T. Graczyk

ZASTOSOWANIA TECHNIKI LOGIKI ROZMYTEJ W MODELOWANIU RUCHU BEZZAŁOGOWEGO POJAZDU GŁĘBINOWEGO TYPU ROV

W artykule przedstawiono problemy opracowania modelu ruchu pojazdu typu ROV z zastosowaniem techniki logiki rozmytej. Szczególnie przedstawiono wyniki eksperymentów związanych z ruchem pojazdu w płaszczyźnie pionowej po zadanych trajektoriach. Badania wykonano na Wydziale Techniki Morskiej Politechniki Szczecińskiej.

słowa kluczowe: *bezzałogowy pojazd podwodny, sterowanie*

APPLICATION OF FUZZY LOGIC TECHNIQUE IN THE ROV MOVEMENTS MODELLING

The paper presents problems of the ROV movement model elaboration basing on the fuzzy logic technique. There are presented results of experiments focusing movements of the ROV in a vertical plane according to defined trajectories. Investigations have been carried out at the Faculty of Maritime Technology, Szczecin University of Technology, Poland.

keywords: *unmanned underwater vehicle, control*

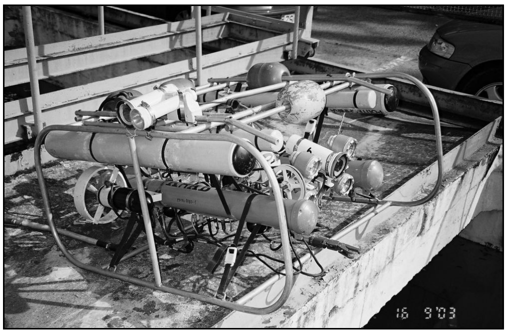
INTRODUCTION

At present remotely operated vehicles (ROVs) are widely used in deep ocean technology inspecting underwater constructions, being a tool base for divers or carrying out simple jobs.

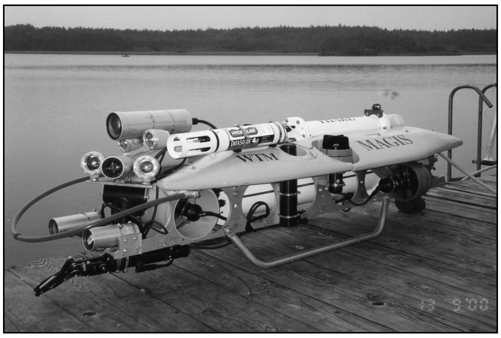
Despite of extensive outfitting the controlling of an ROV is difficult particularly in limited visibility, strong current and in the vicinity of offshore structures. The attempts at classical models of motions developing of an underwater vehicle with the application of conventional PD, PID regulators, aiding or eliminating an operator's work, turned out to be very problematical for accomplishment. The mathematical model of an ROV carrier in the sea is very complicated with large number of hydrodynamics coefficients. The coefficients determined in tank facility conditions become dubious when the replacement of carrier equipment, change of cruising depth and umbilical cable length or work in current are to be done. The classical model of motions can be questionable in such situations.

For this reason the research currently carried out aiming at the application of artificial intelligence methods for the design of intelligent digital controllers which do not require the exact knowledge of control system mathematical model or only the simplified one which could have been tuned in situ when the particular task is to be completed.

Efforts in development of such systems have been conducting at the Szczecin University of Technology for couple of years applying ROVs KRAB and MAGiS, Fig. 1, completed and operated by the Underwater Technology Team at the Faculty of Maritime Technology [1, 4].



a



b

Fig. 1. ROV underwater devices.
a. – KRAB vehicle, b. – MAGiS vehicle.

The article presents the problems with developing of a neural model of an ROV vertical motions. The data was obtained experimentally during tests carried out in technological basin facility at the Faculty of Maritime Technology, [3].

