Simulation of Digital Content Distribution Using a Multi-Agent Simulation Approach

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Abstract. Over the past few years it has become clear that the Internet will play an ever greater role in the distribution of digital contents. Our main aim is to provide businesses in the digital contents sector with a tool which will enable them to take informed business strategy decisions and become more competitive by adapting their traditional business models to the new, demanding reality. To achieve this objective, we have applied multi-agent based simulation (MABS) technology to implement prototypes of music and news market models. In our simulations, agents represent market stakeholders that act autonomously according to their interests and interact with other agents inside the market environment. This allows end users to investigate the implications of a variety of decisions and strategies by running simulations starting from different initial conditions. Simulation results can be then analysed, either intuitively or through a statistical analysis, and this (together with flexibility) provides one of the main advantages of this MABS approach.

Keywords. Multi-Agent Simulation, Digital Content Distribution Market.

Introduction*

Digital content distribution is changing rapidly due to the emergence and spread of new business models and technologies. Specialised portable hardware, designed to store and give digital access to contents such as news, books, music, or video, will soon make digital contents reachable by a large number of consumers. To achieve success, e-businesses are being forced to rethink traditional, strategic business models, the role of IT (information technology), processes and relationships along the whole length of the supply chain ([2]). This is because, as Wurman ([13]) argues, with the advent of e-commerce, the marketplace as traditionally understood (in the 'town square') has become more global and to a greater extent more virtual. Businesses need to understand the dynamics of this new market and gain insight into how to exploit the impending paradigm shift in content, marketing, and distribution.

Our main aim is to provide businesses in the digital contents sector with a tool which will help them to take informed business strategy decisions and, therefore, to become more competitive by adapting their traditional business models to the new marketplace.

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At this aim, we have implemented first versions of music and news market models that are based on multi-agent simulation and market data extracted both from extensive sector surveys ([6] and [7]) and from close interaction with real content providers. They allow market participants in the digital contents sector to run a variety of scenarios and observe the impact they have both on their businesses and on the competitive digital contents landscape. The insights gained during these simulation runs provide them with a better understanding of the hitherto unexplored dynamics of the market, and permit them to adjust their own business models to the new competitive demands.

Multi-agent based simulation (MABS) ([3]) uses models that incorporate agents, where agents are understood as autonomous computer programs that are goal-directed and interactive and that are located in, and react to their simulated social and physical environment ([12]). In our simulations, agents represent market stakeholders that act autonomously according to their interests and interact with other agents inside the market environment. This allows end users to investigate the implications of a variety of decisions and strategies by running simulations starting from different initial conditions. Simulation results can be then analysed, either intuitively or through a statistical analysis, and this (together with flexibility) provides one of the main advantages of this MABS approach.

1. Music and News Distribution Market Models

We have focused on modelling the structure and behaviour of two markets: the on-line music and the news markets together with their constituents or stakeholders. Each model consists of a population of content providers and customers that mainly interact by buying and selling products. A stakeholder (both provider and customer) usually has an intention to reach certain goals and uses strategies that allow it eventually to reach these goals. We have chosen to simulate a business-to-consumer (B2C) on-line music market (and thus, providers are retailers and buyers represent population segments) and a business-to-business (B2B) on-line news market (all stakeholders are companies). Both models are SW prototypes in an ongoing project, and in due course we shall extend the models to include a larger number of stakeholder categories and interactions, a more sophisticated range of stakeholder actions and the possibility of agent learning. Using our prototypes, users can create markets, and for each market, define as many products, providers and customers as required (see Fig. 1):

- Every *product* is characterised by its own features (attributes that take values based on the type domain chosen by the user). Product offers and requests are central to the model, since they define what is being traded in the market.
- *Provider* agents offer products under certain conditions (e.g. subscription period) and interact with customers by advertising and selling these product offers.
- *Customer* agents reach their goals by buying products that best satisfy them.

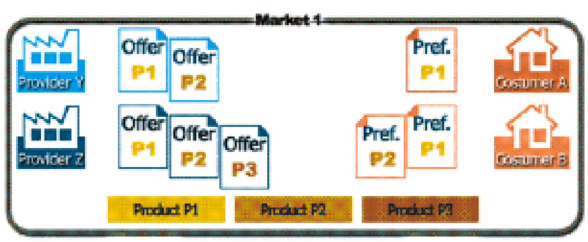

Figure 1. Conceptualisation of the main components in the market model

The market acts as the environment for both provider and customer agents. It includes the products they trade, and provides general utilities such as model setup, advertising facilities, or market information. This last service includes information about reached deals and the most fashionable product. Fashion is modelled in terms of market sales, and hence the product in fashion is the top selling product.

