Wall-Follower

Xiaodong Fang

EEL5666
Intelligent Machines Design Laboratory
University of Florida
School of Electrical and Computer Engineering

TAs: Tim Martin
Josh Weaver

Instructors: Dr. A. Antonio Arroyo
Dr. Eric M. Schwartz

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Abstract

Wall follower is an automatic wall following and color detecting robot. It is a small size (8 inch * 8inch * 6inch), highly integrated intelligent system based on an Atmel ATXmega A1 micro controller. It utilizes ultra-sonic and infrared range finders together with two motors on the rear of the aluminum platform to implement obstacle avoidance as well as wall following. A CMU camera is used to provide on-board color detection.

Keywords: intelligent machine, robot, color detection, wall following, CMU camera

Introduction

Automatic navigation of robots is always regarded as a critical part of machine intelligence. While outdoor navigation can be achieved using GPS technology, satellite-based indoor navigation is limited due to poor signal reception and high requirement on accuracy.
Therefore many indoor navigation methods are developed and used instead. These methods include computer vision technology, sensors of different perspective of view, etc.
The Wall-Follower is an indoor navigation robot which will automatically approach and follow a wall. It will also detect a certain color while it is following a wall. This feature can be used by other advanced robots in a lot of indoor and outdoor applications such as parallel parking, charge position detecting by a vacuum robot, etc.
Followed by this brief introduction to Wall-Follower, the overall integrated system will be shown. Then the author will give separate introductions to the control board, the mobile platform, the actuation part and sensors. After the introduction to software, experimental results, future improvements and conclusions are given in the end.

Integrated System

The integrated system of Wall-Follower is made up of five major components: sensors, an aluminum mobile platform, actuation system including two motors to drive and steer the car, two battery packs, and the most important, an Epiphany DIY control board. All other components are mounted on the aluminum platform. Sensors detect the outside world and give the information to the micro controller on the control board. While running the pre-stored program, the micro controller will according to data read from sensors give orders to motors regarding how to make the car move. The finished robot is shown in figure 1, and a component outline can be found in figure 2.

