The Fourteenth International Conference on Automated Planning and Scheduling (ICAPS-04)

Shlomo Zilberstein, Jana Koehler, and Sven Koenig

■ The Fourteenth International Conference on Automated Planning and Scheduling (ICAPS-04) was held in Canada in June of 2004. It covered the latest theoretical and empirical advances in planning and scheduling. The conference program consisted of tutorials, workshops, a doctoral consortium, and three days of technical paper presentations in a single plenary track, one day of which was jointly organized with the Ninth International Conference on Principles of Knowledge Representation and Reasoning. ICAPS-04 also hosted the International Planning Competition, including a classical track and a newly formed probabilistic track. This report describes the conference in more detail.

The International Conference on Automated Planning and Scheduling (ICAPS) is emerging as the premier forum for researchers and practitioners in planning and scheduling. The annual ICAPS con-ference series was formed in 2003 by merging two biannual conferences: the International Conference on Artificial Intelligence Planning and Scheduling (AIPS) and the European Conference on Planning (ECP). It covers the latest theoretical and empirical advances in planning and scheduling, from new theoretical frameworks and algorithms to practical implementations in a variety of domains.

ICAPS-04 was held June 3–7, 2004, in Whistler (British Columbia) during sunny weather. This was the first time that ICAPS was held in Canada. Whistler, a year-round pedestrian resort that is two hours away from Vancouver, turned out to be an excellent choice. In addition to dining, shopping, and nightlife, Whistler offered an endless variety of outdoor activities including mountaintop sightseeing, mountain biking, hiking, canoeing, fishing, and even glacier skiing. ICAPS-04 was colocated with the Ninth International Conference on Principles of Knowledge Representation and Reasoning (KR-04), the Tenth International Workshop of Nonmonotonic Reasoning (NMR-04), and the International Workshop on Description Logics (DL-04).

The conference program consisted of one day of tutorials, one day of workshops (including a doctoral consortium), and three days of technical paper presentations. The first day of the main technical program was organized jointly with KR-04 and featured six technical papers from each conference and a mutual invited speaker, Patrick Doherty (Linköping University), who presented "Advanced Research with Autonomous Unmanned Aerial Vehicles." ICAPS-04 and KR-04 also held a well-attended joint festival that included poster presentations by the participants of the doctoral consortia of both conferences, presentations of the results of the International Planning Competition, and 11 live demonstrations of planning systems by researchers from corporations, government agencies, and academic research labs. These demonstrations included systems for autonomous spacecraft planning, Web services planning, course scheduling, adaptable manufacturing scheduling, multiagent coordination, and planning systems that took part in the International Planning Competition.

The main technical program consisted of the presentation of the accepted papers in a single plenary track. Printed proceedings are available from AAAI Press. For the first time, the papers of the main conference are also available on the home page of ICAPS-04 (icaps04.icaps-conference.org), together with the abstracts from the doctoral consortium and the system demonstrations. This year, the scope of ICAPS was extended by reaching out to research communities that were underrepresented at ICAPS in the past. The main technical program of ICAPS-04 contained, in addition to papers on classical symbolic planning, more papers on search, probabilistic planning, and scheduling than in previous years. ICAPS-04 received a record 119 submissions of which 37 were accepted by an international program committee of 62 planning and scheduling researchers. The papers were

presented in sessions on cognitive robotics, knowledge in planning, search, scheduling, planning and scheduling applications, probabilistic planning, classical planning, model checking and plan recognition, and nondeterministic planning.

The ICAPS-04 awards committee selected the paper "Conformant Planning via Heuristic Forward Search: A New Approach" by Ronen Brafman (Ben-Gurion University) and Jörg Hoffmann (Albert-Ludwigs Universität Freiburg) for the Best Paper Award. The paper "Multiple Pattern Databases" by Robert Holte (University of Alberta), Jack Newton (University of Alberta), Ariel Felner (Bar-Ilan University), Ram Meshulam (Bar-Ilan University), and David Furcy (Georgia Institute of Technology) was the runner-up for the award. The awards committee selected the papers "A Planning Heuristic Based on Causal Graph Analysis" by Malte Helmert (Albert-Ludwigs Universität Freiburg) and "Breadth-First Heuristic Search" by Rong Zhou (Mississippi State University) and Eric Hansen (Mississippi State University) for the Honeywell Best Student Paper Award. The paper "Trading Places: How to Schedule More in a Multi-Resource Oversubscribed Scheduling Problem" by Laura Barbulescu (Colorado State University), Adele Howe (Colorado State University), Darrell Whitley (Colorado State University), and Mark Roberts (Colorado State University) was the runner-up for the award. In addition to presentations of the accepted papers and the talk by Patrick Doherty, the main conference included two more invited talks. Michela Milano (Università di Bologna) presented "Artificial Intelligence Meets Operations Research: A Constraint Programmer's Point of View," and Reid Simmons (Carnegie Mellon University) presented "Planning for an Uncertain Future."

