Multi-Agent Based Simulation of Consumer Behaviour: Towards a New Marketing Approach

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Abstract: Theoretical concepts dealing with consumer behaviour issues from studies led in various research areas: marketing, psychology, sociology and economics. This paper presents a multi-agent simulation of consumer behaviour based on an integrating approach. Our goal is to create virtual populations including several thousands of artificial consumers that exhibit realistic behaviours in the context of a competing market. These populations are used to test the effects of marketing strategies. Existing consumer behavioural models are not well suited for the realization of such market simulations including a large number of artificial consumers. In this work a consumer behavioural model based on the concept of behavioural attitude is introduced to solve this problem. It proposes to integrate and organize most of the fundamental notions elaborated within the aforementioned research areas. This paper shows the difference of our modelling approach compared with actual marketing studies. It describes the CUstomer BEhaviour Simulator (CUBES) software based on this model and reports preliminary results of our modelling.
Keywords: Multi-agent simulation; Behavioural attitude; Virtual population; Consumer behaviour modelling

1. INTRODUCTION

Consumers interact, through processes such as imitation and conditioning, with individuals and groups of individuals (friends, family, etc.). In addition to these interactions, the brands' advertising campaigns influence the consumers' choice. Brands refer here to service suppliers or product distributors. The consumers' purchasing or adoption decisions influence reciprocally the brands' marketing policy. Interactions between the different actors (consumers and brands) of a given market can be analysed to study the consumers' behaviours.

Multi-agent simulations [Bouron and Collinot, 1992 ; Drogoul et al., 1992] have offered during the last decade an interesting methodological issue and an innovative tool for specifying and validating behavioural individual models that are believed to be at the origin of emergent social and organizational phenomena. These simulations are particularly suitable in situations where the contribution of individual behaviours to the global collective behaviour of a population cannot be explained in a deductive way. They have proposed interesting explanations of such emergent phenomena in the socio-economic context [Beckenbach, 2000]. In our work, multi-agent simulation provides an experimental validation of a behavioural model. It enables us to study the relations between observable actions at an individual level and global emergent phenomena such as the segmentation of the population according to behavioural profiles.

The objectives of the CUBES project (CUstomer Behaviour Simulator) are to develop a software for simulating consumers' behaviours in a competitive market including several brands and to build a virtual population of consumers including several thousands of individuals, that reproduce real market properties (segmentation, evolution) independently of a given product. CUBES provides the simulation of (1) *behavioural attitudes* (BA) of consumers, (2) impacts of consumption acts resulting from these attitudes, (3) retroactive effects of these acts on the consumers themselves,

(4) brand reactions to the market evolutions and their retroactive effects on the individual behavioural attitudes. We have showed in [Ben Said and Bouron, 2001b] that the CUBES model covers the main concepts of previous theoretical works on consumer behaviour such as consumer involvement, innovation diffusion and opinion leaders. In this paper we describe a series of simulation experiments performed with this model. We show through the experiments' results that macro emergent market phenomena could be explained in terms of basic behavioural attitudes such as imitation, innovativeness and mistrust.

The following section gives an illustration of existing consumer models and an overview of a multi-agent simulations in socio-economic context. It underlines the originality of our modelling approach, centred on the search for generic consumer behaviour properties, while current marketing works are focused on case studies for specific market segments. The third section describes CUBES and more particularly its behavioural model of consumer agents. Finally, the fourth section describes some simulation results and their interpretations.

2. THEORETICAL FRAMEWORK

2.1 Consumer Theoretical Framework

Consumption has been considered from several points of view that we have merged in a consumer theoretical framework illustrated in figure1.

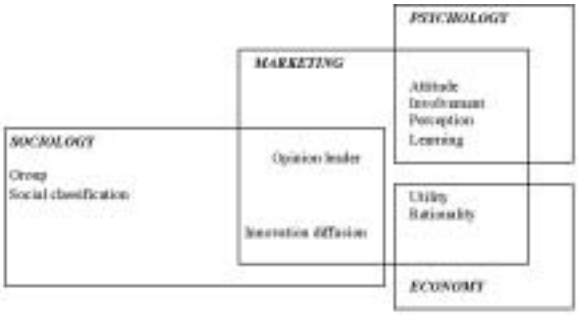

Figure 1. Theoretical framework.

