Computational Foundations of Social Choice

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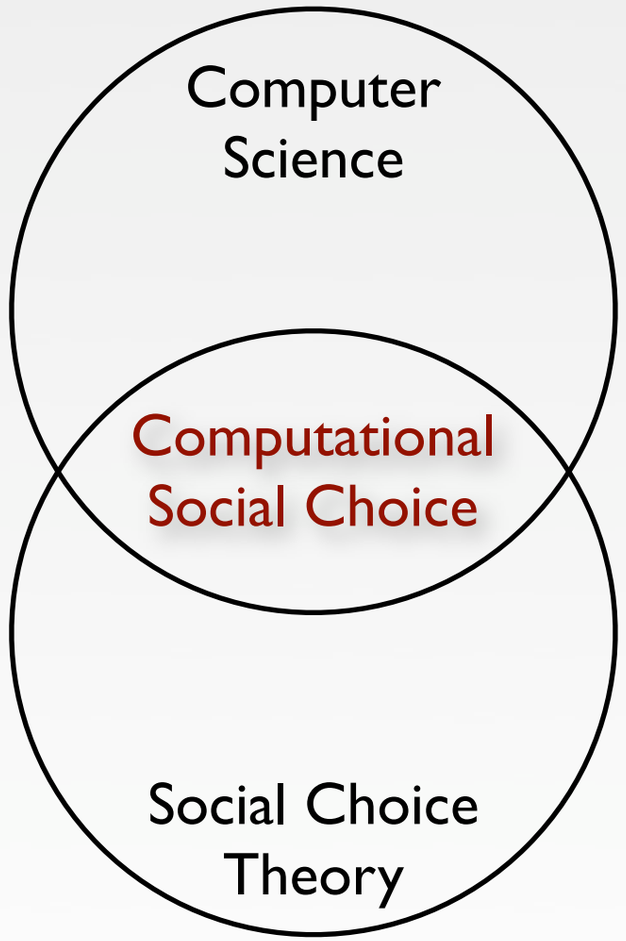
Computational Social Choice

- What is computational social choice?
  - A new interdisciplinary field of study at the interface of social choice theory and computer science
- What is social choice theory?
  - Social choice theory studies the aggregation of individual preferences
- Key concepts
  - Preference relation: typically transitive and complete
    - Set of preference relations over given set of alternatives A : $\mathcal{R}(A)$
  - Social welfare function $f : \mathcal{R}(A)^n \rightarrow \mathcal{R}(A)$
  - Social choice function $f : \mathcal{R}(A)^n \rightarrow A$
  - Social choice correspondence $f : \mathcal{R}(A)^n \rightarrow 2^A$

Computational Social Choice

- Bidirectional transfer
- Computer science ➠ Social choice
  - Apply complexity theory, algorithms, learning theory to problems of social choice
- Social choice ➠ Computer science
  - Import concepts from social choice to solve questions arising in AI (e.g., in societies of autonomous software agents), webpage ranking, or collaborative filtering



	Game Theory	**Social Choice Theory**
precursors	Cournot (1801-1877) Borel (1871-1956)	Condorcet (1743-1794) Borda (1733-1799)
early positive results	2-Player zero-sum games: security level (Minimax Theorem, v. Neumann, 1928)	Voting among 2 alternatives: majority rule (May's Theorem, 1952)
seminal monograph	*Theory of Games and Economic Behavior* (v. Neumann & Morgenstern, 1944)	*Social Choice and Individual Values* (Arrow, 1951)

Equivocality when more than 2 players/alternatives are involved
Various "solution concepts"

recent trend	"Algorithmic Game Theory"	"Computational Social Choice"

Project Participants

Principal Investigators:

AI TCS — Felix Brandt (University of Munich)

AI LOG — Ulle Endriss (University of Amsterdam)

AI — Jeffrey Rosenschein (The Hebrew University)

