2011

ANALYSIS OF THE FIRE FIGHTING ROBOT

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Content

ABSTRACT

With two sonar sensors do the obstacle avoiding, two sharp IR sensors do the wall following, AR-4, the fire fighter robot, can search a maze. And with the flame sensor on top of the robot, AR-4 can do the job of looking for the flame, which is a candle hiding in the maze, while exploring the maze. Once the flame sensor finds the fire, AR-4 goes towards to it, and extinguishes it with a fan installed on the front of the robot.

EXLCUSIVE SUMMARY

As we can see in the picture of AR-4, the two sonar sensors are installed in the front of the robot, which is used to avoid obstacles in the maze. The measuring range of the sonar sensor is 20—100 centimeters. For a small robot as AR-4(15cm*8cm), 20cm is kind of long, because the robot can never get close to the obstacle, which makes the job of exploring maze very difficult. In this situation, I added a moving forward program on the obstacle avoiding, which is, whenever these sonar sensors detect an obstacle, the AR-4 moves toward to the obstacle a little bit, and then do the obstacle avoiding job. After this improvement, the obstacle becomes smoother.

The two sharp IR sensors installed on the right side of the robot are used to follow the wall. Their measuring range is 5—50 centimeters, which is perfect for the wall following program. In the program, I use the "delta=front-rear" to keep the robot parallel to the wall. As we can see, the IR sensors are on the right side of the robot, so when exploring the maze, AR-4 always turn left.

The next important sensor is the flame sensor, which is on the top of the robot. The Figure 1 shows that the flame sensor is mounted on a servo. Since the robot always follows the wall, if the candle is in the middle of the maze, the robot may not find it. The sensor on the servo can solve this problem: every time the robot meets a corner, the robot brakes, and the servo turns around. Then, the flame sensor is able to search almost every corner of the maze.

The most interesting part of the fire fighter robot is the fan. In the beginning I have no idea how to create a device that can put out the flame. There are recommendations that I can use the fan from a GPU, but it seemed to be a little too small for the robot. Then I realize that since all parts of the robot is made of wood, I can curve a fan with wood by myself. This idea is realized within an hour. And it's powerful enough to extinguish the fire.

The bumper sensors on the front are installed to prevent the robot from running into a dead end. Once the robot goes to a corner and unable to move forward or turn left/right, the bumper sensor which is a switch will be activated. Then the AR-4 goes backward and gets rid of the dead situation.

INTRODUCTION

This article first introduces the integrated system which is the heart of the robot. Then the mobile platform and the actuation, they are combined together to make the robot move. Special sensors are the most important parts. For AR-4, there are sonar sensors, sharp IR sensors measuring the distance, flame sensor detecting the fire, and bump sensors in case of an extreme situation. After introduction to these special sensors, the behavior of the robot, including obstacle avoiding, wall following, fire extinguishing, etc. will be discussed.

Reference: data sheet of sensors

INTEGRATED SYSTEM

AR-4 has 9V battery as the power supply. The 9V power goes to the board as well as to the motors. AR-4 has 2 motors, 1 servo, 1 flame sensor, 2 sonar sensors, 2 sharp IR sensors, and 2 bumper sensors.

AR-4 uses ATxmega64A1 as the processor. It includes the motor controller and servo controller. The ADC channels are used to communicate with sonar, sharp IR and flame sensor. The bumper sensor is connected to the I/O port.

Picture of AR-4:

