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Final Report

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Abstract

My robot design is an autonomous mobile sentry unit which finds targets based on image recognition. This is a circular robot design with its structure made of wood. The robot is ground-based and drives around on two wheels. It patrols its area and performs basic obstacle avoidance. It captures images of its surroundings and detects people using facial detection. When a person is detected, the robot will aim at them and shoot foam darts at them.

Executive Summary

Mobile Autonomous Robot Sentry (MARS) was designed and built for the Intelligent Machines Design Lab (IMDL) at the University of Florida in Spring 2012. It was developed using the Epiphany DIY board and various commercial products, modified to fit the design. The design, layout, parts, and behaviors of MARS are outlined in this document. MARS can be seen in Figure 1.

Figure 1: Mobile Autonomous Robot Sentry (MARS)

Introduction

The idea for this robot is inspired by the Nintendo 64 video game Perfect Dark by Rare Ltd. In the game, there is a weapon called the Laptop Gun. This weapon has a special feature which allows it to be mounted onto a wall or floor and then act as an autonomous sentry gun which will shoot at any person who comes into its range of sight.

Figure 2: Laptop Gun from Perfect Dark in sentry gun mode

This robot is an upgraded version of this weapon which is mobile. This is called the Mobile Autonomous Robotic Sentry (MARS). This robot drives around patrolling an area and looking for people using facial detection. When a person is detected, the robot will aim and fire foam darts at them.

Integrated System

The robot is controlled by the Epiphany DIY board, from Out of the Box, LLC [1].

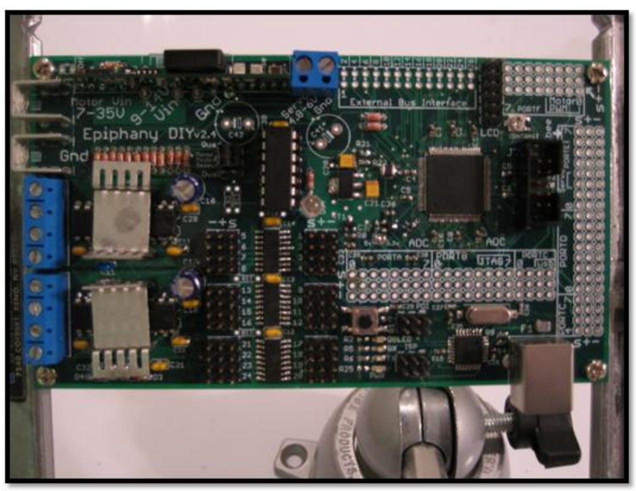

Figure 3: Epiphany DIY board

The power supply of the board consists of an 8 piece AA battery holder with 8 1.2V rechargeable AA batteries, which can be recharged with a smart charger.

The layout of the bottom and top halves of the platform are shown in Figure 4 and Figure 5.

