with the mapping of tasks from the external task space to the internal task space.

CTA and the construction of user models is primarily a knowledge acquisition process. Therefore, it usually falls to a knowledge engineer, using one of the CTA methods, to acquire the necessary information through the study of user behaviors and the systematic correlation of these behaviors to various user goals. Once the model developer has fully specified the relationships between actions and goals, the user model may be developed.

M&S APPLICATION AREAS INCORPORATING USER MODELING: NEEDS AND BENEFITS

Many M&S application areas realize the need to incorporate user modeling features into the application area. This section presents three selected M&S application areas ready to realize the influence of user modeling in the immediate future. We first discuss the area of intelligent agents (IAs) and the necessity and benefits for user modeling for IAs. As many M&S applications will rely on IA technology to fulfill future requirements, this subsection is intentionally explanatory. The next two subsections discuss the M&S applications of operator interface assistance and decision support and computer generated actors (CGAs) and the necessity and benefits for user modeling within these fields.

Intelligent Agents

For the past several years, the research and development communities have published an extensive number of papers dealing with agents, sometimes termed intelligent agents, and systems that claim to employ agents. These systems span diverse application areas such as e-mail filtering, information retrieval from the web, electronic commerce, entertainment, and spacecraft control. This wide variety of application areas along with the promise of benefits from agent technology contribute to a confusing picture concerning the IA research field. To reduce this confusion, there have been many attempts made to define an agent or what constitutes an agent. Although there is no agreed upon agent definition, there exists a convergence of opinion on the characteristics of an agent. An agency relationship is present when one party (the principal) depends on another party (the agent) to undertake some task on the principal's behalf. Utilizing this relationship, an agent is a computer software system whose main characteristics are situatedness, autonomy, adaptivity, and sociability [30]. In addition, all four characteristics must be present simultaneously for a system to qualify as an agent. Situatedness means that the agent receives some form of sensory input from its environment and performs some action that changes its environment in some way. The physical world and the simulation environment are examples of environments in which an agent can be situated. Autonomy means that the agent can act without direct intervention by humans or other agents and that it has control over its own actions and internal state. Adaptivity means that an agent is capable of (1) reacting flexibly to changes in its environment; (2) exercising goal-directed initiative, when appropriate; and (3) learning from its own experience, its environment, and interactions with others. Sociability means that an agent is capable of interacting in a peer-to-peer manner with other agents or humans. Because of its flexibility, the agent paradigm provides a new approach and promise for building complex software [30].

To narrow this view into the world of M&S environments, an IA is a computer entity that collaborates with and helps a M&S user by perceiving dynamic conditions in the environment; acting to affect conditions in the environment; reasoning to interpret perceptions and solve problems; drawing inferences; and determining actions [1][11]. Another perspective places the IA directly into the human information processing path and states that an agent is simply a software program that automates some stage(s) of the human-information-processing cycle leading to a decrease in human effort [17]. Norman's [20] model of the human-information-processing cycle provides (1) the ability to identify the cognitive processes and the linkages between the cognitive processes and the user's goals that must be supported with IA operation and (2) the mechanism to link the user's goals to operation within the environment. From the execution side, the stages of Norman's model are (1) forming an intention to act, (2) translating this intention into a planned sequence of actions, and (3) executing this sequence. The stages of the evaluation side of Norman's model are (1) perceiving the state of the world, (2) interpreting this perception in light of prior action, and (3) evaluating this change with respect to the initial goal. To enable the efficiency, focus, and utility of the human-information-processing cycle, IAs are typically examined from this human-information-processing model perspective to determine where they may be used to assist in the processing cycle. The emphasis on this type of examination and subsequent utilization of IAs comes from the belief that the greatest impediment to assisting human users lies in communicating their intent and making results intelligible to them [17], hence the necessity for user modeling and the determination of user intent within IAs.