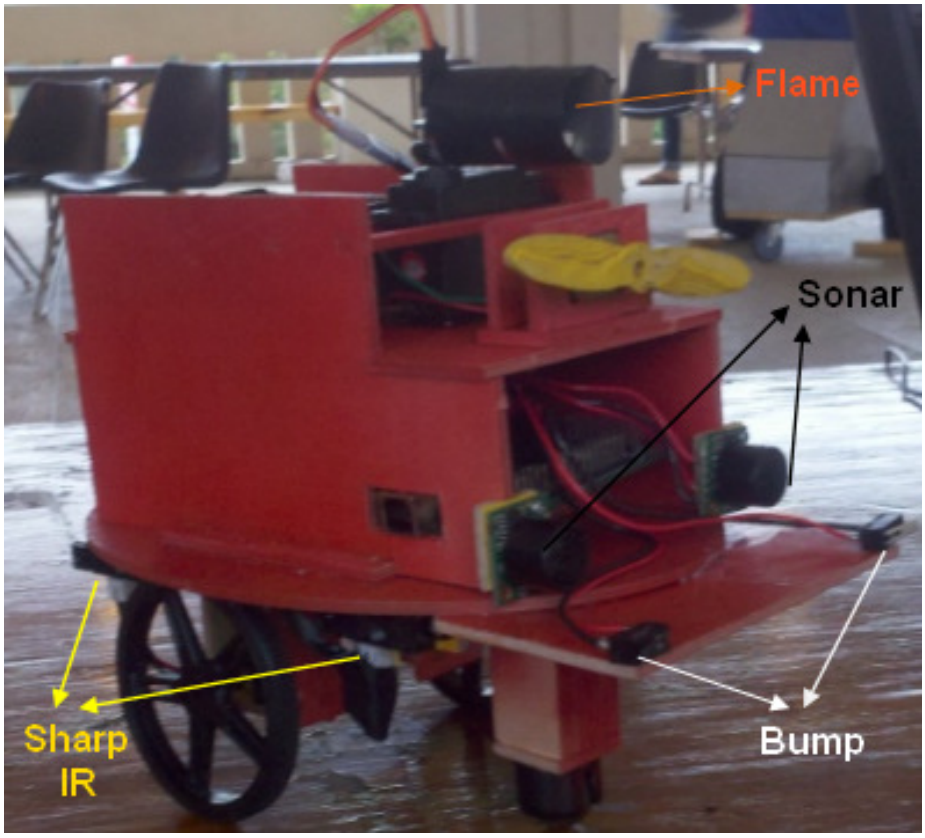

Figure_1 Photo of AR-4

Power System:

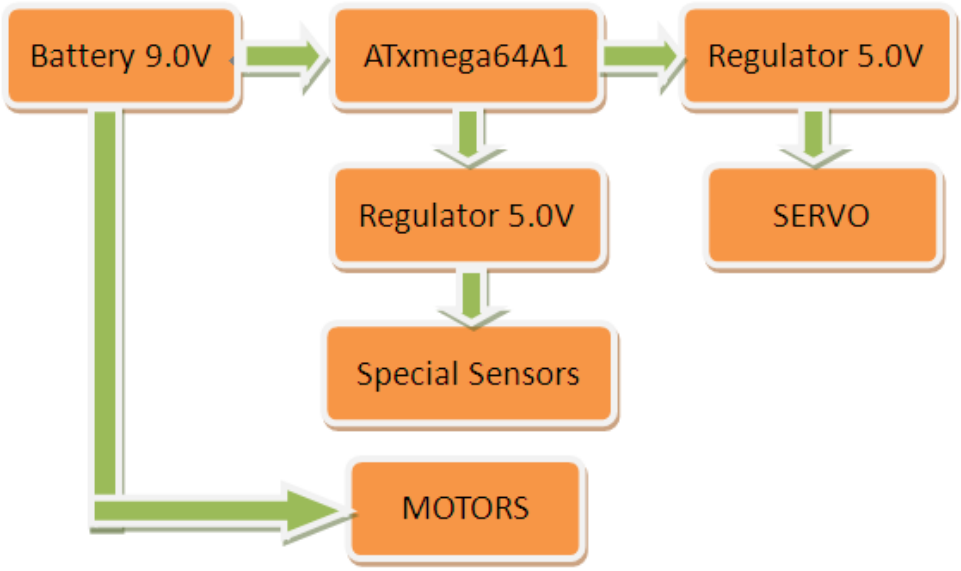

Figure_2 Power System

Control System:

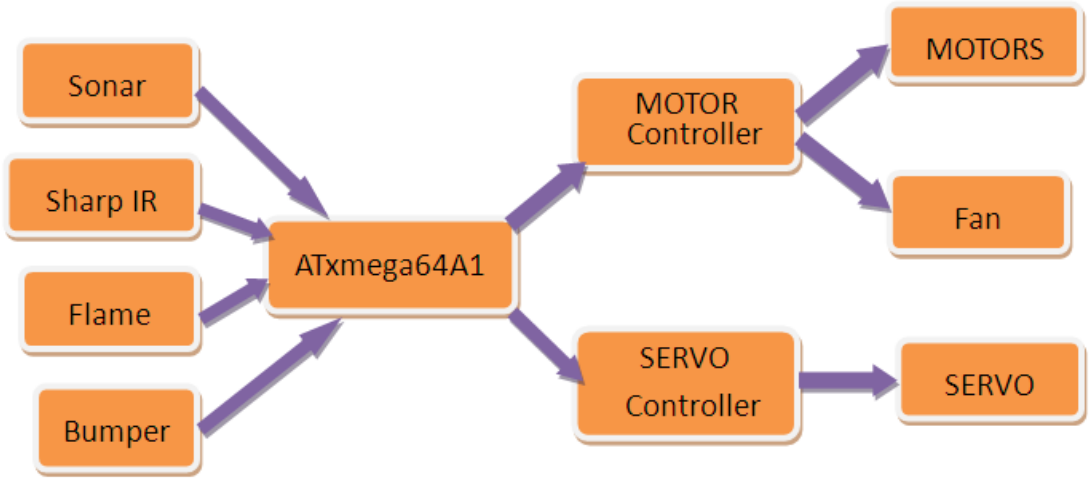

Figure_3 Control System

MOBILE PLATFORM

Designing a mobile platform is the first step of building AR-4. It is designed on the SolidWorks 2010 software. As we can see in the following figure, the main platform is an elliptic board. The two wheels connected with motors are on the backside of AR-4. A universal wheel is in front of these two wheels.

The ATxmega64A1 board is right on top of the elliptic platform. Above the board, there are servo with flame sensor, batteries, and fan. The sonar sensors and bumper sensors are mounted in the front of AR-4. The sharp IR sensors used to follow the wall are installed on the right side of AR-4.

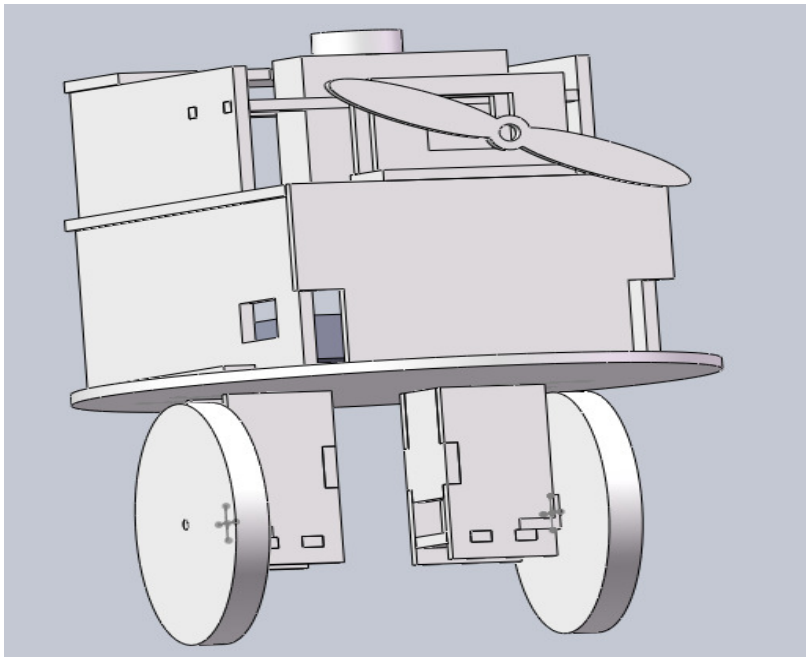

Figure_4 mobile platform on SolidWorks 2010

During the building of AR-4, I found out that building AR-4 with an elliptic platform is kind of a mistake, because AR-4 is a fire fighter, and the elliptic shape is not the traditional way for a fire truck. So, if there is a second chance, I will build the AR-4 with a rectangular platform. Another reason for the rectangular platform is that there is no area for the bumper sensors, and I have to add an extra wooden board for the installation of bumper sensors.

