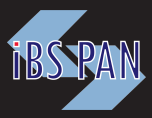

INSTYTUT BADAŃ SYSTEMOWYCH
POLSKIEJ AKADEMII NAUK

TECHNIKI INFORMACYJNE TEORIA I ZASTOSOWANIA

Wybrane problemy
Tom 4 (16)

poprzednio

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I ZARZĄDZANIU

Pod redakcją
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DYNAMIC PROGRAMMING FOR R&D SECTOR DEVELOPMENT

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Abstract. We propose a systemic approach to the development of R&D sector in Poland. The System maps the R&D sector using a neural network, which provides an object for dynamic programming in the task of searching for a better solution.
Keywords: R&D sector, neural networks, dynamic programming, the task of searching for a better solution

1 INTRODUCTION

The sustainable development of the country in the time of globalization requires a systemic approach to development planning. In recent years, appear an increasing number of documents and reports that introduce the long-term forecasting of states development scenarios. Development scenarios pointed outs risks that may significantly impact on slowing economic growth. Threats removal should begin as soon as possible, and an important role in solving problems must meet the Research and Development (R&D) sector that its potential should use for proper recognition and correction recommendations in a timely fashion, and well in advance.

R&D sector condition depends on very many factors is also inscribed in the country's economic situation, strongly depends on the innovative approach of politicians and business executives. An essential part of the development of the R&D sector is the proper use of the resources that are allocated for the sector.

The system is required to solve problems, because due to the complexity of problems intuitive solutions will not return acceptable results. One of the possible system solutions is economic model of the R&D sector. The model is mapped to neural network which provides an object for dynamic programming where decision-making process may improve the outcome of the sector. An important role in improving the economic performance of the country should play to develop the R&D sector, which in the world of global economy has a big impact on the performance of the country's development.

In the paper we would like to present the assumptions of supporting system, which offers executing long-term analysis of the R&D sector development. It will support decision-making processes, enabling to obtain the best results in its development planning for decisions.

It will be presented to the R&D sector modeling using neural network and search for a better solution using dynamic programming. Dynamic programming is applied in the search for decision-making data which may improve the results achieved by R&D sector.

2 THE PROPOSED SYSTEM SOLUTION

Emergence of the reports ”Poland 2030. The third wave of modernity” [2], ”Poland 2030. The Challenges of Development” [3], ”Foresight 2020 Poland” [17] and OECD [13] is an important step in terms of strategic thinking about the future development of the country with the participation of the R&D sector. However, the documents represent only a starting point from which we can start a systematic approach leading to the implementation of the long term strategy.

Earlier start of strategy implementation will create the higher chances to achieve success in the field of economic development, scientific and social development of the country. Given the scale of the project, it is important to approach to system implementation of the strategy versus intuitive approaches. We present hereafter the elements of execution, which in our opinion should be taken into account for government organizations, academics and businessmen participating in the implementation of the strategy.

Implementation of the development strategy must consider the part of the R&D sector, which significantly can change the negative trend and the advance development of risk mitigation methods. If we face issue of restricted the people resources who can actively develop national product method of eliminate the risk is to increase the productivity of the resources making GDP.

Significant R&D infrastructure development is conducive to the emergence of innovative solutions. R&D infrastructure is a complex structure, which must be adapted to the financial and organizational state capacity. R&D infrastructures consist of:

- Polish Academy of Sciences
- R&D Units
- Higher education institutions operating in the field of R&D
- Knowledge and technology parks

• Innovative Enterprises

Appropriate organizational link between objects of scientific research circumstance, to ensure the proper financing of the necessary conditions for the success which in the long-term will be a trend reversal GDP in Poland presented in OECD report [13].

An important element of the system approach should be to find the most sensitive points of the system, which changes today, will help reverse the negative trend in the scale of decades.

System presented in this article is focused on improving the performance of R&D sector in Poland, so that by means of an appropriate sector strategies developed in support of the development of the country.

The implementation of long-term strategies and development can take place in an environment that is difficult to forecast in a dozen years. It seems like a reasonable approach to the challenges facing the system in the implementation of the strategy; this may increase the probability of implementation success. In addition, system approach allows eliminating the rudimentary errors which may appear in the definition of resources and financial capacity needed for the proper implementation of the strategy.

