Agent based simulation of dynamic pricing policies of academic courses

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Andrés F. Rojas A.
Mathematical engineering student
EAFIT University

Paula A. Escudero M.
Mathematical Science Department
EAFIT University

***Abstract*—In the search for improving revenue, many producers and service providers have started to inquire and apply different pricing policies. Several methods have been developed from various mathematical approaches, mainly they take into account product's characteristics and the demand dynamics in order to build an optimal pricing strategy. Several economic segments are adopting a more dynamic approach to pricing goods and services, although in education fees this phenomenon has not been addressed as extensively as in other types of businesses. This paper proposes a conceptual model prototype that gives an overview of the dynamic pricing problem in academic courses.**

I. Introduction

The assignation of a service or a product's price is one of the crucial aspects of the dynamics between the manufacturer or service provider and the customer. It is common that the price is set by an empiric process based on passed observations of the system. There are different ways for describing, analyzing and improving pricing strategies, mathematical or simulation models can help reduce the effects of using empiric knowledge and experimenting on the real system without having to alter its operation and functionality.

The pricing problem representations previously mentioned have been developed from various approaches: game theory, optimization and simulation among others, provide a wide variety of models for approaching the price strategy problem. One of them is the dynamic pricing policy; it has been widely used over products or services that are perishable, for example hotel rooms and airplane tickets among others. If products with this characteristic are not bought by customers before the sales horizon ends they become a loss profit.

The dynamic pricing strategy aims to minimize the loss profit by obtaining the optimal price for different periods of time or segments, a further explanation of this pricing strategy is provided in [1]. This pricing strategy has multiple mathematical representations over the optimization approach, other examples can be found in [2,3].

A simulation model approach could help explore scenarios and improve the application and understanding of this type of pricing strategy, specially for someone that is looking for ways to increase its revenue based on a perishable product. Specifically, agent based simulation has been proved to be a powerful tool to model human decision making processes, also it has been widely used to describe pricing variation and financial market behavior [4], there are several examples in topics like auctions [5], especially energy auctions [6]. In addition, ABMS also has been used to represent the public reaction to specific products, some examples are [7] and [8].

Specifically in this paper, EAFIT's Language Center will be considered since they are looking for ways to improve its revenue, one way to do so may be by the implementation of a dynamic pricing strategy. The model proposed will be compatible with the Language Center characteristics, in this case the perishable good or service will be the limited allocations in the courses they offer. Even though there is a lack of evidence regarding applications of dynamic pricing policies in academic courses, agent based simulation seams an appropriate methodology for modeling this type of problem, considering its scope and the uses.

Therefore, the aim of this investigation is to build a conceptual agent based simulation model that represents the dynamics between a service provider and their clients (in this case the Language Center and the students). The model should capture characteristics and price dynamics of the product over time, initially the product considered will be the quotas of one level of a given course offered by the Language Center, also the intended model could give a description of the client reaction over the changes in the behavior of the product (like the application of dynamic pricing).

The importance of this investigation can be summed up in the following aspects:

- The way EAFIT's Language Center actually operates does not have a mathematic modeling approach which can support their decision making processes and help them gain understanding of the system's behavior.
- The previous work in agent based modeling and simulation, and dynamic pricing policies are scarce, in addition, there has not been found any application in academic courses.

The paper is structured as follows. Section II presents a literature review, section III gives a description of the methodology used in the creation of the conceptual model, section IV presents an application of the methodology in the process of conceptual modeling, and finally, section V provides the work conclusions and further work.

II. Literature review

A first glance to the literature pointed some investigations that share the agent based simulation methodology and some of the desired model characteristics. Considering that one of the principles of modeling is to keep the model simple, a good example of model simplicity is Mizuta [5] were the price dynamics and the human interaction in Internet auctions was studied with an agent based simulation model. They defined clients as two different types of agents: the first type of agent represented the client that bids gradually, the second one captures the snipers behavior. The sniper is the one that bids a higher amount of money at the end of the auction, its behavior is difficult to capture due to its apparently irrational nature. In this model the price is a stochastic variable.