From a psychological point of view, studies of consumer behavior are interested in cognitive information processing leading to brand comparison and purchase decisions. Purchase is analyzed through *perception*, *learning* and information-treatment processes. These processes are re-used in marketing to describe and qualify consumer behaviors [Zielinski et al., 1984]. Principles resulting from learning theories and based on reward stimuli are exploited to analyze the brand loyalty phenomenon and to predict the effects of promotional advertising campaigns. Theoretical concepts relative to perception are declined in the scope of attitude theories for analyzing the nature of links between the consumer and the product or the advertisement. They are considered to increase the favorable opinion towards a product or a brand and to maintain a positive reinforcement of this opinion [Frank, 2000].

From a sociological point of view, consumption is considered as an activity related to the sociability relationships between individuals belonging to different social *groups*. Groups (family, friends, social class) refer to sets of individuals sharing common values. They constitute a privileged network for interacting and exchanging information. Groups, according to their cohesion degree, influence more or less the consumer purchase decisions. Two main concepts are introduced in this context, which are innovation diffusion and opinion leaders.

From the economic point of view, the individual consumption behavior is described as being a process leading to a rational choice based on variables such as the price and the cost of information search An attempt to integrate principles resulting from micro-economic and psychological theories regarding consumer behavior such as psychological attitude and the economic utility concepts has been made in [Antonides, 1989].

The marketing point of view is mainly based on the derivation of concepts defined in other research domains as it has been illustrated in [Ben Said and Bouron, 2001b]

2.2 Consumer Behaviour Models

During the past few decades, a large volume of literature has been published dealing with various aspects of consumer behaviour. Generally, consumer behavioral models have attempted to provide a global vision of the purchase decisional process. Fundamental studies were undertaken mainly in the sixties [Andreasen, 1965; Howard et al., 1969]. These works describe individual behavioral components. More recently, models resulting from marketing works, such as [Engel et al., 1995], tend to reduce the complexity of the preceding models in order to obtain operational marketing decision tools. These models provide a general outline of the consumer behavior but give few operational descriptions of the considered cognitive processes. Consequently they are not well suited for designing operational behavior models that have to be used in the simulation of several thousands consumers. CUBES solves this

problem by introducing a model focused on elementary behavioral primitives. These primitives are intended to be fundamental and operational.

CUBES is a break with current consumer behavior works in the sense that the CUBES approach is not targeted on a given population segment and a given type of product. A strong assumption of our approach is that it is possible to provide interpretations of behavior in general, and of consumption in particular, in terms of elementary attitudes related to behavioral primitives such as imitation, opportunism and mistrust that are not specific to the purchase behavior. The combination of these attitudes gives a behavioral profile description that determines the consumer purchase decisions in a market.

CUBES introduces stimuli based on promotional offers, brand loyalty, and innovation but does not consider the price as a determinant factor to the consumer choice. There are several marketing theories in agreement with this assumption which consider that the price does not play a fundamental role during the purchase process [Katona, 1975]. The CUBES model is composed of generic behavioral elements which model behavioral attitudes (Cf. section 3).

2.3 Multi-agent Simulations in the Socio-economic Field

Multi-agent simulations are used in various fields of social sciences (economy, policy, social psychology). The *Aspen* project [Bassu and Pryor, 1996] is a micro simulation of the United States economy. More than 10000 agents represent various economic actors such as banks, companies, Stock Exchange and households. Another interesting example is the simulation realized by Janssen M.A. [Janssen and Jager, 2000] that analyses the effects of satisfaction and uncertainty on the consumer behaviour. This simulation considers about twenty consumers based on an agent model including several cognitive components. *InfoSumers* [Brannon, 1994] is an other example of a multi-agent simulator. It simulates the diffusion of innovation in the clothing fashion domain and the influence of interactions between suppliers and consumers on structuring the textile market.

