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FORECASTING ECONOMICAL DEVELOPMENT ON THE BASE FUZZY LOGIC TYPE-2

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In the modern times forecasting of economical development of the different countries depends not only on local factors of development but also on such global factors as oil price in the world market and average growth rate of the world economy. It is necessary to take into account these factors while modeling economical development in different countries.

Recently Fuzzy Logic Type-2 tools have been applied for forecasting of development of different processes and events. Necessity for application of Fuzzy Logic Type-2 tools in economical forecasts is coherent with main economical indicators of development which express average values connected to big intervals of uncertainties.

Fuzzy Logic Type-2 more broadly describes problems of uncertainty in many fields. Concept of Fuzzy Logic Type-2 was originally proposed by professor L.Zadeh. [1]. Later this theory was developed by J.M.Mendel, N.N.Karnik and other authors. [2]-[5].

In this paper we have applied Fuzzy Logic Type-2 to construct model of the economical development of Azerbaijan Republic taking into account global factors.

Input parameters of the model were oil price in the world market – OPR, world GDP growth rates – WDR, volume of foreign investment – INV, volume of oil export – OEX and the output is – average growth rate domestic product - GDR of the Azerbaijan.

A Type-2 Fuzzy Logic system is a rule-based system comprising five components: fuzifier, fuzzy rules, inference, type-reducer and defuzzifier.

Using information about main economical parameters (OPR, WDR, INV, OEX, GDR) for the Azerbaijan [6] and world economy [7] by using expert opinion were constructed supporting parameters of the model, which is illustrated allowing table:

Parameters of the model table 1

Indicators	Low	Average	High
INV	- ∞ – 2.00	1.50 – 4.00	3.50 - ∞
OPR	15.00 – 35.00	30.00 – 50.00	45.00 - ∞
OEX	400.00 – 2000.00	1900.00 – 5000.00	4500.00 - ∞
WDR	- ∞ – 0.50	0.40 – 3.00	2.50 - ∞
GDR	0.80 – 5.00	4.50 – 11.00	10.00 – ∞

At the fuzification stage we have used a Gaussian primary membership function with fixed mean, $\boldsymbol{m}$, but uncertain standard deviation $\boldsymbol{w}(\boldsymbol{x}) = \exp\left[-\frac{1}{2}\left(\frac{\boldsymbol{x}-\boldsymbol{m}}{\boldsymbol{\sigma}}\right)^2\right] \quad \boldsymbol{\sigma} \in [\boldsymbol{\sigma}_1, \boldsymbol{\sigma}_2]$

For each value of $\boldsymbol{\sigma}_i$ there is a corresponding membership curve. In the case of the interval type-2 fuzzy set, the upper membership function is:

$$\overline{\boldsymbol{w}}(\boldsymbol{x}) = \boldsymbol{N}(\boldsymbol{m}, \boldsymbol{\sigma}_2; \boldsymbol{x})$$

The lower membership function is defined by - $\underline{\boldsymbol{w}}(\boldsymbol{x}) = \boldsymbol{N}(\boldsymbol{m}, \boldsymbol{\sigma}_1; \boldsymbol{x})$.

For each interval of the table 1 we have computed mean $\boldsymbol{m}_{ij}$ (i=1,..,5; j=1,2,3) and standard deviation $\boldsymbol{\sigma}_{ij}$ (i=1,..,5; j=1,2,3). Using Gaussian membership function mean and

standard deviation upper and low membership functions have been defined (fable 2, 3 and fig. 1).

Upper degree of the membership function table2

Upper	Low		Average		High	
	$\underline{w}_{i1}$	$\overline{w}_{i1}$	$\underline{w}_{i2}$	$\overline{w}_{i2}$	$\underline{w}_{i3}$	$\overline{w}_{i3}$
INV	0.00	2.33	1.08	4.42	2.25	0.00
OPR	11.67	38.33	26.67	53.33	33.33	0.00
OEX	133.33	2266.67	1383.33	5516.67	3333.33	0.00
WDR	0.00	0.58	-0.03	3.43	1.58	0.00
GDR	0.10	5.70	3.42	12.08	8.33	21.67

Lower degree of the membership function table3

Lower	Low		Average		High	
	$\underline{w}_{i1}$	$\overline{w}_{i1}$	$\underline{w}_{i2}$	$\overline{w}_{i2}$	$\underline{w}_{i3}$	$\overline{w}_{i3}$
INV	0.00	1.67	1.92	3.58	4.75	0.00
OPR	18.33	31.67	33.33	46.67	56.67	0.00
OEX	666.67	1733.33	2416.67	4483.33	5666.67	0.00
WDR	0.00	0.42	0.83	2.57	3.42	0.00
GDR	1.50	4.30	5.58	9.92	11.67	18.33

Using economical data for Azerbaijan for 1997-2008, fuzzy logic rules were constructed years for each input and output parameter, which are demonstrated in table 4.

System of rules for 1997-2008 years. table 4

Years	INV	OPR	OEX	WDR	GDR
1997	Low	Low	Low	High	Average
1998	Low	Low	Low	Average	Average
1999	Low	Low	Low	High	Average
2000	Low	Low	Low	High	High
2001	Low	Low	Average	Average	Average
2002	Average	Low	Average	Average	High
2003	Average	Low	Average	Average	High
2004	High	Low	Average	Average	Average
2005	High	Average	High	High	High
2006	High	High	High	High	High
2007	High	High	High	High	High
2008	High	High	High	Average	High
2009	High	High	High	Average	Average

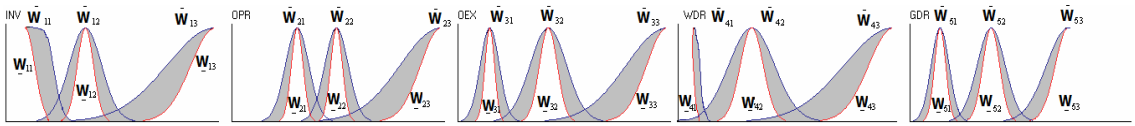

Fig.1 Membership functions interval type-2 fuzzy logic set.

