User Interfaces and Scheduling and Planning: Workshop Summary and Proposed Challenges

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Abstract

The User Interfaces and Scheduling and Planning (UISP) Workshop had its inaugural meeting at the 2017 International Conference on Automated Scheduling and Planning (ICAPS). The UISP community focuses on bridging the gap between automated planning and scheduling technologies and user interface technologies. Planning and scheduling systems need UIs, and UIs can be designed and built using planning and scheduling systems. The workshop participants were representatives from government organizations, industry, and academia with various insights and novel challenges. We summarize the discussions from the workshop as well as outline challenges related to this area of research, introducing the now formally established field to the broader user experience and artificial intelligence communities.

1 Introduction

Automated planning and scheduling (PS) technologies have been used in applications ranging from supply chain management to robotics to space mission planning. Many of these technologies were designed by members of the International Conference on Automated Planning and Scheduling (ICAPS) community. However, the utility of such systems for others outside the community is often constrained by the user interface design. Members of the ICAPS community as a whole have noted that application developers are overlooking automated PS technologies in domains where it should be used, and the lack of good user interfaces may be one reason for this.

Recent advances in novel user interface modalities such as natural language processing (Munteanu et al. 2017) and augmented reality (Chi, Kang, and Wang 2013) also call for investigation as ways to facilitate human-planner interaction. While natural language processing systems have been developed over at least the past twenty years, the advent of commodity spoken language systems and natural language processing systems (Tractica 2017) provides exciting opportunities for integration with automated PS. Augmented reality is a 'rising' technology that, when coupled with computer vision systems, can provide new, potentially disruptive methods for supporting plan execution, if not planning. There is also the potential for automated PS to help design user interfaces. Workflows for many different user interface tools can be constructed using planning systems (St. Amant 1999) as well as other automated reasoning technologies. Historically, there have been a small number of investigations of this type.

The User Interfaces and Scheduling and Planning (UISP) workshop[1] featured eight presented papers (Freedman and Frank 2017), two invited talks, and a community panel. Based on the positive response to this workshop, we propose future directions for the community as well as an invitation to connect with other related communities in Section 4.

1.1 Planning and Scheduling

One of the earliest areas of research within artificial intelligence (AI), planning studies the selection of sequences of actions to accomplish tasks, but also involves studying the representation of knowledge and information, and developing problem solvers using search methods and heuristics. The resulting plans or schedules are executable action sequences that satisfy all the imposed constraints.

Although this research has created many useful techniques and formulations for problem definitions and solutions, the algortihms and methods are often not very friendly to users outside the research community. With some exceptions, capturing knowledge and plan display is done via text files, without any guide or visual aids. This approach is suitable for researchers, but not users of planning and scheduling systems, and is a barrier to wider adoption of innovations in the field.

2 The UISP 2017 Workshop

2.1 Themes in Presentations

PRIDE-AVR is an integration of the PRIDE (Izygon, Kortenkamp, and Molin 2008) system – which helps model and execute procedures that NASA astronauts use to manage plans – with augmented, virtual, and hybrid reality technologies. The system (Bonasso et al. 2017) (visualization shown in Figure 1(4)) is demonstrated on three use-cases: (i) an augmented reality browser; (ii) a virtual/hybrid reality demonstration; and (iii) an on-board graphics-based system used to train astronauts for extravehicular activities.

[1] http://icaps17.icaps-conference.org/workshops/UISP/

Figure 1: Snapshots of interfaces discussed in the workshop. Clockwise from top-right corner, these correspond to presentations from authors of (Magnaguagno et al. 2017; Bryce et al. 2017; Chakraborti et al. 2017; Bonasso et al. 2017; Benton et al. 2017; Sengupta et al. 2017). Salient features of these interfaces are discussed in Section 2.1 and also summarized in Table 1.

CRADLE is a plan recognition algorithm (Mirsky, Gal, and Tolpin 2017) to analyze users' interactions with the interface of a financial services company. The algorithm is used to decrease the amount of information that an analyst needs to consume in order to flag abnormalities and other patterns from among the various traces of users' interactions with the financial system.

