New Design of Mobile Robot Path Planning with Randomly Moving Obstacles

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Abstract

The navigation of a mobile robot in an unknown environment has always been a very challenging task. In order to achieve safe and autonomous navigation, the mobile robot needs to sense the surrounding environment and plans a collision-free path. This paper focuses on designing and implementing a mobile robot which has the ability of navigating smoothly in an unknown environment, avoiding collisions, without having to stop in front of obstacles, detecting leakage of combustible gases and transmitting a message of detection results to the civil defense unit automatically through the Internet to the E-mail. This design uses the implementation of artificial neural network (ANN) on a new technology represented by Field Programmable Analog Array (FPAA) for controlling the motion of the robot. The robot with the proposed controller is tested and has completed the required objective successfully.

Keywords: Mobile robot, Field Programmable Analog Array (FPAA), Artificial Neural Networks, Gas sensor.

تصميم جديد لانسان آلي متنقّل متتّبع للمسار بوجود عقبات عشوائية

الخلاصة

إن تنقل الإنسان الآلي في بيئة غير معروفه كان دائماً مهمة صعبة للغاية. لأجل تحقيق حركة ذاتية و آمنه، يحتاج الإنسان الآلي إلى تحسس البيئة من حوله و رسم لنفسه مساراً خالياً من العوائق. يركز هذا البحث على تصميم و تنفيذ إنسان آلي متنقّل لديه القدرة على التنقل بسلاسة في بيئة غير معروفه وتفادي الاصطدام، دون الاضطرار إلى الوقوف أمام العقبات والكشف عن تسرب الغازات القابلة للاحتراق و أرسال رسالة بالنتائج إلى و حدة الدفاع المدني . هذا التصميم يقوم ببناء شبكة عصبية اصطناعية باستخدام تقنية جديدة هي المصفوفات التناظرية القابلة للبرمجة حقلياً (FPAA) للسيطرة على حركة الإنسان الآلي. تم فحص منظومة الإنسان الآلي المقترحة و قد حققت أهدافها المطلوبة بنجاح.

الكلمـات الدالـة: الإنسـان الآلـي المتنقّـل، المصـفوفات التناظريـة القابلـة للبرمجـة حقليـاً، الشـبكات العصـبية الاصطناعية، متحسس الغاز.

Introduction

Mobile robot is one of the advanced technology that has been used for various purposes in many application fields include transportation, exploration, industry, service, education, etc [1]. Mobile robot is a kind of robot which has self-planning, self-organizing, self-adapting ability and working in complex environments [2]. The mobile robot system can sense environment from various sensors (e.g. sonar, laser range finder, IR, and CCD etc.) [3].

Neural networks have served as biological controllers beginning with the first evolved brain. A major advantage of a neural network-based controller is its ability to adapt its behavior to meet the requirements of a changing environment. ANNs, coarse models of biological neural networks, have been and presently are being used to implement controllers in complex systems such as robots [4].

FPAAs are analog integrated circuits based on configurable analog blocks and programmable interconnections [5]. FPAAs are the counterparts of the field programmable gate arrays (FPGAs) in analog domain [6].Unlike the FPGAs, which contain a large number of modules and interconnections allowing arbitrary configurations of combinatorial and sequential logic, FPAAs typically contain a small number of Configurable Analog Blocks (CABs). The resources of each CAB vary across different devices, both commercially available and research oriented. Typically, a CAB contains operational amplifier(s), programmable capacitor arrays (PCAs), programmable interconnections and either programmable resistor arrays for continuous-time circuits or configurable switches for discrete time (switched-capacitor) circuits [7].Figure (1) shows A Schematic of the AN221E04 FPAA.

Compared to digital hardware, FPAAs have the advantage of interacting directly with the real world because they receive, process, and transmit signals totally in the analog domain (without the need to do A/D, D/A conversions) and are suitable for real time applications [8].

This paper presents new design of mobile robot uses the implementation of ANN on analog devices for controlling the robot's motion as well as the implementation of security functions.

The Hardware architecture of the mobile robot

The mobile robot consists of electronic, electrical, or mechanical units in addition to other components. This robot architecture consists of two systems, the first is motion and obstacles avoidance system, the second is the security system. These two systems combine with each other constituting a self-controlled integrated system. Figure (2) shows the two systems of the robot.

Motion and obstacles avoidance system

The architecture of the robot system consists of FPAA kit with AN221E04's chip as controller, a dc motor to move the robot, a driver circuit to provide the

motor with power and an ultrasonic sensor to avoid collisions.

Ultrasonic Sensor

Ultrasonic sensors are commonly used in mobile robots due to their low cost and easiness of use. This robot uses a Parking sensor and it is of a high technology product. It adopts ultrasonic wave sensors to measure the distance between the robot and the obstacles. The sensor transmits an ultrasonic wave and produces an output pulse that corresponds to the time required for the burst echo to return to the sensor. By measuring the echo pulse width, the distance to the target can be easily calculated. The sensor provides the ability to measure the distance from 0.3 cm to 2.

