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Price estimation based on business model pricing strategy and fuzzy logic

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Abstract

Pricing, as one of the most important aspects of a business, should be taken seriously. Whatever affects a company's pricing system tends to affect its profits and losses as well. Currently, many manufacturing companies fix product prices manually by members of an organization's management team. However, due to the imperfect nature of humans, an extremely low or high price may be fixed, which is detrimental to the company in either case. This paper proposes the development of a fuzzy-based price expert system (Expert Fuzzy Price (EFP)) for manufacturing companies. This system will be able to recommend appropriate prices for products in manufacturing companies based on four major pricing strategic goals, namely: Product Demand, Price Skimming, Competition Price, and Target population.

Keywords: price estimation | pricing strategy | fuzzy logic | fuzzy inference system | expert system

Ⅰ. INTRODUCTION

Setting a price for a good or service can be difficult given the number of factors that go into determining pricing. Furthermore, precise pricing may be based on values that are difficult to ascertain without extensive investigation. As a result, many businesses attempt to price a good or service incorrectly, resulting in costly errors. Price is heavily influenced by the market a company enters or the consumer segment it targets. Prior to establishing pricing, it is critical to have solidly supported and reliable knowledge of a targeted customer segment [1]. Choosing an appropriate price for a new product or service may be one of the most difficult challenges for small business owners. Costing a good or service is simple, but price is heavily influenced by the market. Pricing for a product or service must be sufficient to cover all costs and generate a profit, but it must also consider what other companies charge and what customers are willing to pay. As a result, it is critical to comprehend the impact of pricing on profitability and to be able to select the best pricing strategy for a business.

Fuzzy logic has become an important component of marketing science due to the development and benefits of using membership functions rather than clear values [2]. Marketers can use fuzzy logic as a powerful tool when developing their marketing models. The introduction of "if-then" rules, rather than precise values, has resulted in the introduction of a new method for marketers to conduct marketing analysis.

Hence because of the complexity involved in determining the price of any given product or service, this paper considers four major business model pricing strategies namely: Product Demand, Price Skimming, Competition Price, and Target population, as key to effectively estimate price. Furthermore, it combines the already proven functionality of fuzzy inference systems furnished with an adequate knowledge base in form of “If-Then” rules to produce true predictions of supposed price.

This paper has seven sections. In section I the topic and idea of the paper is introduced. Section II is the related work and literature review. Then the business model pricing strategies is described in Section III while Section IV presents the Expert Fuzzy Price system. Section V has the experiments and results, and section VI discusses the conclusion.

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II. RELATED WORK

Related works are reviewed in this paper to stay current on the current state of thought regarding product price fixing by manufacturing companies. The review is useful because it allows or assists researchers in situating or connecting their study to previous research in the field. Some of these works are discussed below.

The pricing problem of a transportation service provider company is considered in the study of [3]. The goal was to use probabilistic dynamic programming to find optimal prices. To identify demand levels under different prices and other journey characteristics, a fuzzy IF-THEN-rule-based system is used. The results of optimal pricing policies show that using dynamic pricing instead of fixed pricing increases revenue. Thus, diversifying pricing policies under different conditions is advantageous to the company.

They developed a Fuzzy Inference System format (FIS) based on a hybrid algorithm in [4]. This FIS recommends appropriate manufacturing decisions to the user based on competitive priority and project properties. In project-based organizations, the rules and relationships governing the parameters contributing operational strategy are acquired through a guided integrated process and in the form of an expert system.

(i) Expert System: An expert system is a computer-based system that has been enhanced with a knowledge-based component to provide 'intelligent' advice or decision. This is accomplished using a rule-based inference scheme. Expert systems have proven useful in a wide range of real-world applications, including engineering, medicine, space exploration, and management [7].
Fuzzy expert systems are an extension of traditional expert systems in that they can represent and deal with uncertainty using fuzzy rules and fuzzy information processing. Figure 1 depicts the architecture of our proposed expert fuzzy system (FES).