1.1 Products

Products represent goods traded in the market, and can be defined by sets of features such as size or price. Products are generic descriptions specified as sets of attributes, each of them having a name, a type and, when required, a set of possible values. Types are:

- Numerical: the attribute having this type can take any numerical value.
- Numerical Range: values must be comprised between a minimum and a maximum.
- Set: the attribute values belong to an unordered list of labels. For ex., list of colours.
- Ordered Set: values are an ordered list of labels (e.g. quality: {low, medium, high}).

Products define the domain of product offers. As next subsection states, an offer is a product representation containing specific values per attribute.

We have defined different products for our on-line music model (*Temporary Download*; Full *length streaming* **-**see Fig. 2-; *Permanent Download*, and *Burning*) as well as for the news model (*Breaking news*; *Printed newspaper*; *Sport news*; *Finance and business news*; and *Alerts*). Products can have any number of attributes but many of them are common for each model. Some attributes for news products are: price, format, source quality, ads, subscription period, delivery freq., #themes, field expertise, customisation, etc.

Product name: Full Length Streaming
Attributes:

- Price: Numerical interval [0, 3]. Prices must be comprised between 0 (meaning free) and 3. Values are normalised to price per 1 song. Units are euros (€).
- Bitrate: Numerical values.
- Type of Content: Set of {“Back Catalog”, “New Release”, “Premium”} label values.
- Codecs: Set of {“WMA”, “Real Audio”, “AAC”} values.

Figure 2. Example of a music product definition *Full Length Streaming*.

1.2 Offers

Providers can offer a product with different conditions, and thus they can generate any number of offers by assigning different attribute values to one product. Nevertheless, customers not only buy products because of their specific features, but also because of the characteristics of the provider itself. Therefore, our prototype allows to add a set of provider attributes to each offer analogously to product attributes.

As shown in figure 3, seven different provider attributes have been defined for our music model: ‘Offline brand’ indicates whether the provider is “click and mortar” or if it only distributes music through the on-line channel; ‘International’ means the provider is able to distribute to more than one country; ‘Scope’ distinguishes between generalist and specialized providers; ‘Area of expertise’ only applies to specialized providers and indicates what kind of music do they distribute; ‘Credibility’ ranks in qualitative values (‘low’, ‘medium’, and ‘high’) different credibility levels; “Market share” measures the provider’s position in the market; and finally, “Staff” quantifies with labels the size of the company in relation to dedicated workers. News provider attributes are equivalent.

1.2 Requests

Requests (see Figure 4) allow customers to define desired values for each attribute in the offer definition (analogously to offers, they include both product and provider attributes).

Offered product: Full Length Streaming
Product attributes:

- Price = 0.15
- Bitrate = 50
- Type of Content = “Back Catalog”
- Codecs = “Real Audio”

Provider attributes:

- Offline brand = “Yes”
- International = “Yes”
- Scope = “Generalist”
- Area of expertise = “Non-applicable”
- Credibility = “High”
- Market share = 30
- Staff = “More than 50”

Figure 3. Example of a Full Length Streaming offer

Requested product: Full Length Streaming
Product attributes:

- Price = [1, 2], LIB, 0.4
- Bitrate = 128, 0.3
- Type of Content = “Back Catalog”, 0.1
- Codecs = “Real Audio”, 0.2

Provider attributes:

- Offline brand = “Yes”, 0.2
- International = “Yes”, 0.3
- Editorial scope = “Generalist”, 0.1
- Area of expertise = “Non-applicable”, 0.1
- Credibility = [“Medium”, “High”], MIB, 0.1
- Market share = 50, 0.1
- Staff = “More than 50”, 0.1

Figure 4. Example of a request for Full Length Streaming

Customer agents state their preferences as either a single value or a range of preferred values. In the latter case, all values in the range are desirable, although customers can establish slopes for the preferences. In this manner, a FLAT preference means all values are equally preferred; MIB (More is Better) indicates higher values are preferred to lower ones; whereas LIB (Less Is Better) states the opposite.

When customer agents specify their preferences for product attributes, they also need to provide a weight value per attribute, which signals the importance the customer gives to that attribute. By convention, all weights in the product attributes collection must sum to 1. And the same applies for providers’ attributes.