1. DISCRETE LINEAR MODEL OF VERTICAL MOTION OF THE UNDERWATER KRAB VEHICLE

The objective of the work is the setting up the neural model of an ROV motion in the vertical plane. The used approach is the transformation of continuous model describing ROV motions into a discrete model. After formulation of a difference equation a transformation into Artificial Neural Network (ANN) can be carried out. The possibilities of the presented approach for the objective accomplishment are given in Fig. 2.

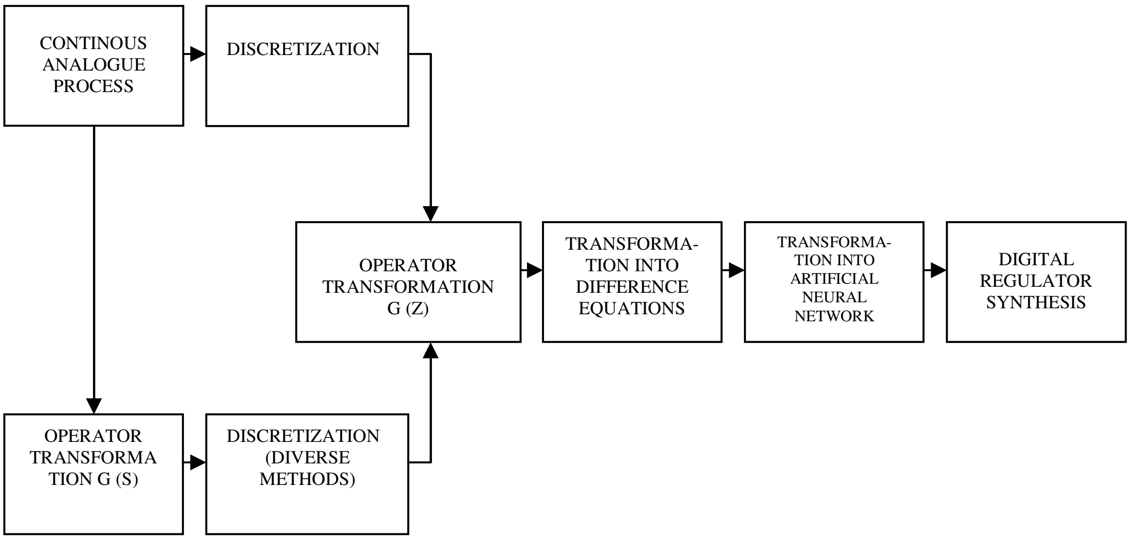


Fig. 2. Flow chart of the setting up the KRAB vehicle model of motion.

$$G(s) = \frac{Z(s)}{P_z(s)} = \frac{k_m}{s(sT_m + 1)} \qquad T_m > T_s \tag{1.1}$$

where:

k_m – gain,
T_m – inertia time,
T_s – sampling time.

After discretisation applying Zero Hold Order method and then simulation in the Simulink environment of MATLAB software the difference equation (1.2) has been obtained:

$$z(k) = B_1^* p(k-1) + B_0^* p(k-2) - A_1 z(k-1) - A_0 z(k-2) \tag{1.2}$$

where:

$$B_0^* = \frac{k_m}{a} B_0 \qquad B_1^* = \frac{k_m}{a} B_1 \qquad B_0 = 1 - c - aT_s \cdot c \qquad B_1 = T_s \cdot a - 1 + c$$

$$A_0 = c \qquad A_1 = 1 - c \qquad a = \frac{1}{T_s} \qquad c = e^{-aT_s}$$

The equation is a base for the determination of input/output structure of the designed ANN, Fig. 3.

