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PREDETERMINED MOVEMENT OF MOBILE ROBOT USING NEURAL NETWORKS

Oleh Adamiv [1)], Vasyl Koval [2)], Iryna Turchenko [3)]

Ternopil Academy of National Economy, Institute of Computer Information Technologies,
3 Peremoga Square, 46004, Ternopil, Ukraine, http://www.tanet.edu.te.ua
1) oad@tanet.edu.te.ua, 2) vko@tanet.edu.te.ua, 3) vtu@tanet.edu.te.ua

Abstract: *This paper describes the experimental results of neural networks application for mobile robot control on predetermined trajectory of the road.Theret is considered the formation process of training sets for neural network, their structure and simulating features. Researches have showed robust mobile robot movement on different parts of the road.*

Keywords: - *Mobile Robot, Neural Networks, Robot control*

1. INTRODUCTION

The robotic systems of the new class, with adaptive possibilities and artificial intelligent widely entered to the practical application among the dominate simple industrial robots, that work with hardly predetermined (unchanged during their activity) programs. The adaptive mobile robots with different sensing tools, sensors systems is one of the important components of flexible manufacturing systems and have the possibility to reconfigure its actions depending on the information received from the environment. Without such robots the robotization process is impossible in the unprofitable area, space, underwater and other extreme fields [5, 10, 11].

One of the important tasks that arise for mobile robot control is the movement trough predetermined road [8, 11]. At that the trajectory of the road can be defined as a marking on the highway or the industrial road. The task of the robot in such case is to reach the end point of movement going through the predetermined trajectory. Such approach allows creating the cheap autonomous systems, which can be widely implemented in industry. Therefore, development of the approach to the control by the mobile robot movements through the predetermined trajectory is topical.

In this paper it is considered the system for control by the mobile robot movements through the predetermined trajectory using neural networks. The neural networks are able to train, organize the self-structure and update to the changes in the environment instead of existing mathematical methods [2, 3, 11]. However a special formation procedure of training set for training process is needed for using of neural networks that is considered below.

2. FORMATION OF TRAINING SET

For training of neural network it is necessary to form a training set. For this one the training vectors were created that describe the most typical parts of the road trajectory. The target vector has to correspond to the desired direction of robot movement. The process of training set formation for neural network is shown on Fig. 1

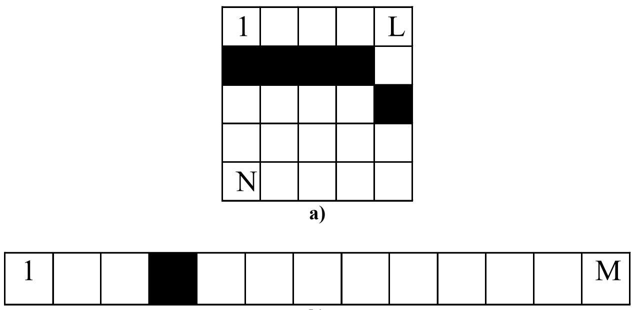

Fig. 1 - a) The input matrix of camera readings; b) output

The process of input values formation of training set for neural network is provided on the bases of one row of binary matrix:

$$x_i = \{p_{i1} \dots p_{iL}\}, \quad i = 1..N,$$

where i – is a row of binary matrix of the camera, L –is a horizontal size of matrix of the camera.

Finally the input vector of neural network can be expressed as:

$$X = \{x_1 \ldots x_N\}^T,$$

where N – is a number of input neurons of neural network

The output vector for training set can be expressed as:

$$Y = \{y_1 \ldots y_M\},$$

where M – is a number of output neurons of neural network.

Thus, the training set is represented by the sets of input and output vectors:

$$TS = \{X_1 Y_1, X_2 Y_2 \ldots X_k Y_k\},$$

where k – is a dimension of training set.

The back propagation algorithm is used for the training of neural network [1, 4, 6, 9] that is considered in the next section of the paper.

3. STRUCTURE OF NEURAL NETWORK

For formation of mobile robot movement direction three-layer neural networks are used with feed forward links. Its architecture is shown on Fig.2.

The input layer consists of N=25 neural elements. The input vectors $\vec{X}$ are the entrance for this layer. The hidden layer of neural network consists of H=10 and the output layer consists of M=13 output neurons. The number of hidden layers neurons is based on the results of previous researches. Each output neuron of the neural network has determined direction of robot movement. In each moment of time there is only one active neural element on the output of neural network, which determine of the current direction of the robot movement.

