USING ANYLOGIC AND AGENT-BASED APPROACH TO MODEL CONSUMER MARKET

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Abstract

In the highly dynamic, competitive and complex market environments (such as telecom, insurance, leasing, health, etc) the consumer's choice essentially depends on a number of individual characteristics, inherent dynamics of the consumer, network of contacts and interactions, and external influences that may be best captured within the Agent Based modeling paradigm. The Agent Based modeling is especially advantageous in the consumer market domain as it allows to leverage the full amount of individual-centric data from the CRM (Customer Relationships Management) systems highly available these days. Although there are no universal straightforward instructions for building Agent Based models, there are certain common steps and patterns. The goal of this paper is to introduce the patterns in consumer market modeling most frequently met in our consulting practice. The modeling language of AnyLogic is used throughout the paper.

Keywords: Agent Based Modeling, Market modeling, Strategist games, AnyLogic

Presenting Author's biography

Andrei Borshchev, Co-founder and CEO, XJ Technologies. Andrei received his MSc in 1989 from Technical University of St.Petersburg, Russia in Computer Science & Complex Systems Modeling. In early 1990s he worked for Hewlett-Packard Labs applying verification and simulation techniques to a number of HP products. Co-founded XJ Technologies in 1992. Completed PhD in Simulation Modeling in the TU of St.Petersburg in 1995. From 1998 led the design and development of an innovative multi-method simulation tool AnyLogic, and then its launch in the commercial simulation tool market. Andrei is a member of the System Dynamics Society and a constant contributor to the International System Dynamics Conference, the Winter Simulation Conference and other major events in the worldwide simulation community. Andrei has published over 50 papers and conducted numerous lectures, workshops, and training sessions on simulation modeling and AnyLogic.

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1 Introduction

During the last decade numerous developments have resulted in significant methodological progress in consumer market modeling. While traditional statistical and equation-based methods continue to be useful, new approaches, such as Agent Based Modeling (ABM) successfully address their well known limitations, e.g. the necessity of "perfect mix" assumption for aggregated categories of consumers (see e.g. [2], [3] and [4]).

In the highly dynamic, competitive and complex market environments (telecom, insurance, leasing, health, etc) the consumer's choice essentially depends on a number of individual characteristics, inherent dynamics of the consumer, network of contacts, external influences that may be best captured within the Agent Based modeling paradigm, especially taken the high availability of individual-centric data from the CRM (Customer Relationships Management) systems.

The leading market analysts worldwide are using ABM to gain deeper insight in the market dynamics and to elaborate optimal strategies for their companies.

Although there are no universal straightforward instructions for building Agent Based models, there are certain common steps and patterns. The goal of this paper is to introduce the patterns in consumer market modeling that are most frequently met in our consulting practice. In the final section we also discuss the limitations of ABM.

2 The application area

We will concentrate on what we can call a generic services market where different providers compete for customers by introducing various tariff plans, pricing schemes, working with dealer networks, running ad campaigns, etc.

The consumers (sensitive to pricing, but also to a number of other factors) in turn shop around looking for the solution best matching their usage patterns.

The consumer market models need to be capable of estimating the demand and its structure, predicting the market and market share dynamics based on competing players' policies, comparing strategic scenarios, and performing optimizations.

3 Agent based modeling

The key characteristic of any agent based model is that such model is essentially decentralized. ABM takes bottom-up view when producing a reflection from the real world domain to the models domain. In ABM we focus on individual behavior rules, and the global behavior emerges as a result of many individual activities. This is different to e.g. System Dynamics where the modeler starts thinking in terms of aggregates (such as "potential adopters" and "adopters" in the textbook product diffusion model introduced by Bass [1]). We refer you to [5] for the detailed comparison of existing approaches in simulation modeling.

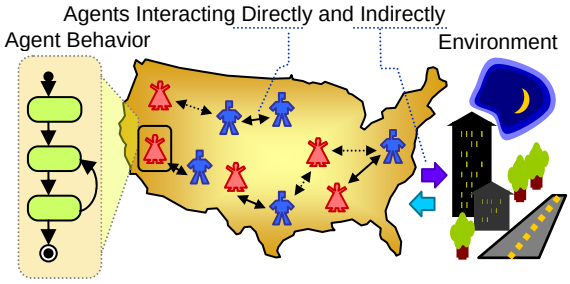

Fig. 1 Agent based model structure

Agents in consumer market models typically represent people, companies, branches, dealers, projects. Each agent has its variables, parameters, behaviors. There may be a network of contacts between agents which is used to model the exchange of relevant information. There also can be an environment affecting the agents and being affected by them.

4 Agents-consumers

The most critical part of the model development is construction of an agent representing a consumer with a necessary level of details. This is typically done by a *modeling expert together with a marketing expert* in a series of discussions. For the modeler it is very important to learn what we actually know about the consumers, what we can assume, what data is available.

Technically, an agent-consumer has *variables*, *parameters* and *behavior*. By parameters we mean values mostly constant during a simulation run, such as gender or martial status and by variables – changing values, such as current tariff plan, or satisfaction level.

