## KAPITEL 3 / *CHAPTER 3* [3]
## RADIAL-BASIS NEURAL NETWORKS FOR ENTERPRISES ACTIVITY PREDICTION

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### Introduction

Taking into account modern conditions of constant changes, ensuring effective operation of the business is rather a difficult task. Social challenges dictate the rules of the enterprise market. It is becoming more and more of a priority to ensure competitiveness, which further determines the effectiveness of the activity. This in turn requires the implementation of innovative models of marketing policy.

Thus under conditions of uncertainty and instability of external and internal environment implemented innovative marketing solutions should ensure the growth of productive performance of the enterprise. Under such conditions, it is necessary to use modern research methodology of the company's activity, including the use of mathematical modeling system.

### 3.1. Research analysis and task formulation

The works [1 – 4] describe methods of modeling the performance indicators of the enterprise, based on mathematical statistics methods. However, these methods are suitable only in case of linear relationship between model input and output. At the same time, methods of regression-correlation analysis allow to build a separate model for each indicator, which is not effective in making decisions about the strategy of the enterprise as a whole, and requires substantial computational cost. In [1, 3] it is indicated, that clustering methods and neural network techniques are quite common nowadays. These clustering methods make it possible to receive the groups of similar objects, and artificial neural networks are able to model and predict the studied processes.

For modeling and forecasting processes with deep instability the most suitable are artificial neural networks with radial basis functions [5 – 7]. These neural networks have only one hidden layer, therefore, the task of the synthesis of architecture is reduced to calculating the number of neurons in the hidden layer. Artificial radial-type neural networks are able to learn quickly on a inhomogeneous and limited data sample, which is a significant advantage over other perceptron-type neural networks.

In view of the above, the purpose of the research is to develop the architecture of artificial neural network with radial basis functions to predict the performance of an enterprise based on the implementation of marketing decisions.

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### 3.2. Analysis of enterprise activity main indicators

The main performance indicators, which demonstrate the effectiveness of the company, which is engaged in production and sales, is sales profitability, income from the sale without taxes and revenue. Factors affecting the efficiency of the enterprise functioning and ensure its competitiveness in the market – are marketing costs, in particular, the cost of outdoor advertising, advertising in the media, print, Internet, packaging design, promo (participation in festivals, special exhibitions, forums, company tasting excursions), the cost of promotional training for marketers, costs for printed matter of a promotional nature. The factors mentioned above should be divided into immediate impact factors (advertising in various media), related (packaging design, design of flyers, participation in promotional events) and providing (trainings for marketers) [8].

To build an optimal architecture of the artificial neural network with radial-basis functions for modeling and forecasting of enterprise activity, considering the implementation of marketing solutions, we need to consider in detail the structure of the specified artificial neural network.

### 3.3. Radial basis artificial neural networks structure features

Radial-basis artificial neural network has an input, hidden (radial basis) and source layer, which is illustrated in Figure 1.

