University of Florida
Department of Electrical Engineering

EEL 5934
Intelligent Machines Design Laboratory

Final Report
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ABSTRACT

The robot that I have designed and built is a security robot. It moves randomly around in an enclosed space such as a building while looking for intruders with a pyroelectric sensor. When an intruder is found, the robot moves toward the intruder while sounding an alarm (a piezoelectric speaker). It uses three sensor systems: infrared sensors, bumpers, and a pyroelectric sensor. The sensors are used to support three behaviors: object avoidance, IR sensor calibration, and locating intruders. The infrared sensors and bumpers are both used for object avoidance. The bumpers are also used for calibrating the infrared sensors. The pyroelectric sensor is used for locating intruders which it sees as heat sources. The robot is built on a circular wooden platform with a 12-inch diameter. It receives power from a pack of 8 AA batteries which is carried on the platform. It uses a pair of servos which have been converted into DC motors to move around. The motors can both be moved forward or in reverse or can be turned at different speeds to cause the robot to turn. I wrote the behavioral software in Interactive C and have successfully tested the individual behaviors.

EXECUTIVE SUMMARY

My project for this semester has been a security robot. It was designed to move randomly around an enclosed area while searching for intruders. When it finds an intruder, it sounds an alarm while moving toward the intruder. If it loses sight of the intruder, it stops moving and continue to sound an alarm so security personnel can see where the intruder was last sighted. While it is patrolling, it avoids colliding with objects by using three infrared sensors. However, the effectiveness of these sensors varies with the size and color of the object it is trying to avoid. I solved this problem by adding bumpers to the mobile platform. Aside from detecting any obstacles that the infrared sensors miss, the bumpers are also used to make the infrared sensors more sensitive. The robot has its own power supply -- 8 AA batteries -- and is microprocessor controlled. It is an inexpensive but useful security system.

