University of Florida

Department of Electrical and Computer Engineering

EEL 5666

Intelligent Machines Design Laboratory

Final Report
"Panther"

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Student Name: Sarah Jones

TAs: Tae Choi and Uriel Rodriguez

Instructor: A.A. Arroyo

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1. Abstract

During times of war, many soldiers lose their lives in combat. I propose a solution to this problem: An intelligent, autonomous physical agent capable of entering the field of battle and attacking the enemy. As a solution to this problem, I created a small-scale replica of a tank called Panther. Completely independent of human control, Panther is capable of entering a room by following walls, acquiring targets based on sources of heat, and firing a projectile at those sources of heat.

2. Executive Summary

The first step of the project was to create the robot's physical structure, including the platform and treads. For the platform holding the treads, I used the base of an RC tank. On top of that, I placed a wooden platform, which slopes up to the turret. The turret also came from the RC tank. For movement, I installed two servos to control the sprocket on the treads, another servo to move the turret side to side, a dc motor to move the projectile launcher up and down, and another dc motor to launch the projectile.

The second step was to install all of the hardware components and integrate those components with the elements on the platform. IR detector/emitter pairs were placed on the wooden platform. The pyroelectric sensor was installed on top of the turret. The electronic board and batteries were placed underneath the turret. The servos and dc motors were connected to the electronic board.

To complete the construction of the robot, the software was designed to control the hardware and be the "brains" of Panther. With the software, I created behaviors, including an actuation algorithm for controlling the servos and dc motors, a obstacle avoidance algorithm, a collision recovery algorithm, wall-following algorithms, and a target acquisition algorithm.

After the initial integration of the software and hardware, extensive debugging procedures and experiments were undertaken. Unlike other software applications, the results change constantly when working with a robot. As a result, every possible reaction to a situation must be considered. Finally, the most difficult part of this procedure was understanding the limitations of the robot and using these limitations as an advantage.

3. Introduction

The German's PzKpfw V Panther (1942 – 1945) was the best medium tank of World War 2. The tank had three armaments: the maneuverable long-barreled, high velocity 75 mm gun, a flexibly mounted machine gun, a coaxial machine gun, and a grenade launcher. Due to its size, the tank had a higher speed and greater maneuverability than other tanks of the era. Finally, the well-sloped hull and turret allowed for shot deflection. My robot, Panther, implements a scaled-down version of this war machine. Panther avoids obstacles, recovers from collisions, and follows walls, while searching for sources of heat. Once a source of heat is found, Panther shoots at the target using a projectile launcher similar to the 75-mm gun of the German's PzKpfw V Panther.

Dr. Arroyo, Dr. Schwartz and other of the University of Florida's ECE Department run the Machine Intelligence Laboratory (MIL). As a reference, I have used the experiences of previous students in this laboratory for help in designing my own robot. Also, the book *Mobile Robots: Inspiration to Implementation* by Joseph Jones, Bruce Seiger, and Anita Flynn provides basic hardware fabrication and assembly skills. The book *C Programming: A Modern Approach* by K.N. King provides a reference for the C Language. The ImageCraft 68HC11 Compiler and Development Environment (ICC11) was used to compile the code into assembly language. The Machine Intelligence Laboratory has a customized version of ICC11 for the MTJPRO board.

In the future, this project could lead to more sophisticated tanks. The military has already taken measures to end the number of casualties on the field of battle. Remote control jets are being used to bomb targets. Hopefully, in the future, soldiers will also be taken out of tanks and replaced by artificial intelligence; thus, ending the unneeded loss of lives.

