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Using fuzzy logic in business

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Abstract

Nowadays, the trader is forced to navigate a plethora of information about the products it has to offer. For the customer, some characteristics of a product are more important than others. The salesperson must consider this information. Therefore, sales-people often use computers in order to serve customers quickly. Conventional programming languages are based on Boolean logic. They are well suited to develop systems whose behaviour can be well represented by mathematical models. However, in terms of developing systems that mimic human-like decision-making, mathematical models fall short. Human judgment and evaluation neither follows Boolean logic, nor any other conventional mathematical discipline.

This paper seeks to show the benefits of using fuzzy logic in trading. It shows a simple and very fast system that demonstrates how to select a suitable lawn mower, according to customer requirements and preferences. The proposed system can then be used on any offered range. The benefits of such a system are then confronted with the opinions of sales-people themselves.

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Keywords: Fuzzy logic; evaluation; customer service; many-valued logics; multi-criteria decision making

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1. Introduction

In business, the customer and the satisfaction of his needs and wishes should be the most important consideration. If the dealer has only few products in stock, the situation is simple. He probably has a perfect overview of all the products and can easily advise the customer. However, we live in an age of supermarkets and hypermarkets, where individual retailers offer hundreds, if not thousand, of products. It is therefore not possible for the salesperson to remember all the products up for sale, or their parameters. He alone cannot quickly and

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comprehensively advise and serve the customer. It is therefore the computer's task to remember all the details; yet the computer works according to classical two-way logic, evaluating only "true" or "false".

Thus, it is necessary to have a clear definition of the customer. For example, the request "nice price mowers, with an average range" should be translated into well-defined selection criteria. These could be: lawn mowers costing from 2800 to 3800 CZK, with ranges from 300 to 700 square meters. Unfortunately, these criteria are not acceptable in some cases: a mower costing 2590 CZK with a range of 500 square meters would be appreciated by the customers, but does not meet the criteria for selection. Another mower costing 2990 CZK with a range of 300 square meters would meet the selection criterion, even if the mower meets less requirements than the first one.

This problem concerning selection criteria can be solved by the introduction of fuzzy logic. With its introduction, a machine can (like a human) make decisions and control systems on the basis of inaccurate information. The introduction of fuzzy logic eliminates problems with sharp boundary variables and leads to a more natural "perception" of the world.

This paper shows the selection of a suitable mower on the basis of fuzzy logic – that is, how to use fuzzy logic to serve customers more quickly and efficiently. The procedure is demonstrated using a set of 12 mowers. The salespersons selected the appropriate membership function; the customers placed their demands in the form of parameters. There are many different forms of fuzzy inference (Fullér, 1996). We will use two. Despite initial ignorance of fuzzy logic, such a system would be welcomed by the sales-people themselves.

2. Fuzzy logic

The idea of fuzzy logic first appeared in 1965 (Zadeh, 1965), where the basic concept of fuzzy logic – the fuzzy set – was defined. Nowadays it is the subject of many technical works – for example, (Bojadziev & Bojadziev, 2007) or (Klir, 1995), in conjunction with trade (Cox, 1995) and (von Altrock, 1997) – which describe the theory of fuzzy sets and fuzzy logic. The motivation for implementing fuzzy logic was the need to establish the possibility of capturing partial membership in a set. Until then, an element either belonged in a set or not, i.e. either true or false was valid (see Fig. 1.). However, in real life, nothing is just black or white. There are many shades of gray in between (see Fig. 1.).

a.) b.)

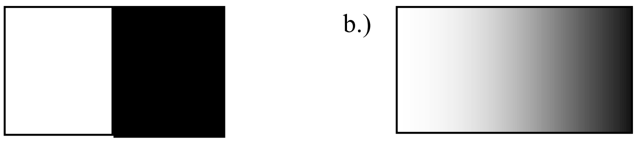

Fig. 1. (a) black or white ; (b) shades of gray

Fuzzy logic is a sub discipline of mathematical logic in which logical statements are valued with a degree of truthfulness. It differs from the typical propositional logic that uses only two logical values – truth and falsehood, usually written as 1 and 0. Fuzzy logic can operate with all values within the interval <0, 1>, which are infinite. Values are assigned using membership functions. The simplest ones are shown below (Chen & Pham, 2001) or (Jura, 2003):

$$L(x,a,b)=\begin{cases} 1 & x<a \\ \dfrac{b-x}{b-a} & a\le x\le b \\ 0 & x>b \end{cases} \qquad \Gamma(x,a,b)=\begin{cases} 0 & x<a \\ \dfrac{x-a}{b-a} & a\le x\le b \\ 1 & x>b \end{cases} \qquad (1)\quad (2)$$

