Fuzzy Rule Based Innovation Projects Estimation

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Abstract
In this paper we suggest a expert system for decision making support about quality of innovation projects. The system is based on some linguistic expert rules formalized in the form of fuzzy knowledge bases. Results of decision making by the system are good concordant with expert assessments of quality.

1. Introduction

Estimation of innovation project quality level is an important task of any Innovation Fund. Instant and correct solution of this task, that can generally be accomplished only by specialist economists, allows to manage of financial resources optimally. In this connection it is necessary to design computer based information systems providing intelligent support for Innovation Fund's personnel in decision making.

In this paper we suggest a expert system for decision making support about quality of innovation projects quality of innovation projects. Expert statements reflecting interconnection between project partial figures and level of quality are formalized using fuzzy knowledge bases.

2. Types of decisions and partial figures of quality

Innovation project quality estimation is used for making one of the following decisions: d_1 - to finance, d_2 - to finance after retrofit, d_3 - to finance when means are available, d_4 - to reject.

Let us use letter D to designate integral figure of innovation project quality. To estimate this figure we will use the following information:

X - level of the enterprise-applicant which is estimated using the following partial figures: x_1 - level of enterprise leader, x_2 - enterprise assets, x_3 - enterprise liabilities, x_4 - enterprise balance profit, x_5 - enterprise debt receivables, x_6 - enterprise indebtedness under credits. To estimate enterprise leader level we take into account the following figures: a_1 - sociability, a_2 - fidelity, a_3 - education, a_4 - leader work experience, a_5 - comfortless;

Y - technical economic level of the project, in point for which estimation the following partial figures are used: y_1 - project scale, y_2 - project novelty, y_3 - development trend priority, y_4 - degree of perfection, y_5 - juridical protection, y_6 - ecology level;

V - expected sales level;

Z - financial level of the enterprise-applicant which is estimated using the following partial figures: z_1 - ratio of internal funds to innovation funds; z_2 - innovation fund means return.

The task of estimation is in bringing one of the decisions $d_1 \div d_4$ into correspondence with some innovation project with known partial figures.

3. Fuzzy knowledge bases

Hierarchy diagram of accepted innovation project quality figures is shown on Figure 1 in the form of fuzzy logic inference tree [2] to which this system of relations corresponds:

$$D = f_D(X, Y, V, Z), \qquad (1)$$

$$X = f_X(x_1, x_2, x_3, x_4, x_5, x_6), \qquad (2)$$

$$x_1 = f_{x_1}(a_1, a_2, a_3, a_4, a_5), \qquad (3)$$

$$Y = f_Y(y_1, y_2, y_3, y_4, y_5, y_6), \qquad (4)$$

$$Z = f_Z(z_1, z_2). \qquad (5)$$

Elements of the tree are interpreted in the following way:

- the root - assessment of innovation project quality;
- terminal vertices - partial figures of project;
- nonternimal vertices (double circles) - fuzzy knowledge bases;
- graph edges going out of nonterminal vertices - enlarged figures of project quality.

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Partial figures in point $x_1 \div x_6$, $a_1 \div a_5$, $y_1 \div y_6$, V, z_1 and z_2 and also enlarged figures X, Y, Z are considered as linguistic variables [3]. To estimate the introduced linguistic variables we will use the unitary scale of qualitative terms: vL - very low, L - low, lA - lower than average, A - average, hA - higher than average, H - high, vH - very high. Each of these terms represents some fuzzy set preset using the following membership function model [2]:

$$\mu^t(x) = \frac{1}{1+\left(\frac{x-b}{c}\right)^2}, \qquad (6)$$

where $\mu^t(x)$ - membership function of variable x to term t; b and c - membership function parameters - coordinate of maximum and concentration coefficient.

