

Fuzzy Virtual Card Agent for Customizing Divisible Card Payments

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Abstract: E-commerce customers may have a problem when paying for the purchase of a major item, if its price is larger than the available credit on their credit card. In the brick and mortar world, this problem would be solved by paying part of the bill with cash or with a second credit card. In e-commerce, however, this has not been an option. Furthermore, even when a customer could pay the whole purchase with one of her credit cards, she may prefer to first max out another card with a lower interest rate. The overall goal of this research is to provide customers with the capability of customizing their payments by splitting an e-commerce payment over multiple cards, while taking into account a set of competing preferences over policies and constraints of various cards in determining which cards to use. This paper presents an intelligent card management system, called *Fuzzy Virtual Card Agent (f-VA)* that supports the customer's divisible payment decision. By modeling the customer's preferences using weighted fuzzy set memberships, the *f-VA* considers the preferences over the card issuers' policies, such as credit limits, interest rates and many others as well as the policies imposed by the secondary issuers, such as employers, and suggests the best combination of cards to the customer. The customer can take advantage of the suggestion by the *f-VA* or modify it immediately on the Web. Our approach provides customers with a more flexible card payment method for online purchases and can be extended to any types of purchases, such as mobile commerce payments.

1. Introduction

An e-commerce customer may face a problem when paying for the purchase of a major item, if its price is larger than the available credit on each of her credit cards. While the total available credit on all her cards may well exceed the sale price, the merchant would not be able to complete the sale because today's e-commerce systems can only accept a single credit card for a single transaction. In this case, it is in the best interest of the merchant to allow the customer to split the payment over multiple credit cards. I

It is also in the interest of the customer to gain the flexibility of splitting a purchase price over several cards. For example, a customer may have a preferred card **A** with a low interest rate and a second card **B** with a high interest rate. Without an option of splitting

the purchase price over several cards, the credit limit and prior spending on **A** may leave her to pay the purchase with the higher interest rate card, **B**. The customer, however, would be better off if she could first max out the remaining credit on card **A** and then pay the balance of the purchase price with card **B**, lowering her high interest balance on **B**.

How to split a purchase price over multiple cards, however, is a complex decision to make. Today's typical customer carries a wide variety of cards with a corresponding variety of incentives, such as frequent flyer miles, cash back, introductory low interest rates, promotional gifts, etc. In addition, some credit cards are issued through employer organizations, called secondary card issuers, with company specific policies, such as that the card is allowed only for business expenses or for office supplies, which will further affect the choice of cards. Furthermore, sellers may impose their own constraints such that not every credit card is accepted everywhere. Lastly, the choice of the ideal card (or card combination) often depends on the paying habits of the customer and the calendar date of purchase. Most customers would prefer to pay with a credit card, which will buy them a delay. Thus, all other factors being equal, a customer would prefer to use a card where the closing date is 20 days away over a card where the closing date is only 2 days away. For customers who carry large balances over long periods, the interest rate is an important decision factor. For the customers who pay their bills off every month and do not care about interest rates at all, on the other hand, the closing date might be more important.

Therefore, while it is clearly in the interest of a sophisticated credit card user to be able to split a purchase price over multiple cards, as described above, she may find herself in a state of confusion about how to split the payment exactly. We call this problem of choosing an optimal card or card combination the *divisible payment decision problem*.

Since the criteria for choosing a set of credit cards for payment are diverse and differ from one customer to another, customers need help in keeping track of all their cards and their incentives and constraints. In addition, at the time of making a purchase, customers need help with the complex decision of how to optimally split a purchase over multiple cards. In this paper, we report on a prototype implementation of a *fuzzy virtual card agent*, which allows split credit card payments and helps the customer optimize the distribution of his charges over multiple cards. This paper is organized as follows. The background review of the divisible credit card payment system is provided in Section 2. Section 3 introduces our fuzzy Virtual Card Agent. Experimental results are shown in Section 4. Finally, the conclusions are presented in Section 5.

2. Previous Work and the Divisible Credit Card Payment System

Much research on credit card payments for e-commerce focuses on the security issues [1]. In order to reduce the fraud with the permanent card numbers, the card issuing banks, such as American Express, Discover, and MBNA, may issue a one-time use credit-card number instead. A study about payment with single-use credit card numbers appeared in [2]. In our paper, the idea of single-use credit card numbers is applied to divisible card

payments. According to the infrastructure presented in [5], the system creates single-use credit card numbers called *virtual card numbers*.

