ECAI 2015 - International Conference – 7th Edition
Electronics, Computers and Artificial Intelligence
25 June -27 June, 2015, Bucharest, ROMÂNIA

Mobile system with real time route learning using Hardware Artificial Neural Network

Alin Mazare[1], Laurentiu-Mihai Ionescu[1], Adrian-Ioan Lita[2], Gheorghe Serban[1], Marin Ionut[1]
[1]Department of Electronics, Computers and Electrical Engineering
University of Pitesti, Faculty of Electronics, Communications and Computers
Pitesti, Romania
[2]Politehnica of Bucharest, Splaiul Independentei no. 313, sector 6, Bucharest, ROMANIA
laurentiu.ionescu@upit.ro

Abstract –**This article presents a solution for tracking a mobile system using an artificial neural network. The mobile system collects data from the environment using an ultrasonic transmitter and receiver then data is processing using a binary artificial neural network. Some templates have been pre-loaded into the system to avoid blockages or additional routes. The solution is implemented on a SOC manufactured by Xilinx: Zync7000 Artix which consists of an FPGA and an ARM processor. The FPGA contains hardware neural network, command units and acquisition unit, while the processor contains the interface that provides patterns for learning process and communication interface (Ethernet interface).**

Artificial neural network, Field programmable gates array, Real time learning, Real time pattern recognition

I. INTRODUCTION

The appearance of FPGA circuits (Field Programmable Gates Array) has revolutionized the design of the intelligent algorithms. The concept of algorithms “hard-ification” consists in hardware implementing these algorithms and is based on performing parallel computing rather than sequential processing.

In general, the artificial intelligence algorithms are used to solve problems difficult to treat by conventional methods. There are three major classes of algorithms: neural networks, evolutionary algorithms and fuzzy system used in most fields [1]. The first two methods having pseudo random solutions is difficult to determine response time since it varies even with the same input data. In their conventional form (implemented on a computer) the algorithms cannot be used for real time response solutions. That it is because learning and converging process takes place in an unknown number of steps.

By hardware implementation and parallelization of component modules the learning or converging time can be reduced to allow a real time response, thus more and more applications can use embedded circuits for real-time monitoring [2].

Artificial neural networks can be implemented using hardware parallel modules instead sequentially steps in more efficient ways, in terms of the rate of learning and testing [3].

There are many techniques presented for hardware implementation of the neural networks, some of these being treated in recent papers: digital circuits [4] [5], optical and analog circuits [6].

Usually, intelligent algorithms are not real time solutions. This is because they are based on pseudo random search method and it is difficult to determine the convergence time. We have a convergence time that varies within a wide range, bounded by a minimum and maximum limit.

The hardware acceleration for intelligent algorithms obtains a much smaller convergence time so that the maximum range is somewhere below the limit required by the application deadline in real time.

Our solution uses a neural network implemented in FPGA. By having a parallelization of all neurons and weights, the calculations are occurring at the same time for all modules in the network. The network is used for real time learning and response. In this way is done the identification of patterns of routes by the mobile system in order to have an optimal trajectory.

The paper is divided into several sections. The following section shows the mobile system (mobile robot) and premises to have in mind when we decided to use a hardware integrated artificial neural network. The section will describe the control system component modules. The next chapter presents detailed characteristics of the artificial neural network which is the brain of the system. Finally, the last chapter shows the experimental results and conclusions.

II. INTELLIGENT MOBILE SYSTEM

A. *System presentation*

Figure 1 shows the mobile system. It contains a module that is named head, with ultrasonic sensors - a transmitter and a receiver. The head is connected to the body using a servo motor. This allows rotation of the head by an angle up to 180°. At every angle of 18 degrees, the system makes an acquisition (transmit pulse and receive echo pulse) which determine the distance to obstacles. The Central Unit - composed of processor (PS programmable system) and FPGA (programmable logic PL) learns some possible routes and then makes decisions and signals the motors. The aim is to avoid blocking (entrance between obstacles) and the unnecessary routes.

B. *Central unit*

Figure 2 shows the central control unit.

978-1-4673-6647-2/15/$31.00 ©2015 IEEE

As can be seen in the figure, the system consists of several modules. First we have a control unit of the head. This is a logic circuit which generates periodic servo motion control signals for a number of degrees (scrolls from 0 to 180 degrees).