We assume requested values are preferred but not mandatory. Therefore, a customer will still consider an offer not perfectly fulfilling all its requirements. For each attribute in the request, customers can specify whether its attribute value is mandatory or not. In our model, this feature is very useful for attributes such as ‘Codecs’ because if, for example, a customer can only reproduce ‘Real Audio”, then a very good offer in WMA is of no value.

1.2 Multi-Criteria Decision Making for Matching Requests and Offers

When buying, customers do always look for offers that satisfy their necessities. We compute this satisfaction by matching requests and offers with an extension of the Multi Attribute Utility Theory (MAUT [5]) that incorporates fuzzy functions.

Matching degrees are computed with iSOCO’s fuzzy matching engine iMatcher, which scores and ranks each offer according to the customer’s preferences (see [9] and [10] for details and design guidelines). Each attribute preference in an offer is internally represented as a satisfaction function, which corresponds to the membership function of the fuzzy set [4] defined by the preference. X axes on these functions correspond to attribute domains (types in product definitions) and Y axes are satisfaction degrees normalized to 1. Y values are assigned based on the preferences (preferred values and slopes).

As an example, fig 5 shows satisfaction functions for Price and Quality attributes: most preferred values (1 € / Excellent) get maximum satisfaction (that is, 1); last preferred values (2 € / V.Good) get a 0.5; and values outside the preferred range get satisfaction degrees that decrease proportionally down to 0 so that offered values that do not match preferences exactly still can have a positive (but small) satisfaction.

Outside non-Flat intervals, those values ‘close enough’ to the preferred side (i.e., max. value in an MIB interval or min. value in an LIB interval) do also take satisfaction values inside [0.5, 1]. By 'close enough' we consider values within a neighbourhood of the interval that is computed as a percentage β of the interval length. In our implementation, β has been fixed to 10% for usability reasons. In this manner, the satisfaction function defined for Price attribute in Figure 5 a) has a [0.9, 1] 'close enough' interval.

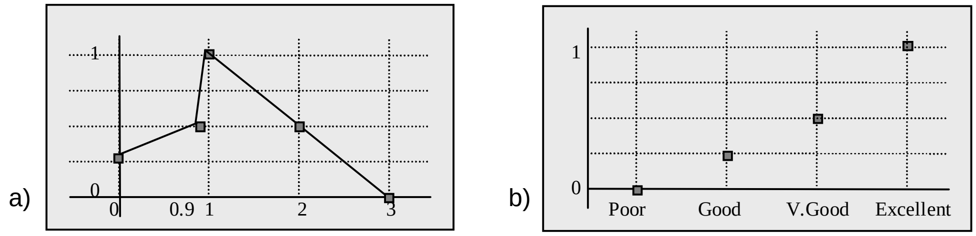

Figure 5. Satisfaction functions: a) for the Price attribute S(1)=1, S(2)=S(0.9)=0.5, S(0)=0.275, S(3)=0 and b) for a Quality attribute, for which values are an ordered set of labels.

If no slope information is associated to a preference (i.e. neither LIB nor MIB slopes have been defined), satisfaction must behave symmetrically and assign satisfaction values that decrease proportionally with the distance to the preferred values on both sides of the interval. For example, if the preferred value is 'Medium', both 'Low' and 'High' offered values should take the same satisfaction degree.

On the contrary, symmetry does not apply for non-Flat preference intervals: satisfaction degrees for offered values falling on the left side outside an LIB interval decrease with a slope twice smother than right-sided values (and it is analogous for MIB intervals). Following the example in Figure 5 a), satisfaction values for prices between 2 and 3 decrease with a slope of -0.5, whereas prices in [0, 0.9] increase their satisfaction with a slope of 0.25. Therefore, if a 'Full Length Streaming' product is offered for free, the price attribute will take a satisfaction degree of 0,275. Considering the offer shown in figure 3, the 0.15€ price value will result in a satisfaction degree of 0.3125.

Finally, once attribute satisfaction degrees have been computed for every attribute, overall matching degrees are afterwards computed as a weighted mean of individual attribute satisfaction degrees. This weighted mean uses the weights the customer has specified for each attribute in its request.

2. Stakeholder Agents

2.1 Provider Agents: On-Line Content Providers

Although telco/PTTs, Internet service providers, and technology providers have a role in most on-line distribution markets, music and news markets do have their own set of stakeholders. In this manner, music markets do have artists, label/record companies, music portals and payment system providers whereas the news market includes journalists, news agencies, portals, on-line media companies, and search engines.