On the whole, the price of the good is one of the key components of a dynamic pricing model, it is very important that the prices and market characteristics of the courses in the Language Center are properly represented in the model. Since there are not reported models of dynamic pricing for academic courses, it is necessary to review the literature published on models that consider other type of goods with similar characteristics. For instance, Jinlong et al. [7] built a simulation model that included the concept of product's life cycle. They developed a model that represented long lasting products, which are products that are only bought once. This characteristic is also presented in an academic course, since people usually take a particular course only once. The complete product's life cycle modeled by Jinlong et al. is as follows:

- Introductory face: The product is unknown to the market.
- Growth face: The product is accepted by the market and due to its pressing boom the price becomes dynamic and the market characteristics change (there is a market pressure induced by the product's competition).
- Maturity face: The price becomes more stable, the products market position determines its variation.
- Decline face: The end of the cycle.

In addition, Lin et al. [8] proposed a representation of a dynamic pricing policy over product lines that have a cannibalism phenomenon. It means that several products of the same manufacturer are competing against each other in the market. The fact that this model is applied to a product chain, or line, is interesting because a language course can be seen as a chain of products (levels) that a student can buy.

The models described up to now are examples of the representation of client-product behavior. If a much more complex representation of the human interaction is needed, there are other types of models, such as energy auction models, that could serve as reference. Ziogos. N. P [6] reviewed the literature of the most significant studies in this field using agent based simulation methodology.

Other type of models, consider the behavior in the pricing policy, moving from a static price policy to dynamic pricing. For example, Kowalska-Pyzalska et al. [9] studied the "temporal dynamics of consumer opinion regarding switching to dynamic electricity tariffs and the actual decisions to switch". The way they managed to deliver a description of a human decision making process towards a change introduced to the market, bears a close relation with this paper's intended model proposition. Then, Kowalska-Pyzalska et al. [9] will also be taken into account as a benchmark. In addition, Valenzuela et al. [10] developed a model that represents the response of consumers to dynamic energy prices. The agents of the model changed their behavior based in a forecasted price; this forced them to modify their consumption habits, seeking a higher consumption in hours when the price is expected to be lower. Although this study is oriented towards changes in the habits of customers, these changes are induced by a simulated human behavior respond, which is why [10] will be taken into consideration for building this project's model.

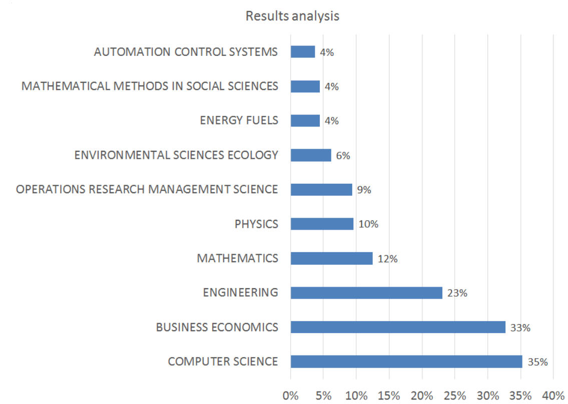

Fig. 1: Results analysis for the string ('Agent based' AND 'dynamic pricing').

For a more complete overview of the previous work in this field, a systematic literature review was carried out using the *Web Of Science (WOS)* database, the searched strings, the period of time in which the search was bounded and the number of results are shown in Table I.

Searched string	**Years of search**	**Number of results**
('Agent based' AND 'dynamic pricing')	All	649
	2005 - 2015	540
((('Agent based') AND ('dynamic pricing')) AND ('academic courses')))	All	0
(('dynamic pricing') AND ('academic courses'))	All	0
((('dynamic pricing') OR ('revenue management')) AND ((academic courses) OR (tuition fees) OR (university schedule)))	All	42
	2005 - 2015	20
("tuition" AND "pricing")	All	27
	2005 - 2015	18

Table I: Systematic search parameters and number of results.

The results of the search conducted using the string ('Agent based' AND 'dynamic pricing') are classified by the research areas and shown in the Figures 1 and 2.