ACTUATION

Figure_5 Micro Metal Gear Motor and 90*10mm Wheels

In the actuation system, AR-4 uses the micro metal gear motor as the moving power. This motor is very small but powerful. Since AR-4 is also in small size, this kind of motor is perfect for it. The 90*10mm wheel is a big wheel for the size of AR-4. In the beginning of the design, I wanted the AR-4 to move as fast as it can, and a bigger wheel has a faster speed. However, during the testing

of the fire extinguishing, I realize that the fast speed may result in the inaccuracy of sensor information because it moves so fast that there is no time for the sensors to react.

Figure_6 HS-646MG Servo

The HS-646MG Servo is used to expand the searching scope of the flame sensor. Like I mentioned before, if AR-4 always follows the wall and the candle is in the middle of the maze, it may never find the flame. So we add a servo to support the flame sensor and help the flame sensor search more area: every time there is a left turn, AR-4 will stop and turn the servo, and then the flame senor is able to look for the flame in the middle areas of the maze.

SENSORS

Sonar Sensor

Figure_7 Sonar Sensor

The flame to be put out is hidden behind a bunch of blocks. So the fire fighting AR-4 has to be capable of obstacle avoiding. We use sonar sensors to do this job.

Sonar sensor converts the energy into ultrasound and measure the distance from the sensor to the obstacle by calculating the feedback time of the ultrasound.

The sonar sensor I use is Maxbotix LV-EZ1, which is featured as:

- 42kHz Ultrasonic sensor
- Operates from 2.5-5.5V
- Low 2mA supply current
- 20Hz reading rate
- RS232 Serial Output - 9600bps
- Analog Output - 10mV/inch
- PWM Output - 147uS/inch
- Small, light weight module

AR-4 has two sonar sensors. Both of them are installed on the platform, facing to the front direction to detect the obstacles when finding the flame. By measuring the distance between the AR-4 and the obstacle, the sonar sensor tells the robot when to make a turn or just moving forward.

So the obstacle avoiding is an easy job for the sonar sensors. But it would be complicated when we combine the sonar sensors with a PIR sensor to find the flame.

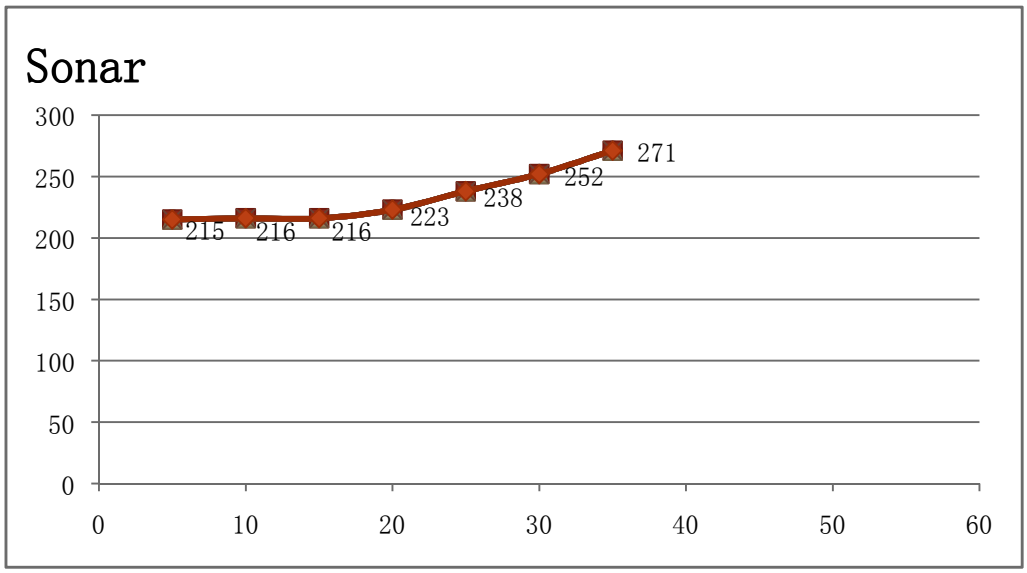

Figure_8 Sonar Sensor Test Data

The figure above shows the measuring information of a sonar sensor. As we can see, the measuring range of the sonar sensor is beginning from 15cm, which is a little far for the robot. To search more areas in the maze, whenever there is an obstacle, AR-4 should goes toward to the obstacle as close as possible and then goes to the obstacle avoiding program. But the sonar sensor cannot provide a close range. And I have to let AR-4 goes toward to the obstacle a little bit every time before the obstacle avoiding.

