MULTIAGENT MODELING AND SIMULATION OF CONSUMER BEHAVIOR TOWARDS PAYMENT SYSTEM SELECTION

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ABSTRACT

Digital retail payments have evolved during the last years mostly due to technology innovations. New actors enter the payments market, increase competition and threaten banks' dominance. Consumers' behavior is critical within this context, since they are the ones that will finally adopt or reject a payment innovation. In this paper we propose a model of consumer behavior towards payment system selection based on multi-agent simulation. It is based on a multi-agent platform that models consumers as intelligent agents and formats their behavior according to rules extracted from past payments data, experts' knowledge and marketing research. Contributions from social science and network economics also refine the agent's behavior in order to simulate accurately the domain. This paper presents the overall model and an initial analysis of payments domain, defining major actors in the domain and their interpretation to agents.

INTRODUCTION

Payments industry influenced by technology trends and encouraged by legislation is undergoing rapid changes. New entrants in the market of payment systems are reducing banks' shares and increase competition (Markose and Yiing 2000). This framework, forces all players to innovate in order to increase their competitive advantages. However, high investment costs, network effects and lots of failures due to unpredictable consumer adoption characterize new innovative payment solutions. Traditional tools for decision making are not suitable for this complex environment. Several consumer adoption models, mostly from marketing and social research, provide decision makers initial tools for their decisions. However, payment system providers need more intelligent techniques to support their decisions.

Decision challenges are both strategic and tactical for payment service providers and especially banks. Strategic decisions deal with market entrance or exit, appropriate positioning to the market of payments (Chakravorti and Kobor 2003) and selection of right portfolio mix of payment instruments and methods. Tactical decisions refer to selection of appropriate marketing mix and operational issues of payment systems (Humphrey et al. 2001). From past experience we may notice that payments innovations are not always adopted from consumers in retail payment market (Chakravorti and Kobor 2003), (Chakravorti 2000). We may notice both failures like SET, and success stories like PayPal, that were not easily to be predicted. Particularities of payments market, like network effects (McAndrews 1998), impose new needs in decision support. Traditional decision support in the domain is based mostly on historical data analysis and marketing research, where patterns of consumer's behavior are extracted, used to forecast adoption of payment innovations.

This paper approaches the problem of the payments domain by using multi-agent based simulation to simulate consumer behavior towards selection of payment system. Though in initial steps, we consider that multi-agent based simulations proves to be a valid approach for domains with strong network effects. Our effort is to integrate multi-agent technology into a decision support tool as a bottom-up approach of the domain. Simulation is used as a qualitative tool that may provide decision makers efficient estimations about payment systems' adoption, in complement with top-down approach and marketing data. We develop the model in collaboration with a large bank that also provides experts knowledge and real payments data for the validation of the model.

In the remainder of the paper we provide some background and related work in the usage of agent based simulation in relevant domains, present an overview analysis of the payments domain, introduce the model and architecture and conclude with a discussion of future directions of this work.

BACKGROUND AND RELEVANT WORK

Contributions to our study come from two major sources. The first one is network economics studies related to retail payments. Network economics (Economides 1996) is a research field that contributes to

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our approach. Researchers in the field approach payments domain from a network economics perspective (Chakravorti 2003), (Chakravorti and Roson 2004), either emphasizing in network effects that are present in such industries (Guibourg 2001), or studying adoption (Saloner and Shephard 1995) under the presence of network effects. Although these studies focus mostly on economic issues, they provide evidence for the network characteristics of retail payments.

The second one is agent based modeling and simulation, which has been lately used in various scientific areas that study complex systems (Jennings and Wooldridge 1998). The term simulation means the process of designing a model of a real system and conducting experiments with this model for the purpose of understanding the behavior of the system and/or evaluating various strategies for the operation of the system.