In general, business economics and computer sciences are the two areas in which the majority of results are found, being mathematics and operation research also two important refer-

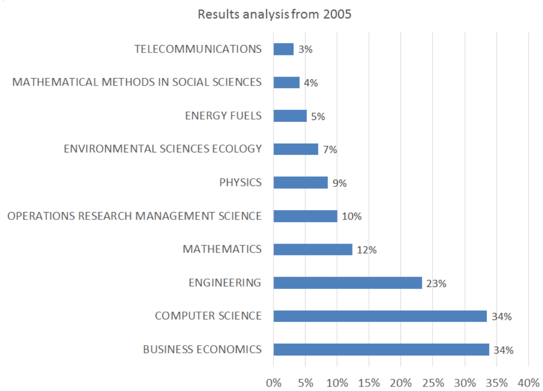

Fig. 2: Results analysis for the string ('Agent based' AND 'dynamic pricing') from 2005.

ence areas. Some of the registered examples of the literature review (using the last two strings from Table I) are [11–15].

For instance, [11] shows how a statistical analysis is conducted to describe the decision making and changing behavioral dynamics of students in England that are in the market for higher education student programs. The study was motivated due to changes in the tuition fee policies used by England's education institutions. It surveyed 1549 students,and with the collected data, they identified several key aspects that will guide a last year high school student's choice, being financial issues more important than institution quality or career and work issues among others. Also by statistical analysis [12] studies how institutionally-funded financial aid generates additional revenue. Guidelines are given for educational institutions to improve their operability costs funding taking into account discounts and financial help for students. In a way, it gives some parameters for giving financial aid without sacrificing the financial stability of the institution. A similar study is made by [13] in which an admission model is proposed. The admission model seeks to optimize revenue by combining private students and tuition programs.

A third relevant work is the pricing model based on Multivariate Linear Regression is proposed in [14]. Using the qualitative method firstly, then quantitative analysis and the method of gray relational analysis three key influential factors for the regression are identified.

On the other hand, [15] approaches the pricing problem from an other point of view, addressing the satisfaction of the client. A mathematical model is proposed in which two types of satisfaction are considered, the first one refers to the client's family satisfaction, and the second one describes a social or government satisfaction over the financiation of students tuition, the model is optimized using a particle swarm metaheuristic, then, the result serves as a benchmark for proposing the price strategy.

In general, it seems that among the previous work there are key aspects and important model developments that address several pricing strategies that could help in the development of the conceptual model, having said that, as far as we know, dynamic pricing strategies have not been used directly on academic courses, but regarding this area, there are several pricing strategies and examples of measuring core fundamentals regarding the application and description of the demand

In the next section this work's methodology will be explained

III. Methodology

The research project intends to follow the methodology proposed by Salamon [16]. He proposes a guideline for building an agent based model that takes into consideration the following stages:

- The formulation of the problem is set as a task for a solution.
- The task should be evaluated searching the most appropriate way to solve it.
- The model has to be checked for consistency.
- The development platform should be selected.
- The simulation model is confronted with the real system to examine if it is a faithful representation of it.

Each stage has a more detailed process that is going to be taken revised during the development of the whole project. Similarly, Tako and Robinson [17] states a clear and organized methodology to build conceptual simulation models, although it is oriented towards system dynamic's and discrete event simulation modeling, it provides a series of steps compatible with the agent based simulation model scope. The faces of the development are shown in Figure 3.

This paper focuses the attention on developing the conceptual model (the right side of Figure 3), it will be validated and implemented as a computer model, afterwards, the computer model will be verified and validated. It is important to note that as Figure 3 shows, all the faces are cyclical and each one depends on the other ones to produce a quality model. The above described steps are applied in the next section.

IV. Model design

According to the methodology described in section III, a series of steps are proposed for achieving a successful conceptual model, in this section the intent is to follow them as recommended.

A. *Task formulation*

This step intends to specify the task in a formal way, this step should provide sufficient information about the system for the next steps to come.

This simulation's main goal is to represents the dynamics between a service provider and their clients, it should also capture the product's characteristics and price dynamics over time, and give a representation of the client reaction over the changes in the product's behavior (like the application of dynamic pricing).

Since the case study is EAFIT´s Language Center; we will be simulating the reaction of the customers of one course towards changing the pricing policy. If a client is interested in taking a level he should first register as a student, once the registration is completed, the student compromise is to pay the issued bill. The strategy behind this is to encourage students to a prompt payment so they have the enough cash flow to cover the fix and basic costs of the level before they start.