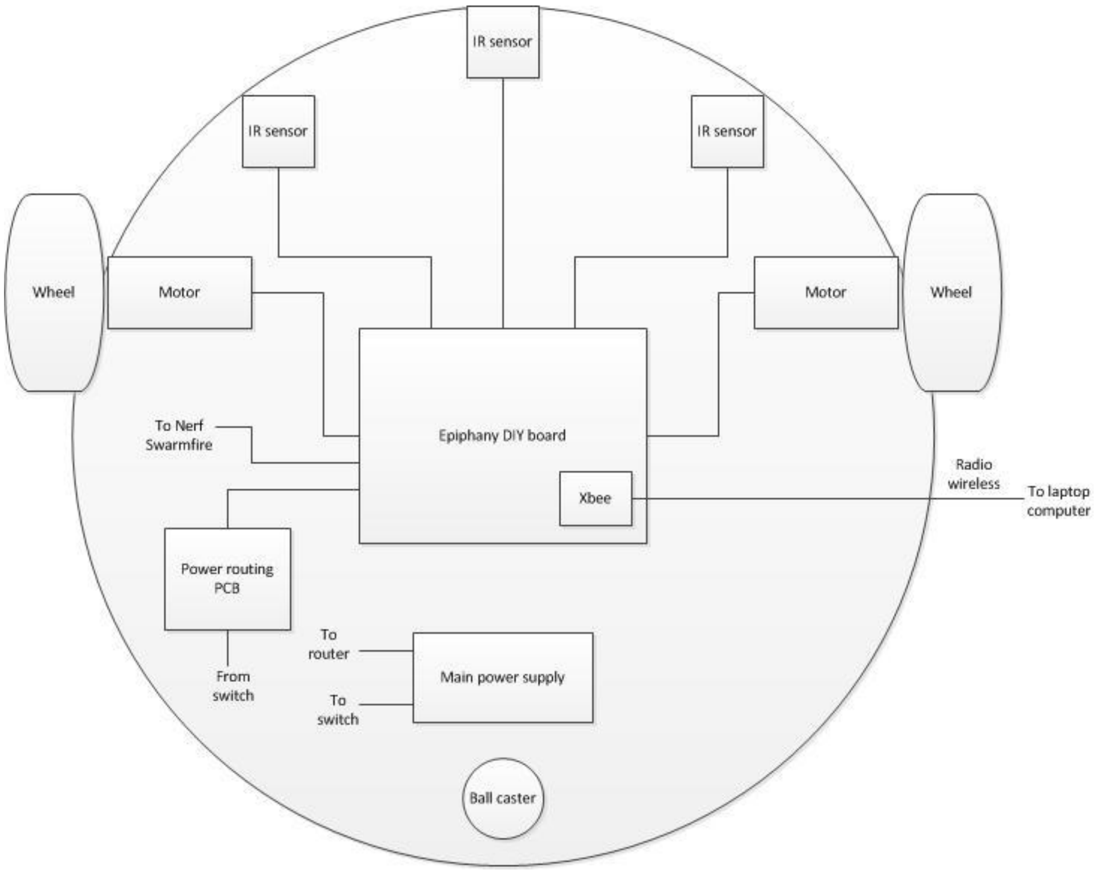

Figure 4: Layout of bottom half of MARS platform

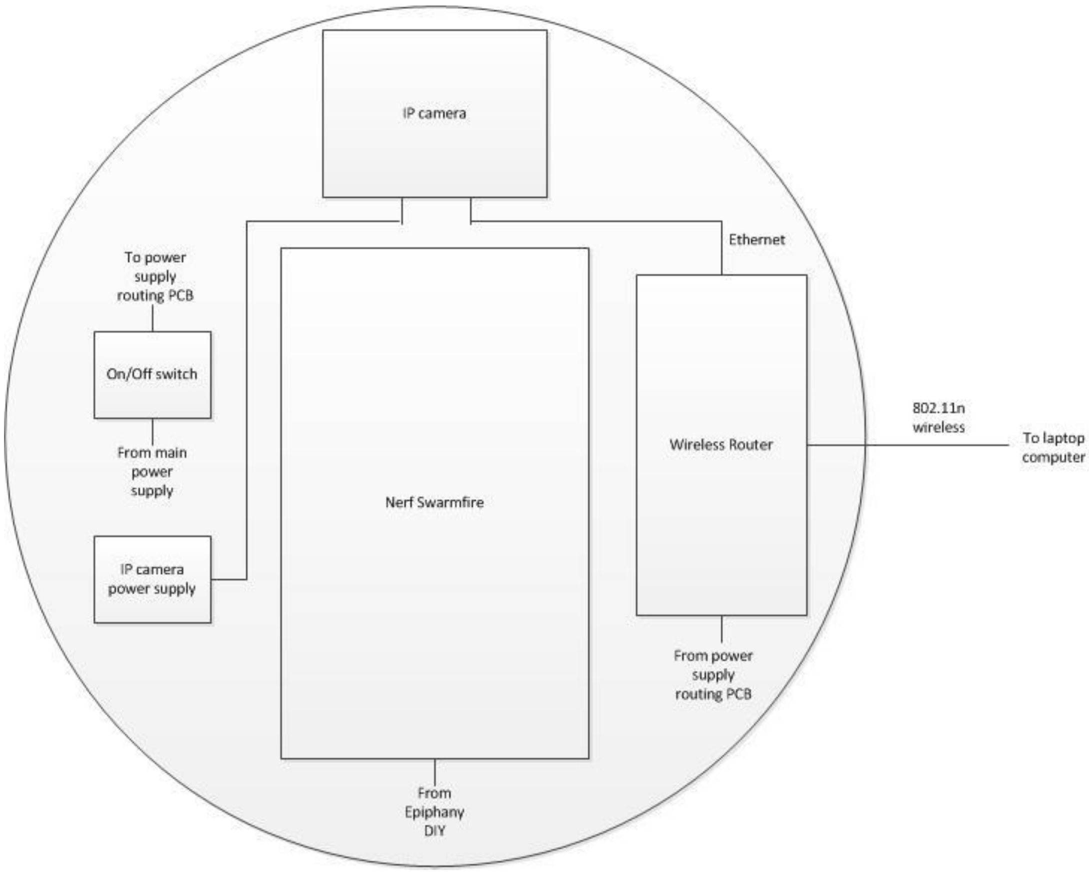

Figure 5: Layout of top half of MARS platform

The board is interfaced with motors, which are attached to wheels, in order to drive the platform around an area. It is also interfaced with IR proximity sensors in order to perform basic collision and obstacle avoidance.

An IP Camera is be used in order to capture images from the environment and transmit them wirelessly to a nearby laptop, where image processing using the OpenCV library is done to detect people's faces. Based on information gathered from image processing, the laptop wirelessly transmits commands to the board via Xbee which gives the robot information about its target. The robot is interfaced with a foam dart shooter which will fire at the target when given commands from the laptop. The laptop's communication with the robot is shown in Figure 6.

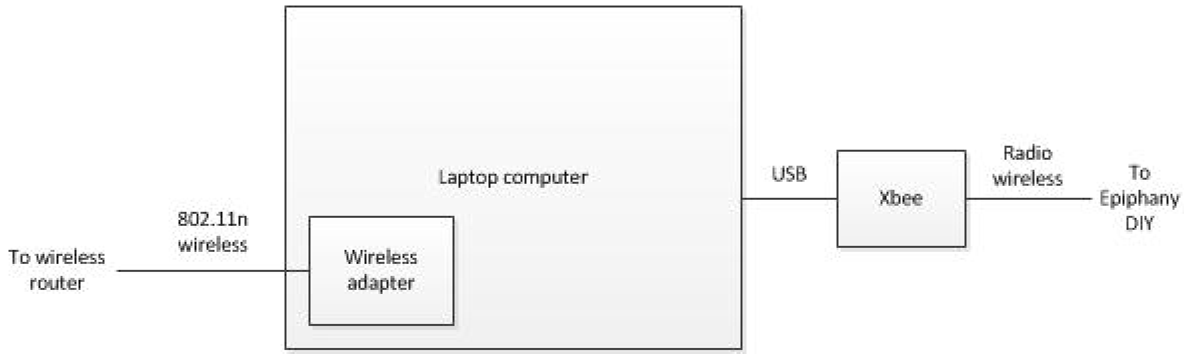

Figure 6: Communication to/from laptop computer

Mobile Platform

The robot's mobile platform consists of two circular pieces of wood, approximately 1 ft. in diameter. There is a higher and lower piece of wood which connect to form a dual-platform design. The lower piece is used to mount the Epiphany DIY board, IR