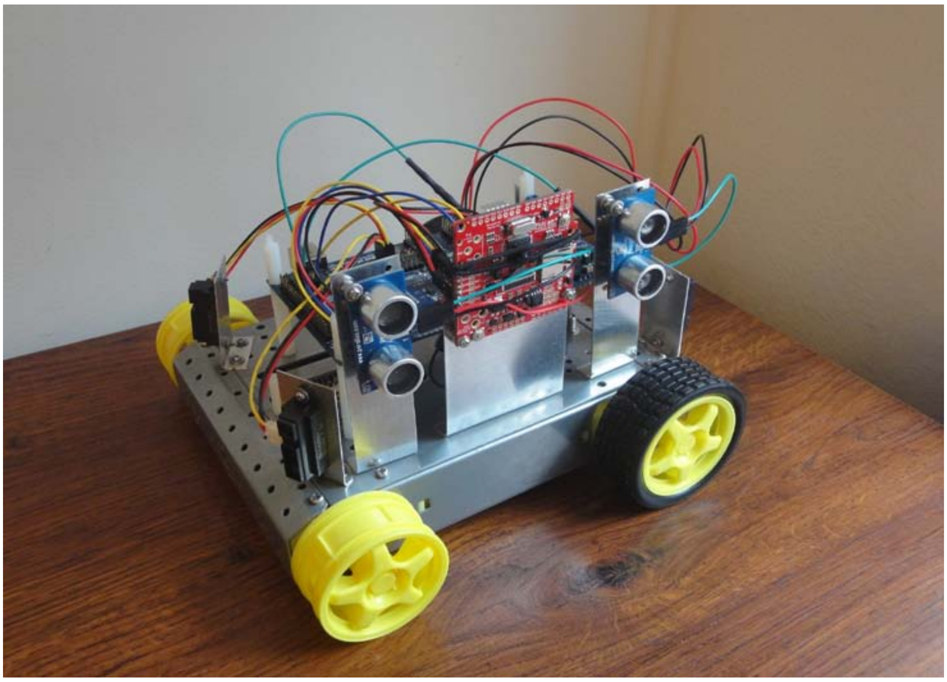

Figure 1, the finished robot

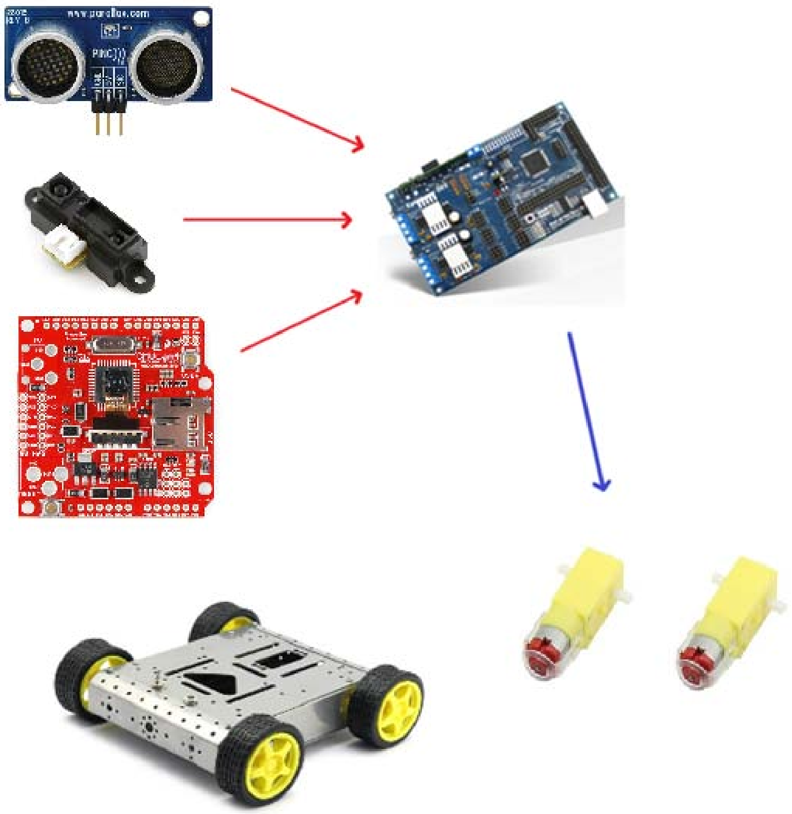

Figure 2, component outline

Control Board

The Epiphany DIY (figure 3) is a highly integrated, fully featured, open source and open hardware development board for the ATXmega A1 or A1U series.[1][2][3] Besides all the features ATXmega A1 has, the board itself has built-in motor and servo controllers, 3.3V and 5V regulators, USB serial communication port, 5V-3.3V ADC range shifter, etc.
This board is highly recommended to be used for IMDL students because of its abundance of counters, serial communication ports, ADC's and other peripherals.

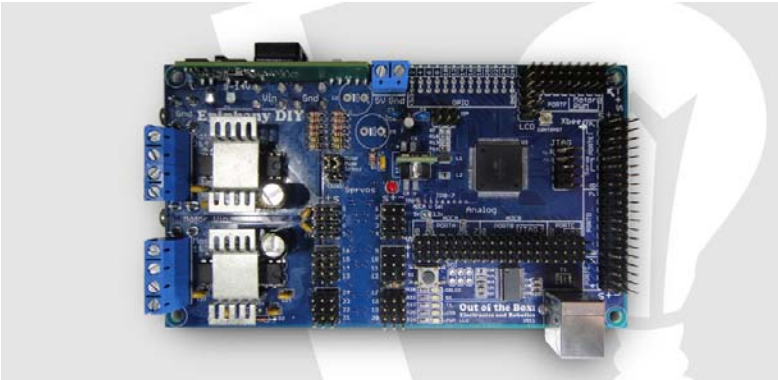

Figure 3, Epiphany DIY board

Figure 4, aluminum four wheel drive arduino platform

Mobile Platform

The Wall-Follower is based on an aluminum four wheel drive arduino platform (figure 4). Two motors and two battery packs are mounted inside the body. The control board and all the sensors will be mounted on the top of the car-body. While mounting the board and sensors, plastic pillars and aluminum sheets are used.

Actuation

Two 6V geared motors are used in Wall-Follower, while the other two free spinning wheels are mounted on empty motor cases. Thus forwarding, reversing and turning can be performed by controlling the speed of two motors separately. However, when testing the robot even with lowest workable PWM duty cycle, the motors still turned out to be too fast for the application. The solution is to power on the motor, in software, for part of the time in a macroscopic cycle, in addition to the PWM signal sent to the motor. This mechanism can be explained in figure 5.

