Converter Structure of Time-and-Frequency Signals Parameters into Code of Two Variables on the Radial-Based Networks Basis

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Abstract — **Reasons for radial-based network application for converters creation of time-and-frequency signals parameters of two variables are given. Converter structure of time-and-frequency signals parameters into digital code of two variables on the radial-based networks basis is constructed. The converter decomposition on two components in which the second component is a radial-based network is offered. The network training example of the frequency converter in a position code of two variables is given.**

Keywords — converter; frequency; time interval; digital code; radial-based neural network.

I. Introduction

Now the artificial neural networks apparatus is an effective remedy [1]. Process of the formalized synthesis of devices for information form conversion, defined as neuronetwork transformers, is carried out on its basis [2]. These devices operate with the variables provided in the frequency form f, time slot duration τ, the signal change period T, its amplitude in the form of tension *U*, number – impulse n or positional N codes. These devices represent an analog-to-digital neuronet.

Questions of the neuronetwork linear and non-linear analog-to-digital converters synthesis, implementing the functional dependences of one variable, are discussed in known publications [3 – 6]. However, questions of the neuronetwork converters synthesis, implementing functional dependences of two variables, aren't described.

The necessity of reproduction of two and more variables number functions usually encountered in ballistic and navigation tasks, problems of control and monitoring of moving objects, different technological processes, and also in the tasks connected with research and simulation of difficult autoregulation systems.

Devices for functions reproduction, the function convertors, been independent or been a part of different information and measuring, control and test and other components, realize computation of required dependences, characteristics linearization, formation of correction functions or nonlinearities simulation.

Structures of neuronetwork convertors of time-and-frequency signals parameters in a code of two variables on a basis of the perceptron networks are offered in this work.

II. Creation Features of the Function Converters on the Radial-Based Networks Basis

The function radially changing round some center set by a point *c*, and accepting nonzero values only in neighborhoods of this center is called as radial-based function. Radial function argument is the distance between the current point x and center c, i.e. $\varphi = \varphi(\|x - c\|)$ [7].

Radial-based networks are successfully applied in tasks of recognition, classification, prediction and approximation [7, 8]. In this regard research of opportunities of structures creation of the function generators on the basis of radial-based networks which allow to combine conversion process with functional dependences computation is expedient.

The neurons having radial-based activation functions are logical addition of neurons with step and sigmoidal activation functions [7]. Mac-Cullock – Pitts neuron is activated when it has a single (positive) output for the points of space lying on one side ($\sum_i w_i x_i - \theta \geq 0$) of hyperplane $\sum_i w_i x_i - \theta = 0$, and zero (negative) – for the points lying on other side. The neuron with radial-based function also divides space of input parameters into two parts, however, the separating surface is the hypersphere here (fig. 1). For the points of space lying in a hypersphere, the output of radial-based neuron is positive, and for the points lying outside of a hypersphere, it is equal to zero.

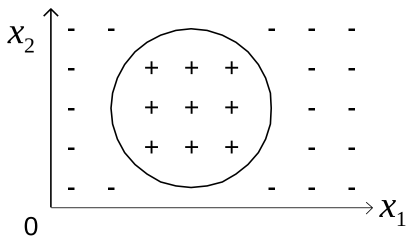

Fig. 1. Division of space into two parts by radial-based neuron.

Radial-based neurons have the advantage which is that with their help it is easier to construct the surface providing division of input parameters into classes [8]. In this regard on radial-based networks there is no need to use a large number of the hidden layers. The typical radial-based network has one hidden layer. Synoptic neurons weights of the hidden layer are equal to one, and neurons of an output layer have the linear activation functions. The radial-based network consisting of one neuron of a distributive layer, hidden layer neurons and one output neuron is shown in fig. 2.

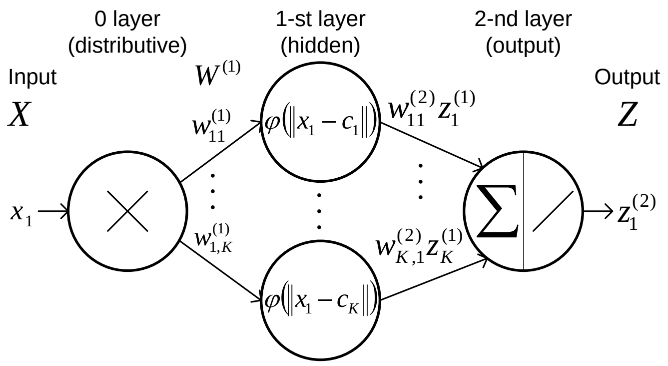

Fig. 2. The radial-based network having one input, one output and radial-based neurons of the hidden layer.