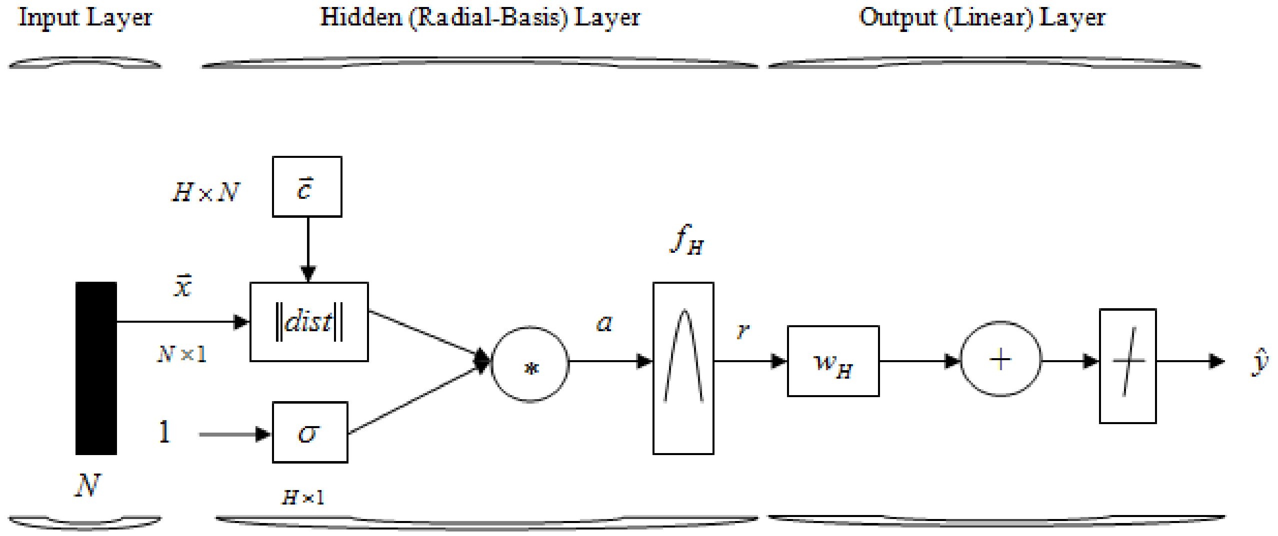



**Figure 1 – Architecture of artificial neural networks with radial basis functions**

As we can see in Figure 1, the input layer consists of input neurons $\vec{x}_i$, $i$=1,…,$N$. The values of radial basis functions are calculated in the hidden layer, an argument of which is the distance (dist) from the vector of inputs $\vec{x}_i$ to predefined vector of centers $\vec{c}_h$ radial basis functions, which is multiplied by the offset value (window width) $\sigma$, $h$=1,…,$H$ – the number of neurons in the hidden layer. The result is a value $a$. Centers and offset are the parameters of the receptive field of the radial basis functions, which are calculated using the formula:

$$f_h(\vec{x}) = \|\vec{x} - \vec{c}_h\|\sigma, \quad (1)$$

where based on Euclid's metric $\|\vec{x} - \vec{c}_h\| = \left( \sum_{i=1}^{N} (x_i - c_{ih})^2 \right)^{\frac{1}{2}}$.

If we use the the Gauss function as a radial basic, the expression (1) takes the form:

$$f_h(\vec{x}) = \exp\left( -\frac{1}{2}\|\vec{x} - \vec{c}_h\|^2 \sigma^{-2} \right). \quad (2)$$

The output layer of a radial-type artificial neural network consists of linear parameters – synaptic coupling coefficients $w_h$. Given this, the output signal of an artificial neural network with radial basis functions can be calculated using the formula:

$$\hat{y} = w_0 + \sum_{h=1}^{H} w_h f_h(\|\vec{x} - \vec{c}_h\| \cdot \sigma^{-2}). \quad (3)$$

Development of radial-type artificial neural network architecture involves tuning the receptor field parameters and weighting coefficients [10].

To calculate the centers of radial basis functions clustering methods are typically used. As the research results follows, the most suitable is the subtractive clustering algorithm [9], which is easy to implement, and the number of clusters is governed by a single parameter - the cluster radius.

We describe the algorithm based on the sequence of steps.

Step 1. Set the radius of the cluster and identify potential centers of clusters corresponding rows of input data *X*.

Step 2: Calculate the potentials of possible cluster centers and choose the area with the greatest potential - as the center of the first cluster.

Step 3. Exclude such clusters by recalculating the potentials for other possible cluster centers.

Step 4. Identify the next center of the cluster with maximum potential.

Step 5: Check the condition of the maximum value where potential cluster center does not exceed the predetermined threshold – clustering radius. If yes, proceed to Step 3. Otherwise, we finish the algorithm.

Typically, the radius of the cluster is set at interval [0;1], but the best clustering results are obtained when the cluster radius is within [0,2;0,5]. The width parameters of the radial basis function window are set experimentally.

So, if the radial-type artificial neural network architecture is written as $x$:$h$:$y$, than the value of inputs $x$ and outputs $y$ – are known, and as a result of subtractive clustering algorithm we will get a number of radial basis functions, corresponding to the number of neurons in the hidden layer $h$.

The algorithm for adjusting the parameters of the output layer – weighting coefficients, is based on the criteria of the error function [11]. Neurons are added iteratively to the hidden layer until the sum of squares of errors will not be less than the set value or until the maximum number of neurons will not be used.

The resulting architecture of the artificial neural network is optimal for modeling and forecasting of the performance idicators of the company, if it adequately reflects the real processes relating to the enterprise activity based on the marketing policy and has prognostic properties.

It should be noted that these algorithms must run in parallel, because in terms of recalculating the structure of artificial neural network with radial basis functions it is necessary to reconfigure the centers of basis functions [12].

