Agent based simulation of dynamic pricing policies of academic courses

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1. Problem statement

EAFIT´s language center uses empiric knowledge to assign the courses fees and resources associated with the offered services. Even though this process has worked fine until now, there are different methodologies to help describe, analyze and improve the real system, and reduce the effects of using empiric knowledge; this involves the experimentation (of different influential factors) on the real system. It has been proved that mathematical or simulation models can help tackle this kind of problems. Moreover, since EAFIT´s language center is considering the implementation of dynamic pricing strategy, a simulation model help explore scenarios that could support the decision making process for a smooth transition towards the new pricing system.

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 [1], there are several examples in topics like auctions [2], especially energy auctions [3]. On the other hand, ABMS also has been used to represent the public reaction to specific products, some examples are [4][5]. Even though there have not been found any applications in academic courses, agent based simulation seams an appropriate methodology for modelling those type of problems, considering its scope and previous uses.

2. Objectives

2.1. General objective

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), that captures the product´s characteristics and price dynamics over time, and also could give a plausible client reaction over the changes in the product´s behavior (like the application of dynamic pricing).

2.2. Specific objective

- Literature review.
- Create a conceptual model diagram that represent the dynamics between a customer and a service provider (in a general scenario), keeping the model as simple as possible.
- Introduce key aspects of the models revised in the literature for capturing a more accurate representation of the client behavior towards price changes in the service provided (taking in to a count how the literature models represent human and price dynamics over time).
- Build a simulation model that represents the initial approach to the problem.

3. Background

According to the main objective, set agent-based model will have to be able to: represent the supply and demand dynamic interaction, analyze the evolution of the product´s price in time, represent the product´s market characteristics and capture the reaction of the client towards the changes in the product´s price over time.

In the literature,e there has been found some investigations that share the agent based simulation methodology and some of the desired model characteristics.

Considering that one of the principles of modelling is to keep the model simple, a good example of model simplicity is *Mizuta, H., & Steiglitz, K. (2000).* [2]. The price dynamics and the human interaction in internet auctions was studied with an agent based simulation model. They defined clients as 2 different types of agents, the first type of agent represented the client that bids gradually, and the second type 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 changes in the price are stochastic variables.

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. (2011)* [4] built a simulation model that included the concept of a products 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 was modelled as follows:

1. Introductory face: The product is unknown to the market.
2. 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).
3. Maturity face: The price becomes more stable, the products market position determines its variation.
4. Decline face: The end of the product´s cycle.

In addition, *Lin et al. (2011)* [5] proposed a representation of a dynamic pricing policy over product lines that have a cannibalism phenomenon, which 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 until this point 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 (2011)* [3] reviewed the literature of the most significant studies in this field using agent based simulation methodology.

Other type of models, consider the change in the pricing policy, moving from a static price policy to dynamic pricing. For example, *Kowalska-Pyzalska et al. (2014).* [6] 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 plausible representation of a human decision making process towards a change introduced to the market, bears a close relation with the future work the intended model should be able to do. Then, [6] will also be taken into a count as a benchmark.

Also, *Valenzuela et al. (2012)* [7] developed a model that represents the response of consumers to dynamic energy prices. The agents changed their behavior based in a forecasted price, this forced them to change 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 customer´s habits, these changes are induced by a simulated human behavior respond, which is why [7] will be taken in to a count for building this project´s model.

4. Justification

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 modelling approach which can support their decision making processes and help them gain understanding over the system's behavior.
- The previous work in agent based modeling and simulation, and dynamic pricing policies are few, in addition, there has not been found any application in academic courses. Thus we think there is a need to fulfill this void.

5. Scope

The investigation main scope is to produce a conceptual model that can be easily applied (in any type of agent based simulation software). This model has to be able to capture all the basic demand, supply and price dynamics from a human interaction point of view.

It is very important that the model is able to do all the above mention things and still remain as simple as possible so that the future manipulation of it remains flexible enough to serve as a tool to examine different case scenarios by being independent of any specific aspect searching a mode universal approach to the problem.

It is important to clarify that in this project there are no intentions of working with real data from the language center. This is considered to be part or the further work proposed.

6. Methodology

The research project intends to follow the metholology proposed on the book *Developing Computer Simulations for a Better Understanding of Social Processes* by *Tomas Salomon* [8]. In this book he proposes a guideline to build agent based models that take into a count the following faces:

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

Each face has a more detailed process that is going to be taken into a count during the development of the whole project.

In addition, Tako, A. A., & Robinson, S. (2010) [9] 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 the Figure below.