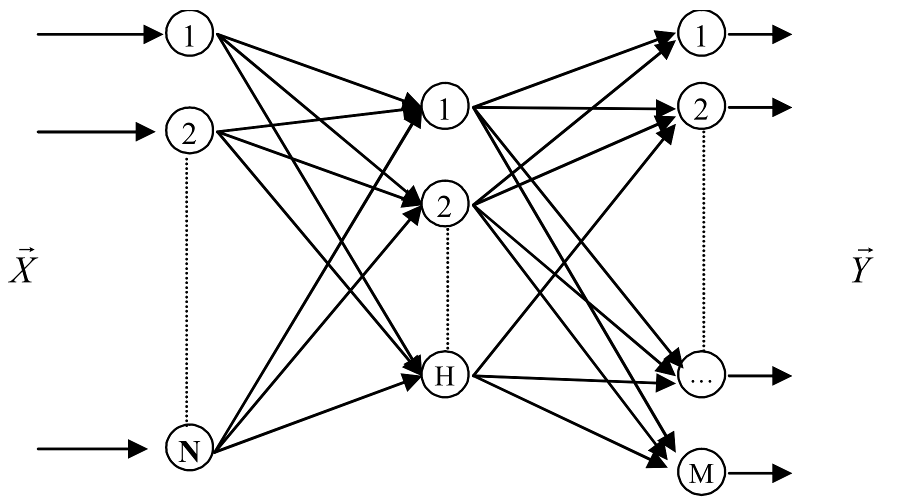

Fig.2 - Architecture of neural network.

The output value of j-neuron of the output layer is:

$$y_j = F(S_j), \qquad (1)$$

$$S_j = \sum_{i=1}^{H} \omega_{ij} y_i - T_j, \qquad (2)$$

where F – is the nonlinear transformation function; Sj – is the weighted sum of j- neuron of output layer; y_i – is the output value of i-neuron of penult layer; w_{ij} and T_j - are the weight and the threshold of j- neuron of output layer correspondingly.

The output value of the neuron of hidden layer is:

$$y_i = F(S_i), \qquad (3)$$

$$S_i = \sum_{l=1}^{N} \omega_{li} y_l - T_i, \qquad (4)$$

The nonlinear transformation function is used as the sigmoid activation function:

$$F(S) = \frac{1}{1+e^{-cS}}, \qquad (5)$$

where c>0 – is the constant coefficient, which characterize the width of sigmoid activation function on abscissa axis.

The back propagation algorithm consists of the following steps [1, 11]:

1. Set the adaptive learning rate α $(0<\alpha<1)$ and minimal sum-squared error E_m, which is necessary to achieve at training.
2. Initialize the weight factors and thresholds of neural network by a random law.
3. Sequentially enter of training vectors to the input of neural network. At that for each training vectors execute the following steps:

a) execute the phase of straight propagation of training vectors through the neural network according to (1-5).

b) execute the phase of back propagation of vectors. As the result is determined error γ_j of neural elements of all layer of neural network:

$$\gamma_j = y_j - t_j,$$

$$\gamma_j = \sum_i \gamma_j F'(S_i)\,\omega_{ij}.$$

In the last expression index i characterize of neural elements of next layer in corresponding with the layer j.

c) for each layer of neural network change the weights and thresholds of neural elements:

$$\omega_{ij}(t+1) = \omega_{ij}(t) - \alpha\gamma_j F'(S_j) y_i,$$

$$T_j(t+1) = T_j(t) + \alpha\gamma_j F'(S_j).$$

4. Calculate the summary mean-square error of neural network:

$$E = \frac{1}{2}\sum_1^k \sum_1^j (y_j^k - t_j^k)^2,$$

where k – is the dimension of training sets.

5. If $E>E_m$ then go to step 3 of the algorithm. Otherwise the algorithm of back propagation error is finished.

This algorithm is functioning until summary mean-square error of neural networks is more than determined error $E>E_m$.

4. EXPERIMENTAL RESEARCHES

For the experimental researches the common structure of mobile robot control is defined (Fig. 3). The mobile robot is equipped by the video camera assigned for depicting of the predetermined trajectory of the road. The unit of image processing provides transformation of the images from the video camera to the binary matrix.

The unit of movement direction observation provides the transformation of binary matrix to the input vector X, which is entered to the input of multi layer forward neural network for receiving of output vector. Such vector forms the movement direction of the robot in every moment of time. Then it is inputted to the controller of the robot.

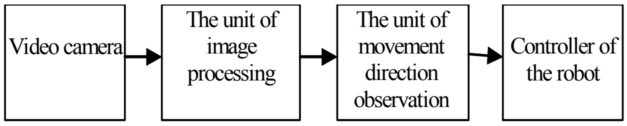

Fig. 3 - Structure of systems for mobile robot control.

During simulation of such system 5x5 binary matrix was used. For the experiments the software was designed using the Matlab 6 tools for simulating of neural network and mobile robot movement [7].

