The Research on Customer Lifetime Value in Multi-Agent Artificial Market

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Abstract

This paper is to build a Multi-Agent Artificial Market (MAAM) based on the theory about multi-agent system, and the mechanism of MAAM includes the kernel factors in real market, such as market environment, price policy, product utility, customer satisfactory and loyalty index, and recommendation among customers. The result of model validity shows that MAAM has the similar characteristics as the real market, and it provide an experimental environment by which we can take advantage of MAAM to research how CLV evolves in the complex economic environment under the controllable condition.

1. Introduction

Firms are increasingly adopting a customer-centric approach to marketing in this context, and Customer Lifetime Value (CLV) becomes critical. However, many companies do not use CLV measurements judiciously. One of main reasons is that they do not know which factor is the most important for CLV and how to balance their resource and customize the customer's experience to create highest value. The challenge that most marketing managers currently face is to achieve convergence between marketing actions and CRM (Rajkumar 2004), and they may often ask themselves what the CLV should be if they change some of the factors influencing customer relationship.

To find the answer for that question, the resource they own is that a list of customers who have ever done business with the firm, as well as information on the frequency and timing of each customer's transaction. A normal research path is carry out a market survey on a sample selected from customer base, and analyze customer's behaviors and characteristics based on their answers. To get a sound result as much as possible, the market survey should have appropriate sample number and proper sampling method. However, expanding the scale of survey needs more investments on fund and manpower. And even more, the processes of sampling, surveying and analyzing are time-consuming. The investments on fund and manpower could be controlled and compensated in later, but the opportunity cost caused by missing of business chance will be invaluable.

The economic simulation based on theory of complex system modeling provides original research method and analyze tool. A real market actually is a very complex system made up by a large number of participator with the capability of adaptive. On the one side, the inactive among market participators springs up various market rules in the macroscopic view. And on the other side, such existing rules will counteract the each participator, so the market groups up and becomes mature with the interaction of participators behavior and market rules.

2. CLV Measurement

The various components of CLV include purchase frequency, contribution margin, and marketing costs (however, the various CLV components can vary depending on the industry). To calculate the CLV for each customer or the equity of the entire customer base, researches have to propose proper methods to analyze information about the existing customer base and predict the probability value of customer future transaction. Some of the antecedents of purchase frequency and contribution margin can be calculated uncomplicated under the help of information technology, but how to predict customer retention or the likelihood of a customer staying, and the number of expected purchase in the future is not an easy task.

In contractual settings, researchers are interested in predicting customer retention or the likelihood of a customer staying in or terminating a relationship. However, in non-contractual settings, the focus is more on predicting future customer transaction level because there is always a chance that the customer will purchase in the future. Previous researchers have used the variable P(Alive), which represents the probability that a customer is alive (and thus exhibits purchase transaction) given his or her previous purchase behavior (Reinartz and Kumar 2000), to predict future customer transaction level in non-contractual settings.

One method for predicting future customer transaction is to predict the frequency of a customer's purchases given his or her previous purchases records, which assure that customers are most likely to reduce their frequency of purchase before terminating a relationship. Such a methodology enables a customer to return to the supplier after a temporary dormancy in a relationship. This is

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called the “always-a-share” scenario. However, another method of measure assumes that when a customer terminates a relationship, he or she does not return to the supplier. This is also called the “lost-for-good” scenario (Rust, Zeithaml, and Lemon 2004). If a customer is won back after termination, the company treats the customer as a new customer and ignores its history with the customer. The two measure methods mentioned above are suit for different industries. The lost-for-good approach is better reflects the characters of customer in a market with intense competition than always-a-share. Thus, we use the lost-for-good approach in this study. Given antecedents purchase records, predictions of transaction probability, costs of product or service, and discount rate, the CLV function we use can be represented as in (1):

$$CLV = CCV + \sum_{i=1}^{n} (p_i - c_i) \cdot \gamma \cdot (1+d)^i / \tau \qquad (1)$$

where

CCV = Customer current value calculated from antecedents purchase records;

p_i = price of product or service in i th year;

c_i = cost of product or service in i th year;

τ = purchase frequency in the future;

γ = probability of transaction in the future;

d = discount rate from money (set at zero in this study because the length of customer relationship is short).