The proposed solution system supporting decisions during periods of long-term R&D sector is based on three pillars. The first pillar of the system is a model of R&D sector in Poland created with the use of neural network. The second pillar is dynamic programming, which uses a data delivered by first pillar to provide opportunities on analyzing impact of decision-making variables to system outputs. The third pillar is an expert or analyst that whereas the support system works in terms of limit values for the decision variables behavior system and seeks to ensure that the output parameters were the most suitable for development strategy in terms of acceptable input variable ranges.

3 R&D SECTOR MODEL BY NEURAL NETWORK

R&D sector model is a very important element of the proposed decision support system. Without that model it is hard-to-find elements need to be modified in order to achieve the expected goal. There are various methods for creating a model of R&D sector in Poland. In my opinion, an interesting method for modeling R&D sector in Poland is model based on neural network, next to the mathematical model or the statistical solution.

In reviewed bibliography we were not able to find out examples of models for R&D sector. Interesting solutions for macroeconomic model of the country was founded in the scientific descriptions by Ph. D. Paweł

Rościzak from the University of Łódz. His website, roszczak.com, presents EMIL and Makrosim applications based on neural networks. Makrosim is a project carried out at the University of Łódz. The aim of the project was to build a computer system that based on the introduced macroeconomic data allows a user to stimulate economic growth. EMIL is the econometric model of the Sweden economy, whose creators are Prof. Jan B. Gajda from the University of Łódz and Prof. Claes-Hakan Gustafson from the University of Orebro (Sweden). EMIL model is based on the demand and supply side of the economy, investments, expected inflation, depreciation of capital, export, demand change, dynamic features of supply and the balance of the labor market.

Data for R&D sector are available on the websites of statistical agencies including the Central Statistical Office (GUS, Poland) and Eurostat as well as in the reports and studies of the sector.

To build R&D sector model using neural network it is used the application Neuroph Studio developed by Zoran Sevarac and team of Belgrade University, Serbia.

Neuroph Studio application helps to create a neural network by sharing libraries Java Neural Network Tools and graphical user interface which allows creating, learning, testing and writing constructed neural network. Neuroph Studio supports most known neural network architectures.

3.1 DATA SELECTION

Data selection to the model of R&D sector in Poland has been performed based on the analysis of the sector structure, where areas of activity and decision-making variables were defined. The statistical data to be used for learning neural network should be verified by the following tests [16]:

- Chi-square test of independence,
- Correlation ratio,
- Coefficient of convergence Czuprowa,
- Evaluation of independence and correlation.

This is an important element in design of the system, because inappropriately selected data will affect the accuracy of the model of R&D sector in Poland then might lowered the quality of the outcome results.

3.2 NEURAL NETWORK LEARNING

Neural network learning takes place through the upload input to Neuroph Studio application. Data is prepared in the form of tables with input and

output data. Data is entered to the MLP (Multi-Layer Propagation) neural network with three hidden layers (16, 8, and 4).

Network learning takes place through the use of available data in the proportions 60/40 learning and testing data. The learning process ends when it reached the stop criteria as Max error = 0.01 and Learning Rate = 0.02

3.3 NEURAL NETWORK VERIFICATION

Neural network verification will be performed by comparing generated neural network forecasts with the empirical values [35] as following measures:

$$MPE = \frac{1}{T}\sum_{t=1}^{T}\frac{(\tilde{y}_t - y)}{y_t}100, \tag{1}$$

where MPE is percentage error, $\tilde{y}_t$: number of inputs and y_t: empirical value.

$$MAPE = \frac{1}{T}\sum_{t=1}^{T}|\frac{(\tilde{y}_t - y)}{y_t}|100, \tag{2}$$

where MAPE is absolute percentage error, $\tilde{y}_t$: forecast value and y_t: empirical value.

$$RMSPE = \sqrt{\frac{1}{T}\sum_{t=1}^{T}\frac{(\tilde{y}_t - y)}{y_t}}, \tag{3}$$

where RMSPE - the root means square percentage error, $\tilde{y}_t$: forecast value and y_t: empirical value.

3.4 CONVERSION OF NEURAL NETWORK IN THE FORM OF AN EXPLICIT

Dynamic programming is used an explicit form of neural network in the form of a matrix. For a one-way three-layer neural network outputs from each of the layers go on entry into another layer of neurons.

Hereafter is a schema of the multilayer one-way network: where R - number of inputs, S^w- number of neurons in the first layer, the second and third; f^w - activation function of the neuron layer, p Ű input data, W^w - weight matrix layer, b^w- value of the bias layer, a^w - output layer.

