University of Florida

Department of Electrical and Computer Engineering

EEL 5666 – Spring 2004

FINAL REPORT

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ABSTRACT

The robot follows a line in order to complete tasks on a simulated warehouse floor. Based on input from the user, the robot fetches a pallet from the warehouse and returns to the entrance with the desired inventory. The robot can also be asked to place a pallet somewhere in the warehouse. One or both of these tasks can be completed with on a single trip. On its travels, the robot reads barcodes on the right side of the line that determine where it turns and how fast it travels. For example, a straight line should be traversed more quickly than a line with tight turns so the robot makes the necessary adjustments. If an obstacle prevents the robot from initially reaching its goal, it attempts another path or eventually returns unsuccessfully with a message to the user.

In order to move any pallet the robot must be able to raise the forks to the desired height, retrieve or put away the object, and return to the floor without damaging itself, the warehouse shelving, or the pallet.

Successful completion of the desired task is a combination of following the warehouse line to the destination, moving the pallet to or from the shelving, and returning home to the user.

EXECUTIVE SUMMARY

In an attempt to make the warehousing of products easier, Kirby's objective is to move a pallet between a series of warehouse shelves. To complete this task, the robot initially takes a command from the user that describes to and from which warehouse the object will be moved. After the instruction is processed, Kirby is ready to work and begins moving forward searching for the warehouse line to track. While moving blindly around the floor, Kirby eventually reaches a specially encoded barcode positioned ¾" from the line and then makes an intelligent decision about which direction to take at the next intersection. An intersection is considered to be the current tracked line with at least one 90º turn as an option. In most cases on the simulated floor this will happen when Kirby has to either go straight, or turn left or right so that it can achieve its intermediate destination. If it were not for these barcodes, Kirby would not know which way to turn and therefore it is unlikely that the destination would be reached. Once Kirby arrives at a warehouse, it needs to either pick up or drop off the pallet. If it is picking up a pallet, Kirby needs to lower the forks to the proper height prior to arriving; however, if it is dropping off the pallet, then the forks are not lowered until after arrival. Once this process is complete, Kirby moves to the next warehouse and performs the opposite operation and then navigates its way home to complete the mission.

Since Kirby is a worker robot, it does not enjoy staying at home and if left unattended for a certain amount of time will attempt to reverse the work it just completed. For demonstration purposes only, this process will repeat until Kirby is either turned off or until it receives a new command from the user.

INTRODUCTION

It may be necessary for a controlled warehouse environment with which there exists little to no human interaction. Such a circumstance arises from the storage of hazardous waste, large volumes of currency and precious metals, or any other situation where it is imperative that human error be kept to a minimum. By using a robot to accomplish the task, the service is provided with least risk. In addition, robots may be more efficient than humans by operating under conditions not conducive to human productivity such as little or no lighting or even in a non-climate controlled workspace.

The purpose of this project is to introduce a miniature design for an autonomous agent that performs warehouse functions. The example applications listed above represent a fraction of the possible uses for this technology.

Through the following pages, information will be presented on how such a system is realized. The integrated system described below gives a high level description of the project while saving the nuts-and-bolts for the sections covering the mobile platform, actuation, sensors, and robot behaviors.

INTEGRATED SYSTEM

Before it is possible for Kirby to perform any task, it needs to sense its surroundings in order to determine which actions will be needed to achieve the task. Through each of its three main sensors, the robot constantly receives data from the real world. This can include the distance of the nearest object with the help of the ultrasonic ranging module, or where the robot is in relation to the line it is attempting to track. While sensing the from the barcode scanner occurs less frequently, it allows Kirby to make informed decisions on which direction it needs to move so that it arrives at the desired destination.

Each sensor is able to control actuation and movement of a particular part of the robot, and working as one cohesive unit allows Kirby to have full functionality. With the aid of a mediator function, each motor is controlled with the input of all sensors rather than having one sensor control the speed of all the motors. Refer to figure 1 below to see a high level approach to how the three motors are controlled.

The key to integrating any part of the robot is independent testing through incremental development. For example, to get Kirby to track a line and avoid potential obstacles at the same time requires the integration of the line tracking and sonar ranging modules. The first step is to have the motors be controlled by the information gathered by the sonar module. If an object is detected within a certain distance threshold then the motors should stop, otherwise they should spin. Next is to make sure that the robot can track a line. After successful programming of the tracking code, it is time to integrate the two together to work as one. If both sensors have low level control of the motor hardware then even though the sonar recognizes an obstacle, it is possible the line tracker still may cause the robot to move towards the obstacle. Some way of prioritizing the sensor inputs is needed so that when there is an obstacle, for example, the robot ceases movement regardless of what action the tracking sensor wants the motors to perform.

Once these two sensors have been integrated with the motors and each other, the barcode scanner needs to be added and included in the mediation process. By doing this one sensor at a time, it increases the chances that everything will work cohesively and not against each other.