4. Integrated System

The brain of the robot is Motorola's 68HC11 microprocessor mounted on Mekatronix's MTJPRO11 board. Main characteristics of the MTJPRO11 board:

1. IO Abilities
    a. Eight digital outputs.
    b. Three digital input ports with program-optional automatic digital waveform capture.
    c. Hardware generation of a 40KHz signal to modulate IR and sonar.
    d. The processor data bus and an 8-bit address decoder port enable expansion for up to four external 8-bit Digital Input and four external 8-bit Digital Output ports.
    e. Five, eight-bit analog input channels available. Combined with external analog multiplexers and Digital Input address decoding, each analog channel could be multiplexed to as many channels as the external multiplexer allows.
2. 32Kbytes of SRAM, hex addresses 0x8000 to 0xffff
3. High speed, 5-volt synchronous serial bus (SPI), up to 1 MHz data rate available through a 7-pin connector
4. Five-volt serial communication interface (SCI), connects to MB2325 through 6-wire cable

Table 1 shows the IO ports that the Panther utilizes.

Port	**Connection**	**Function**
Analog Input Port PE0	Left Bumper Switch	Contact Sense
Analog Input Port PE0	Right Bumper Switch	Contact Sense
Analog Input Port PE2	Left Front Infrared Detector	Proximity Sensor
Analog Input Port PE3	Center Infrared Detector	Proximity Sensor
Analog Input Port PE4	Right Front Infrared Detector	Proximity Sensor
Analog Input Port PE5	Pyroelectric Detector	Heat and Motion Sensor
Digital Output Port 0x7000	40 kHz IR LEDs	Emitter for Proximity
Digital Output Port PA3	Left Wheel Servo	Drive Left Wheel
Digital Output Port PA4	Left/Right Servo	Move Turret Left and Right
Digital Output Port PA5	Projectile Launcher Motor	Launch Projectile
Digital Output Port PA6	Up/Down Motor	Move Turret Up and Down
Digital Output Port PA7	Right Wheel Servo	Drive Right Wheel

Table 1: IO Ports

Figures 1 and *Figure 2* describe the theory of operation for Panther. *Figure 1* shows the behaviors of object avoidance, collision recovery, and wall-following. After the system is initialized, Panther begins to move forward. Then, it checks if something is hitting the bumper. If so, Panther backs up, and turns away from the object pushing on the bumper. Next, Panther checks if any objects are nearby. If so, Panther follows that object. If no object is found, Panther continues to move forward. This process of checking for objects and moving accordingly is done for a certain amount of time. Once time runs out, Panther stops moving begins target acquisition. *Figure 2* shows the behavior of target acquisition. The turret is moved side to side, constantly checking the pyroelectric sensor. Once heat has been detected, Panther launches the projectile at the source of heat and returns to the behaviors shown in *Figure 1*. If no heat is detected, then Panther returns to the behaviors shown in *Figure 1*.

While Panther undertakes the behaviors described in the Theory of Operation, LEDs on the front of the tank indicate which behavior is being accomplished. The green, yellow, and red LEDs, which are labeled “1”, “2”, and “4” on the tank, are used to indicate the direction of motion of the tank while Panther is avoiding obstacles, recovering from collisions, or following the wall. The green LED indicates the tank is moving forward or backward, the yellow LED indicates if the tank is moving right or left, and the red LED indicates if the tank has stopped. The red and yellow LEDs, which are both labeled “3”, are used to indicate the steps in the target acquisition process. While the Pyroelectric sensor is scanning the room for heat (by moving back and forth on top of the turret), the yellow LED is on, and once the target has been acquired, the red LED is on. Finally, all LEDs light up when the projectile is being launched.