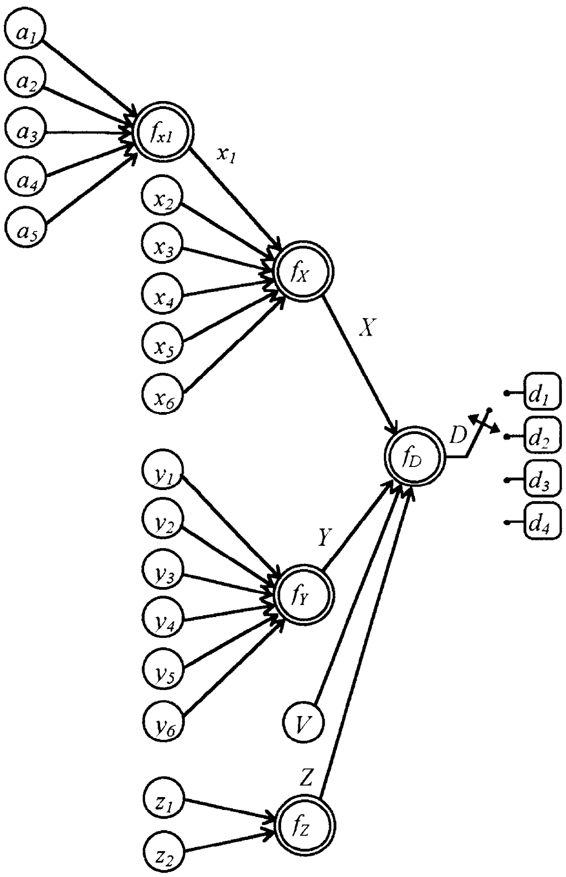

Figure 1. Fuzzy Logic Evidence Tree

All linguistic variables are viewed on the unitary universal set $U=[0,100]$. Parameters of membership functions are introduced in Table 1.

Table 1

Membership functions parameters

Term	vL	L	lA	A	hA	H	vH
b	0	17	33	50	67	83	100
c	15	15	15	15	15	15	15

Using introduced quality terms let us represent relations (1) - (5) in the knowledge base form by Tables 2 - 6. Each line in this tables corresponds one linguistic rule «If - then» obtained from a group of experts under leadership of Vinnitsa Chapter of Ukraine Innovation Fund Director Dr N. Petrenko.

Table 2

Knowledge about relation (1)

X	Y	V	Z	D
H	H	H	H	d_1
hA	H	H	H	
H	H	H	hA	
hA	hA	hA	hA	d_2
hA	H	H	hA	
hA	hA	H	A	
H	H	A	A	d_3
H	A	A	A	
H	A	hA	A	
L	L	L	L	d_4
A	L	L	L	

Table 3

Knowledge about relation (2)

x_1	x_2	x_3	x_4	x_5	x_6	X
L	L	L	L	L	H	L
H	H	H	lA	lA	lA	lA
H	H	H	A	A	lA	A
H	H	H	hA	hA	A	hA
H	H	H	H	H	L	H
H	H	H	A	hA	L	

Table 4

Knowledge about relation (3)

a_1	a_2	a_3	a_4	a_5	x_1
vL	vL	vL	vL	vL	vL
L	L	L	L	L	L
lA	A	lA	A	lA	lA
A	A	A	A	A	A
hA	H	hA	H	A	hA
H	H	H	H	H	H
vH	vH	vH	vH	vH	vH

Table 5

Knowledge about relation (4)

y_1	y_2	y_3	y_4	y_5	y_6	Y
vL	vL	vL	vL	vL	vL	L
L	L	L	L	L	L	
A	A	L	L	L	A	lA
A	A	A	A	A	A	A
H	H	H	H	H	H	hA
vH	vH	vH	vH	vH	vH	H

Table 6

Knowledge about relation (5)

z_1	z_2	Z
vL	vL	L
A	L	lA
A	A	A
hA	H	hA
vH	vH	H

5. Fuzzy Logic Equations

Using Tables 2 ÷ 6 and operations: «·» (AND - min) and « ∨ » (OR - max), it is easy to write the system of fuzzy logic equations [2] which connect the membership functions of integral figure and of partial figures of the innovation project quality:

