A Qualitative Decision-Making Approach Overlapping Argumentation and Social Choice

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Abstract. Collective decision making is classically done via social choice theory with each individual expressing preferences as a (total) order over a given set of alternatives, and the group's aggregated preference is computed using a voting rule. However, such methods do not take into account the rationale behind preferences. Our research hypothesis is that a decision made by participants understanding the qualitative rationale (i.e., arguments) behind each other's preferences has better chances to be accepted and used in practice. To this end, we propose a novel qualitative decision process which combines argumentation with computational social choice. We show that a qualitative approach based on argumentation can overcome some of the social choice deficiencies.

1 Introduction

Taking decisions is a part of our everyday life. From the simplest ones, e.g., choosing which movie we are going to watch in the theater, to the most complex ones, e.g., selecting a government, a decision has to be made. The way to achieve a decision though can be a very complex task. Usually decision makers make their decisions based on different criteria and aspects that they consider to be important. One should wonder then what happens when we want to take a justified and fair collective decision, which leads us to the following questions. *How do agents form their thoughts and reason their preferences?* How should we aggregate them in order to have a democratic collective decision? That is the problem we are dealing with in this paper.

The commonly used way of making such a collective decision is using social choice theory. Each agent of the group expresses her preference as a total order over a set of alternatives, and then the group's preference is computed from the individual preferences using a voting rule. In the classical voting, the collective decision is computed from quantitative methods by taking into account only the agents' preferences without knowing why the agents have these preferences and what is the rationality behind it. Thus, classical social choice presents a framework where the justifications for the agents' preferences are not considered.

We believe that qualitative methods where humans can understand the reasoning behind the preferences have more chances to be accepted.This gives us the motivation to combine Argumentation with Computational Social Choice: we believe that enriching the collective decision making procedure with an argumentation framework will provide the explanation behind the decision. To this end, we are placing the decision problem within the boundaries of an *abstract argumentation framework*. Abstract argumentation provides a flexible and robust tool for non-monotonic reasoning. It was introduced by Dung [4] and is based on the evaluation of interacting entities called arguments. The argumentation systems are represented by graphs, where the nodes represent the arguments and the edges represent the attacks, or conflicts, between them. Various semantics defined by Dung and other researchers have been proposed to identify coherent sets of arguments, which are based on the attack relations between them.

In our problem, the decision to be recommended lies on a set of *alternatives*. The decision will be derived from the justified preferences of the set of *agents* over the alternatives. The justified preferences are the outcome of a deliberation phase where each agent reveals her preferences and their justifications. The collection of agents' rankings is known as *preference profile*. The preference profile of the agents and the justifications are used to build an argumentation framework that will help us build the *justified preference profile*, which includes the preferences produced after the deliberation and corresponds to the different collective viewpoints of the agents. The objective is to fairly aggregate the justified viewpoints by using a *voting rule*.

The classical problem in social choice theory is which voting rule is the most appropriate for aggregating the preference profile. Unfortunately, due to the impossibility results by Arrow [1] and Gibbard-Satterthwaite [5, 6] there is no hope of finding a voting rule that can be "perfect". Despite that, social choice theory has enhanced our perception among proposed voting rules, where each of them has different characteristics, qualities and weaknesses. One of the most prominent rules in the history of social choice, and which is generally acclaimed as a founding method of the field, is the one proposed by the Marquis de Condorcet. The *Condorcet method* [3] relies on comparisons between each pair of alternatives. An alternative x is said to beat alternative y in a *pairwise election (comparison)* if a majority of agents prefer x to y, i.e. rank x above y. The alternative who beats every other alternative in a pairwise comparison is the winner. Unfortunately, there are preference profiles where the collective preferences are cyclic, i.e., not transitive. For example if we have 3 alternatives x, y, z and the results of the pairwise comparisons are: x beats y, y beats z and z beats x then we say that a *voting cycle* occurs. This contradictory phenomenon is known as the *Condorcet paradox* [2]. Despite this paradox, the Condorcet criterion is widely acclaimed as the most intuitive way of voting and it is the aim of this paper to provide an approach that always avoids the Condorcet paradox thanks to the construction of justified preference profiles.