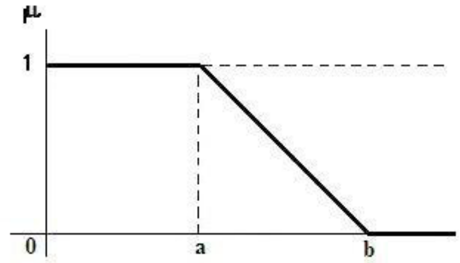

Fig. 2. – L-membership function

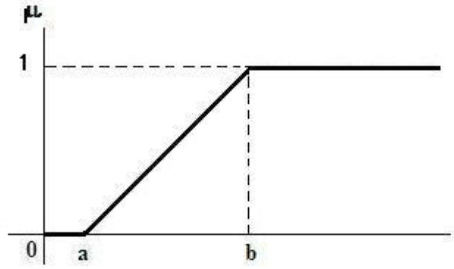

Fig. 3. – Γ- membership function

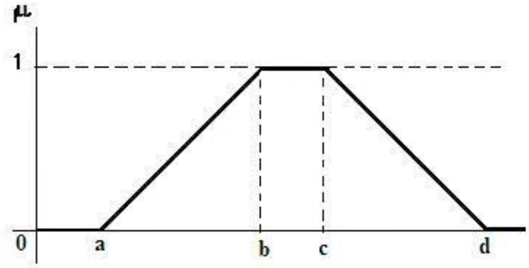

Fig. 4. – Π -membership function

$$\Pi(x,a,b,c,d)=\begin{cases} 0 & x<a \\ \dfrac{x-a}{b-a} & a\le x<b \\ 1 & b\le x\le c \\ \dfrac{d-x}{d-c} & c<x\le d \\ 0 & x>d \end{cases} \quad (3)$$

Fuzzy logic is one of the many-valued forms of logic, and can be more suitable for a variety of real decision-making tasks than classical logic, because it makes the design of complex control systems easier. The entire system then operates according to the following 3 steps:

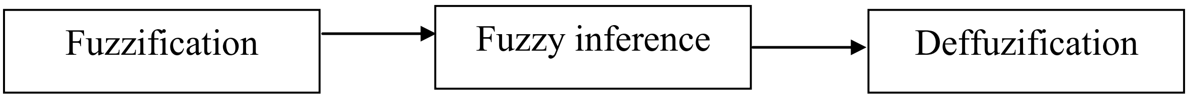

Fig. 5. – Solving a problem using fuzzy logic

The particular steps of problem-solving using fuzzy logic (Fuzzification – the transformation of fair input values; Fuzzy inference – the definition of system behavior using rules; Defuzzification – the obtaining of resulting values) are explained in detail in the cited literature. (For example (Dostál, 2008)).

3. Formulation of the problem

Examples of the use of fuzzy logic in supporting decision-making processes are described by many authors (Bezděk, 2011). The purpose of this article is to show how it is possible to choose the most suitable product on the basis of customer requirements and customer preferences with respect to individual parameters. The result will be a simple and fast system using fuzzy logic, which operates in three steps (see Fig. 5.). The same system can then be used for any product offered by a dealer.

For demonstration purposes, electric lawn mowers with the following properties were selected from the (Zahradní trendy 2012):

Table 1 Input data – lawn mowers

Lawn mowers number	Producer	Model	Cutting width (cm)	Performance (Watt)	Collection bag (l)	Mowing area (m^2)	Price (CZK)
1	Einhell	BG – EM 1030	30	1000	28	250	1290
2	Einhell	BG-EM 1743 HW	43	1700	52	700	2990
3	Einhell	BG-EM 1536 HW	36	1500	40	600	2990
4	Einhell	RG-EM 1843 HW	43	1800	63	800	4290
5	AL-KO	3.2 E	32	1000	30	250	1890
6	Black&Decker	EMAX32	32	1200	35	200	2390
7	AL-KO	3.8 E	38	1300	43	500	2590
8	AL-KO	Comfort 40 E	40	1400	43	600	3390
9	Gardena	PowerMax 32 E	32	1200	29	300	2990
10	Black&Decker	Emmax 38l	38	1600	45	500	3990
11	Gardena	PowerMax 36 E	36	1500	40	500	4990
12	Bosch	Rostak 40	40	1700	50	750	6199

Of course, there are far more machines in the Baumax database than this list includes. However, the listed ones appeared in the Summer 2012 catalog, and thus, we consider these for illustration.

