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MODERN SOFTWARE TOOLS IN SUSTAINABLE DEVELOPMENT PROGRAMMING

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ABSTRACT: The article attempts to analyse existing approaches to management support of sustainable development particularly with use of tools based on neural networks. The article uses the analysis of literature to exemplify the implementation of computer-aided regional governance in the context of implementation of the principles of sustainable development. The added value is the presentation of examples of the usage of neural networks for programming of sustainable development at the regional level.

KEY WORDS: sustainable development, sustainable development indicators, neural networks, sustainable development programming

Introduction

The objective of the sustainable development idea is to increase the quality of life of societies to the requirements for sustainable ecological, spatial and social development. It has been accepted by 179 countries in the world. However, the adoption of a set of recommendations and guidelines for sustainable development is not synonymous with their compliance. Therefore, alongside with attempts to implement the principles of sustainable development, the need to create standards for measuring the progress of its implementation has arisen. The Division for Sustainable Development of United Nations has prepared a comprehensive measurement tool which include the monitoring of all spheres of human activity: economic, environmental, cultural and institutional. In addition to the indicators of the United Nations, there are other indicators for monitoring the implementation of sustainable development. The most important of them are the European sustainable development indicators. These indicators allow to compare the development of the EU member states.

The scope of this article is to describe the use of artificial neural networks for decision support in the socio-economic process. A neural network ability to approximate any kind of deterministic function, makes them particularly useful in the field of business, economic and environmental applications, which generally are compounds described by means of unspecified, non-linear functions. Optimizing decision-making process generally involves the enlargement of knowledge of the decision maker on the aspects that are the subject of a decision. Artificial neural networks can be used to assess the development of enterprises, cities, regions and countries. The aim of this article is to examine the usefulness of neural networks to optimize management decisions regarding sustainable development programming of the OECD countries, including Poland. On the basis of selected factors, the 29 OECD countries are rated and grouped according to the degree of development. Factors affecting the assessment of the implementation of sustainable development are grouped into four categories: economic, cultural, social and environmental.

An overview of literature

Nowadays it's difficult to find research field where solutions based on neural networks were not used, or at least were not attempts to use them (Tadeusiewicz, 2000, p. 3). Selected applications of neural networks have

been placed in table 1. A very serious issue is a small number of publications documenting unsuccessful attempts to apply neural networks in various computational problems. Moreover, this problem concerns also other computational methods. The value of publication is still associated with the successful application, while unsuccessful attempts also have an important cognitive feature. Unsuccessful attempts are good way to enrich knowledge about limitations of selected method.

Table 1. Neural networks economic applications

Sector	Application areas
Insurance	Decision support and risk management
Banking and finance	Reliability of debtors assessment, money laundering detection, time series prediction, predicting exchange rates, bankruptcy prediction, investment portfolio diversification, estate valuation, assessment of investment profitability, verification of profitability of contracts
Logistics	Trips scheduling, routes planning
Production management	Production process control, project management, service operations planning, forecasting the demand level
Marketing	Consumer characteristics identification, sales forecasts, marketing strategies targeting
Power engineering	Energy demand forecasting, minimizing the cost of Energy production

Source: (Lorek, 2010, p. 107).

An interesting example of neural networks application is a system for control and evaluation of sustainable development. The issue of sustainable development has an increasingly important role. Idea of the concept of sustainable development is dated to the beginning of the 70's (Rogall, 2010, p. 79). The concept of sustainable development is one of the most important category of modern economics.

Theoretical aspects of the definition of sustainable development implies specific practical action. In the practical sphere, sustainable development concept can mean (Borys, 1999, p. 68):

- perceiving the interdependence of economic phenomena, social and natural sciences, in particular linking the environment and quality of life of society;
- rejection of economic criteria supremacy and inclusion of neglected so far, environmental and social categories;
- balance between advantages and disadvantages must include economic, social and environmental issues, instead simple accounting involving only economic categories;

- assumption, that the natural environment is an organic entity, subject to evolutionary processes and incidental revolutionary transformations (usually due to human activities or natural disasters).

Sustainable development of the country requires a corresponding development at the regional level and specific areas within the regions. Developing a system for conducting an analysis of management decisions with respect to the regional economy, requires a number of assumptions. The most important assumptions are (Khanna et al., 1999, p. 113):

- consideration of the limitations of finite natural resources and the ability of assimilation of the environment;
- integrated approach to the issue of the interrelationship between natural resources and the environment;
- modeling of the economy as the processing of natural resources and their distribution in order to meet human needs and expectations;
- use as a measure of welfare satisfaction of citizens, instead of synthetic indicators as GDP;
- clearly highlighting the dimension and irreversibility of time;
- appropriate spatial distribution.