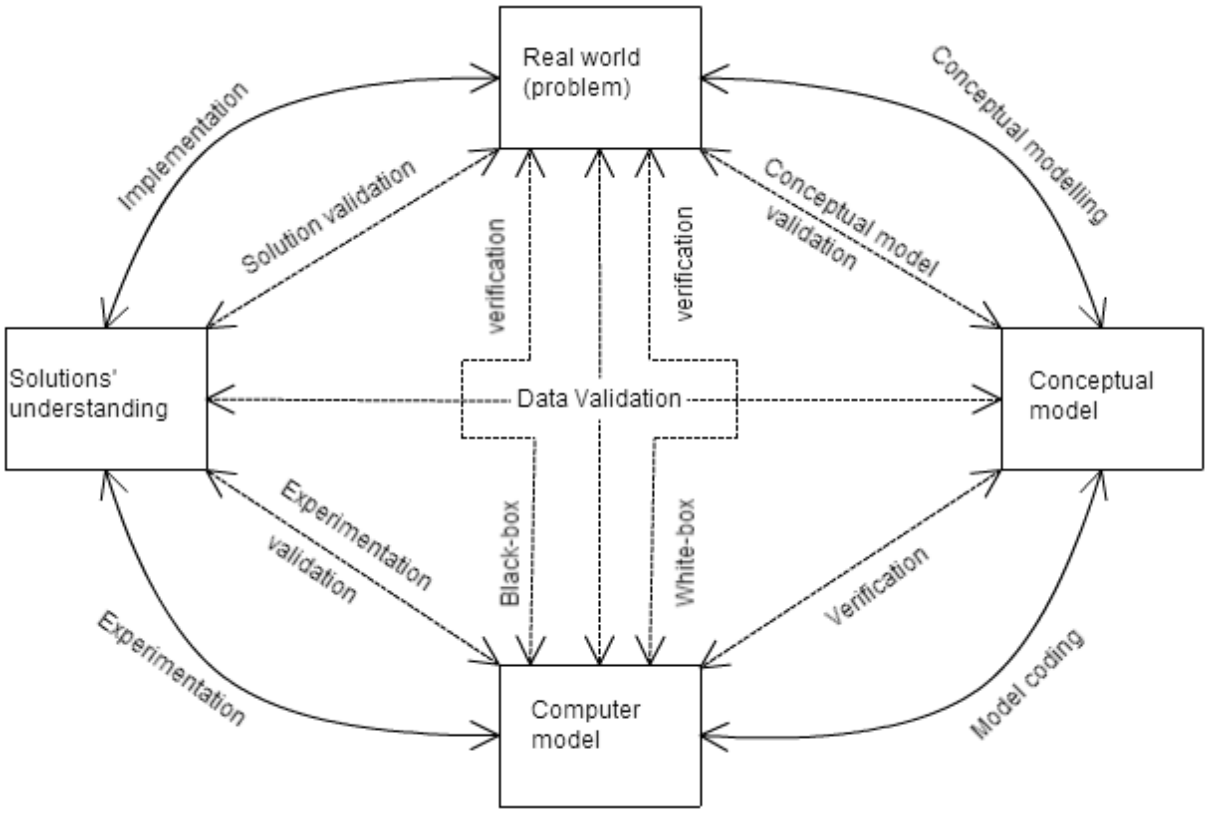

Figure1. Graphical summary adaptation of the model building faces proposed by [9].

During this project the attention will be focused on the right side of Figure 1, in which the conceptual model is extracted from the real word problem, it is validated and it is implemented as a computer model, afterwards, the computer model will be verified and validated. It is important to note that as Figure 1 shows, all the faces are cyclical and each one depends on the other ones to produce a quality model.

7. Schedule

Week	Activity
1	Literature review
2	Literature review
3	Pre-project due date
4	Presentation
5	Recollection, and data analysis / conceptual model construction
6	Recollection, and data analysis / conceptual model construction
7	Recollection, and data analysis / conceptual model validation
8	Model codification
9	Model codification
10	Oral progress report
11	Model development
12	Model development
13	Model development

14	Simulation model verification and validation
15	Simulation model verification and validation
16	Final project report preparation
17	Project report
18	Final project presentation preparation
19	Final presentation

Table 1. Activities schedule.

8. Budget

The services and articles required in this project are summed up in the next tables.

Service	Cost
Printing	50,000
Photocopies	50,000

Table 2. External services required and their costs.

All the money needed to cover the above mentioned expenses will be financed by the student.

9. Intellectual property

The intellectual property over this work will belong to Professor Paula A. Escudero M. who is acting as tutor, and the student Andrés F. Rojas A.

10. Bibliography

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