NEURO-FUZZY BASED APPROACH TO THE ASSESSMENT OF INNOVATIVE PROJECTS

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Abstract: A proposition of the Adaptive Network-Based Fuzzy Inference System ANFIS for the assessment of innovative projects is presented in the paper. The most important aspects of innovative project's analysis are characterised and then (chosen) innovation criteria were used to assess innovation from the point of view of a risk. The example of neuro-fuzzy inference system is constructed with the empirical data for selected enterprises from Opole Province.

Keywords: Innovation, assessment of innovative project, innovative risk, ANFIS.

1. Introduction

Making economic decisions is connected with calculating profit and loss that is looking for the best possible solution of a given decision problem. This action is related to the decision-making process which consists in elaborating and analysing a given set of solutions variants. Regardless of the decision-making subject, the process is always directed into one of the possible ways of a given purpose achievement [1, 2].

Today, the world of science and business pays a lot of attention to the aspect of *innovation.* It was J.A. Schumpeter who introduced it to economic sciences determining five possible situations connected with the innovation importance [2, 4]. Innovations are characterised as new solutions, improvements of a purposefully designed character. They are aimed at the first (in a given area/society) practical application in the context of achieving social and economic benefits. They determine new trends in the development of companies. However, their implementation is not easy. An effective improvement of innovations requires an analysis of risk which is connected with a given project.

During the realization of an innovative undertaking, numerous dangers can occur. The most important ones are those which cause that a enterprise does not achieve its targets. The risk analysed in the article concerns the fact of not achieving the targets set by a enterprise [4]. The literature on this subject concerns multiaspect approach to risk which is subject to analysis in the scope of:

- decision making theories,
- management theories,
- scientific and technological development process.

An analysis of an innovation risk is connected with the necessity of making an assessment of its technical and economic features in many aspects. Ideas of analysis are subject to an assessment from the point of view of many criteria. The most frequently enumerated elements are as follows [6]:

- chances of technological success,
- time of realisation,
- realisation cost,
- adjustment to market needs – demand,

- profit from the fulfilment.

A possibility of using the Adaptive Network-Based Fuzzy Inference System ANFIS to assess the technical innovation risk is presented in the article. Technical innovations concern technical and technological changes, which most often lead to the creation of product and process innovations [2, 4, 6, 7, 8]. System ANFIS combines the ability of presenting and processing fuzzy knowledge and the ability to study neuron networks. This tool is useful when the possessed data are not complete and the analysed process is characterised with non-linearity of analyses. Chosen conclusions made in the scope of the Innovative Economy Operational Programme (PO IG) for the years 2007-2013 and the Regional Operational Programme of Opole Province (RPO WO) for the years 2007-2013 were used in the system elaboration.

2. Innovative projects assessment

In the years 2007-2013 in Poland, the development of innovation was supported by many programmes realised in the scope of European funds. An example of such an action can be the Innovative Economy Operational Programme (PO IG) [10]. In Opole Province 41 requests for financial compensation were submitted out of which: 18 requests were recommended to the allocation of financial compensation. These requests were submitted in the scope of the Innovative Economy Operational Programme (PO IG), namely the paragraph 4.4 which is aimed at entrepreneurs making initial investment of high innovation potential. In the end, 16 requests were accepted. The value of the financial compensation of the fulfilled undertakings exceeded PLN 291 million [10, 12].

In this period, there was also a possibility of getting support in the scope of regional programmes which indirectly (by means of chosen priority axes) supported the development of innovation. An example of such a form of support for the Opole Province is the Regional Operational Programme of Opole Province (RPO WO) for the years 2007-2013, in particular its subparagraph 1.3.2 – Investment in innovation in companies. In the scope of this form of financial support, 182 projects of the total value exceeding PLN 556,20 million were fulfilled (the data at the end of October 2013) [13].

Financial support for the development of innovation in the enterprise is subject to an assessment because of the fact of stating conditions limiting the fulfilment of a given project. These conditions, depending on the kind of financial support can have different forms. However, they are usually connected with obligatory and additional indicators which in the area of necessary indicators form a potential set of acceptable solutions.

An assessment of requests is made in two stages, in the scope of formal requirements and the content. The list of necessary criteria for formal requirements is uniform. The second stage of assessment which is the result of a subjective experts' opinion is a problem. Experts have limit values of particular indicators given, however it does not change the fact that in the end, they make their own evaluation by giving a particular number of points according to their own views. Such a way of assessment does not allow to compare the submitted applications in an objective way. It is possible to somehow generalize experts' opinions by means of using the neuro-fuzzy system to assess the risk connected with innovation projects. Knowing the risk connected with fulfilment of a given project we are able to make an objective assessment of an innovation project.