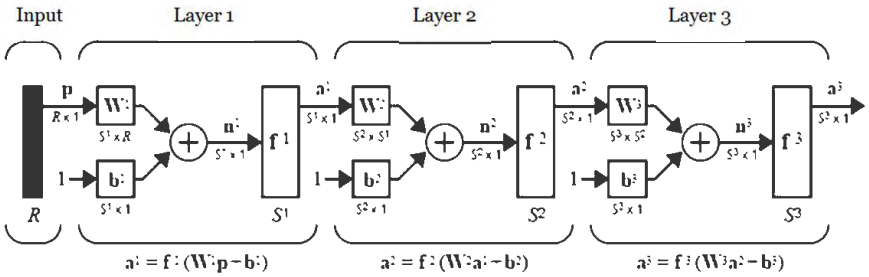

Fig. 1. Duzinkiewicz K., Grochowski M. -Three layer one-way neural network schema using Mathlab symbols [8]

The dimensions of the matrix for the neurons of the layer are as follows [8]:

$$p = \begin{bmatrix} p_1 \\ p_2 \\ \vdots \\ p_R \end{bmatrix} W = \begin{bmatrix} w_{1,1} & w_{1,2} & \cdots & w_{1,R} \\ w_{2,1} & w_{2,2} & \cdots & w_{2,R} \\ \vdots & \vdots & \ddots & \vdots \\ w_{S,1} & a_{S,2} & \cdots & w_{S,R} \end{bmatrix} b = \begin{bmatrix} b_1 \\ b_2 \\ \vdots \\ b_S \end{bmatrix} a = \begin{bmatrix} a_1 \\ a_2 \\ \vdots \\ a_S \end{bmatrix} \tag{4}$$

Where:

p - input data vector, $R \times 1$,

W - weight matrix layer, $S \times R$,

b - matrix biases, output data matrix, $S \times 1$,

R - number of inputs,

S - number of neurons in layer.

The explicit form of the equation of neural network with three layers of hidden has the form:

$$a^3 = f^3(W^3 f^2(W^2 f^1(W^1 p + b^1) + b^2) + b^3) \tag{5}$$

where a^3 is the output of the third layer, f^w: activation function of the neuron layer, W^w: weight matrices layers, p: input data matrix and b^w: matrix of the bias layer.

For dynamic programming system data is moving from the neural network outputs in the form of a matrix of weights and transformations functions. Dynamic programming will give an expert or a system analyst the decision-making data. Thus, dynamic programming system will evaluate the best solution with the desired data range of decision-making variables.

4 DYNAMIC PROGRAMMING

Dynamic programming problem has been referred to as seeking the best solution for the decision-making variables introduced by an expert or analyst, examining the impact of input variables for output parameters.

An expert or analyst can simulate behavior of using the preferred development strategy of R&D sector during the examined period of time. May apply different strategies by observing how the system responds to change the parameters of decision-making variables.

Dynamic programming problem is defined as the search for the better solutions for output parameters at intervals defined by the input parameters in the range defined by expert or analyst.

Dynamic programming problem is resolved using the DP2PNSolver package developed by [20], which enables to resolve issues in a dynamic programming.

DP2PNSolver utility contains modules on two levels: the first Level contains the entrance to the introduction of the specification for discrete problem DP.

The specification of the problem being processed is on Petri net interim (PN) representing the Bellman network (BN).

Interim tier problem is standardized to mathematical modeling problem. The optimal solution to the problem is provided by a second layer called the output in the form of a code (Java or Excel sheet).

We use the package DP2PNSolver [24], which is available in the personal computer application with installed Java SDK 1.4.2 with the compiler ”javac”.

5 DYNAMIC PROGRAMMING DATA VERIFICATION

Input to the dynamic programming problem come from a neural network model, which is the model of the R&D sector in Poland. A very important step before defining a dynamic programming problem is to verify whether the problem is resolved against of Markov property [11].

This means that when deciding d1, d2, ..., dk in subsequent k stages the stage sn+1 at the end of the stage n , that depend entirely on the stage of sk+1 after decision dk+1, dk+2, ..., dn.

If the problem has properties you can apply dynamic programming method for Markov and Markov property follows the principle of Bellman optimality:

"The optimal Strategy has the property that, regardless of what was the initial state, and what were the initial decisions, the remaining decisions must create optimum strategy due to the condition being the result of these initial decisions."

