Review of
Intelligent Scheduling

Steve Chien

Intelligent Scheduling, Monte Zweben and Mark Fox, eds., Morgan Kaufmann Publishers, San Francisco, California, 1994, 754 pages, $54.95, ISBN 1-55860-260-7.

Intelligent Scheduling is a system-oriented book on scheduling systems. Each chapter describes a scheduling system in terms of the particular scheduling problems being addressed, design assumptions, and the overall paradigm being used. The book is divided into two sections: (1) scheduling methodologies and (2) application case studies. The methodology chapters focus on research systems and scheduling techniques. The application chapters focus on fielded embedded scheduling systems and describe difficulties and lessons learned.

As a guide to current methods in AI-based scheduling, the book is an excellent reference. *Intelligent Scheduling* provides an eminently readable guide to the predominant general approaches, including iterative repair techniques, dispatching methods, and constraint-based techniques. The chapters provide an excellent description of the overall approaches behind the scheduling systems and a good description of the target problem classes.

The book is useful to a lesser degree to managers and practitioners with scheduling problems. Unfortunately, the chapters in *Intelligent Scheduling* rarely provide examples of the actual data-structure input to the systems described. This lack of examples is unfortunate because often, the best way for a practitioner to get a feel for the usability of a system from a practical standpoint is to see an actual problem encoding. In defense of the editors, including such materials would have significantly increased the length of the book.

A major strength of the book is its tie to real applications. In the introduction, the editors mention their frustration with AI work being focused on toy problems. They also state that scheduling systems have been applied to many real problems. Although scheduling work has certainly been more closely tied to real problems than AI in general, readers should note that many of the systems described in the methodology section of the book have only been applied to *test-bed*, or scenario, problems.

Another strength of the book is its balance between breadth and depth in covering AI scheduling techniques. It reads somewhere in between a readings in scheduling and a textbook, more structured and flowing better than the former but too system centric for the latter. Although there is considerable repetition between the chapters, this repetition allows the reader to skip to sections of interest.

One weakness of the book is that it is AI search centric. Little attention is devoted to comparisons to more mathematical techniques such as those from operations research (OR). Although including this area would have made the book a 10-volume set, comparisons to OR-based approaches in the introduction and in the related work areas of each chapter would have been helpful in understanding

many issues. For example, why have AI-based approaches garnered success in these particular applications? How have OR-based approaches done in these same applications? Why are AI-based approaches not widely used for other large-scale scheduling applications, such as automobile manufacturing or airline scheduling (or are they)? How are OR techniques doing in these other application areas? What makes AI-based techniques more suitable for one set of applications than another?

Scheduling Methodologies

The scheduling methodology section is well organized and reads well. The Fox and Smith chapters gently introduce the reader to the often-confusing jargon of manufacturing scheduling. They also motivate and illustrate many of the key concepts in scheduling (and other real AI applications): hard and soft constraints, preferences and utility, and others.

The remainder of the methodology section describes many difficult research problems faced by scheduling systems that attack these problems. Smith motivates the importance of the rescheduling problem and issues with nondisruptive rescheduling very well. An important message for researchers is that the schedule-once or plan-once model doesn't work in the real world.

Many of the scheduling systems described use a flexible control architecture (basically an open introspective control architecture like a blackboard). OPIS is indicative of many of the systems with its control architecture and multiple problem-solving methods. When such an architecture is used, the interesting point is not the architecture but, rather, the way it is used to implement different specialist strategies—how the strategies are selected and coordinated and what strategies are used. Fortunately, these descriptions are plentiful and detailed. The reader can easily see the recurring themes of iterative repair (such as with GERRY) and heuristic search. Johnston and

Minton have a chapter on the modeling and analysis of the effectiveness of this paradigm, and Miyashita and Sycara describe a case-based approach to repair selection. In contrast, the chapter by Van Hentenryck describes how scheduling can be encoded in a constraint language. The chapter by Le Pape relates these control architecture and constraint language issues, describing a view of scheduling as the control of constraint propagation in an introspective control architecture.