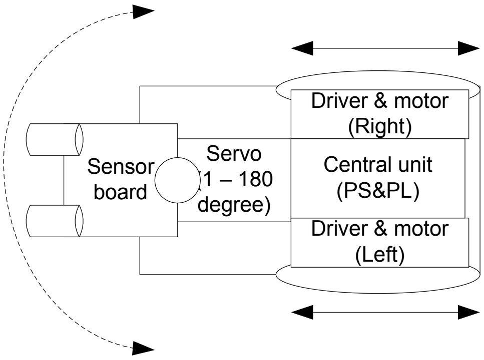


Fig.1. Mobile system – block diagram

In parallel it generates the impulse to be transmitted by ultrasound emitter. There are two modules: the module responsible with servo motor interface and pulse generator, both controlled by the control unit head.

The ultrasound sensor receives the echo pulse and its interface measures the arrival time of echo. Based on this it calculates the distance to an obstacle.

As mentioned for one position of the robot the distances are calculated making 10 measures increasing angle of the servo with 18 degree at each measure. The 10 values are stored in memory positions and will represent inputs for artificial neural networks – the brain of the system, the decisional unit. The network is trained with a set of templates in order to avoid obstacles but also to avoid potential situations that may lead to blocking the mobile system in a set of obstacles or carrying out unnecessary routes. The set of distances are taken as inputs in neural networks and decisions are taken by recognizing certain situations that may arise on their route.

This is the reason for using neural network: it is a solution that does not rely on identifying the obstacles but recognizing certain situations that lead to collisions and ultimately avoid them.

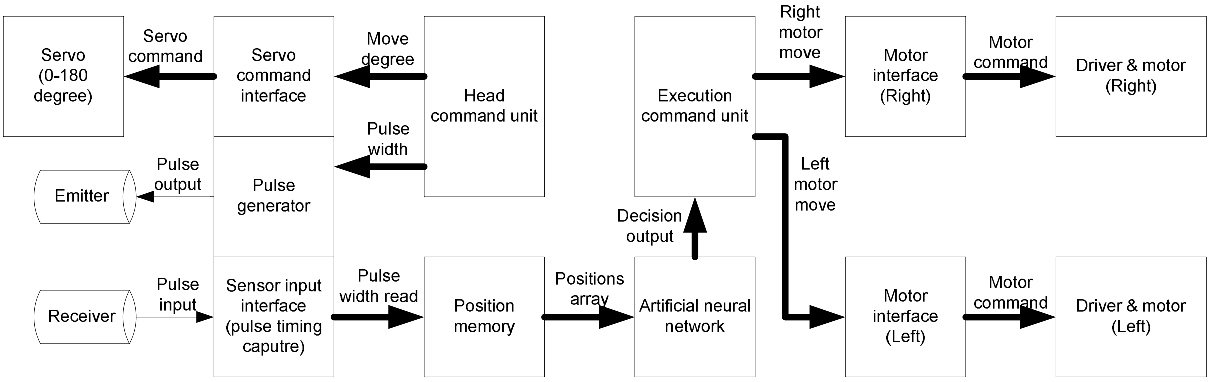


Fig.2. Central unit – full integrated in Zynq 7000 SOC

The decisions of the neural network are transmitted to the control unit which dealing with motors management - ensuring robot movement in a certain direction.

The centerpiece – better said brain of the system - is represented by Artificial Neural Networks.

III. ARTIFICIAL NEURAL NETWORK

We designed an artificial neural network (Boolean), and feed-forward back-propagation learning algorithm.

The structure of a binary neural network is shown in Figure 3. Binary neural network neurons are characterized by the binary values (0 or 1) for the neurons and weights. To compensate the limited field of binary values (only 0 and 1) update of weights is performed using pseudo-random numbers.

To achieve the diversity in the values of weights were implemented finite states machines (FSM), in which the transition takes place according to the error, but also according to a pseudo random sequence. In Figure 4 is shown the structure of FSM weight module.

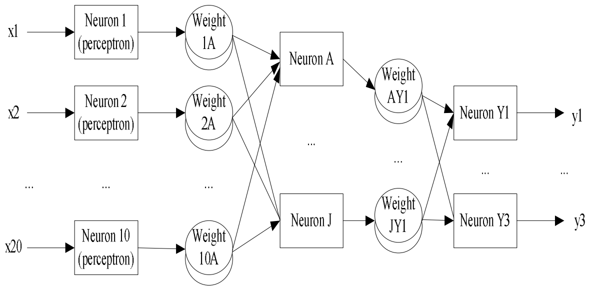


Fig.3 Neural network (10-10-3) block diagram. In our solution weights are stored in finite state machines with pseudo-random transitions activation

The output of weight is 0 or 1. The command output may take the following entries: state of the neuron connected to the weight module (repeated or inverted) or values 0 (low) or 1(high). This depends by the error status that comes from the network output and by a pseudo random number generated by RNG generator (each weight has its own RNG generator).