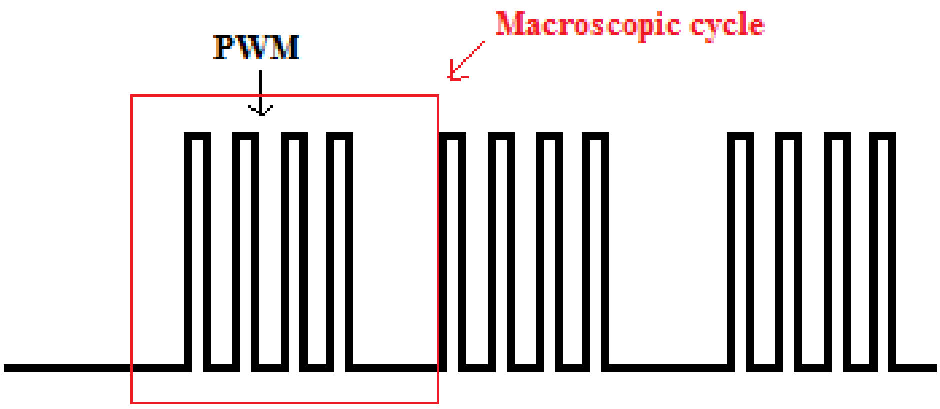

Figure 5, software level calibration of motor speed. PWM signal is sent to the motors during part of the time in the macroscopic cycle. The motors are actually repeating start and stop in each macroscopic cycle. This will cause the robot to move slower.

Sensors

There are three types of sensors on Wall-Follower: ultra sonic range finders, infrared range finders and a CMU camera. The two IR range finders in the front of the robot are used for obstacle avoidance. The two ultra-sonic range finders on the side are used to detect a wall and tell the micro controller the robot's relative position to the wall. The CMU camera is used to track a predetermined color type while the robot is following a wall. It tells the micro controller the position of detected colored object in the camera's vision so that the microcontroller can react to the position.

Ping))) ultra-sonic range finder

Figure6, PING))) ultra-sonic range finder

This wide range sensor can detect the distance between 2cm to 3m with narrow acceptance angle. It works with 5V supply voltage and standard TTL logic. The only signal pin is used for both input and output communication. While triggered by a typical 5us positive pulse, it will return a pulse width signal which is proportional to the distance detected. Its clock diagram is shown in figure 7[4]. The ATXmega micro controller can capture the pulse width by the internal event system without using any interrupt function to control the counter [3].
A serial resistor is connected between the sonar signal pin and the on-board input/output pin. The resistor together with a built-in clamp diode will protect the on-board input transistor from breaking down due to 5V received signal from the sonar.

