Vehicle price estimation using fuzzy systems

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***Resumen*—One of the most profitable and moving markets in the last decades is the automobile market, due to its constant production and the long useful life of a vehicle, so having a method to help in the estimation of prices makes this task easier. In this paper we will implement fuzzy logic for the creation of a price estimation model subject to three variables of interest: cylinder capacity, model and accessories.**

I. INTRODUCTION

Currently it is more feasible for anyone to have access to a vehicle, so the automobile market is becoming wider and with more variety, so that before it was considered a luxury product of the highest strata, now anyone can get a vehicle. Cars over time have become a problem for world economies, because the mass production of these generates an accumulation of vehicles in large cities, considering that the useful life of a vehicle is high most of the market is made up of a variety of used cars that have been gradually increasing with frequent replacements of cars in recent years [2].

In this paper we want to estimate the price of a vehicle depending on three variables of interest, which are the most important when purchasing a vehicle. It is desired to implement the fuzzy logic method based on intermediate degrees of fulfillment of a premise using three defuzzification methods to compare the results so that the most convenient way to describe the process of finding the best price of the vehicle can be chosen.

Boolean logic is known as the most precise of all sciences and theoretical disciplines. Most modern science and mathematics are based on its principles. Despite the advantages of its accuracy, Boolean logic has the disadvantage of not being able to reproduce the patterns of human thought. Thus, in the mid-sixties, Professor Lotfi Zadeth of the University of California at Berkeley, seeking to make up for this deficiency of traditional logic, created what is now known as fuzzy logic.

As a theoretical mathematical discipline, fuzzy logic is designed to react to continuous changes of the variable to be controlled and differs from Boolean logic in that it is not restricted to two single values of 0 and 1 . Instead it allows partial values and multivalues of truth. It can be stated, as demonstrated by Bart Kosko, that Boolean logic is a special case of fuzzy logic. This discipline is especially advantageous for problems that cannot be easily represented by mathematical models because the data are incomplete or because the process is too complex [3].

II. STATE OF THE ART

Fuzzy logic is a system that has been implemented for years for the creation of models more in line with reality and more associated with human thinking, so that the investigation of the price of a specific market such as cars has already been explored by different authors, due to the versatility of fuzzy systems a varied manipulation of different visions of the estimation of the price of a vehicle is evidenced. A clear example of this is manifested in the article by Hong Tau Lee & Sheu Hua Chen where a nonlinear programming model is proposed to identify the fuzzy parameters and their vagueness for the generalized regression model, this situation occurs because the input data are conceived as facts or events of an observation that are uncontrollable or not influenced by the observer, instead of the controllable levels of the factors in an experiment [1].

The quantity of used cars has been gradually increasing with frequent car replacements in recent years. The price of used cars is an important aspect of the trading market. Accurate and effective price forecasting has become more and more important as trading information for consumers when buying a used car. In other commodity markets such as the stock market, agriculture commodity markets and supermarkets, price forecasting has always been the focus of studies because of its importance (Baba & Kozaki, 1992; Snyder, Sweat, Richardson, & Pattie, 1992; Wang, 2002). Simply speaking, a used car is also a commodity, the price of which can be forecast in the same way. However, a used car has different characteristics from other commodities because it is a used commodity. The sale price will be affected by the rate of depreciation, mark of car, manufacturing year, engine style, etc. Therefore, a consumer finds it difficult to accurately obtain the purchasing price of a used car. An excessively simplistic price forecasting method using a forecast of the commodity price will unsurprisingly be inaccurate. In recent years, many intelligent forecasting techniques have been developed, such as fuzzy system (Al-Kandaria, Solimanb, & El-Hawaryc, 2004; Chen, Cheng, & Teoh, 2007; Chen & Wang, 1999; Lee & Chen, 2001; Pai, 2006), artificial neural network (Catalão, Mariano, Mendes, & Ferreira, 2007; Law, 2000; Malik & Nasereddin, 2006; Srinivasan, 1998; Yalcinoz & Eminoglu, 2005; Yao, Li, & Tan, 2000), and adaptive neuro-fuzzy inference system (Singh, Sinha, & Singh, 2007; Zaheeruddin & Garima, 2006). In the above-mentioned methods, the ANN and ANFIS proved to be simple and powerful tools for forecasting a practical system. For example, Gareta and others (Gareta, Romeo, & Gil, 2006) used an artificial neural network to forecast short-term hourly electricity pool prices [2].