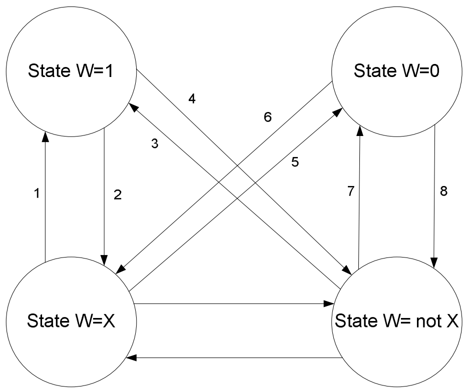
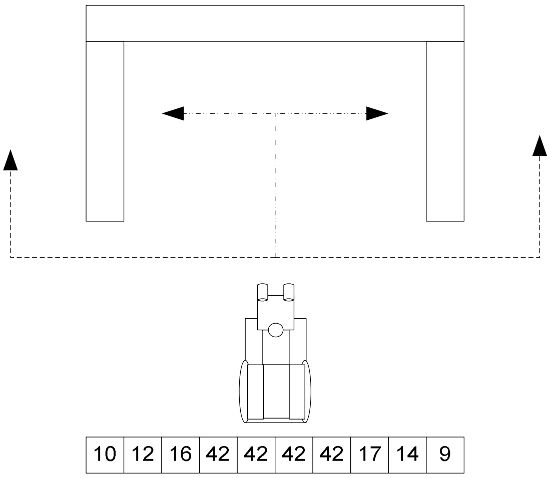


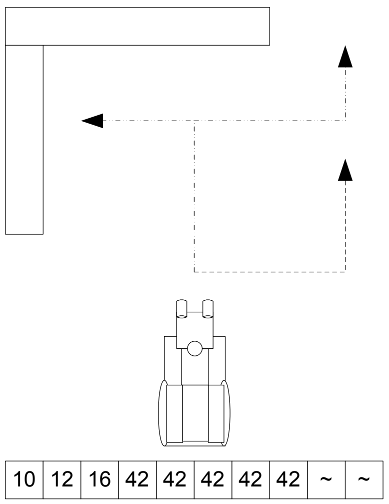
Fig.4 Weight finite state machine. Output w can be only 1 or 0. The machine has 4 states, 2 for w=1 and 2 for w=0. Transition between states is performed by events on error inputs (inputs with e) and events on random input (from RNG)

IV. EXPERIMENTS AND RESULTS

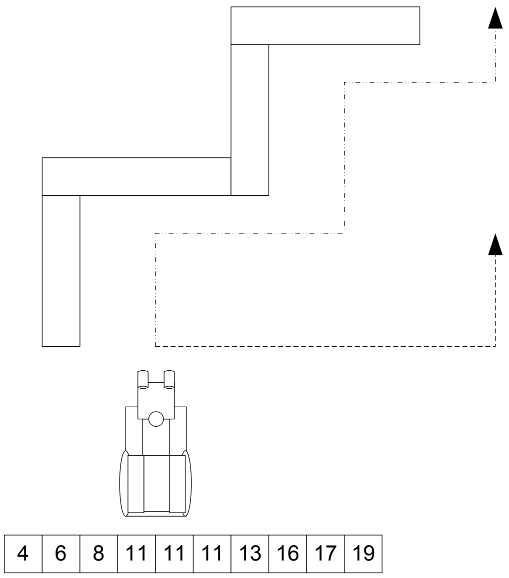
The experiments were started by training the network for three patterns (Figure 5). Subsequently the system is tested in situations like those learned or situations similar to those.The aim is that the mobile system to avoid blocking the corners or additional routes that appear to exploring single or multiple corners. The special feature in our application is the real-time response of the system.



a)



b)



c)

Fig.5 Three possible situations which are avoided by autonomous mobile system using artificial neural network: a) blocking in a closed corner, b) additional routes to a corner and c) additional routes to a double corner. With line dot are represented incorrect routes and line learned correct routes

It used an artificial neural network of 10 neurons in the input layer (corresponding values for the 10 position system). It uses a threshold function that converts numeric values from sensors (stored in memory position) in binary values 1 or 0.

The network has 10 neurons in the hidden layer and 5 in output layer. It can thus encode three distinct situations that may arise - all three situations shown in Figure 5.

ANN configuration is presented in table below:

Table 1. ANN configuration used.