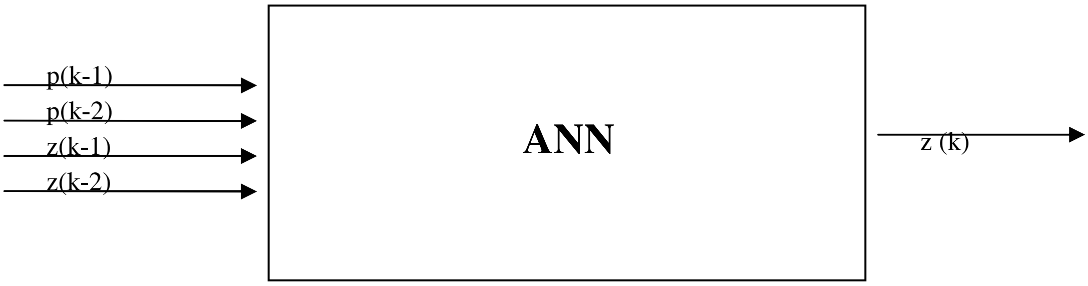


Fig. 3. Flow chart of the ANN representing neural model of KRAB vehicle motion where inputs/output are:

p(k-1) – depth propeller controlling voltage in a k-1 step,
p(k-2) – depth propeller controlling voltage in a k-2 step,
z(k-1) – depth gauge voltage in a k-1 step,
z(k-2) – depth gauge voltage in a k-2 step,
z(k) – depth gauge voltage in a k step.

The values of voltages: depth propeller controlling and depth gauge have been recorded during experiments in the technological basin. A conversion of the measured data has been carried out forming a sequence of k, k-1, k-2 steps.

2. CONDITIONS FOR GATHERING LEARNING DATA USED FOR ANN TRAINING

It has been initially assumed that the developed neural model of KRAB ROV will be confined to the conditions of testing facility limitations. The testing facility at the Faulty of Maritime Technology is a basin having dimensions 20 x 6 x 5 m. The measuring grid has been plotted on the wall of the basin with curvilinear traces, Fig. 4. The basin in not equipped with planar or vertical motion mechanism.

For the tracking-based identification of control system multi-channel measuring circuit has been connected with the possibility of voltage changes recording. The signals recorded where those controlling horizontal, vertical and planar propellers responsible for rotation and planar motion. The changes of voltage of depth gauge and time can be recorded as well. Recording is carried out when vehicle moving according to given trajectory (vertical plane in the considered case). The assumed trajectory was achieved by an operator who steered the vehicle with the help of camera mounted to it. The measuring grid was visible on the camera as well as particular trajectories. The laser indicator placed on the vehicle and coupled with the camera was a motion marker.

The laser indicator gave a point visible on the wall of the basin and explicitly locates the vehicle in the reference to the courses marked on the wall. The 100 mm scale gradation marked on the basin wall provided sufficient accuracy for the determination of deviation from assumed motion trajectory. The image from the camera visible for the KRAB vehicle operator is presented in Fig. 5.

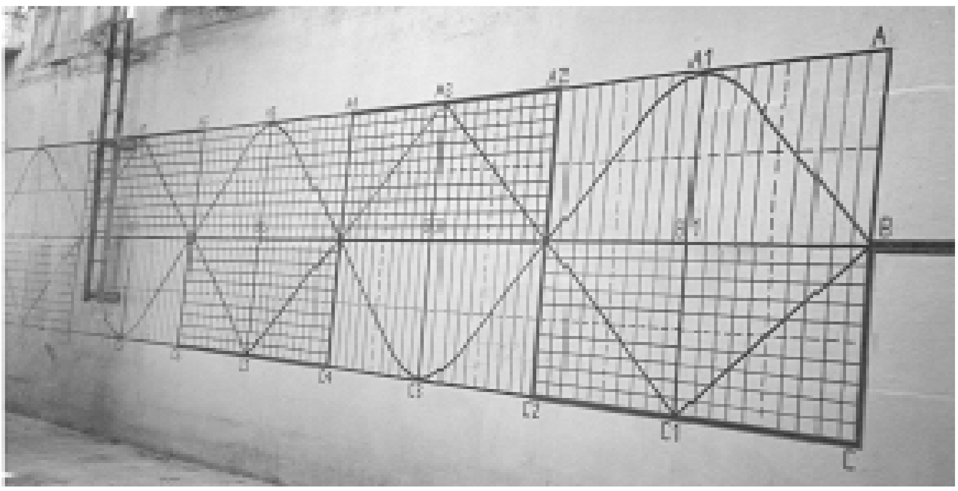


Fig. 4. The measuring grid and trajectories plotted on the basin wall.