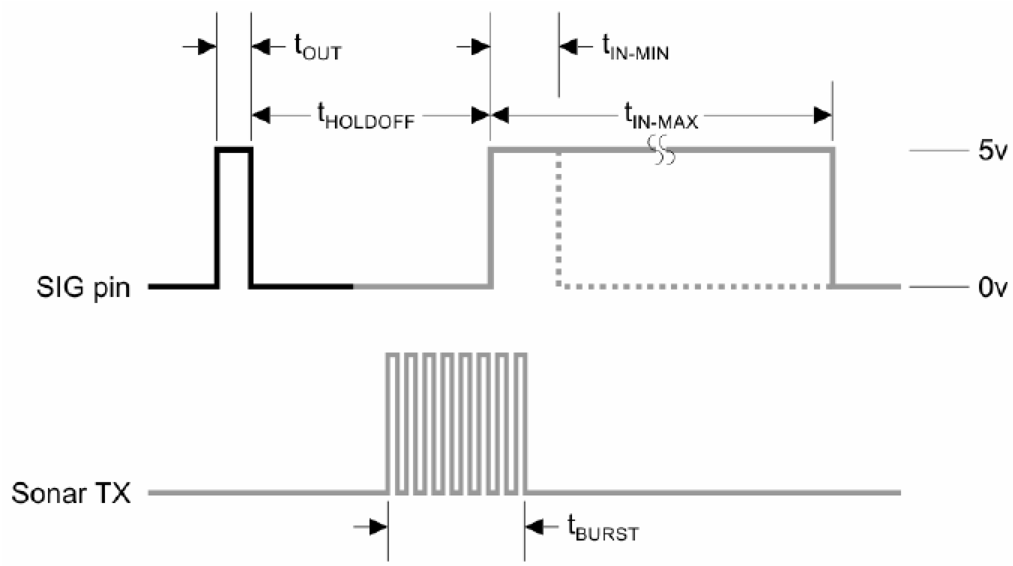

Figure7, clock diagram of PING))) ultra sonic range finder

The two sonars are mounted on the same side of the robot as shown in figure 1. If the front sonar detects a longer distance from the wall, the robot will turn left so that it is closer to the wall than the rear sonar. Then the robot will go straight to approach the wall. After it approached to a certain distance from the wall, the Wall-Follower will waggle to follow the wall while detecting the color via the CMU camera.

Sharp GP2D120XJ00F IR Range Finder

This range finder detects from 3cm up to 30cm. It needs a 5V supply, but gives analog output inversely proportional to the distance detected ranging from 0 to 3.1V [5]. If the left IR detects an obstacle, the robot will turn right, and if the right IR detects an obstacle, the robot will turn left. If both of them detect obstacles, the robot will halt.

Figure 8, Sharp GP2D120XJ00F IR Range Finder

CMU camera V4 (special sensor)

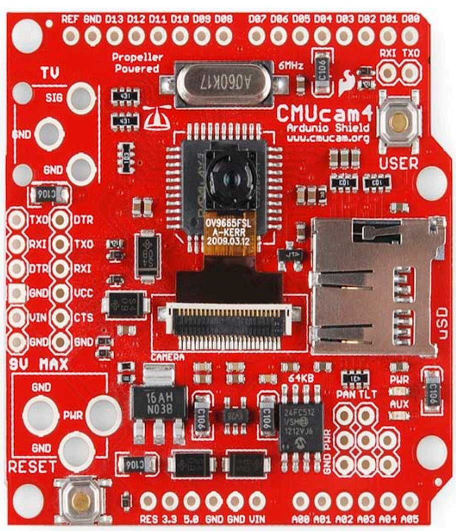

Figure 9, CMU camera version 4 from Sparkfun.com

The CMU camera is a fully programmable embedded computer vision sensor. It provides on-board color tracking with a 160*120 resolution at the highest speed of 30 fps. 5V supply voltage is needed and it works perfectly with 3.3V communication. Other features include micro SD card access and automatic servo control.

The way to use this CMU camera is not complicated. Particular commands in viewable ASCII code need o be sent to the camera via USART port, and after a certain latency, it will return an ASCII viewable message indicating whether the command is acknowledged and if yes, together with possible return values.

Two examples are given below: [6]

```
: TC 0 100 0 100 0 100 '\r'          Get tracking data
ACK
T 59 79 50 25 109 94 85 170
'\r'                                 Abort
:
```

```
: GH 0 3 '\r'                        Get histogram data
ACK
H 1 2 4 8 16 32 64 128
'\r'                                 Abort
:
```

Figure 10, communication examples between micro controller and CMU camera

The message after the colon in gray font is the command, and those in black font are responses from the camera, among which 'ACK' means the command is acknowledged.

The first command asks the camera to track color pixels with red channel value between 0 and 100, green channel value between 0 and 100, and blue channel value between 0 and 100, where the maximum color values are all 255. Returned message starting with 'T', indicating this is a certain type of data. Among all the numbers, much attention is paid on the first two, which are the mean values of X and Y coordinates of tracked pixels. This can be seen as the center of captured color object.

The second command asks the camera to return histogram of the image it sees in 2^3 bins. And the returned data after 'H' is the histogram values divided into 8 bins.

When the X coordinate is on the left half of the camera vision, the robot will reverse to track the object, and if the X coordinate if on the right half of the camera vision, the robot will move forward to track the object.

Software design

The software is developed in Atmel studio. All codes are written in C, and some of the functions are from Out of The Box Robotics [7]. The software flow chart is shown in figure 11 below.