2 Preliminaries

Social Choice Theory. We consider a set of $N = \{1, \ldots, n\}$ *agents* and a set of *alternatives* A, $|A| = m$. Each agent $i \in N$ has preference relations ($\succ$) over the alternatives denoted with $x \succ_i y$ which means that agent i *prefers* alternative x to y. We define that each preference relation satisfies transitivity and hence, the set of all the preference relations for agent i produces a linear (total) order $\succ_i$ on A, i.e., the ranking of agent i over the alternatives. Let $\mathcal{L}_A$ be the set of linear orders over A. A *preference profile* $\succ_{PP} = \langle \succ_1, \ldots, \succ_n \rangle \in \mathcal{L}_A^n$ is a collection of the linear orders for all the agents. A *voting rule* is a mapping $f : \mathcal{L}_A^n \to 2^A \setminus \{\emptyset\}$ from preference profiles to nonempty subsets of alternatives, which designates the winner(s) of the election. For two candidates $x, y \in A$, and $\succ_{PP} \in \mathcal{L}_A^n$, alternative x *beats* y in a *pairwise comparison* if $|\{i \in N : x \succ_i y\}| > n/2$, that is, if a (strict) majority of agents prefer x to y. A well-known voting rule is the *Condorcet method*: the *Condorcet winner* is an alternative that beats every other alternative in a pairwise comparison. The *Condorcet paradox* is a situation in which collective preferences can be cyclic (i.e. not transitive), even if the preferences of individual agents are not cyclic. A *voting cycle* occurs when we have 3 alternatives x, y, z such that $|\{i \in N : x \succ_i y\}| > n/2$, $|\{i \in N : y \succ_i z\}| > n/2$, and $|\{i \in N : z \succ_i x\}| > n/2$.

Argumentation. In order to be general with regards to the deliberation step, we are using the abstract argumentation framework proposed in [4]:

Definition 1 (Argumentation framework). *An argumentation framework (AF) is a pair* $(\mathbf{A}, \mathbf{R})$*, where* $\mathbf{A}$ *is a finite nonempty set of arguments and* $\mathbf{R}$ *is a binary relation on* $\mathbf{A}$*, called attack relation. Let* $a, b \in \mathbf{A}$*,* $a\mathbf{R}b$ *means that* a *attacks* b *.*

The coherent sets of arguments (called "extensions") are determined according to a given semantics whose definition is usually based on the following concepts:

Definition 2 (Conflict-free set, defense and admissibility). *Given an AF* $(\mathbf{A}, \mathbf{R})$*, let* $a \in \mathbf{A}$ *and* $\mathcal{S} \subseteq \mathbf{A}$*,*

- $\mathcal{S}$ *is* conflict-free *iff there does not exist* $a, b \in \mathcal{S}$ *such that* $a\mathbf{R}b$*.*
- $\mathcal{S}$ defends *an argument* a *iff each attacker of* a *is attacked by an argument of* $\mathcal{S}$*.*
- $\mathcal{S}$ *is an* admissible set *iff it is conflict-free and it defends all its elements.*

Definition 3 (Semantics). *Given an AF* $(\mathbf{A}, \mathbf{R})$*, let* $\mathcal{E} \subseteq \mathbf{A}$*.* $\mathcal{E}$ *is*

- *a* complete *extension iff* $\mathcal{E}$ *is an admissible set and every argument which is defended by* $\mathcal{E}$ *belongs to* $\mathcal{E}$*.*
- *a* preferred *extension iff* $\mathcal{E}$ *is a maximal admissible set (wrt set inclusion* $\subseteq$*).*
- *the* grounded *extension iff* $\mathcal{E}$ *is a minimal (wrt* $\subseteq$*) complete extension.*
- *a* stable *extension iff* $\mathcal{E}$ *is conflict-free and attacks any argument* $a \notin \mathcal{E}$*.*

Given a semantics, the set of extensions of $(\mathbf{A}, \mathbf{R})$ *is denoted by* $\mathbf{E}$*.*

It should be noted that in this paper we focus on the preferred semantics since it ensures the existence of at least one extension, which is needed since extensions will be used as voters, and their maximality, which ensures that each extension represents a full ranking over the alternatives. Other semantics will be considered in future work.

3 A Decision Model Based on Justified Preferences

In the proposed model we are considering the case of taking a decision using a qualitative argumentative approach and voting theory. Observe that the suggested process is an argumentative approach that relies on combining the qualitative preferences and not a voting rule whose role is to aggregate the individual preferences with quantitative methods. In our problem we have a set of alternatives and the agents whose justified preferences over the alternatives will determine the decision to be taken. Each agent provides a justification for each of the preference relations on the alternatives and we demand the preference relations to be transitive so a ranking with the preferences of the agent is built. We use this information to formulate arguments which express the agents' preferences. More precisely, we are going to distinguish between three types of arguments: *preference relation* arguments, *ranking* arguments and *generic* arguments.

Preference relation arguments. A preference relation argument a_{xy} represents a *justification* given by an agent to consider the preference $x \succ y$. Note that we may have multiple a_{xy} arguments, in the case where some agents have different justifications for the preference $x \succ y$. The set of preference relation arguments is denoted $\mathbf{A}_P$.