Controller Design

Neural networks are recommended for intelligent control as a part of well knows structure with adaptive critic. At present, most of the works on system control using neural networks are based on multilayer feed forward neural networks with back propagation learning or more efficient variations of this algorithm [9].The feed forward back propagation neural network algorithm is used for training this design because it provides accuracy and agreement with the requirements of the system.

In this design, AN221E04 is used to implement ANN on FPAA to control two DC motors. The Anadigm® AN221E04 is a reconfigurable analog device based on switched capacitor technology. The implementation of ANN by using FPAA technology is achieved in two steps:

- Training the network and obtaining the weights.
- Hardware Neuron Creation in FPAA

Training the network and obtaining the weights

In the training step, the network processes the inputs and compares its resulting outputs with the desired outputs. Errors are then propagated back through the system for adjusting the weights which control the network. The set of data which enables the training is called the "training set". During the training of a network, the training set of data is processed many times for optimizing the connection weights. In this process both the inputs and outputs are provided, therefore this type of training is known as supervised training. The feed forward network with two layers and two neurons in each layer with a consistent (+1 V) is used as a basis. MATLAB software is used to implement the feed forward back propagation algorithm because it provides accurate simulation and optimal weights.

Hardware Neuron Creation in FPAA

The Anadigm® Designer software provides block-level circuit implementation; therefore it is easy to create a hardware neuron using the CAMs made available by the Anadigm. The neural network with parameters that obtained from MATLAB software is mapped into the FPAA device using only one SumDiff CAM in the hidden layer and another SumDiff with Comparator CAM in the output layer. The input signals are multiplied by a gain which representing the weight of neuron. If the sum of the weighted inputs is above the threshold value, the neuron becomes active and vice-versa. The implementation of hardware neural on AN221E04 is described in Figure 3.

The Power supply System

The power supply system of the mobile robot is provided by three 6-voltage battery with 4Ah connected in parallel to provide +12V. The power

needed by two DC motors is provided directly from a battery .The L7805CV regulator is used to provide +5v to a FPAA kit, a driver circuit, a gas sensor and a transceiver.

Driver circuit

The H-Bridge circuit is interfaced between the FPAA and two DC motors. The most important use of the H-Bridge is to provide power to two DC motors and to isolate the other IC's from electrical problem that may occur. The H-Bridges allow forward and reverse motor control by closing one or the other pair of diagonally opposing switches. The driver used in this design is L298N. The L298N is a high voltage and high current dual full-bridge and it has two enable inputs that are provided to enable or to disable the device depending on the input signals. Figure (4) shows the connection circuit of H-bridge circuit and two DC motor.

This design uses two 12VDC Reversible Gear Head Motors to drive the two wheels of the robot. The H-bridge circuit drives the two DC motors simultaneously. To turn the motor foreword direction, a high voltage (+5 volts or logic '1') is given to the input 1 line, while a low voltage (0 volts or logic '0') is delivered to the input 2 line. To turn the motor in the opposite direction, logic '1' is given to the input 1 line, while logic '0' is given to the input 2 line. The other motor is controlled in the same way based on the input 3 and 4.

Security System

The security system is integrated by many functions. One of the most important functions in the security system is the Detection of the leakage of combustible gases. The security system is divided into two parts, the first part is the detection circuit of the leakage of combustible gases that has been installed on the robot body, and it is used to sense smoke or any gas leakage and transmits a signal of detection result to the receiver circuit. The second part is the receiver circuit. This circuit receives the signal that was transmitted from the detection circuit of the leakage of combustible gases which is connected to the computer.

The detection circuit of the leakage of combustible gases

The detection circuit of the leakage of combustible gases consists of a gas sensor, LM324 and a transceiver. This part is used to sense gases leakage and then transmits a warning signal from the robot side to the computer side, while the second part consists of an alarm and an interfacing circuit.

In the sensor's circuit, the MQ-4 sensor is used. This sensor consists of SO2 material, this material is of a lower conductivity in clean air. But when the air contains combustible gases, the material becomes more conductive with the increased level of gases in the air. Figure (5) shows the sensor's construct.

Alarm and Computer interfacing circuit

The circuit of the alarm and computer interfacing consists of a transceiver, microcontroller, two LEDs, alarm and buffer. In this circuit the signal that is received by the transceiver enters into the microcontroller, and then the microcontroller processes it and gives two signals. The first signal is used to run the alarm which can be turned off only manually and its design consists of LED and alarm. The second signal that is given from the microcontroller is entered to the computer via the parallel port. After receiving this signal, the computer will send a warning message automatically to the civil defense unit through the internet. MATLAB software is used to send messages to E-mail through the

Internet. Where this software provides a function that can be used to send E-mail through the Internet directly. Figure (6) shows the alarm and interfacing circuit.

Experiment's Results

To evaluate the performance of the mobile robot systems, the prototype design of mobile robot was put in a spacious environment where there are a number of obstacles in its way as well as gas leak artificially. Instead of remote controlling by users, the experiment's results show that the mobile robot was able to avoid obstacles in its way and detect gases leakage successfully. Finally, the motion of robot while avoiding two obstacles is shown in Figure (7).

