Using of Multi-agent based simulation method in investigating consumer behavior.

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Abstract

This study was amid to identify opportunities and benefits resulting from using multi-agent based simulation in investigations of consumers behaviour. There is described the essence of the method, discussed the main directions of its applications and identified complementarities to other approaches, which are used in the analysed scientific area.

Key words: multi-agent based simulation, consumer behavior.

استعمال طريقة المحاكاة المعتمدة على الوكلاء المتعددين(MABS) في مجال دراسة سلوك المستهلك.

ماكوشاتا لاتجونسكي   اغاتا فارفجينك   فاطمة محمد الفريجي

معهد تكنولوجيا المعلومات في الادارة   كلية العلوم

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الخلاصة

يهدف البحث الى تعريف الفوائد والتسهيلات الناتجة من استعمال طريقة المحاكاة المعتمدة على الوكلاء المتعددين في مجال دراسة سلوك المستهلك، وتم خلال البحث وصف لجوهر الطريقة ومناقشة تكاملها ومقارنتها مع الطرق الاخرى التي استخدمت في مجال التحليل العلمي لسلوك المستهلك.

كلمات المفاتيح: طريقة المحاكاة المعتمدة على الوكلاء المتعددين، سلوك المستهلك.

Introduction

In the contemporary, multidimensional, dynamic and competitive marketing environment, consumer behaviour depend on many different, very often difficult to grasp, types of factors (Tab. 1). The complexity of these factors arrangement is very well illustrated by the model of consumer behaviour called black box model. Including most of the types of factors mentioned in Fig. 1, it shows relations between external stimuli, consumer's features, the course of decision-making process and his reaction expressed in his choices. When analysing the arrangement shown in the model, it is necessary to take into consideration the fact that its elements change in time. In consequence, investigating consumer behaviour becomes too complicated for traditional analytic methods.

Table (1): Types of factors influencing consumer behavior.

Author	Types of factors
Enis (1974)	personal, social
Cross and Peterson (1987) and McCarthy and Perreault (1993)	social, physical
Dibb and Etal (1991)	personal, social, physical
Cohen (1991)	marketing mix, physical
Zikmond and Amico (1993)	social, environmental, individual
Narayyana and Raol (1993) and Lancaster and Reynold (1998)	physical, social, culture
Keegan (1995)	social, culture, economic, geography
Setlow (1996)	personal, marketing mix, environmental
Stanton (1997) and Pride i Ferrell (2000)	social, physical and attitudinal
Kotler and Armstrong (1999, 2007)	physical, social, culture, personal
Straughan and Roberts (1999)	demographic and lifestyle

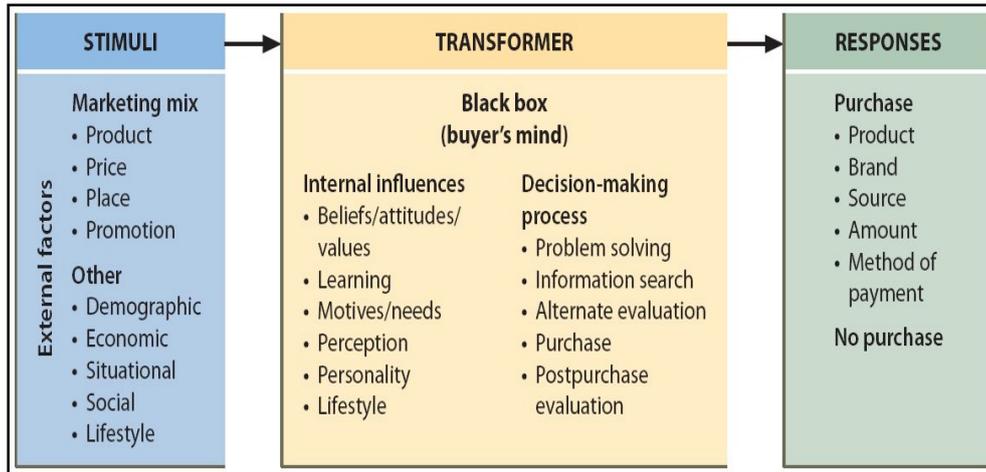Source: own elaboration based on: (11; 36; 50; 61;,47;,59)

Figure (1): Consumer black box model Source: own elaboration based on:(31; 30)