Using economical data for Azerbaijan for 2000 year and Mamdani fuzzy logic inference methods solution of the problem has been obtained and result is illustrated in the following figure 2.

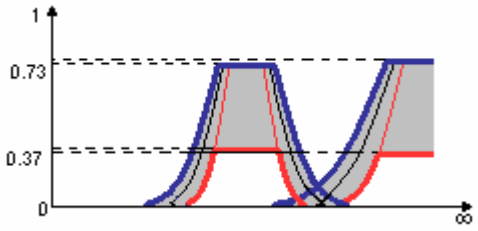

Fig.2 Type-2 Fuzzy Sets.

In the stage of type reduction we have applied Karnik-Mendel algorithm which is explained as follows:

The y_l determination:

1. Initialization $\underline{x}_i (i = \overline{1,2,....,N})$ through equation in order to increase, i.e. $\underline{x}_1 \langle \underline{x}_2 \langle ... \langle x_N$. Wait selection w_i according to $\underline{x}_i$.

2. Calculate w_i through $w_i = \dfrac{\underline{w}_i + \overline{w}_i}{2} \qquad i = \overline{1,2,...,N}$

then calculate $y = \dfrac{\sum_{i=1}^{N} \underline{x}_i w_i}{\sum_{i=1}^{N} w_i}$

3. Find $k (1 \le k \le N-1)$, such that, $\underline{x}_k \le y \le \underline{x}_{k+1}$

4. Set $w_i = \begin{cases} \overline{w}_i & i \le k \\ \underline{w}_i & i \rangle k \end{cases}$

and calculate $y' = \min\limits_{\forall w_i \in [\underline{w}_i, w_i]} \dfrac{\sum_{i=1}^{N} \underline{x}_i w_i}{\sum_{i=1}^{N} w_i} = \dfrac{\sum_{i=1}^{K} \underline{x}_i \overline{w}_i + \sum_{i=K+1}^{N} \underline{x}_i \underline{w}_i}{\sum_{i=1}^{K} \overline{w}_i + \sum_{i=K+1}^{N} \underline{w}_i}$

5. If $y' = y$, stop and set $y_l = y$ and call k L. Otherwise go to the stage 6.

6. Set $y = y'$ and go to stage 3.

The y_r determination:

1. Initialization $\overline{x}_i (i = 1,2,....,N)$ in order to increase, i.e. $\overline{x}_1 \langle \overline{x}_2 \langle ... \langle \overline{x}_N$. Wait selection w_i according to $\overline{x}_i$.

2. Calculate w_i through $w_i = \dfrac{\underline{w}_i + \overline{w}_i}{2} \qquad i = 1,2,....,N$

then calculate $y = \dfrac{\sum_{i=1}^{N} \overline{x}_i w_i}{\sum_{i=1}^{N} w_i}$

3. Find $k (1 \le k \le N-1)$, such that, $\overline{x}_k \le y \le \overline{x}_{k+1}$

4. Set $w_i = \begin{cases} \underline{w}_i & i \le k \\ \overline{w}_i & i \rangle k \end{cases}$

and computed $y' = \max_{\forall w_i \in [\underline{w}_i, \overline{w}_i]} \frac{\sum_{i=1}^{N} \underline{x}_i w_i}{\sum_{i=1}^{N} w_i} = \frac{\sum_{i=1}^{K} \overline{x}_i \underline{w}_i + \sum_{i=K+1}^{N} \overline{x}_i \overline{w}_i}{\sum_{i=1}^{K} \underline{w}_i + \sum_{i=K+1}^{N} \overline{w}_i}$

5. If $\boldsymbol{y}' = \boldsymbol{y}$ stop and set $\boldsymbol{y}_r = \boldsymbol{y}$ and call k R. Otherwise go to the stage 6.
6. Set $\boldsymbol{y} = \boldsymbol{y}'$ and go to stage 3.

Application this algorithm gives us following results: $\boldsymbol{y}_r = 12.84; \boldsymbol{y}_l = 9.75$. Result of defuzzification $\boldsymbol{y}_s = \frac{9.75 + 12.84}{2} = 11.3.$ Difference between calculated and factual mean equals to 0.275 point. This process of calculation were apllied for every year between1997-2009 and two rules with minimum deviation have been choosen for forecasting the GDP growth rate for Azerbaijan in 2010-2012 years. Results are illustrated in the following table 5.

Results of forecasts table5

Forecasting	Years	Upper			Center			Lower		
		y_l	y_c	y_r	y_l	y_c	y_r	y_l	y_c	y_r
Pessimistic	2010	15.0	17.0	19.0	15.0	18.6	22.2	15.0	20.3	25.5
	2011	24.4	26.4	28.3	24.4	28.0	31.6	24.3	29.6	34.8
	2012	33.7	35.7	37.6	33.7	37.3	40.9	33.7	38.9	44.1
Optimistic	2010	19.3	21.9	24.4	18.7	22.5	26.3	18.1	23.1	28.1
	2011	28.6	31.2	33.7	28.0	31.8	35.6	27.4	32.4	37.4
	2012	37.9	40.5	43.0	37.3	41.1	44.9	36.7	41.7	46.7

Application of the type-2 fuzzy sets gives us possibility to get several forecasted variants of economical development and choose better parameters for management of the socioeconomic system.

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