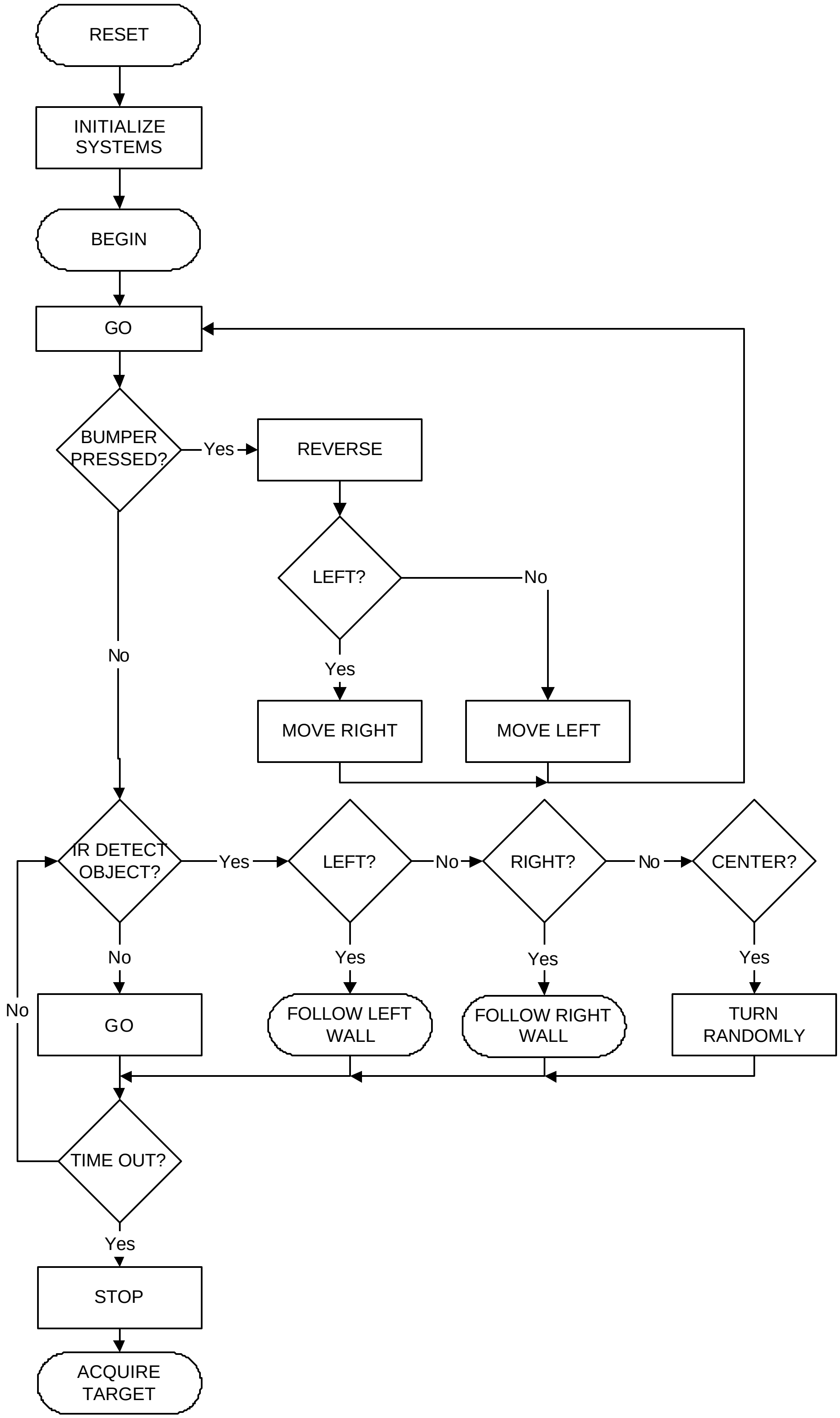


Figure 1: Theory of Operation—Object Avoidance, Collision Recovery, and Wall Following behaviors