Furthermore, in order to simplify the issue, we assume that the customer does not come with a clear idea of the manufacturer or model of lawn mower that he prefers. However, these kinds of conditions may be included in the evaluation system. For the selection of a suitable lawn mower, we just consider the numerical characteristics shown in Table 1.

Input data (Table 1 Input data - lawn mowers) are converted to values between 0 and 1 (see Section 5.1: Fuzzification). The resulting value is then calculated for each mower (see Section 5.2: Fuzzy Inference). Finally, all values are sorted in descending order (see Section 5.3: Defuzzification).

4. Examined data

Customer requirements are miscellaneous. They should tell us how important the individual items of the products are for them. Thus, they should assess them with the so-called preference points which express the importance. These points must proportionally reflect the buyer’s concept of the kind of product he is looking for. That is, if "price" is assigned 20 points and "performance" 10, it must mean that the price of the product is, for the buyer, twice as important as its performance.

Customers answer the following questions:

- How much are they willing to pay for the mower?
- What is the minimum mowing area required?
- What is the minimum collection bag capacity required?
- What is the minimum cutting width required?
- What power output should your mower have?

We consider three customers with the following requirements:

Customer A – has a clear understanding of all the characteristics of the offered mowers, but considers them all to be on the same level. This means that no characteristic is preferred. Thus, the preference points must have the same value.

Customer B – the mower must meet only two requirements: those concerning price and mowing area. Price is three times more important for him. Other characteristics are not important at all, and so the assessment will not take them into account. The numerical scores for these items will be filled with arbitrary values. The preference point values will be taken as zero.

Customer C – has a clear idea about the value of the individual characteristics of the offered mowers. In addition, he prefers price over the other items. Mowing area and cutting width are each half important as price. In terms of importance given to other items, the two items concerning technical properties are each a quarter as important as price.

Table 2. The requirements of all customers

Customer	A		B		C	
	Requirements	Preference points	Requirements	Preference points	Requirements	Preference points
Price	4200	2	6000	60	2000	8
Mowing area	300	2	750	20	650	4
Collection bag	45	2	40	0	30	2
Cutting width	35	2	40	0	44	4
Performance	1600	2	1500	0	1200	2

Preference points are converted into percentages.

Table 3. Preferential points of customers in percent

	Price	Mowing area	Collection bag	Cutting width	Performance
Preference points customer A	0.20	0.20	0.20	0.20	0.20
Preference points customer B	0.75	0.25	0.00	0.00	0.00
Preference points customer C	0.40	0.20	0.10	0.20	0.10

5. Data evaluation using fuzzy logic

5.1. Fuzzification

First, it is necessary to evaluate how each mower satisfies customer wishes with respect to individual parameters. We will use the appropriate membership function. The shapes of the membership functions were discussed with actual dealers.

- Price – customer´s ideal value = y, mower´s price = x: the price is then characterized by the membership function : L(x, y, 1,2* y)
- Mowing area – customer´s ideal value = y, mower´s value = x: this value is then characterized by the membership function: Γ(x, 0,6*y, y)
- Collection bag capacity – customer´s ideal value = y, mower´s value = x: this value is then characterized by the membership function : Π(x, 0,8*y, 0,9*y, 1,1*y, 1,2*y)
- Cutting width – customer´s ideal value = y, mower´s value = x: this value is then characterized by the membership function : Π(x, 0,8*y, 0,9*y, 1,1*y, 1,2*y)
- Performance – customer´s ideal value = y, mower´s value = x: this value is then characterized by the membership function: Π(x, 0,6*y, 0,8*y, 1,2*y, 1,4*y)

The results (2 decimal places) are presented in the Table 4.