WEB PLANNER is a cloud-based planning tool that provides code editing and (search) state-space visualization capabilities. The tool (Magnaguagno et al. 2017) consists of three main interface components, shown in Figure 1(1): (i) a text-based domain and problem editor as well as a plan visualization in text; (ii) various tree-based visualizations of the search-space; and (iii) a *Dovetail* visualization, which tracks the progress of ground predicates through the state-space from initial to goal states.

Conductor combines the plan synthesis problem with domain modeling. It uses a *"visualization metaphor derived from metro maps to display facts as transit routes and step preconditions as stations"* (Bryce et al. 2017) as shown in Figure 1(2). Insets show the visualization of these fact routes in a toy planning domain (left) and in a NASA Extravehicular Activity (EVA) procedure (right).

CHAP-E (Benton et al. 2017) aims to improve aircraft pilot's situational awareness and decision making. It uses hierarchical plan representation (Figure 1(5)) and causal links (inset) to provide *"guidance toward executing procedures based on the aircraft and automations state and assists through both nominal and off-nominal flight situations"*.

RADAR is a plan authoring tool (Sengupta et al. 2017) that explores the different roles of an automated planner in the deliberative process of a human planner in the loop, beyond just plan synthesis. It is the first-of-its-kind paper to explore the scope of decision support across the full spectrum of the automation hierarchy (Parasuraman and Riley 1997), especially as it relates to the role or "personality" of the automated planning assistant. Use cases are provided in a mock emergency response scenario as seen in Figure 1(6).

Æffective introduces augmented reality as an alternative vocabulary of communication in proximal operation of robots for both projection of intentions and real-time feedback when replanning during a plan's execution (Figure 1(3) bottom right inset). The system (Chakraborti et al. 2017) also uses electroencephalographic signals (Figure 1(3) top right inset) to close the communication loop for preference learning and plan monitoring. A centralized dashboard (Figure 1(3) left inset) visualizes the shared brain of the agents (humans and robots) in a semi-autonomous workspace.

Complexity Metrics denote the complexity of various workflows (plans, schedules) with an eye towards collaborative, planner-assisted settings. The work's (Talamadupula, Srivastava, and Kephart 2017) main motivation is to highlight existing metrics for human comprehensibility of plans and schedules; devise a framework for evaluating existing workflows according to such metrics; and to motivate the planning community to incorporate some of these metrics into the plan synthesis process.

2.2 Themes in Invited Talks

User Interfaces for eXplainable Planning (XAIP) This talk focused on the need and challenges of designing user interfaces to enhance *transparency* and *explicability* in PS systems. While the topic of explainable AI (XAI) is mainly concerned with learning techniques (i.e., explaining neural networks), PS are also very relevant to the topics of trust and transparency, which are the main needs that XAI tries to address. Moreover, AI Planning is potentially well-placed to be able to address the challenges that motivate the research

Paper ↓ / Feature →	GUI	NL	MR	BCI	BE	Synthesis	Execution	Modeling	Visualization	Mixed-Initiative
PRIDE-AVR	✓	✗	✓	✗	✗	✗	✓	✓	✓	✗
CRADLE	✗	✗	✗	✗	✓	✓	✓	✗	✗	✗
WEB PLANNER	✓	✗	✗	✗	✗	✓	✗	✓	✓	✗
Conductor	✓	✗	✗	✗	✗	✓	✗	✓	✓	✗
CHAP-E	✓	✗	✗	✗	✗	✓	✓	✗	✓	✗
RADAR	✓	✗	✗	✗	✗	✓	✗	✗	✓	✓
Æffective	✗	✗	✓	✓	✗	✗	✓	✓	✓	✗
Complexity Metrics	✗	✗	✗	✗	✓	✗	✗	✓	✗	✗

