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## MATHEMATICAL METHOD OF ENTERPRISE COMPETITIVENESS LEVEL EVALUATION BY USING HOPFIELD NETWORK

***The article grounds the expediency of neural networks application to solve complex economic classificational tasks. The appropriate method of evaluating enterprise competitiveness level applying Hopfield network is developed.***
***Keywords:*** *competitiveness level; formalization; Hopfield neural network.*

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## МАТЕМАТИЧНИЙ МЕТОД ОЦІНЮВАННЯ РІВНЯ КОНКУРЕНТОСПРОМОЖНОСТІ ПІДПРИЄМСТВА НА ОСНОВІ НЕЙРОННОЇ МЕРЕЖІ ХОПФІЛДА

***У статті обґрунтовано доцільність застосування апарату нейронних мереж для розв'язання складних економічних класифікаційних задач. Розроблено відповідний метод оцінювання рівня конкурентоспроможності підприємства на основі мережі Хопфілда.***
***Ключові слова:*** *рівень конкурентоспроможності, формалізація, нейронна мережа Хопфілда.*
***Табл. 2. Рис. 1. Літ. 19.***

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## МАТЕМАТИЧЕСКИЙ МЕТОД ОЦЕНКИ УРОВНЯ КОНКУРЕНТОСПОСОБНОСТИ ПРЕДПРИЯТИЯ НА ОСНОВЕ СЕТИ ХОПФИЛДА

***В статье обоснована целесообразность использования аппарата нейронных сетей для решения сложных экономических классификационных задач. Разработан соответствующий метод оценки уровня конкурентоспособности предприятия на основе сети Хопфилда.***
***Ключевые слова:*** *уровень конкурентоспособности, формализация, нейронная сеть Хопфилда.*

**Introduction.** The successful activity of Ukrainian companies becomes more difficult under the conditions of financial, industrial and political crises not contributing to their competitiveness. In order to solve this problem, the evaluation of com-

petitiveness level of local companies should be clearly formalized. This will allow developing a competitive strategy and continuing support.

**Analysis of research and publications.** At the present stage of development, the theory and practice of evaluation competitiveness of companies and management has processed great scientific achievements of methods and models that describe the competitiveness within a particular object, product, company, state etc. Specifically, M. Akhmatova and Y. Popov (2007), O. Mlotok (2009), R. Fathutdinov (2007) identified the problem of evaluating enterprise competitiveness basing on the theory of product quality by evaluating its use value; A. Krotkov and Y. Yelenyeva (2001) are the representatives of the method for analysis of competitive advantage which is performed by comparing the levels of relevant enterprise indicators with the analog indicators of its competitors, where the highest level of index indicates the most competitive company. There are other approaches to evaluate competitive level of a company, for example; the integral method, investigated by G. Azoyev (2007), V. Bilousov (2008), N. Pavlova (2006) and others. This approach is implemented by analyzing the ratio of expected company level profitability and the optimal level of it by using Herfindahl index, Rozenblyut index, Gini coefficient and CR4 concentration index. The matrix methods are represented by the matrix BCG, the matrix of forces by M. Porter and the SWOT analysis. The researchers of this method are, for instance, I. Ansoff (1989), M. Porter (1979) and others. Y. Golubkov (2007) and O. Mlotok (2009) presented the method of effective competition based on comparing the position of a company of particular industry with business competitors and average performance of its industry.

Other famous economists are G. Bagiyev (1996) and I. Lifts (2001). G. Bagiyev (1996) is the founder of the research method of marketing and competition. He has compiled the theory and practice of benchmarking. I. Lifits (2001) has maintained that enterprises development and competitiveness depend on the level of conformity of companies with consumers expectations.

**Unsolved aspects of the problem.** Unfortunately, the existing approaches to determining the level of product competitiveness, company or country are not clearly formalized and allegorized. They are based on highly limited sets of quantitative estimate parameters only and they do not account for dynamic internal and external effects of entities business operations. The current approaches are difficult to realize and they are characterized by limited information, they do not allow evaluating the competitiveness of enterprises systematically. All these factors are making the process impossible for automation and constructive use (Moshnov, 2008).

Mathematical tools of artificial intelligence, such as fuzzy sets and genetic algorithms, help to solve economic problems under the conditions of constant development, changes of economic system and improving of automation management decisions. In particular, it is very effective in evaluating enterprises competitiveness. Despite this, each of the devices has drawbacks: fuzzy sets require a complex procedure to identify the appearance and shape of membership functions; threshold elements require a powerful array of expert information for quality processing and they are based on hierarchical complex functions which are interchangeable according to its weight and genetic algorithms require a complex configuration etc.

