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Fuzzy inference system for investment value assessment based on historical data

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***Abstract*. The analysis of financial parameters is of fundamental importance when planning one or another investment in shares of a given company. It is important for such an analysis to consider some basic numerical parameters such as: annual revenue growth for the last few years, gross, operating, and net profit margins, price/earnings ratio, current price, average annual price, and other historical data for analysis. In this research, an investment decision-making approach based on fuzzy logic is proposed, which evaluates various aspects of a given company's activity. Mamdani method and the fuzzy logic toolset in MATLAB were used. A set of fuzzy rules forms the basis of the investment evaluation system and determines the investment type recommendation, depending on the financial data provided. Simulation experiments with different inputs prove the correct approach and the adequate solutions that can be obtained. The precise set of input variables and well-thought-out logical rules can achieve a reduction in risks for specific investment intentions.**

Keywords: fuzzy inference system, investment value, membership function.

I. INTRODUCTION

Fuzzy Inference Systems (FIS) are successfully applied in areas such as IT project management [1] and cyber security [2], as well as for total risk calculation for new projects of any type [3]. In this scientific report, a simulation fuzzy inference system (FIS) based on the principles of fuzzy logic ([4][5]) is proposed for investment value estimation. It uses Mamdani's method described in [6] for odd controlled systems to analyse financial parameters. The system aims to help in making investment decisions, evaluating the main or different areas of a given company's activity. The use of artificial intelligence and in particular fuzzy logic systems to support investment decisions [7] [8] and stock market behavior in general have been well studied and researched, such as in [9] [10] [11] [12] [13] [14] because even the smallest changes in the values of given indicators should be included in the in-depth analysis that every financial operation requires. The expectations are that, after the application of such decision support systems, the risks will be maximally reduced and the profits - increased, which is desired by every single company.

II. MATERIALS AND METHODS

To achieve the set goals, Fuzzy Logic Toolbox in Matlab was chosen, as it offers, in addition to multifunctional programming options, wide-ranging adaptability of the synthesized models, both to input values and when exporting to other programming and implementation environments. Linguistic variables at the input of the FIS in this case are of different dimensions and not all of them have numerical units, therefore Mamdani's method of operation [6] was chosen.

The fuzzy input variables are 6, and the goal of their selection is to achieve maximum informational activity, given the multifactorial influence of statistical data on the formation of economic trends and potential. The only output variable expressing the purpose of the study is "Type of Investment". Input Linguistic Variables:

- Revenue-Gr-4Y (annual revenue growth for the last 4 years).
- Gross-Profit-Margin.
- Operating-Income-Margin.
- Net-Profit-Margin.
- P/E Ratio (Price-to-Earnings Ratio).
- Current Price, compared to 5Y (current price compared to the annual average of the last 5 years).

The structure of the Mamdani type FIS is depicted in Fig. 1.

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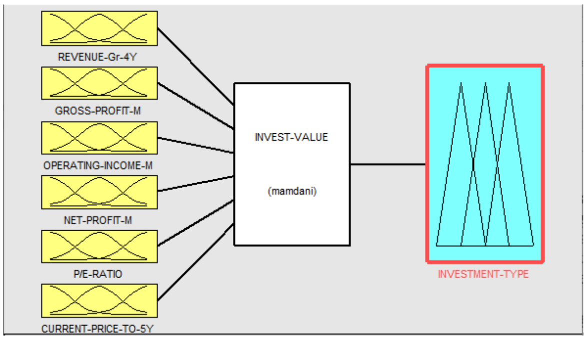


Fig. 1. Fuzzy Inference System "Invest value"

For the membership functions for all the input fuzzy variables, the shape of trapezium is selected, because with its use one of the higher levels of density is achieved during each of the input values determination. The membership functions for simulation purposes are named and positioned as followed for each of the six input variables:

1. *Annual Revenue Growth for the last 4 years*
range (-100;100)
mf 1.1 "Negative" < 0
mf 1.2 "Slow" 0 - 15
mf 1.3 "Fast" 15 - 25
mf 1.4 "Rapid" > 25

2. *Gross Profit Margin*
range (-100;100)
mf 2.1 "Negative" < 0
mf 2.1 "Average" 0 - 20
mf 2.1 "High" 20 - 40
mf 2.1 "Exceptional" > 40

3. *Operating Income Margin*
range (-100;100)
mf 3.1 "Negative" < 0
mf 3.2 "Low" 0 - 10
mf 3.3 "Good" 10 - 15
mf 3.4 "High" > 15

4. *Net Profit Margin*
range (-100;100)
mf 4.1 "Negative" < 0
mf 4.2 "Low" 0 - 10
mf 4.3 "Healthy" 10 - 20
mf 4.4 "High" > 20