Figure 2: Theory of Operation—Target Acquired

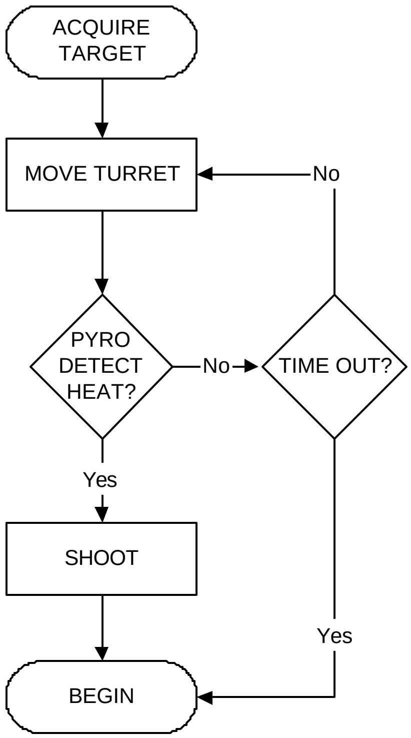
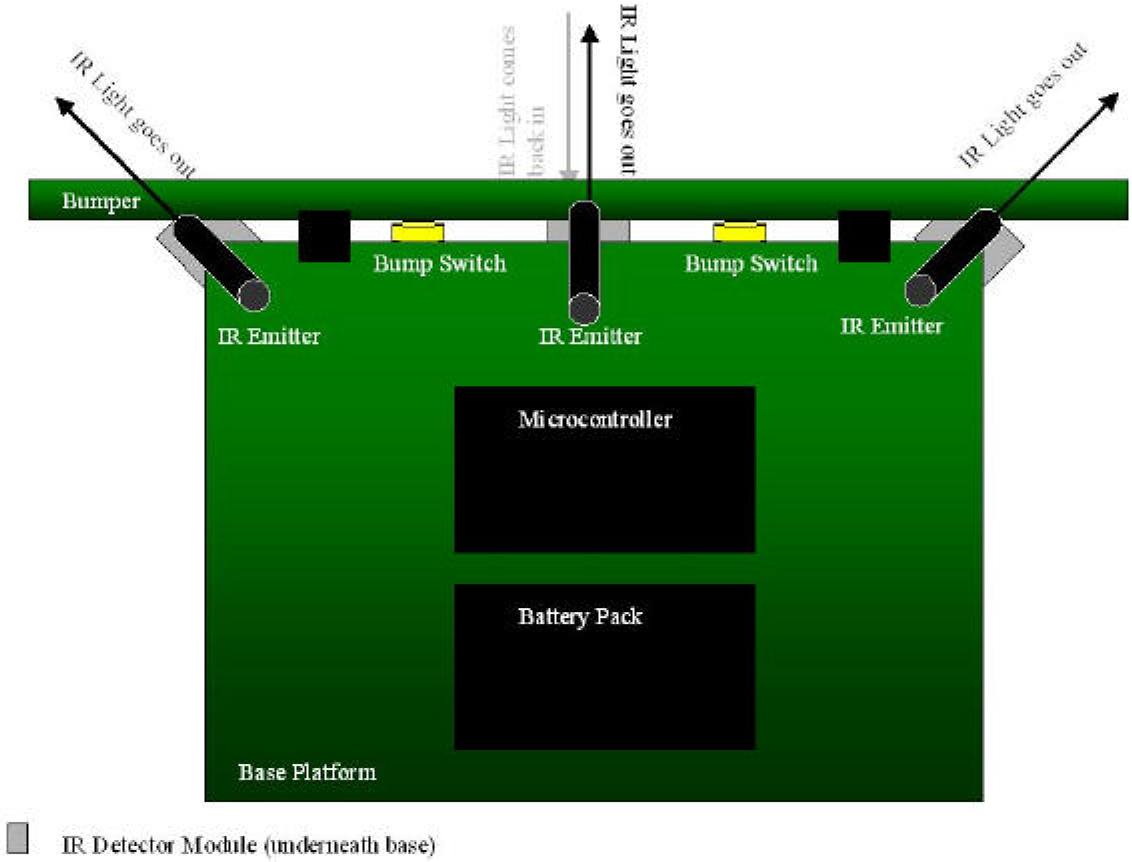


Figure 3: Base platform



5. Mobile Platform

For the treads and wheels, I originally bought the treads, sprocket, and wheels separately. As a result, I had to cut up the treads to fit the system. However, since the wheels were not specifically made for the type of tread, the tread continuously fell off, when the tank was turning. I decided to replace the entire system with the treads and system of wheels from the RC tank. Each of the seven wheels has independent suspension and grooves to hold the treads in place. The sprockets are located at the front of the tank. The system of wheels is held together with a plastic base. I placed this plastic base below the base platform. While not as flexible as using wheels, treads allow the robot to maneuver in tough terrain, which is the normal environment for a tank.

