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Review Article

Application of Markov decision process in customer behaviour

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Abstract: Customer is the source of business income, a stable customer base is the guarantee of enterprise survival and development of enterprises by using Markov decision process, decision-makers in the new decision point in time, to the latest state of observation system and adopt an original decision, decided in a well-posed option set an action sequence, and then choose to create value and total revenue in this sequence the most significant behavior, obtain the best marketing strategy, formulate relevant enterprise actual customer, dynamic programming model.

Keywords: Markov decision-making process; Customer behavior; State transition; The marketing strategy

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1 Introduction

The rapid development of the Internet has brought us into the information age, and the business environment of enterprises has undergone drastic changes. In the highly disturbed conditions of the market, competition between enterprises is intensifying, the homogenization of products, shortening the life cycle of the phenomenon makes enterprises rely solely on outcomes has been challenging to maintain a competitive advantage. The rapid development of information technology makes customers no longer a passive recipient; there are more communication channels between customers and enterprises, telephone, Internet, virtual communities and other communication methods to make the communication between enterprises and customers more involved. In this context, enterprises in production, marketing, service and a series of links are to be adjusted accordingly with changes in customer demand, the capture of customer behaviors, is a hot issue of constant concern to the business community and academia, the study of customer behaviors and to obtain the best marketing strategy is an essential basis for customer management decisions throughout the life cycle of the enterprise, only the real solution to the modelling of customer behaviors, to make in the enterprise better implementation. Markov decision process can be used as a theoretical tool to study the problem of optimizing multi-stage decision processes in a stochastic environment, characterized by the fact that the decisions made depend only on the current state of the system and selected actions, independent of history[1]. Markov decision process has Markov properties, shifting probabilities and payoffs only related to the current state and activities are chosen in the At the new decision point in time, the decision-maker should observe the latest state of the system and take an original decision, and so on[2]. This paper is based on the Markov theory, using the Markov decision process to obtain a sequence of actions of customer behaviors, to generate the maximum value and total benefit, to give a quantitative customer behaviors of the theoretical basis for the decision of business managers.

2 Model building

The Markov decision process is a sequential decision model that takes into account the uncertainty of the present and future decision outcomes[4]. It is a system that is capable of transferring from one state to any other possible country, and at each decision time point, the decision-maker selects one action from the set of available fitness modes of operation based on the current state of the system, which affects the probability of the next transfer and generates immediate and subsequent gains (or losses), and the decision maker's decision facing the problem will tend to make the entire decision The gains (or losses) obtained over the cycle are maximized. The Markov decision process steps and model parameters are as follows.

(1) At the moment, observe the state of the Markov chain.

(2)After seeing this state, the decision-maker needs to select an action from the set of possible decisions, noting that the set of potential effects can be different for different countries.

(3)Depending on the current state and the action taken, a corresponding gain (or loss) is generated.

(4)The probability of the transfer changes as a result of the work.

(5)Time increases and the shift occurs again, repeating the above process.

(6)The optimal strategy is the sum of the expected gains from each decision or remaining transfer.

$$v_i(t) = \max_{k \in A_i}[q_i^{(k)} + a\sum_j p_{ji}^{(k)} v_j(n-1)]$$

(7)Optimal policy per single cycle.

Definition:

$$p_i(n) = k^* \quad (1)$$

$$\max_{k \in A_i}[q_i^{(k)} + a\sum_j p_{ji}^{(k)} v_j(n-1)] = q_i^{(k^*)} + a\sum_j p_{ji}^{(k^*)} v_j(n-1) \quad (2)$$

3 Model examples

Consider a computer service company that will be closing down after five years of operation for a corporate transition. The number of customers served by the computer service company each year depends only on the number of customers served in the previous year, and the number of customers served is classified into two states, high and low, through the survey data shows that if the service number in a state of high volume, the company's expected profit will be $10 million, but if the service number tate is in a state of low volume, the company's expected profit decreases to $5 million, at the end of each year, the company for this year's operation situation, corresponding measures. These measures has the certain influence on the mode of operation in the late, at the same time, the future of the next year the amount of the number of service may change due to the taking of measures, the company's earnings also there will be some impact. The company has three options: $4 million to fully upgrade the service system to improve performance and increase the number of customers served, or spend only $2 million to perform regular maintenance on the system, or take no action and spend nothing. The data show that the probability of various shifts in the customer's next year state is as follows: the possibility of the number of people served in a high state is 0.4 if the company does not take any attitude; the likelihood of the number of people served in a high state is 0.8, If the service system is only comprehensively upgraded, the probability of the number of service personnel in the next year is 1. If the service customer was in a low state in the previous year, the likelihood that the number of people served will remain in a small state in the following year is 0.9 if the company does not take any country; if only maintenance of the service system is performed, the probability that the number of people served will remain in a low state in the following year is 0.6.