Radial-based neurons, as a rule, realize activation functions of the following form:

$$F(S) = e^{-\frac{S^2}{2\sigma^2}}, \qquad (1)$$

where $S = \|X - C\|$ – Euclidean distance between an input vector X and activation function center C;

σ^2 – the parameter of a Gaussian curve called window width [9].

The formula (1) for the input vector consisting of one variable is:

$$F(x, c) = e^{-\frac{(x-c)^2}{2\sigma^2}}. \qquad (2)$$

III. The converter structure of two variables on the radial-based network basis

For the purpose of structure simplification of the function converter $f(x_1, x_2) \to y_N^*$ with positional result coding y_N^* it is expedient to realize decomposition of the converter on two neural network components (fig. 3).

As the first component of the offered system are the neuronets (fig. 3) which realize linear conversion operations $z_1^* \equiv x_1$ and $z_2^* \equiv x_2$ appear (z_1^* and z_2^* – positional codes, proportional to analog variables). The second component is the radial-based network which realizes the operation of non-linear conversion $f(z_1^*, z_2^*) \to y_N^*$. Thus the structure (fig. 3) realizes conversion operation $f(x_1, x_2) \to y_N^*$ of analog values x_1 and x_2 to a positional code y_N^* of a look (3):

$$y_N^* = \beta_m \beta_{m-1} \ldots \beta_1 = \sum_{i=1}^{m} \beta_i(x) \cdot 2^{i-1}, \qquad (3)$$

where m – binary digits number.

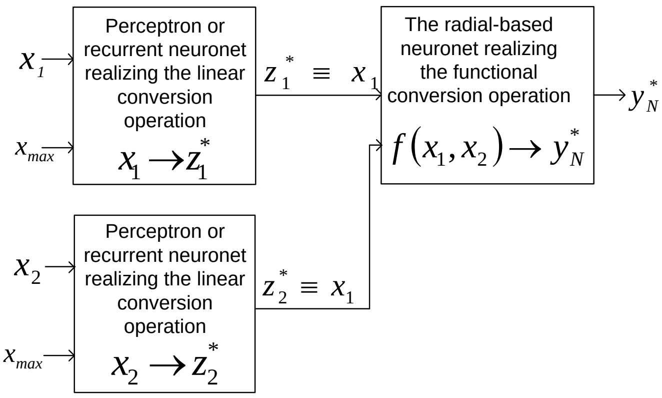

Fig. 3. The converter decomposition on two components.

The first component represents a stage of two-neural perceptrons (fig. 4).

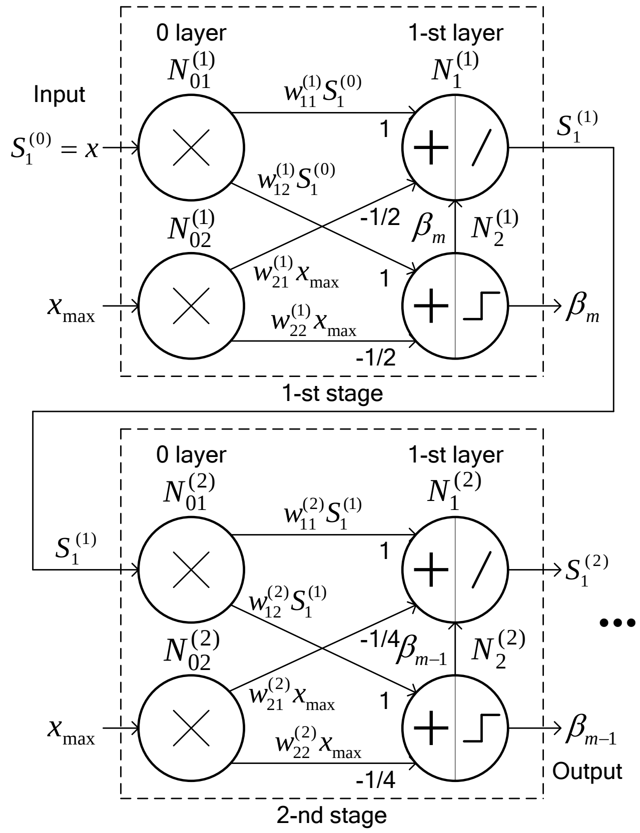

Fig. 4. Converter structure with cascading of perceptrons with the linear and threshold functions of activation.