$$\mu^{d_1}(D)=\mu^{H}(X)\cdot\mu^{H}(Y)\cdot\mu^{H}(V)\cdot\mu^{H}(Z)\vee$$

$$\vee\,\mu^{hA}(X)\cdot\mu^{H}(Y)\cdot\mu^{H}(V)\cdot\mu^{H}(Z)\vee$$

$$\vee\,\mu^{hA}(X)\cdot\mu^{H}(Y)\cdot\mu^{H}(V)\cdot\mu^{hA}(Z);$$

$$\mu^{d_2}(D)=\mu^{hA}(X)\cdot\mu^{hA}(Y)\cdot\mu^{hA}(V)\cdot\mu^{hA}(Z)\vee$$

$$\vee\,\mu^{hA}(X)\cdot\mu^{H}(Y)\cdot\mu^{H}(V)\cdot\mu^{hA}(Z)\vee$$

$$\vee\,\mu^{hA}(X)\cdot\mu^{hA}(Y)\cdot\mu^{H}(V)\cdot\mu^{A}(Z);$$

$$\mu^{d_3}(D)=\mu^{H}(X)\cdot\mu^{H}(Y)\cdot\mu^{A}(V)\cdot\mu^{A}(Z)\vee$$

$$\vee\,\mu^{H}(X)\cdot\mu^{A}(Y)\cdot\mu^{A}(V)\cdot\mu^{A}(Z)\vee$$

$$\vee\,\mu^{H}(X)\cdot\mu^{A}(Y)\cdot\mu^{lA}(V)\cdot\mu^{A}(Z);$$

$$\mu^{d_4}(D)=\mu^{L}(X)\cdot\mu^{L}(Y)\cdot\mu^{L}(V)\cdot\mu^{L}(Z)\vee$$

$$\vee\,\mu^{A}(X)\cdot\mu^{L}(Y)\cdot\mu^{L}(V)\cdot\mu^{L}(Z);$$

$$\mu^{L}(X)=\mu^{L}(x_1)\cdot\mu^{L}(x_2)\cdot\mu^{L}(x_3)\cdot\mu^{L}(x_4)\cdot\mu^{L}(x_5)\cdot\mu^{H}(x_6);$$

$$\mu^{lA}(X)=\mu^{H}(x_1)\cdot\mu^{H}(x_2)\cdot\mu^{H}(x_3)\cdot\mu^{lA}(x_4)\cdot\mu^{lA}(x_5)\cdot\mu^{lA}(x_6);$$

$$\mu^{A}(X)=\mu^{H}(x_1)\cdot\mu^{H}(x_2)\cdot\mu^{H}(x_3)\cdot\mu^{A}(x_4)\cdot\mu^{A}(x_5)\cdot\mu^{lA}(x_6);$$

$$\mu^{hA}(X)=\mu^{H}(x_1)\cdot\mu^{H}(x_2)\cdot\mu^{H}(x_3)\cdot\mu^{hA}(x_4)\cdot\mu^{hA}(x_5)\cdot\mu^{A}(x_6);$$

$$\mu^{H}(X)=\mu^{H}(x_1)\cdot\mu^{H}(x_2)\cdot\mu^{H}(x_3)\cdot\mu^{H}(x_4)\cdot\mu^{H}(x_5)\cdot\mu^{L}(x_6)\vee$$

$$\vee\,\mu^{H}(x_1)\cdot\mu^{H}(x_2)\cdot\mu^{H}(x_3)\cdot\mu^{H}(x_4)\cdot\mu^{lA}(x_5)\cdot\mu^{L}(x_6);$$

$$\mu^{vL}(x_1)=\mu^{vL}(a_1)\cdot\mu^{vL}(a_2)\cdot\mu^{vL}(a_3)\cdot\mu^{vL}(a_4)\cdot\mu^{vL}(a_5);$$

$$\mu^{L}(x_1)=\mu^{L}(a_1)\cdot\mu^{L}(a_2)\cdot\mu^{L}(a_3)\cdot\mu^{L}(a_4)\cdot\mu^{L}(a_5);$$

$$\mu^{lA}(x_1)=\mu^{lA}(a_1)\cdot\mu^{lA}(a_2)\cdot\mu^{lA}(a_3)\cdot\mu^{A}(a_4)\cdot\mu^{lA}(a_5);$$

$$\mu^{A}(x_1)=\mu^{A}(a_1)\cdot\mu^{A}(a_2)\cdot\mu^{A}(a_3)\cdot\mu^{A}(a_4)\cdot\mu^{A}(a_5);$$