### 3.4. Synthesis architecture of radial-basis neural network for the prediction task of the enterprise activity

Let's run experiments on the example of enterprise reporting, engaged in the production and sale of dairy products PJSC «Ternopil dairy». Given the experimental data, denoted by $\vec{x} = (x_1, x_2, x_3, ..., x_{11})$ – the cost of marketing activities – factors affecting the performance indicators of the enterprise activity as the inputs of an artificial radial type neural network, and $y_1, y_2, y_3$ – effective performance indicators: profitability, revenue and the income from the sale without taxes, as output neural network signals. As the incoming and outgoing data of different dimensions, then it is advisable to standardize them for better presentation of the simulation results.

For conducting the research an application package Matlab was, which is effective for mathematical modeling through built-in toolboxes. This greatly simplifies the work, since some algorithms can be invoked by specifying the feature and entering the necessary parameters.

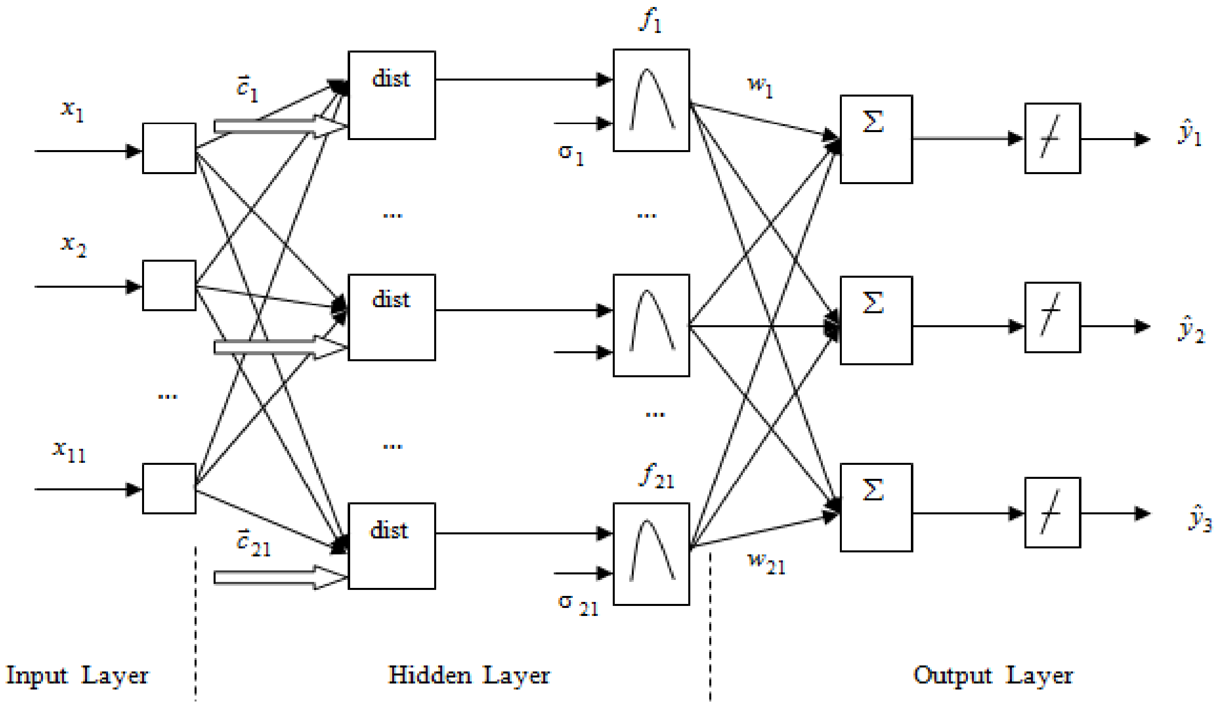



**Figure 2 – Optimal architecture of a radial artificial neural network for modeling and forecasting of enterprise activity**

In view of the above, the radial-type artificial neural network has 11 radial neurons in the input layer neurons and 3 output neurons, namely 11:*h*:3. At the initial stage of synthesis of architecture of artificial neural network of radial type we get architecture 11:60:3. This architecture is very complex and, according to research results, does not have predictive properties. We obtain the optimal architecture for modeling and forecasting the studied parameters at the fifth iteration of the algorithm settings specified neural network architecture 11:21:3, which is shown in Figure 2.