Our current music prototype focuses on music distribution companies (that comprises recording industry, and on-line retailers including music portals), so that provider agents correspond to real players in the on-line news market such as Sony or Fnac.fr. On the other hand, we have modelled six different news content provider agents that characterise the Portuguese news market: Reuters and Lusa as news agencies; Publico.pt and Diario de Noticias as generalist news papers; and Record and A Bola as sports newspapers. For each of them, we have characterised their attribute values and we have defined both the set of products they can provide and their corresponding offers.

2.1.1 Provider Agent Behaviours

In order to sell a product, every provider agent must advertise their offers, so that customer agents are aware of what is on the market when choosing the one to buy. Customers are supposed to forget advertisements and so providers keep advertising their offers at each step in the simulation. Advertising is done to all customers in the market (without customer segmentation) and similarly, provider agents do not favour customer aggregated demands nor apply customer loyalty policies.

In our current models, provider agents have information that is currently used for display purposes, but we plan to apply it in marketing policies in future implementations. This information is about all deals a provider has reached during the current step, as well as about all its deals done during the whole simulation. Provider agents also listen to the advertisements of their competitors, and thus they know which products are being offered and under what conditions. Finally, the market provides the “product in fashion” service, which allows each provider agent to know the top-selling product.

2.2 Customer Agents: On-line Content Consumers

Together with content providers, customers are key players in content distribution markets: they have purchasing goals and present a variety of buying behaviours.

Our B2C music market model defines customer agents representing two major end consumer segments: “Early adopters” and “Ordinary Music Buyers”. In general, “Early adopters” are willing to pay higher prices for those music products of “New Release” type of contents, whereas ordinary music buyers will tend to prefer low prices.

Our online B2B news market customer agents buy pieces of news in order to add value to their own products: “Mobile operators” distribute them to their consumers through SMS and WAP (so these are the format attribute values they request); Web portals increase the attractiveness of their web sites; Institutional sites provide their customers and employees with a news service; and Newspapers also buy news from other news providers.

2.2.1 Customer Behaviours

We have defined and implemented five buying behaviours. Nevertheless, all behaviours respect mandatory attributes in requests: an offer will be discarded if it does not offer a requested value of a mandatory attribute. Following the example in figure 5 a), an offer having a Price value outside the [1, 2] interval would be discarded.

“*Buy Best Offers Behaviour*” models “rational” customers and tries to satisfy its own request as much as possible: it first computes the matching degree of each request against all providers’ offers for the same product, and then chooses the best one.

“*Buy Cheapest Offers Behaviour*” models “bargain hunter” customers. It uses requests just to look for products and to check mandatory attributes, since they simply choose the offer with lowest price.

Some customers have such strong preferences for specific providers (which must be specified) that they always buy from them. “*Be Loyal to Provider Behaviour*” use requests to see which offers from this provider fit best (otherwise it does not buy any of them).

Some other customers decide to buy fashionable products. “*Follow Fashion Behaviour*” first checks whether the product that is currently in fashion is required (the agent has a request for it), and afterwards, chooses among all available offers.

“Satisfy Requests Exactly Behaviour” is our final type of behaviour and it models customers that are extremely demanding, so that their requests must be satisfied exactly. This behaviour has been implemented by treating all attributes in the request as mandatory.

3. Simulation

Once the model has been defined, it is possible to simulate its evolution with time. We use RePast [8] as the underlying simulation engine. From the many well - known software development environments for agent- based simulation (Swarm; RePast; Ascape; NetLogo; AgentSheets; MAML and, SDML); we have chosen RePast on the grounds of criteria such as portability and support and despite the fact that it does not provide support for agent development. Our agent and environment classes are hooked to RePast classes so we can use its simulation controls and display library.

Top area in figure 6 shows our simulation toolbar. Simulation consists of repeating steps (ticks) until a preset limit is reached or the user clicks on the stop button in the control bar. For each time step, the following sequence of actions is performed:

1. Provider agents advertise their offers.
2. Both customer and provider agents listen to advertisements.
3. Customer agents try to satisfy their requests: they acquire products based on their buying behaviours. Each purchase involves a deal with the corresponding provider.
4. There is a deliberation period for all agents. Mostly, this time is used to perform actions such as updating historical data.