5. *P/E Ratio (Price-to-Earnings Ratio)*
range (-100;100)
mf 5.1 "Negative" < 0
mf 5.2 "Undervalued" 0 - 15
mf 5.3 "Average" 15 - 25
mf 5.4 "High" 25 - 40
mf 5.5 "Very high" > 40

6. *Current Price, compared to 5-year average*
range (-100;100)
mf 6.1 "Cheap" < -30
mf 6.2 "Bargain" -30 - -15
mf 6.3 "Low margin of safety" -15 - 0
mf 6.4 "Expensive" > 0

Membership functions of the input fuzzy variable "Revenue Growth for the last 4 years" is depicted in figure 2. Another input variable "Price-to-Earnings Ratio" is depicted in Fig.3.

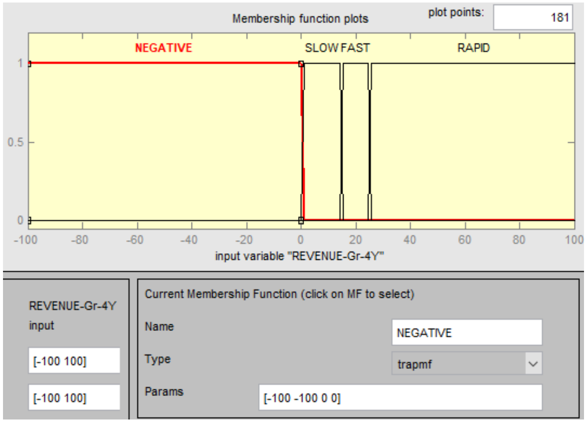


Fig. 2. Membership functions of the input fuzzy variable "Revenue Growth for the last 4 years"

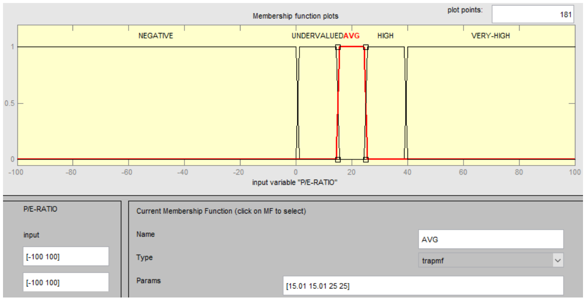


Fig. 3. Membership functions of the input fuzzy variable "Price-to-Earnings Ratio"

The output fuzzy variable Type of Investment with range (0; 4) is designed with the following membership functions (fig. 4): Avoid (0 - 1), Risky (1 - 2), Worthy (2 - 3), Very profitable (3 - 4). These membership functions are depicted in fig. 4.

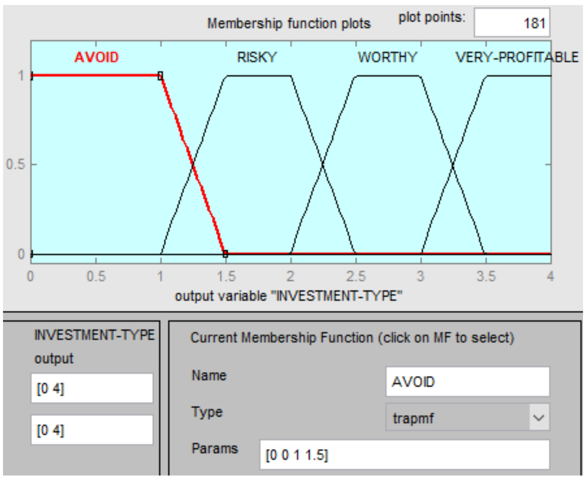
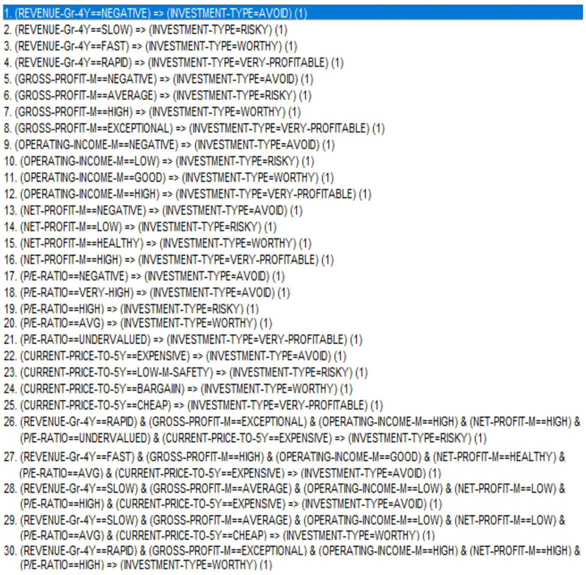


Fig. 4. Membership functions of the input fuzzy variable "Price-to-Earnings Ratio"

The designed structure of input and output linguistic variables is connected to a system of 30 fuzzy rules, where an investment logic is followed at different combinations of values of the input fuzzy variables. Each rule is designed to represent a combination of values for the input variables and determine the classification of the investment. These rules are formed based on an exemplary investment evaluation system and determine the recommendation for the type of investment, depending on the financial statistics provided. This kind of data can be obtained from specialized databases or web sites such as [15]. The system of rules is depicted in fig. 5.