Table 4. Values assigned to individual mowers

	Price			Mowing area			Collection bag			Cutting width			Performance		
Customer Lawn mowers	A	B	C	A	B	C	A	B	C	A	B	C	A	B	C
1	1,00	1,00	1,00	0,58	0,00	0,00	0,00	0,00	1,00	0,57	0,00	0,00	0,13	0,33	1,00
2	1,00	1,00	0,00	1,00	0,83	1,00	0,44	0,00	0,00	0,00	1,00	1,00	1,00	1,00	0,00
3	1,00	1,00	0,00	1,00	0,50	0,81	0,89	1,00	0,00	1,00	1,00	0,18	1,00	1,00	0,75
4	0,89	1,00	0,00	1,00	1,00	1,00	0,00	0,00	0,00	0,00	1,00	1,00	1,00	1,00	0,00
5	1,00	1,00	1,00	0,58	0,00	0,00	0,00	0,00	1,00	1,00	0,00	0,00	0,13	0,33	1,00
6	1,00	1,00	0,03	0,17	0,00	0,00	0,00	0,75	0,33	1,00	0,00	0,00	0,75	1,00	1,00
7	1,00	1,00	0,00	1,00	0,17	0,42	1,00	1,00	0,00	1,00	1,00	0,64	1,00	1,00	1,00
8	1,00	1,00	0,00	1,00	0,50	0,81	1,00	1,00	0,00	0,57	1,00	1,00	1,00	1,00	1,00
9	1,00	1,00	0,00	1,00	0,00	0,00	0,00	0,00	1,00	1,00	0,00	0,00	0,75	1,00	1,00
10	1,00	1,00	0,00	1,00	0,17	0,42	1,00	0,75	0,00	1,00	1,00	0,64	1,00	1,00	0,33
11	0,06	1,00	0,00	1,00	0,17	0,42	0,89	1,00	0,00	1,00	1,00	0,18	1,00	1,00	0,75
12	0,00	0,83	0,00	1,00	1,00	1,00	0,89	0,00	0,00	0,57	1,00	1,00	1,00	1,00	0,00

5.2. Fuzzy inference

The values obtained through the fuzzification process are now multiplied by the percentile preference points. It is necessary to obtain each mower´s resulting value using a suitable fuzzy operation. The operation of conjunction seems to be appropriate for this purpose.

We define binary operation ⊗ in the real interval <0,1> as fuzzy conjunctions, which satisfy the following axioms for all a, b, c ∈ <0.1>:

$$a \otimes b = b \otimes a \qquad \text{commutativity} \qquad (4)$$

$$(a \otimes b) \otimes c = a \otimes (b \otimes c) \qquad \text{associativity} \qquad (5)$$

$$(a \le b) \Rightarrow (a \otimes c) \le (b \otimes c) \qquad \text{monotony} \qquad (6)$$

$$a \otimes 1 = a \qquad \text{neutral element} \qquad (7)$$

The most suitable fuzzy inference for our fuzzy inference from all known fuzzy conjunctions (cf. (Fullér, 1996)) seems to be the following:

$$a \otimes b = \min(a, b) \qquad \text{fuzzy conjunctions based on minimum} \qquad (8)$$

$$a \otimes b = a \cdot b \qquad \text{fuzzy conjunctions based on product} \qquad (9)$$

The resulting values (3 decimal places) for each fuzzy conjunction are presented in the Table 5.

Table 5. The final scores of mowers

		1	2	3	4	5	6	7	8	9	10	11	12
Minimum	**A**	0,000	0,000	0,178	0,000	0,000	0,000	0,200	0,114	0,000	0,200	0,012	0,000
	B	0,000	0,208	0,125	0,250	0,000	0,000	0,042	0,125	0,000	0,042	0,042	0,250
	C	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Product	**A**	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
	B	0,000	0,156	0,094	0,188	0,000	0,000	0,031	0,094	0,000	0,031	0,031	0,156
	C	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000

5.3. Defuzzification

Defuzzification transforms the results of the fuzzy inference into output variables. The resulting order arises simply from comparing the calculated values for the selected fuzzy inference with the defuzzification, as shown in the following table:

Table 6. The resulting order of mowers

		1	2	3	4	5	6	7	8	9	10	11	12
Minimum	**A**	6	6	3	6	6	6	1	4	6	1	5	6
	B	9	3	4	1	9	9	6	4	9	6	6	1
	C	1	1	1	1	1	1	1	1	1	1	1	1
Product	**A**	6	6	3	6	6	6	1	4	6	1	5	6
	B	9	3	4	1	9	9	6	4	9	6	6	2
	C	1	1	1	1	1	1	1	1	1	1	1	1

Customer A – (offered mowers: AL-KO 3.8 E, Black & Decker Emmax 38 liters). According to the parameters set, the system evaluated two lawn mowers as meeting the customer´s requirements, both to the same degree. It is then up to the customer which mower he/she chooses, either under the already evaluated criteria or by including other criteria.