As stated previously, humans form cognitive models of their environment to make sense of the information they observe. By analogy, an IA may also use a cognitive model of its environment and its user as it determines how to assist the user. Applying cognitive psychology to the problems of IAs and HCI is not straightforward [4]. Recall that a cognitive model represents the human user as a collection of goals and a set of actions to accomplish the goals. Therefore, the cognitive model allows the IA to attempt to determine the goals of the user. Once the agent has determined the user's goals, it then locates a set of actions that will assist the user in accomplishing the goal. In a given situation, the agent must decide the goals to pursue and the methods used to achieve them. On the other hand, using a behavioral model, an IA examines the stored sequences of user actions, searching for a situation similar to that currently observed by the agent. The system does not attempt to determine the user's goal, as with a cognitive model, but directly predicts future user actions based on the status of the environment and past user actions. When utilizing behavioral modeling, the agent monitors the activities of the user, keeps track of all his actions over time, finds patterns, and automates these actions [18].

Intelligent agents are a key aspect of many currently developing M&S applications. The framework necessary to support the integration of human cognition into the increasing computational power of the simulation environment derives its basis from IA technology. Intelligent agents can be developed with current technology to perform information fusion, analysis, and abstraction, as well as deriving information requirements and controlling information display. These agents perform functions for the tasks of reasoning to direct system data acquisition, data assessment, information synthesis, and information display. IA techniques can be utilized to enable the user to understand the derived information, synthesis operations, and available processing options. IA technology also forms the basis for computer generator actor developments, mission planning generation and rehearsal, intelligent tutoring and training, training operator assistance, simulation scenario generation, simulation environment assessment, and user decision support. All of these M&S systems are employed to assist, train, or educate a user. Without the knowledge of what the user requires for assistance, training, or education being present within the system, which is embodied in the user model, these M&S IA endeavors can only hope to be scripted, brittle, and skeletal devices that only partially realize the enhancements to operator performance that a true IA system can provide.

Operator Interface Assistance and Decision Support

The idea of providing the user with assistance to handle the information overload of a dense M&S environment is so intertwined with the purpose that necessitates the assistance, to provide user decision support, that the two topics are difficult to separate in terms of requirements. Whether the operator is a commander, staff personnel, training instructor, or trainee, the M&S applications and real-world training and education based upon these systems are increasingly complex and automated. Therefore, no matter the operator, more reliance will be placed upon the computer system to assist and direct the human operator in the operation, use, and manipulation of the computer system for training, assessment, or mission rehearsal.

Most work done to date within the user modeling community and application of results from user modeling fall into the realm of operator assistance whether that assistance be purely computer interface support or for the more complex requirement of decision support. However, one could argue that intelligent interface operation is primarily done to preclude tedious operation of the interface and to reduce information overload to enable more effective operation within the work environment. Hence, intelligent interface support can be considered as a factor of the decision support area, as most DoD M&S applications utilize intelligent interface operation to enable better decision making on the part of the system operator. In addition, the more current applications in the interface and decision support area are based on intelligent agent technology, as demonstrated by the popularity of the term intelligent interface agent [2][3][5][6][34]. Two straightforward user modeling application areas are training operator assistance and simulation scenario generation assistance. Two more complex applications include the focus of operator attention to critical or important environmental aspects within the battlespace, whether the operator be a commander or a training systems controller, and dynamic collaborative interfaces to enable environments for staff problem solving for mission planning and rehearsal.

The participation in a M&S environment that accurately models the real world in all its complexity and variety places an enormous cognitive burden upon the user. The cognitive burden is overwhelming because the user must attempt to understand the simulation environment, extract relevant information, analyze this information, operate the system, and make decisions based upon the information. Because the information is difficult to locate and may have a short time period of relevance, the quality of human decision making suffers and the operator's performance degrades over time due to fatigue and overwork. While advances in user interface design can address some of this problem, the problem of information overload can not be addressed solely through development of a better interface or the creation of ad hoc analysis tools. User models are incorporated to improve user access to the simulation environment display parameters, analysis reports, conferencing and collaboration capabilities, intelligent agents for user assistance, motion and orientation controls, recording devices, and situation awareness aids. To be effective in assisting the simulation environment user, intelligent agents for operator assistance and decision support rely upon a prediction of user intent.