The one-day tutorial program included five half-day tutorials that attracted more than 100 participants. The "Planning and Learning" tutorial described ways to improve current planning and scheduling techniques using a variety of learning approaches. The "Planning Using Partially Ob-servable Markov Decision Processes" tutorial described ways to cope with uncertainty in planning using abstraction, problem decomposition, and heuristic search that generalize similar techniques used by traditional planners. The "Constraint Satisfaction for Planning and Scheduling" tutorial emphasized methods developed by the constraints community rather than the planning community. The "Planning on the Web" tutorial covered challenging planning problems that arise in the context of gathering and integrating information from the Web. Finally, the "Robot Motion Planning" tutorial described several planning problems faced by robots and covered solution methods from exact planning techniques to sampling-based methods. The workshop program consisted of three full-day workshops on "Connecting Planning Theory with Practice," "Integrating Planning into Scheduling," and "Planning and Scheduling for Web and Grid Services."

ICAPS-04, continuing a tradition started at ICAPS-03, included a doctoral consortium for students doing Ph.D. research in planning and scheduling. The doctoral consortium was attended by 20 students from the United States and Europe. All of them received scholarships that covered their conference registration fee and a substantial part of their travel expenses. The program of the doctoral consortium consisted of meetings and scheduled activities for students to meet each other, a poster session that allowed students to present their work to all conference participants and receive feedback from them, and a mentoring program that introduced students to senior researchers with similar interests.

ICAPS traditionally also hosts the International Planning Competition, a biannual event that promotes a better understanding of existing planning methods and fosters the exchange of benchmark problems and algorithms within the community. The International Planning Competition at ICAPS-04 was the fourth one in the series and featured an expanded two-track program.

The classical planning track con-tinued the tradition of evaluating planning systems in deterministic challenge domains. The organizers extended the planning description language PDDL2.1 used in the previous competition with derived predicates ("domain axioms") and timed initial literals for modeling time windows. A total of 18 groups participated in the classical track, entering 22 planners (including different versions of the same planner) into the competition, which featured seven different benchmark domains. Five of the domains were new and compiled from real-world applications such as airport ground traffic control, oil derivative transportation in pipelines, power supply restoration, model checking communication protocols, and universal mobile telecommunications system program setup. Out of these 22 systems, 7 competed in the optimal track, where planners had to give guarantees on the quality of their plans. The results obtained by the best systems in the classical track were impressive and often improved the previous state of the art by orders of magnitude.

The new probabilistic planning track evaluated planning systems that can cope with uncertainty about the outcomes of actions. The organizers developed a new planning description language, PPDDL, for expressing probabilistic planning domains including actions with uncertain effects, action-specific costs, and goal rewards. Twenty-two groups initially signed up for the probabilistic track, and 10 planners from four continents were formally entered. Two weeks before the conference, the participants were presented with 20 problems in PPDDL format. Their planners were required to connect remotely to a domain simulator for evaluation and maximize their expected value over 30 trials within a time limit of 15 minutes per domain. A planner from Purdue University, FF-rePlan, won the overall "First Place" award, using an approach that solved deterministic versions of each domain and simply replanned when the plan failed. Although six of the test domains were designed to foil a replanning approach, FF-rePlan worked sufficiently

well on the other test domains to secure the top spot. Prizes were also awarded in four other categories.

A booklet with more than 60 authors containing overviews of the competing systems in the classical and probabilistic tracks was distributed to all conference attendees. Information about the planning tracks was also displayed during ICAPS-04, including posters with plots of the performance of the planners entered into the classical track. Additional information is available on the home page of the International Planning Competition "ipc.icaps-conference.org."