The question of usefulness of analytical methods in investigating complex arrangements was frequently discussed in literature. For instance, H. Simon describes the phenomenon of mathematic aphasia, which is an inclination to oversimplify analytical model– as long as theoretical problems disappear, as well as any connection to reality. On the other hand, according to G. Niemeyer, major obstacles in investigating complex arrangements by means of analytical methods are a result of the following premises(10): nonlinearity of the relations between the elements of the arrangement, requirement for complex approach to analysis, the existence of "Loose" connections between major factors of the arrangement as well as "difficult-predictability" of complex arrangement's behaviour. A similar view is presented by J. W. Forrester, who claims that the effective reflection of complex arrangement behaviour lies beyond the borders of traditional analytical methods (16). He thinks that the only effective tool is a method based on heuristic approach to problems solving - computer simulation, understood as a system simulation on a digital machine. Almost identical view is presented by Cempel who claims that in getting to know complex arrangements, simulation is the only tools which, because of its ability to manipulate space-time, allows seizing and understanding faraway cause-effect relations in time and space bound by many feedbacks (9).

One of the computer simulation methods is Multi Agent Based Simulation (MABS),which concept originates from observing emergent and adaptive biological systems. The aim of the article is to show opportunities and benefits resulting from using multi-agent based simulation in investigations of consumers behaviour. There has been described the essence of the method, discussed the main directions of its applications and identified complementarities to other approaches, which are used in the analysed scientific area.

The essence of multi-agent based simulation

The origins of multi-agent based simulation can be drawn from such disciplines as: complex adaptive systems, complexity science and system science. In a form comprehensible for computers it was first implemented by means of cellular automatons, created independently by S. Ulam and J. von Neumann in the 1940s. However, not until the beginning of 1970s it began to take shape in which it is known these days. It happened when J. Conway created *Game of Life*(18). The current definition of agent appeared at the beginning of the 1990s(26). From that moment on the development of MABS accelerated considerably and during the last decade it gained a great popularity as a research method in many scientific fields, which is illustrated by Fig. 3 (34). In multi-agent based simulation the investigated arrangement is modelled as a set of autonomous units, called agents. In multi-agent model decision-making processes are being described in microscale, for each agent separately. Out of joining actions of many agents and their interactions between themselves and with the environment in which they function, there is created an image of the investigated phenomenon in macroscale (Fig. 3)(49).
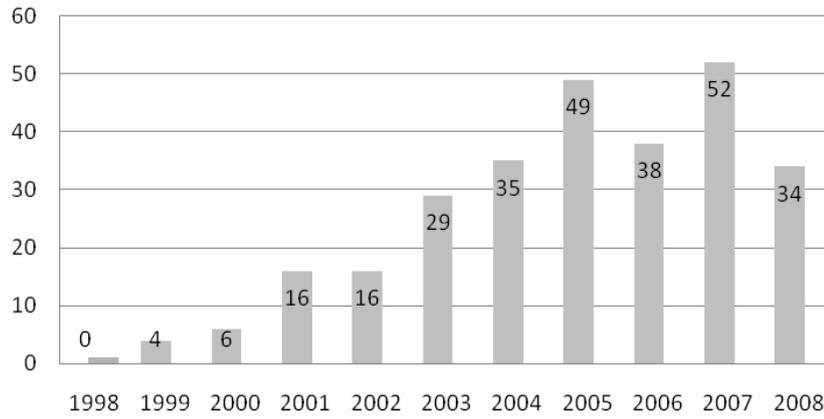
Figure (2): Number of articles concerning multi- agent based simulation from 1998- to July 2008– divided into particular years source:(22).
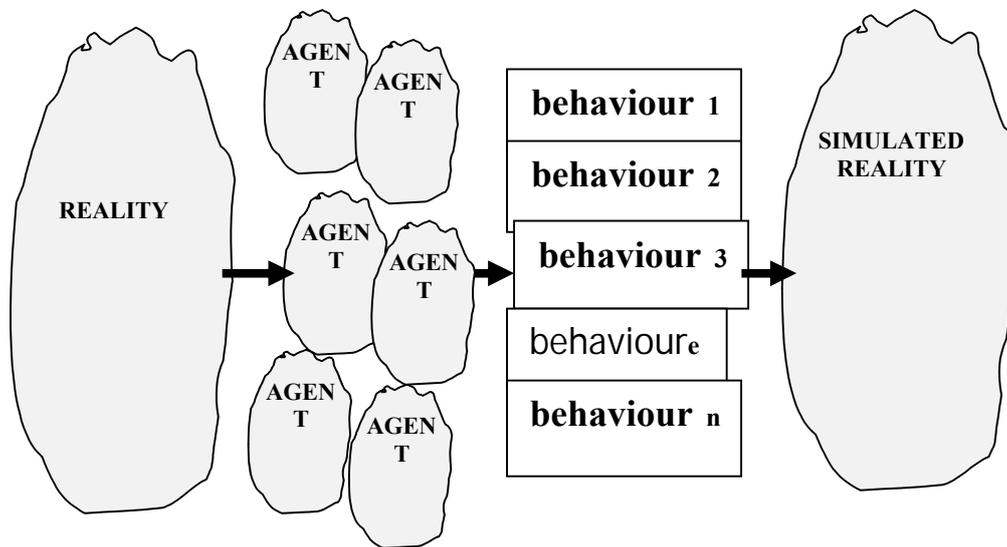