5.1 DYNAMIC PROGRAMMING TASK

Dynamic programming task is defined as the search for the better solutions for output parameters at intervals defined by the input of an expert or analyst:

$$a_5^3 = f^3(W^3 f^2(W^2 f^1(W^1 p + b^1) + b^2) + b^3), \tag{6}$$

where a^3 is the matrix output, a_1^3: investment in fundamental research, a_2^3: investment in R&D sector, a_3^3: investments in innovative enterprises, a_4^3: investment in science and technology parks, a_5^3: transfer the results to the economy, f^n: activation functions of neurons in each layer neural network, W^n: weight matrices of neurons in each layer neural network, b^n: bias in the individual layers of the neural, p_n: decision-making matrix input, p_1: expenditures on R&D sector, p_2: business expenditures on R&D sector, p_3: expenditures on education system, p_4: expenditures for the support system and p_1, p_2, p_3, p_4 belong to a range of expert decision-making data.

Neural network maps impact go to exit through a system of weights of neurons that are explicit. The weight shall be transferred to the dynamic programming system, so we have a system reproduces the behavior of the R&D sector-development on the input parameters, which will be introduced by an expert or analyst. From this stage dynamic programming system is ready for analysis and presentation of results for the search for a better solution.

5.2 BETTER SOLUTION APPROACH

The concept of better solution approach might be a subject of experts preferences, concerning the development of R&D sector. In our opinion, a better solution is the direction the development of the sector R&D, which allows maximizing the transfer of research results to economy and business. Better solution is based on the following decision-making variables:

- Expenditures on R&D sector,
- Business sector expenditures on R&D sector,
- Expenditures on education system,
- Expenditures for the support system.

Decision-making variables in range preferred by expert or analyst give data output on relocation resources where transfer of R&D sector research results to economy is set up as goal for maximizing allocation:

- Investment in fundamental research,
- Investment in R&D sector,
- Investments in innovative enterprises,
- Investment in science and technology parks.

We have defined goal for the system to get better results on transferring R&D outcomes to economy what might positively influence on economy development.

The transfer of R&D sector research results to economy [23] is to our understanding a key element that can prevent long-term slowdown of GDP growth, what determined our own definition of better solution. Better solutions approach is implemented in dynamic programming problem as following steps:

•For each input range is the maximum value of dynamic programming task decision transfers the results of research to the economy and business.

•Dynamic programming task is performed in four steps separately for any given decision.

•In each step, only one decision is a test range, the remaining data is fixed. The value of a decision giving the greatest value of transfers in the next step, for the next decision is the value of a constant.

•The result is a collection of four decision-making parameters that give the value of the maximum transfer of the results of R&D sector to business and the economy.

5.3 CONCLUSION

Study the possibility of improving the results of the R&D sector is very interesting research. This seems particularly important when we get the signs that the passive observation of the surroundings will not produce results, which can be regarded as satisfactory.

Find the appropriate factor blocking the development of the country requires a systems approach with a large commitment to the R&D sector which has the necessary intellectual capital to solve nontrivial R&D sector development problems. our suggestion of the system solution is based on the methodology of neural network and dynamic programming, so that first to create a model R&D sector in Polish and then find the most sensitive parameters and propose realistic solutions that will reduce the risk of slowdown growth of GDP.

The signal of the possible not sophisticated development gross domestic product growth of 1% in the years 2030-2060 according to OECD forecasts must unleash social energy to find reasons, recommendation changes and perfect execution of these changes to the country's growth has not been below aspirations of society.

It is important to approach system solution with decision support system as intuitive problems solving is not sufficient to resolve issues in complex environment of global economy. System solution might increase success rate of eliminating factors influencing on slowdown growth of GDP. R&D sector must play key role on supporting sustainable state development.

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KONIECZNOSC INTELIGENTNEGO PROGRAMOWANIA DYNAMICZNEGO DLA ROZWOJU SEKTORA B+R

Streszczenie. W artykule przedstawiono propozycje systemowego podejścia do zagadnienia rozwoju sektora B+R w Polsce. System odwzorowuje sektor B+R z wykorzystaniem sieci neuronowej, która stanowi obiekt dla programowania dynamicznego w poszukiwaniu lepszego rozwiązania.
Słowa kluczowe: B+R, sieci neuronowe, programowanie dynamiczne, poszukiwanie lepszego rozwiązania

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