Behavior is the *decision making logic*, typically triggered by certain events and conditions. Random factors play important role in AB models: most of decisions are probabilistic. Parameters and variables are involved when the logic is invoked.

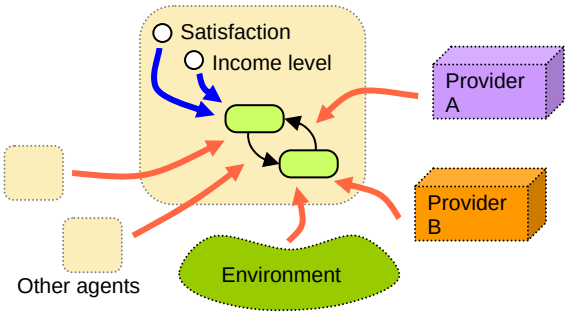

Fig. 2 External and internal influences

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Factors influencing the agent behavior can be external and internal, see Fig. 2. The external ones typically are same for all agents and are originated by the environment, by service providers. Internal factors are consumer individual preferences and needs, his knowledge, etc.

Sometimes if we wish to model the agent behavior continuous in time we use System Dynamics fragments (i.e. systems of equations) inside the agent. But most frequently we use statecharts as a clear and intuitive way of representing human decision logic. We use AnyLogic [7] in all our consulting projects because it provides a very high degree of flexibility in choosing the modeling technique: it supports System Dynamics, Agent Based and Discrete Event modeling and arbitrary combinations of these approaches.

The service providers may at the beginning be modeled as a part of the static environment (basically as "available options"), but later on they may become agents as well (yet obviously of another type).

4.1 The main statechart of a consumer

A very generic model of a consumer behavior would be a statechart with the structure shown in Fig. 3. As the markets being considered are characterized with a very high level of penetrations, each agent potentially has a need to use a service. From this viewpoint an agent initially either uses services on or not yet. Non-users population can be further divided into *addressable* market, which may be influenced by ads and *passive* population currently not interested in the service. The passive agents eventually become addressable – this depends on their internal dynamics. Transition from addressable state to the user state may be triggered, among other things, by marketing efforts, personal income change, and word of mouth and depends on the penetration level. As typically such models are constructed for a particular service provider, the user state can be further divided into *our client* state and *competitor's client* state.

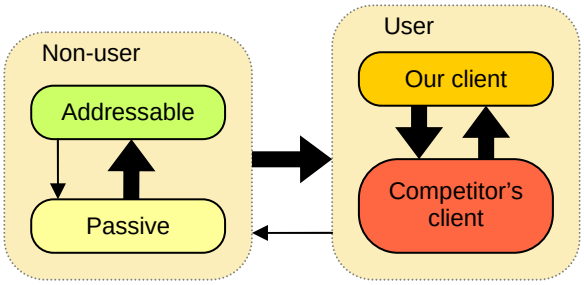

Fig. 3 The main statechart of the agent-consumer

Transitions from addressable to inert or from users to non users are in most cases negligible, but can be included into the model as well.

Once the agents are created and parameterized and environment is set up the model can run. At the beginning of a simulation the initial conditions should be defined such as the initial market size, market shares, penetration rate etc.

4.2 Evaluating a service

The agents-consumers are constantly monitoring the available services and matching them to their personal usage patterns. Although price is a key point for significant fraction of users, some select quality over price or combinations of those metrics. The set of value added options to the main service (e.g. in cell telecom: games, messaging, internet, etc) is also important. The consumers are also sensitive to advertisement and dealer's recommendations. Consumers exchange information when contacting each other and may influence each other's preferences. The choice may also be driven by the choice of family members and friends (which operator are my family members with?). The individual parameters such as e.g. frequency of travel and geography of travel (coverage area, roaming) or social status and obviously income may need to be considered as well.

The information exchange between the agents (word of mouth) is modeled explicitly as periodic "contact" events resulting in contacting individuals variables change. Various types of social networks may be used (see e.g. [6]). The important micro networks such as families, colleagues, classmates may be modeled.

The satisfaction from using a service that develops gradually with experience may significantly affect the user's further decision. Therefore the usage history is in many cases included among the agent's variables.

All these factors result in the consumer's *attitude*, or perception of a particular service or brand. It is important to have a *quantitative measure* of that attitude. We frequently use a utility function calculated over the set. The utility function is a sum of P_i*W_i where P_i is a normalized value of a service attribute (cost, expected savings, quality, marketing saturation, etc.) and W_i is the relative importance of the attribute for the agent.

4.3 Switching behavior

If the quantitative value of the attitude for a provider exceeds the corresponding value for the currently used provider for more than a certain delta, a provider switch may occur. That delta characterizes the *loyalty* (or inertia) of the user and can vary from one consumer to another.

Each agent periodically invokes its decision rules and may switch to another tariff or company. The triggers for invoking the rules may be periodic such as "review bill each month", sporadic "visit a store on average once per several weeks", or condition-based such as "monthly expenses reach a certain percent of the income".

