Agent-based Artificial Consumer Market and Optimization of Defensive Strategies

Jürgen Wöckl*†

Abstract

This paper deals with a simulation approach to explore optimal defensive strategies concerning an entrance of a new firm in a gradually saturated consumer market. The question is how to react on a new entrance from the view of the incumbents and also how to succeeds entering the market from the view of the new entrant.
A agent-based artificial consumer market (AB-ACM) has been designed to provide an experimental environment for the optimization task. The AB-ACM has been formulated very generally to make sure all interested marketing and management related strategies can be considered. Optimization methods are applied to the artificial market to derive optimal strategies obtaining maximal profits to keep competitive and to find optimal reactions for both - the entrant and the incumbents in the market. In the concluding simulation study there is one questions of interest concerning the adaptation of the strategy to obtain maximal profits - the effect of varying heterogeneity of the considered consumer aspiration points. The resulting optimal price-budget combinations remain stable up to a certain degree of heterogeneity. Then a threshold is reached from which further disaggregating the market will lead to boundary solutions.

1 Introduction to the AB-ACM

The artificial market is made up of a constant number of consumers which are represented by artificial agents creating a agent-based framework. Each consumer has an individual aspiration point of attributes which the preferred product should possess. The choice process of the artificial consumer depends on the knowledge of the products offered at the market and the attitude the consumer gained by comparing his aspiration point to the perceived attributes of the product (see [Buchta and Mazanec(2001)]). In the environment it is assumed that each firm just provides one product and therefore the profit of the firm equals the price times sales of its product reduced by the budget spent for advertising. Additionally the variables price and budget are relevant for the attitude of a consumer regarding to the product. The attitude depends to the advertising budget of a firm weighted by the price of the product. At the initial time ($t_0 = 0$) no consumer agent knows anything about the products and the firms on the market, and their choices cannot be made rationally - in the context of choosing a product best fullfilling their aspirations. Primary through the advertising of the firms the consumers get information about the products and their attributes and so they are able to choose the best fitting product. The success of each firm/product depends on the price, the attributes and the invested advertising budget. These variables has to be optimized by all firms in the market, especially at the time of entry of a new firm attacking a segment allready covered by an incumbent.

2 Functionality of the AB-ACM

The following equation (1) shows the evolvement of the attitudes att_{ijk} of a consumer i regarding to the attribute k of product j. This differential equation consists of two parts where the first describes the growth of the attitudes of the advertised attributes starting at 0 up to 1 dependent on the actual relative advertising budget. The second part describes the decay due to the forgetting of the product attributes by the consumers. The appropriate function $b(\cdot)$ is defined in equation (2) and (3).
In the following the indices i denote the aspiration groups, j the brands, k the product attributes and t the time.
The differential equation responsible for the temporal modification of the attitudes p of those attributes which are advertised is the following:

$$\begin{aligned} \frac{d\,att_{ijk}(t)}{dt} &= \frac{1}{price_j^*} \cdots \\ &\quad \cdot \left[aif(budget_j)(1 - att_{ijk}(t)) \right. \\ &\quad \left. - b(t, budget_j) att_{ijk}(t)\right] \qquad (1) \end{aligned}$$

where $aif(budget_j)$ indicates the advertising impact function depending to the advertising budget of product j,

*Adaptive Methodology and Corporate Learning; WU-Wien; juergen.woeckl@wu-wien.ac.at
†ARGESIM; TU Wien; jwoeckl@osiris.tuwien.ac.at

$b(t, budget_j)$ characterize the forgetting rate of the consumer and $price^*_j$ refer the relative price of product j:

$$aif(budget_j) = e^{\alpha - \frac{\beta}{budget_j}}$$

$$price^*_j = \frac{price_j}{\frac{1}{J}\sum_{j=1}^{J}(price_j)}$$

In this equation the oblivion rate is described by:

- for non-advertised attribute:

$$b(t, budget_j) = b_0 \tag{2}$$

- for advertised attribute:

$$b(t, budget_j) = \frac{1}{1 + \mathcal{F}(t, budget_j)} \tag{3}$$

with

$$\begin{aligned} \mathcal{F}(\cdots) &= budget_j(t) \cdots \\ &\cdot \int_0^t \frac{budget_j(\tau)}{\sum_j (budget_j(\tau))} \cdots \\ &\cdot e^{-b_0\,(t-\tau)} d\tau \end{aligned} \tag{4}$$

Equation (3) describes the advertising effect of budget spent in the past. The amount of all advertising budgets effects the present consumers' attitude. The factor $b(t, budget_j)$ in the ODE (equ. 1) regulates the latency of advertising effects - in other words the oblivion of the consumer. So alternating advertising strategies are successfull because of the nonlinear continuation of the effect former advertising budgets. If the advertising is stopped, after some time the effect vanishes and the oblivion rate of the consumers regarding the specific product increases and the attitude decreases continuously. The utility of the consumer i with respect to each product j can be measured using the proportional distance between the appropriate aspiration point and the attitude corresponding to brand j and is calculated as

$$uti_{ij} = \frac{max(distance_{ij})}{distance_{ij}}. \tag{5}$$

3 Design of the Agent-based Environment

The agent-based environment has been implemented using Python and Matlab and the object oriented structure of the agent is shown in fig. (1). The number of agents and firms are constant and for the experiments we used 300 consumer agents and 4 firm agents. The consumers are divided into three equal segments, each containing 100 consumers. The three segments are well separated and all the consumer aspiration points of a segment are normally distributed around a segment specific common ideal point. At initial time $t_0 = 0$ three of the firm agents are in the market and after some time the steady state of each firm serves one segment has arose. This follows because in this state each firm earns sufficient money from the 100 consumers they are serving exclusively and beetween the firms there is no competition necessary. After the market is in this stable but still partly saturated state, the fourth firm enters the market and attacks the segment of one of the incumbents. The market is fully saturated if all consumers have perfect information about all firms/products. The saturation of the market is one of the design factors of this study. In the next section the design and the hypothesis of the study are presented in more detail.

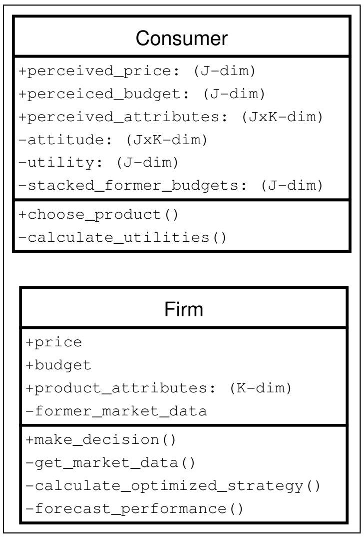

Figure 1: Class Diagrams of the agents 'Consumer' and 'Firm'

4 Experiments and Results

The market which in this study is assumed as an exemplary application for the optimization task consists of three well separated consumer segments each of them treated by a single firm. To optimize their individual profits the brands are able to set the price of the product and the advertising budget to evoke higher consumer preferences and thus higher market shares. After a period of increasing market saturation a new firm enters the market in a specific segment and thus attacks the position of

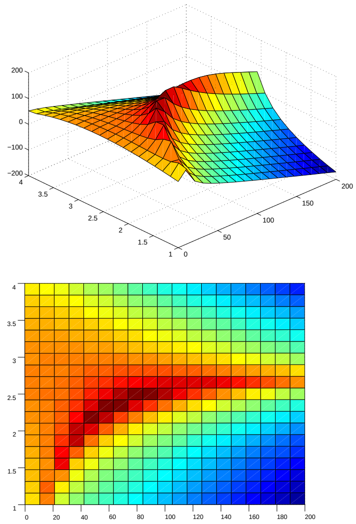

Figure 2: Surface plots of the profits of the incumbent for several price-budget combinations under a fixed entrance strategy in a homogeneous market ($\sigma^2 = 0$)