3. Multi-Agent Artificial Model

The main title (on the first page) should begin 1-3/8 inches (3.49 cm) from the top edge of the page, centered, and in Times 14-point, boldface type. Capitalize the first letter of nouns, pronouns, verbs, adjectives, and adverbs; do not capitalize articles, coordinate conjunctions, or prepositions (unless the title begins with such a word). Leave two blank lines after the title.

Multi-Agent Artificial Model (MAAM) describes an artificial market in virtual world, which includes keen factors in real market, such as the economy activity participants (company and customer), the communication channel between company and customer, the interactive rule amount customers, and customer’s behavior and feelings. Figure 1 shows the framework of MAAM.

A. External Environment

The external environment consists of three tiers, such as market layer, product layer and price layer.

1) Market Layer: Market layer defines a special artificial regional, which provide a place where company and customer have a opportunity to contact and transact. A market grid with two dimensions represents the market in MAAM. The parameter of Xsize and Ysize determines the size of market, and the square of market grid reflects the scale of market.

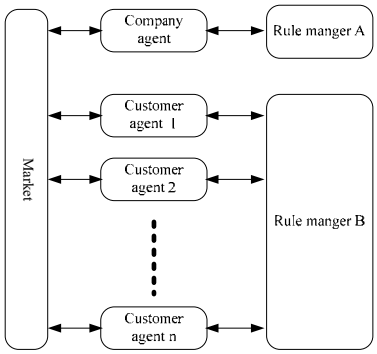

Fig. 1. Framework of MAAM.

2) Product Layer: In real market, company put designated product to satisfy customer’s need, while in MAAM, each grid of product layer is assigned a random value corresponding company distribute product in real market randomly. So the value (x, y) represents the number of product in the coordinate axis with x and y.

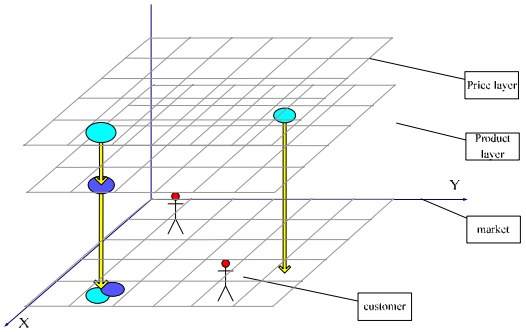

Fig. 2. The contractures of each tier in MAAM.

3) Price Layer: The price layer defines the price of each grid randomly in MAAM. So the price of product is determined by the product’s position projecting on the price layer, and the Price (x, y) means that the product in the grid (x, y) should be soled by the value of price. The figure 2 describes the contracture of each tier in MAAM.

B. Agents in MAAM

In MAAM, there has tow kinds of agents, company and customer. The company agent has the functions like what company does in real market, determining the number of product and its position in market grid, defining the price of product, executing customer satisfactory program and customer retention project, and balancing the resource of market assigned to improve customer satisfactory level or content customer.

Customer is another participant in MAAM. There are a large number of customer agents moving randomly in the market grid with certain velocity, purchasing product in artificial market due to their demands, evaluating the utility of product and level of service, adjusting his Satisfactory and Loyalty Index (SLI) about the company,

and even exchange his feelings with other agents. When the SLI below a certain valve, the customer will not purchase product any more and choose to withdraw from market.

C. Main Methods

To indicate typical behavior and feelings of company and customer in real market, we use six kinds of methods in MAAM, such as deciding price, customer acquisition and retention, purchasing, degree of satisfactory and loyalty, evaluating utility of product, and customer recommendation

Just like in real market, we define the price of product fluctuates in a certain range, as in (2).

$$price=Math.random() \times pricevariable + pricelevel \quad (2)$$

Math random ( ) is a function to generate number randomly between 0 and 1. Pricevariable defines the range of price fluctuating, and pricelevel describes the basic level of price.

