Mechanism Design for Social Good

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Introduction

Across various domains—such as health, education, and housing-improving societal welfare involves allocating resources, setting policies, targeting interventions, and regulating activities. These solutions have an immense impact on the day-to-day lives of individuals, whether in the form of access to quality healthcare, labor market outcomes, or how votes are accounted for in a democratic society. Problems that can have an outsized impact on individuals whose opportunities have historically been limited often pose conceptual and technical challenges, requiring insights from many disciplines. Conversely, the lack of interdisciplinary approach can leave these urgent needs unaddressed and can even exacerbate underlying socioeconomic inequalities.

To realize the opportunities in these domains, we need to correctly set objectives and reason about human behavior and actions. Doing so requires a deep grounding in the field of interest and collaboration with domain experts who understand the societal implications and feasibility of proposed solutions. These insights can play an instrumental role in proposing algorithmically-informed policies. In many cases, the input data for our algorithms may be generated by strategic and self-interested individuals who have a stake in the outcome of the algorithm. To get around this issue, we can deploy techniques from mechanism design, which uses game theory to align incentives or analyze the strategic behavior of individuals who interact with the algorithms.

The Mechanism Design for Social Good (MD4SG) research agenda is to address problems for which insights from algorithms, optimization, and mechanism design have the potential to improve access to opportunity. These include allocating affordable housing services, designing efficient health insurance markets, setting subsidies to alleviate economic inequality, and several other issues af-

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fecting many individuals' livelihoods. research area falls at the interface of artificial intelligence, theoretical computer science, and the social sciences. Since the fall of 2016, the authors of this piece have been coorganizing the Mechanism Design for Social Good research group, workshop series, and colloquium series Abebe and Goldner [2016, The group comprises a large network of researchers from various disciplines, including computer science, economics, sociology, operations research, and public policy. Members of the group partner with domain experts in non-government organizations, think tanks, companies, and other entities with a shared mission. The mission is to explore new frontiers, garner interest in directions in which algorithmic and mechanism design insights have been under-utilized but have the potential to inform innovative interventions, and highlight exemplary work.

In this piece, we discuss three exciting research avenues within MD4SG. For each of these, we showcase ongoing work, underline new directions, and discuss potential for implementing existing work in practice.

Access to Opportunity in the Developing World

New technologies and data sources are frequently leveraged to understand, evaluate, and address societal concerns across the world. In many developing nations, however, there is a lack of information regarding underlying matters—whether that be the prevalence of diseases or accurate measurements of economic welfare and poverty—due to the unavailability of high-quality, comprehensive, and reliable data UN [2014]. This limits the implementation of effective policies and interventions. An emerging solution, which has been successfully demonstrated by the Information Communication Technology for Development (ICT4D) research community, has been to take advantage of high phone and Internet penetration rates across developing nations to design new technologies which enable collection and sharing of high-quality data. There has also been recent work from within the Al community to use new data sources to close this information gap Abebe et al. [2018], Jean et al. [2016]. Such Al-driven approaches surface new algorithmic, modeling, and mechanism design questions to improve the lives of many under-served individuals.

A prominent example is in agriculture, which accounts for a large portion of the economy in many developing nations. Here, viral disease attacks on crops is a leading cause of food insecurity and poverty. Traditional disease surveillance methods fail to provide adequate information to curtail the impact of diseases Mwebaze and Biehl [2016], Mwebaze and Owomugisha [2016], Quinn et al. [2011]. The Cassava Adhoc Surveillance Project from Makerere University implements crowd-sourcing surveillance using pictures taken by mobile phones in order to address this gap Mutembesa et al. [2018]. The tool is set up as a game between farmers and other collaborators, and aims to collect truthful, high-value data (e.g., data from hard-toreach locations). This approach underlines interesting challenges, such as how to optimally incentivize individuals to collect highquality information and how to augment this information with existing methods. issues arise in other domains-e.g., in citizen science and in computational sustainability Xue et al. [2016a,b]. Finding solutions in the context of the developing world may therefore have a broader global impact.