3. Innovative projects assessment criteria

The decision making process concerning innovation is always connected with risk. It is possible to divide this process into activities connected with (see [14]):

- subjective assessment of a given task (problem),
- evaluation of potential results,
- assessment of the project – stating the risk connected with the project fulfilment,
- choice (to implement or not).

In the first stage, the main conditions limiting the decision on the implementation or rejecting a given project are stated. The following criteria were chosen to the system construction:

1. The size of enterprise – characteristics which in an important way relates to the enterprise possibilities in the context of financing of innovation. Four values are acceptable: 1 – micro-enterprise, 2 – small enterprise, 3 – medium enterprise, 4 – large enterprise.
2. Innovation scale – market success of innovation is related of availability of a given solution in the market. So innovation scale was presented as a one of classification of innovation (criterion of novelty): 1 – scale of world, 2 – scale of country, 3 – scale of industry or enterprise.
3. Period of usage of the technology in the world - the project is very risky when the technology related to it is used in the world for a shortly period. It is due to the assumption that the technology is not completely checked/ tested as far as chances of technical success are concerned. Two values are acceptable: 1 – less than one year, 2 – no longer than three years.
4. Period of project's realisation – an indicator directly related with the cost criterion of the innovation's assessment.
5. The ratio of external financing to the size of the whole project – an indicator which informs how great is the loan demand connected with the realisation of the innovation.
6. Current ratio – indicator which informs about the capacity of the enterprise to pay all current liabilities by liquidating the reserves of current assets.
7. Debt ratio – a ratio of total debt x 100% to total assets.

Evaluation of objects is based on assigning required values to chosen criteria. The third stage is set by the system on the basis of the entered training data. The final result informs about a degree of risk connected with an implementation of a given project expressed in points. An assessment of a project is related to searching the set of admissible solutions that is such solutions in which risk is acceptable. On such a basis a final decision concerning allocation of financial support to a given project is made.

4. **Neuro-fuzzy system proposed by J.-S. R. Jang**

A popular neuro-fuzzy system implemented by J.-S.R. Jang – Adaptive-Network-based Fuzzy Inference System, ANFIS [15] – is used in order to build an automatic system for the innovative projects risk assessment. This system uses a set of conditional fuzzy rules in the form of Takagi-Sugeno-Kanga (TSK). A general form of the model can be presented as follows [15]:

$$\textbf{If } x_1 \text{ is } A_1 \text{ and } \ldots \text{ and } x_N \text{ is } A_N \textbf{ then } y=f(x_1,x_2,\ldots,x_N) \tag{1}$$

where: x_n (n=1,…,N) constitutes system input, which is described by linguistic values A_n and the system output y is a linear dependence f of the input values. For the first order fuzzy system TSK i-th output $y^{(i)}(\mathbf{x})$ is in the following form:

$$y^{(i)}(\mathbf{x}) = p_0^{(i)} + p_1^{(i)}x_1 + p_2^{(i)}x_2 + \ldots + p_N^{(i)}x_N = \mathbf{p}^{(i)T}\mathbf{x}' \tag{2}$$

where: $\mathbf{p}^{(i)}$ means N+1 dimensional function parameters vector, and $\boldsymbol{x}$' – output vector with an additional element equal to 1, $\mathbf{x}' = \begin{bmatrix} 1 \\ \mathbf{x} \end{bmatrix}$.

ANFIS reflects the way fuzzy logic works by means of neuron network based on four hidden layers. Neuron network for the system with N inputs, one output and two exemplary (K=2) conditional rules is presented in the Figure 1.

