INTERACTIVE ADVISORY SYSTEMS

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ABSTRACT

Smart algorithms can be used to process large amounts of data and come up with an "optimal" solution according to the criteria set up by the model of the system. But how should a user interact with such advisory systems? In this paper, we discuss the ability for users to interact with advisory systems at many levels. Thus, rather than only have the ability to use the advisory system to generate a solution, the user has the ability to 1) ask the system to generate alternative solutions based on different criteria or 2) use the system to evaluate a user-generated plan. This provides the user with the benefits of a more flexible advisory tool. Should the "optimal" solution generated by the advisory system be "non-optimal" from the user's perspective (because of knowledge or parameters not taken into account by the system), the user can either change the criteria used by the system to reflect this new knowledge, or tweak the final solution and still take advantage of the system's capabilities to evaluate and compare the solutions.

Keywords: human-automation interaction; advisory systems; decision support systems; user-interface design; optimization algorithms; mixed-initiative systems; planning, scheduling

INTRODUCTION

Often, advisory systems use some sort of smart algorithm (either an optimization algorithm or a knowledge-based expert system) to evaluate the computer-known parameters of a situation and generate a suggested plan of action for human operators to implement. In some cases, the advisory system has the capability to also implement the plan automatically, if authorized. There are many examples of such systems in use today. We suggest in this paper that in order to make such systems more flexible and more useful, human supervisors should have the ability to interact with the advisory system at several levels and be able to still take advantage of the automation's number-crunching capabilities. We next describe two different types of capabilities that might be useful.

At one level, the human supervisor might want the ability to adjust the criteria being used by the automation and then have the automation re-generate a solution using the new criteria. At another level, perhaps the criteria used are not the issue, but the solution itself is not practical or "optimal" from the human's perspective. It would be useful in such a case for the human supervisor to be able to adjust the solution and then have the automation evaluate the alternative solution using the same criteria it uses to generate a solution in the first place.

As a means to explain these concepts further, we describe the development of an advisory tool, the Thermal Energy Storage Advisor, which was first intended to assist building operators by generating an optimal charge/discharge Thermal Energy Storage plan. We argued, however, for the inclusion of the above-mentioned interaction features, so that the same smart algorithm that was used to generate the optimal plan could also be used to evaluate user-generated plans, or to generate a different optimal plan based on tweaked inputs to the system. We begin by describing the use of Thermal Energy Storage systems, and the difficulty with which building operators have today in developing an effective charge/discharge plan.
Thermal Energy Storage As An Alternative Or Supplemental Cooling Strategy

The electric utility industry is moving towards "real time pricing" and offering its larger customers (such as large commercial building operations) a one day preview of the utility rates that will be in effect over the next 24 hours. This gives those customers the ability to potentially adjust their cooling strategy to minimize their electric utility costs. One such strategy is to use a thermal energy storage (TES) system, "charging" the system overnight when the utility rates are low, and "discharging" the system the next day when the rates are high. Charging the system consists of using chillers (that are normally used to cool the building) to instead cool large tanks of water. (Because cooling demand is much lower overnight, there is usually chiller capacity available to cool the TES system.) Discharging the system consists of circulating the cold water as a means of cooling the building. Pumping the water uses much less electricity than running the chillers, so this kind of a strategy can yield a large cost savings to the building owner if there is a large price differential between the time when the TES system is charged and when it is discharged.

Many factors go into the decision to use or not use the TES system. For example, if predicted load for the building is higher than the anticipated capacity for the chillers, then the TES system has to be used to provide supplemental cooling to the building during the peak periods. This might happen during very hot summer days, or during days when one or more chillers are undergoing maintenance. On other "middle of the road days" it is less obvious as to whether the TES system should be used. It takes manual effort to discharge and charge the TES system, so the TES system should not be used unless it is economically viable.

It is also difficult to predict exactly when the system should be charged and discharged. The TES system, once fully charged, can only cool for so long before it is fully discharged. Since it takes several hours to charge the system, one wants to make sure that there is TES capacity remaining if predicted load is going to exceed chiller capacity. In other words, if utility rates are very high in the early morning hours, it would seem to make the most sense to fully discharge the TES system during those peak cost periods. However, if the demand for cooling the building is predicted to be much higher during later hours in the day, it is essential that the TES system still has charge available to cover the additional demand.

One also needs to take into account the amount of time between charging and discharging the system. Once fully charged, the cooled water will slowly warm up, essentially losing its charge. Thus, for maximum effectiveness, the time between the end of the charging cycle and the beginning of the discharging cycle should be minimized.

THE THERMAL ENERGY STORAGE ADVISOR

Because of the complexities involved in deciding when to charge and discharge the TES system, we developed an advisory tool that generates an "optimal" TES plan. This advisory tool uses an optimization algorithm that takes as input the hourly rates provided by the utility, the time to charge the TES system, the discharge capacity of the TES system, (which dissipates over time once the charging cycle is complete), the cooling capacity of the chillers, and the predicted cooling demand for the building (which depends on the day of the week and the predicted outside temperature and humidity).
As output, the algorithm generates a 24-hour schedule, which tells the operators of the building during which hours they should charge the system and during which hours they should discharge the system. It also displays the associated cost savings (as compared to not using the TES system at all). Figure 1 shows a graphical representation of these input and output parameters. Figure 2 shows the user interface for a sample plan, both in graphical format and table format. The cost savings is shown in the upper right hand corner.