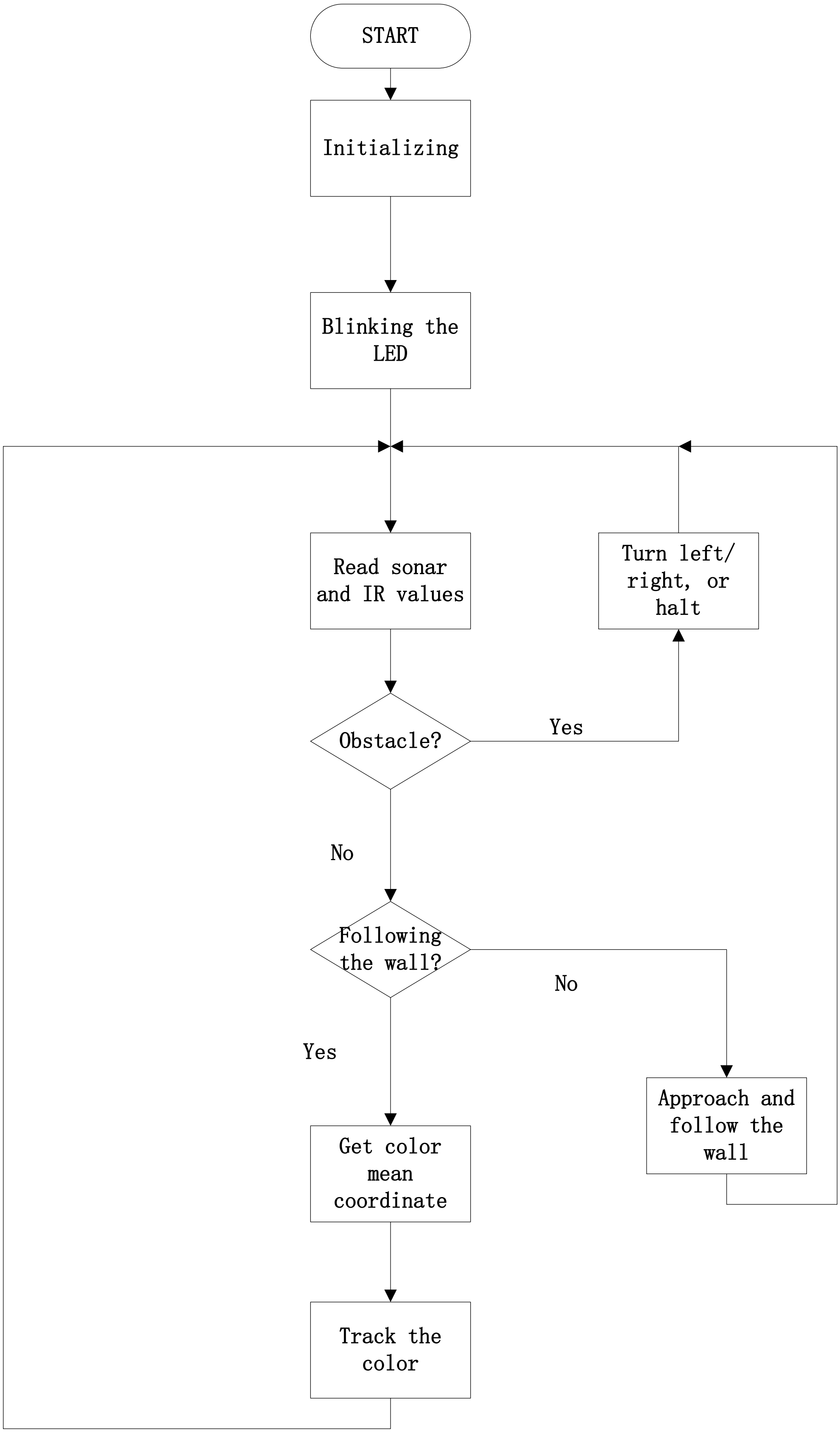

Figure 11, software flow chart of Wall-Follower

Experimental Results

Wall-Follower achieved its target on demo day. When approaching the wall, it is working fine. After it gets closer to a wall and starts to follow it, due to the slow reaction of the CMU camera to the command, the speed of the robot is a little bit slow. However, it works pretty good to detect the color and then follow it.

Future improvement

Future improvement can be made on faster detection of the color object, and automatic color threshold adjustment. Many advance applications can be achieved based on the features of Wall-Follower, including parallel parking, automatic indoor navigation and so on.

Conclusion

A comprehensive introduction to the hardware and software design of a car robot, the Wall - Follower is shown in this report. The robot works pretty well and shows a great potential for future uses.

Acknowledgement

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References

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