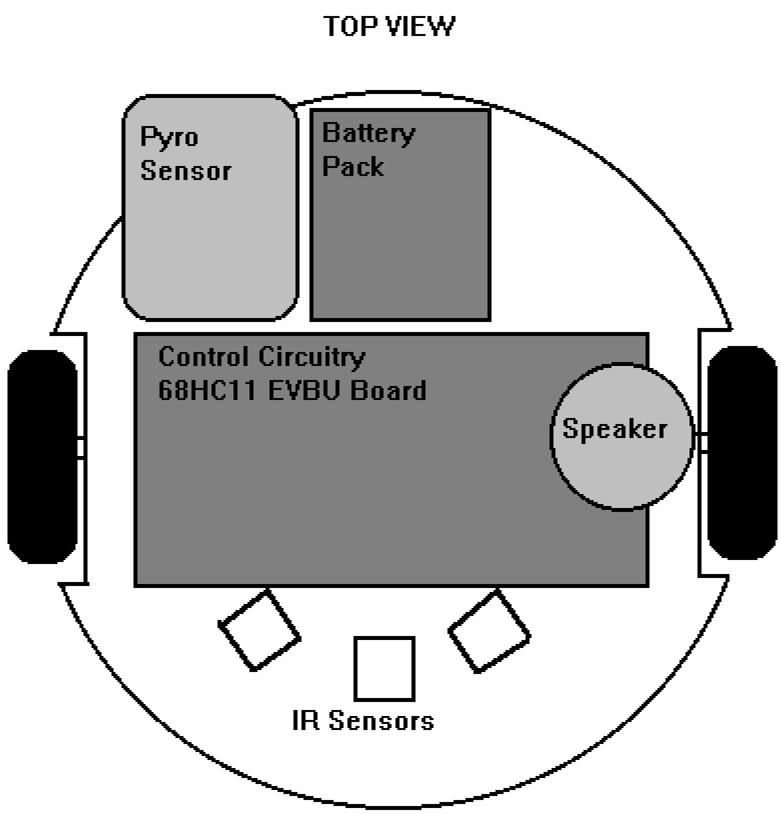
INTRODUCTION

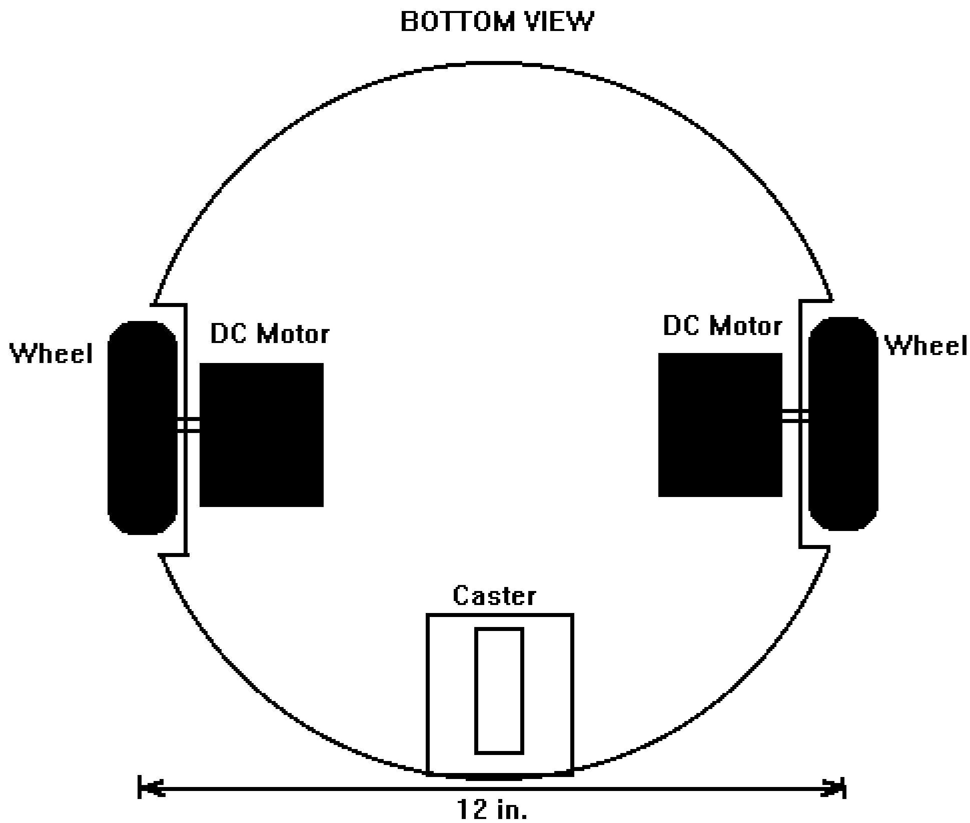
The project that I have recently completed is an autonomous security robot. It was required to use three sensor systems and three behaviors to accomplish the task that I assigned to it -- searching for intruders. The robot was designed to randomly patrol an enclosed space and to sound an alarm and move toward any intruders that it detects. This process consisted of building the individual subsystems and connecting them together. The robot is autonomous since it has its own power supply and means of actuation (DC motors). The behaviors are controlled by software and can be easily changed.

INTEGRATED SYSTEM

This autonomous agent is divided into the following sub-systems: mobile platform, actuation, sensors, and control circuitry. The mobile platform is the structure upon which the rest of the subsystems are implemented. It allows the robot to function without need of any external support or control inputs. Actuation is accomplished by two DC motors. A piezoelectric speaker is also used to produce an alarm sound. By using actuation, the robot is able to move around in and interact with its environment. The motors are controlled by signals from the control circuitry. The sensors that this robot uses provide all of the inputs from the outside world. The robot uses three sensor systems: infrared sensors for object avoidance, bumpers for calibrating the infrared sensors and object avoidance, and a pyroelectric sensor for locating heat sources (people). Input information from these sensors is used by the control circuitry to control the robot's behavior. The control circuitry consists of a microprocessor and all supporting circuitry. It uses the behavioral software to control the movements of the mobile platform via actuators. The combination of these systems allows the robot to patrol for intruders, locate and home in on intruders, and sound an alarm. Power is supplied by a battery pack. A diagram of the layout of these components on the platform is shown below.

Figure 1: Integrated System





MOBILE PLATFORM

In constructing the mobile platform for this robot, I had two main requirements: the platform needed to be large and sturdy and the platform needed to be lightweight. Plywood turned out to be a good compromise between these requirements. The platform for this robot is a plywood disc with a diameter of twelve inches and a thickness of 1/4 of an inch. The sensors, speaker, power supply, and control circuitry are located on top of the platform and the wheels and motors are on the bottom. The 68HC11 EVBU board is attached to the platform with nuts and bolts. The rest of the components are attached with hot glue. Hot glue works well for this application since is can be easily removed and reapplied.