In MAAM, the parameter of SLI indicates the life of a customer, and the customer churn when SLI below a certain value. The company is able to acquire new customer, which need given resource of market. The number of new customer joining in artificial market is defined in (3).

$$NewAgent = GainRatio \times DeadAgent \quad (3)$$

GainRatio is the rate of customer acquired by company, which determined by the resource spent on customer acquisition. DeadAgent is number of customer churn at any tick.

Customer moves randomly in the artificial market very tick. If the target grid has product, customer will take it. It is the reason that product is assigned in the market grid randomly, customer's opportunity to contact product is also distribute randomly, which accords with the hypothesis in Pareto/NBD model that customer's makes purchase according to passion process with rate λ.

The function of evaluate utility represents customer feelings about the utility of product, involving utility of product, monetary and time cost spent on purchase, as (4).

$$\psi = f(u,p,t) = \alpha \cdot u - \beta \cdot p + \theta \cdot t \quad (4)$$

u means the utility of product，and p defines the price of product. t shows the time spent on choosing and purchasing product, and we use tick to represent time in MAAM. The parameter of α, β, θ mean the weights of utility, price and time separately. As mentioned above in this study, the value of SLI changes depending on the utility of product. When the utility is positive, SLI increase a unit, and vice versa. The degree of SLI change be set due to susceptibility of customer to satisfactory. Further more, when a customer moves to a grid without product, his value of SLI will decrease a unit.

We define that a market grid can only contain a customer, so if the target grid has obtained by another customer, the position confliction occurs in artificial market. Agent take advantage of position confliction to communicate and exchange their feelings about the company, and the result is that number of product each customer owned do not change, but the SLI of each customer becomes the half of sum of two customer's SLI.

D. Event Schedule

How to dispatch the order of the behavior of agent and event in MAAM is described in table I.

TABLE I
DISPATCHING THE ORDER OF THE BEHAVIOR OF AGENT AND EVENT IN MAAM

Step	Agent	Behavior
1	Company	Deciding product price, assigning product to market, customer acquisition
2	Customer	Moving in market grid randomly, purchasing product
3	Customer	Evaluating the utility of product, modifying SLI at any tick
4	Customer	Communicating and exchanging SLI when position confliction.
5	Customer	Do not buy product any more and choose withdraw from artificial market when SLI below valve.
6	Company	Calculating the number of product sold to customer, revenue and number of customer remain in artificial market.

4. Result of MAAM and Examining Model

A. Result of MAAM

As shown in figure 3, the result of MAAM reflects the main character of keen factors in artificial market.

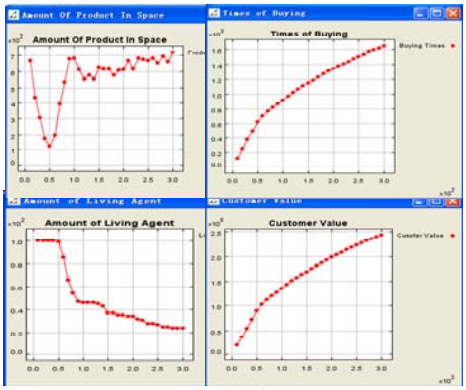

Fig. 3. Result of MAAM.

From the top left of figure 3, it is clear that product is sold rapidly in the early period, so the number of product remains in market decrease fast. With the number of product in market declining, the opportunity to meet product will also bring down, which lead customer

dissatisfactory to company, and customer will choose to withdraw from market. That is what we can see from bottom left of figure 3, the amount of customer in artificial market reduces quickly from 50 ticks to 100 ticks, and then the speed of customer churn becomes slow. On the right of figure3, both times of buying and customer values are increase as the time goes on. However, the decreasing of curve's slope indicates that number of transaction and customer values go down at the same time unit.

B. Examining Model

1) Data: To validate the correctness and validity of MAAM, we compare the result of MAAM with the data from CRM database of a large, multinational company (ITCOM). The product categories in the database represent different spectra among high-technology products. For the product categories, the buyer and seller choose whether to develop their relationships, and there are significant benefits to maintaining a long-standing relationship for both buyers and sellers.