1. (REVENUE-Gr-4Y==NEGATIVE) => (INVESTMENT-TYPE=AVOID) (1)
2. (REVENUE-Gr-4Y==SLOW) => (INVESTMENT-TYPE=RISKY) (1)
3. (REVENUE-Gr-4Y==FAST) => (INVESTMENT-TYPE=WORTHY) (1)
4. (REVENUE-Gr-4Y==RAPID) => (INVESTMENT-TYPE=VERY-PROFITABLE) (1)
5. (GROSS-PROFIT-M==NEGATIVE) => (INVESTMENT-TYPE=AVOID) (1)
6. (GROSS-PROFIT-M==AVERAGE) => (INVESTMENT-TYPE=RISKY) (1)
7. (GROSS-PROFIT-M==HIGH) => (INVESTMENT-TYPE=WORTHY) (1)
8. (GROSS-PROFIT-M==EXCEPTIONAL) => (INVESTMENT-TYPE=VERY-PROFITABLE) (1)
9. (OPERATING-INCOME-M==NEGATIVE) => (INVESTMENT-TYPE=AVOID) (1)
10. (OPERATING-INCOME-M==LOW) => (INVESTMENT-TYPE=RISKY) (1)
11. (OPERATING-INCOME-M==GOOD) => (INVESTMENT-TYPE=WORTHY) (1)
12. (OPERATING-INCOME-M==HIGH) => (INVESTMENT-TYPE=VERY-PROFITABLE) (1)
13. (NET-PROFIT-M==NEGATIVE) => (INVESTMENT-TYPE=AVOID) (1)
14. (NET-PROFIT-M==LOW) => (INVESTMENT-TYPE=RISKY) (1)
15. (NET-PROFIT-M==HEALTHY) => (INVESTMENT-TYPE=WORTHY) (1)
16. (NET-PROFIT-M==HIGH) => (INVESTMENT-TYPE=VERY-PROFITABLE) (1)
17. (P/E-RATIO==NEGATIVE) => (INVESTMENT-TYPE=AVOID) (1)
18. (P/E-RATIO==VERY-HIGH) => (INVESTMENT-TYPE=AVOID) (1)
19. (P/E-RATIO==HIGH) => (INVESTMENT-TYPE=RISKY) (1)
20. (P/E-RATIO==AVG) => (INVESTMENT-TYPE=WORTHY) (1)
21. (P/E-RATIO==UNDERVALUED) => (INVESTMENT-TYPE=VERY-PROFITABLE) (1)
22. (CURRENT-PRICE-TO-5Y==EXPENSIVE) => (INVESTMENT-TYPE=AVOID) (1)
23. (CURRENT-PRICE-TO-5Y==LOW-M-SAFETY) => (INVESTMENT-TYPE=RISKY) (1)
24. (CURRENT-PRICE-TO-5Y==BARGAIIN) => (INVESTMENT-TYPE=WORTHY) (1)
25. (CURRENT-PRICE-TO-5Y==CHEAP) => (INVESTMENT-TYPE=VERY-PROFITABLE) (1)
26. (REVENUE-Gr-4Y==RAPID) & (GROSS-PROFIT-M==EXCEPTIONAL) & (OPERATING-INCOME-M==HIGH) & (NET-PROFIT-M==HIGH) & (P/E-RATIO==UNDERVALUED) & (CURRENT-PRICE-TO-5Y==EXPENSIVE) => (INVESTMENT-TYPE=RISKY) (1)
27. (REVENUE-Gr-4Y==FAST) & (GROSS-PROFIT-M==HIGH) & (OPERATING-INCOME-M==GOOD) & (NET-PROFIT-M==HEALTHY) & (P/E-RATIO==AVG) & (CURRENT-PRICE-TO-5Y==EXPENSIVE) => (INVESTMENT-TYPE=AVOID) (1)
28. (REVENUE-Gr-4Y==SLOW) & (GROSS-PROFIT-M==AVERAGE) & (OPERATING-INCOME-M==LOW) & (NET-PROFIT-M==LOW) & (P/E-RATIO==HIGH) & (CURRENT-PRICE-TO-5Y==EXPENSIVE) => (INVESTMENT-TYPE=AVOID) (1)
29. (REVENUE-Gr-4Y==SLOW) & (GROSS-PROFIT-M==AVERAGE) & (OPERATING-INCOME-M==LOW) & (NET-PROFIT-M==LOW) & (P/E-RATIO==AVG) & (CURRENT-PRICE-TO-5Y==CHEAP) => (INVESTMENT-TYPE=WORTHY) (1)
30. (REVENUE-Gr-4Y==RAPID) & (GROSS-PROFIT-M==EXCEPTIONAL) & (OPERATING-INCOME-M==HIGH) & (NET-PROFIT-M==HIGH) & (P/E-RATIO==HIGH) => (INVESTMENT-TYPE=WORTHY) (1)