Several researchers incorporate agent technology. Mainly, they use agent technology to model actors of the domain as intelligent agents and simulate the domain. The scope of agent based simulations is either to automate tasks for decision makers by reducing human involvement in strategy games, or to analyze the domain as a bottom-up method by studying emerging phenomena from agents' interaction. Following we mention some works that use multi-agent modeling and simulations in the form of modeling a market segment and simulating actors' behavior in relevant do-mains.

Agent technology is used in (Matsatsinis et al. 2003), an agent based system for decision making in product penetration strategy selection. It is based on MARKEX (Matsatsinis and Siskos 1999) and uses agent technology to replace human based tasks with agent based ones under the supervision of decision maker. Kyrylov (Kyrylov and Bonanni 2004) develops an agent based simulation model for the telecommunications market as a strategy game to support decision making. He models consumers and services' providers as agents and simulates their interaction in a residential area in order to minimize human involvement in the game playing.

Robertson (Robertson 2003) models a network of banks and consumers in a multi-agent based simulation. The work focuses on bank strategic decision support through the study of agents' interactions that come out from the simulations. Another marketing decision support approach based on agent based simulation is (Csik 2003). In the context of an artificial market he models consumers and firms as agents and creates simulation model in order to assist marketing decisions. Similarly, Schwaiger (Schwaiger and Stahmer 2003) proposes SimMarket, a multiagent system that models a supermarket and simulates consumer behavior supporting decision making in this market.

Ben Said et al (Said et al. 2002), (Said et al. 2001) propose CUBES, a framework that integrates knowledge from several different research areas concerning consumer behavior such as marketing, sociology, psychology and economics, and a multi-agent simulation of consumers in order to study market phenomena. SIMSEG project (Buchta and Mazanec 2001) utilizes agent technology in an artificial consumer market.

OVERVIEW ANALYSIS OF RETAIL PAYMENTS DOMAIN

Actors

Mostly banks, telecommunication companies and payment service providers provide payment services. Banks provide a full range of payment services, and keep an outstanding role in the domain. Though new entrants threaten their revenues, their exclusive access to core services layer provides them unique competitive advantages. Telecommunication companies started to offer payment services in the domain based on their own networks infrastructure. Till now they are the major competitors of banks, but not able to provide total solutions due to restricted access to core services. Payment service providers (PSPs) have evolved as intermediaries or aggregators providing only payment services in collaboration with actors that operate in network and core services layer. For example, a PSP may provide payers a single gateway to multiple payment networks (e.g. electronic, mobile) and payment instruments (e.g. credit card, debit card). Most common payment networks are comprised of three major actors: banks, merchants and customers.

Banks deliver a number of payment instruments through different payment channels to their customers. Services are provided either directly to the customer (ATM) or through access at the point of sale (POS) located at the merchants' site. In this case merchants act as intermediaries between the consumers and the payment service providers.

Merchants act as the intermediary between the bank and the customer, since they provide access to the customer at the point of sale, whether it is physical (POS) or through internet. Merchant's role is critical for the adoption of a payment system by customers.

Customers of payment services are mainly retail consumers, which use payment instruments for their purchases. In most implementations, merchants accept consumer payments by providing appropriate payment interface to consumers (POS). In some cases an additional intermediation level exists (payment service provider) that connects banks with merchants (Fig. 1).

Network effects

Several studies claim that network effects or positive network externalities are present in retail payments market, and characterize payment instruments as network goods. Their perceived value depends on the number of the existing users that have adopted them. A network effect is the increasing utility that a user derives from consumption of a product as the number of other users who consume the same product increases. Telephone, telefax or the internet are some classical examples where network externalities exist. In some cases referred as indirect network externalities, the beneficial size effects can also arise because of complementarities between markets (Guibourg 2001). However, compatibility between the products is necessary in order to produce positive network effects. For example, it is necessary that retailer's terminals (POS) can process the information imbedded in a specific card in order to accept a payment from this card. Also Payment systems such as ATMs and EFTTPOS require certain infrastructure and standards, such as information routing switches and telecommunication lines in order to operate in compatibility.