There have been studies on divisible e-cash payment protocols [3, 4]. These studies focus on payment solutions that ensure anonymity while allowing electronic coins to be divisible. That is, each coin can be spent incrementally as long as the total purchases are limited to the monetary value of the coin. These works look at multiple purchases and multiple merchants while this paper is about one purchase with one merchant but with multiple credit card issuers.

Most studies on credit card payment do not focus on the credit card user's practical decision-making problem. However, users may face a complex utility optimization problem during each purchase, namely, which card would be the best one to use among multiple cards for this particular purchase. Most of the early recommender systems are based on simple database queries [11]. Fuzzy logic has been used in modeling market structure since it can handle the uncertainty associated with customer choice [6]. Based on a customer's demographic information, the potential of a visitor as a purchaser of services is classified using fuzzy methods [7]. Fuzzy logic has also been used to cluster customers into several groups based on the customers' data [12]. Miao et al. have conducted a case study on a recommender system regarding automobile purchases [13]. A general introduction to fuzzy set usage can be found in [14].

In the above studies, only the general possibilities of fuzzy technology in e-commerce were discussed. The customer's perspectives on credit-card usage have been addressed in the literature [15,16,17] but not from the perspective of split card payment decisions. In this paper, the fuzzy Virtual Card Agent has been developed not only to obtain the best combination of credit cards with respect to the customer's perspective but also to simplify the complexity of choosing the combination of cards, with many constraints and policies to be considered.

Park et al. [5] has proposed an infrastructure and protocol that support divisible credit-card payments of a single purchase, as shown in Figure 1. In their infrastructure, a *Virtual Card* (V-Card) is created and used each time the customer wants to use a combination of cards. This new infrastructure modifies the existing systems in two ways. First, to support the divisible card payments, the *Virtual Card Manager* (VCM) is added to the merchant side. The VCM handles the V-Card approval process between the merchant and the respective credit card issuers for all the cards in a V-Card. Second, to support the customer's card-usage decisions and to generate a V-Card, the new infrastructure provides the customer with a *V-Card Agent* (VA). As which card(s) to use is a complex decision, an optimization model is built into the VA. Based on the user's preferences, the VA generates a solution that may suggest using multiple cards for a single purchase.

Unfortunately, the optimization model in [5], a linear programming model that maximizes the customer's additive utility function, was rudimentary at best. It considered only a couple of limited card features and provided no details on how to build the utility function (i.e., how to compute the value of the weight for each feature). Our subsequent study suggests the difficulty in creating and maintaining the customer's utility function.

The effectiveness of the VA affects the performance of the whole divisible payment system. Therefore, how to develop an effective and efficient VA that can accommodate numerous card features and policies has remained as an important research issue.

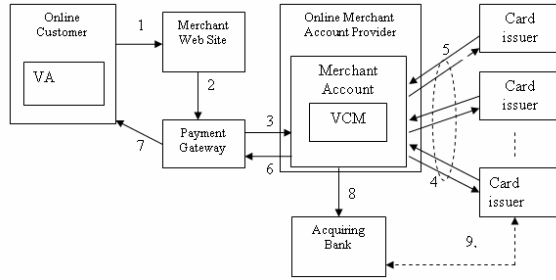


Figure 1. The Virtual Card Payment Infrastructure (Adopted from [5]).

3. Fuzzy Virtual Card Agent

The VA's optimization process requires a computing environment. While one may imagine that in the future a person shopping in a store will be able to use a PDA (a palmtop) to compute an optimal card split and then transfer the solution by Bluetooth or infrared signal to the cash register, this is not currently a viable situation. Therefore, online purchases, which provide a natural computing environment, are our choice for the implementation of the divisible card payment infrastructure. Our approach for the divisible payment decision problem is based on combining fuzzy set theory and user-chosen weights and thresholds with a greedy algorithm, as described below.