(ii) Fuzzy Logic (FL): Fuzzy logic is a variable processing approach that allows multiple truth values to be processed by the same variable. Fuzzy logic attempts to solve problems by using an open, imprecise spectrum of data and heuristics to generate a range of accurate conclusions. Fuzzy logic is intended to solve problems by considering all available information and making the best decision possible given the input. MATLAB 7.6.0 fuzzy logic toolbox was used to build the fuzzy inference system for this study.

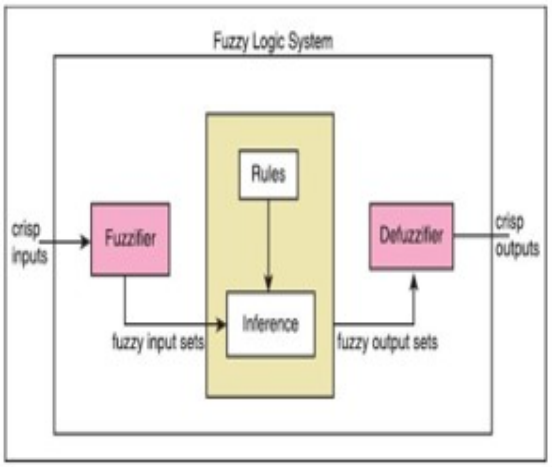

Figure 1. System Architecture.

FL uses a simple, rule-based IF X AND Y THEN Z approach to solve control problems rather than attempting to mathematically model a system. The FL model is empirical in nature, relying on an operator's experience rather than technical knowledge of the system.[8]

The set is a fundamental concept in mathematics. On a universe of discourse X, the definition of a crisp set A is based on the premise that an element of X either fully belongs to A or not. By allowing partial membership of an element to a set, fuzzy sets emerge [9].

Given two fuzzy sets, A and B, of the universe of discourse X having membership functions μA(x) and μB(x) respectively, the following operations may be defined:

$$\begin{aligned} &\text{Complement A}: \mu A(x) = 1 - \mu A(x) \\ &\text{Union A}\cup\text{B}: \mu A \cup B(x) = \max\{\mu A(x), \mu B(x)\} \\ &\text{Intersection A}\cap\text{B}: \mu A \cap B(x) = \min\{\mu A(x), \mu B(x)\}. \end{aligned} \quad (1)$$

Just as a Membership function describes the degree to which a variable belongs to a set, a Linguistic variable is one that can take words in natural language as its values. The membership functions can have different shapes like triangle, trapezoidal, Gaussian, etc.

(iii) Fuzzy Inference System (FIS): In general, fuzzy inference is the process of using fuzzy logic to create a mapping from a given input to an output. It's a method that interprets the values in the input vector and, based on some sets of rules, assigns values to the output vector. Figure 1 shows the basic architecture of FIS.

• The rule or knowledge base, containing fuzzy production causal rules of the form "IF A THEN B", A and B being fuzzy sets defined on the input and output domains respectively, as well as the definitions (membership functions) of the possible values of A and B.

• The inference engine, responsible for evaluating the fuzzy rules of the knowledge base.

• The interfacing module, responsible for obtaining inputs from and providing outputs to the user.

• The fuzzification and defuzzification modules (fuzzifier and de-fuzzifier), which convert a crisp input to a fuzzy set and a fuzzy set to a crisp output respectively [10].

III. BUSINESS MODEL PRICING STRATEGIES

A pricing strategy is the approach your company takes when pricing its products or services. Your pricing strategy should aim to maximize sales and profits, outperform competitors, and provide the best service to your customers [5]. A pricing strategy is something that far too many companies implement without giving it any serious consideration. This lack of consideration is a mistake and can cause them to lose money. [6] In this paper, we consider four (4) major pricing strategies which will serve as the input parameters for our system, namely ;

(i) Competitive Pricing (CP): This is the practice of setting your product or service prices based on the pricing of your competitors in your market or niche rather than on your company's costs or desired profit margins.