The success of ICAPS-04 is due in large part to the exceptional logistical support of the American Association for Artificial Intelligence (AAAI) and the generous contributions of its sponsors: the Computational Sciences Division at NASA Ames Research Center, the Research Institute for Advanced Computer Science (RIACS), the NASA Intelligent Systems Project, the NASA Jet Propulsion Laboratory (JPL), the National Science Foundation (NSF), the Air Force Office of Scientific Research (AFOSR), Defense R&D Canada, National ICT Australia (NICTA), Honeywell, and AAAI. The workshop chairs were Michael Beetz (Technical University of Munich) and Karen Myers (SRI International). The tutorial chair was Sylvie Thiébaux (the Australian National University). The software demonstration and paper submission management chair was Lloyd Greenwald (Drexel University). The doctoral program chair was Eric Hansen (Mississippi State University). The chairs of the classical track of the International Planning Competition were Stefan Edelkamp (Universität Dortmund) and Jörg Hoffman (Albert-Ludwigs Universität Freiburg). The chairs of the probabilistic track were Michael Littman (Rutgers University) and Håkan Younes (Carnegie Mellon University). The publicity chair was Richard Goodwin (IBM T. J. Watson Research Center). Finally, the sponsorship chairs were Fahiem Bacchus (University of Toronto), Gérard Verfaillie (LAAS-CNRS), and Richard Washington (RIACS/NASA Ames Research Center).

ICAPS-05 will be held June 5–10, 2005, in Monterey, California (USA) and will feature for the first time a competition on knowledge engineering for planning and scheduling. Information about ICAPS-05 is available on its home page (icaps05.icaps-conference.org). Additional information about the ICAPS conference series in general is available on its home page (www.icaps-conference.org).

Shlomo Zilberstein (shlomo@cs.umass.edu) is an associate professor of computer science and director of the resource-bounded reasoning laboratory at the University of Massachusetts Amherst. He received a B.A. in computer science summa cum laude from the Technion—Israel Institute of Technology and a Ph.D. in computer science from the University of California, Berkeley. Zilberstein is a recipient of National Science Foundation RIA (1994), CAREER (1996), and ITR (2002) awards, best paper awards from ECAI (1998) and AAMAS (2003), and the Lady Davis Visiting Associate Professorship at the Technion (2000). His research interests include anytime algorithms, decision theory, design of autonomous agents, heuristic search, information gathering, principles of metareasoning, planning and scheduling, reinforcement learning, and resource-bounded reasoning. He has published more than 100 refereed papers on these topics. Zilberstein is a member of the editorial board of the *Journal of Artificial Intelligence Research* and the *Journal of Autonomous Systems and Multi-Agent Systems*. He has participated in the program committees of numerous AI-related conferences and was conference cochair of ICAPS-04.

Jana Koehler (koe@zurich.ibm.com) is a research staff member and project leader at the IBM Zurich Research Laboratory where she leads a group working on model-driven software engineering for business process integration. She received a diploma in computer science and science of science from Humboldt Universität in Berlin in 1988 and earned a Ph.D.

in computer science at the German Research Center for Artificial Intelligence from 1990 to 1994 where she developed a special interest in the design and complexity of planning algorithms. From 1995 to 1996, she was a visiting scholar at the Universities of Linköping (Sweden) and Maryland (USA) as well as a postdoc at the International Computer Science Institute at Berkeley (USA). In 1996, she became an assistant professor at the Albert-Ludwigs Universität Freiburg (Germany). In 1998, she became a consultant for Schindler Elevators (Switzerland) and in 1999 joined the company, where she developed distributed algorithms for high-end elevator control. In 2001, she joined the IBM Research Laboratory in Zürich. Koehler won several scientific and best-paper awards and was nominated full and associate professor in computer science. She was conference cochair of ICAPS-04.

Sven Koenig (skoenig @usc.edu) is an associate professor in computer science at the University of Southern California. His research centers around techniques for decision making (planning and learning) that enable situated agents (such as mobile robots or decision-support systems) to act intelligently in their environments and exhibit goal-directed behavior in real time, even if they have only incomplete knowledge of their environments, imperfect abilities to manipulate them, limited or noisy perception, or insufficient reasoning speed. Koenig received master's degrees from the University of California at Berkeley and Carnegie Mellon University and a Ph.D. degree in computer science from Carnegie Mellon University. He is the recipient of NSF CAREER and ITR awards, an IBM Faculty Partnership Award, and the Raytheon Faculty Fellowship Award. Several of his students have won awards for their research. Koenig has edited one book and published more than 70 papers in various areas of artificial intelligence and robotics. He is on the editorial board of *Computational Intelligence* and was conference cochair of ICAPS-04.

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