Lack of information also leads to inefficiencies in existing systems, presenting a possibility to introduce solutions that abide by existing cultural and technological constraints. For instance, large price discrepancies and major arbitrage opportunities present in markets for agricultural products in Uganda suggest large market inefficiencies Ssekibuule et al. [2013]. To alleviate this, Newman et al. [2018] introduce Kudu—a mobile technology that functions over feature phones via SMS service. Kudu facilitates transactions between farmers in rural areas and buyers at markets in cities by allowing sellers and buyers to post their asks and offers. Kudu has been adapted by users across Uganda and many trades have been realized through this system.

Availability of new technologies also presents opportunities to tackle fundamental problems related to poverty. Advances in last-mile payment technologies, for example, enable largescale, secure cash transfers. GiveDirectly leverages this and the popularity of mobile money across the world to create a system where donors can directly transfer cash to recipients GD, Blattman and Niehaus [2014]. GiveDirectly moves the decision about how to use aid from policy-makers to recipients, giving recipients maximum flexibility. Such aid generates heterogeneity in outcomes-e.g., families may use aid to start a business, pay rent, cover health costs, and so on. Policymakers used to prioritizing specific outcomes may be uncomfortable by such a model. A research question then is: can we predict how a given population will use aid? Likewise, how can we target people for whom the interventions will make the largest difference? Aid has historically been targeted on the basis of finding the most deprived people. The ability to model heterogeneous treatment effects opens the door for designing more nuanced mechanisms that fairly and efficiently allocate subsidies in order to maximize a desired outcome.

Problems in the developing world surface unique challenges at the intersection of Al. ICT4D, and development economics. lutions often have to be implemented in resource-constrained environments (e.g., over feature phones or with low network connectivity) Brunette et al. [2013], Patel et al. [2010]. Key populations of interest (e.g., women, people living in rural parts, individuals with disabilities) may not be easily accessible Sultana et al. [2018], Vashistha et al. [2015b,a]. Individuals may have low-literacy Sambasivan et al. [2010]. Lack of understanding of sociocultural norms and politics, furthermore, may inhibit proposed interventions Vashistha et al. [2018]. All of these highlight the need for a multi-stakeholder approach that leverages technological advances, innovative technical solutions, and partnerships with individuals and organizations that will be impacted by the solutions. MD4SG fosters one such environment in which insights from across these disciplines inform the design of algorithms and mechanisms to improve the lives of individuals across the world.

Labor, Platforms, and Discrimination

Online platforms are ubiquitous, providing a vast playground for algorithm design and artificial intelligence. Every policy decision, however, impacts and interacts with the platform's strategic users. In this section, we will focus on online labor markets and how discrimination effects stem from a platform's decisions. Past work begins to investigate some aspects of platforms, of strategic agents, and of discrimination in labor markets, but there are still major opportunities for work at the intersection, and insights from mechanism design and AI are ripe for the job.

One central issue surrounding labor markets is that of hiring, in which a firm takes information about a potential candidate and makes an employment decision. Firms act as classifiers, labeling each applicant as "hire" or "not hire" based on an applicant's "features," such as educational investment or a worker's productivity reputation. In the process of making hiring decisions, however, the firm may potentially make discriminatory decisions—perhaps by using protected attributes, or by not correcting for differences in applications that stem from systemic discrimination Bertrand and Mullainathan [2004], Marlowe et al. [1996]. Bias in hiring decisions may arise due to implicit human bias or algorithmic bias, in which algorithms replicate human and/or historic discrimination that is reflected in the data on which they are trained Broussard [2018], Eubanks [2018], Noble [2018], O'Neil [2016].

