Design and Implementation of Hardware’s Firefighting Legged Robot

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Abstract. This paper discusses about hardware design for firefighting legged robot. This research aims to design and make a robot control system hardware of firefighting legged robot. This research realize a firefighting legged robot contest, which using microcontroller of ATMEGA128. Robot search for fire and extinguish the fire in the changing space condition. It uses many kinds of sensor. Sound activation (sound sensor) is used to start all the process to be performed by the robot. Robot start navigation after sound activation has been activated. Sensor ultrasonic used to detect the distance to the wall. Line sensor is used to detect the white line when robot will enter the room and detect candle location. To detect light of candle, it used UVTron flame detector. When robot crashes the furniture so limit switch will be used for moving away from the crashed object. Robot must blow on a fire candle at candle location (white color). The tools used to turn off the flame is the fan (DC motor). The result show that firefighting legged robot has been function and working of the various sensors and controller. Overall, the system can work well and stable according desired requirement.

1. Introduction
Firefighting legged robot contest refers to Trinity College International Robot Contest (TCIRC). The objective of the contest is to build a robot, which will extinguish fire in the quickest time possible [1]. In some cases, the rules of TCRIC are adjusted to condition in Indonesia. The Firefighting robot is designed to search for a fire in a small floor plan of a house of the specific dimension, extinguish the fire by using the fire extinguisher, and then return to the front of the house [2].

The robot will be placed in the field of fire modeled in a labyrinth with 4 rooms. One room contained a candle representing the point of fire. Robot must be able to find the fire and then extinguish it. The better locomotion performance of hexapod robot in uneven floors may be obtained by use of a great number of different kinds of sensors. The signals generated by these sensors may be used to represent the real state of the robot and its interactions with the environment [3].

There are four different types of system unit is use 1) Locomotion system 2) Fire detection system 3) Extinguishing system 4) Communication system. The Locomotion system is used for obstacle detection and ultrasonic range finder to find the distance between obstacle and system. Fire detection system is used for the detection of fire in this the gas sensor is used. Extinguishing system is for successfully extinguish the fire [4]. Extinguisher detects and extinguishes the fire sensed by a sensor.

Microcontroller is the heart of the project. Microcontroller controls all the parts of the robot by the use of programming. In this robot as the fire sensor senses the fire, it sends the signal to microcontroller [5]. This paper discusses about electronic system or hardware controller which has an important role in a robotic design. The electronic system in the robot consist of the main controller circuit, the sensor circuit, the motor controller circuit for moving six legs.
2. System Architecture
The goal of the contest is to build a legged robot which will extinguish a fire in the quickest time possible. A candle will represent the fire, the robot must find and then extinguish fire. The last, it returns to the start position. Design of hardware controller must be compatible with the rules. Figure 1 represent all hardware controller needed.

![Figure 1. Block diagram of hardware controller](image)

ATMega 128 is the brain of firefighting legged robot. All program control is executed there. The input microcontroller, consist of sound activation, line sensor, fire detector sensor (UVTron), ultrasonic sensor, limit switch, servo controller. The output microcontroller is connected to the fan motor driver, ultrasonic sensor, servo controller and a character LCD to display the condition of robot. Servo controller able to control 18 servos. Power supply is used separately between motor and supply system.

3. Hardware Design

3.1 Minimum system circuit
Minimum system circuit is designed by using 128. Schematic of minimum system firefighting legged robot can be seen in figure 2. Input voltage of minimum system is 5V in VCC. Schematic of minimum system shows pin usage for ultrasonic sensor, UVTron sensor, sound activation, servo controller, line sensor, motor driver, limit switch, stop button and LCD.

![Figure 2. Schematic of minimum system ATMega 128](image)
3.2 Sound Activation Circuit

3.2.1 Transmitter Circuit. Transmitter can generate sound from 3 kHz — 4 kHz. Transmitter circuit used to decrease voltage is shown in figure 3. Transmitter requires 5V DC power supply. The output of this power supply will be connected to transmitter as VCC. Transmitter circuit can be seen in figure 4.

![Figure 3. Schematic of minimum system ATMega 128](image3)

![Figure 4. Schematic of transmitter circuit](image4)

To design sound generator (transmitter) is required IC LM 555 and buzzer. According to rules of robot contest, frequency that should be emitted is about 3.8 kHz.

3.2.2 Receiver Circuit. Receiver circuit is used as a sound receiver from specific frequency that can be seen in figure 5. Sound transmitted by the sound activation is received and converted to electrical energy by the condensor mic, then pass signal to the signal amplifier component (using LM358 as amplifier), from signal amplifier data will be filtered by IC tone decoder LM567. IC will filter the frequency between 3-4 kHz.

