System initiative influenced by underlying representations in mixed-initiative planning systems

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Background

Mixed-initiative artificial intelligence systems are ones where the system can take the initiative to solicit further input from the user or where the user can take the initiative to interrupt the processing of the system to provide additional input (see (Haller, McRoy, & Kobsa 1999), (Cox 1999)). Mixed-initiative systems contrast with other AI systems which perform automated reasoning given input from a user, producing output without further interactivity.

To date, the design of mixed-initiative AI systems has been largely done independently by researchers in various subareas of AI, including intelligent tutoring systems ((Aist 1997), (Lester, Stone, & Stelling 1999)), planning systems ((Allen 1994), (Cox & Veloso 1997), (Burstein & McDermott 1996)) and interface agents ((Fleming & Cohen 1999), (Rich & Sidner 1998), (Cesta & D'Aloisi 1999)). The aim of our research is to develop some general guidelines to direct the design of mixed-initiative AI systems in a more principled manner. To this end, our plan is to first study the requirements of various kinds of mixed-initiative applications and to then identify some guiding influences for successful system design.

In particular, we hope to provide some concrete answers about what characteristics of an application domain make it particularly well-suited to a mixed-initiative approach, and what factors must be considered by a system in determining whether or not it is appropriate to take the initiative in a given situation. We also intend to build on the limited existing work on evaluating the effectiveness of mixed-initiative AI systems.

A possible first step for our general framework will be the development of a formula for a system to use in determining whether or not to take the initiative in a given situation, to ask the user for assistance. Only preliminary thought has been given to this so far, but several factors have been identified which should be incorporated into any such formula:

- the likelihood that a user will have the *ability* to help with a given problem;
- the likelihood that a user will be *willing* to help;
- the perceived cost of a system-user interaction (and the potential cost of *not* communicating).

From this list, it is clear that a high-quality user model will be an essential element of any system which hopes to work together with a user to accomplish a particular task. An effective system will take charge on certain aspects of the task which are well-suited to machine intelligence, but will yield to the user when he has superior abilities for a specific subtask, or when it is essential that the user's preferences be satisfied. In order to achieve this goal, a system must have a solid grasp of what the user's abilities and preferences are.

The cost of communication discussed above involves determining if it is "worth it" to ask the user for help in a given situation, or if it is better to just go ahead with incomplete information. This would incorporate many of the user modeling issues discussed earlier, as well as several other factors. What are the time restrictions? If something must be done quickly, it may be best for the system to perform an action with its current knowledge, rather than attempting a rushed interaction with the user. How *crucial* is it, in the current context, that the absolute best choice be made, or that the user's preferences be satisfied at any cost? If a critical decision is being made, and the user is believed to have appropriate knowledge, then an interaction may be necessary. Furthermore, the system must weigh all of this against the risk that the user will not be able to understand what it is saying, and that a more expensive clarification dialogue will be needed.

The Role of Representation

As discussed earlier, in developing guidelines for designers of mixed-initiative systems, one focus will be on specifying when the system should take the initiative to solicit further input from a user. This is dependent in part on a process of projection, whereby the system determines whether interaction with the user would be successful and profitable at this point in time. As part of this process, the system must evaluate the usefulness of the current shared representation for allowing the user to respond to the interaction the system plans to initiate.

If the system determines that the current representation is problematic for the user to participate successfully, the system could simply forgo interaction and continue to process itself; another possibility, however, is for the system to effect a change to the representation which will then provide for a more effective communication with the user.

The bottom line is the following: as part of the system's decision making with respect to taking the initiative in a mixed-initiative system, the system should determine the user's view of the representation of the current plan and evaluate whether the user can successfully participate, given this view. In cases where the representation is determined to be incomplete or incorrect or simply described at an improper level of detail, the system then has the potential to effect a repair of that representation.

Cast in these terms, our research is relevant to the topic of representational issues for real-world planning systems, since it attempts to specify the conditions under which representations may be evaluated and updated during mixed-initiative planning.

Illustrating the Use of Representation

An example of a collaborative problem solving system where the issue of shared representation is carefully addressed is that of Collagen (Rich & Sidner 1998). User and system work together in order to get a travel plan generated for the user. There is a commonly viewed map of the USA, with routes indicated. An abbreviated display of the past dialogue history is also presented, in a hierarchically structured format of related discourse segments, with discourse segment purposes indicated.

