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Fuzzy multi-objective modeling of effectiveness and user experience in online advertising

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ABSTRACT

The focus placed on maximizing user engagement in online advertising negatively affects the user experience because of advertising clutter and increasing intrusiveness. An intelligent decision support system providing balance between user experience and profits from online advertising based on the fuzzy multi-objective optimization model is presented in this paper. The generalized mathematical model uses uncertain parameters for content descriptors that are difficult to be precisely defined and measured, such as the level of intrusiveness and the change in performance over time. The search for final decision solutions and the verification of the proposed model are based on experimental results from both perceptual studies, which are evaluating visibility and intrusiveness of marketing content as well as online campaigns providing interaction data for estimation of effectiveness. Surprisingly, the online response to the most noticeable advertisements with highly perceived visibility and intrusiveness was relatively low. During the field study performed in order to compute the model parameters, the best results were achieved for advertising content with moderate visual influence on web users. Simulations with the proposed model revealed that a growing level of persuasion can increase results only to a certain extent. Above a saturation point, a strategy based on extensive visual effects, such as high-frequency flashing, resulted in a very high increase of intrusiveness and a slightly better performance in terms of acquired interactions. Proposed balanced content design with the use of intelligent decision support system creates directions towards sustainable advertising and a friendlier online environment.

1. Introduction

The evolution of electronic media and the increasing role of online advertising within marketing strategies has created space for both researchers and practitioners to explore new areas. Attempts are frequently made to design online media and interactive content to achieve better results with the use of persuasion, colors, animations and call-to-action messages (Yun & Kim, 2005). Other areas include: the identification of the factors affecting effectiveness for specific sectors (Tsai, Chou, & Leu, 2011) or with more general applications (Robinson, Wysocka, & Hand, 2007), the real-time optimization of keyword selection (Cookhwan, Sungsik, Kwiseok, & Ch, 2012), and the use of methods based on multivariate testing or stochastic models (Chakrabarti, Agarwal, & Josifovski, 2008). While these methods are used in the operational environment, solutions which are implemented at tactical level require other approaches in terms of media planning. In this field, optimization methods are used for better advertisement allocation, and several solutions and models related to linear optimizations (Langheinrich, Nakamura, Abe, Kamba, & Koseki, 1999) are available, as well as their extensions (Chickering & Heckerman, 2000) towards recent models trying to deal with a multi-objective approach (Du & Xu, 2012). While earlier solutions focused mainly on increasing outcomes, the growing share of advertising content within websites is resulting in negative side effects. As a result, users perceive advertising clutter with a high share of advertising space being spread among editorial content (Ha & McCann, 2008). A drop in user experience

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is observed when more and more intrusive advertising techniques are used to attract user attention (Brajnik & Gabrielli, 2010; Zha & Wu, 2014). Earlier research in this field was mainly focused on the effect of intrusiveness on brand awareness and memory (Chatterjee, 2008). Dedicated measures were introduced to evaluate the level of intrusiveness based on scales defined by Li et al. (Li, Edwards, & Joo-Huyn, 2002) and later used in various areas (McCoy, Everard, Polak, & Galletta, 2007; Zha & Wu, 2014).

While most of the earlier methods focused on measuring intrusiveness or improving the performance of online marketing, the research presented in this paper proposes a multi-objective approach to media planning based on trade-off solutions while taking into account criteria related to user experience, web portal profits and results for advertisers. The study integrates results from perceptual and field experiments followed by simulations which use the proposed model based on fuzzy parameters. These parameters represent the uncertain characteristics related to the online environment and intrusiveness of the advertising content. The model includes effectiveness factors based on two elements: firstly, on direct responses in the form of those registered by advertising server interactions (e.g. clicks), and secondly, on the costs for advertisers related to the revenue of the web operator.

This study has yielded findings that have an impact on online system design, as well as managerial insights into interactive campaign planning. The conclusions are as follows:

- The highest number of interactions were acquired for content with the relatively low perceived intrusiveness detected in the perceptual study;
- Highly intrusive advertisements with vivid effects and a large flashing area attracted attention, but the number of acquired interactions was smaller than in the case of less intrusive content;
- Simulations showed that an increased level of persuasion can improve results to some extent only, which was made obvious by the relatively low online results for highly visible advertisements;
- The visibility of online advertisements increases results, but above certain saturation points, increases in the effect are very low and are noted by a high growth of intrusiveness;
- Different relationships between outcomes and the level of persuasion were observed for each campaign, but a saturation point denoted by a high immediate growth of intrusiveness was characteristic for all cases;
- For all campaigns, the substantial growth of intrusiveness resulted in only slightly better performance in terms of acquired interactions.