One recent line of work investigates hiring policies that achieve diversity or statistical parity (with respect to certain groups) among the hired workers, and how workers make their investment decisions (e.g. whether to attend college) based on the hiring policies in place. Coate and Loury [1993], Fryer Jr and Loury [2013], Hu and Chen [2017] study settings where there is some known underlying bias or historical discrimination against certain groups; the aim is to characterize hiring policies that are optimal-subject-to-fair-hiring, and to quantify any loss in efficiency compared to optimal-but-discriminatory policies. These works explore two settings: first, when hiring decisions must be "group-blind," that is, they cannot take group membership into account, and second, when they are "group-aware". The aim is to choose hiring policies that will mitigate discrimination against protected categories. Hu and Chen [2017] highlights additional complexity that arises in dynamic settings where workers are hired based on investment decisions (e.g. college GPA) in an initial temporary labor market (e.g. internships) and this job creates a worker's initial productivity reputation that is then used in the permanent labor market. Many of these findings also discuss "trade-offs" between group-blind and group-aware policies.

Another aspect of labor markets is that a worker may have the ability to pay to change a feature of her application in some illegitimate or unfair way in order to improve her outcome in the labor market. Hardt et al. [2016] examine this problem from a robust machine learning perspective. Under certain assumptions of the cost required to change an applicant's reputation, they characterize classifiers that optimally compare to the original reputation (before the applicant modified it).

These are only two aspects at the interplay between hiring and strategic agents; hiring, furthermore, is only one aspect of the labor market. Consider today's popular online labor markets, such as Mechanical Turk, Upwork, Task Rabbit, and Lyft, in which the platform's goal is to match workers to employers or jobs. In these labor markets, the platform's decisions, even at a granular level, have a large impact on the workers and firms. Consider the following platform decisions. Visibility: How many firms can workers see at a time? What capacity do they have to search job offers? Can workers see jobs and jobs see workers? Initiation: Which side (or both) can submit applications? Initiate messaging? Set contract terms? Information: What information is displayed about parties on the opposite side? Name? Photo? Ethnicity? Wage history? Reputation?

Each of these decisions impacts the outcome—not only the quality of the match, but also whether (and how much) discrimination occurs. In a recent paper, Levy and Barocas [2017] outline categories of platform decisions which may mitigate or perpetuate discrimination in labor markets, including the high-level categories of setting platform discrimination policies or norms,

structuring information and interactions, and monitoring/evaluating discriminatory conduct.

In offline labor markets, it may be challenging or infeasible to collect data to understand the nature and extent of discrimination. Online labor markets, on the other hand, vield rich data about employer-employee interactions and present the possibility of conducting experiments aimed at reducing bias and discrimination or other desired societal objectives. For instance, Barach and Horton [2017] look at the impact on hiring of hiding workers' wage history. Horton and Johari [2015], Horton [2018] look at the impact of trying to elicit additional information (features) from workers or firms, and the impact of this strategicallyreported information on hiring. Horton [2017] examines who the hired worker population is when a minimum wage is imposed on one platform. Each of these provide insights into labor dynamics that may inform platform design and interventions.

Online labor markets provide a rich playground for techniques from algorithms, AI, and mechanism design to study how each aspect of platform design impacts discriminatory effects, workers' actions, and the desired objective for the platform.

Allocating Housing and Homelessness Resources

Allocation of resources—such as public housing, housing vouchers, and homelessness services—has a long history in the economics and computation literature. Even simple-to-state problems here have given rise to challenging research questions, many of which are still open. Increased scarcity of housing resources, growing need for services, and the use of algorithmic decision-making tools all open up several avenues with major opportunities for reforming policies and regulations. Here, we discuss some foundational work, new challenges, and opportunities that emerge at the nexus of algorithm and mechanism design, AI, and the social sciences.

