Tutorial: Optimal Marketing and Pricing in Social Networks

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ABSTRACT

We discuss the use of social networks in implementing viral marketing strategies. In the first part of this tutorial, we study *influence maximization* or how the structure of the social network affects the spread of behaviors and technologies. In the second part, we then consider how one might monopolize these natural processes to generate revenue in a *revenue maximization* setting.

Categories and Subject Descriptors

J.4 [**Computer Applications**]: Social and Behavioral Sciences—*Economics*

General Terms

Algorithms, Economics

Keywords

Social Networks, Influence, Revenue

1. INTRODUCTION

Social networks pervade our lives and significantly influence the decisions we make. Our decisions to buy a cell phone, go to college, or smoke a cigarette are fundamentally affected by the decisions of our friends. Traditionally, social scientists have studied the effects of social networks on decision-making in a very abstract sense or in explicit small-scale settings. However, the proliferation of social-networks on the Internet has allowed companies to collect information about social-network users and their social relationships, yielding explicit information regarding connections in massive social networks. As a result, it has become increasingly relevant to understand how the social network structure affects the choices of the society it describes, and how this knowledge can be leveraged to monetize these networks in an Internet setting.

In this tutorial, our main focus will be on how to leverage network structure to promote a product and/or maximize revenue. Consider a company interested in promoting a product. As one agent adopts the product, this impacts other potential adopters. Such an effect is called an *externality.* Externalities that induce further adoption of the product are called *positive externalities.* These externalities significantly influence the diffusion of the product in the social network and the revenue that can be extracted during this diffusion process.

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2. TUTORIAL OUTLINE

2.1 Background Material

The tutorial begins with a basic introduction to the notions and techniques used throughout the theoretical literature. We will give a brief overview of game theory, mechanism design, probability, and graph theory. These concepts will be introduced through motivating examples of strategic and stochastic network formation games and basic bimatrix games on networks. Thus, while learning these basic techniques, attendees will be exposed to some classic results on social networks from the economics, computer science, and social science literature.

Attendees will also be introduced to the basic model underlying the papers discussed in this tutorial. We will present mathematical definitions of social networks, networked goods, and externalities. The theoretical concepts will be complemented with intruiging examples of these phenomena from empirical literature.

The results covered in this section of the tutorial include:

- Nash, John (1950): *Equilibrium points in n-person games*, Proceedings of the National Academy of Sciences 36(1):48-49.
- Myerson (1981): *Optimal Auction Design*, Mathematics of Operations Research 6(1):58–73.
- Watts and Strogatz (1998): *Collective Dynamics of 'Small-World' Networks*, Nature 393:440–442.
- Barabasi and Albert (1999): *Emergence of Scaling in Random Networks*, Science 286:509–512.
- Jackson and Wolinsky (1996): *A Strategic Model of Social and Economic Networks*, Journal of Economic Theory 71(1):44–74.
- Bala and Goyal (2000): *A Noncooperative Model of Network Formation*, Econometrica 68(5):1181–1229.

2.2 Influence Maximization

We next study how to leverage externalities and network structure in marketing strategies. The basic idea is that a market can choose a set of agents to target and convince these agents to adopt the product. These agents then become early adopters and influence their friends to adopt the product as well. By carefully selecting an influential set of agents, a company can maximize its marketshare through the subsequent natural product diffusion.

We focus on two models depending on whether the product diffusion is probabilistic or strategic. In probabilistic models, each agent adopts the product with a probability that depends on which of his or her neighbors already own the good. Early adopters are important in this model; they are the ones who start the cascade of adoption in the rest of the network. The question thus becomes, which agents should a marketer target in the hopes of creating early adopters? If a marketer targets too dense a set of individuals, it is possible that they don't have many friends without the product, and so have limited influence. On the other hand, if the targeted set is too sparse, then no remaining node will know many early adopters and so again the cascade stops. In fact, as we will discuss, finding the optimal set to target is computationally infeasible. However, we will present techniques that find an approximately optimal target set.