The proposed model makes it possible to search for a final decision during the interactive process. The model includes a representation of the global goals of the web portal owner and local objectives for specific advertisers with their own preferences. Results from the study are presented in seven sections. The structure of this paper is as follows: Section 2 presents the literature review related to online media optimization and planning, Section 3 includes the problem statement and the conceptual framework, Section 4 explains the optimization model with fuzzy parameters and the algorithm used to get solutions are presented, Section 5 presents the experimental results from the field experiment, and Sections 6 and 7 include the discussion and the conclusion, respectively.

2. Literature review

The increasing importance of interactive technologies in marketing has been observed recently, and new disciplines like marketing engineering, computational advertising or computational social science are gaining more and more attention from both practitioners and scientists. New forms of communication create areas in these fields with several directions, such as the design of advertising content, usage of persuasion and call to action messages, and testing different layouts or changing the structure of advertisements using data about consumer behavior (Urban, Liberali, MacDonald, Bordley, & Hauser, 2013; Zorn, Olaru, Veheim, Zhao, & Murphy, 2012). Other areas deal with real time campaign optimization and searching for the best methods for resource exploitation with the use of stochastic models (Chakrabarti, Kumar, Radlinski, & Upfal, 2008), adaptive personalization (Kazienko & Adamski, 2007), or context based ad selection (Teng-Kai & Chia-Hui, 2011). Looking at the problem of online campaign planning from another perspective, the managing of multiple resources with the use of operational research typically occurs at the strategic level.

Interactive media has created the ability to measure different effects and use them in the decision-making process. The new metrics are used in this field for media planning (Novak & Hoffman, 1996; Pavlou & Stewart, 2000) with quantitative approaches (Cookhwan, Kwiseok, & Ch, 2011; Hoffman & Novak, 2000). Planning methods are developed with the new specifics of online media; however, conventional media planning is also applicable (Cannon, 2001). The foundation for performing marketing actions is the planning and scheduling campaigns at different locations with the use of different creations. This can be based on the applications of the Rositer–Percy grid to online advertising and analysis based on the planned behaviors and site pre-visit intentions (Wu, 2007). Various scheduling and execution plans are implemented within advertising servers to select specific content as an answer to a request coming from a web browser (Amiri & Menon, 2003). One of the first applications of optimization models in this field is based on the analysis of keywords entered by the user to the search engine, which allows for optimization of the ad delivery process (Langheinrich et al., 1999). The task was formulated as a linear programming problem and the restrictions include impressions in a given period, which was related to the number of ads shown on behalf of each advertiser. An extension of the above concept is based on the research of Chickering and Heckerman, which shows the solution for a uniform distribution of emissions as a result of a two-stage optimization (Chickering & Heckerman, 2000) which identifies the likelihood of diversion from the issue of advertising in the analysis of data obtained from the operating environment.

The optimal emission plan allows calibrating the ad server in such a way to obtain the maximum number of interactions in a given period of time. Chickering stresses that the main drawback of this solution is the sensitivity of the results to small changes in the estimated probability. Another extension was proposed by Tomlin with the goal to avoid exposition to a narrow target group with the usage of statistically derived entropy maximization (Tomlin, 2000). The results showed that a nonlinear approach can be used as a component of other models for advertising inventory management. Decomposition of the problem and separation of the advertising impressions was made possible by adding a quadratic punishing which enabled better advertising efficacy (Jie & Ding-Wei, 2004). The model proposed in (Langheinrich et al., 1999) was extended towards the estimation of click-through rates and computing the probabilities of impressions based on the trade-off between exploration and exploitation (Nakamura & Abe, 2005). The presented approach introduced solutions for multiple banner impressions and advertising inventory management. Other approaches are based on the operational level and work through tracking user sessions and maximization of clicks probability (Gupta, Khurana, Lee, & Nawathe, 2011). The solution is based on Bayesian models and generates a ranking of advertisements with assigned probabilities. It is