Given a set of credit cards $C = \{c_1, c_2, \dots, c_n\}$, and a set of policies or criteria applicable to each card, $P = \{p_1, p_2, \dots, p_m\}$, we can define the customer's preferences for different policies as weights dependent on the policies as shown in (1).

$$\text{Customer's preference for policy } j \text{ on card } i: w_i(p_j), \quad (1)$$

where $0 \leq w_i(p_j) \leq 1$, $1 \leq i \leq n$, and $1 \leq j \leq m$. Typically, we assign the same weights of policies to all the n credit cards (i.e., $w_1(p_j) = w_2(p_j) = \dots = w_n(p_j)$), and use $w(p_j)$ instead of $w_i(p_j)$. For instance, a customer may give a higher weight to interest rate and a lower weight to frequent flyer miles, but she will assign the same weights of policies to all her cards. Of course, the preference of one policy/criterion over another varies between customers.

The customer may consider a certain value for each policy as favorable. For example, an interest rate below the prime rate or 1000 frequent flyer miles might be viewed as

favorable conditions. This is modeled by a threshold value of policy j , $t(p_j)$. Similar to the case with weights, we apply the same threshold value of a policy to all the credit cards.

Each policy j for each credit card i has a “current” value, $v_i(p_j)$. When the policy’s value is below the threshold value, there are degrees of goodness of the policy. These degrees of desirable values of a policy are represented by *fuzzy set membership values*. Equation (2) represents the fuzzy value for each policy j on card i , $f_i(p_j)$. The fuzzy membership value is “1” if the current value of the policy/criterion is equal to or greater than the threshold value; otherwise, the membership value will be calculated by the first part of equation (2).

$$\begin{cases} f_i(p_j) = \frac{v_i(p_j)}{t(p_j)} & , \text{if } v_i(p_j) < t(p_j) \\ 1 & , \text{otherwise} \end{cases} \quad (2)$$

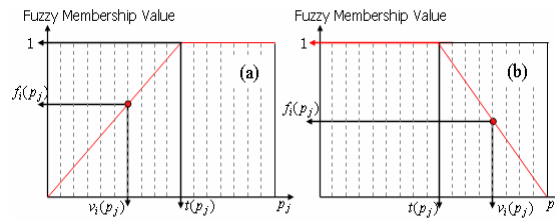


Figure 2. An example of determining the fuzzy membership value of a certain criterion

The fuzzy membership values are determined for each criterion/policy of each credit card separately. There are two types of criteria. First, the larger the value of the criterion is, the more desired it is by the user, as shown in Figure 2(a). Second, the smaller the value of the criterion is, the more desired it is, as shown in Figure 2(b). To limit the complexity of the user interface and the user friendliness for a population that is not familiar with fuzzy sets, we use the linear shoulder shape fuzzy membership functions [14], as shown in Figure 2. Figures 2(a) and 2(b) show the shapes of a right and a left shoulder, respectively. More complex or user defined fuzzy functions are achievable but require additional computing overhead to implement. Note that the fuzzy membership function is not generated until the user determines the threshold value.

Figure 3 shows a fuzzy membership function for a policy/criterion of *closing date*. Note that the actual criterion used is the number of days remaining until the closing date. That is, the difference of the closing date and the current date is the parameter of interest. Naturally, most people would prefer to use a credit card for which the closing date is far away. Suppose “10” is the threshold value of this criterion. Then the fuzzy membership values for the numbers of remaining days 4, 6, 8, 13, and 18 are 0.4, 0.6, 0.8, 1, and 1, respectively.

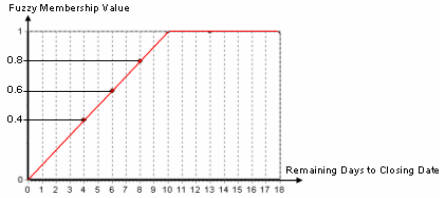


Figure 3. Fuzzy Membership

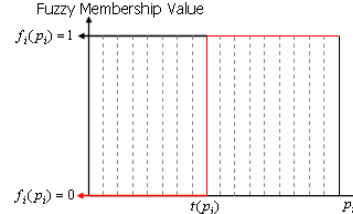


Figure 4: Fuzzy Membership for Office Supplies

For some credit card usage policies, such as “the credit card can only be used to purchase office supplies,” where the criterion is binary, the fuzzy membership function generates either 1 or 0 as shown in Figure 4.