TCS — Jörg Rothe (University of Düsseldorf)

ECON — Remzi Sanver (Instanbul Bilgi University)

Associated Partners:

AI ECON — Vincent Conitzer (Duke University)

TCS — Edith Elkind (University of Southampton)

TCS LOG — Edith Hemaspaandra (Rochester Institute of Technology)

TCS — Lane Hemaspaandra (University of Rochester)

AI LOG — Jerome Lang (University of Toulouse)

ECON — Jean-Francois Laslier (Ecole Polytechnique Paris)

AI — Nicolas Maudet (Universite Paris-Dauphine)

Aims & Objectives

- Social choice and theoretical computer science
  - To deepen our understanding of algorithmic and complexity-theoretic issues in social choice
- Social choice and logic
  - To develop logic-based languages for modeling and reasoning about social choice problems and preference structures
- Social choice and artificial intelligence
  - To apply established techniques from AI, such as preference elicitation and learning, to problems of social choice

The Community

- Where do we meet?
  - International Workshop on Computational Social Choice (COMSOC)
    (coordinated by Ulle Endriss and Jerome Lang)
    - 1st COMSOC, Amsterdam, 6-8 December 2006
    - 2nd COMSOC, Liverpool, 3-5 September 2008
    - 3rd COMSOC, Sept.-Dec. 2010
  - Dagstuhl Seminars
    - Computational Issues in Social Choice, 21-26 October 2007
    - Computational Foundations of Social Choice, 7-12 March 2010

- Where do we publish?
  - Conference proceedings: AAAI, IJCAI, TARK, STOC, FOCS, AAIM, ...
  - Journals: AIJ, JAIR, SCW, MSS, JACM, TCS, ...
    - forthcoming MLQ special issue "Logic and Complexity in Computational Social Choice" (edited by Paul Goldberg and Jörg Rothe)

Main Topics

- Computational aspects of evaluating voting rules
  - Theorem (Bartholdi et al., 1989): There is no social welfare function that is neutral, consistent, Condorcet, and efficiently computable (unless P=NP).
  - Other issues: *efficient algorithms, approximation, exact computational complexity, etc.*
- Computational hardness of manipulation
  - Theorem (Bartholdi et al., 1989): There is a social welfare function that is easy to compute, but not efficiently manipulable (unless P=NP).
    - Moreover, this function is neutral, Condorcet, Pareto-optimal, etc.
  - Other issues: *few alternatives, weighted voting, typical-case, approximation, heuristics, other types of manipulation (agenda setting, bribing, using multiple identities, ...), etc.*

Main Topics (cont.)

- Computational aspects of fair division
  - How to fairly divide one or more goods among a set of agents
    - e.g., cutting a cake
  - Algorithmic complexity of division procedures
  - Indivisible goods (resource allocation)
- Social choice in combinatorial domains
  - Combinatorial structure gives rise to exponential growth
    - multiple referenda, committee election
  - Representation of preferences (e.g., graphical or logical)
    - CP-nets, weighted propositional formulas
    - important factors: *compactness, expressiveness, computational properties*

Main Topics (cont.)

- Computational aspects of coalitional voting games
  - Voting settings are often modeled as cooperative games (e.g., weighted threshold games)
  - Compact representation
  - Computational complexity of game-theoretic solution concepts
    - e.g., the core, Shapley-Shubik power index, Banzhaf power index
  - Manipulation and control
    - e.g., false identities/splitting weight, changing threshold, adding/deleting voters
- Epistemic issues in social choice
  - Incomplete preferences
  - Elicitation of preferences
    - Communication complexity
    - Privacy

The role of logic

- The axiomatic method in social choice theory
- Logic-based preference representation
- Social software
- Epistemic issues in social choice
  - Logic for belief and knowledge
- Logic and complexity
  - PH: 2nd-order logic, NP: existential 2nd-order logic,
    P: 1st-order logic with least fixed-point operator