For reaching of mean square error 10^{-5} training process of neural network was 467 iterations. In generally the mean square error of neural network 10^{-5} was reached for the 400-1200 iterations on average during the experiments.

The diagram of mean square error of neural network is shown on Fig. 4.

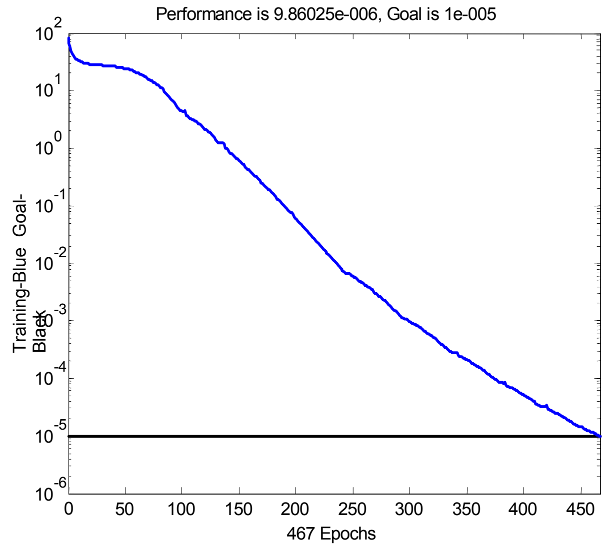

Fig. 4 - Mean square error of training process of neural network.

Simulation of mobile robot movement was executed through randomly generated binary road.

Such road can be simulated by the marking on the highway or benchmark on the industry road.

During simulating of mobile robot movement there was explored that the set of typical directions of robot movement, formed on the stage of training set formation in the section 2 of this paper is insufficient for the robust robot movement through the predetermined trajectory. The robot significantly deviated from the predetermined trajectory on some parts of the road (Fig. 5).

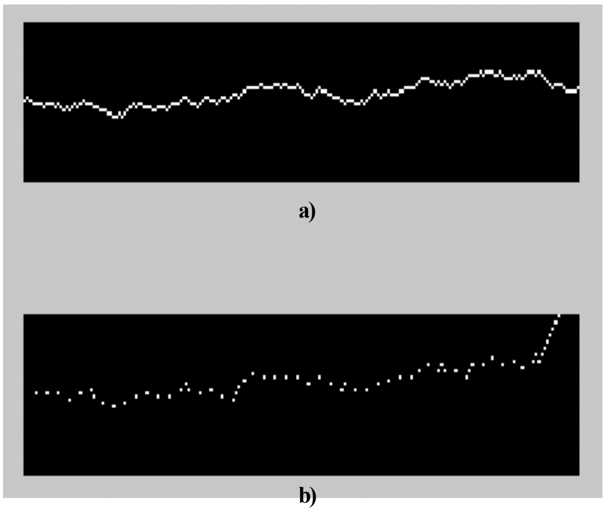

Fig. 5 - Visual interpretation of the robot significant deviation from the predefined trajectory a) predefined trajectory of robot movement; b) the trajectory of robot movement.

Therefore adaptation of neural network to unstable parts of the road was realized. At that the training set was formed for each part of the road. It determines correct movement direction of mobile robot (Fig. 6).

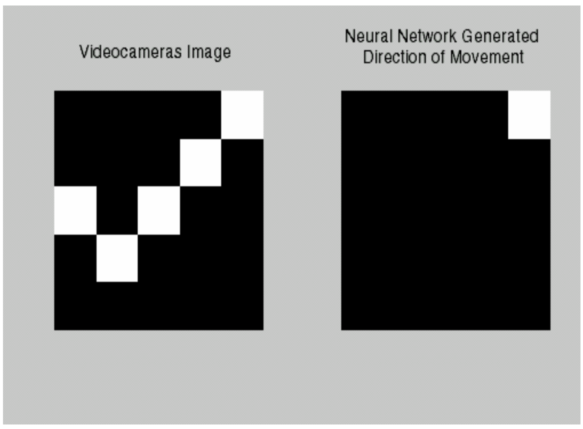

Fig. 6 - The formation of robot movement directions for part of the way.

This one allowed forming the optimal set of training vectors, for providing of robust robot movement on the different parts of the road.

Computer modeling shows (Fig. 7) that designed neural system provides robust control by mobile robot movement in different trajectories with different turning angles. Robot is returned on predetermined road even in the case of deviation from the predetermined trajectory of road in vision bound of video camera. This process was caused by generalization facilities of neural network in the unknown trajectory types, which was absent in training set. As shown on Fig. 7 robot movement was performed not strongly using generated trajectory. Mobile robot movement was caused by generalized marking trend on some parts of the road, despite of insignificant marking deformation. It allows reducing the time of robot movement on 20 percents. Graphical representation of comparative error of deviation of robot movement from given trajectory is shown on Fig. 8. As we can see from the diagram comparative error is 4% on average. Larger values of comparative error from predetermined trajectory were compensated by neural network during robot movement.