Figure (3): The essence of multi-agent based simulation Source: own elaboration based on:(15).

Various disciplines worked out their own ways of understanding the term „agent". It is commonly accepted that agents are placed in certain environment and they are able to take autonomous actions(17; 3). Some of the authors think that every type of independent components (computer program, model, unit, consumer etc.) is an agent(4). The behaviour of an independent component can be described in different ways– ranging from primitive decision-making rules to very complicated artificial intelligence adaptive rules. Other authors maintain that independent consumer behaviour must be adaptive so that it could be called "agent". The term "agent" is reserved for components which, in a way, learn their environment and as a result of this learning change their behaviour. Casti argues that an agent should include rules of the lower order as well as a set of rules of the higher order which determine principles of rules changing. Rules of the lower order describe reaction to the environment while rules of the higher order describe the rules of adaptation (8).

From a practical point of view it can be assumed that an agent has got the following features(36):-

    a. it is an identifiable unit which possesses a certain set of features and rules governing its behaviour and decision-making capabilities.

    b. it is placed in environment in which it cooperates with other agents;

    c. its actions can be directed at achieving a particular goal.

    d. it is autonomous, it can function independently in its environment and in contacts with other agents, at least in certain defined situations.

    e. it is flexible, it has got the ability to learn and adapt.

These assumptions particularly predestine multi-agent based simulation to being applied in investigating consumer behaviour because it can show how out of actions taken by many agents identifying individual and/or organizational consumers arise aggregated marketing phenomena.

2. Directions in applying multi-agent based simulation (literature review):

During last several years there were published many scientific studies showing cases of multi-agent based simulation usage in the discussed area. They very often concern consumer behaviour in context of innovation diffusion, for instance:(57; 48; 56; 40; 53; 19; 14). Another direction in applying MABS refers to research connected with reception of the product by the market(20; 21; 22). A lot of publications show multi-agent based simulation approach usage in the analysis of the companies positioning influence on consumer behaviour(6; 58; 51; 52; 35), while some of them focus on the problem of moral behaviour in relationship marketing(23; 24; 25; 37; 38).

Another important area of applying multi-agent based simulation approach concerns the research of shopping trends on particular markets by means of many individual consumers choices simulation in order to define how and why consumers choose a particular product or service. These types of usage are described by: (12; 5; 54; 60; 43; 33; 45; 55; 32). Some of the studies show more general deliberations on multi-agent based simulation approach in investigating consumer behaviour, for example: (27; 13; 2; 29; 1; 28; 10; 42; 44). They describe multi-agent models of consumer behaviour drawn out of marketing theory and behaviour theories and then they show results of several simulation experiments conducted on the basis of real data taken from a particular market. North depict macro model which allows shopping behaviour simulation on the household level as well as producers and sellers business behaviours on the national market(32).

Among others, applications of multi-agent based simulation in investigating consumer behaviour - described in literature and worth mentioning- are the following models: real supermarkets(46), consumers purchase decision-making process in context of decoy effect)(62) or advertising effectiveness(7).

Despite quite rich literature concerning multi-agent based simulation approach in marketing applications and constant increase of its popularity (which is proved by the fact that the whole issue of „Journal of Product Innovation Management" in 2011 was dedicated

to this subject[1]), some researchers claim (41), that the development of applications in the discussed area is still too slow. The reason of this is seen mainly in the lack of generally acceptable standards of applying multi-agent based simulation in marketing research.