(ii)Price Skimming (PS): It's a dynamic pricing strategy businesses use to increase sales of new goods and services. Price skimming is a strategy usually employed at a new product's debut. This strategy aims to maximize income to the greatest extent possible when customer interest in the product is strong, and your company faces low competition.

(iii) Product Demand (PD): High prices lead to lower demand for goods and services, while low prices lead to increased demand. In this case, the budget management sets a price that ensures adequate demand for their goods and services while also generating an adequate return.

(iv) Target Population (TP): This refers to the social customer base segment that a product or service is made for, when making price decisions. As social class plays a role in customer distribution, one must decide when pricing whether the product is aimed at a high, middle, or low social class strata due to income differences.

IV. EXPERT FUZZY PRICE (EFP) SYSTEM

The flow chart in Figure 2 illustrates the flow of data in the proposed system. The proposed Expert Fuzzy Price (EFP) system is essentially a price estimation system that combines four major business model pricing strategies to a fuzzy inference system to produce a mark off which is an estimation of the cost-plus price of a given item.

(i) System Inputs: The system will take as input four (4) numeric values to represent the four input factors used in this system namely: Product Demand (PD), Price Skimming (PS), Competition Price (CP), and Target Population (TP). The input values will be ranged from 1 to 10 each for the different input factors.

(ii) System Output: The output of the system is a Cost-plus-pricing percentage (CPP), or the systems recommended percentage to be added to the product's original cost to obtain a final product price for the said product.

(iii)Assigning membership functions: Membership function is a function that maps to which degree an object is a member of a set.

Table 1. System Inputs and Output

INPUT	ALIAS	LINGUISTIC VARIABLE	MEMBERSHIP FUNCTION
Product Demand	PD	High, Average, Low	Triangular
Price Skimming	PS	MaxRevenue, PricingPressure	Gaussian
Competition Price	CP	Higher, Lower	Trapezoidal
Target Population	TP	HighClass, AverageClass, BelowAverageClass	Triangular
OUTPUT	ALIAS	LINGUISTIC VARIABLE	MEMBERSHIP FUNCTION
Cost Plus Pricing Percentage	CPP	VeryHigh, High, Average, Low, VeryLow	Triangular

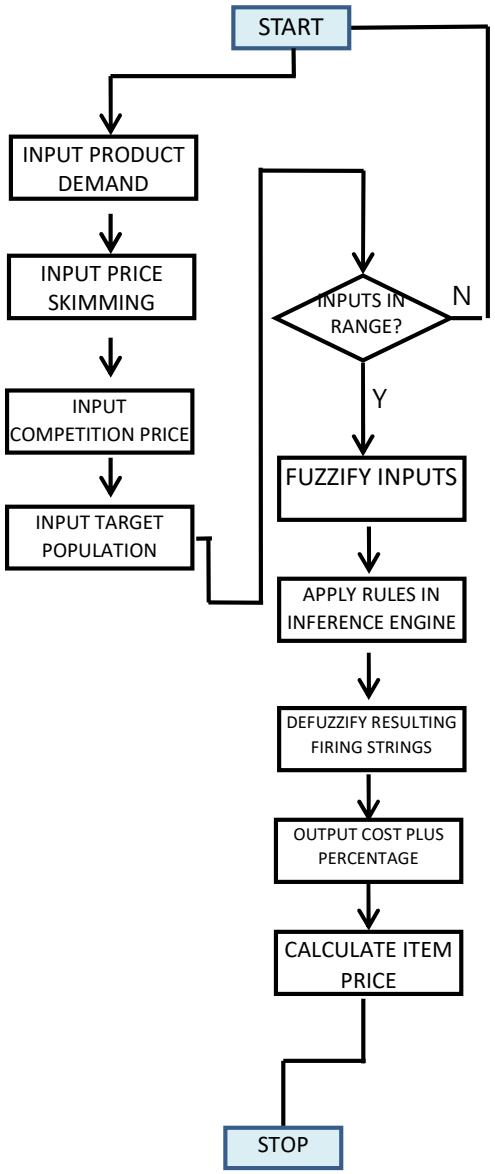

Figure 2 System Flowchart.