Given the membership function and the preference weights for each card policy, the fuzzy V-Card Agent achieves an optimal card combination through the following steps. First, the user initializes the weights and fuzzy sets, based on her preferences, for multiple criteria (credit card policies). The criteria modeled in this paper include the amount of available credit before reaching the limit, the interest rate, the closing date, and the bonus rate. Secondly, the fuzzy membership value of each criterion of each card is determined by the corresponding fuzzy set, taking into account external factors such as the date of the purchase event. Thirdly, for each card, the *f-VA* sums the weighted fuzzy membership values of all constraints and generates a payment suggestion based on the card with the maximum value. Finally, the *f-VA* proposes to the user to pay the purchase amount with the selected credit card. If the selected credit card does not have enough available credit for the whole payment, the *f-VA* repeatedly performs the above procedure until coming up with a combination of credit cards which covers the total purchase price.

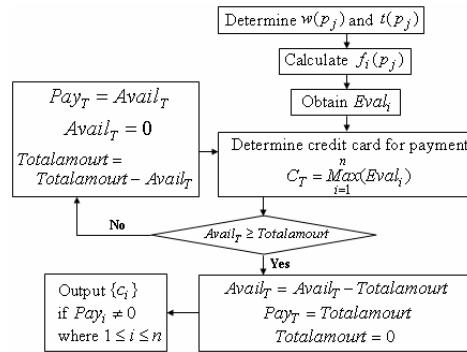


Figure 5. The flowchart of our fuzzy virtual card agent.

Let c_i and $Eval_i$ be the i -th credit card and its evaluation value, respectively. Let $f_i(p_j)$ and $w(p_j)$ be the fuzzy set and the weight of the j -th criterion of the i -th credit

card, respectively. Let n and m be the total number of credit cards and the total number of criteria, respectively. Let C_T and $Totalamount$ be the selected T -th card for payment and the total purchase amount, respectively. Let $Avail_i$ and Pay_i be the available credit and the payment of the i -th credit card, respectively. Following is our algorithm, and its flowchart is shown in Figure 5.

Fuzzy Virtual Card Agent Optimization Algorithm:

1. The user defines her preferences by initializing the weight, $w(p_j)$, and the threshold value, $t(p_j)$, for each criterion/policy.
2. Calculate the fuzzy membership value, $f_i(p_j)$, for each criterion/policy on each credit card, where $1 \leq i \leq n$, and $1 \leq j \leq m$.
3. Obtain the evaluation $Eval_i$ for each credit card c_i by computing

$$Eval_i = \sum_{j=1}^m f_i(p_j) * w(p_j) \quad (3)$$

4. Determine the optimal credit card for payment by

$$C_T = \underset{i=1}{\overset{n}{Max}}(Eval_i) \quad (4)$$

5. If $Avail_T \geq Totalamount$ then pay the whole amount with the “best” card T :

$$Avail_T = Avail_T - Totalamount, Pay_T = Totalamount, \text{ and } Totalamount = 0.$$

Else make a partial payment with the best card:

$$Pay_T = Avail_T, Avail_T = 0, \text{ and } Totalamount = Totalamount - Avail_T$$

6. If $Totalamount = 0$ then we are done:

Output Pay_i if $Pay_i \neq 0$ and a corresponding list of cards, $\{C_i\}$ indicating the suggested payment distribution.

Else Repeat steps 3 to 6 until $Totalamount = 0$.

4. Experimental Results

In order to test our fuzzy Virtual Card Agent system, we have considered four policy criteria, available credit limit, interest rate, closing date, and bonus. After all thresholds and weights are determined, the system evaluates each card using Equation (3). The fuzzy membership function in the system is applied to quantify the user preferences.

Figure 6 shows the list of credit cards a user has and Figure 7 shows the detailed information of a credit card that the user wants to view.