In addition, fuzzy models have been implemented many times with issues related to the control of a vehicle, as expressed by Nurkan yagiz, Lemir sakman & Rahmi guclu with a control of a vehicle model that has five degrees of freedom with a passenger seat using a fuzzy logic controller is studied [4].

III. SYSTEM FUZZY

Fuzzy logic is a rigorous mathematical field, and it provides an effective vehicle for modeling the uncertainty in human reasoning. In fuzzy logic, the knowledge of experts is modeled by linguistic rules represented in the form of IF-THEN logic. Like neural network models [5].

The inputs and outputs established are subject to the modeler's perception and to the computational facility of each variable. The implementation of the model will be done in Python using the scikit-fuzzy library.

III-A. ***Inputs***

- *Cylinder size:* This variable expresses the power and torque produced by an motor, as well as the amount of fuel consumed by a vehicle $[500, 3600]$
- *Model:* This variable expresses the age of a vehicle, i.e. the year of production $[1990, 2022]$.
- *Accessories:* this variable measures the amount of accessories that the vehicle has, being 1 very basic and 10 very equipped, contemplating elements such as luxury wheels, entertainment system, starting system, leather upholstery, luxury finishes and security system $[1, 10]$.

III-B. ***Output***

- *Price:* monetary amount the vehicle costs in millions $[7'000{,}000, 200'000{,}000]$

III-C. ***Linguistic categories***

A fuzzy set is uniquely determined by its membership function (MF), and it is also associated with a linguistically meaningful term. Fuzzy logic provides a systematic tool to incorporate human experience. It is based on three core concepts, namely, fuzzy sets, linguistic variables, and possibility distributions. Fuzzy set is used to characterize linguistic variables whose values can be described qualitatively using a linguistic expression and quantitatively using an MF [5].

In the following graphics, we show the linguistic categories for the inputs and output, each one of these categories is described through a membership function. Also some linguistic categories have linguistic ambiguities such as: Highly, very, little, and others. These ambiguities can described uncertain grade (little bit or a whole lot) in the linguistic category.

$$\text{Cylinder size} = \begin{cases} LittlePowerful \\ Powerful \\ VeryPowerful \end{cases}$$

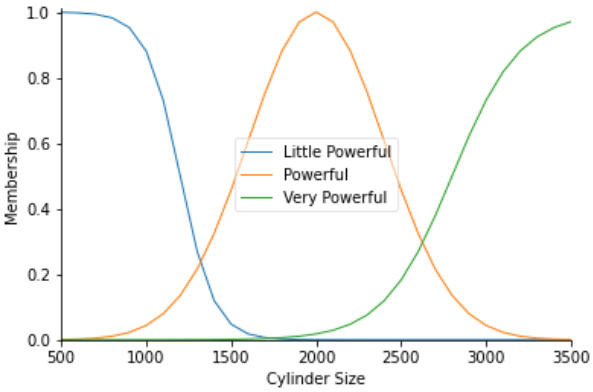

Figura 1. Membership function for the variable Cylinder size

$$\text{Model year} = \begin{cases} VeryOld \\ Old \\ Normal \\ New \end{cases}$$

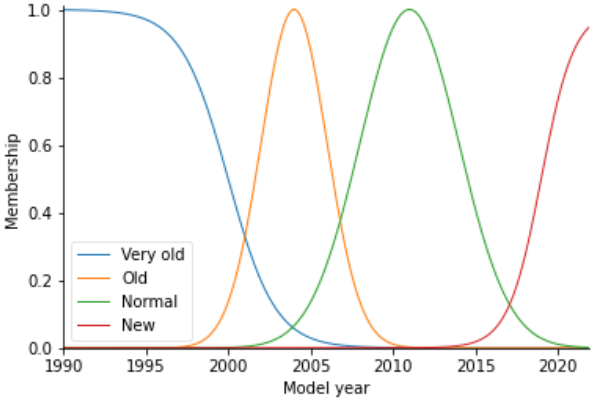

Figura 2. Membership function for the variable Model year

$$\text{Accessories} = \begin{cases} Entry \\ Standard \\ Top \end{cases}$$

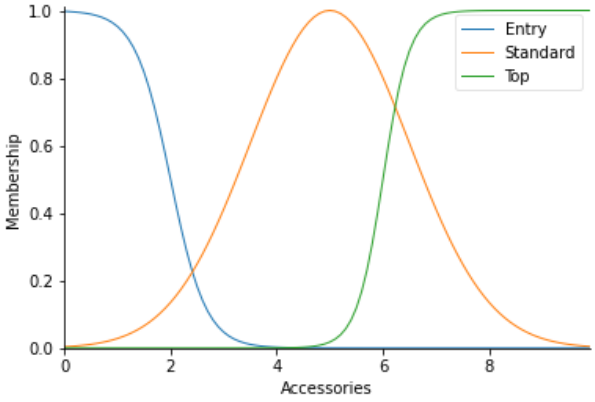

Figura 3. Membership function for the variable Accessories

$$\text{Price} = \begin{cases} Highlycheap \\ Cheap \\ Expensive \\ Highlyexpensive \end{cases}$$