Here we create a hypothetical example to illustrate the potential for analyzing and updating a representation of the task during a collaborative problem solving interaction. Suppose that the system finds a way of transporting the user from Dallas to Boston by going through a third city, Atlanta, which is not currently displayed on the map. In presenting this route to the user for approval, the system can first check to see whether all of its information is represented in the current display. Once it discovers that Atlanta is not represented, it can cause an update to the display, so that both parties can now proceed to discuss the option and so that the suggested route can be indicated on the map.

This example can be addressed within an algorithm for taking the initiative in mixed-initiative planning. As mentioned, one possibility is to have the system's decision to take the initiative depend on a number of factors in a kind of formula. One of these factors could be a judgment that the user can comprehend what the system is requesting from the user, based on the system's understanding of the user's understanding of the current representation. There will be other related factors, including a judgment by the system that the user can comprehend the language used in the interaction, that the user possesses the knowledge being requested and that the user is willing to provide the knowledge being requested. For all of these factors, some kind of user modeling would be ideal.

In fact, for many of these decisions, there may be a simplified default conclusion for all users (*e.g.*, all users who want the system to assist with travel plans are willing to specify their preferences to the system). For the judgment that the current representation provides the user with sufficient information to provide an answer to the system's question to the user, the system could in fact conclude that ANY user, not just this one, would be better served by a representation which displays the information being discussed in the question, hence leading to an update to the display. In other words, a general rule could be applied.

A case which would be more user specific is one where the system wants to display the times of the flights in terms of their local times (*e.g.*, 5:00pm PST, 8:00pm EST, *etc.*). For a user who is less educated, perhaps a grade school student, it may be important to provide more explanation along with these symbols. The need for more detail within the representation would then be determined on the basis of a more specific user modeling phase, and this information could be grafted onto the shared display in a kind of clarification box.

These examples illustrate a direction for a system to follow, when it determines that the current representation does not support successful interaction with the user. One possibility is for the system to effect a change in the representation, and this can be detected by carefully evaluating what is critically needed for the user from the representation before the system takes the initiative.

Of course, another possibility is for the system to simply forgo interacting with the user, continuing to take charge of the problem solving without further input. For example, if the system determines that a very fine-grained display of the map is required in order to get the user's input and that the graphical software does not support this level of detail, the system may decide to simply spare the user of the details of the travel. The extent to which the user needs to be brought on board with the problem solving will be application specific.

The Application of Scheduling

One application which we are planning to investigate in greater detail is that of mixed-initiative scheduling. We are particularly interested in the domain of scheduling large sports leagues. In these domains, there are often constraints to be specified by a user and there may also be cases where the constraints have to be changed or updated dynamically. For example, one may set various constraints about how often one team is allowed to play against another and indicate certain preferences for having teams travel as little as possible. If, however, on a particular date, one field is no longer available, due to some unexpected event, the user should be able to renegotiate the schedule by interacting with the system.

Previous work related to mixed-initiative scheduling includes research by Smith *et al.* (1996) on interactive decision support tools for large-scale scheduling problems, which focuses on supporting the dynamic, interactive process that is typical of practical real-world planning and scheduling activities. Also, Jackson and Havens (1995) have investigated the idea of mixed-initiative constraint satisfaction problems, in which both the user and system can make decisions about assigning values to variables. In particular, they emphasize that no user decisions in such a setting should ever be undone unless they preclude a consistent solution. Anderson *et al.* (2000) have looked at the paradigm of human-guided simple search, in which the user guides the system toward particularly promising areas of a search space; however, they state that their system is interactive but not mixed-initiative, as control is clearly in the user's hands at all times.

Our aim in investigating scheduling as a possible application area for the design of mixed-initiative systems is to develop a more general strategy for determining when each party should be taking the initiative during the problem solving. As a starting point, we can study these existing systems to see if there are any common rules for when the user is brought in to direct the problem solving.

We also feel that the application area of scheduling has much in common with that of planning, in the sense that the final output is something like a plan of action to be followed, with various temporal constraints on the operation of the actions. In fact, in attempting to discover the role of the representation in allowing for effective mixed-initiative planning systems, it may be worthwhile to examine the case of scheduling. Are schedules necessarily much less complex in their representation? Are there cases where the representation can be incomplete or confusing to the user, requiring some repair before interaction can be successful? Are there cases where the required interaction with the user is too complex to do successfully, so that the system decides not to take the initiative?