An accurate user model is generally considered to be necessary for effective prediction of user intent. In addition, most experts agree that an effective intelligent agent "decision" in support of a user must be based on an accurate representation of the users' knowledge and interactions with the system.

The rationale for including user models in assistive systems fall primarily into three main categories: theoretical, historical, and technological [7]. From the theoretical position, theories of situation cognition and naturalistic decision making form the major underpinning of the software development effort for the operator assistance and decision support systems. Therefore, an engineer cannot begin to develop decision making interventions, such as adaptive interfaces or decision training tools or support systems, without a detailed understanding and formal representation of the relationship between decision making expertise and the knowledge that is unique to experts in the domains. Secondly, from the historical point of view, decades of experience in human factors engineering indicate that the design of new or modified systems that include human operators should begin with a detailed mapping of what the human beings are doing or should be doing. This notion of "task analysis" is so strong as to be perhaps the single most unifying principle of human factors [33]. In addition, the research literature reports that systems built or redesigned with a sound CTA producing user models are much more usable, lead to higher human performance, and require less training than those that ignore CTA. The third perspective, technological, is concerned with the effort to develop actual systems that will improve decision making. Many advanced technologies can be incorporated into such systems but require detailed user models with analyses of the decision strategies of the human operators. For example, user models can be used to create intelligent or adaptive user interfaces to the decision support system [27] and the support system itself could incorporate or be designed from models of user strategies [6][15]. Therefore, the development of a detailed and accurate CTA and user model is an enabling condition for application of a broad range of technologies for improving decision performance in a variety of M&S domains.

To comprehensively support operator interface assistance and decision support, a complete approach to software engineering, knowledge engineering, and knowledge acquisition for intelligent interface and decision support systems, with a user model at the heart of the development effort, is necessary. Within the information dense simulation environment, the operator and M&S application must work as a team. Therefore, work tasks must be appropriately addressed by both the computer and the user; in other words, a symbiotic approach is required in software developed for intelligent interface and decision support. In these systems, the computer looks to the user to provide guidance and insight into the information that is necessary to draw complex, high level inferences from the data and to provide guidance for data exploration. The user, on the other hand, looks to the computer to perform the following: data acquisition and management, quantitative and qualitative data analysis, data exploration and data discovery, routine inference to enable decision support, and data and display management. The decision support aspect of the approach relates to the need to enable the user to understand the relevant data and to perform necessary analysis by allowing the system to provide information highlighting and user focus of attention activities. Referring back to the previous discussion on user modeling for the development of systems incorporating agents, user modeling cannot be overlooked and, in reality, is the only methodology available to ensure successful incorporation and use of an intelligent interface and decision support application.

Computer Generated Actors

The component areas of an effective CGA, where an effective CGA is one that can not be recognized in the simulation environment as being controlled by a computer, are the same as those of a real-world operator. These components are decision making, battlefield assessment, information retrieval and analysis, intelligent interface operation, and the wide variety of intelligent processes (agents) that contribute to the overall operational success of the weapon platform. As discussed in the previous subsections, user modeling is an important contributor to all of these component areas. Also, with the current emphasis on incorporating CGAs with realistic behaviors into simulation and training efforts within the Department of Defense modeling and simulation community [24], user modeling is becoming and will continue to play a significant role in the development of CGAs. As with many applications developed for operator interface and decision support, the CGA area is increasing employing the intelligent agent development paradigm, and its necessary requirements for the utilization of user modeling, as its basis [17][29][31].

The techniques of user modeling can be effectively utilized for CGA development by applying a user modeling approach that treats human and computer actors the same in the environment, makes explicit the reasoning about the purpose of system adaptations and decisions, takes into account actor motivation and emotions, and presents a unified model of collaborative, cooperative, and adverse behavior. In addition, employment of a user modeling approach allows the direct incorporation of knowledge derived from various knowledge acquisition efforts, including cognitive task analysis techniques, into the knowledge processing structure of a CGA.

