Budget Allocation in Competitive Search Advertisements

Yanwu Yang[1], Juanjuan Li[1], Jie Zhang[1] and Daniel Zeng[1,2]
[1]The State Key Lab of Intelligent Control and Management of Complex Systems,
Chinese Academy of Sciences, Beijing, 100190, China
[2]Department of Management Information Systems, The University of Arizona, USA
{yangyanwu.isec, lijuanjuan.isec, zhangjie.isec}@gmail.com, zeng@email.arizona.edu

Abstract: This paper proposes a novel budget model based on differential game to deal with budget allocation in competitive search advertisements under a finite time horizon, with consideration of budget constraints. We extend the advertising response function with the dynamical advertising effort u and quality score q to fit search advertising scenarios. We also discuss Nash equilibriums of our model, and study some desirable properties of two kinds of equilibriums in the case with budget constraints: "budget-stable" open-loop Nash equilibrium (BS-OLNE) and "budget-unstable" open-loop Nash equilibrium (BUS-OLNE). We have evaluated our budget model and identified properties with computational experiments. Experimental results show that budget strategies with dynamical advertising elasticity are superior to those with fixed one and our findings on OLNEs are helpful for advertisers to make budget decisions.

Keywords: search auctions; budget optimization; differential game; advertising competition

1 Introduction

The growing prosperity of markets of sponsored search auctions is vastly driven by the influx of millions of advertisers. However, most search engine companies currently provide limited number of advertising slots (e.g. 8--10) on the Search Engine Result Pages (SERPs). The unbalanced relationship between a large number of advertisers and limited advertising space leads to high levels of advertising competition. On the other hand, advertisers or brand managers, especially those from small and medium enterprises (SMEs), usually have serious budget constraints. Therefore, advertisers have to wisely make advertising decisions, in order to survive from the fierce competition and to get the maximized profits.

Advertising competitions cancel out part of effects of promotional expenditures [2]. Thus, an advertiser can not fully optimize her own budgeting strategy without consideration of competitors'. In early literature related to advertisement, decisions on advertising levels are incorporated with advertising/sale response functions to parsimoniously capture the relationship between advertising spending and unit sales [5]. Because marketing environment is time-varying, differential game and optimal control methods are used to capture advertising dynamics and competitive advertising strategies [4].

By considering the entire lifecycle of search advertising, budget decisions in search auctions occur at three levels [6]: allocation across search markets, temporal distribution over a series of slots (e.g. day) and adjustment of the remaining budget (e.g., the daily budget). The objective of this work is to investigate budget allocation strategies at the market (system) level in a competitive setting, in order to get a set of best responses to different strategies adopted by competitors. In this paper, we employ differential game to formulate budget allocation problems in a competitive search market under a finite time horizon. We amends the response function as given in [4] to fit advertising scenarios by introducing the dynamical advertising effort u and quality score q, since major search engines adopt quality-based ranking and pricing mechanism recently. According to [3], there is an exponential relationship between the budget b and the advertising effort u: $u = b^{\alpha}$, where α denotes the advertising elasticity, which is empirically fixed as a constant in traditional advertisements [1]. However, search auctions allow more flexible styles in terms of keywords selection, bids, budget decisions and advertising schedules that to a big degree the mapping from the

advertising budget to the advertising efforts. Specifically, an advertiser can make changes on her advertising strategies at any time in search auctions, and most advertisers are not professional and data (e.g., the historical CPC, the effectiveness of click, etc.) needed for computing optimal daily budget and bidding strategies are uncertain and difficult to obtain. In this sense, we argue that, the relationship between b and u is time-varying: $u = b^{\alpha(t)}$, which also varies in different search advertising markets. Because an advertiser usually has few accesses to get knowledge about her competitors' market share and time-varying advertising performance, we derive open-loop Nash equilibriums (OLNEs) for our budget model with and without budget constraints, and study some desirable properties. In the case with budget constraints, there exists two kinds of OLNEs: "budget-stable" OLNE (BS-OLNE) and "budget-unstable" OLNE (BUS-OLNE). We also conduct computational experiments to evaluate our budget allocation model and identified properties. Experimental results show that budget strategies with dynamical advertising elasticity is superior to those with the advertising elasticity fixed, and our findings on OLNEs are helpful for advertisers to make budget decisions. The advertiser is suggested to increase her advertising budget to a certain market until the reach of BS-OLNEs, that is, to make the equilibrium stay inside of the budget boundary.

2 Conclusions and Future Researches

In this study we present a novel budget allocation model based on differential game under a finite time horizon, aiming to help advertisers to allocate the advertising budget in competitive search advertisements. We derive Nash equilibriums (OLNEs) for our model with and without budget constraints, and also study some desirable properties of two kinds of OLNEs in the case with budget constraints. The preliminary evaluation on numerical experiments indicates that our findings on OLNEs are helpful for advertisers to make budget decisions in competitive environments, and dynamical advertising elasticity is critical for budget strategies. Our ongoing researches focus on (a) evolutionary paths of OLNEs in different information settings and/or with soft budget constraints, (b) budget allocation across multiple search advertising markets with competitive features, and (c) efficient computation of OLNEs for various kinds of situations.

Acknowledgements

We are thankful to anonymous reviewers who provided valuable suggestions that led to a considerable improvement in the organization and presentation of this manuscript. This work is partially supported by NSFC (71071152, 70890084, 71025001, 71102117, 60875049, 60921061) and CAS (2F09N05, 2F09N06).

References

[1] Erickson, G. M.(1992). Empirical Analysis of Closed-Loop Duopoly Advertising Strategies, Management Science, 38 (12), 1732--1749.

[2] Friedman, L.(1958). Game-theory Models in the Allocation of Advertising Expenditures, Operations Research 6, 699--709.

[3] Little, J.D.C.(1979). Aggregate advertising models: The state of the art, Operations Research 27 (4), 629--667

[4] Prasad, A. and Sethi, S. P.(2004). Competitive advertising under uncertainty: A stochastic differential game approach. Journal of Optimization Theory and Applications, 123 (1), 163--185.

[5] Sasieni, M.W.(1971). Optimal Advertising Expenditure, management science 18 (4).

[6] Yang, Y., J. Zhang, R. Qin, J. Li, F. Wang, W. Qi (2011). A budget optimization framework for search advertisements across markets, IEEE Transactions on Systems, Man, and Cybernetics. Part A: Systems and Humans, Accepted.