Discussion

It is worthwhile to explore the development of some general guidelines for designing mixed-initiative artificial intelligence systems which could be applied to the design of any mixed-initiative planning system. The specification for when a system should take the initiative to interact with a user would need to be dependent, in part, on some evaluation of the current shared representation between the system and the user or at least on the system's view of what the user perceives to be the current representation. Modeling this information would enable the system to evaluate the potential success of interaction with the user, at this point in time, leading either to a decision to forgo interaction altogether or, more often we hope, in a procedure to repair impoverished representations so that interaction can then proceed. There are, doubtless, many other factors involved in deciding how to divide the problem solving and dialogue between the two collaborating parties. However, we believe that it is important to attempt to maximize the success of the mixed-initiative system by making conscious decisions about when the initiative should be taken.

In addition to designing systems which can successfully complete the problem solving tasks assigned to them, we should also be concerned with crafting an interaction with a user which does not burden the user, at the same time. This is the topic of evaluating the effectiveness of a mixed-initiative system. Relevant research on this topic includes the work of Walker and Litman on the PARADISE dialogue evaluation system (Walker *et al.* 1997), encompassing both user satisfaction and efficiency. The work of (Fleming & Cohen 1999) on incorporating a formula for a bother factor, registering how often a user may be willing to be bothered, and the work of (Bauer *et al.* 2000) on calculating a user's annoyance level are also of interest.

It is important, therefore, to have a view of collaborative problem solving as a kind of dialogue between the two parties. As a participant in this dialogue, the user must be able to comprehend the current focus of discussion and must be willing to engage in interaction to the extent solicited by the system.

Some relevant related work is that of Brown and Cox (1999) on adjusting the visualization of the problem solving and the task for a user in a collaborative planning environment. In our research, we are also concerned with what to present in the shared view of the current task, so that the user can participate effectively. In addition, we are concerned with whether the system will be understood when it chooses to communicate, which covers both possibly saying more in order to make things clearer to the user and being careful with how things are said. Basically, unclear communication carries with it a high cost and in some circumstances not communicating is the better approach, since the cost of trying to be sufficiently clear in the communication may be prohibitive.

A final important message from our research is the following. Regardless of the form of representation developed to facilitate participation from the user, the decision of when the system should take the initiative in mixed-initiative planning systems should be assessed, very specifically, in terms of both the capabilities of the current user and the complexity of the current task. It will be important to move beyond mixed-initiative paradigms where the specification for when the system takes the initiative is determined beforehand and is intended to apply for all users in all scenarios.

Further Clarifications

In the Background section, we discussed a strategy of developing a formula to determine whether a system should take the initiative or not, during its problem solving activity. Another question for further study is whether the formula should simply be a set of conditions, all of which must be met in order for a system to take the initiative or whether a more quantitative measure can be calculated, which causes a system to take the initiative when a certain threshold value is exceeded.

It is also important to acknowledge that the definition of "initiative" in the design of mixed-initiative AI systems is not always clear (see (Cohen *et al.* 1998)). Some researchers (see (Chu-Carroll & Brown 1998)) distinguish between task initiative and dialogue initiative, for instance. Our research aims to clarify the circumstances under which a system should take the initiative in a mixed-initiative problem solving environment. To us this means primarily identifying when the system would initiate further dialogue with the user - a kind of dialogue initiative. Yet, we are concerned with those cases where the system is communicating with the user for the explicit purpose of advancing the current problem solving activity, therefore exhibiting a task initiative. Even if the system then relinquishes control to the user, allowing him or her to direct the problem solving, this would still constitute initiative on the part of the system, in our interpretation, since the specific questions asked by the system still direct the overall path of the planning task. Part of our future research will in fact involve a further clarification of what we define to be initiative in mixed-initiative artificial intelligence systems.

It is also important to clarify that part of our research project is to determine the circumstances under which the overall solution to an AI problem should not be a mixed-initiative approach at all. The question to investigate here is whether there are applications where allowing the system (or the user) to direct the problem solving entirely is preferable.

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