The remaining chapters in the methodology section address other important problem areas. The chapters by Muscettola and Tate both emphasize the importance of integrated planning and scheduling. Whereas many systems enforce a conceptual separation, this separation can lead to unwieldy search. Sadeh's chapter on MICRO-BOSS describes how a finer-grained control of the search process can improve the scheduling process. Burke and Prosser describe a hierarchical distributed approach to scheduling. Drummond et al. describe contingent scheduling and its relation to reactive scheduling. Finally, Hansson and Mayer describe an approach to dealing with scheduling to optimize multiple objective criteria.

Application Areas

Although the methodology section of *Intelligent Scheduling* is strong, it is the application case study section of the book that really sets it apart from typical AI books or readings. The application section describes in significant detail many of the difficulties encountered in actually fielding scheduling systems as well as interesting characteristics of the specific scheduling applications. This section of the book both makes a convincing argument for the ubiquity of scheduling problems and describes lessons learned that are useful to those fielding real AI systems— whether or not they involve scheduling. Many of the driving issues described in the application chapters are those described in the methodology sec-

tion. However, many application issues were not emphasized by the technologists (such as how to present bottleneck information to the user or how to interact with the user).

Many interesting issues arise in the space applications described in the chapters on SPIKE, GPSS, and OPTIMUM-AIV. In the chapter on SPIKE, issues in dealing with hard and soft constraints arise, and the input observation constraint-specification language is given. The chapter on the GPSS application is exemplary in that it shows a detailed interactive scheduling scenario, highlighting many subtle issues in appropriately conveying information to the user and allowing the user to direct the scheduling system. Finally, the chapter on OPTIMUM-AIV illustrates a more applied view of the integrated planning and scheduling problem.

The semiconductor application section also provides many valuable insights into fielding real scheduling systems. For example, Fordyce and Sullivan describe the overall problem structure of their semiconductor scheduling application in terms of strategic, operational, tactical, and dispatching scheduling and the role of automated scheduling at each of these levels. Kempf and many others emphasize the importance of convincing both management and shop-floor users of the utility of scheduling technology. They also describe how this is affected by the degree to which the automated scheduling process can be structured similarly to the organizational structure of the operating personnel. The chapter by Fargher and Smith describes a planning and scheduling application to order management in which representing and reasoning about uncertainty are central. Finally, Hadavi et al. describe a fielded distributed reactive scheduling system that emphasizes order release control.

The section on heavy manufacturing applications also provides many lessons for scheduling researchers and practitioners. The chapter by Numao highlights the importance of the knowledge-acquisition problem and natural user interaction in the scheduling process. The chapter by

Dorn and Slany illustrates how relaxing soft constraints arises in actual scheduling applications and describes the use of fuzzy rules in solving this problem. The chapter on MACMERL by Prietula et al. highlights the importance of the match between the scheduling paradigm and the organization of plant operations in facilitating acceptance and use. The military applications also echo issues from the methodology and application sections. The chapter on the application of SIPE to crisis action planning highlights the integration of planning and scheduling. Unfortunately, most planning systems lack the capability to address soft constraints (although this is an area of active research). The chapter on DART provides valuable lessons to planning and scheduling practitioners both in terms of the identification of application areas within logistics planning and the illustration of the significant impact of knowledge-based systems.

Summary

In summary, I found *Intelligent Scheduling* a useful and informative guide to AI-based scheduling systems. The methodology section represents good breadth and depth of coverage of many of the prevailing techniques in AI-based scheduling. The application section represents a good resource for AI researchers interested in learning more about fielded scheduling applications. Although the book would be useful as a text for a graduate scheduling course, it adopts a system-oriented view rather than a technique- or concept-oriented view, which would be ideal for textbook use. However, it performs admirably as a general, readable reference to the lively, growing area of AI-based scheduling.

Steve Chien is a technical group leader at the Jet Propulsion Laboratory, California Institute of Technology. He currently leads projects in the areas of planning and scheduling for science data analysis, deep-space–network antenna operations, and spacecraft mission operations.