Fig. 5. Fuzzy rules of the FIS "Invest Value"

Aggregation Method 'sum' is used to combine the different rules and their input values into a common expression. Summing up the values provides a clear view of the cumulative impact of the different rules in the system.

Defuzzification Method 'centroid' is used to centre the values in the decision around the centre of the result area. In this way an easier interpretation and understanding of the results is provided, which can be used to make specific investment decisions.

III. Results and Discussion

The correct functioning of the Fuzzy Inference System has been confirmed with numerous simulation experiments, where logically justified results are obtained for determining the type of investment under different input parameters. In table 1, the results obtained for the respective values of the fuzzy input variables in 10 different experiments which were conducted in MATLAB are recorded.

An example of such a simulation experiment is row 9 in Table 1, where the values of the fuzzy variables have determined membership as follows:

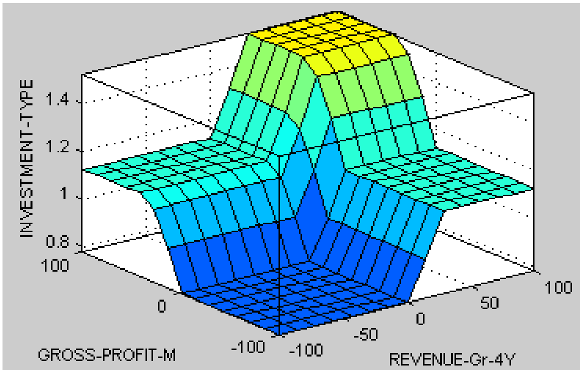
"Revenue Growth 4 Years AVG" = 33.09 ("Rapid")
"Gross Profit Margin" = 30.15 ("High")
"Operating Income Margin" = 12.5 ("Good")
"Net Profit Margin" = 13.97 ("Healthy")
"Price-to-Earnings Ratio" = 21.32 ("Average")
"Current Price, compared to 5-year AVG" = -19.85 ("Bargain")

At these values, FIS obtained "Investment Type" = 2.86 and the investment is classified as "Worthy".

TABLE 1 FIS - SIMULATION EXPERIMENTAL RESULTS

Fuzzy input values						FIS output value
Revenue Growth 4 Years AVG	Gross Profit Margin	Operating Income Margin	Net Profi Margin	Profit / Earnings Ratio	Current-Price, compared to 5 Y AVG	Investment-Type
-15.67	-14.18	4.444	-9.701	-14.18	28.15	0.777
19.85	13.97	19.85	5.147	-6.618	13.97	1.68
21.64	29.1	25.19	14.18	33.58	-7.407	2.52
31.62	46.32	22.79	26.12	47.01	16.3	2.27
34.56	31.62	22.79	25.74	11.03	-36.03	3.44
31.62	13.97	25.74	15.44	-5.147	-36.03	2.45
18.38	16.91	12.5	25.74	19.85	-34.56	2.81
-40.44	-8.088	-6.618	-8.088	-19.85	8.088	0.623
33.09	30.15	12.5	13.97	21.32	-19.85	2.86
19.85	47.79	19.85	5.147	-6.618	13.97	1.92

The shape of the surface in that case is shown on fig. 6. The result is clearly defined.



By introducing more granularity to the input by creating and adding more linguistic variables, the result could be better justified. This can also occur when more fuzzy FIS rules are created.

IV. Conclusions

The use of this approach to create a FIS for the evaluation of an investment could be continued by generating program code and putting this or a similar system into operation when seeking a reasoned opinion on specific investment intentions when the resource time for making the decision is limited.

A similar system can be created to evaluate the impact of a given training [16], weather conditions on flight [17], in predictions and evaluation with artificial intelligence [18] or means to achieve goals related to risk assessment. The application of FIS in a similar approach can summarize various input parameters such as special features of the probing signal [19], cybersecurity assessment methodology [20] or vulnerability analysis in server systems [21].

A comprehensive platform for investment risk analysis could be created by combining this approach with the output of a deep learning system that would serve to derive values for FIS input parameters.

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