So, next time there is an obstacle avoiding, I will choose the sharp IR sensor which is much better at the close range than the sonar. Let's look at the sharp IR sensor right now.

Sharp IR Sensor

Figure_9 Sharp GP2Y0A21YK0F Analog Distance Sensor

There are two sharp IR sensors on the right side of AR-4. They are combined together to do the wall following mission.

Feature summary

- operating voltage: 4.5 V to 5.5 V
- average current consumption: 30 mA (typical)
- distance measuring range: 10 cm to 80 cm (4" to 32")
- output type: analog voltage
- output voltage differential over distance range: 1.9 V (typical)
- response time: 38 ± 10 ms
- package size: 29.5×13.0×13.5 mm (1.16×0.5×0.53")
- weight: 3.5 g (0.12 oz)

The following figure shows the testing data of this sharp IR sensor:

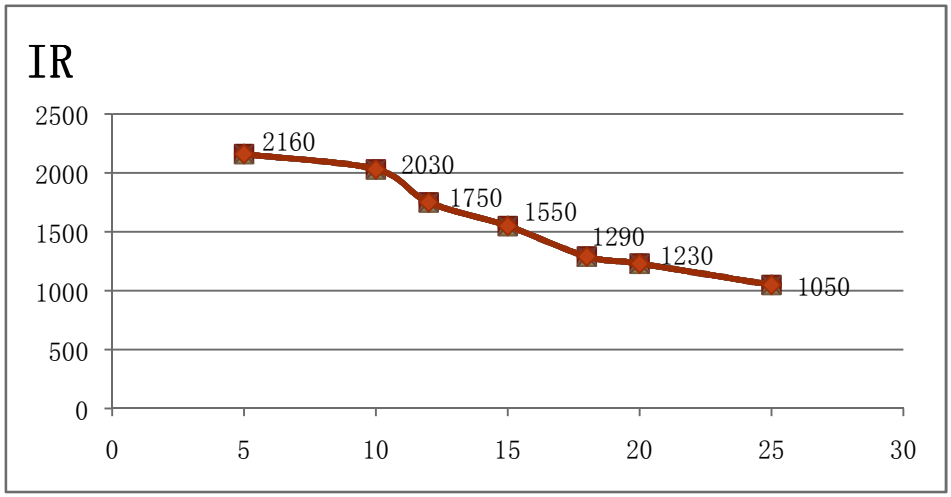

Figure_10 Sharp IR Sensor test data

The sharp IR sensor has a perfect measuring range for AR-4. Although the range on the data sheet is 10-80cm, the test data shows it start from 5cm. With two of them, AR-4 is able to go parallel to a wall.

This is how it is programmed: variable “front” and ”rear” are used to read information from these two sensors, and “delta” equals to “front-rear”. Delta is kept in a small range, and once it goes out

of that range, AR-4 will do some adjustment like turning little left or turning little right. And thus, AR-4 always follows the wall.

Flame Sensor

Figure_11 Flame Sensor

Flame sensor is used to detect the flame by measuring the wavelength of the light. Without the interruption of sunlight, like in a room, the flame sensor can easily find the candle flame.
However, my first choice for the flame detecting is not the flame sensor; it's a PIR sensor. Then after I burnt the PIR in the lab, I ordered this flame sensor. There is another reason for me to choose this flame sensor: PIR detects the movement of stuff, and for a running robot, it is very time consuming to stop and detect the moving candle flame. So, I did a little research and found out this flame sensor. I bought it from eBay, and the seller is in Hong Kong, so I waited like half a month.
Feature of the flame sensor:

- High sensitivity IR receiver
- Extremely sensitive to wave between 760-1100nm
- Power supply indicator lamp
- Comparator output indicator lamp
- AO, real-time thermister voltage signal output
- DO, high / low electric level signal output
- Analog quantity output
- Threshold rollover electric level output
- Threshold adjusted by potentiometer
- Detection Angle Range: About 60 degrees
- Power Supply: 0-15 V DC
- Hole Inner Diameter: Approx. 3mm
- Size (L x W): Approx. 36 x 16mm

There are two signal pins for the flame sensor: DO and AO. When we use the DO pin, the sensor can tell us only two kinds of information: flame and non-flame. The AO, however, can tell us the exact wavelength of different light. But with the control of the sliding rheostat as we can see in the figure above, the number of the AO varies almost every time. So, we just simply use the DO pin.

