Promotion based on digital interaction algorithm

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Abstract. The article is devoted to the modeling of digital interaction by analyzing responses to the promotion of commercial brands through all possible channels of influence on consumer preferences. Formalisms are introduced, a mathematical model is compiled. The calculation of the optimal modes was carried out.

1. Introduction

Nowadays, tools for the interactive exchange of data that carry important business information are in the process of active implementation in the client-provider communications segment [1]. In addition, the ubiquitous development of the Customer Relationship Management (CRM) paradigm provides the basis for a qualitative change in the principles of managing the flow of goods and services in that there is a loop closure in continuous feedback concept [2]. The activities of these systems are based on several main components, which have been developed due to the penetration of the available of smartphone with rich digital functional especially within mobile Internet.

Firstly, a real-time analysis of the effectiveness of omni-channel interaction is based on the most advanced technologies. The ability to work with arrays of clients identified up to a specific person and at the same time to work with a set of data, which includes consumer preferences with their history of acquisitions as well as age, location, movements and other important for business information, is the basis of this type of information influence. In this case, there is used the greatest number of available communication channels and alternatives [3]. At the same time, such software products as XaaS solutions, SIM solutions, active GPS / GLONASS user identification are implemented.

Secondly, the paradigm of search engine optimization (SEO) is maximally realized. This integrated approach provides good search engine results as well as growth in the number of potential customers and maximum income. The main result is associated with an increase in the target return on investment in such an expensive and financially capacious item of budget expenditures as advertising. The Return On Ad Spend (ROAS) is critical for most types of mass-oriented business [4] and primarily for network commerce. The urgency of solving these issues is caused by the proliferation of the Brick and Mortar (B & M) format during organization of a trading business. If the physical presence in the form of a store or show room is based on the developed technologies of interaction with the consumer, the e-commerce requires finding ways to get a high conversion. A management strategy is needed to interact with the potential consumer pool, ensuring maximum conversions with a certain level of return on investment.
The third and decisive factor in the stable development of modern commercial networks was the penetration of the Fifth Party Logistics (5PL) concept [5]. These outsourcers are maximally involved in the current business activities of the client-company, they play a coordinating role while providing physical and information flows and acting as intermediaries, freeing the company from non-core activities.

Since 5PL is based on high-tech, specialized software and digital interfaces for interacting with various companies based on the globalization of the information environment, primary attention of IT units at all levels is given to coordination of virtual digital contact surfaces.

2. **Problem statement**

The formation of the structure of interactive interaction [6] taking into account dynamic and static external factors, as well as the existing technical capabilities is carried out. Mathematical modeling and optimization methods are involved in order to solve the problem. In this case, the criteria are chosen from purely economic considerations: profit maximization, market acquisition, competitiveness.

During the development of a variety of commercial software, on the one hand, modern requirements contain the condition of multi-platform software [7] or platform-independent software and scalability, at the same time, however, provide for their implementation mainly in the form of a mobile application. There should be a placement the application software and system platform in the cloud computing resources of the Internet. The trend of the digital economy means the formulation of practical problems particularly for the specialists in programming. Their implementation is impossible without the use of a wide range of the existing mathematical apparatus and the introduction of interactive interaction methods. It should be noted the active development of a continuously expanding basic set of information about both products and services on the market as well as a deep level of personalized marketing. Software algorithms must be based on mathematical models, as well as data processing using the optimal decision search methods. It is fundamentally important that such an approach will provide market participants with a competitive advantage calculated using scientific methods.

Over the past decade, modern business demonstrates the main trends [8] in the growth of the share of online sales and the merging of enterprises into network structures, primarily in the segments related to the sale of goods and services in retail. Since a large part of the budget allocated for brand promotion is spent on communication in marketing tasks, careful calculation of the optimal balance of the media planning process is crucial. A condition for its effectiveness is the use of a system of measurable quality indicators of commercial activity that has been formed today.

Since consumer preferences that determine market demand are stochastic in nature, the developed stochastic or random process theory is suitable for the formalization of demand process definition. Remarkably, that the indicators used by marketers have full compliance with the characteristics used to describe the processes in a given theory. For example, the time density function (PDF) corresponds to the term Frequency, which is used in the field of media planning, and the corresponding cumulative distribution function (CDF) is used [9] under the term Reach f+.

The use of final indicators to the target audience with a purpose of formalization and providing a solution involves the use of target rating points (TRP), gross rating points (GPR), affinity Index, Index T/U (Target/Universe), Coverage. The optimization criterion is formed through using economically correct CPP (cost per point), as well as CPT (Cost Per Thousand).