The data used in the study cover a four-year period from the beginning of 1998 to the end of 2001. All of the customers are new to the firms and made their first purchase from the manufacturer in the first quarter of 1998. A total of 12,024 prospects were contacted for potential acquisition, and of those, 2908 made at least one purchase in the first quarter of 1998. The average inter-purchase time for an individual customer ranged between 1.5 and 21 months.

2) Comparison: The table II shows the result of comparing MAAM and real market. From the curve of customer retention (CN), times of buying (BN) and customer values, it is clear that MAAM reflect the typical character of real market closely.

TABLE II
COMPARE RESULT OF MAAM WITH ITCOM

	MAAM			ITCOM		
tick	CR	PF	CLV	CR	PF	CLV
0	64	0	0	95	0	0
150	29	19.9	44.7	37	11.0	14.6
300	24	14.8	65.9	21	10.7	34.3
500	18	10.0	74.3	17	10.7	49.7
700	16	7.8	81.3	14	9.6	64.7
1000	16	6.3	94.5	18	9.1	93.9
1500	13	5.0	134.6	11	3.5	144.5

CR = Number of Customer Retention, PF = Purchase Frequency, CLV = Customer Lifetime Value. The unit of CLV is ten thousands of dollars.

5. Implications on CLV

With the help of MAAM, we can do a serial of parallel experiments under controllable condition, which will help us have an insight into how the main parameters in CLV function and CLV itself change in different conditions, such as company scale, size of customer base, customer satisfactory and loyalty index, and customer acquisition.

A. Purchase Frequency

An object of relationship marketing is to ensure future purchase transaction. Purchase frequency is not only a sign of the quality of a relationship (Anderson and Weitz 1992), but also a component of out CLV calculation. As we mentioned above, the decreasing of slope of times of buying curve indicates that purchase frequency of customer decrease along with time generally. And both the company scale and size of customer base has positive influence on purchase frequency of in the early phase of customer relationship, while the SLI and customer acquisition have not notable effects on customer purchase frequency.

B. Customer Retention

Customer retention is an imperative in modern business, and it is also a strategy whose objective is to keep a company's customers and to retain their revenue contribution. From the result of experiment, both the size of customer base and initial value of customer SLI only affect customer retention in the early, however, when tick greater than 500, its influence becomes insignificant. Another discover from these experiments is that susceptibility of customer to satisfactory has negative effect on customer retention. The reason is that lower susceptibility of customer to satisfactory means SLI decrease slowly even when the customer dissatisfy with the product or service, so the customer keeps the relationship with company for a long time.

C. Customer Lifetime Value

To inspect how the control capability affects CLV, we change one of the parameters of MAAM every time, such as company scale, size of customer base, susceptibility of customer to satisfactory, and customer acquisition. Firstly, the company scale has positive effect on CLV. So the more products put in market, the more opportunity for transaction, and create higher CLV in the long run. Secondly, the size of customer base also has positive effect on CLV. But the fact is that initial size of customer base only has influence on customer value at the beginning period. Thirdly, customer with lower susceptibility to satisfactory has longer lifetime, which indicates more chance to purchase in the future and higher CLV. Finally, if we set the parameter GainRatio equal to zero which means without new customer adds in market along with time, the number of customer remain declines rapidly. When tick = 129, all of the initial customer churn completely. At that condition, the CLV is quite lower, and the fact points out that it is very important to acquire new customer for company.

6. Limitations and Further Research

Despite the usefulness of the MAAM model, we realize that it has certain limitations. For example, there has only one company agent in artificial market, which can not describe the phenomena of market with competition. However, because we wish to find main rules and patterns between company and customer in real market, in this research we abstract the concept of market with one company agent.

Another caveat of this research is we study customer acquisition and retention separately. This separation is more easily to find the net effect of single factor. But in the reality, company often takes into account customer acquisition and retention together in practice. So we should consider those two factors at the same time and find the balance between customer acquisition and retention.

Finally, to arrive at empirical generalizations, additional research should investigate the detail mechanism about how customer relationship and CLV affect by customer feelings. The key limiting factor seems to be the unavailability of appropriate data that enable these kinds of tests. However, this research has taken a first step toward a more complete understanding of the drivers of customer relationship and CLV by using theory of CRM and technology of economic simulations.