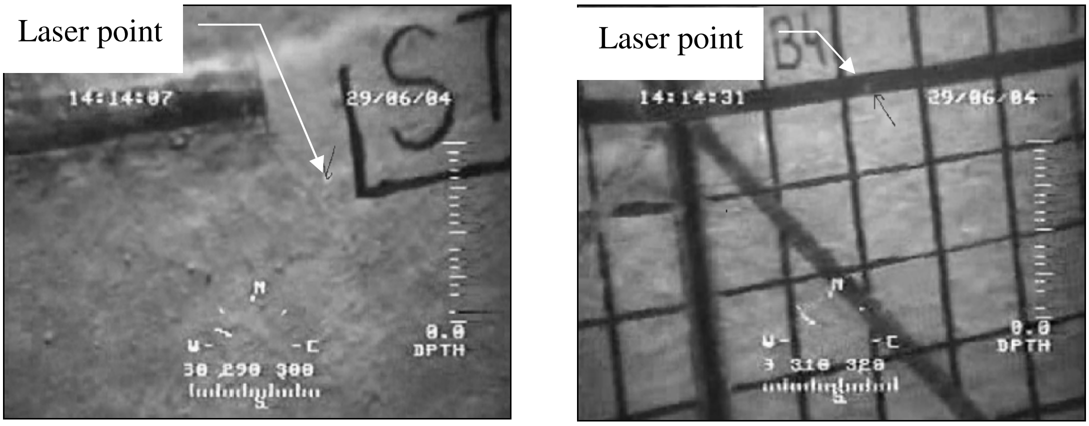


Fig. 5. The image from the camera placed on the vehicle. The laser point is marked by an arrow. An instant of vehicle start at the begin of measuring length is presented as well as straight horizontal motion after completion a way of 4 m.

3. DETERMINATION OF NETWORK STRUCTURE

The first step in composing of neural model of up and down motions in vertical plane is the determination of neural network structure. The problem is not fully described yet and many authors, [5], present a rule of thumb methods rather than exact formulas. It can be stated that the selection of network structure and its connection inside requires some necessary experience and intuition as well. The multi-layer perceptron with three layers (input, output and a hidden layer) transforms any given space X into any another Y by any chosen function, [2, 5]. The network which is used for model of motions development in the vertical plane is given in Fig. 6.

The overall process of neural model designing is as following:

- the Network/Data Manager toolbox from Matlab system is used (part of Neural Network Toolbox),
- to the Network/Data Manager toolbox the net structure determined according to Figure 7 is entered, the learning parameters, learning data and output obtained in the tests are entered as well.
- the input and output testing data sets are entered as well.