Millions of individuals across the US have been evicted or are at risk of experiencing eviction every year. In groundbreaking work, Desmond [2012, 2016] shows that eviction is much more common than was previously doc-

umented. By compiling the first ever evictions database, Desmond shows that there is an estimate of 2.3 million evictions in 2016 alone and argues that eviction is a cause of poverty EL [2018]. Using this database, and other similar datasets, we may be able to employ a combination of machine learning and statistical techniques to gain a better understanding of what causes housing instability and homelessness. We may then be able to build on this work to design algorithms and mechanisms that can improve on allocation policies. For instance, Kube et al. [2018] uses counterfactual predictions to improve homelessness service provisions. By doing so, they realize some gains on reducing the number of families experiencing repeated episodes of homelessness. At the same time, Eubanks [2018] emphasizes that caution must be taken when using automated decision-making tools for allocating limited resources in such high-stakes scenarios. Eubanks argues that such tools may be used to reduce failure rates by caseworkers: but, if not approached with care, they can deepen already existing inequalities. Furthermore, such tools alone are limited: they do not address the lack of housing and homelessness resources or eliminate human biases or discrimination. It is therefore crucial to take advantage of the confluence of insights from cross many disciplines in order to serve the needs of such vulnerable populations.

An issue that is growing in prominence in housing contexts is that of information. Little is documented about how landlords or housing authorities screen applications and make decisions. Ambrose and Diop [2016] show that there is increased restriction in access to rental housing since landlords mitigate information asymmetry by investing in screening tenants. With the increased use and availability of data about individuals, it is of paramount importance to understand the role of information in the decision-making process of entities, such as landlords or housing agencies, who have enormous discretion in how and whether families are housed.

Although the introduction of automated tools introduces acute challenges related to housing, the use of algorithmic techniques dates back several decades and there are many fundamental problems that remain unsolved. An early work here is that of Hylland and Zeck-

hauser [1979], which considers the "house allocation problem" of assigning each individual to one item, such as a house. They introduce a mechanism which satisfies natural efficiency and fairness notions but is not incentive-compatible. That is, individuals may be able to improve their outcome by misreporting their true preferences. Since then, several mechanisms have been proposed, including the popular Randomized Serial Dictatorship (RSD) mechanism, which uses a random lottery Abdulkadiroğlu and Sönmez [1998]. This mechanism is incentive-compatible, but fails to satisfy the fairness criteria of Hylland and Zeckhauser [1979]. It is used as a standard mechanism in many domains, including housing. An outstanding question related to these is then the design of incentive-compatible, fair, and efficient mechanisms for the house allocation problem.

Due to increased scarcity of resources, allocation protocols often involves waiting lists and priority groups. Policy constraints make waitlist design a dynamic rationing problem rather than the static assignment problem discussed above. Dynamic mechanisms present several technical and practical challenges; e.g., incentive-compatibility may be infeasible in dynamic settings due to waiting time tradeoffs for applicants. There are consequential design decisions related to how to manage waitlists and different metropolitan areas have different policies (e.g., setting priority groups, conditions under which individuals are removed from the waiting list, set of choices, and many others). Each of these policies impacts the dynamics of the allocation process, waiting time, and quality of matches. Recent work has studied how to design mechanisms satisfying various desiderata and quantify differences in quality of matches across various mechanisms Arnosti and Shi [2018], Leshno [2017], Thakral [2016], Waldinger [2017].

Conclusion

As the use of algorithmic and AI techniques becomes more pervasive, there is a growing appreciation of the fact that the most impactful solutions often fall at the interface of various disciplines. The Mechanism Design for Social Good research agenda is to foster an environment in which insights from algorithms and

mechanism design can, in conjunction with the social sciences, be used to improve access to opportunity, especially for communities of individuals for whom opportunities have historically been limited. In this piece, we have highlighted MD4SG research avenues related to issues in developing nations, labor markets. and housing. For each of these, we have discussed the need to work in close partnership with a wide range of stakeholders to set objectives that best address the needs of individuals and propose feasible solutions with desired societal outcomes. There are numerous other domains in which this kind of interdisciplinary approach for designing algorithms and mechanisms can improve the lives of many individuals; we invite readers to learn more through our colloquium and workshop series.

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