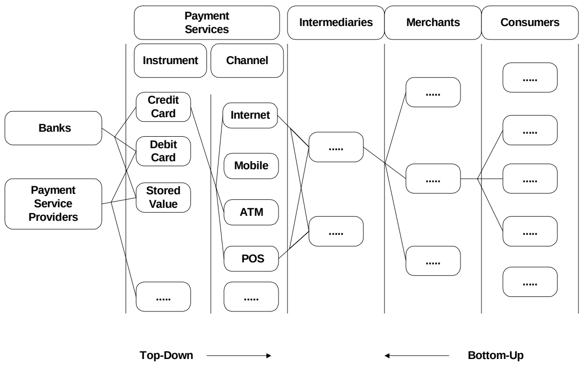

Fig. 1. Overview of the retail digital payments domain

However, for card payments, the potential user does not directly benefit by the number of other cardholders. In this case, the cardholder benefits by the spread of acceptance of the card as means of payment, that is by the size of the installed base of terminals. Naturally, the number of terminals installed increases in the number of card users as the gains of adoption to banks and merchants increase in this number. Thus, indirectly users benefit by other users adopting the technology. There is a snowball effect that is typical of network goods.

SIMULATION MODEL

In this section we present an overview of the model. The model is targeted to operate in the context of a payment systems provider, a bank or a payments organization. So, the proposed architecture is distributed and multi-tiered in order to be able to capture all the necessary input from remote data sources, and integrate necessary modules from real payments infrastructure. All the above contribute, in agent behaviour modelling by defining agent rules that affect simulation results.

All actors of the domain are modelled as agents in the multi-agent engine, and market simulations are executed according to a number of different scenarios. For the simulation engine and simulation development Java/SWARM platform was selected. Swarm is a Java library which implements agent-based technology and can be used to model multi-agent simulation of complex systems.

Consumers

Retail electronic payment is a part of customers' online buying activities as described by the Consumer Mercantile Activities Model (Kalakota and Whinston 1997). The model is comprised of pre-purchase interaction, purchase consummation and post-purchase interaction phases. The payment activity takes place within the purchase consummation phase. A lot of literature exists regarding consumer behaviour models, which attempt to capture the decision process of a consumer. We follow the cyclical model for consumer behaviour (Csik 2003) comprised of the following processes: *problem recognition, information search, evaluation, purchase decision, and post-purchase evaluation* appropriate defined for the payment selection process.

In the *problem recognition* phase consumer initiates the need to buy and accordingly to pay using a payment system. In the simulation level, this phase is not very important and is implemented either by defining deterministic time intervals (fixed) or stochastic ones (using distributions) according to the scenario.

In the *information search* phase consumer has already decided to proceed to a payment and collects information about the available payment methods. For example cash, credit card, debit card, checks etc. In the simulation level all alternatives are equally weighted and all agents share the same information about products that are offered by merchants and banks.

In the *evaluation phase* consumer assesses all the information gathered in the previous phase and according to the personal profile and individual preferences proceeds to the decision phase. Many approaches make use of utility theory models (Matsatsinis and Samaras 2000), (Lilien et al. 1992). In these models consumers compare the choices according to a set of criteria and select their choice. According to the utility theory a choice B will be preferred to a choice A if the expected utility of B is greater than the expected utility of A ($A \prec B \Leftrightarrow U(A) < U(B)$). The evaluation process is the calculation of the expected utility of the payment methods available in the market. Initially, k_{th} consumer forms a vector of the payment methods attributes, which are the criteria, used by the consumer in the evaluation:

$$F = \left[f_1, f_2, \ldots, f_n \right]^K \qquad (1)$$

Next, consumer applies the utility function

$$U(f) = w_1u_1(f_1) + w_2u_2(f_2) + \ldots w_nu_n(f_n) \quad (2)$$

$$\sum_{i=1}^{n} w_i = 1 \qquad (3)$$

where $w_iu_i(f_i)$ is the utility for attribute f_n normalized between 0 and 1, and w_i is a positive number expressing the weight of the attribute. After the calculation of the expected utility of all the payment methods, the consumer comes to the decision phase.