If only the service system is fully upgraded, the probability that the number of people served in the next year will continue to be in a low state is 0.2. Assuming a discount factor of 0.9, how does the company's decision-maker now go about determining how to make

Table 1. Parameter data map

State i	Option k	$q_i^{(k)}$	$p_{i1}^{(k)}$	$p_{i2}^{(k)}$
1 (High)	No measures	10	0.4	0.6
	Maintenance routine	8	0.8	0.2
	All-round upgrade	6	1	0
2 (Low)	No measures	5	0.1	0.9
	Maintenance routine	3	0.4	0.6
	All-round upgrade	1	0.8	0.2

decisions to maximize the company's profitability in these five years(Table 1)?
Using the Markov decision process (1)(2) equation, it is possible to calculate.

$$v_2(5)=\max_{k\in A_i}[q_i^{(k)}+a\sum_j p_{ji}^{(k)}v_j(n-1)]=\max\begin{Bmatrix}5+0.9[0.1\times v_1(4)+0.9\times v_2(4)],\\3+0.9[0.4\times v_1(4)+0.6\times v_2(4)],\\1+0.9[0.8\times v_1(4)+0.2\times v_2(4)]\end{Bmatrix}$$

$$v_1(5)=\max_{k\in A_i}[q_i^{(k)}+a\sum_j p_{ji}^{(k)}v_j(n-1)]=\max\begin{Bmatrix}10+0.9[0.4\times v_1(4)+0.6\times v_2(4)],\\8+0.9[0.8\times v_1(4)+0.2\times v_2(4)],\\6+0.9[1\times v_1(4)]\end{Bmatrix}$$

$$v_2(4)=\max_{k\in A_i}[q_i^{(k)}+a\sum_j p_{ji}^{(k)}v_j(n-1)]=\max\begin{Bmatrix}5+0.9[0.1\times v_1(3)+0.9\times v_2(3)],\\3+0.9[0.4\times v_1(3)+0.6\times v_2(3)],\\1+0.9[0.8\times v_1(3)+0.2\times v_2(3)]\end{Bmatrix}$$

$$v_1(4)=\max_{k\in A_i}[q_i^{(k)}+a\sum_j p_{ji}^{(k)}v_j(n-1)]=\max\begin{Bmatrix}10+0.9[0.4\times v_1(3)+0.6\times v_2(3)],\\8+0.9[0.8\times v_1(3)+0.2\times v_2(3)],\\6+0.9[1\times v_1(3)]\end{Bmatrix}$$

$$v_2(3)=\max_{k\in A_i}[q_i^{(k)}+a\sum_j p_{ji}^{(k)}v_j(n-1)]=\max\begin{Bmatrix}5+0.9[0.1\times v_1(2)+0.9\times v_2(2)],\\3+0.9[0.4\times v_1(2)+0.6\times v_2(2)],\\1+0.9[0.8\times v_1(2)+0.2\times v_2(2)]\end{Bmatrix}$$

$$v_1(3)=\max_{k\in A_i}[q_i^{(k)}+a\sum_j p_{ji}^{(k)}v_j(n-1)]=\max\begin{Bmatrix}10+0.9[0.4\times v_1(2)+0.6\times v_2(2)],\\8+0.9[0.8\times v_1(2)+0.2\times v_2(2)],\\6+0.9[1\times v_1(2)]\end{Bmatrix}$$

$$v_2(2)=\max_{k\in A_i}[q_i^{(k)}+a\sum_j p_{ji}^{(k)}v_j(n-1)]=\max\begin{Bmatrix}5+0.9[0.1\times v_1(1)+0.9\times v_2(1)],\\3+0.9[0.4\times v_1(1)+0.6\times v_2(1)],\\1+0.9[0.8\times v_1(1)+0.2\times v_2(1)]\end{Bmatrix}$$

$$v_1(2)=\max_{k\in A_i}[q_i^{(k)}+a\sum_j p_{ji}^{(k)}v_j(n-1)]=\max\begin{Bmatrix}10+0.9[0.4\times v_1(1)+0.6\times v_2(1)],\\8+0.9[0.8\times v_1(1)+0.2\times v_2(1)],\\6+0.9[1\times v_1(1)]\end{Bmatrix}$$

$$\begin{cases}v_1(1)=\max\{10,8,6\}=10,\ p_1(1)=1\\v_2(1)=\max\{5,3,1\}=5,\ p_2(1)=1\end{cases}$$

According to the decision theory and strategy iterative algorithm, the results were obtained (Table 2).

Table 2. Graph of outcome data (discount factor 0.9)

n	1	2	3	4	5
$v_1(n)$	10	16.3	21.53	26.11	30.24
$v_2(n)$	5	9.95	14.53	19.11	23.24
$p_1(n)$	1	1	2	2	3
$p_2(n)$	1	1	3	3	2

4 Analysis of results

From the above data, for computer service companies, if the number of people served at the beginning of the high state (state 1), then the company's optimal strategy for the next five years is: there are four years left to choose behaviour 3 (full upgrade), then two consecutive years to choose tone 2 (regular maintenance) and finally the remaining two years to choose action 1 (no measures); if the number of people served at the beginning of the low state (state 2). The optimal strategy for the company over the next five years is to choose Behavior 2 (regular maintenance) with four years left, then select Behavior 3 (full upgrade) for two consecutive years, and finally select Behavior 1 (no measures) for the remaining two years. Each year's decision can be based on decision theory and an iterative algorithm of strategy to find the optimal maintenance strategy, using quantitative data to choose the behaviour that will ultimately maximize the value of the company's profitability. The decisions made by the decision-makers of the company affect the functioning of the customers, which directly determines the lifetime value of the customers. In contrast, the lifetime value of the customers directly determines the profitability of the company, using the Markov decision-making process, the decision-makers determine an action in their sequence of steps, this action has an impact on the probability of transferring the next customer, which will directly generate gains or losses. With the help of the quantitative analysis of the model, the decision-maker can instantly see that different choice lead to different gains, and determine the optimal strategy based on the benefits, which is conducive to the long-term development of the enterprise and plays a decisive role in the survival of the enterprise.

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