Panther requires a platform large enough to support the battery packs, the microcontroller, the system of sensors, and the projectile launcher. In order to remain true to the design of the German's PzKpfw V Panther, the base of the platform is rectangular in shape, as shown in *Figure 3*. The original German tank sloped upward to deflect enemy bullets. Thus, Panther has two slopes that ascend to the upper platform.

For the upper platform, I disassembled an RC tank, shown in *Figure 4*. Using Velcro, I attached the upper level to the sloping platforms. This upper platform carries the projectile launcher, is smaller than the base, and is rectangular in shape. Screws hold the projectile launcher to the upper platform.

Finally, for the bumper, which is used in the Bump Network, I attached the bumper with a spring at the center of the front end of the tank. Four pieces of wood are used to keep the bumper in place and ensure that when the bumper is pressed, the bump switches are also pressed. As shown in *Figure 3*, the bumper extends beyond the scope of the front end in order to ensure that the tank does not get stuck on a blind corner.

Figure 4: The RC Tank before disassembly.

6. Actuation

The operation of Panther requires three servos and two dc motors. Two of these servos are used to drive the sprockets, which hold the treads. The last servo is used to turn the projectile launcher left and right. I hacked these three standard servos to create DC gearhead motors by cutting off the tab stop, and removing the potentiometer shaft lock-tab. The two dc motors are used to launch the spring-loaded projectile and to move the project launcher up and down. To control the dc motors I used a Quadruple Half-H Driver (chip SN754410 from TI), which was designed specifically to provide bi-directional drive currents up to 1 A at voltages from 4.5 V to 36 V. Since I only needed the dc motors to move in one direction, I connected the control signals to +5 V, as shown in *Figure 5*. I use PA5 and PA6 to enable the chip. After testing the circuit on the breadboard, I soldered sockets and wire-wrapped to obtain a smaller circuit that could be placed next to the microcontroller.