In the *decision phase* consumer selects only one of the available payment methods. Decision of k_{th} consumer is a probability vector

$$\left[P_i(p_1), P_i(p_2), \ldots, P_i(p_n)\right] \qquad (4)$$

where p_i are the available payment methods in the market. From the expected utility vectors k_{th} consumer calculates an adoption probability for each method and finally decides according to these probabilities. Following a similar methodology like in (Csik 2003) we construct a set of consumer behaviour cases that are depending on the difference between the maximum and minimum values of the expected utility values

$$D = U_{\max} - U_{\min} \qquad (5)$$

that are assigned by k_{th} consumer to the available methods. In addition to the difference parameter, skewness and kurtosis coefficients are also evaluated (Matsatsinis and Samaras 2000). According to the consumer behaviour pattern, the probability is calculated from the expected utility values accordingly (Matsatsinis and Samaras 2000). The rules are stored in a knowledge base that also models consumer behaviour towards payment system selection according to findings from past payments data, marketing models and multi-criteria analysis. Each consumer agent has a personal profile (age, income, gender, etc.) and a number of individual preferences that also affect the final decision.

After the probability evaluation the consumer agent selects the payment method and proceeds to the post purchase evaluation phase. In this phase consumer evaluates the experience and satisfaction level. These results affect the future behaviour of other consumers and produce network effects. In the current simulation stage this phase has not been implemented.

Merchants and Banks

Merchants usually need a certain technology in order to be able to accept payments (EFTPOS). They need also an agreement with their acquiring bank, i.e. the bank that installs the terminal at the merchant's point of sale and that holds the merchant's account. Merchants benefit from the adoption of the technology as it makes it possible to other alternative means of payment, which potentially can increase sales. Merchants also bear the fixed costs of adoption associated with the installation of terminals. However, it is assumed that these costs are lower than the benefits that merchants derive from the adoption of the technology. Thus, if the merchant's bank decides to adopt, the merchant will install the technology, as it implies positive profits. The marginal costs of transactions are assumed to be zero. Merchants' decisions are modelled according to experts data derived from marketing research and past payments data. In the present phase of the model banks and merchants have a limited role. They provide a set of payment methods to consumers and monitor their attributes towards them.

Several scenarios are executed in order to verify the model, and validate it against real payments data. Since the model is still in the preliminary steps, a screenshot of the simulation environment is depicted, where some preliminary simulations have already been executed (Fig. 2). Scenarios are based on experts' knowledge and initially monitor consumer and merchant adoption of payment methods.

CONCLUSION

This paper presents our initial work towards a model of multi-agent based simulations for the retail digital payments domain. We presented a brief overview of the domain analysis, and the model. Future work includes further development of the model, refinement of the architecture and calibration of the simulation engine according to validation results. However, based on our initial findings, multi-agent simulation is a useful tool for domains with high complexity and network effects.

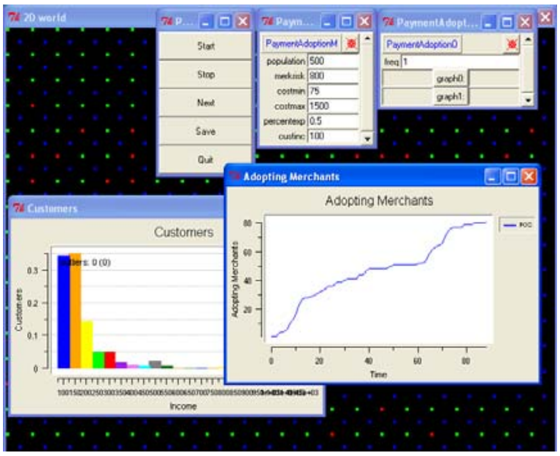

Fig. 2. A screenshot of the SWARM simulation environment

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