ACTUATION

For actuation, I needed motors that could produce the necessary torque at as fast a speed as possible. I accomplished this by using converted Futaba servos. The robot has two of these motors controlling wheels. I used a furniture caster for a third wheel in order to provide the necessary support for the platform. The direction that the robot moves in is controlled by the speed of the two motors. If the motors are moving at different speeds, the robot will turn. When they are moving at the same speed, the robot moves forward or backwards. The circular shape of the platform allows the robot to rotate in place by moving the motors at the same speed but opposite directions. The motors are controlled by an LM293 motor driver which is in turn controlled by the 68HC11 MCU. The motors' control lines are connected to J4 and J5 on the EVBU board (see Appendix A). The motors are employed in all three behaviors as can be seen in Appendix B and Appendix C.

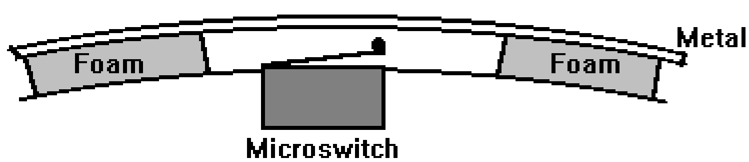
SENSORS

This robot employs three sensor systems: infrared sensors, bumpers, and a pyroelectric sensor. The infrared sensors are used for object avoidance. The bumpers are used to calibrate the infrared sensors and also for object avoidance. The pyroelectric sensor is used for finding and homing in on intruders.

The first sensor system, infrared sensors, is used for object avoidance. To implement this sensor system, I used Sharp infrared sensors which were provided to me in class. These were used to detect 40kHz-modulated IR emitted from IR LEDs. I purchased the LEDs from Radio Shack. The IR sensors produce an analog voltage that is determined by how much of the IR from the LEDs is reflected back into the sensor. When the robot is near an object, a large amount of IR is reflected back. When it is not near any objects, very little IR is reflected. The analog voltage is then read by one of the analog inputs on the 68HC11 EVBU board. I used three such sensors for object avoidance and a third in conjunction with the pyroelectric sensor to alert the robot if the intruder is too close. The IR LEDs connect to pins 5-8 on J6 on the EVBU board (see Appendix A). To limit the current through the LEDs, I used 1kΩ resistors which connect to J7 on the EVBU board.

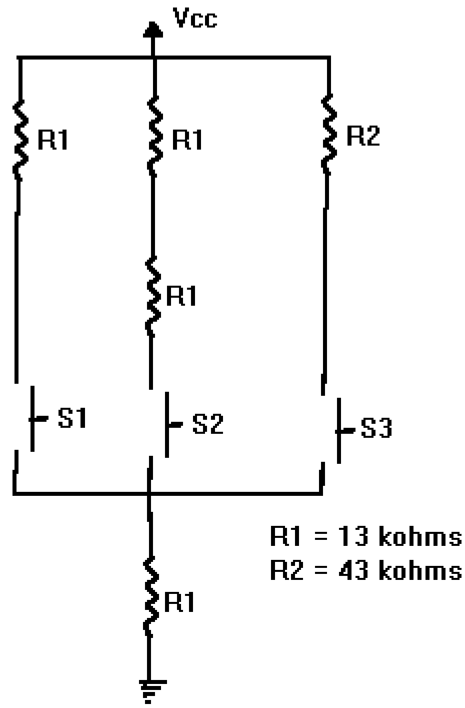
One flaw in the IR sensors is that they respond differently to objects of different colors. Dark objects do not reflect as much IR as light objects do. To compensate for this inconsistency, I added bumpers. The bumpers are used to calibrate the IR sensors and to assist in object avoidance. I implemented the bumpers by using microswitches which I purchased in Radio Shack, pieces of scrap metal that I found in the lab, and some foam rubber which came from the packaging of my 68HC11 EVBU board. A drawing of one of the bumpers is shown below.

Figure 2: Bumper Sensor



There are three bumpers on the platform. They are located in front of each of the IR sensors. The bumpers are all connected to a resistive network that produces a different analog voltage for each combination of states of the bumpers. A circuit diagram of the resistive network is shown below.

Figure 3: Resistive Network



A chart of the values at the analog input on the 68HC11 connected to this resistive network is shown below:

Table 1: Bumper Input Values

Analog_in	Right Bumper	Center Bumper	Left Bumper
0	OFF	OFF	OFF
38	OFF	OFF	ON
127	OFF	ON	OFF
138	OFF	ON	ON
86	ON	OFF	OFF
104	ON	OFF	ON
153	ON	ON	OFF
160	ON	ON	ON

The third sensor system on my robot is a pyroelectric sensor. It allows the robot to locate and home in on people which it sees as heat sources. I removed my pyroelectric sensor from an automatic exterior lighting kit that I purchased at Lowe's. When powered by a 5 volt supply, the pyroelectric sensor produces an analog output voltage of about 3V.