Noteworthy, the analysis of business automation showed rapid development of neural network technologies by constructive use for solving management problems in the last decade. Today leading economic researchers, such as N. Boytsun (2005), V. Vitlinskiy (2012), A. Matviychuk (2005), O. Nedosyekin (2000), O. Rotshtein (2006) and many others use artificial intelligence including fuzzy logic and neural networks for solving classification problems.

These considerations allow the authors of the article to substantiate their own choice of mathematical tools for the formalization of a mathematical model of evaluating the level of competitiveness, based on artificial neural networks. This approach allows us solve the problem of classification successfully (in our case it is identifying the appropriate level of enterprises competition) and reproduction of incomplete images or distorted information (in our case it is the information of real economic activity of companies).

The limited use of expensive expert knowledge is necessary to identify the values of competitiveness only for typical combinations to estimate parameters (in our case – aggregate functions) proposed by the authors, the mathematical model below concluded the exact final decision. All of the above determined the choice of artificial neural Hopfield network to identify the process.

The advantage of this approach among other mathematical tools is the ease of building software to make a network attractive for practical applications particularly in financial and operations management.

**The aim of this research** is to develop measures for competitiveness evaluation of local enterprises by means of Hopfield neural network and their further improvements.

**The study results.** To form the evaluation method of competitiveness, which is based on Hopfield neural network (Kruglov, 2002), the authors developed an appropriate structural model of this process. The result is shown in Figure 1.

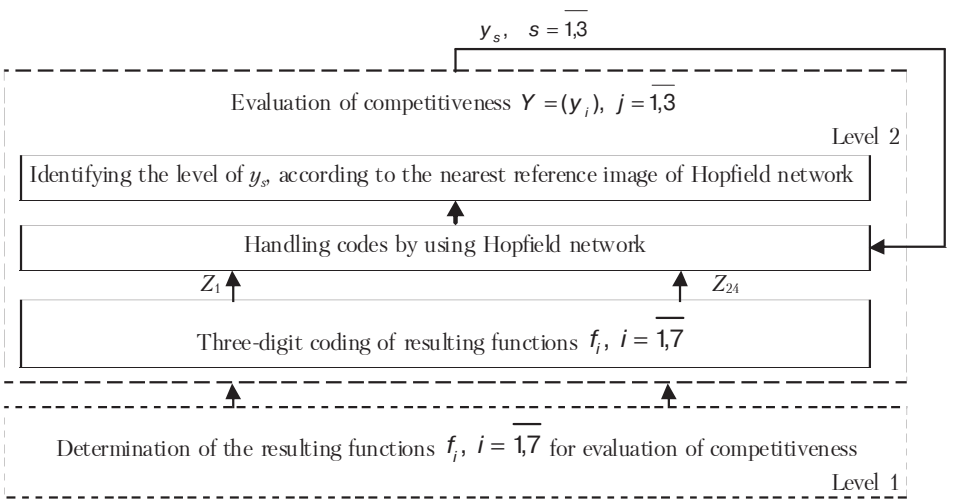


*Figure 1.* **The structural model for evaluation of enterprises competitiveness,** *developed by the authors*

On the first level it is necessary to define the functions $f_i$, $i = \overline{1,n}$ ($n = 7$), they are describing: $f_1$ – efficiency of production activity; $f_2$ – efficiency of marketing and sales promotion; $f_3$ – financial status of a company; $f_4$ – competitiveness of products; $f_5$ – efficiency of enterprise staff; $f_6$ – organization culture and management; $f_7$ – external functioning of a company.

We can propose the incoming function $f_i$ by evaluating 3 ranges based on expert knowledge level of characteristic function, such as, $L$ – low, $M$ – medium and $H$ – high (Table 1). Then we develop the aggregate knowledge matrix of determination of the final decision $y_j, j = \overline{1,3}$ (where $y_1$ – the low competitiveness; $y_2$ – the average level of competitiveness; $y_3$ – the high level of competitiveness) of the set of initial solutions $Y$.

*Table 1.* **The matrix to determine the competitiveness levels,** *developed by the authors*