A very important issue is the proper selection of coefficients whose values affect the overall concept of sustainable development. Indication of whether a factor is an indicator of sustainable development is an extremely complex problem. This problem stems from the fact that sustainable development can't be considered as a single order. Rather, it is the whole set of objectives which are complementary whole. The shape of this total has been the subject of many discussions and debates which resulted in the development of ready sets of indicators that can be used to evaluate sustainable development at local, regional, national or global level. As a sets of indicators, the following sets could be used:

- UN indicators;
- OECD indicators;
- European Union indicators;
- indicators of other international institutions and organizations.

The shape of the presented set of indicators of sustainable development is a matter open to proposals and discussions. Therefore, it's expected that sooner or later, currently finished sets of indicators will change.

Research methods

Despite the large number of sets of factors affecting the level of sustainable development on a global scale, selecting a similar set on a regional scale

might be a problem. The factors which have the greatest impact on the sustainable development of urban areas are following (Diappi et al., 2017):

- level of the education of population;
- area of suburbs;
- unemployment and social exclusion level;
- condition of transport and technical infrastructure;
- crime rate;
- commercial service quality (gastronomy, leisure activities, commercial units);
- public service quality;
- life quality (density of population);
- leisure opportunities;
- economic development;
- natural environment quality;
- revitalization possibilities.

These factors were considered as a base to extract the training set for Self-Reflexive Neural Network (SRNN). The purpose of using this type of network is to provide a structure which changes in response to specific factors like in the case of real urban organism. This kind of approach makes possible to perform two categories of research. The first category may include experiments designed to determine the relationship between the mentioned factors affecting the quality of life in urban areas. The fundamental difficulty in conducting these experiments is that the relationships between the different factors are not only classical, Aristotelian kind, but also have a fuzzy character. The second category includes simulations of possible change scenarios and analysis of their effects. This aspect of the research has significant practical importance. This kind of research allows to estimate the scale of changes and make required preparation or (in the case of grossly bad results of the experiment) take all necessary steps to prevent appearance of that situation. Simulations can predict the change of a single factor, or the entire set of factors, modeling in this way more or less extensive changes to the living conditions in the studied cities. The presented approach allows adaptation to changing social, economic and environmental issues. Flexibility is an essential feature that distinguishes described solution of traditionally prepared development strategies, which are static creations and don't take into account the changes of initial conditions or take into account changes only within the prescribed, strictly specified range.

The problems that occurred when trying to evaluate the degree of sustainable development in urban areas also appear when considering a similar problem on a larger scale. In the evaluation of sustainable development of the countries there is the question what factor should be taken into account

in the analysis. This choice, almost always arbitrary and subjective, fundamentally affects the outcome of the analyzes. Inaccurate or biased selection of source factors will certainly result in the image not having much in common with the real state.

The evaluation of the sustainable development in developed countries needs to take into account the multidimensional aspect of the factors affecting the assessment of the sustainability of a country's development. As an example, the analysis of 29 OECD countries has been performed (Carlei et al., 2011). In the described solution, the factors determining the degree of sustainable development were grouped into four categories: economic, cultural, social and environmental. Among these categories, could be found the following factors (Carlei et al., 2011, p. 160):

- GDP growth,
- GDP growth per capita,
- increase in the level of consumption,
- percentage share of trade in GDP ratio,
- number of Internet users,
- size of export in advanced technology sector,
- level of employment,
- enrollment rate,
- number of people with higher education,
- percent of the population living in urban areas,
- synthetic indicator of the ecological footprint,
- cost of starting business (as a percentage of GDP per capita),
- indicator of ease of doing business,
- level of tax burden,
- percent of the energy produced in hydroelectric power plants.

The analysis of collected data has been performed using Kohonen's Self-Organizing Map. This type of neural network is illustrated on figure 1.

Figure 1 shows self-organizing map, operating on input vector $X = \{x_1, x_2, ..., x_n\}$ equipped with cluster of neurons arranged in *MC* columns and *MR* rows.

Self-organizing maps are commonly used is classification problems. This type of network is learned throughout competitive learning process. During the proces of competitive learning, at the input vector is presented only input set. The aim of this process is to establish a structure, which will be the most accurate possible way to map the interdependence in the training set (Skubalska-Rafajłowicz, 2000, p. 181). It should be noted that in the training set of self-organizing map, a very large role plays redundancy. The presence in the training set a large amount of repetition of similar patterns is a key information in the process of network training (Osowski, 2006, p. 86). The structure created during the training process is a spatial of the similarities among