When a heat source moves in front of the sensor, the analog output voltage varies from 1V to 5V. The pyroelectric sensor produces two different voltage patterns depending on which direction the heat source is moving in. I had some difficulties in programming the 68HC11 to interpret these patterns so I decided to have it just test if something is moving without regard for what direction the heat source is moving in.

All three of these sensor systems produce analog outputs which are sampled by the A/D ports on the 68HC11 EVBU board. These connections are located on pins 43-50 on J3 on the EVBU board (see Appendix A). The table below shows which analog inputs were connected to each sensor system.

Table 2: Sensor Analog Input Connections

Analog Input#	Sensor
1	Bumper
2	Top IR
3	Left IR
5	Center IR
6	Pyroelectric
7	Right IR

BEHAVIORS

This robot has three primary behaviors: object avoidance, infrared sensor calibration, and finding and homing in on intruders. The software for these behaviors is implemented using Interactive C. The algorithms for these behaviors are contained in two files: *behav.c* and *pyro.c*. *Behav.c* contains the object avoidance and sensor calibration routines. *Pyro.c* contains the people locating and tracking routines. It also sounds an alarm using the piezoelectric speaker. The source code for *behav.c* and *pyro.c* is listed in Appendix B and Appendix C, respectively.

The object avoidance routine makes use of the IR sensors and the bumpers. Initially, both of the DC motors are moving forward at 100% power, which causes the robot to move forward. If the left or right IR sensor receives a reading above a threshold level defined in the program, the motor opposite to that sensor will stop moving. This causes the robot to move away from the object in an arc. If the front IR sensor receives a reading above the threshold, the left motor moves forward at 100% and the right motor moves backwards at 100% which causes the robot to rotate in place. It will continue to rotate until the front sensor is no longer reading above the threshold. Once all of the IR sensors are below their threshold levels, the robot will resume moving forward. If one of the bumpers is pushed, then the robot will back up and turn in place for half a second and then resume moving forward. This combination of responses allows the robot to avoid colliding with obstacles.

The sensor calibration routine is part of the same source file as the object avoidance routine since they both involve the same sensors. The robot determines when to change direction based on whether or not the analog output voltage of the IR sensors is above a software-defined threshold level. If one of the bumpers is pushed, then the corresponding IR sensor did not detect an obstacle or did not detect it soon enough to move out of the way. Whenever one of the bumpers is pushed, the threshold level of the corresponding IR sensor is lowered. In order to prevent the robot from becoming too sensitive, the threshold will increase if none of the bumpers is pushed in a thirty second period of time. This constitutes a primitive learning routine.

The third behavioral routine is the locate/track intruder behavior. This behavior is triggered when the pyroelectric sensor picks up a heat source during the object avoidance routine. Once the heat source has been spotted, the robot uses the piezoelectric speaker to sound an alarm and moves toward the heat source. The robot homes in on a heat source by moving in arcs and checking the pyroelectric sensor. When it detects the heat source again, it moves forward for another half second and moves in an arc in the opposite direction that it was moving in previously. This causes the robot to zigzag toward its target. If it cannot re-acquire the target within 20 seconds, it stops moving and continues to sound an alarm. By stopping, the robot conserves battery power and can be used to reveal the last known location of the intruder.

EXPERIMENTAL LAYOUT AND RESULTS

In order to test the object avoidance behavior, I placed several obstacles is a room with the robot and observed its response to the objects. The IR sensors worked fairly well and the bumpers managed to pick up anything that the IR sensors missed. The IR sensors did have some problems with darker objects, but the self-calibration behavior helped with that problem.

I tested the self-calibration routine by repeatedly placing dark objects in front of the robot and observing the change in its response as the threshold level decreased. Based on those observations, I can conclude that the self-calibration routine works.

I tested the intruder locate/track routine by standing in a location where the robot could see me and then allowing it to home in on me. It is able to detect and home in on a person, however the pyroelectric sensor does occasionally read a heat source where there isn't a person.

CONCLUSION

The robot that I have built is autonomous and capable of three behaviors: object avoidance, IR sensor calibration, and tracking an intruder. With these three behaviors, it is able to perform the function of a small-scale security system. The greatest limit on the work that I was able to accomplish on this project was time. The time limitations of a semester limited the complexity of the behaviors that I developed. However, it has met the requirements that were placed upon it.

Appendix A:

Daughter Board Schematic

Appendix B:

behav.c **source code**

Appendix C:

pyro.c **source code**