Computational Social Choice: A Journey from Basic Complexity Results to a Brave New World for Social Choice

Vincent Conitzer
Duke University
conitzer@cs.duke.edu

Research on computational social choice (for an overview, see [9]) arguably began with the seminal papers of Bartholdi, Tovey, and Trick, who considered the computational complexity of determining the winning alternative under a given voting rule [6], the computational complexity of finding a successful manipulation under a given voting rule [5] (see also [4]), and the computational complexity of election control [7]. This line of work was eventually picked up by computer scientists, and many of their early results concerned similar questions. They further studied the complexity of winner determination [26, 34, 28, 10, etc.], manipulation by strategic voting [19, 25, 45, 24, 32, etc.], and control [27, 23, etc.], as well as technically related problems such as bribery [21, 22, 23, etc.] and the possible and necessary winner problems [16, 29, 42, etc.].

These types of problems in computational complexity, and similar problems in communication complexity [18, 37], have been and continue to be fertile grounds for research in and of themselves. However, they have also served as a springboard for research on a number of new topics in computational social choice that go beyond cleanly defined computational problems. For example, what if social decisions need to be taken in combinatorial domains, where multiple interrelated issues require a decision and ranking all the alternatives becomes infeasible [8, 36, 30, 35, 31, 44, etc.]? What if we have explicit probabilistic models of how voters vote [46, 47, 20, 17, 39, 15, 43, 33, etc.]? What if the setting is highly anonymous—e.g., the Internet—preventing us from assessing the identity of a voter [11, 40, 38, etc.]? What if the voters are organized in a social network [14, 12, 13, etc.]? What if the voters and alternatives coincide, for example, when we consider ranking webpages based on their links to each other [1, 2, 3, etc.]?

These fresh topics generally require more basic social-choice-theoretic analysis as a foundation, with algorithmic considerations being the (all-important!) icing on the cake.[1] This provides a great opportunity for the computational

[1] Indeed, as the references above indicate, a number of these topics had already received,

social choice community to engage more deeply with the broader social choice community. With a book on computational social choice in preparation and this year's coordination between the Meeting of the Society for Social Choice and Welfare in Boston and the Workshop on Computational Social Choice immediately afterwards in Pittsburgh, there has never been a better time for such engagement!

References

[1] Alon Altman and Moshe Tennenholtz. Ranking systems: The PageRank axioms. In *Proceedings of the ACM Conference on Electronic Commerce (EC)*, pages 1–8, Vancouver, BC, Canada, 2005.

[2] Alon Altman and Moshe Tennenholtz. Axiomatic foundations for ranking systems. *Journal of Artificial Intelligence Research*, 31:473–495, 2008.

[3] Alon Altman and Moshe Tennenholtz. An axiomatic approach to personalized ranking systems. *Journal of the ACM*, 57(4), 2010. Article 26.

[4] John Bartholdi, III and James Orlin. Single transferable vote resists strategic voting. *Social Choice and Welfare*, 8(4):341–354, 1991.

[5] John Bartholdi, III, Craig Tovey, and Michael Trick. The computational difficulty of manipulating an election. *Social Choice and Welfare*, 6(3):227–241, 1989.

[6] John Bartholdi, III, Craig Tovey, and Michael Trick. Voting schemes for which it can be difficult to tell who won the election. *Social Choice and Welfare*, 6:157–165, 1989.

[7] John Bartholdi, III, Craig Tovey, and Michael Trick. How hard is it to control an election? *Math. Comput. Modelling*, 16(8-9):27–40, 1992. Formal theories of politics, II.

[8] Steven J. Brams, D. Marc Kilgour, and William S. Zwicker. The paradox of multiple elections. *Social Choice and Welfare*, 15(2):211–236, 1998.

[9] Felix Brandt, Vincent Conitzer, and Ulle Endriss. Computational social choice. In Gerhard Weiss, editor, *Multiagent Systems*, pages 213–283. MIT Press, 2013.

[10] Vincent Conitzer. Computing Slater rankings using similarities among candidates. In *Proceedings of the National Conference on Artificial Intelligence (AAAI)*, pages 613–619, Boston, MA, USA, 2006.

and/or concurrently received, some attention in the broader social choice community. Nevertheless, the computational mindset often brings a different perspective on these problems, spurring new research. This has been observed in other fields as well [41].