It should be noted that due to what they represent, the arguments a_{xy} and a_{yx} cannot be considered together in a coherent view point since they are "opposed". Consequently, we assume that those arguments attack each other.

Ranking arguments. A ranking argument represents one of the possible ranking over the considered alternatives. It is important to note that in our setting, we always consider all the possible ranking arguments; it will be the agents' prerogative to justify why a ranking should not be considered as we will see below. We denote by $\mathbf{A}_R$ the set of all the possible ranking arguments and by $\mathbf{A}_{R_{x\cdots y}}$ the set of ranking arguments where the preference $x \succ \cdots \succ y$ is satisfied. Moreover, we define a special ranking argument $a_\emptyset$ that represents a ranking without preference; it can be seen as the blank vote resulting from either non-transitive preference relations or no justified preferences.

Like preference relation arguments, we consider ranking arguments as mutually inconsistent. For this reason, we assume that ranking arguments attack each other, with the exception of $a_\emptyset$ that attacks no argument. In this way, we represent the fact that having a reason to consider a ranking forbids the possibility of considering blank voting. Furthermore, ranking arguments can be attacked by preference relation arguments. Indeed, giving a justification for $x \succ y$ (i.e. giving an argument a_{xy}) is a reason for ignoring the rankings with $y \succ x$ (i.e. $\mathbf{A}_{R_{yx}}$): a_{xy} is attacking the elements of $\mathbf{A}_{R_{yx}}$.

Generic arguments. Generic arguments regroup all the other possible arguments that can arise during a debate. In particular, those arguments are only able to attack other generic arguments and preference relation arguments (for instance if the reason given for considering $x \succ y$ is itself justified to be wrong). It is important to note that while the flexibility offered by the abstract argumentation setting is convenient for its generality, it can also lead to undesirable behaviors. Hence, we propose the following restriction.

Axiom 1 (Independence of preference justifications) *Given two preference relation arguments a_{xy} and a_{uv}, such that $\{x, y\} \neq \{u, v\}$, then there is no generic argument a_g such that both paths of attacks from a_g to a_{xy} and from a_g to a_{uv} exist.*

The intuition is that the discussions about each pairwise preference are independent, i.e. a generic argument cannot have an impact on preferences over different alternatives.

Computing the justified profile. Using the arguments and attacks shown above in an argumentation framework, it is possible to compute the sets of "coherent preferences", represented by the extensions. Hence, it is important to remark that this process allows to move from the direct aggregation of agents' preferences to the aggregation of rational and justified preferences (and their corresponding rankings).

More precisely, multiple extensions are computed (unless there is a consensus among the agents). Each extension contains preference relation arguments and a single ranking argument which corresponds to a coherent aggregation of possible preference relations with their justifications. Hence, it is now possible to consider the extensions as (virtual) voters and aggregate their rankings. We consider the ranking of each extension (except if the extension contains the blank vote) as a *justified preference* $\mathcal{JP}_k$. The set of justified preferences is denoted by $\mathcal{JP}$; hence, $|\mathcal{JP}| = |\boldsymbol{E} \setminus \{\mathcal{E} \in \boldsymbol{E} : a_\emptyset \in \mathcal{E}\}|$. Each justified preference has preferences over the alternatives denoted with $x \succ_{\mathcal{JP}_k} y$ which means that justified preference $\mathcal{JP}_k$ *prefers* alternative x to y. Informally, the collective justified preference profile is the set of all the justified preferences.

Definition 4 (Justified preference profile). *A* justified preference profile $\succ_{\mathcal{JP}} = \langle \succ_{\mathcal{JP}_1}, \ldots, \succ_{\mathcal{JP}_{|\mathcal{JP}|}} \rangle \in \mathcal{L}_A^{|\mathcal{JP}|}$ *is a collection of linear orders for all the justified preferences.*

As noted before, the justified preference profile can have multiple justified preferences (extensions) so we refer to classical social theory for aggregating them. The construction of the justified preference profile allows to avoid the Condorcet paradox.

Theorem 1. *There are no voting cycles in any justified preference profile under the preferred semantics.*

4 Conclusion and Future work

In this paper, we have proposed a framework for decision-making using qualitative preferences instead of social choice methods which rely only on the quantitative aggregation of the individual preferences. The method allows to take into account the justifications behind these preferences, and compute the collective justified preferences which allows to overcome the Condorcet paradox.

As future work, we want to extend our research on Argumentation and Computational Social Choice towards multi-criteria decision-aiding. The combination of these two fields will allow to explain the decisions rationally, which may allow for decisions procedures that will have more chances to be accepted by the society. To strengthen this view we plan to propose quantitative methods that can evaluate the different decision-making procedures, in particular in the context of real world examples.

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