3. CUBES : CUSTOMER BEHAVIOUR SIMULATOR

3.1. Consumer Model

Our consumer behavioural model is based essentially on a set of *behavioural attitudes (BA)* issued from *social processes* and *personality traits* (Figure 2). We considered two social processes to model interactions between the individuals of a virtual consumer population: *Imitation_Process* and *Conditioning_Process*. In our model the role of the BAs issued from these processes is to ensure the diffusion of external stimuli concerning: (1) recommendation and disqualification through the members of the consumer population and (2) loyalty and brand image marketing actions.

We defined three behavioural attitudes issued from personality traits: *Mistrust_BA*, *Opportunism_BA* and *Innovativety_BA*. These BA play the role of reactive modulators that filter and weight the effect of external stimuli.

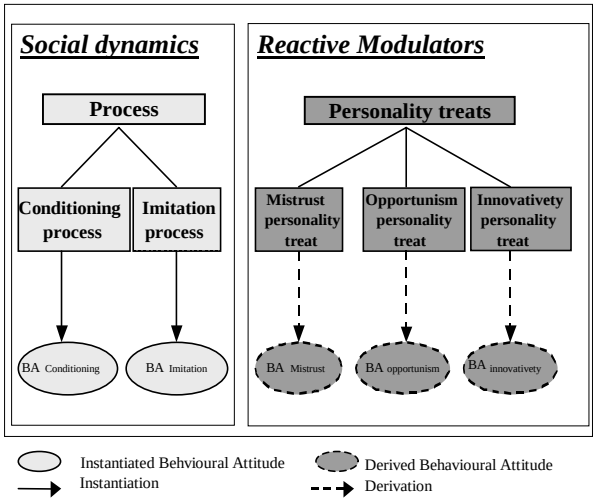

Figure 2. Behavioural attitudes.

The above figure presents the five BA considered in CUBES. Our aim is to show that it is possible to represent uniformly the five resulting BA described above by introducing the concept of *behavioural primitives* (BP).

The consumer agent behaviour is based on the five BA illustrated previously. They determine the agent's opinions relative to the virtual market brands. Behavioural attitudes are formalized uniformly by behaviour. A set of stimuli (publicities, promotions, rumours, innovations, recommendations…) affect positively or negatively the consumer agent opinions. Their effects are weighted according to the consumer agent behavioural profile. BPs are activated after the perception of external stimuli. Each stimulus is characterized by its type (rumour, pub, promotion), its colour and its intensity. The colour indicates the brand to which the stimulus is related. This value is null if the stimulus designs a rumour relative to the whole virtual market. The external stimulus intensity has a numeric value which indicates its force.

Each consumer agent has an opinion on each brands of the virtual market (Figure3).

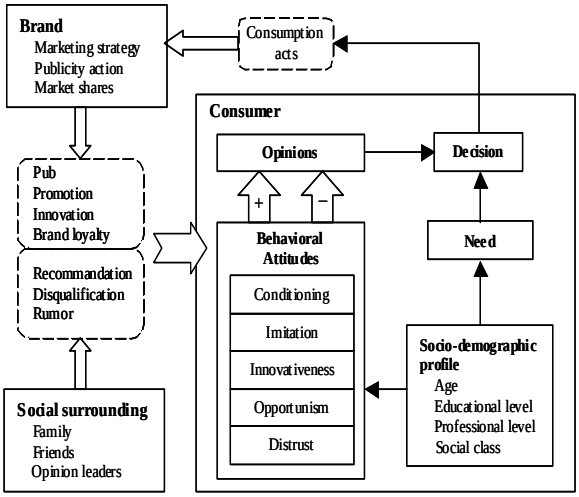

Figure 3: CUBES components.

These opinions change according to the frequency and the filtered characteristics of the stimuli. When a consumer agent perceives a stimulus, the BP mechanism, described in Figure 4, checks if the stimulus belongs to the set of stimuli types that are susceptible to activate this particular BP. In this case, the behavioral primitive intensity (V_{BP}) is compared to a lower inhibiting threshold (Inh_Thr_{inf}) in the case of a positive stimulus and respectively to a higher inhibiting threshold (Inh_Thr_{sup}) in the case of a negative stimulus. V_{BP} expresses the BA intensity formalized by this BP. The lower and higher inhibiting threshold indicate respectively the limit below and above which external stimuli (Ex_St_+) and (Ex_St_-) do not cause any positive or negative reinforcement of the BA intensity. Once the V_{BP} is updated by the addition or the subtraction of a computed value, which is a function of the Ex_St characteristics and the current V_{BP}, the new value of the BP is compared to a third triggering threshold (Trig_Thr) that indicates the BP level above which the external stimulus has an impact on the consumer agent opinions.