Within user modeling, and specifically for its application to CGA behavioral modeling, a representation that exhibits the flexibility and power to deal with the uncertain environment and the dynamics of modeling user goals and actions is required. Employing a knowledge representation that correctly captures and models uncertainty in human-computer interaction can improve the modeling of the user and, therefore, the CGA behavior based upon this user model. For these reasons, development of a representation to capture user goals and actions in the environment through cognitive task analysis and then utilize this representation within a generalized CGA reasoning architecture to produce human-like CGA behaviors is desirable.

CONCLUSION AND RECOMMENDATIONS

User models are becoming recognized as a foundational source of information for use within many types of systems utilized extensively in military modeling and simulation environments for training or mission rehearsal: decision support, battlefield assessment, information retrieval and analysis, intelligent user interfaces, and the wide variety of intelligent software agents. In addition, with the current emphasis on incorporating appropriate human behavior models into simulation and training efforts within the Department of Defense modeling and simulation community, the use of cognitive task analysis and user modeling is becoming an increasingly significant area of interest.

The construction of user models is based on a knowledge acquisition process and, within the AI community, a well accepted rule of thumb is that knowledge acquisition is the bottleneck of any intelligent system design. The acquisition of knowledge for user modeling is no exception. User modeling, as with any other process that is primarily a knowledge acquisition task, is often not employed properly or not used at all due to two main reasons. First, the effort and funding required to undertake a worthwhile CTA effort, fundamental to user modeling, is often underestimated or not understood by project management. Because of this miscalculation, projects often undertake only cursory cognitive task analyses, which do not produce the type of information or the quantity of information necessary to provide a proper user modeling foundation for the project. For this reason, many projects do not realize the potential of user modeling and fail to exhibit the benefit of such an effort. The second major shortfall of the current use of CTA and user modeling is that the approach is often bypassed at the project start, with the notion that the project can acquire the necessary knowledge as the project progresses and its associated system develops. However, the major objectives for performing cognitive task analyses are to determine the human decision processes that drive the operational system, what interventions computerized systems should have in this decision process, and, then, what humans should be doing in conjunction with computerized systems to further operational success. If the information needed to address these critical system design issues is not acquired at the project start, where the information can drive and improve project requirements and system development, the benefits of CTA and user modeling will not be correctly reflected in system development or overall system use and effectiveness.

A crucial step in providing appropriate and timely CTA and user modeling is overcoming the lack information concerning previous efforts conducted in for user modeling. If information concerning prior efforts is readily accessible, project schedule and costs would more closely match the reality of using the CTA and user modeling approach and the effort to develop user modeling products for system development could be jumpstarted from project beginning, thereby maximizing the benefit from the CTA and user modeling process. Therefore, a current necessity is the development of a capability to facilitate information documentation and the subsequent ready access to the documentation to allow re-use of prior user modeling endeavors.

The position advocated in this article arose from the conviction that M&S environments provide a revolutionary means for humans to interact with each other and with information in the areas of training, education, and mission rehearsal. However, techniques that allow users to accomplish a wide variety of work and communication within the simulation environment must be developed to achieve this potential.

Underpinning the varied technological requirements of M&S applications, including IA technology, intelligent interface and decision support assistance, and CGAs, is the need for user modeling. The ability to model the user and to understand the basics of human operation in the simulation environment and in the real world that the simulation environment represents is vital to providing any type of user assistance within the virtual environment. Performance of user assistance requires user modeling; whether that assistance be in the form of decision support, information retrieval and analysis, focus of user attention, or any of the wide variety of IA functions. In addition, the employment of adequate knowledge engineering efforts to include CTA techniques to construct user models should be addressed in development efforts for systems designed to assist a user. Finally, we believe efforts to develop more systematic uses of knowledge acquired in CTA and other techniques for the construction of user models is necessary to successfully employ user models within M&S applications.

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