### 3.5. Enterprise activity indicators modelling.

The structure of the developed architecture of a radial-type artificial neural network for the task of forecasting the activity of company is:

$$\hat{y}_j = w_1 f_1(\|\vec{x} - \vec{c}_1\|\sigma^{-2}) + w_2 f_2(\|\vec{x} - \vec{c}_2\|\sigma^{-2}) + ... + w_{21} f_{21}(\|\vec{x} - \vec{c}_{21}\|\sigma^{-2}). \quad (4)$$

We will demonstrate in Figure 3 a) -c) the results of modeling and forecasting of enterprise performance indicators, considering marketing policy based on the structure of artificial neural network (4). It should be noted that the data sample is divided into training and test (control), which is indicated by a vertical line in the figures. The experiments indicated on the abscissa axis were performed on the basis of five-year data (monthly).

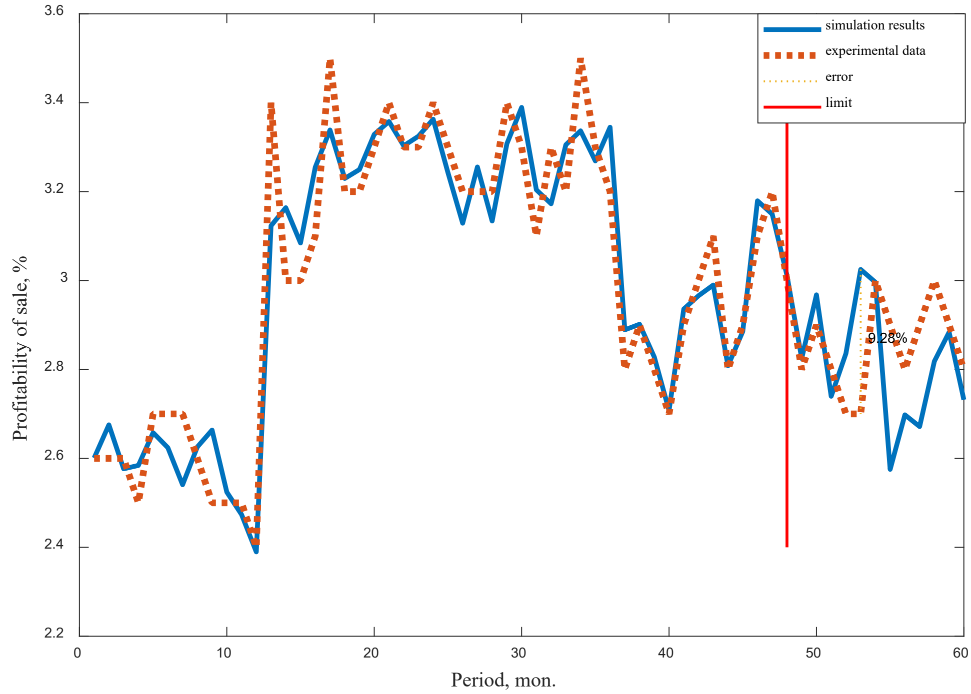
From the simulation results we can see that this profitability of sales (Figure 3a)) significantly depends on the chosen marketing policy of the company. Therefore, from this it follows that the overall marketing strategy of PJSC "Ternopil Dairy" was selected correctly and does not require significant changes in those areas that it is already using. The relative maximum deviation error of the predicted value from the experimental in the forecast period is 9.28%, which proving quite high prognostic properties of the developed artificial radial-type neural network.

The effect of marketing decisions on profit (Figure 3 b)) is not as intense, since the profit of the enterprise in different periods is formed due to non-constant synergistic effects. The source of income of the enterprise is not only the volume of sales, but also aggregate receipts, consulting revenues services.

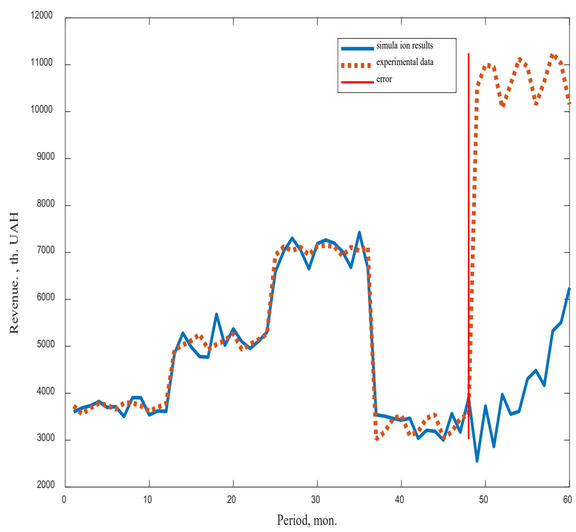
Rapid reaction to innovations is needed in modern world of gadgetry, and change in marketing focus that will provide a significant advantage over competitors. The period of the online addiction of society requires new promote products mechanisms, including increased spending on online advertising – ads on various social platforms, blogging, that in the long run will lead to cheaper costs in general marketing policy. Optimizing marketing solutions towards innovative development with greater use of online platforms make it possible to attract new customers and increase sales.