Table 1: Features of PS interfaces presented at the workshop. (GUI = Graphical User Interface; NL = Natural Language; MR = Mixed Reality; BCI = Brain-Computer Interface; BE = Backend support for planner; Synthesis = plan generation; Execution = plan execution; Modeling = learning and authoring of planning models; Visualization = visualization of planning and execution; Mixed-Initiative = human involved in the plan generation process)

on XAI. *Plan Explanation* is an area of planning where the main goal is to help humans understand the produced plans. This involves the translation of the planner outputs (e.g., PDDL plans) in forms that humans can easily understand; the design of interfaces that help this understanding (e.g., spoken language dialog systems); and the description of causal and temporal relations for plan steps. Note that making sense of a plan is different from explaining why a planner made decisions, which is a key element of XAIP. However, the PS community's work in this area forms a solid basis upon which XAIP can be further developed.

(Fox, Long, and Magazzeni 2017) contains an overview of related work from the planning community. Here we remark that David Smith in his AAAI invited talk presented *Planning as an Iterative Process* (Smith 2012), discussing the broad problem of users interacting with the planning process, which also includes questions about choices made by the planner. Pat Langley et al. more recently used *Explainable Agency* to refer to the ability of autonomous agents to explain their decisions, and they discuss some functions that agents should exhibit (Langley et al. 2017).

A number of challenges for UISP in the area of XAIP were identified, including:

- UISP should help the user explore the space of alternative plans so that the user can understand why one plan is better than others;
- UISP should provide a set of plans, rather than a single plan, so that the user can choose plans according to different metrics (e.g. preferring efficiency vs. risk);
- UISP should facilitate the integration between PS technology and domain knowledge because human expertise should play a role in defining the heuristic for a specific domain;
- UISP should allow the user to accept only part of a plan (rather than accepting of rejecting it as a whole);
- UISP should allow the user to add new (high-priority) goals and modify the planning model at execution time;

In the last few years, planners have become more powerful. PS is used in new (critical) domains (e.g., mining, energy, air/urban traffic control, etc.), and their solutions are much more complex than before (e.g., continuous nonlinear models, differential equations, fluid dynamics, etc.). Prior work in explaining plans should be revisited and extended to handle these new complex scenarios.

'Want to Field Your PS System? Suck it Up!' (Challenges) This presentation surveyed case studies from a company's experience creating customized PS solutions for clients. It is frequently the case that PS technology can be applied to solve existing problems, or to rethink of the solution to an existing problem as a planning or scheduling problem. However, it is also important to keep the clients' inputs and opinions in mind, which may require additional changes that are typically not considered for PS technologies.

These pre-existing real world problems have often been solved in some way already, which has several implications. First and foremost, the customer or stakeholders have a preconceived notion of what the problem is with respect to activities, constraints, preferences, and methods to produce good solutions (typically, but not always, heuristics for producing a plan). More importantly, from the user interface point of view, there is an existing UI, and a body of knowledge about what that UI should look like. Examples include specific UI elements (icons, Gantt / PERT chart elements), color choices (often with very specific meanings), desired layouts, and so on. This combination of pre-existing knowledge, process, and UI design often constrains the use of PS technology. Examples include specific knowledge that is hard to model or integrate with existing solvers, the inability to redisplay plans after new solutions are generated (either as a result of replanning or top-K plans), and the inability to display certain forms of planner output (e.g. explanations).

3 Challenges for UISP Research: Panel Discussion

The workshop included a panel discussion with representatives from academia and industry who have built a variety of PS systems, both with and without user interfaces. A summary of some key issues discussed by the panelists follows.

The PS research community is primarily focused on designing and evaluating algorithms to solve well-formed problems, ranging from scheduling and temporal reasoning to generating optimal policies to manage systems in the presence of uncertainty, and many problems in between. Rarely does our community build user interfaces to our systems, and when we do, it is typically for our own consumption (modeling interfaces, search space visualization, and so on). More crucially, the PS community is not the typical application customer, and therefore neither 'owns' nor understands the desired user interface that a customer wants. In the words of one panelist, "The user will sense and perceive your planning and scheduling system entirely through its user interface." This under-appreciation of customer and particularly user interface needs must be addressed to broaden the use of PS technology.