Figure 2. Sample TES plan generated by the TES Advisory Tool
Making The Tool More Interactive

This system, as originally designed, provides very useful information to building operators, figuring out for them the “optimal” plan based on all that the system takes into account. However, all problems have multiple objectives, and not all of those objectives can be taken into account by a computer-based system. For example, what if there is an important staff meeting just at the time when the workers are supposed to start charging the system? Is it better to change the staff meeting, or will there be all that much difference in the cost savings if charging is started one hour later? Alternatively, what if the predicted load being used by the system is less than what the operators know it will be (because a convention is being held on Sunday, when the building is normally closed?) The system will have generated a faulty plan because of the incorrect predicted load.

In the first case, you would like a system that allows the user the ability to either adjust an existing plan or develop a plan from scratch, and use the system’s capabilities to evaluate those plans in the same way it uses evaluation criteria when generating its own plan. For the example being discussed here, this would mean allowing operators of the TES advisory tool to edit the plan itself, and then have the system compute the cost savings associated with this new plan. If the difference between the “optimal” plan and the plan moved up by an hour is only a few dollars, it may not be worth changing the meeting. If, however, there is a large cost difference, it may be worth re-scheduling the meeting and taking the system’s original advice.

In the second case, you would like a system that allows the user to adjust the parameters being used by the advisory tool to generate a plan. This would mean adjusting the predicted load for the next day, and having the system re-compute a plan with the adjusted load parameters.

In the TES advisory tool, we added in these features using a “What If” screen (see Figure 3), which gives operators the ability to edit plan parameters or the plan itself. All editable parameters are shown in bold-faced text. Once the user changes any of these parameters, the text changes color, and the compute button becomes active. Once the compute button is selected, the system re-generates either a plan, if plan parameters were changed, or just a cost savings if the plan itself was changed. This new plan and cost savings are shown just below the active plan, so that comparisons can easily be made. In order to accept the new plan, the user must select the Accept button, and it becomes the new active plan at the top of the screen.

IMPLICATIONS

Including these kinds of interactive features adds significant complexity to the user interface. Once the possibility exists for editing plans, the system must have the capability to save plans, call up various plans, and activate a particular plan. The possibility for error exists as users may forget to activate the correct plan, for example. The underlying algorithms and programming must also exist to track and save the various plans.

DISCUSSION

The interactive features that were argued in this paper are specific examples of a more general claim by Vicente (1999) that we should allow workers to “finish the design”. Vicente writes, “The most promising path for improving safety in complex socio-technical systems is to deliberately (emphasis in original) design to support adaptation… we need to provide workers with the support they need to play the role of adaptive problem solvers reliably and effectively. We cannot expect workers to fulfill this onerous responsibility unless we provide them with the appropriate set of tools.” (p. 338). Later, he writes, “Rather than designing to support the mythical one best way… the objective is to identify the constraints
that define the boundaries of system safety and reliable performance. We need to make these boundaries visible to workers and provide them with tools that they need to navigate and explore the remaining space of functional possibilities for action.” (p. 339).

This paper explored two ways in particular that we can support the concept of allowing workers “to finish the design” when designing an advisory system that uses an optimization algorithm to generate its advice: 1) allow workers to tweak the constraints used by the system to generate an alternative plan, and 2) allow users to create a new plan or tweak an existing plan and still get evaluation parameters that will allow them to easily compare their plan(s) to the system’s original plan.

Figure 3. The What If page allows tweaking of plan parameters or the plan itself. The system will re-generate a plan and cost savings if plan input parameters are changed, or just re-compute a cost savings if the plan itself is changed.

A second system that has been developed with exactly these features is the Flight Planning Testbed (FPT) (Layton, Smith and McCoy, 1994; Smith, Layton and McCoy, 1999). In this system, pilots and dispatchers can use a computer-based tool to re-route flight paths around bad weather. The system can generate an “optimal” plan automatically when it detects poor weather using default constraints of no turbulence, or the users can change the acceptable constraint levels on amount of turbulence and have the system re-generate a plan. A third option is for the users to change the plan itself, either by creating a new plan from scratch, or tweaking an existing plan. For all of these plans, the system provides useful
comparison data, such as time of arrival and fuel remaining. Smith et al. ran a series of very interesting experiments, comparing the alternative capabilities that such a system provides. Interestingly, for cases where the computer’s “default” reasoning generated a faulty plan (due to task circumstances that the system was not designed to handle), users who had to first generate a plan of their own before asking for a computer-generated plan were much less likely to accept the system’s faulty plan than users of the system who could first get a system-generated plan before exploring alternative plans. This study showed the possibility of an “automation bias” in terms of users judging the acceptability of different plans.

CONCLUSION

With so much automation being introduced into society, it is tempting to be caught up in the design of the automated system, tweaking its capabilities so that it can generate the “optimal” plan, taking into account all the various constraints and potential alternative scenarios. However, there is some information that a computer system will never be able to account for, either because the data is in a form that is not computer readable, or because the users of the system have knowledge that was not available to the designers of the automation. By providing relevant “hooks” into the automation, we can allow users of the automation to still take advantage of the automation’s number crunching and representation capabilities to assist people in evaluating alternative situations in an informed and meaningful way. If we don’t provide such tools, then the user is forced to either accept the automation’s solution, or to generate alternative solutions on their own with no assistance from the advisory system nor the ability to make viable comparisons between the different options. By making the system more interactive, we allow for more cooperative problem solving between user and advisory system, yielding the possibility for more effective overall performance.

REFERENCES