GROUP SCHEDULING AND ASSIGNMENT: COMPLEXITY AND ALGORITHMS

A DISSERTATION SUBMITTED TO THE DEPARTMENT OF COMPUTER SCIENCE AND THE COMMITTEE ON GRADUATE STUDIES OF STANFORD UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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·	dissertation and that, in my opinion, it is fully as a dissertation for the degree of Doctor of
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Abstract

Acknowledgments

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Bibliography

- [1] Harold Abelson, Gerald Jay Sussman, and Julie Sussman. *Structure and Interpretation of Computer Programs*. MIT Press, Cambridge, Massachusetts, 1985.
- [2] Noga Alon, Raphael Yuster, and Uri Zwick. Color-coding. *Journal of the ACM* (*JACM*), 42(4):844–856, 1995.
- [3] George E. Andrews. Euler's 'exemplum memorabile inductionis fallacis' and q-trinomial. *Journal of the American Mathematical Society*, 3(3):653–669, 1990.
- [4] Haris Aziz and Florian Brandl. Existence of stability in hedonic coalition formation games. In *Proceedings of the 11th International Conference on Autonomous Agents and Multiagent Systems*, pages 763–770, 2012.
- [5] Coralio Ballester. Np-completeness in hedonic games. *Games and Economic Behavior*, 49(1):1–30, 2004.
- [6] Robert Baumgartner, Georg Gottlob, and Sergio Flesca. Visual information extraction with Lixto. In *Proceedings of the 27th International Conference on Very Large Databases*, pages 119–128, Rome, Italy, September 2001. Morgan Kaufmann.
- [7] P. Berry, B. Peintner, K. Conley, M. Gervasio, T. Uribe, and N. Yorke-Smith. Deploying a personalized time management agent. In *Proceedings of the fifth international joint conference on Autonomous agents and multiagent systems*, pages 1564–1571. ACM, 2006.
- [8] Anna Bogomolnaia and Matthew O. Jackson. The stability of hedonic coalition structures. *Games and Economic Behavior*, 38(2):201–230, 2002.

[9] Ronald J. Brachman and James G. Schmolze. An overview of the KL-ONE knowledge representation system. *Cognitive Science*, 9(2):171–216, April–June 1985.

- [10] M.H. Chia, D.E. Neiman, and V.R. Lesser. Coordinating asynchronous agent activities in a distributed scheduling system. In *Proceedings of the Third International Conference on Multi-Agent Systems (ICMAS'98)*, 1998.
- [11] Peter Cowling, Graham Kendall, and Eric Soubeiga. A hyperheuristic approach to scheduling a sales summit. In Edmund Burke and Wilhelm Erben, editors, *Practice and Theory of Automated Timetabling III*, volume 2079 of *Lecture Notes in Computer Science*, pages 176–190. Springer Berlin Heidelberg, 2001.
- [12] E. Crawford and M. Veloso. Learning to select negotiation strategies in multi-agent meeting scheduling. *Progress in Artificial Intelligence*, pages 584–595, 2005.
- [13] Andreas Darmann. Group activity selection from ordinal preferences. In Toby Walsh, editor, *Algorithmic Decision Theory*, volume 9346 of *Lecture Notes in Computer Science*, pages 35–51. Springer International Publishing, 2015.
- [14] Andreas Darmann, Edith Elkind, Sascha Kurz, Jrme Lang, Joachim Schauer, and Gerhard Woeginger. Group activity selection problem. In PaulW. Goldberg, editor, *Internet and Network Economics*, volume 7695 of *Lecture Notes in Computer Science*, pages 156–169. Springer Berlin Heidelberg, 2012.
- [15] J.C. de Borda. Mémoire sur les élections au scrutin. 1781.
- [16] K. Decker and J. Li. Coordinated hospital patient scheduling. In *Multi Agent Systems*, 1998. Proceedings. International Conference on, pages 104–111. IEEE, 1998.
- [17] Rodney G Downey and Michael Ralph Fellows. *Parameterized complexity*. Springer Science & Business Media, 2012.
- [18] Jacques H. Dreze and Joseph Greenberg. Hedonic coalitions: Optimality and stability. *Journal of the Econometric Society*, pages 987–1003, 1980.

[19] E. Ephrati, G. Zlotkin, and J.S. Rosenschein. A non-manipulable meeting scheduling system. In *Proceedings of the 13th international workshop on distributed artificial intelligence*, pages 105–125, 1994.