The PS community should also recognize that many applications can benefit from only a subset of existing PS algorithms. To be successful, PS algorithms must only solve the customers' problem effectively; we may not need the full features of an AI planner to succeed. A related challenge is to approach problems without unnecessarily resorting to the language of AI planning, which, though formal and precise, is often hard to understand. The machine learning community, for instance, claims to 'make smart decisions from data'. What is the analogous way of describing what PS technology can do for the customer?

The problem of integrating PS algorithms and the UI requires 'bridging the gap' between the customers' implicit and explicit needs, as well as the capabilities of the algorithms that can be brought to bear to solve the problem. An ideal team consists of the PS algorithm developers and system engineers, human factors or user experience designers who can represent the customer and oversee usability testing, and the project manager who oversees the team and manages project costs and the schedule. The mix of skills on the team ensures coverage of all the key elements for a successful project, but requires significant interaction and integration among team members. User experience and human factors must understand the power and capability of PS algorithms, and PS algorithm developers must recognize limitations on the solution due to the customer needs, ability to formalize the problem, and limitations imposed by the UI design.

Design iterations are critical to project success. Uncertainty about good design and capability is reduced by iteration; customers take ownership of the project as they provide feedback, and iteration can lead to the introduction of more powerful PS algorithms as users begin to appreciate what they offer. Model-based planning should be very well suited to design iteration, since models are declarative and therefore easily changed. In order to take full advantage of this, however, integration with the UI must be equally easy. One challenge of achieving integration is that most PS systems do not produce a 'standard' output format. Defining a standard output that can be easily integrated with UIs would reduce integration challenges. Many applications have pre-existing UIs; thus merely ensuring a PS output standard will solve only part of the problem. Despite these limitations, an interesting challenge for the PS community is to assess existing applications and their associated UIs while considering some systems engineering questions: is there a set of 'canonical' UIs that cover a large number of applications? Can the community define a set of PS output standards that cover these applications?

Finally, while it is unreasonable and unnecessary to expect the entire PS community to actively work on UIs, there was discussion about creating some competitions or design challenges to stimulate interest in this area. Such a competition would differ from the International Planning Competition (IPC) and Knowledge Engineering for PS (KEPS) challenges — it would focus solely on designing user interfaces to display plans and plan changes. While it is tempting to say that the underlying algorithms can be separated from plan displays, some amount of explanation will be required when replanning is performed (and it will be). Ultimately, deep algorithm design decisions may need to be exposed as part of the explanation.

4 Future Directions

Natural language techniques were conspicuous by their absence. Interactions in this space are especially useful while communicating with non-experts in daily life. Recent work looked at verbalization of plans and intentions in natural language (Tellex et al. 2014; Perera et al. 2016) in the context of human-robot interactions. This is an area for future growth in UISP. Perhaps the applications featured in the workshop were geared towards more structured settings with experts in the loop, where more efficient interfaces can be engineered. On the other hand, mixed reality is rapidly emerging as a major player in the space of user interfaces for human-computer interactions. The PS community seems to have also responded to the exciting opportunities of this emerging technology, with two out of the six presentations departing from traditional GUIs to virtual (Bonasso et al. 2017) and augmented (Chakraborti et al. 2017) reality systems. A second workshop will be proposed to the ICAPS 2018 conference. In addition to working with the PS community, it will be important to reach out and establish collaborations with sister communities such as Intelligent User Interfaces (IUI), Human-Computer Interaction (CHI), Human-Robot Interactio (HRI and Ro-Man), and Social Computing (CSCW). This will produce the ideal teams that synergize algorithm developers and designers.

5 Discussion

The recently established UISP research community aims to bridge the gap between PS and UI technologies. The first workshop both introduced current work in this area and identified related challenges that apply to the general user experience of AI community. With the increase in interface modalities and ubiquity of AI amongst users' lives, the research and collaboration opportunities have potential for also bridging the gap between AI and people.

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