3.3 Line Sensor

Line sensor is used as a robot marker when robot entering the home space and candle location for existence of fire. To identify the entrance of the room and candle location, robot will use a line sensor placed at the bottom of the robot. Schematic of line sensor can be seen in figure 6.

![Figure 5. Schematic of receiver circuit](image5)

![Figure 6. Schematic of line sensor circuit](image6)

3.4 Layout of Minimum System

In designing PCB, the first is make the schematic design of electronic. The schematic circuit is created using OrCAD software [6]. Overall layout of hardware controller in layout can be seen in figure 7. Figure 8 shows firefighting robot.

![Figure 7. Minimum system layout](image7)

![Figure 8. Firefighting leged robot](image8)
4. Testing Result
Hardware controller designed will be tested and analyzed to know the output in each circuit. The testing result represent that the circuit can be used for firefighting legged robot.

4.1 Ultrasonic Sensor Testing
In the navigation system testing robot, data taken based on the condition of room. Every existing condition in the room, data is taken and used as a reference robot to determine the direction of the movement. The robot uses 8 ultrasonic sensors: front, diagonal right front, diagonal left front, right, left, diagonal back right, diagonal left back, and back. Ultrasonic selection is adjusted to the program needs when reading the room.

Ultrasonic is commonly used in the distance measurement, because of high precision, low energy consumption, long dissemination distance [7]. Ultrasonic sensor testing is related to the level of accuracy of the ultrasonic sensor used by the robot to detect the distance of the robot with the wall. It is done by comparing the measured value on the ultrasonic sensor with the actual distance. Table 1 shows the result of distance measurement ultrasonic sensor.

| Actual Distance | Detected Distance |
|-----------------|-------------------|
| 3 cm            | 3 cm              |
| 10 cm           | 11 cm             |
| 50 cm           | 54 cm             |
| 100 cm          | 107 cm            |
| 200 cm          | 211 cm            |
| 250 cm          | 265 cm            |
| 300 cm          | 338 cm            |

Table 1. Result testing of ultrasonic sensor

There are error or difference between the actual distance and the measured distance but the measured distance is still close to the actual distance. It is from the delay in the program in the microcontroller and from the sensor response itself.

4.2 Uvtron Flame Detector Testing
This sensor works with ultraviolet transmissions. Fire detected by UVtron while the signal processing unit using the module interface Hamamatsu UVtron. The advantages of this sensor is able to detect ultraviolet light until a distance of 5 meters. In order to test UvTron sensor, it uses external interrupt function by microcontroller. If there is a transition up on this external interrupt pin, then the microcontroller will display the result of fire detection as counter on the LCD. Table 2 shows result testing of UVtron sensor.

| The distance of sensor to fire | Fire condition | Sensor Respon |
|--------------------------------|----------------|---------------|
| 50 cm                          | On             | detected      |
| 100 cm                         | On             | detected      |
| 300 cm                         | On             | detected      |
| 500 cm                         | On             | detected      |
| 550 cm                         | On             | detected      |
| 575 cm                         | On             | not detected  |

Table 2. Result testing of UvTron sensor

The distance testing is about 10 cm to 5.5 m. Through the above data, the UVTron can detect candle light well up to a distance of 5.5 m.

4.3 Servo Motor Testing
Firefighting legged robot uses 18 servos on the legs. Servo controller is used to control servos. Robot can move and work according to the working principle designed. Table shows result testing of servo.
Table 3. Result testing of servo

| Pulse (μS) | Degree of Servo (°) |
|-----------|---------------------|
| 500       | 0                   |
| 600       | 10                  |
| 800       | 30                  |
| 1100      | 60                  |
| 1400      | 90                  |
| 1900      | 140                 |
| 2300      | 180                 |

This testing is done by giving pulse to the servo and then measuring the angle on the servo. This result is used for moving legged.

4.4 Minimum System Testing

Minimum system testing is done by testing the minimum system circuit with downloader to find out whether the minimum system can receive program from compiler. The output voltage and input voltage are obtained when the microcontroller is given program. The result shows the high voltage level of 4.9V and the low voltage level of 0.1V. In conclusion that microcontroller can be function.

Robot try to navigate in getting the extinguishing’s duration. Candle is placed in a position of the room, the robot scan it. The robot will move closer to the candle and extinguish it. The result is the robot successfully scanning the fire and extinguish the fire. Robot take time around 90 to 120 seconds for moving and extinguishing.

5. Conclusion and Future Work

The goal of this research is to develop design and implementation of hardware’s firefighting legged robot. Firefighting legged robot has been designed by using ATmega128. In developing hardware’s firefighting legged robot, this paper has proposed several stages of designing, creating, testing and analyzing. The result testing of hardware controller shows that is capable for firefighting robot. Designing hardware of control system must define the robot strategy. Using the data described at this work, an optimization hardware controller based on functional analysis must be developed.

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