Abstracts

The Magician's Shuffle: Reusing Lottery Numbers for School Seat Redistribution

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Abstract. In many centralized school admission systems, a significant fraction of allocated seats are later vacated, often due to students obtaining better outside options. We consider the problem of reassigning these seats in a fair and efficient manner while also minimizing the movement of students between schools. Centralized admissions are typically conducted using the deferred acceptance (DA) algorithm, with a lottery used to break ties caused by indifference in school priorities. For reassignment, we propose a class of mechanisms called Permuted Lottery Deferred Acceptance (PLDA). After the initial (first-round) assignment is computed via DA, students' preferences change (get truncated) due to the revelation of their outside options. A PLDA mechanism then computes a reassignment of the students by re-running DA; however, students are guaranteed to get at least their first-round assignment (if they still want it) or a school they prefer, and ties are broken according to a permutation of the first-round lottery order. We show that a PLDA based on a *reversal* of the first-round lottery order performs well.

Our theoretical analysis takes place in a continuum model with no school priorities. We characterize PLDA mechanisms as the class of mechanisms that satisfy a few natural properties, which include not removing students from their first-round assignments against their will, a strong form of strategyproofness (against manipulations involving misreporting both the original and changed preferences), and certain efficiency and fairness axioms. We then identify a technical condition, called the *order condition*, essentially requiring that the change in preferences does not modify the relative overdemand for schools. When the order condition is satisfied, all PLDA mechanisms yield identical allocative efficiency, and among all of them, the lottery-reversal based PLDA reassigns the minimal amount of students (from their first-round assignments). Finally, we conduct computational experiments and obtain results that support our theoretical findings. Specifically, we use data from NYC's school choice program to simulate the performance of different PLDA mechanisms in the presence of school priorities, and find that all simulated PLDAs have similar allocative efficiency, while the lottery-reversal based PLDA minimizes the number of reassigned students.

A full version is available at: http://www.columbia.edu/∼yk2577/reallocation.pdf

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Near-Efficient Allocation Using Artificial Currency in Repeated Settings
(Extended Abstract)

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Abstract. We study the design of mechanisms without money for repeated allocation of resources among competing agents. Such mechanisms are gaining widespread use in allocating computing resources in universities and companies, and also distributing of public goods like vaccines among hospitals and food donations among food banks. We consider repeated allocation mechanisms based on *artificial currencies*, wherein we first allot each agent a chosen endowment of credits, which they can then use over time to bid for the item in a chosen auction format. Our main contribution is in showing that a simple mechanism, based on a repeated all-pay auction with personalized endowments and static pricing rules, simultaneously guarantees *vanishing gains from non-truthful bidding* as well as *vanishing loss in efficiency*. Our work lies at the intersection of dynamic mechanism design and mechanisms without money, and the techniques we develop here may prove of independent interest in these settings.

Our work studies the question of whether the *incentive properties and allocative efficiency* of mechanisms with money can be approximated via mechanisms based on an *artificial currency* – one which has no independent valuation outside the setting of the mechanism. This has attracted a lot of attention in recent times due to the establishment of platforms that use artificial-currency systems to solve real-world problems such as university course allocation and food banks.

We consider a problem of allocating a single item between 2 agents $\{a, b\}$ in T consecutive periods $t = 1, 2, \ldots, T$. At time t, agent $s \in \{a, b\}$ has i.i.d valuation $V_{s,t} = v$ with probability $\{\mathbf{q}_s(v)\}$; valuations are independent across agents, and distributions are known publicly. Given any mechanism $\mathcal{M}$ not involving money, agent s's utility is $U_s^{\mathcal{M}} \triangleq \sum_{t=1}^{T} V_{s,t} x_{s,t}^{\mathcal{M}}$, where $x_{s,t}^{\mathcal{M}}$ is the allocation to s at time t. In this setting, it is easy to see that for $T = 1$, no mechanism can be both incentive compatible and efficient; our aim is to use the repeated nature of the process to ensure approximate efficiency and incentive compatibility.

Formally, we define a mechanism to be an $(\alpha, \beta)-$approximate mechanism if it simultaneously guarantees that (i) *truthful play is an α-equilibrium*, i.e.,

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for any agent s, assuming all other agents play truthfully, the utility gain from deviating from truthful play is at most αT, and (ii) *the mechanism is* β*-efficient*, i.e., assuming all agents play truthfully, the loss in welfare from the optimal is at most βT. For example, a uniform lottery achieves $(\alpha, \beta) = (0, \Omega(1))$; on the other hand, we show that a second-price auction with artificial currency has $(\alpha, \beta) = (\Omega(1), 0)$. This raises the question as to whether there are mechanisms where both α and β are $o(1)$. To this end, we propose the *Repeated Endowed All-Pay* (or REAP) mechanism, wherein we first give each agent an endowment of credits, and then in each period, agents are charged credits to report a valuation according to a personalized price function; the item is then allocated to the highest reported valuation. Our main result is the following:

Theorem 1. *REAP is an* (α, β)*-approximate mechanism with* $\alpha = O\left(\sqrt{\frac{\log T}{T}}\right)$, $\beta = O\left(\frac{1}{T}\right)$.

Our result is based on setting prices via a novel LP-based analysis of an auxiliary game, and then showing the sample paths of the mechanism concentrate close to this auxiliary game. In addition, our work suggests several future directions for research on the scope and practicality of mechanisms without money. For details, refer to our full version: https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2852895.

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Multi-unit Facility Location Games

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Motivated by applications in clustering and information retrieval, we extend the classical Hotelling setting (see [1]) to address the scenario where players may control more than one facility. In his seminal work, Hotelling considers a duel between two parties who compete over consumers distributed uniformly over the interval $[0, 1]$; each party locates its facility on that interval, and grabs the proportion of the population closer to it. As it turns out, the only equilibrium in that setting is for both parties to locate their facility at $\frac{1}{2}$. Interestingly, while overwhelming many extensions of that basic setting exist, the economic studies refer to competition between single-facility owners only, which make that work non-applicable to many applications, e.g. in clustering we are typically after selecting several centroids/clusters.

Consider for example the strategic behavior of publishers in the web. Assume a "strong" publisher who controls several outlets of its site which it can maintain, e.g. two different Internet versions of its newspaper. This publisher can be viewed as being able to locate two "facilities" in the space of published data rather than only one; however, a "weak" publisher who can not maintain two such versions will need and be able to locate only one "facility". How would these different powers effect the behavior of the publishers? What would be optimal strategies for the different publishers? This is a novel challenge and question, which illustrates how valuable and deep the understanding of these games may be for theory and practice.

We extend the Hotelling setting to *multi-unit facility location games*, where there are n players, where player i may control **several** facilities. We first analyze competition among the owner of k facilities to the owner of l facilities, for arbitrary (l, k), where $l \leq k$. Our message for this extended Hotelling duel is quite striking: in **no** equilibrium of any such (l, k) facility location duel a facility will materialize in a location which is not part of the social welfare maximizing locations of the player who has k facilities, if she were to locate her facilities under no competition. This is obtained despite the lack of pure strategy equilibrium in any (l, k) duel whenever $l \neq k$.

Moreover, for the n-player setting, we provide sufficient and necessary conditions for a pure strategy profile to be an equilibrium in such game. In particular, we show that a pure-strategy equilibrium exist if and only if there is no

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dominant player who controls more than half of the facilities; in the latter case, under some conditions, a mixed strategy equilibrium of the form obtained in the (l, k) duel does exist.

Reference

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