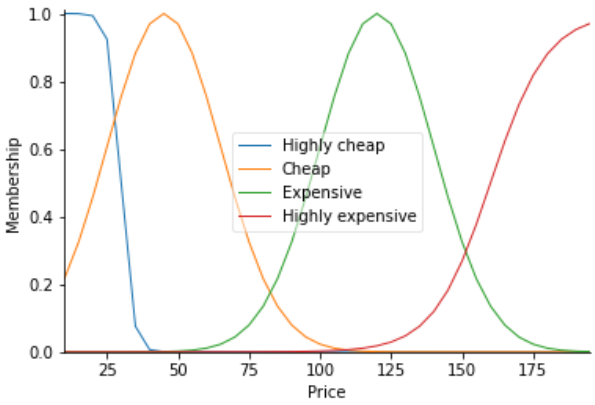

Figura 4. Membership function for the variable Price

IV. T-NORMS AND S-NORMS

The $min()$ function is a T-norm, which corresponds to the intersection operation on classical sets whose degrees of membership are in $\{0, 1\}$. Therefore, this function is the natural extension of the intersection in fuzzy sets. The function $max()$ is an S-norm, which corresponds to the union operation on classical sets whose degrees of whose degrees of membership are in $\{0, 1\}$. Therefore, this function is the natural extension of the union on fuzzy sets.

IV-A. T-norm

$$T_{\text{mín}}(a,b) = \text{mín}(a,b)$$
$$T_{bp}(a,b) = \text{máx}(0, a+b-1)$$

IV-B. S-norm

$$S_{\text{máx}}(a,b) = \text{máx}(a,b)$$
$$S_{as}(a,b) = a+b-ab \quad (1)$$

V. RULES

Fuzzy rules are If-Then statements that describe the action to be taken in response to various fuzzy inputs. The rules are confined to a predefined set of linguistic terms and their syntax is as follows:

IF Antecedente 1 AND Antecedente 2...Then Consecuente 1 AND Consecuente 2...

- Rule#1: If cylinder size is Little Powerful and model year is very old and accessories are Entry, then Price is Highly cheap.
- Rule#2: If cylinder size is Little Powerful and model year is Old and accessories is Entry, then Price is Highly cheap.
- Rule#3: If cylinder size is Powerful and model year is Old and accessories is Standard, then Price is Cheap.
- Rule#4: If cylinder size is Powerful and model year is Normal and accessories is Standard, then Price is Cheap.
- Rule#5: cylinder size is Powerful and model year is Old and accessories is Top, then Price is Expensive.
- Rule#6: cylinder size is Very Powerful and model year is Old and accessories is Top, then Price is Highly expensive.
- Rule#7: cylinder size is Very Powerful and model year is Normal and accessories is Top, then Price is Highly expensive.
- Rule#8: cylinder size is Very Powerful and model year is Very old and accessories is Top, then Price is Expensive.
- Rule#9: cylinder size is Little Powerful and model year is New and accessories is Entry, then Price is Cheap
- Rule#10: cylinder size is Little Powerful and model year is New and accessories is Standard, then Price is Cheap.
- Rule#11: cylinder size is Powerful and model year is New and accessories is Top, then Price is Highly expensive.
- Rule#12: cylinder size is Very Powerful and model year is New and accessories is Top, then Price is Highly expensive.
- Rule#13: cylinder size is Powerful and model year is Very Old and accessories is Entry, then Price is Cheap
- Rule#14: cylinder size is Very Powerful and model year is New and accessories is Standard,then Price is Expensive.
- Rule$15: cylinder size is Little Powerful and model year is Normal and accessories is Standard, Price is Cheap

VI. MODEL

Defuzzification is to map fuzzy subsets of real numbers into real numbers. In an FIS, defuzzification is applied after aggregation. Popular defuzzification methods include the centroid defuzzifier, and the mean-of-maxima defuzzifier. The centroid defuzzifier is the bestknown method, which is to find the centroid of the area surrounded by the MF and the horizontal axis. Aggregation and defuzzification can be combined into a single phase, such as the weighted-mean method [4].
A comparison will be made between the most important methods with respect to a real example of the price of a vehicle subject to fixed parameters.

