Two-sided Matching with Diversity Concerns: An Annotated Reading List

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Diversity concerns come up in many important decision making settings including two-sided matching, in particular centralized student admission matching. We overview papers on the topic of two-sided matching with diversity concerns.

Categories and Subject Descriptors: I.2.11 [**Distributed Artificial Intelligence**]: Multiagent Systems; J.4 [**Computer Applications**]: Social and Behavioral Sciences—*Economics*

General Terms: Theory, Algorithms, Economics
Additional Key Words and Phrases: Market design, two-sided matching, diversity, affirmative action.

Two-sided matching is one of the most prominent success stories of algorithmic economics. This research area received a major acknowledgement when Roth and Shapley won the 2012 Nobel Memorial Prize in Economic Sciences "for the theory of stable allocations and the practice of market design." A typical problem in two-sided matching is to match members of two sides while taking into account their preferences or priorities over each other. Centralized algorithms such as Deferred Acceptance have been deployed to match agents to institutions across the globe. Depending on the application context, the agents are students, job applicants, or doctors and the institution are schools, employers, and hospitals. Recently, such centralized approaches have also been suggested for the college admissions in the USA.[1]

In past few years, diversity concerns have been discussed in many scenarios including student-intake and team compositions. The goals include prioritizing people who have extra talents or are from a historically disadvantaged background. Another possible goal is building more balanced creative teams.

Whereas diversity concerns come up in many real-life contexts, they are are not directly handled by classical matching approaches. This motivates a new theory of two-sided matching that caters for various types of diversity concerns. Next, we highlight some papers on the topic especially with respect to the school choice problem.

(1) A. Abdulkadiroğlu and T. Sönmez. School choice: A mechanism design approach. *American Economic Review*, 93(3):729–747,

This is one of the seminal papers on two-sided matching and one of the first papers on school choice matching. The last section is a masterpiece of fore-

[1] `https://www.chronicle.com/article/can-algorithms-save-college-admissions`

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sight as many actively debated issues including diversity concerns are briefly discussed.

(2) L. Ehlers, I. E. Hafalir, M. B. Yenmez, and M. A. Yildirim. School choice with controlled choice constraints: Hard bounds versus soft bounds. *Journal of Economic Theory*, 153:648–683, 2014.

This one of the most influential papers on the topic. The authors carefully study the impact of treating diversity constraints as hard or soft. The paper popularized the approach of using diversity quotas as soft constraints. Some of the key ideas such as soft quotas were also discussed in earlier in an Theoretical Economics paper by the last three authors. One simplifying assumption the papers use is that each agent has exactly one type. In followup work, this assumption is being challenged.

(3) F. Echenique and M. B. Yenmez. How to control controlled school choice. *American Economic Review*, 105(8):2679–94, August 2015.

The paper improves our understanding of diversity-oriented choice functions that satisfy the substitutes condition. Designing choice functions that satisfy the substitutes condition has proved to be a highly valuable tool in transfering general results from the theory of matching with contracts to the domain of matching under diversity goals.

(4) S. D. Kominers and T. Sönmez. Matching with slot-specific priorities: Theory. *Theoretical Economics*, 11(2):683–710, 2016.

The paper proposes a flexible and innovative approach to capture diversity goals. The key idea of their approach is that each slot of the school has its own priority and slots of a school are filled in a particular order.

(5) R. Kurata, N. Hamada, A. Iwasaki, and M. Yokoo. Controlled school choice with soft bounds and overlapping types. *Journal of Artificial Intelligence Research*, 58:153–184, 2017.

This is one of the earliest works on addressing the problem when students may have multiple and overlapping types. Its conference version was published in 2015 at AAAI. Initially, it mostly got traction within computer science but is deservedly being recognized in the economics literature as well for its innovative approach. Similar approaches have been proposed independently or subsequently in several other papers.

(6) Y. A. Gonczarowski, N. Nisan, L. Kovalio, and A. Romm. Matching for the Israeli "Mechinot" gap year: Handling rich diversity requirements. In *Proceedings of the 20th ACM Conference on Economics and Computation*, pages 321–321, 2019.

The paper exemplifies the impact of the field by taking the full journey from practice to theory and then back to practice. It also addresses the issue of overlapping types and reports on a natural method that was implemented for the problem encountered while matching students for the Israeli "Mechinot" gap year.

(7) T. Nguyen and R. Vohra. Stable matching with proportionality constraints. *Operations Research*, 67(6):1503–1519, 2019.

In contrast to quota-based diversity constraints, the paper considered constraints based on maintaining proportions of types. The methods proposed is based on an extension of Scarf's lemma. The paper exemplifies the application of deep mathematics for an important social problem.

(8) T. Sönmez and M. B. Yenmez. Affirmative action with overlapping reserves. Manuscript, 2020. URL `http://fmwww.bc.edu/EC-P/wp990.pdf`.

In a very lucid piece of work, Sönmez and Yenmez distinguish between accounting a student as taking spots of all type she satisfies versus taking a spot reserved for one of the types. For the latter, they propose a smart approach geared towards achieving optimal diversity. Based on related ideas, a general approach has recently been proposed for allocating scarce medical resources (`https://www.covid19reservesystem.org/`).

(9) O. Aygün and I. Bó´. College admission with multidimensional privileges: The Brazilian affirmative action case. *American Economic Journal: Microeconomics*, 2020.

The paper considers a general model in which each student may have multiple types and each seat within the same school may have different priorities over students. In their model, there are reserved seats for a distinguished subset of combinations of types. The authors also show how a careful analysis of existing systems can uncover adverse incentive and fairness issues.

(10) S. Ahmadi, F. Ahmed, J. P. Dickerson, M. Fuge, and S. Khuller. An algorithm for multi-attribute diverse matching. In *Proceedings of the Twenty-Ninth International Joint Conference on Artificial Intelligence, IJCAI 2020*, pages 3–9, 2020.

Finally, we include a paper in the mix that is different from the others in the list. It takes an optimisation approach to computing diverse matchings where the overall objective is inspired by the Herfindahl index, a statistical measure of concentration and commonly used in economics.

The list is far from exhaustive and there are many other related and exciting papers. As a starting point, the interested reader is recommended to explore papers related to the papers in the list above.