In view of this, in Figure 4 we illustrate dynamics of profitability of sales with increase of Internet advertising cost by 20%.

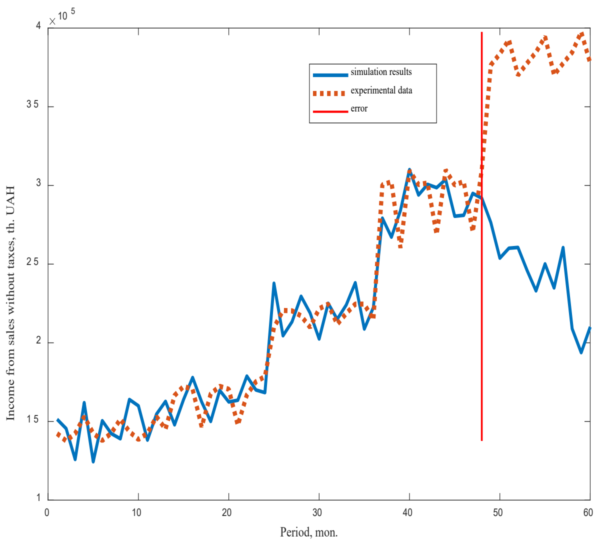
As we can see, the relative maximum deviation error of the predicted value decreased by 2% from the experimental one, which indicates the positive dynamics of the performance indicator.




*a*)




*b*)




*c*)

**Figure 3 – Modeling of performance indicators of the enterprise activity**
a) profitability of sale, b) revenue c) income from sales without taxes on a radial-type artificial neural network

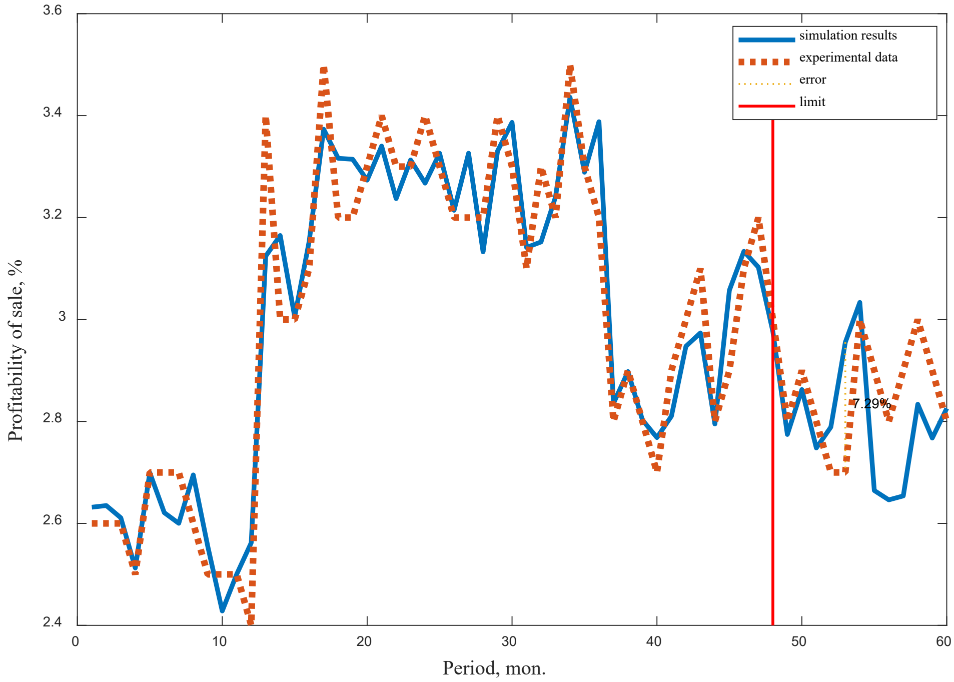



**Figure 4 – Forecasting sales profitability by increasing advertising spend online**

## Conclusions

Consequently, the proposed mathematical tools based on artificial neural networks with radial basis functions makes it possible to simulate the real economic processes, related to the enterprise activity, which is engaged in production and sales, as confirmed by experimental results.

The presented results indicate promising application of radial-basis artificial neural networks for prediction processes with deep instability based on heterogeneous data.