| Row number in a set of values for the function $f_i$ | Linguistic value of functions $f_i$, $i = \overline{1,7}$, $j \in M$ | | | | | | | The level of competitiveness |
|---|---|---|---|---|---|---|---|---|
| $R$ | $f_1$ | $f_2$ | $f_3$ | $f_4$ | $f_5$ | $f_6$ | $f_7$ | $y_i$ |
| 1 | L | L | L | H | L | L | L | |
| 2 | L | L | L | H | L | L | L | |
| 3 | L | L | L | H | L | M | L | $y_1$ = L |
| 4 | L | L | L | H | L | L | M | |
| 5 | L | L | L | H | L | L | M | |
| 6 | L | L | L | H | L | L | M | |
| 1 | M | M | M | M | M | M | M | |
| 2 | M | M | H | M | M | M | M | |
| 3 | M | M | M | H | M | H | M | $y_2$ = M |
| 4 | M | M | M | M | M | M | H | |
| 5 | M | M | M | H | M | M | M | |
| 6 | M | M | M | M | M | H | M | |
| 1 | H | H | H | L | H | H | H | |
| 2 | H | H | C | L | H | H | H | |
| 3 | H | H | H | L | H | H | H | |
| 4 | H | H | H | L | H | H | H | $y_3$ = H |
| 5 | H | H | M | L | H | H | H | |
| 6 | H | H | H | L | H | H | M | |

At the second level of evaluation we displayed values of input functions $f_i$ of the initial solutions $y_j$ on the set by using a matrix of knowledge, based on Hopfield neural network. This network allows us compare the image received for the investigated companies of input vector $K = (k_l)$, $l = \overline{1,L}$ that describes the values code of functions $f_i, i = \overline{1,7}$ with the nearest reference vector $U = (u_l)$.

Each reference vector U uniquely characterizes the specific level of competitiveness evaluation – $y_j$, $j = \overline{1,3}$, which is the output of the model.

Note, the network holds neurons functioning with threshold activation function and gain value "1" and "-1" (Kruglov, 2002). We suggest the coding level of functions $f_i$ by three-digit code, which consists of 1 or -1, such as, $f_i \to$ (-1, -1,-1) the low level of functions; $f_i \to$ (-1,1,-1) the intermediate level of functions; $f_i \to$ (1,1,1) the higher level of functions.

After coding Hopfield network matches the input vector $K = (k_l)$, $l = \overline{1,L}$, $L = 21$, which describes the level of competitiveness of enterprises with the 3 reference samples $u_l$. They are described in Table 2. These standards are compiled on the basis data, granted by experts and presented in Table 2.

*Table 2.* **The reference samples $u_l$ of assessment levels $y_j$, $j = \overline{1,3}$,** *developed by the authors*

| $f_1$ | $f_2$ | $f_3$ | $f_4$ | $f_5$ | $f_6$ | $f_7$ | $u_l$ |
|---|---|---|---|---|---|---|---|
| -1-1-1 | -1-1-1 | -1-1-1 | -1-1-1 | -1-1-1 | -1-1-1 | -1-1-1 | $u_1$ |
| -1-1-1 | -111 | -1-1-1 | 111 | -111 | 111 | 111 | $u_2$ |
| 111 | 111 | 111 | 111 | 111 | 111 | 111 | $u_3$ |

In Table 2 each of the 3 levels of competitive evaluation $y_j$ are described by the set of coded values $u_l$, $l = \overline{1,L}$, $L = 21$ of function $f_i$, which were selected from matrix knowledge as the most informative. Thus, the network identifies a standard that is most typical and each standard in its turn corresponds to a particular level of competitiveness.

This method has been realized at enterprises of different industries. The result of the Hopfield network used at the second level of the structural model is introduced in Figure 1. For example, one of these companies (coded vector of its input functions forms [-1 -1 -1 1 -1 -1 -1 1 - 1 -1 -1 1 -1 -1 -1 -1 -1 -1 -1 1 1]) can be demonstrated by using mathematical package MathLab 7.0, fragment of listing program is shown below.

```
T = [-1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 1 1 1
-1 -1 -1 1 1 1 -1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1]';
net=newHop (T);
X={[ -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 1 -1 -1 -1 -1 -1 -1 -1 1 1 1]'};
[a,b,c]=(net, {1 100}, {},X);
a{100}
ans = -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1 -1
```

The program displays the output pattern u1 which corresponds to the low level of competitiveness. Furthermore, action of the company is to develop a number of activities to improve its level by constructing the corresponding complex target program.

**Conclusion.** The basis of the proposed method is the evaluation of enterprise competitiveness for such main functions, such as the effectiveness of marketing and promotion, the efficiency of company production, staff, competitive products, financial condition, organizational culture and business environment. In our opinion, these functions include the most important assessment of business enterprises by excluding duplication of individual indicators that allow us assess the prospects on industry market quickly and effectively.

In addition, the significant advantages of the proposed method are atomization, clarity, transparency and convenience.

Thus, we can make the following conclusions:

1. The authors' hypothesis regarding efficiency of Hopfield neural network to assess the level of competitiveness is confirmed.

2. The method of determining the appropriate level of competitiveness on the basis of structural and neural approaches is proposed.

3. Structural assessment of competitiveness model based on systems theory allows detailing description for further automating of this process by applying decomposition and stratification approaches.

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