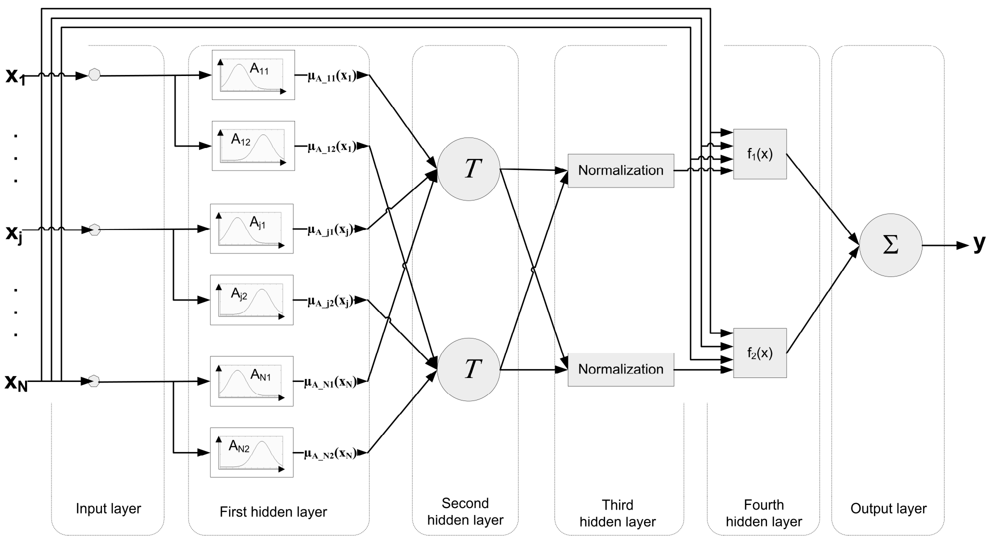

Fig. 1. The ANFIS system which reflects inference of the TSK model with N inputs, one output and two conditional rules

Each layer of the ANFIS network is composed of neurons making the following calculations [15], [16]:

Input layer. Calculations are not made in this layer, only input signals are sent to the first hidden layer.

The first hidden layer. Elements of this layer reconstruct functions of fuzzy sets membership A_{nk}, n=1,2,…,N; k=1,2,…,K, where n means the number of input, k – the number of a rule. The first hidden layer is composed of NK neurons, the output signals of which present the value of an appropriate membership function.

The second hidden layer. This layer is composed of K neurons and calculates the degree of activation ($\tau^{(k)}$ for k-th rule) that is an assessment of premises fulfilment of each conditional rule. An appropriate t-norm operator of N arguments is used for this purpose.

The output value of k-th neuron from the second hidden layer can be written in the following form:

$$o_2^{(k)} = \tau^{(k)} = T(\mu_{A_{1k}}(x_1), \mu_{A_{2k}}(x_2), ..., \mu_{A_{Nk}}(x_N)) = \prod_{n=1}^{N} \mu_{A_{nk}}(x_n) . \quad (3)$$

The third hidden layer. This layer is composed of K neurons, which calculate standardised activation degrees of each conditional rule. Then, a standardised activation degree of k-th rule ($\tau_{nor}^{(k)}$) that is the output value of k-th neuron from the third hidden layer can be written in the following form:

$$o_3^{(k)} = \tau_{nor}^{(k)} = \frac{\tau^{(k)}}{\sum_{i=1}^{K} \tau^{(i)}} . \quad (4)$$

The fourth hidden layer. This layer is also composed of K neurons and each of them determines the product of the rule conclusion and standardised activation degree of this rule in the following way:

$$o_4^{(k)} = \tau_{nor}^{(k)} \mathbf{p}^{(i)T} \mathbf{x}' = \frac{\tau^{(k)} \mathbf{p}^{(i)T} \mathbf{x}'}{\sum_{i=1}^{K} \tau^{(i)}} . \quad (5)$$

The output layer. This layer is composed of only one neuron, determining the output value for the ANFIS network by means of adding values of the preceding layer outputs.

5. Construction of the neuro-fuzzy system to assess innovative projects

The construction of the neuro-fuzzy system is based on data coming from experiments. That is why 48 innovative undertakings for companies of different size were collected and analysed. Examples of innovative solutions (fulfilled in the years 2007-2013) came from Opole Province (Poland). Values of particular assessment criteria were taken from business plans of analysed undertakings. The final assessment of the project risk in the scale from 0 to 10 was given by experts. The set of data was divided at random into training data (40 records) and testing data (8 records).

The first stage of getting to know the network of the ANFIS type is to determine the membership function of fuzzy sets included in premises of conditional rules. A traditional method of dividing the input area by means of equal grid partition has exponential dependence of the number of rules on the number of system inputs. That is why, it makes it impossible to apply the system of high number of inputs, so it will not be used to assess innovative projects. In such a case, a method of data clustering known as *subtractive clustering* (an extension of a mountain clustering method proposed by R. Yager [17]) is applied and it causes generation of significantly smaller knowledge base having "incomplete" base of rules.

One of the most important parameters of the algorithm is the value of the radius of clustering centre – the influence of this parameter on the number of created conditional

rules (Figure 2) and the value of errors (Table 1) was analysed. The larger value of the radius results in less the number of rules. During the analysis, the Gaussian function as a membership function and a linear function of the model output were used.
What is more, the neuro-fuzzy system makes it possible to use the base of knowledge specified by the expert as input assumptions in order to teach about the model. Such a solution requires, however, an appropriate definition of the knowledge base, what is not a trivial issue in view of the conclusion with input dependency functions.