$$\mu^{hA}(x_1)=\mu^{hA}(a_1)\cdot\mu^{H}(a_2)\cdot\mu^{hA}(a_3)\cdot\mu^{H}(a_4)\cdot\mu^{A}(a_5);$$

$$\mu^{H}(x_1)=\mu^{H}(a_1)\cdot\mu^{H}(a_2)\cdot\mu^{H}(a_3)\cdot\mu^{H}(a_4)\cdot\mu^{H}(a_5);$$

$$\mu^{vH}(x_1)=\mu^{vH}(a_1)\cdot\mu^{vH}(a_2)\cdot\mu^{vH}(a_3)\cdot\mu^{vH}(a_4)\cdot\mu^{vH}(a_5);$$

$$\mu^{L}(Y)=\mu^{vL}(y_1)\cdot\mu^{vL}(y_2)\cdot\mu^{vL}(y_3)\cdot\mu^{vL}(y_4)\cdot\mu^{vL}(y_5)\cdot\mu^{vL}(y_6)\vee$$

$$\vee\,\mu^{L}(y_1)\cdot\mu^{L}(y_2)\cdot\mu^{L}(y_3)\cdot\mu^{L}(y_4)\cdot\mu^{L}(y_5)\cdot\mu^{L}(y_6);$$

$$\mu^{lA}(Y)=\mu^{A}(y_1)\cdot\mu^{A}(y_2)\cdot\mu^{L}(y_3)\cdot\mu^{L}(y_4)\cdot\mu^{L}(y_5)\cdot\mu^{A}(y_6);$$

$$\mu^{A}(Y)=\mu^{A}(y_1)\cdot\mu^{A}(y_2)\cdot\mu^{A}(y_3)\cdot\mu^{A}(y_4)\cdot\mu^{A}(y_5)\cdot\mu^{A}(y_6);$$

$$\mu^{hA}(Y)=\mu^{H}(y_1)\cdot\mu^{H}(y_2)\cdot\mu^{H}(y_3)\cdot\mu^{H}(y_4)\cdot\mu^{H}(y_5)\cdot\mu^{H}(y_6);$$

$$\mu^{H}(Y)=\mu^{vH}(y_1)\cdot\mu^{vH}(y_2)\cdot\mu^{vH}(y_3)\cdot\mu^{vH}(y_4)\cdot\mu^{vH}(y_5)\cdot\mu^{vH}(y_6);$$

$$\mu^{L}(Z)=\mu^{vL}(z_1)\cdot\mu^{vL}(z_2);$$

$$\mu^{lA}(Z)=\mu^{A}(z_1)\cdot\mu^{L}(z_2);$$

$$\mu^{A}(Z)=\mu^{A}(z_1)\cdot\mu^{A}(z_2);$$

$$\mu^{hA}(Z)=\mu^{hA}(z_1)\cdot\mu^{H}(z_2);$$

$$\mu^{H}(Z)=\mu^{vH}(z_1)\cdot\mu^{vH}(z_2).$$

The fuzzy logic equations with membership functions of fuzzy terms allow to make the decision about the level of according to this algorithm:

1°. Fix the values of the partial figures for a given project.

2°. Using model (6) define the membership degrees when partial figures values are fixed.

3°. Using logic equations calculate membership functions $\mu^{d_j}(D)$ for all possible decision d_j, $j=\overline{1,4}$. In doing so logic operations AND $(\cdot)$ and OR $(\vee)$ are substituted by *min* and *max*.

4°. Define as decision d^*, for which $\mu^{d^*}(D)=\max_j\left[\mu^{d_j}(D)\right]$, $j=\overline{1,4}$.

6. Partial figures evaluation using thermometer principle

Some of the partial figures consists in the fact that all of them have qualitative character, that is they have no precise quantitative measurement. Therefore, while making estimations of the same figure by several experts there can be various opinions. In addition, the expert is not always capable of making estimation of the partial figure using words though he intuitively feels its level. To overcome these difficulties we can estimate partial figures using *thermometer principle* [2] (Figure 2). Convenience of such approach is in the fact that various sense partial figures are defined as linguistic variables given on the unitary universal set: $U=[0,100]$ which is the scale of a thermometer.