3. Multi-agent based simulation versus other approaches to consumer behaviour research:

Multi-agent based simulation is a relatively new approach in applications connected with investigating consumer behaviour. It appeared as a perfect complement for other methods, because, thanks to the possibility of including business methods in unit descriptions (eg. buys good x, because…) it allows defining holistic effects for the investigated arrangement (eg. he market of goods X has got increase tendency)(39). If we assume, after Rand and Roland, that the most frequently used methods of investigating consumer behaviour are: analytical modelling, empirical and statistical modelling, system dynamics modeling and conducting empirical experiments in consumer choices, we can indicate complementary role of multi-agent based simulation for each of the methods mentioned above (Tab, 2).

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[1] "Journal of Product Innovation Management". (2011). Special Issue on Agent-Based Modeling of Innovation Diffusion, 28(2).152–168.

Table (2): Comparison of the consumer behaviour research methods.

Methods	Facilities	Limitations	Complementary role of MABS
Analytical modelling	Generalizable, creates actionable insights into firm level strategic decisions	Difficult to compare to real-world data, sometimes requires overly simplistic assumptions	Agent-based models can be built from analytical models that include more realistic assumptions and can be compared to real world data.
Empirical and statistical modelling	Useful for finding patterns of behaviour in extant data sets, and for making predictions about future behaviour.	Rarely linked to a behavioral theory at the level of the individual consumer or firm. Requires the right kind of data to exist showing relationships	If a theory of individual-level behaviour can be generated, then agent based models can be created that can be compared to empirical and statistical models.
Consumer behaviour experiments	Provide theoretical insight into consumer decisions and reactions to marketing actions.	Rarely scale up to large groups or examine complex consumer-consumer interactions.	Agent-based models can be built upon consumer behaviour theories and then scaled up to large populations.
System Dynamics Modeling	Allows a systematic examination of an entire complex system of interactions.	Rules of behaviour must be written at the system level and examination of individual-level heterogeneity can be difficult.	Agent-based models can complement larger scale models with a fine-grained resolution when necessary.
MABS	Allows the exploration of individual-level theories of behaviour, but the results can be used to examine larger scale phenomenon	Computationally intensive, not generalizable beyond the instances examined	-

Source: (41)

As the table analysis shows, multi-agent based simulation can be a natural complement for other methods. The greatest benefit coming from applying this approach in investigating consumer behaviour is that the companies and consumers actions can be modelled in accordance with behaviour theories and experiment results can be validated in relation to empirical data – which allows using the model for prediction.

4. Conclusions:

The deliberations show in the paper allow drawing a general conclusion that multi-agent based simulation is a method which can be and is successfully used for investigating consumer behaviour. The following premises, among others, support this idea [2]:

a. multi-agent based simulation allows conducting experiments which take into consideration heterogenic complexity of both levels: individual consumer level and complex marketing environment level.

b. it gives the possibility of modelling interactions between consumers-agents, which increases research results credibility as the modelled real world consists of interacting units.

c. using a computer it is possible to conduct virtually unlimited number of experiments in a short period of time (without any damage to people or environment), which allows investigating impact of many combinations of factors influencing consumer behaviour.

Except undeniable advantages of the discussed method, it is necessary to indicate some difficulties which can occur during its usage. The most important problem can concern the lack of appropriate data and, in consequence, difficulties in identification behaviour rules in the model. Another issue is the necessity of possessing by the researcher advanced programming skills. The first difficulty can be solved by conducting properly organised surveys. On the basis of these surveys using for example the theory of rough sets it is possible to detect rules of investigated consumer groups behaviour. The second confinement can be overcome by using appropriate simulation tool (np. AnyLogic, Swarm, NetLogo[3]).

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2 See.: Rand, W.; Rust, R. Agent-Based Modelling in Marketing: Guidelines for Rigor, op. cit. and Twomey, P.; Cadman, R. Agent-based modelling of customer behaviour in the telecoms and media markets, op. cit.

3 A review of available packets for multi-agent simulation was presented in: Łatuszyńska A., Analiza porównawcza oprogramowania do symulacji wieloagentowej, „Studia Informatica" nr 27. Zeszyty Naukowe Uniwersytetu Szczecińskiego nr 643, Szczecin, 2011, p. 7-20.

The authors are currently preparing a research procedure which joins multi-agent based simulation, survey and rough sets theory. Its aim is to create multi-agent consumer behaviour model on the market of electrical appliances.

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