Customer B – (offered mower: Einhell RG-EM 1843 HW). The offered lawn mower was evaluated as satisfying the customer's two requirements the most.

Customer C – the system assessed this customer´s requirements as impossible to fulfill. We can already see this in Table 5, where the final scores for all mowers are 0. The customer wants a cheap mower which can handle a large mowing area, or a mower which can handle a large mowing area while only having a small collection bag, etc. In this case, it is up to the seller to help change the customer´s requirements. They will proceed according to customer preferences from the least to the most preferred characteristic. All these changes will immediately be evident. The customer may change his requirements and immediately choose the best mower.

6. Retailers´ statement

Between May and July 2012, I approached sales assistants and other employees from the Baumax store in Zlín who had replied to the following questionnaire:

”.... at the moment I am trying to find the degree to which fuzzy logic is applicable in business. I would like to ask you to fill in the following simple questionnaire.

Fuzzy logic allows even partial membership in a set. For you, this would mean the existence of the following system: a customer comes to the store to buy a lawn mower. You enter so-called “preference points” into a simple table of requirements (these “preference points” reflect how particular characteristics of lawn mowers are important to the customer). The system evaluates all mowers in the catalog and then directly offers a product that best satisfies the customer's requirements, as shown in the examples on the following page (three cases: customers A, B and C). You don´t need to learn anything new: just fill in a few numbers and you can immediately see which mower is the best for the customer. This system uses the advantages of fuzzy logic and could be applied to all products offered in your shop (swimming pools, tile, flooring, drills,...).

I have the following questions:

- Do you know about fuzzy logic? Yes – No – Partially
- Do you use fuzzy logic in your work? Yes – No – Partially

- Do you consider the proposed selection system using fuzzy logic beneficial? Yes – No – Partially
- Did the proposed selection system accelerate customer service? Yes – No – Partially
- Would you use fuzzy logic in your work? Yes – No – Partially

We obtained a total of 33 completed questionnaires, 31 of which have been fully completed. The results are as follows:

1) Do you know about fuzzy logic?
1 seller answered "YES", 14 answered "NO", 18 answered "PARTIALLY". In total, 57.5 % of retailers disclosed at least a partial knowledge of fuzzy logic. They were probably already familiar with products that use fuzzy logic systems – modern washing machines, digital cameras with autofocus, some air conditioning, etc.

2) Do you use fuzzy logic in your work?
1 – 16 – 16. This means 51.5 % of sellers revealed that they use (at least) the basic principles of fuzzy logic (at least) partially.

3) Do you consider the proposed selection system using fuzzy logic beneficial?
13 – 2 – 16. The two "NO" answers came from sellers who answered "NO" to all questions and had apparently refused to take the questionnaire seriously. This means that all sellers who completed the questionnaire conscientiously admit (at least partially) the benefits of fuzzy logic.

4) Did the proposed selection system accelerate customer service?
14 – 2 – 16. Again, only the sellers who answered "NO" to all questions expressed a negative attitude. Thus, all sellers who took the questionnaire seriously evaluated the system using fuzzy logic as accelerating customer service.

5) Would you use fuzzy logic in your work?
9 – 5 – 18. This was a surprising answer – if 100 % of sellers consider the system using fuzzy logic as beneficial, then, presumably, 100 % should want to use such a system, because quick customer service leads to greater customer satisfaction and a larger number of customers serviced. This should be the goal of any retailer.

7. Conclusion

This work shows how to use fuzzy logic in order to speed up customer service. In three fast and simple steps, the "best" lawnmower for a particular customer was identified. We had a small number of mowers: only 12 mowers with 8 characteristics. Yet, vendors claim that the use of fuzzy logic accelerates customer service. Therefore, with fuzzy logic, shoppers can be confident that a product is selected according to all their preferences and requirements.

Additionally, the proposed system can detect unrealistic customer requirements. The customer can, together with the dealer, simply identify and revise them.

The system can be applied to any range of products sold in any shop – the wider the range of products, and the greater the number of characteristics, the greater the benefits of using such a system.

The implementation of fuzzy logic in retail, as one of the options of multi-criteria decision-making, has its indisputable advantages.

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