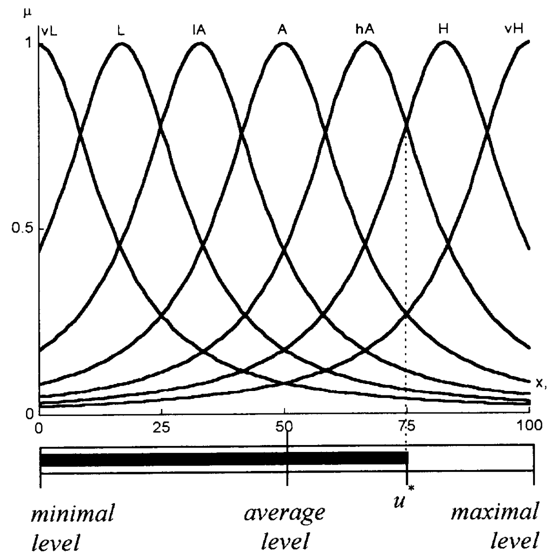

Figure 2. Evaluation using thermometer principle

7. Fuzzy model tuning

The fuzzy logic equations allows to calculate the vector of inferred membership functions for all types of decisions as follows:

$$\mu^{d_j}(X,B,C),\ j=\overline{1,4}, \tag{7}$$

where X - partial figures vector; B and C - vectors of parameters of membership functions.

According to [2] let us define the desirable vector of membership degrees as follows:

$$\left.\begin{array}{ll}(1,0,0,0) & \text{for solution } d_1\\ (0,1,0,0) & \text{for solution } d_2\\ (0,0,1,0) & \text{for solution } d_3\\ (0,0,0,1) & \text{for solution } d_4\end{array}\right\}. \tag{8}$$

Let us define the training data as a set of L pairs as follows:

$$\left(X^l,d^l\right),\ l=\overline{1,M}, \tag{9}$$

where X^l and d^l are input vector and corresponding output for a l-th pair, $d^l\in\{d_1,d_2,d_3,d_4\}$.

The vector of unknown parameters (B,C) which minimizes the difference between theory (7) and experiment (9) can be found by least square method. That is why the problem of fuzzy model tuning can be formalized as follows: it is required to find vector (B,C) which provides the minimum:

$$\sum_{l=1}^{M}\left[\sum_{j=1}^{4}\left[\mu^{d_j}\left(X^l,B,C\right)-\mu^{d_j}\left(X^l\right)\right]^2\right]=\min_{(B,C)}, \quad (10)$$

where according to (8):

$$\mu^{d_j}\left(X^l\right)=\begin{cases}1, & d_j=d^l\\ 0, & d_j\neq d^l\end{cases}, \quad j=\overline{1,4}.$$

To solve the nonlinear optimization problem (10) we have used genetic algorithms of optimization [1].

8. Evaluation examples

The models and algorithms suggested here are realised in an expert system which provides intelligent support in decision making about quality of innovation project. The system is realised on base of FuzzyExpert [2]. Examples of three innovation projects estimations by the suggested fuzzy model are represented in Table 7. Results of decision making by the system are good concordant with expert assessments of quality.

9. Conclusions

We have proposed a fuzzy expert system providing intelligent decision making support for esimation of quality of innovation projects. The system is based on five fuzzy knowledge bases connected hierarchically. Using the system allows to manage finansial resurces of Innovation Fund optimally.

10. References

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[2] A.P.Rotshtein, «Design and Tuning of Fuzzy Rule-Based Systems for Medical Diagnosis». In Teodorescu, N.-H., Kandel, A., and Jain, L.C. (Eds.) *Fuzzy and Neuro-Fuzzy in Medicine*, CRC Press, Boca Raton, USA, 1998, pp 243-289.

[3] H.-J.Zimmerman, *Fuzzy Sets Theory and its Applications*. 3rd ed., Kluwer Academic Publisher, Dordrecht, 1996, 435p.

Table 7

Examples of innovation projects quality estimations

Partial figure	Project 1	Project 2	Project 3
a_1			
a_2			
a_3			
a_4			
a_5			
x_2			
x_3			
x_4			
x_5			
x_6			
y_1			
y_2			
y_3			
y_4			
y_5			
y_6			
z_1			
z_2			
V			
Decision	to finance with means available	to finance	to finance after retrofit