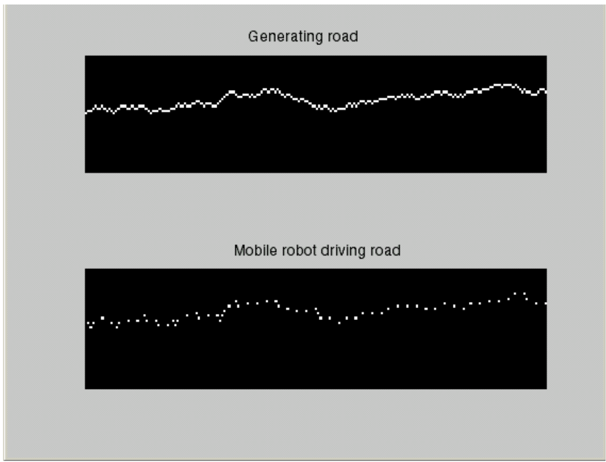

Fig.7 - Simulating of mobile robot movement trough predefined trajectory.

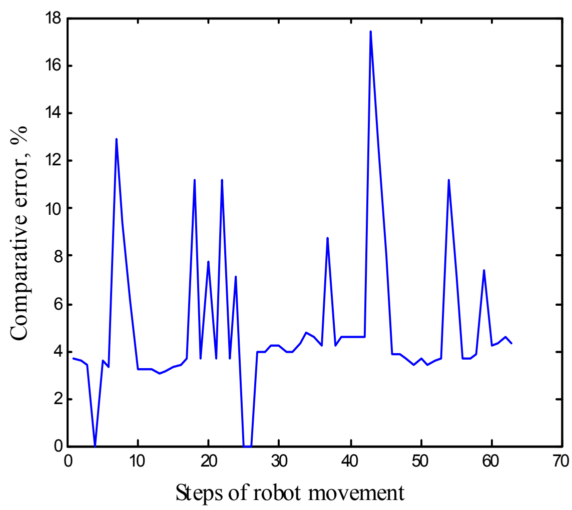

Fig. 8 - Comparative error of mobile robot deviation from the predetermined trajectory.

5. CONCLUSION

In this paper the application of neural networks for mobile robot control on predetermined trajectory is presented. The neural network structure was designed, training set for learning of neural network was formed and software for modeling mobile robot movement was developed during researches. Investigations showed robust mobile robot movement on different parts of the road. The comparative error of deviation of robot movement from predetermined road is 4% on average.

Also the robot movement is performed on general trend direction of the road, instead through deviation of movement trajectory that allows reducing a movement time on 20%. Robot movement time reduction is important for solving tasks of carriage delivering in continuous flexible industry (conveyor manufacture), in the spheres exacting to time delaying, where mobile robots are widely implemented.

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Oleh Adamiv *graduated Ternopil Academy of National Economy in 2000 with speciality "Information Systems in Management", 2001 - Master in Economical Cybernetics. At the moment he is PhD student at the department of Information Computing Systems and Control at Ternopil Academy of National Economy.*

Areas of scientific interests includes: Artificial Intelligent, Neural Networks, Robotics, Autonomous Control, Robot Navigation.

Vasyl Koval *was born in Ternopil in 1975. In 1998 he received B.Sc. in “Management Information Systems” at Ternopil Academy of National Economy, Institute of Computer Information Technologies. In 1999 he obtained M.Sc. in “Economic Cybernetics” at Ternopil Academy of National Economy. Since 1999 he is Ph. D. Student in “Computing Machines, Systems and Networks” at Ternopil Academy of National Economy.*

Now he works as lecturer of Department of Information Computing Systems and Control of the Institute of Computer Information Technologies of Ternopil Academy of National Economy, Ukraine; scientist of Research Lab. of Automation Systems and Network of Ternopil Academy of National Economy.

His research area includes: Robotic Systems; Distributed Systems; Sensor Fusion Techniques; Sensor Fusion Algorithms; Data Acquisition Systems; Stereo Vision; Stereo Matching; Image Processing; Artificial Intelligence; Neural Networks; Robot Navigation Systems; Sensor Systems, etc.

Mrs. ***Iryna Turchenko*** *received her M.S. degree from Ternopil Academy of National Economy, the Institute of Computer Information Technologies in 1997 in Management Information Systems. Now she is a Ph.D. Student of the Information Computing System and Control Department of the Institute of Computer Information Technologies. She is a member of Neural Network Research Group.*

Her main research interests are intelligent robotic systems, multi-parameter sensors and neural networks.