The Intuition method, which relies on the innate intelligence of human domain experts as well as to commonsense understanding of the problem at hand is used for assigning membership functions.

Table 1 shows the systems inputs, output, linguistic variables, and membership functions used in this system. The membership functions of the input variables are defined using an expert opinion. The product demand has been fuzzified into linguistic variables of high, average, and low, while price skimming has been fuzzified into max revenue which represents the rapid sale phase of a product even at a high prize especially at the product's debut. Pricing pressure on the other represents the price drop phase of a product especially when there is competition. Linguistic variables of higher and lower are used to describe competition price, while high, average, and below average class transcribes the target population.

(iv)Fuzzy rule or knowledge base: This provides one or more knowledge representation schemes for expressing knowledge about the application domain.

Our system uses the Mamdani-type rule base, which is of the form:

$$\text{IF } x1 \text{ IS } F1 \text{ AND } \ldots \text{ AND } xn \text{ IS } Fn \text{ THEN } y \text{ IS } G$$

where Fi and G are fuzzy sets, while xi and y are linguistic variables. Mamdani fuzzy inference is a method to create a control system by synthesizing a set of linguistic control rules obtained from experienced human operators. In a Mamdani system, the output of each rule is a fuzzy set. Since Mamdani systems have more intuitive and easier to understand rule bases, they are well-suited to expert system applications where the rules are created from human expert knowledge as in the case of our system. The full Mamdani-type rule base of our system is attached to the appendix section of the paper.

(v)Defuzzification: The method of defuzzification

Table 2. Automobile products and Sale Information.

CAR NAME	PRODUCTION YEAR	COST OF PRODUCTION	MARKET PRICE	COMPETITION CAR NAME	COMPETITION PRICE
Toyota Corolla	2017	$12500	$15000	Hyuandai Avante 2017	$17000
Porsche 911 GT3	2022	$133000	$150000	Mc Laran GT 2022	$215000
Ford F-150 Lightning	2022	$27000	$40000	Nissan Titan King Cab 2022	$40605
Tesla Model 3	2021	$28000	$37000	Hyundai Ioniq Electric 2021	$34000
Ferrari F8 Spider	2020	$220000	$300000	Lamborghini Huracan 2020	$214,866
Kia Morning	2013	$12800	$14000	Chevrolet Spark 2013	$15000

involves taking a single number from the output of the combined fuzzy set. It is used to convert the findings of fuzzy inference into a clear output. In other words, a decision-making algorithm that chooses the optimal crisp value that adequately represents a given fuzzy set. There are different defuzzification methods available but for our system, we used the centroid method. Centroid defuzzification returns the center of gravity of the fuzzy set along the x-axis. If you think of the area as a plate with uniform thickness and density, the centroid is the point along the x-axis about which the fuzzy set would balance. The centroid is computed using the following formula, where μ(xi) is the membership value for point xi in the universe of discourse.

$$\textbf{xCentroid} = \frac{\sum_i \mu(x_i)x_i}{\sum_i \mu(x_i)} \qquad (2)$$

Figure 3 describes the basic structure of the proposed system in the MATLAB toolbox based on the points explained above.

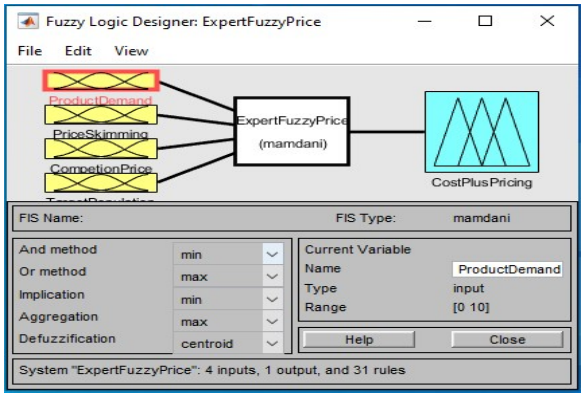

Figure 3. EFP Inference System.

