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SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: CA 16228 – European Network for Game Theory
STSM title: Research on the interplay of strategic behavior and fairness in resource allocation
STSM start and end date: 25/11/2018 to 01/12/2018
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PURPOSE OF THE STSM:

The purpose of this short-term scientific mission has been to initiate a joint effort between the applicant, Ioannis Caragiannis, Associate Professor at the University of Patras, and the host, Maria Kyropoulou, Lecturer at the University of Essex, on the study of resource allocation mechanisms under the lens of game theory. In spite of the extensive recent focus on well-established fairness concepts, our joint work focuses on defining novel fairness concepts that have a nice interplay with efficiency and could be robust against strategic behavior. In particular, our application mentions the goals of simple allocation mechanisms that reach fair and/or efficient outcomes, the investigation of the potential of truthful mechanisms, as well as the deviation of standard deterministic notions to more stochastic ones and the definition of appropriate fairness notions. We have made much progress in the third direction and have initiated a study of the other two.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSM

In a fundamental setting for resource allocation, we have m items and n agents with valuations for each item. The valuations of each agent are additive and the value of the agent for a set (bundle) of items is simply the sum of her values for the items in the set. An allocation is a partition of the items into n bundles so that the i-th bundle is allocated to agent i. Well-known properties such as proportionality or envy-freeness aim to assess whether the allocation is fair for the agents. For example, an allocation is called envy-free when every agent prefers the bundle of items that is allocated to her to the bundle of any other agent. In proportional allocations, every agent feels she has received a fair share of all the items, i.e., a bundle of value at least the $1/n$-th of her value for all items. Recent work has extended these notions to scenarios where the awareness level of the agents about the allocation is limited. For example, the information that is available to an agent in order to conclude whether she considers an allocation as fair or unfair might be restricted by an underlying social graph; an agent may have access to the bundles of agents who are neighbors in the social graph and no access to the remaining bundles.

Despite extensive recent activity on fairness issues in the above setting, research has focused on deterministic allocations and has neglected randomness. For envy-freeness, this is probably due to the fact that the two obvious definitions for random allocations have severe limitations. For example, an ex-post definition of envy-freeness that requires envy-freeness for every realization of a random allocation is as restrictive as its deterministic version. In contrast, an ex-ante definition, that requires envy-freeness with respect to expected values of every agent for her bundle and the bundles allocated to other agents, is not interesting at all: an allocation that selects equiprobably one agent and gives all items to her is ex-ante envy-free.

Motivated by models of incomplete information in game theory, we have introduced new fairness concepts that are appropriate for (distributions of) random allocations. Our main starting point is the following notion of distributional envy-freeness (DEF): A random allocation is DEF if for every pair of agents i and j and every possible realization B of the bundle of items that is allocated to agent i, her value for B is higher than or equal to her expected value for the bundle of items that is allocated to agent j (given that she gets bundle B). In a sense, DEF combines the notions of ex-post and ex-ante envy-freeness that were mentioned above in a way that leads to a very interesting novel fairness concept. Our primary focus during this STSM has been on defining the notion and further extending it by taking into account awareness of agents about the outcomes of the allocation and social relations, and on relating it to fairness concepts for deterministic allocations.

DESCRIPTION OF THE MAIN RESULTS OBTAINED

Consider a resource allocation instance consisting of m items and n agents with valuations for the items. We say that a fairness concept F1 implies fairness concept F2 if every resource allocation instance that admits an F1 allocation also admits an F2 allocation. Usually, such proofs are easy and apply on allocations. For example, envy-freeness implies proportionality in the sense that every envy-free allocation is also proportional. Showing that some implication does not hold is slightly more demanding. For example, in order to show that F1 does not imply F2 in general, we need to construct an instance that has an F2 allocation but no F1 allocation.

We have used these definitions to locate DEF in the known hierarchy of implications (see [2]) between fairness concepts for deterministic allocations. Obviously, DEF is implied by envy-freeness. It also implies proportionality. Its definition is such that every allocation in the support is proportional. The three notions coincide for two agents. For three or more agents, both implications are strict. DEF is incomparable to min-max-fairness (defined in [2]) and epistemic envy-freeness (introduced in [1]). The counter-examples are simple but nice.

We have also refined DEF to obtain a variation that takes into account social relations of the agents. In particular, the property G-DPEF uses a social graph G and requires that agent i is DEF with her neighbors in G and proportional with her non-neighbors. This can be though of as the randomized counterpart of the recently introduced fairness concept G-PEF in [1]. G-PEF implies G-DPEF. We have managed to characterize all social graphs G in which this implication is strict; this includes all graphs besides a few very specific ones. We have also shown a rich hierarchy with G-DPEF depending on the social graph used: G-DPEF implies H-DPEF when H is a subgraph of G and this subgraph relation is necessary for this implication.

[1] H. Aziz, S. Bouveret, I. Caragiannis, J. Lang, I. Giagkousi. Fairness, knowledge, and social constraints. Proceedings of the 32nd AAAI Conference on Artificial Intelligence (AAAI), pages 4638-4645, 2018.
[2] S. Bouveret and M. Lemaitre. Characterizing conflicts in fair division with indivisible goods using a scale of criteria. Autonomous Agents and Multiagent Systems, 30(2): 259-290, 2016.

FUTURE COLLABORATIONS

We plan to continue our work on the fairness concept of DEF. We currently investigate the frequency of instances (with agent valuations for items drawn independently from a common distribution) that admit DEF. We believe that it would be interesting to see how this frequency relates to known results for envy-freeness and proportionality (e.g., in [5] and [6]). Also, we plan to investigate simple mechanisms for achieving (approximate notions of) DEF that can also guarantee some guarantee of efficiency. An example of such a mechanism is the following randomized version of the draft mechanism (see [4]) using a random permutation of the agents. Agents, are asked in a round-robin fashion according to this permutation to pick their best available item. Finally, combining the study of DEF in settings that involve strategic agents is part of our current investigation as well. Proving statements that quantify the interplay of fairness, efficiency, and strategic behavior, along the general lines of our previous joint work [3], is among our future plans.

[3] I. Caragiannis, D. Kurokawa, H. Moulin, A. Procaccia, N. Shah, and J. Wang. The unreasonable fairness of maximum Nash welfare. ACM Transactions of Economics and Computation, 2019, forthcoming.

[4] I. Caragiannis, C. Kaklamanis, P. Kanellopoulos, and M. Kyropoulou. The efficiency of fair division. Theory of Computing Systems, 50(4): 589-610, 2012.
[5] P. Manurangsi and W. Suksompong. When do envy-free allocations exist? Proceedings of the 33rd AAAI Conference on Artificial Intelligence (AAAI), 2019, forthcoming.
[6] W. Suksompong. Asymptotic existence of proportionally fair allocations. Mathematical Social Science, 81: 62-65, 2016.