sensors, power supply, motors, a ball caster, and a circuit board which allows the Epiphany DIY board to control the Nerf Swarmfire. The motors are then connected to wheels to drive the robot. The top piece is used to mount the IP Camera, wireless router, and Nerf Swarmfire.

Actuation

The robot drives around its area patrolling for people. This is accomplished by interfacing two motors to the Epiphany DIY board via its motor drivers and connecting the motors to wheels. The motors are attached to the wheels using mounting hubs and to the platform using Metal Gearmotor brackets. A ball caster is mounted to the back of the platform for support.

Figure 7: 75:1 Metal Gearmotor 25Dx54L mm, Key specs at 6 V: 75 RPM and 80 mA free-run, 85 oz-in (6.1 kg-cm) and 2.2 A stall.

Figure 8: Pololu Wheel 70x8mm Pair – Black

Figure 9: Pololu Universal Aluminum Mounting Hub for 4mm Shaft Pair, 4-40 Holes

Figure 10: Pololu 25D mm Metal Gearmotor Bracket Pair

Figure 11: Pololu Ball Caster with 3/4" Metal Ball

The motors are interfaced to the Epiphany DIY board and the robot can be driven from software. Turning can easily be accomplished by rotating the wheels in opposite directions. This driving capability and the IR proximity sensors are used to perform driving and obstacle avoidance behavior from software.