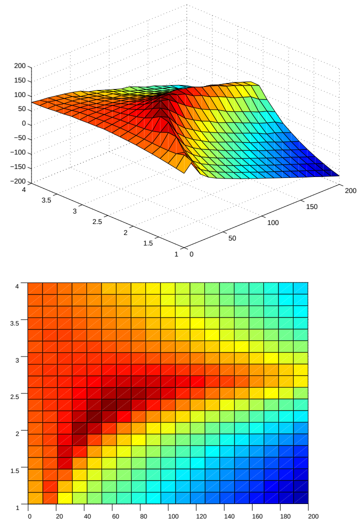

Figure 3: Surface plots of the profits of the incumbent for several price-budget combinations under a fixed entrance strategy in a heterogeneous market ($\sigma^2 = 0.04$)

one incumbent. The emphasis in this study is to derive the optimal reaction of the incumbent as well as the optimal entrance strategy concerning prices and advertising expenditures. The diversification of those optimal strategies varying a certain experimental factor is presented. Here the factor of interest is the heterogeneity of the considered consumer aspiration points. It is expected that the results of the experiment will become more fuzzy with increasing heterogeneity. The firms' target is to optimize their profit, especially after the new entrant participates the market the achievement of an equilibrium is very ambitious. The following figure shows a exemplary plot of the target function for the optimization routines. More results and their interpretation are discussed in the article.

4.1 Optimization of the incumbent varying the "Heterogeneity of the consumers' aspirations"

The experimental factor considered concerns the degree of heterogeneity in each consumer segment. There can either be a single ideal point per segment (homogeneous case) or a more or less diverging pall of individual consumer ideal points (heterogeneous case).

As a first assumption the market segments are homogeneous. That means though each consumer segment consists of 100 consumers, they are assumed to have the same aspiration point. This common aspiration level can be interpreted as the segment ideal point ($\sigma^2 = 0$). Further the incumbents' reaction in case of a fixed entrance strategy is investigated under the assumption that the individual ideal points of the consumers are normally distributed with the segment ideal point as mean and a relatively small variance ($\sigma^2 = 0.04$ and $\sigma^2 = 0.08$) in each segment respectively (fig. 3 and 4). The surface plots are served for all three cases to present the resulting profits for the incumbent under a fixed entrance strategy.

As it can be seen in Figure 2 there is no unique optimum. There exist different price-budget combinations resulting in the same optimal profit for the incumbent. But at least a general tendency concerning price and budget reactions can be read off. More precise the incumbent should reduce its price (down to a value between 2 and 2.5 units) as well as its advertising budget (down to a value in the interval $[50, 100]$) when it is facing a new brand which is entering the market and directly jeopardizing its monopoly in this special market segment.

For the case of distributed ideal points (fig. 3 and 4) the tendency of the prices to stay constant and the budgets to decrease still holds. Prices should be selected from the interval $[2, 2.5]$ and budgets out of $[40, 60]$. Another interesting result the tendency towards a boundary solution. Boundary values like stop spending

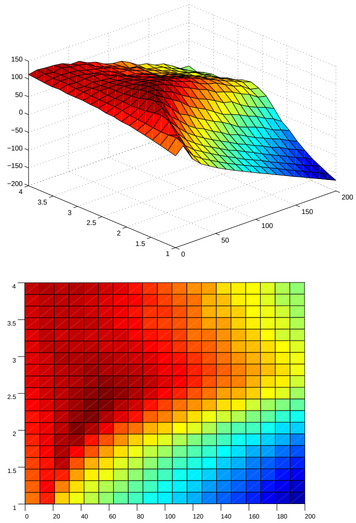

Figure 4: Surface plots of the profits of the incumbent for several price-budget combinations under a fixed entrance strategy in a heterogeneous market ($\sigma^2 = 0.08$)

advertising expenditures at all and set the highest price possible become more and more attractive. For further application studies and a more detail discussion of the strategic suggestions see [Schuster and Wöckl(2005)] and [Wöckl and Schuster(2004)]. Further literature about agent-based implementations and the general approach to the used model can be found in [Buchta and Mazanec(2001)] and [Schwaiger and Stahmer(2003)].

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