V. EXPERIMENTS AND RESULTS

To illustrate the functioning of the system, we used the automobile price billing system to test the proposed system. To run the system, the following assumptions were made:

(i) Car's production year from 2022 – 2017, whose market value is from $70,000 above are of relatively high demand (PD), high class (TP) and are on the maximum revenue generation phase of the price skimming curve.

(ii) Car's production year from 2017 – 2012 whose market value is from $69,000 - $15,000 are of relatively average demand (PD), average class (TP) and are on the pricing pressure phase of the price skimming curve.

(iii) Car's production year from 2012 – below and whose market value is from $15,000 below are of relatively low demand (PD), below average class (TP) and are on the pricing pressure phase of the price skimming curve(PS). The system will take its inputs based on:

i. Product Demand: car production year.
ii. Price Skimming: car production year and price of competition.
iii. Competition Price: price of competition.
iv. Target Population: price of car and car production year. EFP price = Cost Plus Price (CPP).
v. CPP = markup % + cost of production.

Table 2 shows the data source for our system testing, which were sourced from the following websites : https://www.llctlc.com,https://www.caranddriver.com, https://www.kbb.com

Table 3. Experiment Results

CAR NAME	PRODUCT DEMAND	PRICE SKIMMING	COMPETITION PRICING	TARGET POPULATION	COST OF PRODUCT	CPP %	EFP PRICE	MARKET PRICE
Toyota Corolla 2017	7	5	6	5	$12500	17.3	$14663	$15000
Porsche 911 GT3 2022	8	8	8	9	$133000	27.3	$169309	$150000
Ford F-150 Lightning 2022	8	8	5	6	$27000	22.4	$33048	$40000
Tesla Model 3 2021	8	7	4	6	$28000	22.3	$34244	$37000
Ferrari F8 Spider 2020	8	7	4	9	$220000	26.8	$278960	$300000
Kia Morning 2013	5	4	5	4	$12800	11.9	$14323	$14000

Table 4 MAPE Results

CAR NAME	COST OF PRODUCT	CPP %	EFP PRICE	MARKET PRICE	DIFFERENCE	ABSOLUTE VALUE	ABSOLUTE PERCENTAGE ERROR
Toyota Corolla 2017	$12500	17.3	$14663	$15000	-337	337	2.247
Porsche 911 GT3 2022	$133000	27.3	$169309	$150000	19309	1930	12.873
Ford F-150 Lightning 2022	$27000	22.4	$33048	$40000	-6952	6952	17.380
Tesla Model 3 2021	$28000	22.3	$34244	$37000	-2756	2756	7.449
Ferrari F8 Spider 2020	$220000	26.8	$278960	$300000	-21040	21040	7.013
Kia Morning 2013	$12800	11.9	$14323	$14000	323	323	2.307
Mean Absolute Percentage Error (MAPE)= 8.211							

The result of our experiments is illustrated in table 3. This tables contains the resultant figure of car prices as compared to already existing ones. Clear indications from the table indicates that the car prices suggested by the Expert Fuzzy Price(EFP) system is relatively closer or approximate to prior existing prices. To perform system validation / evaluation we used the Mean Absolute Percentage Error (MAPE) method. MAPE is a measure of prediction accuracy of a forecasting method in statistics. Using Microsoft Excel spreadsheet, the result of the evaluation process in shown in table 4. From the table, MAPE=8.211%, this implies that, on average, the forecast's distance from the true value is 8% of the true value.

VI. CONCLUSION

Pricing products and services is a challenging marketing task that significantly affects overall organizational effectiveness, growth, and financial outcomes. Hence, it is essential to analyze all significant price factors. The proposed system uses four major factors, also known as pricing strategies, to influence the price determination process with the aid of fuzzy logic as the key underlying mechanism. The systems takes as input these four factors in the form crisp values and produces as output a mark off percentage price for the said item whose price value is to be recommended. Also, from the system evaluation, the MAPE value derived is 8.211%, meaning that the forecast's average deviation from the true value is 8% (for instance, if the true value is 100%, the forecast is in the range of 92 to 100, or the forecast is in the range of 100 to 108, giving a maximum variation distance of 8%). However, further improvements in the system can still lead to better accuracy of the recommended price points with a better impact on the customer experience.

