Participatory Budgeting Project Strength via Candidate Control

Extended Abstract

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ABSTRACT

We study the complexity of candidate control in participatory budgeting elections. The goal of constructive candidate control is to ensure that a given candidate wins by either adding or deleting candidates from the election (in the destructive setting, the goal is to prevent a given candidate from winning). We show that such control problems are NP-hard to solve for many participatory budgeting voting rules, including Phragmén and Equal-Shares, but there are natural cases with polynomial-time algorithms (e.g., for the GreedyAV rule and projects with costs encoded in unary). We also argue that control by deleting candidates is a useful tool for assessing the performance (or, strength) of initially losing projects.

KEYWORDS

Participatory Budgeting; Election Control; Project Performance

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1 INTRODUCTION

Participatory budgeting is a recent democratic innovation where cities allow their inhabitants to decide about a certain fraction of their budgets [9, 15, 23]. Specifically, some of the community members propose possible projects to be implemented and, then, all the citizens get a chance to vote as to which of them should be funded. Most commonly, such elections use approval ballots, where people indicate which projects they would like to see funded, and the GreedyAV rule, which selects the most approved projects (subject to not exceeding the budget). However, there also are more advanced rules, such as Phragmén [8, 18] or Equal-Shares [21, 22], which produce arguably more fair—or, to be precise, more proportional—decisions [12]. Yet, with more advanced rules come issues about understanding the results. Indeed, recently Boehmer et al. [6] have argued that proposers whose projects were rejected may find it quite difficult to understand the reason for this outcome. To alleviate this problem, they introduced a number of performance measures—mostly based on the bribery family of problems [13, 14]—that attempt to answer the following question: As a proposer of a project that was not funded, what could I have done differently to have it funded? For example, they ask if the project would have been funded if its cost were lower (see also the work of Baumeister et al. [2]), or if its proposer convinced more people to vote for it, or if the proposer motivated some voters to only approve his or her project. Similar bribery-style problems were also used to evaluate the robustness of election results [3–5, 7, 24], or the margin of victory for the winners [19, 25].

In this paper, we follow-up on these ideas, but using candidate control. The main difference is that instead of focusing on circumstances that depend on a project's proposer (indeed, the project's cost is his or her choice, and it is his or her choice what support campaign he or she runs), we focus on external ones, independent of his or her actions (such as some other projects being submitted or not—we disregard the possibility that a proposer might try to discourage other people from proposing projects, albeit we acknowledge that this may happen. In fact, this might even be quite benign: A group of activists focused on making their city more green may discuss among themselves which projects to submit and which to withhold.). Looking at both types of reasons for a project's rejection gives a more complete view of its performance.

Candidate Control. The idea of the control-in-elections family of problems is that we are given a description of an election, a designated candidate, and we ask if it is possible to ensure that this candidate is a winner (in constructive control) or ceases to be a

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Table 1: An overview of our complexity results. In the first column, we list the rules we are interested in. The other columns contain the complexity classification of our problem in one of the three variants: by `unit`, we mean that all input projects are of the same price, `unary` stands for cases where the costs are of size polynomial in $n + m$, and `binary` applies for the variant where costs need to be encoded in binary (and hence can be exponential in n and m). By Del (Add, respectively), we mean that the control operation is project deletion (addition). The complexity classification is the same for both constructive and destructive objectives. Results marked with ‡ hold even if the control is weighted and projects' weights are encoded in binary.

	`unit`		`unary`		`binary`	
	Del	Add	Del	Add	Del	Add
GreedyAV	P‡	P‡	P‡	P‡	NP-complete	NP-complete
GreedyCost	P‡	P‡	P‡	P‡	NP-complete	NP-complete
Phragmén	NP-complete	NP-complete	NP-complete	NP-complete	NP-complete	NP-complete
Equal-Shares	NP-complete	NP-complete	NP-complete	NP-complete	NP-complete	NP-complete

winner (in destructive control) by modifying the structure of the election [1, 14]. Specifically, researchers consider control by adding or deleting either candidates or voters (some papers—including the one that introduced election control [1]—also consider various forms of arranging run-off elections as a type of control). So far, election control was mostly studied theoretically, with a focus on the complexity analysis [1, 10, 16, 17, 20, 26], but some empirical results exist as well [11]. We study candidate control in participatory budgeting, that is, we ask if it is possible to ensure funding of a given project (or, preclude its funding) by either adding new projects—from some a'priori known set of projects—or by deleting them. Our results are theoretical and focus on the complexity of our problems, but we motivate them by project performance analysis. As our performance analysis is based on control by deleting projects, we pay most attention to results regarding this variant of control, and we include the addition case for the sake of completeness and to be in sync with the preceding literature.

Performance Analysis. Let us now discuss how one could use control by deleting candidates to analyze the performance of projects in participatory budgeting (we will use the terms projects and candidates interchangeably, e.g., using "candidates" in the names of control problems). Consider a participatory budgeting election and some not-funded project p. One basic measure of its performance is the smallest number of other projects that have to be removed from the election for p to be funded. The lower this number, the closer was the project to winning: Indeed, perhaps some proposers only managed to submit their projects in the last minute and it was possible that they would have missed the deadline, or some projects were close to be removed from the election due to formal reasons, but the city officials were not strict in this regard. However, it is more likely that such issues would affect cheaper projects than the more expensive ones—which, likely, had more careful proposers—so instead of asking for a smallest set of projects to delete, we may ask for a set with the lowest total cost.

Another way of using control by deleting projects to assess a project's performance is to use probabilistic approach, along the lines of the one taken by Boehmer et al. [4, 5], and Baumeister and Hogrebe [3] for bribery: We ask for the probability that project p is funded assuming that a random subset of projects (of a given cardinality) is removed. The higher it is, and the lower is the number of removed projects, the closer was project p to winning.

A different interpretation of the above measures is that instead of thinking that some projects "barely made it" to participate in the election, we learn how many projects performed better than p. The more projects we need to delete to have p funded (or, to have p funded with sufficiently high probability), the more projects can be seen as critically stronger than p.

Finally, we can use candidate control as a way of assessing rivalry between projects. For example, if project p has a much higher probability of being funded after deleting a random set of projects under the condition that some other project q was included in this set, then we can view q as a strong rival of p.

Contributions. Our results regard the complexity of candidate control for four well-known voting rules, depending on how the costs of the projects are encoded (either in binary, in unary, or as unit costs, which means that each project costs the same amount). We show the overview of our results in Table 1. For Phragmén and Equal-Shares, our results are quite negative—even if all the projects are of cost one, computing an optimal control is NP-hard. For GreedyAV and GreedyCost, the results are much more positive. If projects' costs are encoded in unary, which is the case for most real-life instances, then an efficient algorithm exists. Only if we allow exponential costs, computing control becomes intractable.

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