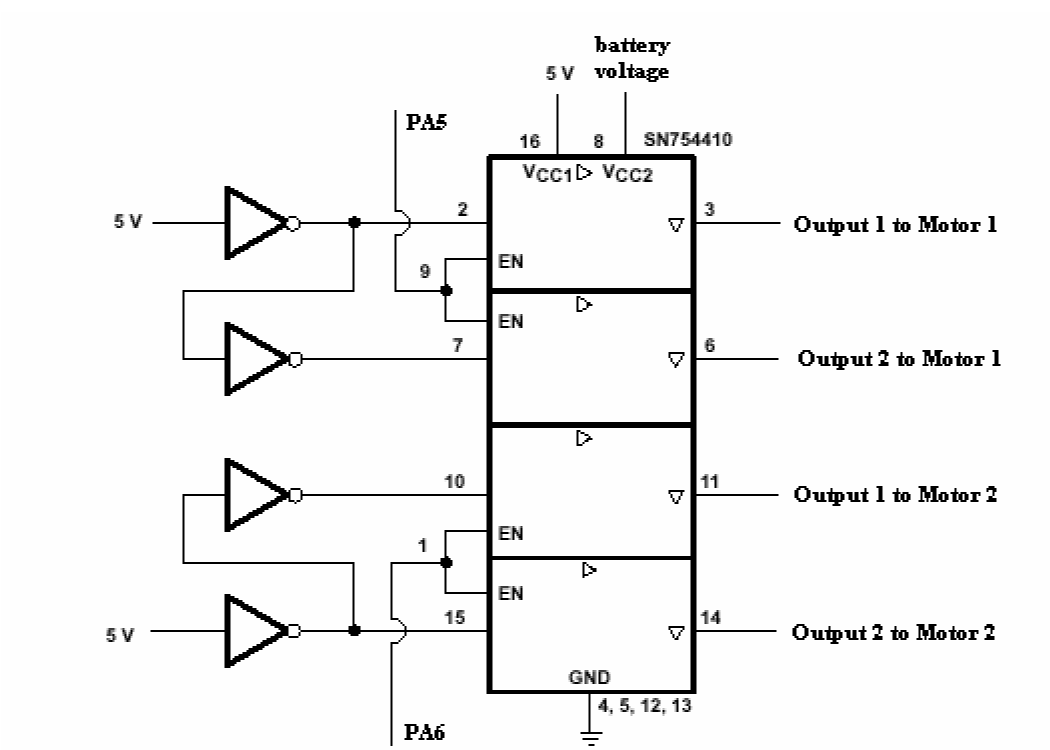


Figure 5: The Motor Driver Circuitry

7. Sensors

7.1 Infrared Sensors

For collision avoidance and wall following behavior, I used two Radio Shack IR detector modules, one Sharp GP1U58 detector module, and three Radio Shack IR emitters. Since all of the detector modules output a digital signal, I hacked them so that I could get an analog signal by first cutting the trace to the output pin and then wiring and soldering the output pin to the analog output. With the analog signal, Panther can make a pretty accurate estimate as to how far away an object is. I used Velcro to place the detector modules underneath the base platform. I placed the three IR emitters on top of the base platform. I positioned the detector and emitter to point in the same direction, as shown in *Figure 3*. To prevent the IR detector modules from being flooded with light, I wrapped the IR emitters in calumniating tubing.

Since these detectors are capable of receiving a signal from 2 to 20 inches, the infrared sensor suite works to detect objects for collision avoidance behavior and for wall-following behavior. When an object is far away, the detector will not detect much infrared light. If the object is out of range, then the output remains steady. As the object nears Panther, more infrared light is reflected off of the object. The detector module detects more light, and as a result the output increases. Based on the input received from the detector module, Panther reacts depending on the behavior being implemented.

7.2 Bump Switches

Panther has two bump switches, which are used to determine when an object is hit. I spaced the bump switches equally along the front of the tank. The bumper is close to the switches, so that when the bumper is pressed with any amount of force, the circuit is complete. Once the switch is hit, an analog output is returned based on which header the switch is wired to.

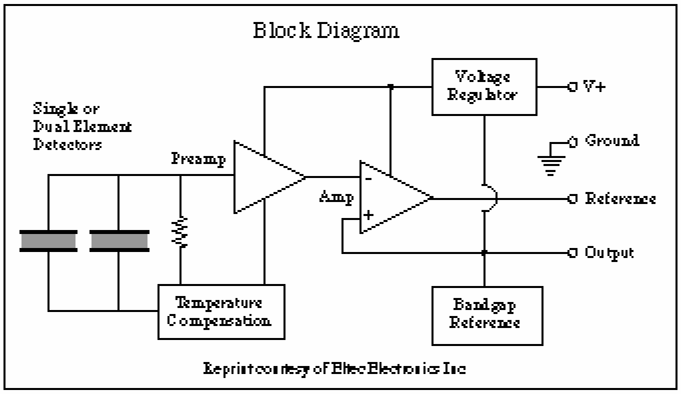


Figure 9: Block Diagram for Eltec Sensor.

7.3 Pyroelectric Sensor

The IR-Eye Integrated Sensor is a parallel opposed dual IR detector with integrated signal processing. This Pyroelectric sensor uses infrared energy detection to find movement of humans and animals. The wavelength of maximum energy radiated by humans is about 10 micrometers. The job of detecting humans boils down to detecting subtle changes of energy in the 8-14 micrometer range while rejecting changes in other wavelengths.

The output typically floats around a steady-state value. When a source of infrared energy in the 8-14 micrometer wavelength moves relative to the field of view of the detector, the differential created in the dual detector elements creates a change in this output. The output will fall when the motion is in one direction and rise with motion in the opposite direction. The detectors stabilize fairly quickly so if the motion stops, the detector will quickly gravitate back to the steady-state value.

To mount this sensor onto the board, I had to first create a cone out of paper. At the wide end of the cone, I placed a fresnel lens. At the narrow end of the cone, I placed the sensor. I mounted this cone onto the projectile launcher, so that the sensor is capable of scanning an area for heat from side to side and from up and down.