Bumper Sensor

Figure_12 Bumper Sensor

The bumper sensor is installed to prevent AR-4 from running into a dead end. Technically, the bumper sensor is a switch. It connects to the I/O ports of the board, and tells the robot whether it touches some obstacle. Once the switch is close, AR-4 will go backward a little and do the obstacle avoiding again.

The second way AR-4 uses the bumper sensor is in the situation of locating the flame. Once the flame the sensor finds the flame, AR-4 goes toward to it, and we don't know when to stop to start the extinguishing program. With the bumper sensors, AR-4 stops as soon as it touches the obstacle which the candle sitting on.

BEHAVIORS

In the maze, AR-4 always goes along the right side of the wall. The flame sensor facing the front keeps looking for the candle hided in the maze. Once there is an obstacle in front of AR-4, it turns left, brake, and the servo on top of AR-4 turns for a large degree and let the flame sensor which is mounted on the servo have a chance to scan the area far from the wall. If there is no flame, AR-4 keeps exploring the maze. And if the flame is detected, AR-4 goes towards to the flame, and then, the fan is activated to put out the fire.

EXPERIMENTAL LAYOUT AND RESULTS

At the beginning of this course, I want to design a messenger, which is a robot with a camera keeps going from someplace to another place and sends information through wireless communication. And that's one of the reasons I choose the fashionable oval as the shape of the platform. The reason I gave this idea up is that the idea is a little simple, and I wanted AR-4 to do something more complicated.

When I have this idea of building a fire fighter, the mobile platform has already been assembled. So I use the platform and build a fire fighter on it.

The performance of AR-4 on the Demo day is not quite satisfying. The wall following and obstacle avoiding were working well. And AR-4 found the candle and extinguished it successfully. But after the fire extinguishing, it is stuck in the corner and can't get out of it. This is the key reason I add the bumper sensors to AR-4. It solved the problem of running into a dead end as well as locating the candle incorrectly.

CONCLUSION

The mission for AR-4 is quite simple: find the candle, put out it and go back. However, programming and testing are much more time consuming than I had imagined. The most annoying part is combining the wall following, obstacle avoiding and searching flame all together. Mistake after mistake, then it works.

If there is a chance to start over, I can do many things much better. First of all, the shape of the platform should be rectangular, which is much more like a fire truck. Secondly, for the obstacle avoiding, I would use the sharp IR sensors instead of the sonar. Because the sonar sensor is not capable of measuring things in a very close range (5-10cm), which makes the robot hard to get close to the obstacle. Finally, I should use the bumper sensor from the beginning of the design. The reason I didn't use the bumper sensors is that I wanted to save time and trouble. But after a long time I tested my program, I realize the fact that bumper sensor can only keep you from trouble. If I use the bumper sensors from the beginning, the programming would be much easier.

DOCUMENTATION

- ATxMega64A1:
  http://www.atmel.com/dyn/products/product_card.asp?PN=ATXMEGA64A1
- Sharp IR sensor:
  http://www.pololu.com/catalog/product/136
- Sonar sensor:
  http://www.sparkfun.com/products/639
- Flame sensor:
  http://www.ebay.com/itm/High-Sensitivity-IR-Receiver-Flame-Sensor-Module-Wave-Between-760-1100nm-New-/130574370065?pt=LH_DefaultDomain_0&hash=item1e66d6c511
- Bumper sensor:
  http://www.sparkfun.com/products/98
- SolidWorks and Code reference:
  https://sites.google.com/site/epiphanydiy/

APPENDICES

The code is provided on this site:
http://plaza.ufl.edu/libinyan/WebSite/AR-4.htm