The current price assignation is made empirically and is done by setting a fixed fee and a fixed discount based some characteristics of the client, for example there are discounts for being a student. They know the equilibrium point is reached from the registration process, so if a level does not reach the equilibrium point in the registration state it will not be open.

It is clear that the price that the Language Center sets, and the discount policy determines the behavior of the clients. If the price is to high many customers will not be able to afford the course, if the price is to low the Language Center will be losing potential income, hence the goal of the Language Center is to get as much utility as possible. On the other hand, the goal of the customer is to pay the least amount of money for the course given the personal finance possibilities, it is clear that the student is then affected by its personal needs and cash flows, this will determine if the customer will register as a student, in case the course is affordable. We will be measuring the total income made by the Language Center as a benchmark. It is fundamental to determine the investigation questions and the way the model is expected to behave.

1) Research problems: The investigation questions are staked. In this case, the model should answer these questions:

- Can the client's behaviors be replicated and explained using an energy auction model?
- What could be a plausible client reaction towards a change in the course pricing policy?

2) Testing criteria: The expected model behavior can be described by the client agent's actions over the purchase of the language course. It can be summarized in the revenue obtained by the Language Center, the simulated income could present variations compared to the real one, never the less,it should be near an expected value.

B. Task evaluation

In this step we need assess the task previously created is suitable for an agent based modeling scheme.

- *Are there entities that can make decisions?* They are entities that make decisions: customers and service provider.
- *Are there many kinds of decision-making entities or many kinds of decisions?* The decisions that can be made by the customer are to enroll as a student and when is going to be the payment made. The service provider should set the base price fee for the course and determines if the course is opened or not, based on the financial equilibrium point.
- *Does it look like the system will have dynamic characteristics?* There are dynamic characteristics in the system since the price will be modified by the demand of the courses, in that sense the future states will depend on past states.
- *Describe the level of detail of the model.* It is hard to treat the problem in its macro level since every client has its own financial characteristics, also it will be very difficult to predict the courses demand on a macro level.
- *Is it difficult to represent the whole situation as a process?* Activities and state diagrams can be made for the entities.
- *Can entities be summed up in one variable?* No, each entity has its own variables and makes its own decisions except for the course fee which is set by the service provider but can be known for all customers.
- *Are special environmental factors important?* The spatial characteristics are important; they determine the buying decision of the agent.

C. Conceptual modeling

In this step the task set before is transformed into a conceptual model. Since one of the research problems states the possibility of describing the behavior of the clients from an adaptation of an energy auction model, the basic structure will be proposed as a basis from witch complexity and detail level will be added according to the future needs. The basic structure of an energy auction model in a general description contemplates two types of agents, the energy producers that have a production capacity and they set a selling price for the energy, and the auction market regulator that starts buying energy from the cheapest seller up until its demand is satisfied, for multiple examples of this kind of models refer to Ziogos [6].

In the adaptation that is planned, the energy producers will represent the clients, and the selling price will become the maximum price each customer is willing to pay for the service provided. On the other hand, the Language Center will be represented by the auction market regulator; in this case the demand will represent the maximum number of students per course. As an initial approach the problem will be reduced to one language class.

For the agent type "Client" the goal will be to set a maximum buying price, this action requires a further investigation on how to model and simulate such economical aspects, this results will also determine the attributes, variables and methods for this class in a programming environment, furthermore the information required for this goal will determine key inputs of the model and should be measurable and acquirable for the model application. The clients do not have the need to communicate or interact among them. Also, this agents will have a method that determines whether they buy or decline the course based on the price offered. In this sense the clients need to communicate with the service provider in order to make that decision, this is a behavior that can be replicated from the online auction models in the literature.

For the agent type "ServiceProvider" the goal will be to maximize its revenue, this will be achieved by processing all clients' maximum buying prices and finding the value range in which the course is all sell out, then a discretization of this range will determine the dynamic pricing segmentation. After the pricing strategy is determined, the simulation will continue until the sales horizon ends. Ones it stops two things can happen: The total number of clients that are able to pay for the course based on the pricing strategy will be determined, or the "ServiceProvider" will determine to not open the course since its equilibrium point has not been reached. Figure 4 shows an activity diagram of the model.