8. Behaviors

Panther has five behaviors: actuation, obstacle avoidance, collision recovery, wall following, and launch sequence.

8.1 Actuation

This algorithm controls the movement of the robot, including the motion of the treads, the movement of the turret, and the launch of the projectile.

8.2 Object Avoidance

For object avoidance, the robot uses the IR sensor suite to detect objects. Based on the analog output from the IR detector modules, Panther reacts according to three possibilities:

- If the object is detected by the left sensor and not the right sensor, then Panther moves to the right.
- If the object is detected by the right sensor and not the left sensor, then Panther moves to the left.
- If the object is detected by center sensor and not the left or right sensor, then Panther moves in a random direction.

8.3 Collision Recovery

Panther recovers from a collision based on the output from the bumper switches:

- If the right bump switch is hit, then Panther backs up and moves left.
- If the left bump switch is hit, then Panther backs up and moves right.
- If both left and right bump switches are hit, then Panther backs up and moves randomly to the left or right.

8.4 Wall Following

For wall following, once an object has been detected on either side of the robot, Panther will follow that object until it no longer is detectable. Using the IR sensor suite, Panther maintains a balanced distance using the two sensors pointing outwards from the robot.

- If the object is closer than 3 inches, then Panther moves away from the object until the object is far enough away.
- If the object is farther than 5 inches, then Panther moves towards the object until the object is near enough.

Once the wall is no longer detected, Panther continues on its course until the next wall is detected.

8.5 Target Acquisition

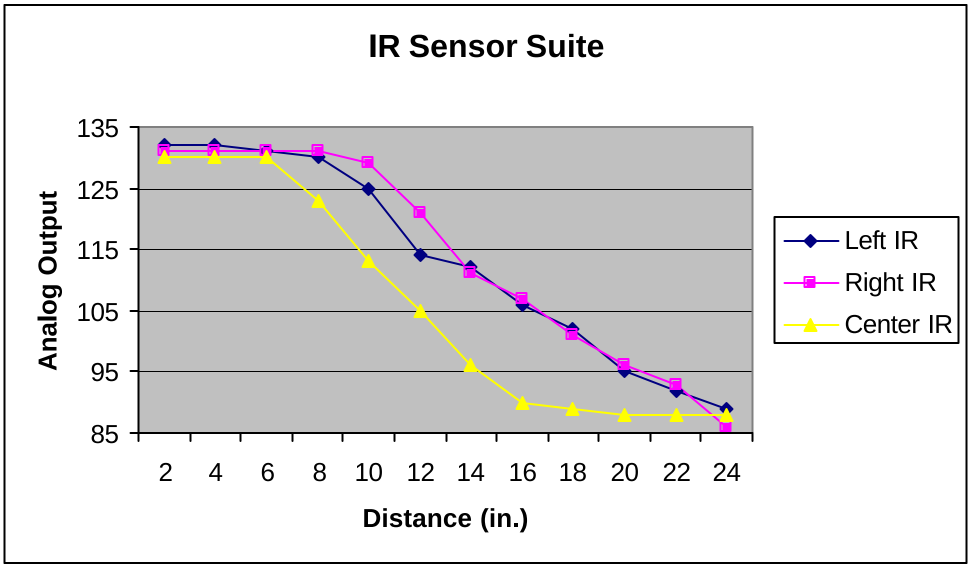
A target is acquired by first moving the turret side to side. While this action is taking place, the pyroelectric sensor is continuously tested. Once a source of heat has been acquired, the projectile is launched.

9. Results

9.1 Infrared Sensor Suite

I tested the IR emitter/detector suite in ambient lighting to simulate the conditions that Panther would be working in. I used a white sheet of paper as the object, since most walls are white. As shown in *Graph 1*, the left and right IR detectors follow similar paths, which becomes linear at about 10 inches. There is slight deviation between 10 and 12 inches. The center IR detector follows a path similar in shape, but very different in values. Between the distances of 6 and 16 inches, the path is linear. Since I will be using these sensors for detecting objects less than 12 inches away, this sensor is more suitable to my needs. In the preferable range, the center

IR provides a greater deviation in values, allowing for more accuracy within the 6 – 16 inch range.