- [20] M. S. Franzin, F. Rossi, E. C. Freuder, and R. Wallace. Multi-agent constraint systems with preferences: Efficiency, solution quality, and privacy loss. *Computational Intelligence*, 20(2):264–286, 2004.
- [21] E.C. Freuder, M. Minca, and R.J. Wallace. Privacy/efficiency tradeoffs in distributed meeting scheduling by constraint-based agents. In *Proc. IJCAI DCR*, pages 63–72, 2001.
- [22] Michael R. Garey, David S. Johnson, and Larry Stockmeyer. Some simplified np-complete graph problems. *Theoretical Computer Science*, 1(3):237–267, 1976.
- [23] L. Garrido and K. Sycara. Multi-agent meeting scheduling: Preliminary experimental results. In *Proceedings of the Second International Conference on Multiagent Systems*, pages 95–102, 1996.
- [24] Georg Gottlob. Complexity results for nonmonotonic logics. *Journal of Logic and Computation*, 2(3):397–425, June 1992.
- [25] Georg Gottlob, Nicola Leone, and Francesco Scarcello. Hypertree decompositions and tractable queries. *Journal of Computer and System Sciences*, 64(3):579–627, May 2002.
- [26] M. Hannebauer and S. Müller. Distributed constraint optimization for medical appointment scheduling. In *Proceedings of the fifth international conference on Autonomous agents*, pages 139–140. ACM, 2001.
- [27] A.B. Hassine, X. Defago, and T.B. Ho. Agent-based approach to dynamic meeting scheduling problems. In *Proceedings of the Third International Joint Conference on Autonomous Agents and Multiagent Systems-Volume 3*, pages 1132–1139. IEEE Computer Society, 2004.

[28] Russell Impagliazzo and Ramamohan Paturi. Complexity of k-sat. In *Computational Complexity*, 1999. Proceedings. Fourteenth Annual IEEE Conference on, pages 237–240. IEEE, 1999.

- [29] N. R. Jennings, A. J. Jackson, and London E Ns. Agent-based meeting scheduling: A design and implementation, 1995.
- [30] Hooyeon Lee and Yoav Shoham. Optimizing time and convenience in group scheduling. In *Proceedings of the 2014 international conference on Autonomous agents and multi-agent systems*, pages 1345–1346. International Foundation for Autonomous Agents and Multiagent Systems, 2014.
- [31] Hooyeon Lee and Yoav Shoham. Stable invitations. In *Proceedings of the Twenty-Ninth AAAI Conference on Artificial Intelligence, January 25-30, 2015, Austin, Texas, USA.*, pages 965–971, 2015.
- [32] Hector J. Levesque. Foundations of a functional approach to knowledge representation. *Artificial Intelligence*, 23(2):155–212, July 1984.
- [33] Hector J. Levesque. A logic of implicit and explicit belief. In *Proceedings of the Fourth National Conference on Artificial Intelligence*, pages 198–202, Austin, Texas, August 1984. American Association for Artificial Intelligence.
- [34] P. Maes. Agents that reduce work and information overload. *Communications of the ACM*, 37(7):30–40, 1994.
- [35] Leon Mann, Mark Radford, Paul Burnett, Steve Ford, Michael Bond, Kwok Leung, Hiyoshi Nakamura, Graham Vaughan, and Kuo-Shu Yang. Cross-cultural differences in self-reported decision-making style and confidence. *International Journal of Psychology*, 33(5):325–335, 1998.
- [36] T.M. Mitchell, R. Caruana, D. Freitag, J. McDermott, D. Zabowski, et al. Experience with a learning personal assistant. *Communications of the ACM*, 37(7):80–91, 1994.
- [37] Bernhard Nebel. On the compilability and expressive power of propositional planning formalisms. *Journal of Artificial Intelligence Research*, 12:271–315, 2000.

[38] D.E. Neiman, D.W. Hildum, V.R. Lesser, T. Sandholm, et al. Exploiting meta-level information in a distributed scheduling system. In *PROCEEDINGS OF THE NA-TIONAL CONFERENCE ON ARTIFICIAL INTELLIGENCE*, pages 394–394. JOHN WILEY & SONS LTD, 1994.

- [39] Katharina Reinecke, Minh Khoa Nguyen, Abraham Bernstein, Michael Näf, and Krzysztof Z Gajos. Doodle around the world: Online scheduling behavior reflects cultural differences in time perception and group decision-making. In *Proceedings of the 2013 conference on Computer supported cooperative work*, pages 45–54. ACM, 2013.
- [40] S. Sen and E.H. Durfee. A formal study of distributed meeting scheduling. *Group Decision and Negotiation*, 7(3):265–289, 1998.
- [41] S.T.F. St. Satisfying user preferences while negotiating meetings. 1997.
- [42] K. Sycara, S.F. Roth, N. Sadeh, and M.S. Fox. Distributed constrained heuristic search. *Systems, Man and Cybernetics, IEEE Transactions on*, 21(6):1446–1461, 1991.
- [43] T. Tsuruta and T. Shintani. Scheduling meetings using distributed valued constraint satisfaction algorithm. In *ECAI*, pages 383–387, 2000.
- [44] John Von Neumann and Oskar. Morgenstern. *The Theory of Games and Economic Behavior*. Princeton University Press, 1947.
- [45] J. Wainer, P.R. Ferreira, and E.R. Constantino. Scheduling meetings through multiagent negotiations. *Decision Support Systems*, 44(1):285–297, 2007.
- [46] James Zou, Reshef Meir, and David Parkes. Strategic voting behavior in doodle polls. In *Proceedings of the 18th ACM Conference on Computer Supported Cooperative Work & Social Computing*, pages 464–472. ACM, 2015.