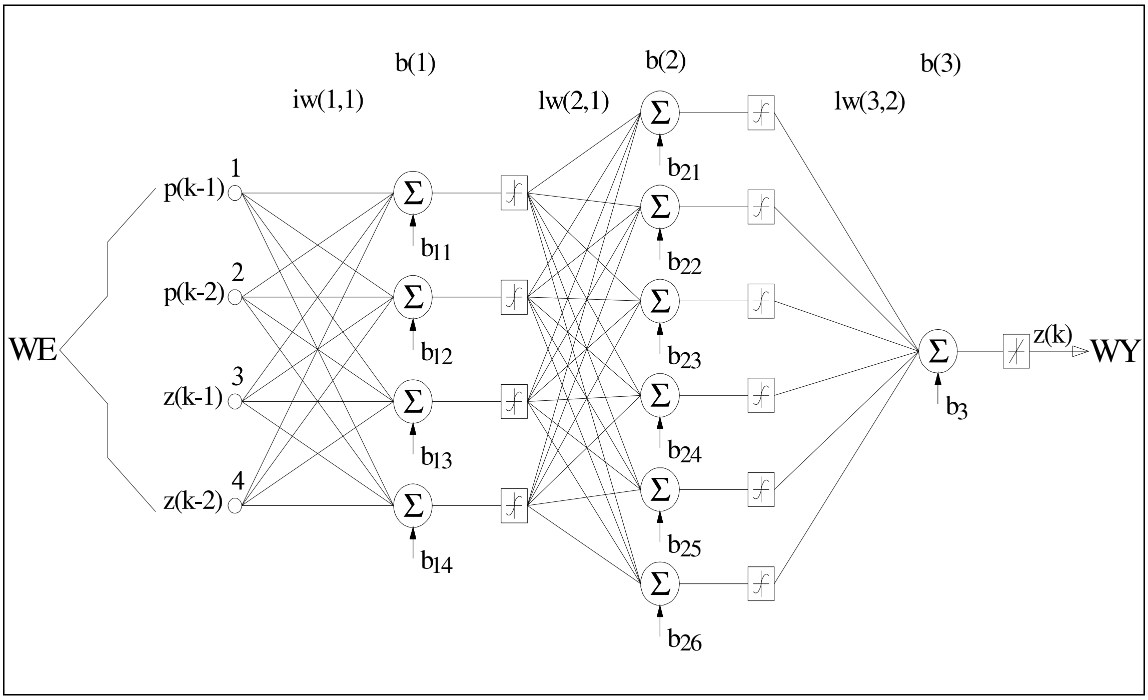


Fig. 6. Functional block structure of neural network - model of up and down motions of KRAB vehicle in the vertical plane [7].

The input learning data are used for generating the values of coefficients initiating the network work and are minimal and maximal values from the first file of learning set. The entering of the data translates into the generating by the software the weights between inputs and input layer and values of weights and biases for other layers.

The network trained in four steps, Fig. 7, then is tested with the help of testing data. The results of testing have been presented as an absolute error in Fig. 8. The absolute error is defined as difference between values of output results (simulation) of the testing file and corresponding results of network output obtained from the real testing file.

Then the successive steps of training are performed with the use of successive learning files and the testing is carried out (with the same files as in the first step). The neural model of ROV motions is finally obtained in fourth step and the values of weights and biases are given.

4. SUMMARY AND CONCLUSIONS

Analyzing the movement of the ROV presented in the article – up and down trajectory straight ahead – it can be stated that the mean absolute error after four learning steps for testing data was +0,012 V in the range of positive error values and -0,014 V for negative ones. After calculating to length measure it matches the deviations of 0,022 m and -0,028 m respectively to considered depth. Mean value of relative error for presented cases was 2,7 % (not shown in the article).

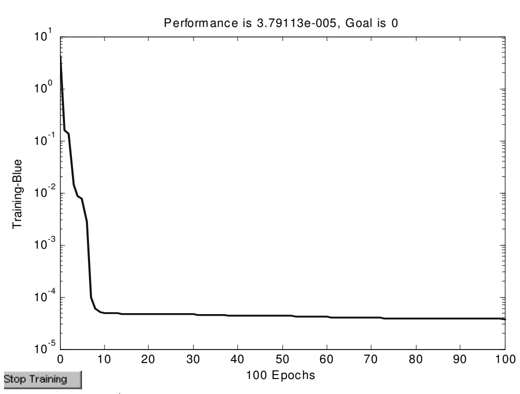
If we take into consideration these values of the absolute and relative errors determined during neural model of KRAB vehicle testing it can be stated that the model approximates the real conditions with sufficient accuracy for testing and learning data.

During further continuation of the research the problem worth to be examined is studying the curvilinear courses of an ROV. The general structure of an ANN could be designed then for better modelling of vehicle movements in vertical plane and remaining two reference planes.