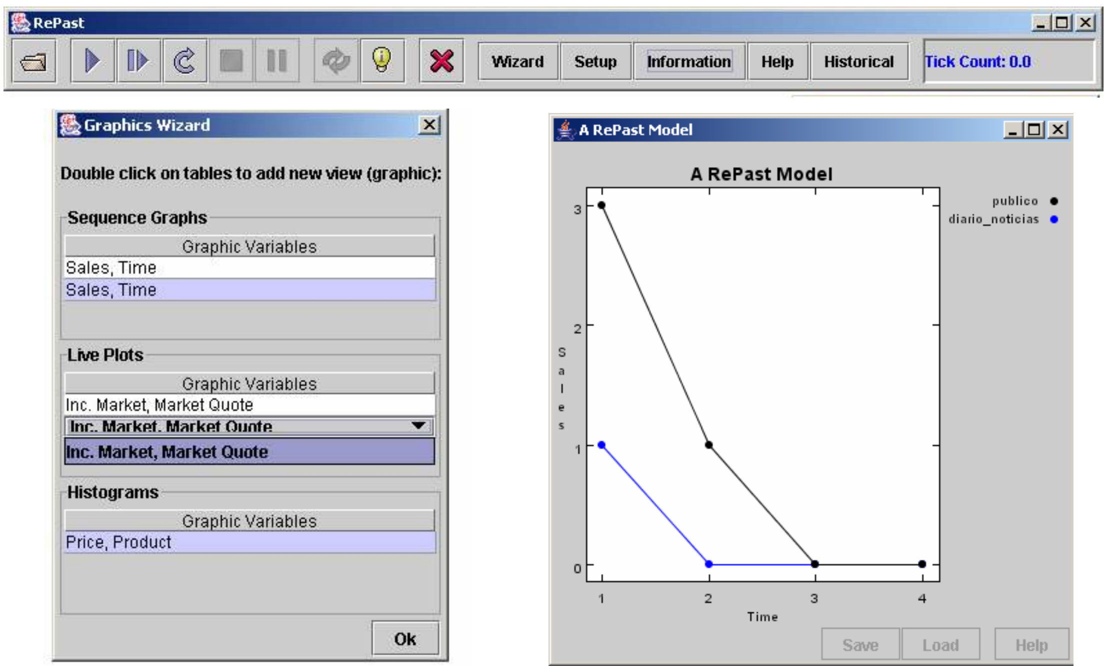

Figure 6. Top: Simulation toolbar (RePast enhanced) includes buttons such as Start, Step, Stop, Wizard for output definition (opened in bottom left side), Agent Information, Historical Information, orTick Display. Bottom right: sequence graph showing a simulation output of sales along time.

3.1 Simulation Results

Results are provided as graphical output information that can be interpreted and analysed by users. Our model has been derived from a close interaction with real on-line music and providers such as Fnac.fr and Publico.pt, who are the targeted end users. Business strategy decisions are mainly taken based on provider performance indicators. Thus, our prototype displays providers' variables such as market share or actual sales, which proved to be understandable by users.

Simulation setup allows users to create different scenarios by defining new products, offers and requests, or by changing the number of agents and their behaviours in the model. Then, for each step in the simulation, output graphs do continuously show the market evolution. As an example, bottom side of figure 6 shows a sequence graph displaying the number of sales per time per provider, which are distinguished by colours. As we can see, for the second tick, Publico sold 1 news product whereas Diario de Noticias sold none. Additionally, pie charts depict market shares and histograms show the range of prices and number of product units that are being sold in the whole market. Finally, users can compare the results of different simulations by recording and replying them.

4. Conclusions and Future Work

Still in its infancy, organisational simulation is currently a booming area of research in both academia and practice ([1] and [11]). In this work, we apply the MABS approach because of its intuitive analysis (agents represent stakeholders, act according to their interests and interact within the environment) and flexibility to define different scenarios.

Based on RePast, we have developed an application where we have modelled an online music market as well as a news market. However, the application is totally flexible and could also be used to model other markets. In the end, it is the user who decides what attributes the products have and who the providers and customers are.

This paper presents an ongoing work. We are currently working in two dimensions: the models and the software tool. On the one hand, we are adding budget considerations and strategy rules to agents. And, on the other hand, we are improving the software tool (which by now is a prototype) to become a real product. Long term plans include adding learning capabilities to agents, including reputation mechanisms, and exploring other means of result analysis to help in following agent co-evolution inside the market.

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