APPENDIX A

The rules of the proposed fuzzy if-then-rule based system:

1. IF PD is high AND PS is max Revenue AND CP is higher AND TP is highClass THEN CPP is high
2. IF PD is average AND PS is maxRevenue AND CP is higher AND TP is highClass THEN CPP is high
3. IF PD is Low AND PS is max Revenue AND CP is higher AND TP is high class THEN CPP is Low
4. IF PD is high AND PS is pricing Pressure AND CP is higher AND TP is highClass THEN CPP is high
5. IF PD is average AND PS is pricing Pressure AND CP is higher AND TP is highClass THEN CPP is Low
6. IF PD is low is AND PS is pricing Pressure AND CP is higher AND TP is highClass THEN CPP is very low
7. IF PD is high AND PS is max Revenue AND CP is lower AND TP is highClass THEN CPP is very high
8. IF PD is average AND PS is maxRevenue AND CP is lower AND TP is highClass THEN CPP is high
9. IF PD is low AND PS is maxRevenue AND CP is lower AND TP is highClass THEN CPP is high
10. IF PD is high AND PS is pricingPressure AND CP is lower AND TP is highClass THEN CPP is high
11. IF PD is average AND PS is pricingPressure AND CP is lower AND TP is highClass THEN CPP is average
12. IF PD is low AND PS is pricingPressure AND CP is lower AND TP is highClass THEN CPP is average
13. IF PD is high AND PS is maxRevenue AND CP is higher AND TP is averageClass THEN CPP is high
14. IF PD is average AND PS is maxRevenue AND CP is higher AND TP is averageClass THEN CPP is high
15. IF PD is low AND PS is maxRevenue AND CP is higher AND TP is averageClass THEN CPP is low
16. IF PD is high AND PS is pricingPressure AND CP higher AND TP is averageClass THEN CPP is high
17. IF PD is average AND PS is pricingPressure AND CP is higher AND TP is averageClass THEN CPP is low
18. IF PD is low AND PS is pricingPressure AND CP is higher AND TP is average Class THEN CPP is low
19. IF PD is high AND PS is maxRevenue AND CP is lower AND TP is averageClass THEN CPP is high
20. IF PD is average AND PS is max Revenue AND CP is lower AND TP is averageClass THEN CPP is average
21. IF PD is low AND PS is maxRevenue AND CP is lower AND TP is averageClass THEN CPP is low –
22. IF PD is high AND PS is pricingPressure AND CP is lower AND CPP is averageClass THEN CPP is average
23. IF PD is average AND PS is pricingPressure AND CP is lower AND TP is averageClass THEN CPP is low
24. IF PD is low AND PS is pricingPressure AND CP is lower AND TP is averageClass THEN CPP is veryLow
25. IF PD is high AND PS is maxRevenue AND CP is lower AND TP is belowAverage THEN CPP is average
26. IF PD is average AND PS is maxRevenue AND CP is lower AND TP is belowAverage THEN CPP is low
27. IF PD is low AND PS is maxRevenue AND CP is lower AND TP is belowAverage THEN CPP is low
28. IF PD is average AND PS is pricingPressure AND CP is lower AND TP is belowAverage THEN CPP is very low
29. IF PD is average AND PS is pricingPressure AND CP is higher AND TP is belowAverage THEN CPP is low
30. IF PD is low AND PS is pricingPressure AND CP is higher AND TP is belowAverage THEN CPP is low
31. IF PD is low AND PS is pricingPressure AND CP is lower AND TP is belowAverage THEN CPP is very low.

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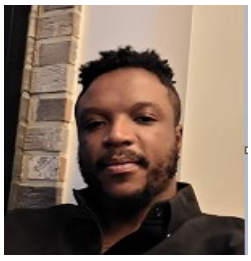

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