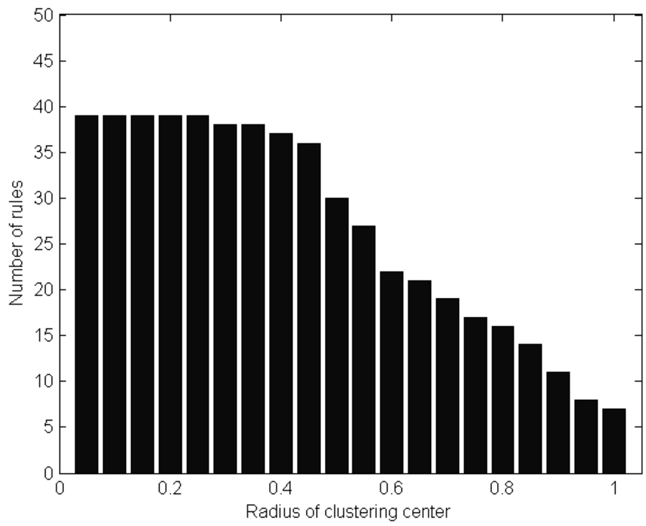

Fig. 2. The influence of the radius of clustering centre on the number of conditional rules

The next step is to choose the optimization method of the created neuro-fuzzy structure. The implementation of the neuro-fuzzy system in Matlab offers two methods to choose from: a classic algorithm of backpropagation and the so-called hybrid method which is a combination of the algorithm of backpropagation with gradient descent and the method of least squares. The recommended hybrid method was used as it is a quickly convergent and very effective algorithm.

6. Results of analysis in the ANFIS system

Several neuro-fuzzy networks structures were analysed. The structures had a different number of rules, depending on the applied value of the clustering centre radius. In order to assess the quality of the network training a root mean square error (RMS) of the network reply for training and testing data sets is applied:

$$RMS = \sqrt{MSE} = \sqrt{\frac{1}{m}\sum_{i=0}^{m-1}\left(y_i - y'_i\right)^2} \qquad (6)$$

where: m – the number of tests made,

y_i – the anticipated value of i-th test of the network,

y'_i – the real value of i-th test of the network.

When learning the neuro-fuzzy network, the RMS error values are decreasing together with successive training epochs (Figure 3). Initial membership functions for input criteria are precisely adjusted. Examples of final membership functions are presented in the Figure 4.

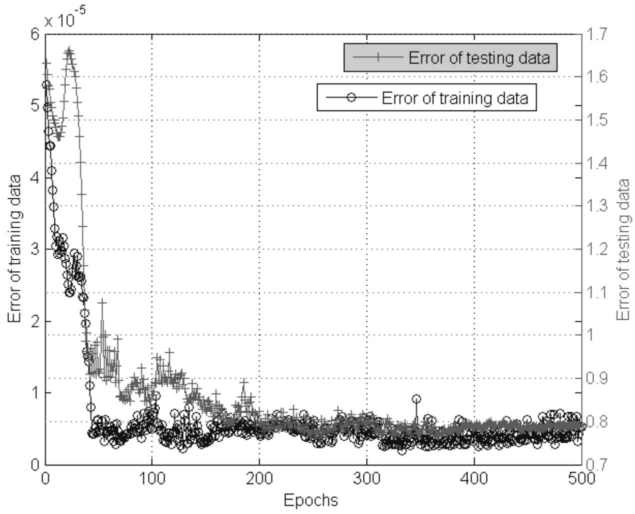

Fig. 3. The values of RMS errors in successive epochs for the neuro-fuzzy system with 11 rules

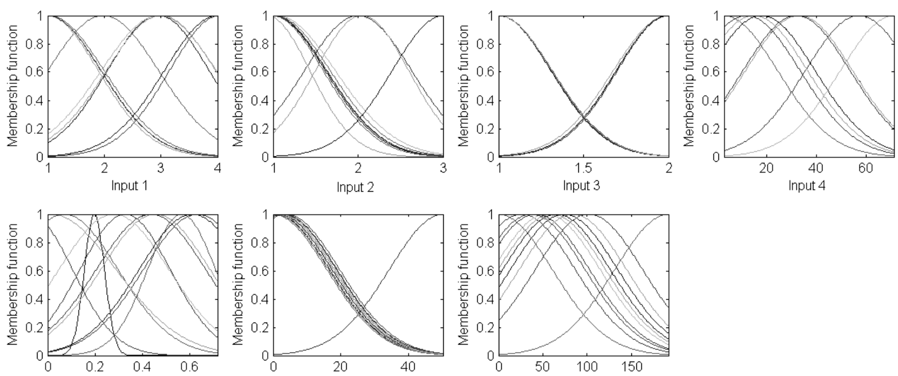

Fig. 4. Adjusted membership functions for inputs, for the neuro-fuzzy model with 11 conditional rules (input 1 – the size of enterprise, input 2 – innovation scale, input 3 – period of usage of the technology in the world, input 4 – period of project's realisation, input 5 – the ratio of external financing to the size of the whole project, input 6 – current ratio, input 7 – dept ratio)