We will use the full arsenal of feedback tools to calculate the necessary data for the mathematical model. First of all, these are the tools of the concept of Web 3.0 [10] built into the Internet portals and websites. This specific combination of the two main data sets provides the necessary market picture. In particular, server log processing is used to drill down into traffic, as it contains information that assesses and analyzes websites [11] and, in addition, relevant statistics on their visitors.

Since the set of information of search robots has already been generated in the information flows of Feed, and the history file of already made purchases is integrated into the data exchange structure, after appropriate processing of these flows, the result will be the aggregate indicators necessary for the
simulation. Further, these resources provide a tool [12] for considering a particular stratum on a number of grounds, for example, by gender, age, interests, financial well-being, geo-targeting, etc. At the same time, saving of a set of all possible information in access log protocols, such as unique visitor, is used. Further, tying the traffic data to the time scale, you can get statistics on consumer preferences [13]. Google Analytics (GA) as well as any similar metric can also be used. By the way, since this service is synchronized with Google AdWords, it contains data on the duration of the visit, the geography of visitors, the conversion rate of sites [14], which allows it to be used for optimizing multi-channel and omni-channel interaction modes with consumer community.

3. The main formalisms

In order to state the problem, we define a number of basic mathematical formalisms [15], as well as a set of corresponding constraints. By the term commercial network (sales network) is viewed an extended category of market subjects. In addition to the concept of a community of enterprises operating under centralized management - a single brand, coordinated marketing and distribution, subjects have been introduced to take into account social network penetration, interconnection with Internet portals, global network clients, and mobile interaction, for example, “Google+”. This provides the basis for linking the performance of the enterprise to the dynamics of market needs in real time. This effect was obtained [16] by integrating information on landing pages into the system of job evaluation, collecting economically important consumer leads as well as target leads. Based on this information, the conversion rate, loyalty level, remarketing tag is determined. Tools such as RLSA (Remarketing Lists for Search Ads) from the Google search engine, retargeting and others implemented in common search engines provide, as a result, a vector of indicators (Remarketing Lists for Search Ads) from the Google search engine, retargeting and others implemented in common search engines provide, as a result, a vector of indicators needed to optimize the economic performance of a network business.

In the formalization of the mathematical model [17], we introduce a set of estimates of the market state, having an order $M$. These can be absolute indicators, quantifiable in the form of demand or sales, as well as relative, measured in comparison with previous periods of commercial activity. You can also use statistics in a specific market segment.

There will be introduced a definition of transition matrix $P^0 = \{ p_{ij}^0 \}, \ i, j = 1,...,M$ as the matrix of probability, formed according to marketers’ data [18]. At the same time, the costs of promotion are taken into account in the total figures. Indexes $i, j$ have the following meaning: they denote the probability of transition from state $i$ to state $j$ equal $p_{ij}^0$. Thus, the rows contain complete groups of events, and the total matrix $P^0$ is a right stochastic matrix. From the data on the income of the commercial network is determined by the profit matrix $R^0 = \{ r_{ij}^0 \}, \ i, j = 1,...,M$.

Next the value $K$ will be determined as an equal to the number of types of interaction with the consumer community. These include marketing, advertising, brand promotion, lead acquisition, landing pages, expositions, and other types of media planning [19] and the possible impact on consumer demand preferences. According to this, we introduce a set of transition matrices $P1, P2, ..., PK$, where $P_k = \{ p_{ij}^k \}, \ for \ k = 1,...,K$, and the indices of matrix elements take the values: $i, j = 1,...,M$. The value $\Omega_k, \ k = 1,...,K$ will stand for expenses for each type of promotion. The relationship between the level of market activity and information about economic activity is determined by the calculation of profit matrices $R1, R2, ..., RK$, where $R_k = \{ r_{ij}^k \}$, and also: $k = 1,...,K$ when $i, j = 1,...,M$.

Elements of matrix $RK$ calculated by solving the N/A equation (Nerlove–Arrow equation), which links the activity of promotion $q(t)$, consumer preferences $\Lambda(t)$ and $\vartheta$ - product promotion efficiency: $\frac{d\Lambda(t)}{dt} = \vartheta q(t) - k\Lambda(t)$.
Accordingly, the decrease in income is taken into account at the expense of $\Omega_k$. It should be noted that the elements of matrices $rk_{ij}$, the corresponding values of profit, in turn, are functions of the following arguments: $rk_{ij}(q, \Lambda, \theta, t)$. Essentially important in the calculations is the consideration of the time factor. This is due to the fact that planning is done on a fairly long horizon [20], what causes instability due to a dynamic, rapidly changing market situation. In addition, the relevance of the promotion is reduced due to the influence of competition in this market segment of other participants. The Nerlove-Arrow equation of the dynamic model takes this circumstance into account. As an assumption, in this research it is customary to calculate the indicators periodically, with a certain step or discrete $\Delta t$, for example, ones a week.