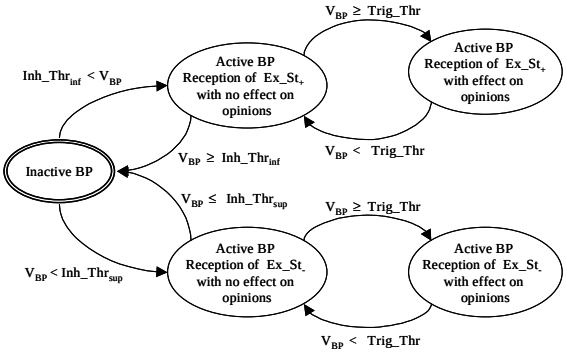

Figure 4. Behavioral primitive state diagram.

The triggering and the two inhibiting thresholds are expressed as a function of the consumer agents' socio-demographic profile and the initial specified simulation parameters. Indeed, the population is initially divided into several segments according to attributes such as age, family and professional status.

3.2. CUBES Description

CUBES is a software hat simulates a population of consumer agents interacting concurrently. The CUBES simulator software includes a simulation engine, tools to parameterize and control the simulation and tools to observe the simulation output. It re-uses the Swarm simulation engine (http://www.swarm.org). It offers the possibility to follow the evolution of the simulation and to observe the emergence of collective phenomena. The different CUBES tools have been presented in [Ben Said and Bouron, 2001a].

4. EXPERIMENTAL RESULTS

4.1. Behavioural Attitude Evolution

The first series of simulation experiments reported in this paper concern the evolution of the five behavioural attitudes considered in our model. We start by creating a consumer agent population whose individuals have initially randomly distributed behavioural attitudes intensities. Two experimentation contexts were tested. We simulate in both experiments a population of 5000 consumer agents within a virtual market including 3 competing brands. In the first experiment we consider a "young" population including 15-25 years old individuals.

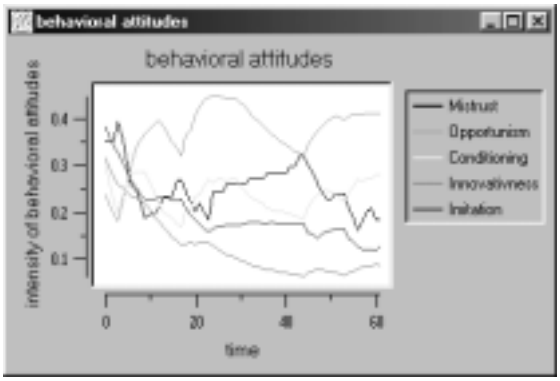

Figure 5. Average intensity evolution of behavioural attitudes for a 15-25 years old consumer agents.

Figure 5 illustrates a graph describing results relative to this experiment. It indicates the average

intensity evolution of the five behavioural attitudes. We can notice an unstable oscillation over the 60 simulation steps for the five behavioural attitudes. This phenomenon is explained by the high interaction level (frequency and intensity) between consumer agents belonging to this particular population segment. In fact, brands in CUBES use reactive marketing strategies based on
the communication of a number of publicity stimuli (promotions, innovative products, brand loyalty actions..) whose effects on individuals are amplified through their diffusion in the population. Thus the high communication rate between the consumer agents tends to destabilize the behavioural attitude intensities.

In the second one, we consider an "old" population including 45-65 years old individuals. Simulation results shown in figure 6 indicate that the average intensities of the five behavioural attitudes converge and are kept stable after about 15 simulation step.

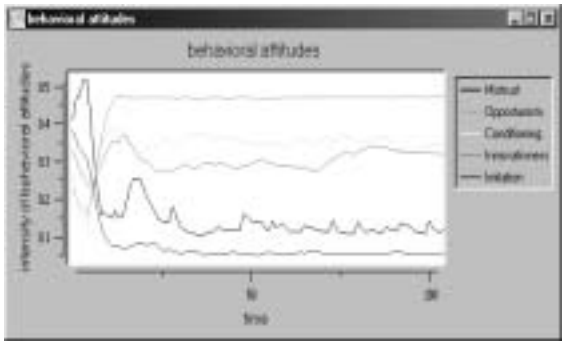

Figure 6. Average intensity evolution of behavioural attitudes for a 45-65 years old consumer agent population.