The values of RMS errors for both training and testing data are calculated for all analysed network structures. A smaller amount of rules does not have any negative influence on adjusting the model to data. Conversely, the most efficient mapping of the assessment results for testing data is obtained for the system of a smaller number of rules (11 rules). The results of calculations are presented in the Table 1 and in the Figure 5.

Tab. 1. Results of the ANFIS system

Radius of clustering center	Number of rules	Error RMS for training data	Error RMS for testing data
0,05	39	3,99497E-06	1,633685315
0,1	39	3,62259E-06	1,64044571
0,15	39	4,36669E-06	1,667469742
0,2	39	6,19844E-06	1,668625113
0,25	39	5,44093E-06	1,628474892
0,3	38	1,0328E-05	2,308489244
0,35	38	9,48172E-06	1,452781394
0,4	37	1,53781E-05	3,199982751
0,45	36	1,35533E-05	3,331422834
0,5	30	3,28984E-05	1,255996636
0,55	27	3,29894E-05	1,283981372
0,6	22	1,16001E-05	1,210277871
0,65	21	1,14449E-05	1,145590157
0,7	19	3,03685E-05	1,329650369
0,75	17	3,8474E-05	1,132757151
0,8	16	4,29507E-05	0,941956272
0,85	14	8,83532E-05	1,020484202
0,9	**11**	**3,26114E-06**	**0,761656623**
0,95	8	2,12275E-05	1,266826641
1	7	1,97E-05	0,988542016

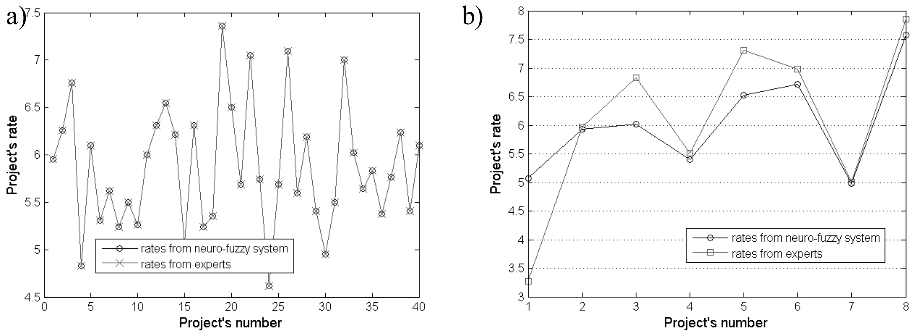

Fig. 5. A comparison of innovative projects assessment:
a) for training data, b) for testing data

7. Conclusions

The neuro-fuzzy system ANFIS is an auto-regulating system which adjusts the shape of the membership functions in the premises and polynomial coefficients in the conclusion to measurement input-output data. In case of a system used to assess the innovative projects risk, the created tool can well reflect the results of outputs for training data. In case of testing data, errors are significantly bigger. It results from the fact that assessment of the innovative projects risk is a subjective experts' opinion, so an assessment algorithm which has once been elaborated cannot reflect detailed assessments for all projects. Thus, it is possible to draw conclusions that an application of the elaborated tool to assess the innovative projects risks will make it possible to objectify assessments given by organisations supporting innovation development in the country or in a given region. An example of using a created neuro-fuzzy system to assess the innovation projects risk is presented in the Table 2. It is certain that the tool is not able to eliminate an expert in the assessment process, it can however be an important element supporting the process.

Tab. 2**.** An example of using a created neuro-fuzzy system to assess the innovation projects risk

Size of enterprise	**Innovation scale**	**Period of usage of the technology in the world [year]**	**Period of project's realisation [month]**	**The ratio of external financing to the size of the whole project**	**Current ratio**	**Debt ratio**	**Innovation project risk (skale 0 -10)**
small	world	<1,3>	71	0,26	1,18	70,79	6,49
large	country	(0,1>	9	0,30	1,47	46,83	5,31
medium	world	(0,1>	18	0,27	1,55	65,34	5,62
micro	world	<1,3>	15	0,52	0,90	71	7,10
large	enterprise	(0,1>	28	0,28	1,92	38,40	5,86

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