Size	Value
Input neurons (perceptron)	10
Hidden layer	10
Output layer	5
Weight modules input-hide layer	100
Weight modules hide-output layer	50
Number of patterns learned	3

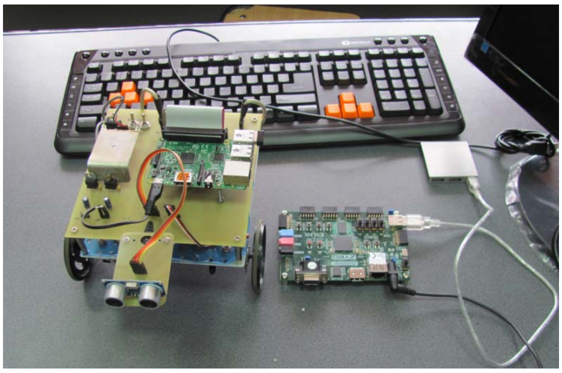
As can be seen in figure 5, the network has been trained with 3 patterns (presented in a,b,c). After that, the system has been tested in real conditions. The response has been correct in 90% cases.

In Table 2 the characteristics of the acquisition of the sensor are presented.

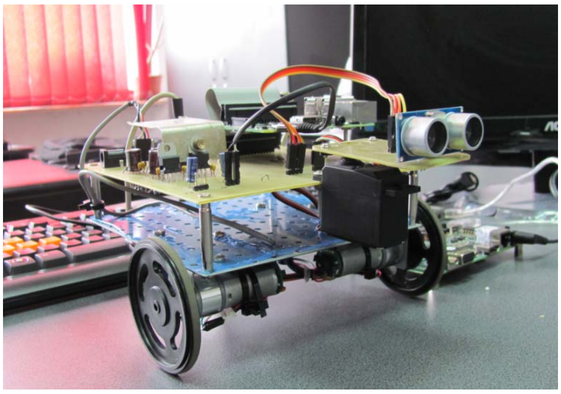
Table 2. Ultra sound measuring

Size	Value
Number of ultra sound acquisition for single position	10 (18 degree angle)
Acquisition time (1 sample)	50 ms
Pulse width	5 ms
Time tick (echo measure)	10 us

Finally, the entire system was integrated in Zynq 7020, a system on chip manufactured by Xilinx. The training and network interfacing was done by processor while the rest of the system is implemented in FPGA. This allowed the implementation of block head unit that operates in separate command, in parallel with artificial neural networks (which work parallels at the level of neurons and weight circuits) and motor control unit.



a) Mobile system and Zybo board (Zynq 7000 based)



b) Mobile system head detail

Fig.6 Images with system

As can be seen from Table 3 there is a very fast network response, which can be used as real-time intelligence solution.

Table 3. Resources used and response time

Size	Value
Logic allocated inside FPGA (including acquisition module)	~50% neural network 7% resources for acquisition TOTAL 63%
Convergence time (learning time)	Max. 300 ms
Normal operation response time (including acquisition module)	~12 ns delay path in neural network 5 ns delay path for 1 single acquisition module (after echo receiving) 20 ns delay path for motor command TOTAL 37ns

V. CONCLUSIONS AND FUTURE TRENDS

As it can be seen from the results, even network training phase takes less than one second. Instead, the testing regime, the system can identify the position of a track in less than 1 us. If we take the servo response speed, used to position the ultrasonic sensor for investigation of space around the mobile system, it can be seen that the response system (including the stage of recognition) is much faster - the time varies with several times the size.

The novelty brought is the integration of the whole application and the ability to respond in real time. Future research directions are related to increase the number of learned patterns and to implement “in-place” learning mechanisms.

REFERENCES

[1] Belu, Nadia; Anghel, Daniel Constantin; Rachieru, Nicoleta, „ Application of Fuzzy Logic in Design Failure Mode and Effects Analysis”, NNOVATIVE MANUFACTURING ENGINEERING, Book Series: Applied Mechanics and Materials, Volume: 371,Pages: 832-836, 2013

[2] 1. E. Ceuca, A. Tulbure, A. Taut, O. Pop, I. Farkas, “Embedded System for Remote Monitoring of OBD Bus”,ISSE 2013 , 36th International Spring Seminar on Electronics Technology „Automotive Electronics” May 8 – 12, 2013, Alba Iulia, Romania

[3] R. Rojas, " Neural Networks: A Systematic Introduction", Springer-Verlag, Berlin, 1996

[4] Sardar, S., Babu, K.A., “Hardware implementation of real-time, high performance, RCE-NN based face recognition system”, Proceedings of the 13th IEEE International Conference on Embedded Systems and 27th International Conference on VLSI Design, ISSN 1063-9667, pp. 174-179 , Mumbai, 2014.

[5] Nazari, S., Faez, K., Amiri, M., Karami, E., “A digital implementation of neuron–astrocyte interaction for neuromorphic applications”, Neural Networks 66, pp. 79-90, 2015

[6] Payvand, M., Rofeh, J., Sodhi, A., Theogarajan, L.,” A CMOS-memristive self-learning neural network for pattern classification applications”, Proceedings of the 2014 IEEE/ACM International Symposium on Nanoscale Architectures, NANOARCH 2014