4. Calculation

The application of the methods of the optimization theory requires the construction of a mathematical model, determining the maximum profit by conducting events promoting the goods and services on the $N$ periods of duration $\Delta t$, planning horizon.

Optimization, according to the decision method adopted in the work, we will start with the last $N$ period by Bellman principle of optimality, denoting the profit optimization equation $G_n(i)$, where $n$ - stage number (current), $i$ - arbitrary value reflecting the market condition based on consumer preferences. Since the income is equal to the sum of the products of the probabilities of transition to the elements of the profit matrix $\sum\limits_{j=1}^{m} pk_{ij}rk_{ij}$ and the products of the elements of the transition probabilities of the known optimizing solution $\sum\limits_{j=1}^{m} pk_{ij}G_{n+1}(j)$, then you can write an expression to find the optimal value of the following form: $G_n(i) = \max_\lambda \left\{ \sum\limits_{j=1}^{m} pk_{ij} \left( rk_{ij} + G_{n+1}(j) \right) \right\}$.

This maximization formula for $k$ - interaction allows the programmer to build a convenient recurrent algorithm for computer. At the same time, we enter for the current stage $n$ planning horizon, except for the value of the optimal profit $G_n(i)$, also variable sum over $i$ - rows of matrices: $\lambda k_i = \sum\limits_{j=1}^{m} pk_{ij}rk_{ij}$. This makes it possible to finally get an expression acceptable for the development of expert programs: $G_n(i) = \max_\lambda \left\{ \lambda k_i + \sum\limits_{j=1}^{m} pk_{ij} + G_{n+1}(j) \right\}$ for the area $n \in [1, N-1]$, with the entered boundary condition $G_{N+1}(i) = 0$ and for any $i = 1, \ldots, M$.

In order to demonstrate the described methods of mathematical modeling and determine the conditions for the optimal solution, we divide the planning horizon by $N = 3$ stages and take the specific values of economic indicators. For these purposes, we use the reports of the company “Mobyco”, which specializes in consumer goods. Since competition in this segment is strong and there are many other players, there is a strong demand volatility. Therefore, the company monitors the main sales indicators with a frequency of two weeks, which allows to reflect the real dynamics of the market and promptly respond to it. Based on information from marketers, the following transition probability matrices were formed:

$$
P^0 = \begin{bmatrix} 0.15 & 0.54 & 0.31 \\ 0.12 & 0.5 & 0.38 \\ 0.05 & 0.05 & 0.9 \end{bmatrix} \quad P^1 = \begin{bmatrix} 0.4 & 0.5 & 0.1 \\ 0.05 & 0.44 & 0.51 \\ 0.1 & 0.31 & 0.59 \end{bmatrix}
$$
Using information about the operating activities of "Mobyco", as well as the structure of expenses for promotion, the elements of the profit matrix were obtained (values are in thousand Euros):

\[
R^n = \begin{bmatrix} 9350 & 6420 & 2100 \\ 7580 & 5540 & 1250 \\ 5150 & 3270 & 1008 \end{bmatrix}, \quad R_1 = \begin{bmatrix} 6730 \\ 7220 \\ 4970 \end{bmatrix}, \quad R_2 = \begin{bmatrix} 4150 \\ 3420 \\ 2350 \end{bmatrix}, \quad R_3 = \begin{bmatrix} 770 \\ 400 \\ -1800 \end{bmatrix}
\]

The values of the profit vectors are calculated using the formulas mentioned above in this paper. This results in this kind of promotion \( k \), the use of which leads to an economically optimal result:

\[
G_1 = (5520.3; 4154.6; 163.5); \quad k_1 = (1,1,2); \quad G_2 = (9145.7; 6956.5; 2099.9); \quad k_2 = (2,1,2);
\]

\[
G_3 = (12190.5; 9528.3; 4473.5); \quad k_3 = (2,1,2).
\]

These based on estimates of current demand \( m = 1,2,3 \) calculation results mean that during the first planning period the expenses of the enterprise budget for promotion are expedient in the first and third cases, and only in the third case are investments in advertising necessary in the first half of the second month. Accordingly, the calculated maximum profit is equal to the corresponding positions of the vectors \( G_n(i) \) for \( n = 1,2,3 \).

5. Conclusions

The above calculation shows that even on problems of small dimensionality of arguments, it is necessary to use computer calculations and serious mathematical models [21]. This is due to the fact that during commercial activity in the conditions of market uncertainty, only the mathematical apparatus of stochastic processes can provide the manager with the ability to make economically optimal management decisions.