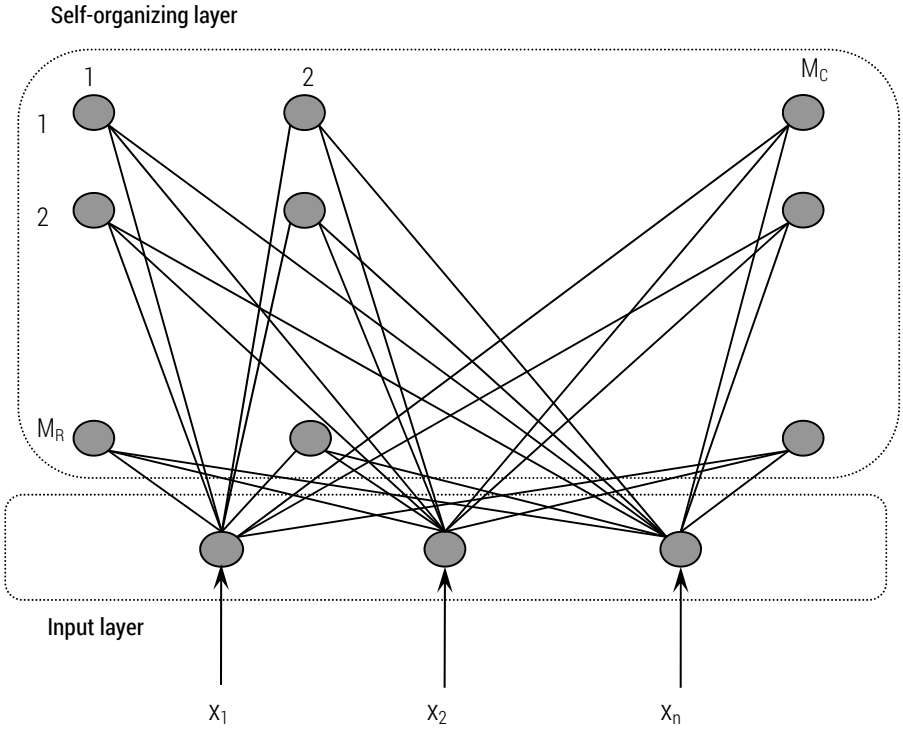

Figure 1. Kohonen's Self-Organizing Map
Source: (Carlei et al., 2011, p. 162).

elements of training set. As in the case of networks with supervised learning process, the underlying concept of self-organizing maps is nature's phenomenon. The process of learning of self-organizing maps is an analogy for the process of differentiation of neural structures in the nervous system during the acquisition of experiences. Clearly, there is a similarity to the cerebral cortex , which shows the spatial variation and a special kind of map covering a wide area of vital body functions (Statsoft, 2001, p. 52).

Results of the research

Conducting the analysis using self-organizing network resulted in grouping the countries, which are characterized by a similar set of features. The specified groups are presented in table 2.

Table 2. Categorization of OECD countries

Group	Countries
A	Australia, New Zealand, Great Britain, USA, Canada, France, Germany, Japan
B1	Norway, Denmark, Iceland, Sweden, Switzerland, Finland, Holland
B2	Belgium, Sth. Korea, Austria, Ireland
C	Spain, Italy, Portugal, Greece, Turkey, Poland, Mexico
D	Czech Republic, Hungary, Slovakia

Source: (Carlei et al., 2011).

In group A are countries with relatively low GDP growth rate, high share of high-tech industries in the ratio to GDP, high level of education, high degree of urbanization and low tax burdens. In groups B1 and B2 there are countries with higher levels of employment and a lower share of high-tech industries in relation to the countries of A group. The difference is also the lower level of consumption. Countries from groups C and D (including Poland) have less developed education systems and infrastructure. The countries grouped in group D are closest to the countries of groups B1 and B2. Disturbing observation is assigning Poland to the group of countries currently undergoing a period of economic difficulties connected with the occurrence of social unrest. This fact may prove that there is no base for an optimistic opinion of the situation, which is often promoted by government and political spokespersons.

Conclusions

There is no doubt that the artificial intelligence, in particularly neural networks, passed through the period of dynamic development. During this development, progress has been made also in the field of computational capabilities of modern computers. A phenomenon that has existed concurrently to that described above, is the emergence of a new class of problems that pose new, demanding research challenges. Some of these challenges are undoubtedly implementation and evaluation of sustainable development. The problems starts at the definition level. A coherent set of factors affecting the implementation of sustainable development have been emerged after many discussions. Nonetheless, there is still dilemma, whether the proposed set of factors would be most suitable for particular solution. Purely utilitarian considerations indicate the simplest solution, described with the lowest number of parameters. The lowest number of parameters, the less work needed to put in necessary data collection and processing. Moreover, the developed model is simpler and more readable.

Nonetheless, after analyzing solutions for the classification of countries in term of sustainable development, it's obvious that a large number of input parameters is, and probably will be, necessary. It's difficult to imagine an attempt to characterize the degree of development of entire country by means of one or several factors. The implementation of sustainable development has to be multidimensional (implementation at global, national and regional level) and has to be done in several ways (multiple goals to achieve). The range of factors, objectives and actions must cause difficulties in learning and systematizations of facts, actions and plans by human perception. In this situation it's necessary to reach for methods of supporting and optimizing decisions. In this context, artificial neural networks have a lot to offer for potential decision-makers.

The contribution of the authors

Elżbieta Lorek – 50%
Paweł Lorek – 50%

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