Acknowledgments

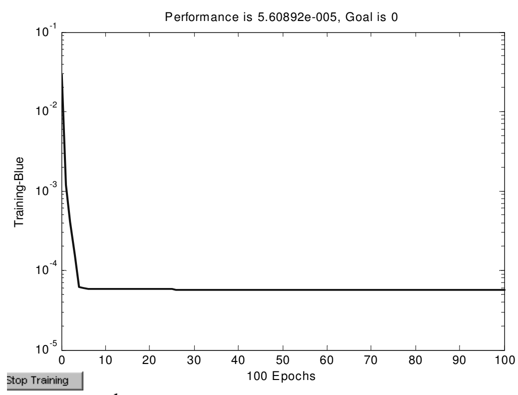
This work has been performed within the project No 4 T12C 020 26 supported by the Ministry of Education and Science, Poland, entitled ”System monitoringu głębinowego dla warunków niebezpiecznych” (Underwater monitoring system for hazardous conditions).

mse



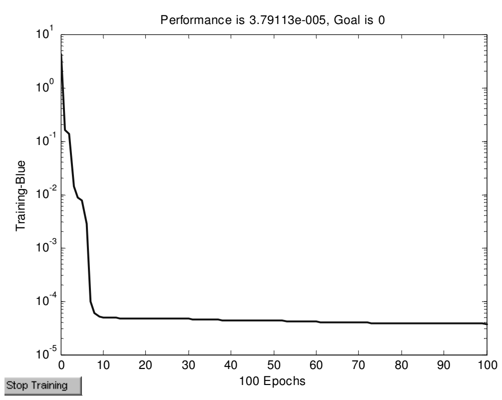
1st step, research file we1221A

mse



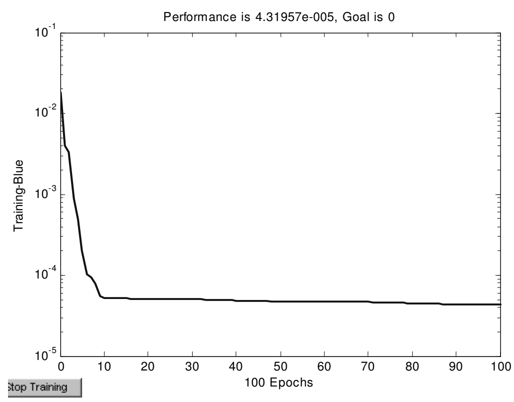
2nd step, research file we1150A

mse



3rd step, research file we1155A

mse



4th step, research file we1125A

Fig. 7. Learning process in the first step [X axis – number of epochs in learning process, Y axis – mean square error] – Network 7A_4 4.