VI-A. Case 1

	Parameters	**Values**
INPUTS	*Cylinder Size*	2000
	Model year	2010
	Accessories	3
OUTPUT	*Price*	40'000.000

Cuadro I
REAL DATA ON THE PRICE OF A VEHICLE

Table 1 shows the real case of a mid-range vehicle in which the displacement is 2000, the 2010 model and has a rating of 3 with respect to the assessors, so that according to the decision rules the car would more or less correspond to be classified as inexpensive.

Defuzzification method		
Method	*Values*	*Error*
Centroid	48032965	6.7 %
Mom	48032965	6.7 %
Bisector	47655432	5.9 %

Cuadro II
DATA OBTAINED BY DIFFERENT METHODS

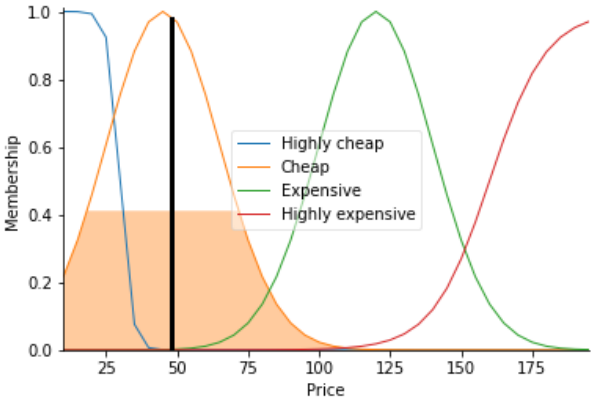

Figura 5. Membership function for the variable Model year

VI-B. Case 2

	Parameters	Values
	Cylinder Size	3600
INPUTS	*Model year*	1999
	Accessories	10
OUTPUT	*Price*	160'000.000

Cuadro III
REAL DATA ON THE PRICE OF A VEHICLE

Table 3 shows the case of a mercedez benz G class 3600 displacement, 1999 model and full in accessories, categorizing this vehicle as very powerful, very old and Top.

Defuzzification method		
Method	*Values*	*Error*
Centroid	130908652	18 %
Mom	121103549	24.7 %
Bisector	128962554	19 %

Cuadro IV
DATA OBTAINED BY DIFFERENT METHODS

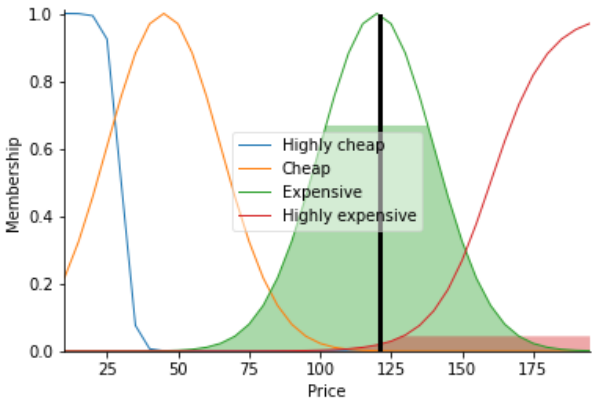

Figura 6. Membership function for the variable Model year

VII. CONCLUSION

Given the characteristics of fuzzy logic, it can be concluded that the lexical uncertainty or inaccuracies very characteristic of human language generate uncertainties and inaccuracies in the generated model, so it is observed that the estimates of the price of a vehicle made with this method of fuzzy logic, can be improved with the implementation of more decision rules that cover more of the linguistic universe helping to reduce the estimation error.
The greatness of this estimation method, which does not require data for the construction of a very good model, stands out. It gives a clear example that experience and knowledge of the environment provide the necessary information to generate a very good model. It is evident that this technique has a great area of research and development given its versatility and good results at the time of implementation.

REFERENCIAS

[1] S. H. C. Hong Tau Lee. Fuzzy regression model with fuzzy input and output data for manpower forecastingand. 2001.
[2] H.-C. C. Jian-Da Wu, Chuang-Chin Hsu. An expert system of price forecasting for used cars using adaptive neuro-fuzzy inference. 2008.
[3] G. T. Muñoz. Tutorial on fuzzy logic. 2000.
[4] L. s. . R. g. Nurkan yagiz. Different control applications on a vehicle using fuzzy logic control. 2008.
[5] J. L. . K. L. D. Yue Wu, Biaobiao Zhang. Fuzzy logic and neuro-fuzzy systems: A systematic introduction. 2014.