Conclusions

This paper presented a design and implementation of the mobile robot which contains two systems, motion and security systems. In the motion system, the neural network controller is used to accomplish avoiding obstacles in its way. This controller uses two layers with back propagation Neural Network algorithm. This controller is implemented as a real time system using FPAA. In the other word, the security system which is implemented has included gases leakage detection tasks. Finally, the two systems have been tested and the practical results showed their effectiveness.

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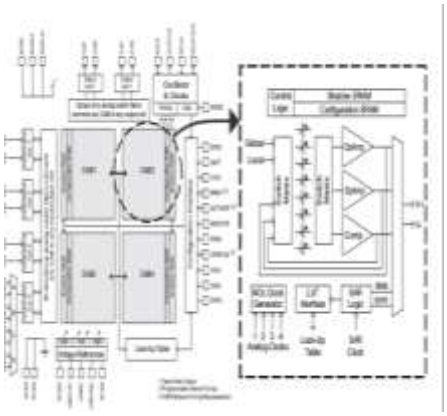

Figure (1): The left: A Schematic of the AN221E04 FPAA. The right: Inside Configurable Analog Block.

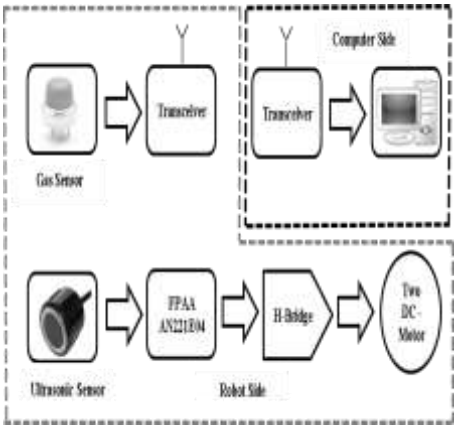

Figure (2): A System model of the security robot.

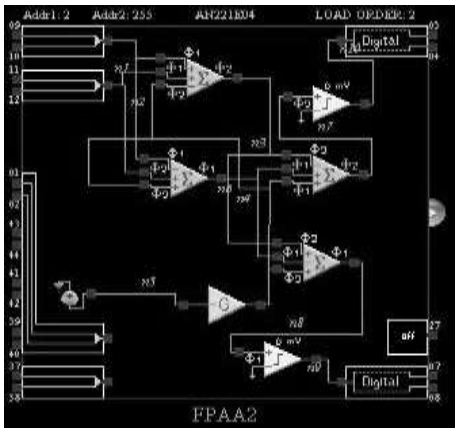

Figure (3): The implementation of a two-layer ANN in one FPAA.

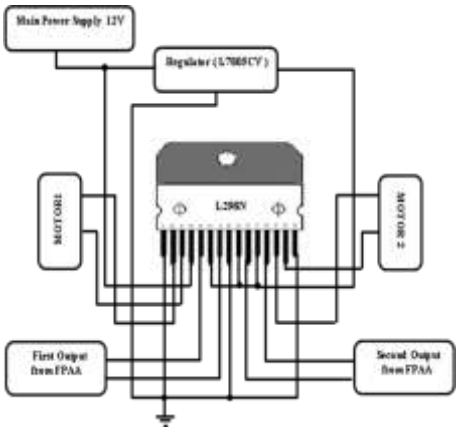

Figure (4): The connection between the H-bridge circuit (L298D) and DC-motor.

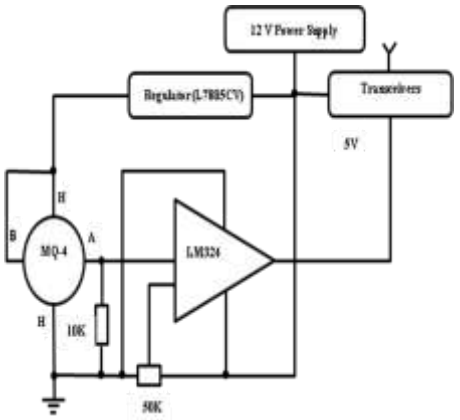

Figure (5): the circuit of the gas sensor in the robot side.

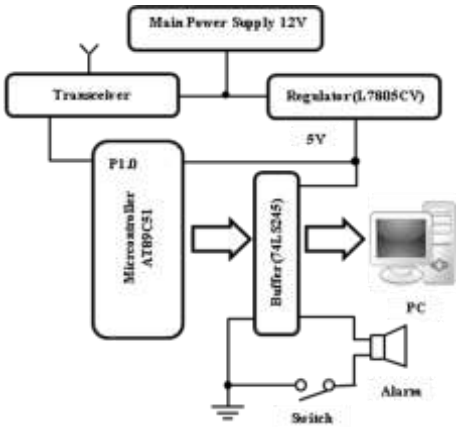

Figure (6): The circuit of the alarm and interfacing circuit.

(1) (2) (3)

(4) (5) (6)

(7) (8) (9)

(10) (11) (12)

(13) (14)

Figure (7): The motion of robot while avoiding two obstacles