3.2. Emergent Market Shares Equilibrium

In the following we report two results relative to the evolution of market shares in the virtual market. In the first experiment we consider an initial market situation dominated by one brand. Initially, BRAND0 in the Figure 7 has 70% of customers in a virtual market including 7000 consumer agents. The rest of customers are equally distributed between the two other competing brands. After more than 90 simulation time steps we can observe a lock-in effect where BRAND0 conserves its dominance on the market despite several attempts of BRAND1 and BRAND2 to pick up BRAND0 customers. Thus the two dominated brands remain with a marginal market shares during all the simulation.

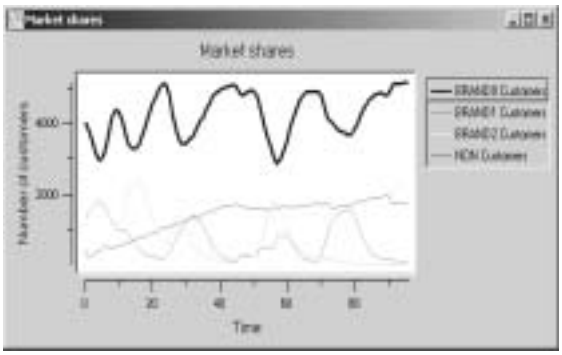

Figure 7. Evolution of market shares in a lock-in situation.

In the second experiment, we start the simulation an equally distributed market shares between the 3 competing brands. The population includes 7000 consumer agents as in the first experiment. The graph in Figure 8 indicates that competition among the brands is cyclic over the 120 time steps of the simulation. This phenomenon is observed in the evolution of real market shares where few brands are sharing the customers. What we are emphasising here is that it is possible to reproduce realistic market evolutions using the CUBES behavioural model using elementary and basic behavioural attitudes.

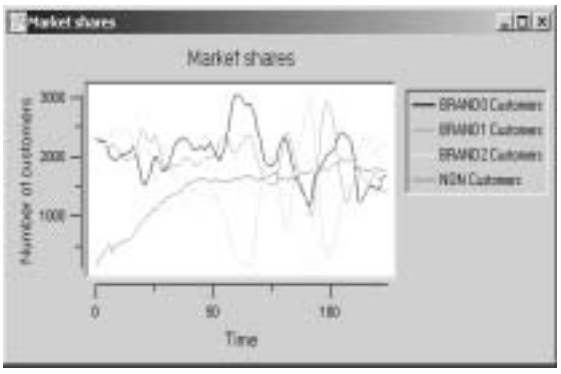

Figure 8. Market shares evolution in an initially equilibrated market.

5. CONCLUSION

This paper has presented the CUBES modelling approach based on elementary behavioural attitudes and the interaction between the virtual market actors in a competitive context. The developed approach is based on the definition of a theoretical framework, integrating concepts modelled in several fields of study. Two differences with former works about consumer behaviour studies have been emphasised : (1) the concepts are simultaneously considered at individual and collective levels, whereas most of the former studies are centred on only one given analysis level (2) the consumer cognitive functions

are derived from generic behavioural components intrinsically related to the interaction aspect whereas until now they were mainly defined as reasoning and data processing processes. A simulator was implemented on the basis of the CUBES model and experiments including several thousands of consumer agents have been performed. Through the results of these experiments we have shown that it is possible to reproduce and provide explanations of observed phenomena at a macro level in terms of individual characteristics.

Our future works consider mainly two issues relative to the developing and experimenting of CUBES. First, we intend to develop new tools for observing, qualifying and quantifying emergent phenomena. Second, we plan further experiments with CUBES where more complex brand marketing strategies are elaborated and highly heterogeneous populations are taken into account. For this purpose we are now developing a methodological approach to experiment and validate large scale simulation systems, as CUBES where large data sets are manipulated.

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