Graph 1: IR Sensor Suite

9.2 Bump Network

I performed the test on the bump network simply by pressing on the bumper on the side of each switch. As shown in *Table 2*, the output changes depending on which switch is pressed.

	Right	Left	Right/Left
Output	79	128	150

Table 2: Bump Network

9.3 Pyroelectric Sensor

I performed the first test of the sensor simply by moving the sensor back and forth across my body. I first determined the range of values for the steady state to be between 131 and 134. To determine this range, I pointed the sensor at the walls and turned off the lights, which tend to interfere with the sensor. The output of the sensor changed between values in this range. Next, holding the sensor 1-foot away, I moved the sensor from left to right across my body. While my body was on the left side of the sensor, the values escalated from the steady state value up to the value of 150 and back down. While my body was on the right side of the sensor, the values decreased from the steady state value down to 110 and back up. The next step was to repeat the process, but this time moving the sensor from right to left across my body. While my body was on the right side of the sensor, the values escalated from the steady state value up to the value of 158 and back down. While my body was on the left side of the sensor, the values decreased from the steady state value down to 123.

10. Conclusion

On the whole, this project was successful. I created a mobile, autonomous robot that was capable of following the wall, avoiding obstacles, and recovering from collisions, while searching for sources of heat. Once a source of heat was found, the projectile was launched.

Through the course of this project, I learned a great deal. First of all, I learned some basic Mechanical Engineering, which was completely foreign to me at the beginning of the project. Second, I learned how to integrate software and hardware so that the two components work together to form an intelligent agent. Third, I learned new testing and debugging procedures. Finally, I learned to use the limitations of the robot as an advantage. Once I began to think like the robot, I gained a better understanding of how the robot saw the world. With this understanding, I could navigate more accurately around the house.

This project has many capabilities and also many deficiencies. The main deficiency lies in the pyroelectric sensor. After many tests, the sensor never proved any common reaction to movement from a certain position. If a person moved through the left side of the field of view, the sensor would output lower values than the steady state. Then, the output would change if tested again. For this reason, there was no accuracy in determining where a person was. Also, the detector would be thrown off by light. For this lack in ability, I was unable to incorporate the up and down movement of the projectile launcher. For some reason, the sensor never picked up heat sources when moved up and down on the projectile launcher. Thus, the robot never moves the projectile launcher up and down, even though the capability is there.

11. Acknowledgements

I would like to thank my advisors, Dr. Schwartz and Dr. Arroyo, for their advice and encouragement toward the successful completion of this project. Additional thanks go to the TAs, Uriel Rodriguez and Tae Choi, for all of their assistance. I would also like to thank my friend, DJ, for helping me through all of the mechanical aspects of the project.

12. References

[1] Jones, Flynn, Seiger. "Mobile Robots: Inspiration to Implementation." 2nd Edition. A.K. Peters Publishers. Natick, MA. 1998.

[2] King, K.N. "C Programming: A Modern Approach." WW Norton. London. 1996.

[3] Martin, Fred. "The 6.270 Robot Builder's Guide." MIT Media Lab. Cambridge, MA. 1992.

13. Appendix A: Parts and Supplies

MTJPRO11 Board
Servos
    Mekatronix
    316 NW 17 Th St., Suite A
    Gainesville, FL 32603
    Phone: 352-376-7373
    www.mekatronix.com

IR Detector Module
IR Emitter
    Radio Shack
    13th St.
    Gainesville, FL 32609
    www.radioshack.com

Pyroelectric Sensor
    Acroname, Inc.
    4894 Sterling Dr.

Boulder, CO 80302
Phone: 720-564-0373
www.acroname.com

Motor Driver Chip
Texas Instruments
www.ti.com

RC Tank
Blowguns Northwest, Inc.
http://www.blowgunsnw.com/

14. Appendix B