The robot fires foam darts at its targets by using a modified Nerf Dart Tag Swarmfire blaster. This is a foam dart shooter which runs on batteries in order to achieve automatic fire.

Figure 12: Nerf Dart Tag Swarmfire foam dart blaster

The Swarmfire is modified in order to run on the robot's battery supply and to interface with the Epiphany DIY board. Since the Swarmfire operates by turning a motor on and off to trigger automatic fire, it can be controlled via the board's motor drivers. The Swarmfire casing is stripped down to the bare minimum in order to simplify the design and minimize weight.

Sensors

The robot is equipped with three IR proximity sensors which are used to inform the robot when it reaches a wall or other object and perform obstacle avoidance. These are interfaced with the Epiphany DIY board via its ADCs.

Figure 13: Sharp GP2D120XJ00F IR proximity sensor

The image processing system that detects people is created using an IP Camera which captures images and transmit them wirelessly to a nearby wireless router, then to a laptop computer where image processing can be done.

Figure 14: Cisco-Linksys Wireless-N Internet Home Monitoring Camera

Figure 15: Belkin N150 wireless router

The computer periodically captures images from the IP Camera and analyzes them using the OpenCV image processing library in order to detect people in the robot's line of sight. When a person is detected, the computer notifies the Epiphany DIY board on the robot so that it will fire the foam darts.

The computer is equipped with a USB Xbee interface in order to transmit information about the target acquired back to the Epiphany DIY board. The board is also equipped with an Xbee chip in order to receive these transmissions.

Figure 16: XBee Explorer Dongle

Figure 17: XBee 1mW Chip Antenna - Series 1 (802.15.4)

Behaviors

The robot drives around its area patrolling for people. It uses its IR sensors and motor-controlled wheels to perform obstacle avoidance. This is accomplished with a driving behavior that maps out all IR sensor possibilities and assigns appropriate turning behaviors.

The image processing system allows the robot to detect people and notify the main program on the Epiphany DIY board. The facial detection behavior is accomplished using the OpenCV library and adapted in part from an implementation found online [2]. The horizontal location of the face within the field of view is also determined. The robot then performs targeting and firing behavior, which is accomplished by the laptop sending commands back to the robot indicating when to fire and which direction the target is in. The robot will then aim the Nerf Swarmfire towards the target and trigger firing of the foam darts.

Experimental Layout & Results

The robot's driving behavior was developed by a trial and run methodology. IR sensor input and corresponding turning behaviors were continually tweaked until a reliable driving methodology was developed.

The facial detection behavior was also developed with a trial and run methodology. The frame rate and quality of the camera's video stream were changed until lag was minimized and facial detection remained reliable. The first 150 frames are skipped to minimize lag from the initialization of the connection. A short delay between sending firing commands was given so that the robot would not get stuck in a continually firing phase. The firing command is also only sent when faces have been detected in three consecutive frames in order to prevent against false positive detections. Eyes can also be detected, but this was found not to be reliable enough to determine robot behavior. It was found that faces can be detected from close range and from a far standing range. This can be seen in Figure 18. The reliability of facial detection at further distances is determined by the lighting in the environment.

Figure 18: Facial detection at close and far range

Conclusion

MARS was completed on time and employs the behaviors proposed. It patrols its area and performs basic obstacle avoidance. It captures images of its surroundings and detects people using facial detection. When a person is detected, the robot will aim at them and shoot foam darts at them.

Documentation

Progressive documentation of the development of MARS as well as source code can be found online [3].

Appendices

Please see source code found online [3].

References

[1] "Epiphany DIY", Out of the Box, LLC, http://sites.google.com/site/epiphanydiy/
[2] "OpenCV v2.4.0-beta documentation, OpenCV Tutorials, objdetect module.Object Detect, Cascade Classifier", http://opencv.itseez.com/doc/tutorials/objdetect/cascade_classifier/cascade_classifier.html
[3] "Mobile Autonomous Robotic Sentry (MARS)", http://plaza.ufl.edu/tyler727/imdl/