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Appendix

A. Schedule Function iin MAAM

The minimum unit of time is day, and we use one tick in MAAM to represent a day in reality. In Repast, the buildShedule function service as dispatcher to determine which event take place and interval between events.

```
public void buildSchedule(){
// print information in Repast output area.
System.out.println(“Running BuildSchedule”);
// initial and update the product, price and customer agent in market grid.
displaySurf.updateDisplay();
// begin the action of schedule from tick = 0.
schedule.scheduleActionBeginning
(0,new ArtificialMarketStep());
// count the number of customer retention in artificial market very 10 ticks.
```

```
schedule.scheduleActionAtInterval
(10, new ArtificialMarketCountLiving());
// update product's position in market grid very 10 ticks.
schedule.scheduleActionAtInterval
(10, new ArtificialMarketUpdateProductInSpace());
// update position of customer remaining in artificial market very 10 ticks.
schedule.scheduleActionAtInterval
(10, new ArtificialMarketUpdateLivingAgent());
// count the total number of buying in artificial market very 10 ticks.
schedule.scheduleActionAtInterval
(10, new ArtificialMarketUpdateTimesBuying());
//      count the CLV in artificial market very 10 ticks.
schedule.scheduleActionAtInterval
(10, new ArtificialMarketUpdateCustValue());
// update the status of customer, and set his color to blue if his SLI less than a certain valve very 10 ticks.
schedule.scheduleActionAtInterval
(10, new ArtificialMarketUpdateAgentWealth());
}
```

B. Results from Parallel Experiment

With help of MAAM, we do a serial of parallel experiments to research how the parameters in artificial market affect customer retention, purchase frequency and customer lifetime value. Table III shows that the value of product in MAAM is set by five different values from 200 to 2500, and other parameters keep the same. (Other schemas of parallel experiment and result are not listed in the paper due to the limited space.)

The table IV describes the result of parallel experiment. We collect data about the number of customer remain, purchase frequency and customer lifetime value every certain tick. The result of parallel experiment provides data to research how these kernel factors in CLV change with market environment.

TABLE III
INITIAL PARAMETER OF PARLLLEL EXPERIMENT

parameter	A	B	C	D	E
Product	**200**	**500**	**1000**	**2000**	**2500**
WordXSize	50	50	50	50	50
WordYSize	50	50	50	50	50
NumAgents	100	100	100	100	100
AgentMaxSati	50	50	50	50	50
AgentMinSati	30	30	30	30	30
IncrSatiRatio	0.4	0.4	0.4	0.4	0.4
DecrSatiRatio	-0.4	-0.4	-0.4	-0.4	-0.4
IncrLoyaRatio	0.4	0.4	0.4	0.4	0.4
DecrLoyaRatio	-0.4	-0.4	-0.4	-0.4	-0.4
GainRatio	0.05	0.05	0.05	0.05	0.05
ChurnValve	0	0	0	0	0

TABLE IV
RESULT FOR PARALLEL EXPERIMENT

	A	B	C	D	E
tick =150					
CR	28	36	43	53	58
PF	3.1	4.7	7.5	9.6	9.9
CLV	7.3	11.1	17.3	21.7	23.3
tick = 500					
CR	12	10	21	28	34
PF	1.9	2.8	4.2	5.8	7.2
CLV	14.4	20.8	31.5	43.5	54.9
tick = 1000					
CR	7	8	12	20	19
PF	1.3	1.8	3.2	4.6	5.5
CLV	20. 0	26.6	47.8	68.7	82.9
tick = 1500					
CR	4	6	8	13	11
PF	1.1	1.5	2.5	3.8	4.4
CLV	23.5	32.2	56.7	85.2	99.6
tick = 2000					
CR	4	5	6	10	9
PF	0.9	1.2	2.1	3.2	3.7
CLV	25.4	36.4	63.2	97.1	109.6

CR = Number of Customer Retention, PF = Purchase Frequency, CLV = Customer Lifetime Value. The unit of CLV is ten thousands of dollars.