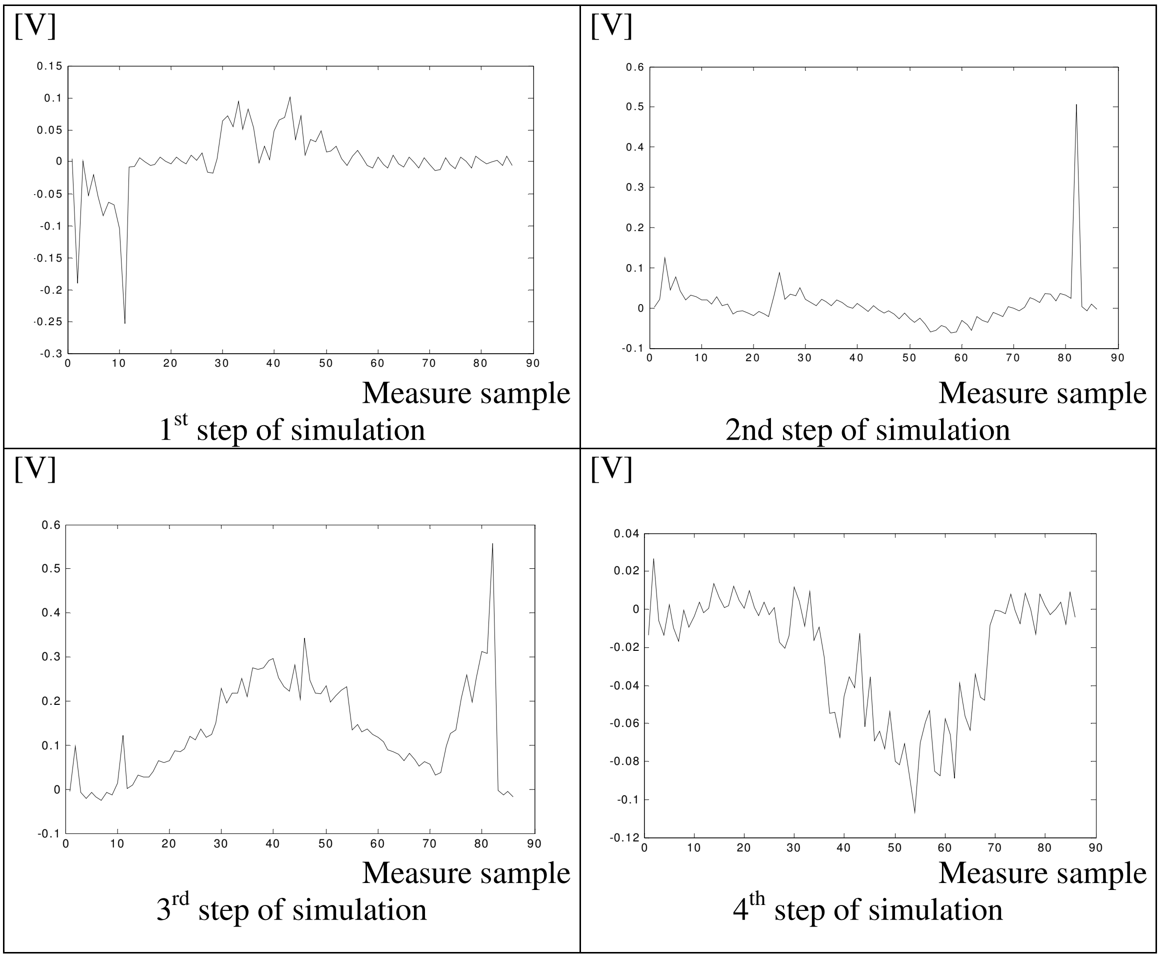


Fig. 8. The absolute error in consecutive steps of simulation (research file we1209A and we1209, 1st to 4th step of simulation).

REFERENCES:

1. Graczyk T., Matejski M.: The ROV Movement Modelling applying fuzzy logic technique, 2nd PetroMin Underwater Technology Conference : “The Next Phase”, Kuala Lumpur, Malaysia, 12-13.12.2006.
2. Korbicz J., Obuchowicz A., Uciński D.: Sztuczne sieci neuronowe. Podstawy i zastosowanie. (Artificial neural networks. Basics and application). Akademicka Oficyna Wydawnicza PLJ, Warszawa 1994.
3. Matejski M.: Metoda opracowania i weryfikacji modelu ruchu bezzałogowego pojazdu podwodnego w płaszczyźnie pionowej w ograniczonych warunkach eksperymentalnych (Elaboration and verification method of movement model of an ROV in a vertical plane in restricted experimental conditions, doctor thesis, Szczecin University of Technology, 2006.
4. Matejski M., Graczyk T.: Discrete Linear Models of ROV Movement in Limited Experimental Conditions, PetroMin Underwater Technology Conference: What's New ?, Kuala Lumpur, Malaysia, 8-9 Dec. 2005.
5. Świętnicki Z., Wantoch-Rekowski R.: Sieci neuronowe w zastosowaniach wojskowych. (Military applications of neural networks). D.W. BELLONA, Warszawa 1998.
6. Computer software MATLAB 7.0.1,The Language of Technical Computing, Licence 101976.

Recenzent: dr hab. inż. Jerzy Garus

Autor: dr inż. Tadeusz Graczyk
Politechnika Szczecińska, Zakład Technologii Okrętów
71 – 065 Szczecin al. Piastów 41
tel.: +91 449 – 46 – 96
e-mail: tadeusz.graczyk@ps.pl