Card No.	Card Nick Name	Account No.	Expiration Date	
card1	yc1	null	null	View Details
card2	yc2	null	null	View Details
card3	yc3	null	null	View Details
card4	yc4	null	null	View Details
card5	yc5	null	null	View Details
card6	yc6	null	null	View Details
card7	yc7	null	null	View Details

[Let's Register Another Card in This System CLICK HERE](#)

Figure 6: List of credit cards of the customer

Card Nick Name : yc1
Card No. : card1
Account No. : null
Expiration Date : null
Credit Limit : 1000
Interest Rate : 10
Credit Limit : 1000
Monthly Minimum Payment : null
Closing Date : 28
Balance : 0
Available Money : 1000
Balance : 0
Flight Miles : 1
Cash Back : 8
Bonus Coupon : 8
Cash Back : 1

Figure 7: Detailed information

Figure 8 shows an example of how the user influences the fuzzy set for the closing date criterion. For example, if a user prefers to make a payment no earlier than 10 days, he will input 10 as the threshold value as shown in Figure 8(a). Figure 8(b) contains the graphical display of the selected fuzzy set for the closing date, based on the desired threshold value, of 10, which was obtained in the step shown in Figure 8(a).



(a) Entering the threshold value (b) Graphical display of the fuzzy set for closing date
Figure 8. The adjustment of the fuzzy sets.

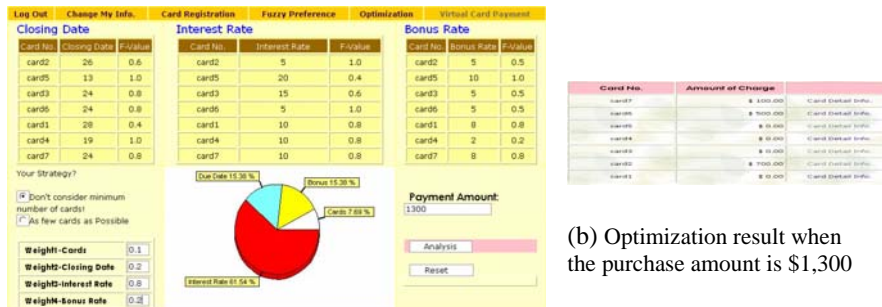


Figure 9 (a) Weight assignment

(b) Optimization result when the purchase amount is \$1,300

The user may choose between two variations of our implementation. She may ask for a minimal number of cards, or indicate that she does not care about the number of cards being used but is rather concerned about the supported criteria, such as closing date, interest rate, and bonus rate. The interface for the weight assignment of our f -VA system is shown in Figure 9(a). The graph located in the center of Figure 9(a) represents the distribution of the weights, which is obtained by the following equation:

$$D_i = \frac{W(P_i)}{\sum_{j=1}^n W(P_j)}, \quad (5)$$

where D_i indicates the normalized weight of criterion/policy i relative to the weight sum of all criteria. For example, the normalized weight of the criterion interest is 61.5%, computed as $(0.8/(0.1+0.2+0.8+0.2))$. Figure 9(b) shows the optimization result when the purchase amount is \$1,300. The payment is split over three credit cards. After the user has accepted the result of the optimization, the system creates the VC. Combining the numbers of all the cards involved in the payment generates the card number for the VC. The timestamp represents the time when the VC was created.

5. Conclusions and Future Work

We have presented our implementation of a *Virtual Agent* in which a weighted fuzzy set algorithm is used to model user preferences. The use of weights allows users to express relative preferences between criteria. The use of fuzzy sets allows time-dependent and parameter-based computations which determine the evaluation of a card on a daily basis.

We are currently working on the implementation of other modules in Figure 1, including a (simulated) merchant Web site and simulated Web sites for several card-issuing banks. In addition, we are adding functionality to the f -VA of inquiring (checking) the available credit limits from issuing banks before generating a VC. This functionality is needed because, although our system can keep track of the purchases done through the f -VA, it may not know about the purchases made outside (for example, the card purchases made at a local supermarket).

Several immediate improvements of our implementation and our model are possible. First, the customer could be given the ability to select a fuzzy membership function of his liking by graphically deforming the diagram representing it (see Figure 8). This would allow more complex fuzzy sets without requiring any more knowledge of the user. Other improvements of the user interface are also possible. Secondly, more policy features (in addition to the ones modeled in this paper) should be accommodated. Thirdly, the user should be able to permanently pre-select certain features as irrelevant. For example, a card user who pays off his bill every month would not be interested in the interest rate, so she should not have to say so every time she uses the virtual card system. Fourthly, a more sophisticated optimization model could be possible. Our current model makes a greedy decision at each stage about which card is best, as opposed to trying to achieve an overall optimization. Finally, a split payment system might be of interest in the business-to-business community. This remains a major issue for future work.

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