Informed Decision-Making via Voting

Doctoral Consortium

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ABSTRACT

I study voting games where agents' preferences depend on a non-directly observable state variable. The decisions to be made are affected by the preferences, the noisy information on the state variable, and the (coalitional) strategic behaviors of the agents. My research demonstrates that strategic agents reach "good" decisions in majority voting. Under the majority rule, we show the equivalence between equilibria in the vote and behaviors that get the decision preferred by the majority as if the state variable is known to all. Furthermore, if a round of polling votes is conducted before the majority vote, the same "good" decision can be reached under a natural "informative + sincere" equilibrium. Future directions include a more generalized preference model, extending the results to more than two candidates, and studying more applications.

CCS CONCEPTS

• **Theory of computation** → **Algorithmic game theory**.

KEYWORDS

Computational Social Choice, Information Aggregation, Algorithmic Game Theory

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1 INTRODUCTION

Nowadays, voting is the most widely adopted method to make an array of collection decisions in every corner of life for every purpose, including public political elections, seeking the correct answer on crowdsourcing platforms, and jury decisions. In most cases, voting aims to aggregate the information and preferences of the voters and reach a decision representing the majority's wish.

Example 1.1. Suppose the community decides to vote on whether to accept more restrictive policies (Accept) or keep the status quo (Reject) towards an approaching COVID-19 pandemic. The consequence of the vote depends on the fact whether the pandemic is of High risk or Low risk. More voters tend to accept the restriction when the risk is High than when it is Low. The risk level cannot be observed directly. Instead, every voter receives a (noisy) private signal reflecting the risk level. Moreover, voters from different social groups have different intrinsic preferences and will act on their own interests. For example, youngsters may lean more to Reject than elders. **Can agents reach a "good" decision via voting?**

Three key challenges lie in answering such a question. Firstly, the preferences of agents depend on a state variable for which they only have noisy information. Therefore, they do not have full information on their preference. Secondly, agents play strategically and may collaborate on strategic behaviors. Finally, the individual preferences also vary from agent to agent.

When agents have the same objective of revealing the correct state (for example, jurors trying to discover the truth), the celebrated Condorcet Jury Theorem [2] shows that the majority rule can reveal the state with a high probability if all the agents honestly reflect their signal in the votes (named *informative voting*). However, such behavior fails to form a Nash Equilibrium, as shown by Austen-Smith and Banks [1]. The key idea is that an agent's vote only makes a difference when all other votes form a tie (named pivotal case). Therefore, strategic agents only care about their utility conditioned on the pivotal case, which (hypothetically) brings large information on the state variable. Austen-Smith and Banks' results attract a large literature to study strategic behaviors in binary voting under a game theoretical context. Wit [9] and Myerson [7] show the existence of equilibria to reveal the state with high probability.

When agents have diverse preferences, literature adopts the criterion of *informed majority decision*, which is the majority-vote decision to be made if every voter has full information of the state variable (and consequently, their preferences). Feddersen and Pesendorfer [4] show that the Nash equilibrium is unique and always leads to the informed majority decision. Schoenebeck and Tao [8] propose a mechanism incentivizing informative voting from agents and leading to the informed majority decision with high probability.

Nevertheless, two aspects remain unaddressed by the previous work. Firstly, previous works focus on Nash equilibrium which considers only individual strategic deviations, while agents can increase their impact on the votes by forming strategic coalitions with others. Secondly, previous work focuses on the existence of certain equilibrium reaching a " good decision". However, given the existence of the "bad" equilibria [9], i.e. those who do not reach the informed majority decision, it is uncertain which equilibrium agents will play. One response to multiple equilibria is to select one equilibrium more "natural" than another, namely *equilibrium selection.* However, such selection cannot guarantee that agents will play the more "natural" equilibrium, and the criterion of selection is sometimes unclear and subjective.

As a consequence, the following research question remains unanswered: **does binary voting always lead to the informed majority decision with coalitional strategic agents?**

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2 THE WISDOM OF STRATEGIC VOTING

We [5] give a surprising confirmative answer to this question under mild assumptions: coalitional strategic behaviors have a positive impact on achieving the informed majority decision and outperform classical non-strategic behaviors. We show that every equilibrium leads to the informed majority decision (with high probability), and every voting profile that leads to the informed majority decision is an equilibrium. This gives merit to strategic behavior in reaching good decisions. Our result extends to the setting with more than two world states and non-binary signals. We present the binary setting to convey the main idea without adding complexity.

Preliminaries. n agents vote between two alternatives, Accept **A** and Reject **R**, under the majority rule. There are two possible world states $W \in \{L, H\}$ (for Low risk and High risk respectively). The world state is not directly observable to the agents. Instead, each agent i receives a private signal $s_i \in \{\ell, h\}$. Signals of different agents are i.i.d. conditioned on the world state. An h signal is more likely to occur in world state H than in L. The prior on the world state and the signal distributions are common knowledge.