The study shows that the connection of a set of economic indicators of an enterprise activity with the data obtained from the presented model provides a real financial tool for effectively determining ROR (rate of return) or ROI (return on investment). Thus, in a mode close to real time, it is possible to carry out planning of both current and prospective activities using the feedback mechanism with the consumer. The ability to adjust plans dynamically means switching to leading economic indicators. As a result, optimization of the most important item for cost saving for commercial promotion of goods and services is achieved.

References

[1] Borisoglebskaya L N and Sergeev S M 2018 Model of assessment of the degree of interest in business interaction with the university Journal of Applied Economic Sciences vol XII 8(54) pp 2423-48
[2] Provotorov V V 2015 Boundary control of a parabolic system with distributed parameters on a graph in the class of summable functions Automation and Remote Control 76(2) 318-22
[3] Krasnov S V, Sergeev S M, Mukhanova N V and Grushkin A N 2017 Methodical forming business competencies for private label Reliability, Infocom Technologies and Optimization (Trends and Future Directions) 6th International Conference ICRIPTO pp 569-74
[4] Podvalny S L and Provotorov V V 2015 The questions of controllability of a parabolic systems with distributed parameters on the graph International Conference Stability and Control Processes in Memory of V.I. Zubov (SCP) pp 117-9
[5] Iliashenko O, Krasnov S and Sergeev S 2017 Calculation of high-rise construction limitations for non-resident housing fund in megacities E3S Web of Conferences High-Rise Construction 2017 p 03006
[6] Romansky R and Kirilov K 2018 Architectural Design and Modelling of a Web Based Application for GDPR Clarification AIP Conference Proceedings (American Institute of Physics), Proc. of the 44th International Conference on Applications of Mathematics in Engineering and Economics (AMEE’18) 2048 pp 060006
[7] Kamachkin A M and Yevstafyeva V V 2000 Oscillations in a relay control system at an external disturbance. Control Applications of Optimization 2000: Proc of the 11th IFAC Workshop 2 pp 459-62

[8] Provotorov V V, Ryazhskikh V I and Gnilitskaya Yu A 2017 Unique weak solvability of a nonlinear initial boundary value problem with distributed parameters in a netlike region Vestnik of Saint Petersburg University 13(3) 264-77

[9] Aleksandrov A and Zhabko A 2003 On stability of solutions to one class of nonlinear difference systems Mathematical Journal 44(6) 951-8

[10] Aleksandrov A, Aleksandrova E and Zhabko A 2014 Asymptotic stability conditions for certain classes of mechanical systems with time delay WSEAS Transactions on Systems and Control 9 388-97

[11] Alexandrova I and Zhabko A 2018 A new LKF approach to stability analysis of linear systems with uncertain delays Automatica 91 173-8

[12] Kiseleva E, Artemova E, Litvinenko I, Kirillova T, Tupchienko V and Wang Bing 2017 Implementation of Innovative Management in the Actions of the Business Enterprise International Journal of Applied Business and Economic Research 15(13) 231-42

[13] Kravets O J, Podvalny E S and Barkalov S A 2015 Quality assessment of a multistage process in the case of continuous response functions from resource influences Automation and Remote Control 76(3) 500-6

[14] Krasyuk I A, Bakharev V V, Kozlova N A and Mirzoeva D D 2017 Staffing in the sphere of trade: the main issues and prospects of solution Proc. of 2017 IEEE 6th Forum Strategic Partnership of Universities and Enterprises of Hi-Tech Branches 6 48-50

[15] Aleksandrov A and Zhabko A 2014 Delay-independent stability of certain classes of nonlinear systems Applied Mathematics Letters 34(1) 43-50

[16] Aleksandrov A, Zhabko A and Hu G-D 2014 Delay-independent stability conditions for some classes of nonlinear systems IEEE Transactions on Automatic Control 59(8) 2209-14

[17] Podvalny S L, Provotorov V V and Podvalny E S 2017 The controllability of parabolic systems with delay and distributed parameters on the graph Procedia Computer Science pp 324-30

[18] Yanenko M 2016 Cost-Based Brand Management International Business Management 10(26) 5991-5

[19] Krasyuk I A and Medvedeva Y Y 2018 Resource support in business analytics of innovative development of trade and technological systems IEEE Conference on Data Science: Challenges of Digital Transformation pp 482-8

[20] Karelin V V 2010 Penalty functions in the control problem of an observation process Vestnik of Saint Petersburg University Series 10 4 pp 109-14

[21] Kapustina I V, Kirillova T V, Ilyina O V, Razzhivin O A and Smelov P A 2017 Features of Economic Costs of Trading Enterprise: Theory and Practice International Journal of Applied Business and Economic Research 15(11) 1-10