[11] Vincent Conitzer. Anonymity-proof voting rules. In *Proceedings of the Fourth Workshop on Internet and Network Economics (WINE)*, pages 295–306, Shanghai, China, 2008.

[12] Vincent Conitzer. Should social network structure be taken into account in elections? *Mathematical Social Sciences*, 64(1):100–102, 2012. Special Issue on Computational Foundations of Social Choice.

[13] Vincent Conitzer. The maximum likelihood approach to voting on social networks. In *Allerton'13: Proceedings of the 51st Annual Allerton Conference on Communication, Control, and Computing*, pages 1482–1487, Monticello, Illinois, USA, 2013.

[14] Vincent Conitzer, Nicole Immorlica, Joshua Letchford, Kamesh Munagala, and Liad Wagman. False-name-proofness in social networks. In *Proceedings of the Sixth Workshop on Internet and Network Economics (WINE)*, pages 209–221, Stanford, CA, USA, 2010.

[15] Vincent Conitzer, Matthew Rognlie, and Lirong Xia. Preference functions that score rankings and maximum likelihood estimation. In *Proceedings of the Twenty-First International Joint Conference on Artificial Intelligence (IJCAI)*, pages 109–115, Pasadena, CA, USA, 2009.

[16] Vincent Conitzer and Tuomas Sandholm. Vote elicitation: Complexity and strategy-proofness. In *Proceedings of the National Conference on Artificial Intelligence (AAAI)*, pages 392–397, Edmonton, AB, Canada, 2002.

[17] Vincent Conitzer and Tuomas Sandholm. Common voting rules as maximum likelihood estimators. In *Proceedings of the 21st Annual Conference on Uncertainty in Artificial Intelligence (UAI)*, pages 145–152, Edinburgh, UK, 2005.

[18] Vincent Conitzer and Tuomas Sandholm. Communication complexity of common voting rules. In *Proceedings of the ACM Conference on Electronic Commerce (EC)*, pages 78–87, Vancouver, BC, Canada, 2005.

[19] Vincent Conitzer, Tuomas Sandholm, and Jérôme Lang. When are elections with few candidates hard to manipulate? *Journal of the ACM*, 54(3):Article 14, 1–33, 2007.

[20] Mohamed Drissi-Bakhkhat and Michel Truchon. Maximum likelihood approach to vote aggregation with variable probabilities. *Social Choice and Welfare*, 23:161–185, 2004.

[21] Piotr Faliszewski, Edith Hemaspaandra, and Lane A. Hemaspaandra. The complexity of bribery in elections. In *Proceedings of the National Conference on Artificial Intelligence (AAAI)*, pages 641–646, Boston, MA, USA, 2006.

[22] Piotr Faliszewski, Edith Hemaspaandra, and Lane A. Hemaspaandra. How hard is bribery in elections? *Journal of Artificial Intelligence Research*, 35:485–532, 2009.

[23] Piotr Faliszewski, Edith Hemaspaandra, Lane A. Hemaspaandra, and Jörg Rothe. Llull and Copeland voting computationally resist bribery and constructive control. *Journal of Artificial Intelligence Research*, 35:275–341, 2009.

[24] Piotr Faliszewski and Ariel D. Procaccia. AI's war on manipulation: Are we winning? *AI Magazine*, 31(4):53–64, 2010.

[25] Edith Hemaspaandra and Lane A. Hemaspaandra. Dichotomy for voting systems. *Journal of Computer and System Sciences*, 73(1):73–83, 2007.

[26] Edith Hemaspaandra, Lane A. Hemaspaandra, and Jörg Rothe. Exact analysis of Dodgson elections: Lewis Carroll's 1876 voting system is complete for parallel access to NP. *Journal of the ACM*, 44(6):806–825, 1997.

[27] Edith Hemaspaandra, Lane A. Hemaspaandra, and Jörg Rothe. Anyone but him: The complexity of precluding an alternative. In *Proceedings of the National Conference on Artificial Intelligence (AAAI)*, Pittsburgh, PA, USA, 2005.