The utility of an agent is a function of the true world state and the voting winner. Agents can be categorized into three types based on their preferences. Predetermined agents prefer the same candidate regardless of the world state: friendly agents who always prefer **A** and unfriendly agents who always prefer **R**. The third type is contingent agents who prefer **A** in state H and **R** in state L.

The *informed majority decision* is the majority vote outcome as if the world state is common knowledge. We focus on the scenario where no predetermined agents can dominate the vote. Therefore, the informed majority decision is **A** when the world state is H and **R** when the state is L, which aligns with the contingent agents.

The strategy of an agent σ_i is a mapping from their signal to a distribution on $\{\mathbf{A}, \mathbf{R}\}$, and a strategy profile is a vector of strategies of all n agents. For a strategy profile Σ, $A(\Sigma)$ is the likelihood that the profile reaches the informed majority decision, named *fidelity*.

A strategy profile Σ is an ε-strong Bayes-Nash Equilibrium (BNE). if there does not exist a group of deviators D and a deviating strategy such that (1) all deviators get non-decreasing expected utility after deviation and (2) the expected utility of at least one deviator increases by ε. The ε-approximation is adopted because the non-approximated strong BNE may not always exist.

Our asymptotic results consider a sequence of strategy profiles $\{\Sigma_n\}_{n=1}^{\infty}$ that share the same common prior, signal distribution, and the fraction of each type of agents. For the majority vote, we focus on strategies where predetermined agents always vote for their preferred candidates.

Theorem 2.1 (Han et al. [5]). *Given an arbitrary sequence of profiles $\{\Sigma_n\}$, if $A(\Sigma_n)$ converges to 1 as n goes to infinity, then for every n, Σ_n is a ε-strong BNE with $\varepsilon = o(1)$; if $A(\Sigma_n)$ does not converge to 1, there exist a constant ε and infinitely many n such that Σ_n is NOT an ε-strong BNE.*

Theorem 2.1 provides a strong guarantee on strategic voting reaching a good decision. No matter what equilibrium strategic agents play, the informed majority decision is reached with high probability, and there is no need to worry about "bad" equilibria and equilibrium selection. On the contrary, informative voting achieves informed majority decisions only when a stronger assumption is enforced. In this way, we claim that strategic voting "prevails" the non-strategic behaviors.

3 THE ART OF TWO-ROUND VOTING

While equilibria in the majority vote always reach "good" decisions, they are usually asymmetric or mixed and difficult to calculate. This motivates us to find more natural equilibriums under new voting schemes. We [6] show the existence of such equilibrium reaching "good" decisions when a polling stage is added before the voting.

In the two-round voting mechanism, agents first cast a polling vote. The first round does not decide the winner, but agents observe the counts of votes for each candidate. Then, agents cast the second-round majority vote that decides the winner. A strategy in the two-round voting consists of two parts. The first-round strategy maps an agent's signal to their first-round vote. The second-round strategy maps the signal and the first-round outcome to their second-round vote. The definition of ε-strong BNE is updated accordingly.

Every equilibrium in the two-round mechanism also leads to the informed majority decision with high probability. Moreover, we reveal the natural "informative + sincere" equilibrium that combines classic non-strategic behaviors studied in [1]. In such an equilibrium, contingent agents vote informatively (reveal their signals) in the first round and sincerely (vote for the candidate that is more likely the informed majority decision) in the second round.

Theorem 3.1 (Han et al. [6]). *The "informative + sincere" profile has fidelity converging to* 1 *and is a ε-strong BNE with $\varepsilon = o(1)$.*

The idea behind the equilibrium is simple. Informative voting in the first round helps the agents to reveal the world state almost surely. Theorem 3.1 implies that communication benefits aggregation by "simplifying" the equilibrium.

4 PROSPECT AND FUTURE DIRECTIONS

The prospect of my line of research is to provide theoretical guarantees (and possibly empirical supports) on the capability of majority voting to reach informed, fair, efficient, and incentive-aware group decisions in a wide range of uncertain environments, as far and clear as possible. Majority voting is the most widely applied and accepted scheme to aggregate preference and make collective decisions, yet its outcome is not as straightforward as it may seem. A clear picture of the strategic behaviors and the outcome of the vote provides helpful perspectives on when and how "good" decisions are to be made and eventually benefits the stakeholders.

There are multiple future directions I plan to look at. Firstly, I would like to incorporate agents with a generalized utility model. For example, Deng et al. [3] studies strategic behaviors when there are two types of contingent agents whose preferences are opposite. It will be interesting to build up a full spectrum of agents' preferences. Secondly, existing literature in this line of work is restricted to binary voting, i.e. voting with two candidates. It will be an interesting yet challenging task to extend the analysis to settings with more than two candidates. Finally, I would like to leverage the theoretical findings to study more applications of voting, such as community notes and peer review.

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