The above described process will repeat several times seeking homogeneity in the simulation outcome. After this the more adequate pricing strategy can be determined.

V. Conclusions and further work

- The conceptual modeling process is ongoing and is proven to require more time than anticipated, nevertheless the methodology provided by Salamon [16] and Tako and Robinson [17] has been a fundamental guide and benchmark in the process. That being said, the further work will propose the continuation of the conceptual model creation accordingly to the methodology described in this paper.
- Further research is needed to determine the maximum buying price for the clients. There may be mathematical models in economics that could provide a solution for this problem.
- The discretization or the price range made by the "ServiceProvider" could be made from various approaches; game theory or optimization models could be of use.
- In a further work, the validation and verification process should have a more active role.

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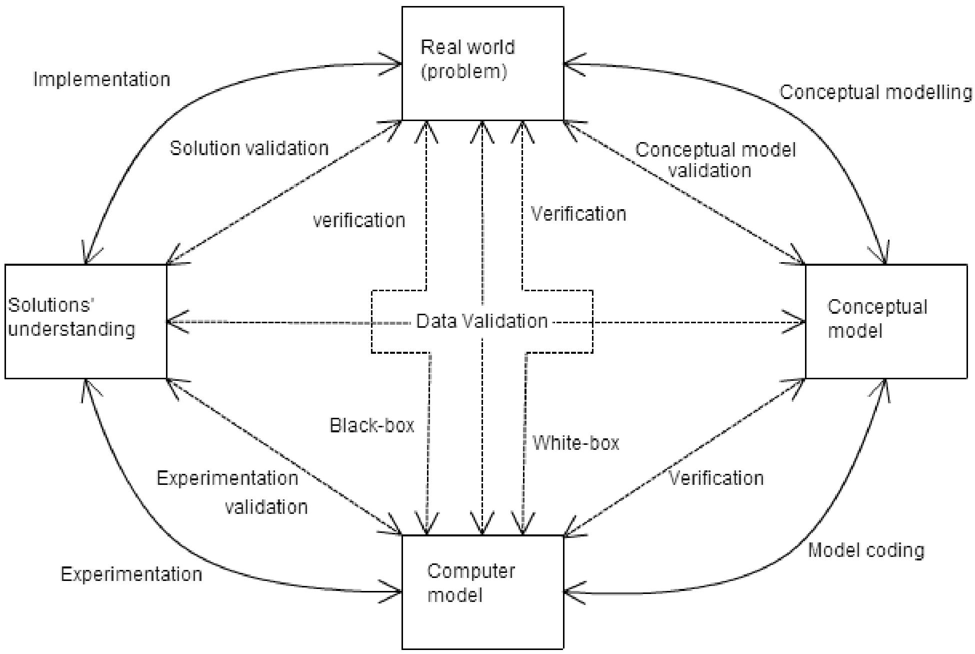

Fig. 3: Graphical summary adaptation of the model building faces proposed by Tako and Robinson [17].

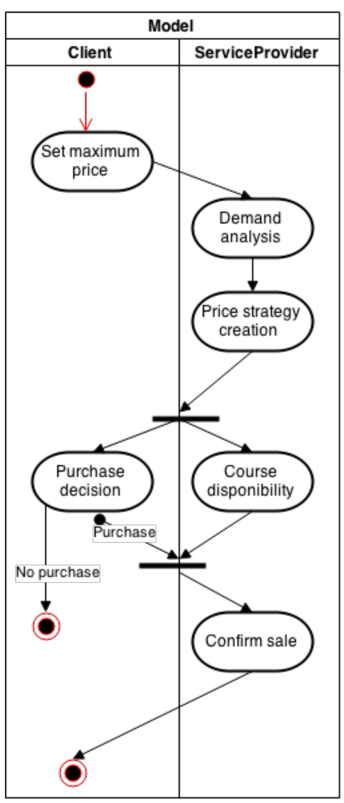

Fig. 4: Activity diagram of the proposed model.