[28] Edith Hemaspaandra, Holger Spakowski, and Jörg Vogel. The complexity of Kemeny elections. *Theoretical Computer Science*, 349(3):382–391, December 2005.

[29] Kathrin Konczak and Jérôme Lang. Voting procedures with incomplete preferences. In *Multidisciplinary Workshop on Advances in Preference Handling*, 2005.

[30] Dean Lacy and Emerson M.S. Niou. A problem with referendums. *Journal of Theoretical Politics*, 12(1):5–31, 2000.

[31] Jérôme Lang and Lirong Xia. Sequential composition of voting rules in multi-issue domains. *Mathematical Social Sciences*, 57(3):304–324, 2009.

[32] Nina Narodytska, Toby Walsh, and Lirong Xia. Manipulation of Nanson's and Baldwin's rule. In *Proceedings of the National Conference on Artificial Intelligence (AAAI)*, pages 713–718, San Francisco, CA, USA, 2011.

[33] Ariel D. Procaccia, Sashank J. Reddi, and Nisarg Shah. A maximum likelihood approach for selecting sets of alternatives. In *Proceedings of the 28th Annual Conference on Uncertainty in Artificial Intelligence (UAI)*, pages 695–704, Catalina Island, CA, USA, 2012.

[34] Jörg Rothe, Holger Spakowski, and Jörg Vogel. Exact complexity of the winner problem for Young elections. In *Theory of Computing Systems*, volume 36(4), pages 375–386. Springer-Verlag, 2003.

[35] Donald G. Saari and Katri K. Sieberg. The sum of the parts can violate the whole. *The American Political Science Review*, 95(2):415–433, 2001.

[36] Marco Scarsini. A strong paradox of multiple elections. *Social Choice and Welfare*, 15(2):237–238, 1998.

[37] Travis C. Service and Julie A. Adams. Communication complexity of approximating voting rules. In *Proceedings of the Eleventh International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS)*, pages 593–602, Valencia, Spain, 2012.

[38] Taiki Todo, Atsushi Iwasaki, and Makoto Yokoo. False-name-proof mechanism design without money. In *Proceedings of the Tenth International Joint Conference on Autonomous Agents and Multi-Agent Systems (AAMAS)*, pages 651–658, Taipei, Taiwan, 2011.

[39] Michel Truchon. Borda and the maximum likelihood approach to vote aggregation. *Mathematical Social Sciences*, 55(1):96–102, 2008.

[40] Liad Wagman and Vincent Conitzer. Optimal false-name-proof voting rules with costly voting. In *Proceedings of the National Conference on Artificial Intelligence (AAAI)*, pages 190–195, Chicago, IL, USA, 2008.

[41] Jeannette M. Wing. Computational thinking. *Communications of the ACM*, 49(3):33–35, March 2006.

[42] Lirong Xia and Vincent Conitzer. Determining possible and necessary winners under common voting rules given partial orders. *Journal of Artificial Intelligence Research*, 41:25–67, 2011.

[43] Lirong Xia and Vincent Conitzer. A maximum likelihood approach towards aggregating partial orders. In *Proceedings of the Twenty-Second International Joint Conference on Artificial Intelligence (IJCAI)*, pages 446–451, Barcelona, Catalonia, Spain, 2011.

[44] Lirong Xia, Vincent Conitzer, and Jérôme Lang. Strategic sequential voting in multi-issue domains and multiple-election paradoxes. In *Proceedings of the ACM Conference on Electronic Commerce (EC)*, pages 179–188, San Jose, CA, USA, 2011.

[45] Lirong Xia, Michael Zuckerman, Ariel D. Procaccia, Vincent Conitzer, and Jeffrey Rosenschein. Complexity of unweighted coalitional manipulation under some common voting rules. In *Proceedings of the Twenty-First International Joint Conference on Artificial Intelligence (IJCAI)*, pages 348–353, Pasadena, CA, USA, 2009.

[46] H. Peyton Young. Condorcet's theory of voting. *American Political Science Review*, 82:1231–1244, 1988.

[47] H. Peyton Young. Optimal voting rules. *Journal of Economic Perspectives*, 9(1):51–64, 1995.