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Report on the Doctoral Dissertation of Grzegorz Pierczyński

This is my report on the doctoral dissertation of Grzegorz Pierczyński, entitled "Proportional Participatory Budgeting", which the candidate submitted for consideration to the Faculty of Mathematics, Informatics and Mechanics at the University of Warsaw.

Summary. The dissertation is concerned with the design and analysis of mechanisms for selecting projects to be funded in a participatory budgeting exercise on the basis of the votes submitted by citizens. Aside from an introductory chapter outlining and motivating the work, a chapter recalling the details of the familiar mathematical model of voting in participatory budgeting, and a brief concluding chapter at the end, the material is organised in two parts.

The first part is concerned with the development and analysis of the so-called Method of Equal Shares, a voting rule for participatory budgeting in which the voters are endowed with a virtual currency and projects are purchased in sequence from the currency held by their supporters, in a manner that tries to balance payments across supporters as much as possible. This novel method is superior to the standard method currently used for almost all participatory budgeting exercises across the world, as it can achieve a level of proportionality the standard method cannot. The method is defined and analysed both for the (most common) case of elections in which citizens vote by approving a subset of the available projects and the case where citizen vote by providing ordinal rankings of the projects. A shortcoming of the method is that, in its basic form, the method is not exhaustive, meaning that it will often not spend all of the available budget. Several different methods for completion are investigated, and the method of successively increasing the virtual budget is found to perform best.

The second part of the thesis explores several demanding desiderata for methods of participatory budget that go beyond what the Method of Equal Shares can provide. Specifically, the focus is on notions of proportionality that go beyond the more established notions of proportionality discussed in the first part. While it is possible to

design methods that outperform the Method of Equal Share in view of very specific such desiderata, the overall conclusion is nonetheless that the Method of Equal Shares provides the currently best available compromise between ease of use and offering strong (though not necessarily *the* strongest) proportionality guarantees.

In methodological terms, the thesis combines algorithmic, axiomatic, and data-oriented approaches. Regarding the algorithmic perspective, concrete implementable algorithms are provided for the methods discussed, and there is an emphasis on seeking methods that can be computed in polynomial time. The axiomatic method, originating in economic theory, is used to provide a formal analysis of the fairness properties different methods of allocating the budget can provide. Normative properties are defined in formal unambiguous ways, and specific methods are proven to either satisfy or fail those properties. Finally, the same methods are also evaluated on data, both synthetic data and data of real-world participatory budgeting elections, to understand how well a given method does in term of desiderata that might not be fully satisfied in theory but with respect to which it might still perform reasonably well in practice. In fact the collection of this data, and the making available fo that data though the Pabulib.org site, is in itself an important service to which the candidate has contributed in the course of the work on his doctoral dissertation.

Publications. The dissertation is based on four distinct peer-reviewed publications that have appeared in the archival proceedings of international conferences, namely the AAAI Conference on Artificial Intelligence, the International Joint Conference on Artificial Intelligence, the Annual Conference on Neural Information Processing Systems, and the Conference on Web and Internet Economics.

These are all first-rate publication venues, and overall this represents a very good publication record for someone nearing the end of their doctoral studies. The recognition of the scientific community for the work done, as evidenced by these publications, provides an important additional signal for quality.

Impact. Participatory budgeting is an important and timely research topic, given the increased use of participatory budgeting as tool to improve both democratic participation and the quality of public spending decisions across the world. The significance is particularly high in the Polish context, given that Polish law stipulates that a particularly high proportion of the public budget must be invested into such schemes.

Remarkably, the main method developed in and advocated by the dissertation already has been fielded in practice, in two Polish and one Swiss community. This is a great example demonstrating the potential for the immediate relevance of deep work in theoretical computer science to our everyday lives. The candidate and his supervisor are to be commended for having achieved this kind of direct link between theory and practice.

Evaluation. The dissertation presents a comprehensive investigation of a clearly delineated subject: the design and systematic analysis of a method for participatory budgeting that satisfies demanding requirements in terms of proportionality (i.e., treating

all groups of voters fairly) while having low computational complexity and being easy to adapt to different settings (specifically, to different formats for representing the preferences of voters). The design of the Method of Equal Shares presents an important contribution, and the comprehensive analysis of the method is convincing and insightful.

The dissertation impresses with both its technical depth and its breadth of perspectives. Regarding the latter, the combination of axiomatic work with a rich study of the behaviour of the methods considered on real-world data is particularly commendable.

The quality of presentation of the dissertation is very good. It has been thoughtfully written and carefully edited. The use of examples is particularly helpful.

Recommendation. On the basis of the findings described in this report, I recommend that the candidate be given the opportunity to defend his dissertation in public and subsequently be awarded the doctoral degree.

Completed on the 23rd of February 2024 in Amsterdam.

Ulle Endriss