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5 Agents-companies

The next step may be to model the market players as agents as well. Those agents are adaptive – they change depending on the market indicators.

Typically, the simulations run for more than one year. Each year breaks down into smaller periods each characterized by its operating plan, which includes investments breakdown: advertising, new tariff plans, increasing quality, etc. The companies monitor the key performance indicators and change the operating plans for future periods, following a certain strategies.

6 Using CRM data to populate the model

Two main sources of data are typically used for model parameterization. The first one is a company database with statistics on how customers use services. In e.g. telecom these data include durations of calls, amount of data transferred, timestamps of using value added services etc.

The second type of data source is results of user surveys (containing e.g. answers to questions such as why they choose a specific tariff or which tariff they would use).

Most of the survey data cannot be directly used to parameterize the agent behavior, therefore analysis or survey processing should be done. The processing may result in distributions such as e.g. the "probability for tariff plan change if a certain price change occurs". This distribution can be used in the model in the agent switching logic.

The historical aggregated data (as well as some CRM data) may be used to calibrate the model (to select the parameter values when they cannot be measured in the real life).

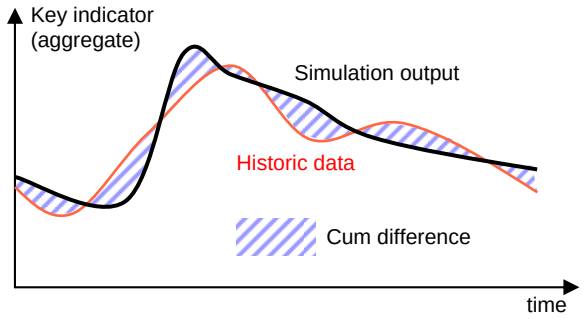

Fig. 4 Minimizing deviation from historic data

Fig. 4 shows two curves – simulation output and a historical data. By minimizing the difference between the curves you can find the more adequate parameter values. An automatic optimizer can be very helpful for model calibration, especially when a combination of several parameters needs to be found.

7 Building strategist games

The simulation model may be considered as a test bench helping to obtain the system reaction on certain inputs. It allows the user to interrupt the simulation, apply changes and resume the simulation from the interruption point. Simulation UI typically contains charts showing the dynamics of key variables. This enables development of *strategist games* based on the simulation model.

Such a game is designed as a multi-user distributed virtual environment where several participants (e.g. regional managers of one company) compete to develop strong tactical and strategic skills.

Players use customized client interface to make decisions and observe results. It displays dialogs for different actions such as defining investments, adding/removing tariff plans, etc. Another view available in the client contains running charts from the simulation. Client interfaces are synchronized by a server (see Fig. 5).

The purpose of Server Application is to synchronize the client applications, execute the whole simulation, maintain database. At the end of each decision making period the server application receives parameters from clients, obtains the new state of the market model using the inputs and the current state, and returns results back to clients.

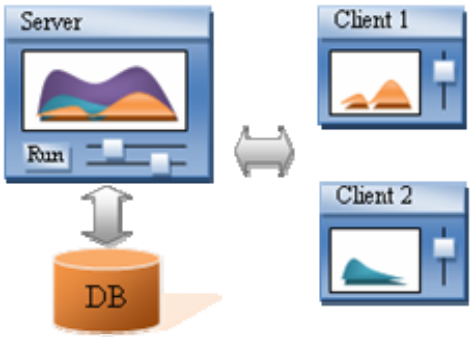

Fig. 5 Minimizing deviation from historic data

8 Conclusions

The Agent Based approach enables the modeler to capture much more detailed consumer behavior than is possible in any equation based or static model. History, learning, preferences and contacts are examples of such behavior. Capturing these details allows higher quality predictions in specific consumer markets.

The data typically available form a company CRM and customer reviews can be *directly* used to parameterize the consumer behavior in the Agent Based model, which is another great advantage. The "traditional" aggregated historical data may be used to calibrate the AB model.

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It is also important that, due to the high level of details, the ABM can provide output statistics of virtually any level of granularity: from individual to fully aggregate.

AB models are however computationally intensive and therefore may hit limits of today's desktops. Although there are several ways for scaling down AB models, they still belong to the domain of art rather than to the domain of technology.

Another thing to keep in mind is data problem. It is always tempting to add more and more sophisticated logic to an agent, but increasing number of agent properties may hit the lack of adequate data.

An interesting extension of AB model of a consumer market is its link to a model of the service provider infrastructure (or to a model of a Supply Chain in case of a product). As AnyLogic supports the Discrete Event modeling approach typically needed to model production, logistics and service logic, we sometimes develop such combined models. This is probably the only proper way to explore the interaction of the marketing strategies and service, or IT infrastructure, or supply chain operation. Such analysis can discover potential problems of very subtle nature, e.g.: making a certain type of service too attractive for customers would bring more users that the infrastructure can efficiently handle, which in turn will result in the mass dissatisfaction with the quality of service and users switching to another provider.

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