Which each stage (see fig. 4) consists of two neurons of a distributive layer and two neurons of an output layer. Thus the output layer first neuron $N_1^{(i)}$ of a i-stage has the linear activation function, and the second neuron $N_2^{(i)}$ – the threshold one. From an output of the first neuron the analog partial sum $S_1^{(i)}$, and from an output of the second neuron – bit β_{m-i+1} of an equivalent y_N^* is withdrawn (3). So, the bit β_{m-i+1} and the sum $S_1^{(i)}$ are created as sequence of activation functions:

$$\beta_{m-i+1} = F^{(1)}\left(w_{1,1}^{(i)} \cdot S_1^{(i-1)} + w_{2,1}^{(i)} \cdot x_{\max}\right),\ i = 1,\ 2, \ldots,\ m, \quad (4)$$

$$S_1^{(i)} = w_{1,1}^{(i)} \cdot S_1^{(i-1)} + \beta_{m-i+1} \cdot w_{2,1}^{(i)} \cdot x_{\max},\ i = 1,\ 2, \ldots,\ m, \quad (5)$$

where $S_1^{(0)} = x$; $x_{\max}$ – conversation standard;

$F^{(1)}$ – threshold activation function:

$$F^{(1)}\left(S_i^{(1)}\right) = \begin{cases} 1, if \ \ S_i^{(1)} \geq \theta_i^{(1)}; \\ 0, if \ \ S_i^{(1)} < \theta_i^{(1)}, \end{cases}$$

where $\theta_i^{(1)}$ – neuron threshold.

The matrixes $X^{(i)}$ and $Z_N^{*(i)}$, describing input and output signals of a stage will assume an air:

$$X^{(i)} = \left\lfloor x_1^{(i)}, x_2^{(i)} \right\rfloor = \left\lfloor S_1^{(i-1)}, x_{\max} \right\rfloor, \quad (6)$$

$$Z_N^{*(i)} = \left\lfloor \beta_{m-i+1}, S_1^{(i)} \right\rfloor, \quad (7)$$

where $i = 1,\ 2, \ldots,\ m$; $S_1^{(0)} = x$.

In matrix form set (4) – (5) taking into account matrixes of inputs (6) and outputs (7) for all bits of an equivalent z_1^* will assume an air:

$$\begin{cases} Z_N^{*(1)} = F^{(3)}\left(W^{(1)T} \cdot X^{(1)}\right), \\ Z_N^{*(2)} = F^{(3)}\left(W^{(2)T} \cdot X^{(2)}\right), \\ \ldots \\ Z_N^{*(m)} = F^{(3)}\left(W^{(m)T} \cdot X^{(m)}\right), \end{cases} \quad (8)$$

where $W^{(i)T} = \begin{Vmatrix} w_{1,1}^{(i)} & w_{2,1}^{(i)} \\ w_{1,2}^{(i)} & w_{2,2}^{(i)} \end{Vmatrix}$ – the transposed matrixes of weight factors between distributive and output layers of a two-neural perceptron;

$F^{(3)}$ – activation function: the linear for $x_1^{(i)}$, threshold for $x_2^{(i)}$.

For the linear conversion of analog value x the scales values of their synoptic communications obtained as a result of stages two-neural perceptron training are provided to its digital equivalent z_1^* by matrixes:

$$W^{(i)T} = \begin{Vmatrix} 1 & -1/2^i \\ 1 & -1/2^i \end{Vmatrix},\ i = 1,\ 2, \ldots,\ m.$$

The second component (see fig. 4) of a network is described by expression:

$$y_N^* = F^{(2)}\left(w_{i,1}^{(2)} \sum_{i=1}^{n} e^{-\frac{\left(z_1^* - c_i\right)^2 + \left(z_2^* - c_i\right)^2}{2\sigma^2}}\right), \quad (9)$$

where z_1^* and z_2^* – the network first component outputs;

$F^{(2)}$ – linear activation function;

$w_{i,1}^{(2)}$ – weight factors between outputs of the 1st layer and inputs of the 2nd layer of a network.

Weight coefficient $w_{j,i}^{(2)}$ between the hidden and output layer of a radial-based network can be defined from a condition of a network square error minimum [13]:

$$\varepsilon = \sum_{q=1}^{Q}\left[\sum_{j=1}^{J} w_j^{(2)} \varphi\left(\left\| X_q - C_j \right\| - d_q\right)\right]^2.$$

where Q – learning examples quantity;

d_q – the expected values of network output neuron.

CONCLUSION

Reasons for radial-based network application for converters creation of time-and-frequency signals parameters of two variables are given.

The structure of converter of time-and-frequency signals parameters into digital code of two variables on the radial-based networks basis is constructed.

The converter decomposition on two components in which the second component is a radial-based network is offered.

The network training example of the frequency converter in a position code of two variables is given.

The offered converter model of frequency in a code of two variables is realized on hardware description language VHDL for FPGA.

The offered structure of converters of time-and-frequency signals parameters into a digital code of two variables on radial-based network will allow to lower a conversion error, and also to reduce terms of similar devices design.

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