In strategic models, we focus on settings in which agents have multiple products to choose from, and agents receive positive payoffs by having similar products as their neighbors. In such cases, it is of interest to understand which products will receive significant marketshare. We study a setting in which one product initially has complete marketshare. We wish to introduce a new superior product and study whether this product will pervade the network. Again, the key question is which early adopters should be targeted. We discuss two main models. In the first model, agents must choose between the technologies. In these cases, we show how to compute when a superior technology will gain marketshare; essentially, one can derive a threshold on the relative qualities. If the new technology is sufficiently superior, it will become a monopoly in the market. Next, we show how compatibilities between technologies affects this process. It turns out that inferior technologies can in fact ward off the invasion of a superior technology by adopting a limited level of inter-operability.

The results covered in this section of the tutorial include:

- Domingos and Richardson (2001): *Mining the network value of customers*, In Proceedings of Knowledge Discovery and Data Mining (KDD).
- Kempe, Kleinberg, and Tardos (2003): *Maximizing the Spread of Influence through a Social Network*, In Proceedings of Knowledge Discovery and Data Mining (KDD).
- Mossel and Roch (2007): *On the Submodularity of Influence in Social Networks*, In Proceedings of ACM Symposium on Theory of Computing (STOC).
- Morris (2000): *Contagion*, Review of Economic Studies 67:57–78.
- Immorlica, Kleinberg, Mahdian, and Wexler. *The Role of Compatibility in the Diffusion of Technologies Through Social Networks*, In Proceedings of ACM Conference on Electronic Commerce (EC).

2.3 Revenue Maximization

A far-sighted seller can take advantage of positive externalities to increase revenue. For instance, to influence many buyers to buy the good, the seller could initially offer some buyers the good for free. Indeed such selling techniques are already employed in practice. TiVo, a company which makes digital video recorders, initially gave away its digital video recorder for free to a select few. Such promotions may be an effective way to create a buzz about the product.

The basic idea of giving away the item for free can be generalized in a couple of ways: First, rather than offering the item for free, sellers could offer discounts. There is a trade-off: larger discounts decrease the revenue earned from the transaction while increasing the likelihood of a sale and the influence on future buyers. *How large should the discounts be?* Second, the sequence in which sales happen has an impact on the effect of externalities. Influence is generally not symmetric. Often popular, well-connected users wield more influence. Clearly, we would like sales that have the potential to cause further sales to occur earlier. *In what sequence should the selling happen?* The goal of this paper is to explore marketing strategies that optimize a seller's revenue.

We investigate the marketing and pricing problems over social networks in two different parts: In the first part, we allow price discrimination and design pricing pricing strategies that can target special social network users with specific offers. In the second part, we discuss optimal pricing strategies in settings without price discrimination, and by using publicly known posted pricing.

The results covered in this section of the tutorial include:

- Hartline, Mirrokni, and Sundararajan (2008): *Optimal Marketing Strategies over Social Networks*, In Proceedings of World Wide Web Conference (WWW).
- Mirrokni, Roch, and Sundararajan: *Optimal Posted-Price Marketing with Influence Propagation over Social Networks*, manuscript.
- Akhlaghpour, Ghodsi, Haghpanah, Mahini, Mirrokni, and Nikzad: *Iterative pricing with positive network externalities*, manuscript.
- Ahmadi, Ehsani, Ghodsi, Haghpanah, Immorlica, Mahini, and Mirrokni: *Optimal equilibrium pricing over social networks*, manuscript.

3. BIOGRAPHY

Nicole Immorlica. Dr. Immorlica is an assistant professor in the theoretical computer science group at Northwestern University. She joined Northwestern in September 2008 after postdoctoral positions at Microsoft Research in Redmond, WA, and Centruum voor Wiskunde en Informatica (CWI) in Amsterdam, Netherlands. She received her Ph.D. from MIT 2005. Her work has been instrumental in applying economic and computer science techniques to problems at the forefront of computer science research, including models of diffusion on social networks, the design and analysis of ad auction markets, and the development of general auction mechanisms for various production functions.

Vahab Mirrokni. Dr. Mirrokni is a Senior Research Scientist at Google NY. He joined Google Research in July 2008 postdocs at Microsoft Research in Redmond, WA; MIT CSAIL in Cambridge, MA; and a research scientist position in the strategic planning and optimization group at Amazon.com. He received his PhD from MIT 2005. His research areas include algorithmic game theory, approximation algorithms, and social network analysis. At Google, he is working on various algorithmic and economic problems related to the Internet search, online advertisement, and social network advertising.