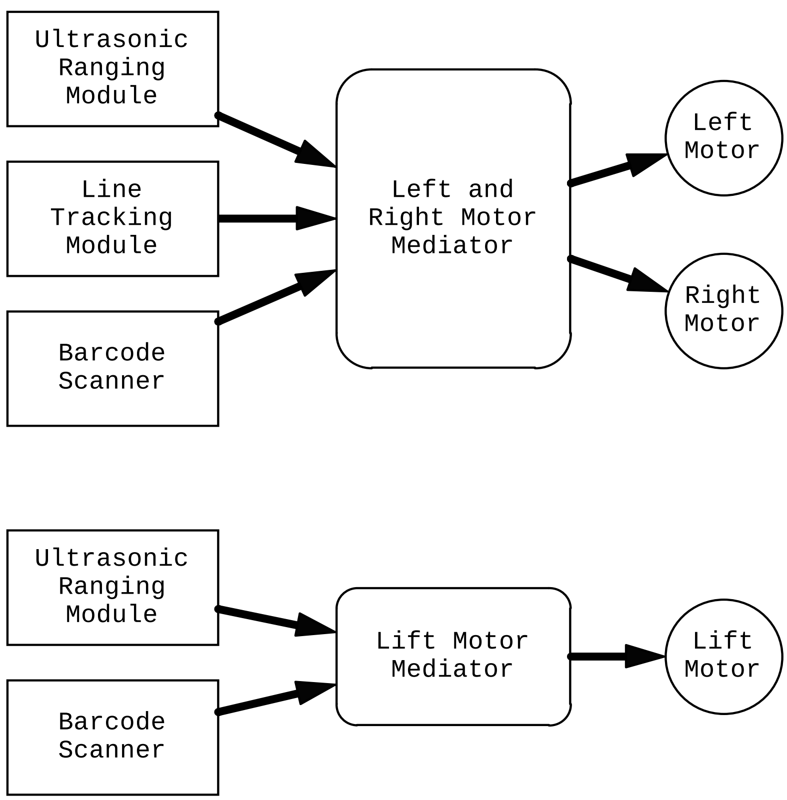

Figure 1 - Sensor Controlled Motor Speed Mediation

MOBILE PLATFORM

To replicate the actions of a traditional forklift, the following structural components are necessary. First, the robot must retain a low center of gravity. This is accomplished by keeping the majority of the weight as low to the ground as possible, especially while mobilizing with the fork lifted above the ground. Having two 3.5” diameter wheels and their respective motors positioned two thirds of the way from the back of the fork also aid in the stability of the robot and help prevent the lifting device from becoming top-heavy and tipping the robot forward. A total of four casters are used further maintain stability. The batteries are located as close to the back of the vehicle as possible in order to minimize any potential for tipping. Additional weights may also be added to the rear of the vehicle to prevent the robot from becoming unstable.

The lifting mechanism is constructed using two metal guide bars that promote upward and downward motion by impeding the lateral movement and rotation caused by the rotating screw and the lifting nuts. This device is connected at the front base of the robot with the motor and also is connected halfway up the boom to the midpoint of the platform. The total boom height is approximately 16 ½” which allows for a range of 10” between fully lowered and fully raised.

Despite being able to raise and lower the fork successfully, Kirby suffered from a design flaw that could have been repaired if it were caught early enough. The design mistake revolves around not having a screw with a thick enough diameter to prevent bending of the screw while it is rotating. A 1/8” diameter screw was used, and it is believed that a screw with at least ¼” diameter would have been sufficient. The bending of the screw has a detrimental effect on the lifting motor because it causes the screw to be at an awkward angle and the motor must compensate for this angle with a larger amount of torque than is required when lifting under no load. In addition, the pitch between the screw threads was too small and required too fast a motor to raise and lower the fork in a timely fashion. With a motor running at 300 RPM it took about 70 seconds for the fork to be fully raised from the fully lowered position. This length of time is much too long for any useful lifting or lowering operation.

ACTUATION

Wheels & Movement

It is important for a lifting robot to remain balanced with the wheels firmly in contact with the ground. Two 3.5” diameter rubber wheels with a width of 2.25” provide enough traction to keep the robot well balanced. This is a much better solution than the original idea of using 4” diameter wooden wheels. Since these wheels only had a width of 0.25” and the traction came from a single rubber band, they had a tendency to slip on many types of surfaces when accelerating or turning. The wooden wheel design also promotes platform vibration because of the solid structure of the wood and the lack of give. Due to the wide rubber tread of the 3.5” wheel design, the vibration to the platform is minimized when moving along hard surfaces.

Lifting Mechanism

To lift the light-weight pallets, the robot employs the use of a screw to raise or lower a series or nuts that are connected to the fork. By doing this it is possible to lift large amounts of weight with relatively little effort by the motor. An additional advantage of using a screw and nut design is when the fork is in the raised position it does not require any torque to keep it in place. The problems encountered by the initial design of the mechanism and their solutions can be found above at the end of the section Mobile Platform.

SENSORS

Devantech SRF-08 Ultrasonic Ranging Module

Scope

The ultrasonic ranging module is used for obstacle avoidance by allowing the microprocessor to cease all forward motion once an object is within a given distance threshold of the front of the forks. Since this particular sonar is accurate to within half an inch, the module is also used for distancing when the forks are being positioned underneath the pallet so that the pallet may be lifted into the air.

Theory

An ultrasonic ping is released by the module and the device determines how close the nearest object is based upon the length in time it takes for the ping to be returned. The calculation is based on the speed of sound at sea level, and depends upon the air itself (not on sound amplitude, frequency, or wavelength).

Objectives

To add input to the motor mediator functions so that Kirby can cease forward movement when it encounters an object within a certain distance threshold. Once the robot is near a warehouse (as a result of scanning a particular barcode), the obstacle avoidance for the robot turns off and Kirby relies solely on another barcode to stop.

References

Vendor: Go-Advanced Robotics or Acroname

Contact: www.go-advanced.com or www.acroname.com

Part Number: SRF-08

Price: $43.00

Sensor Software Algorithm

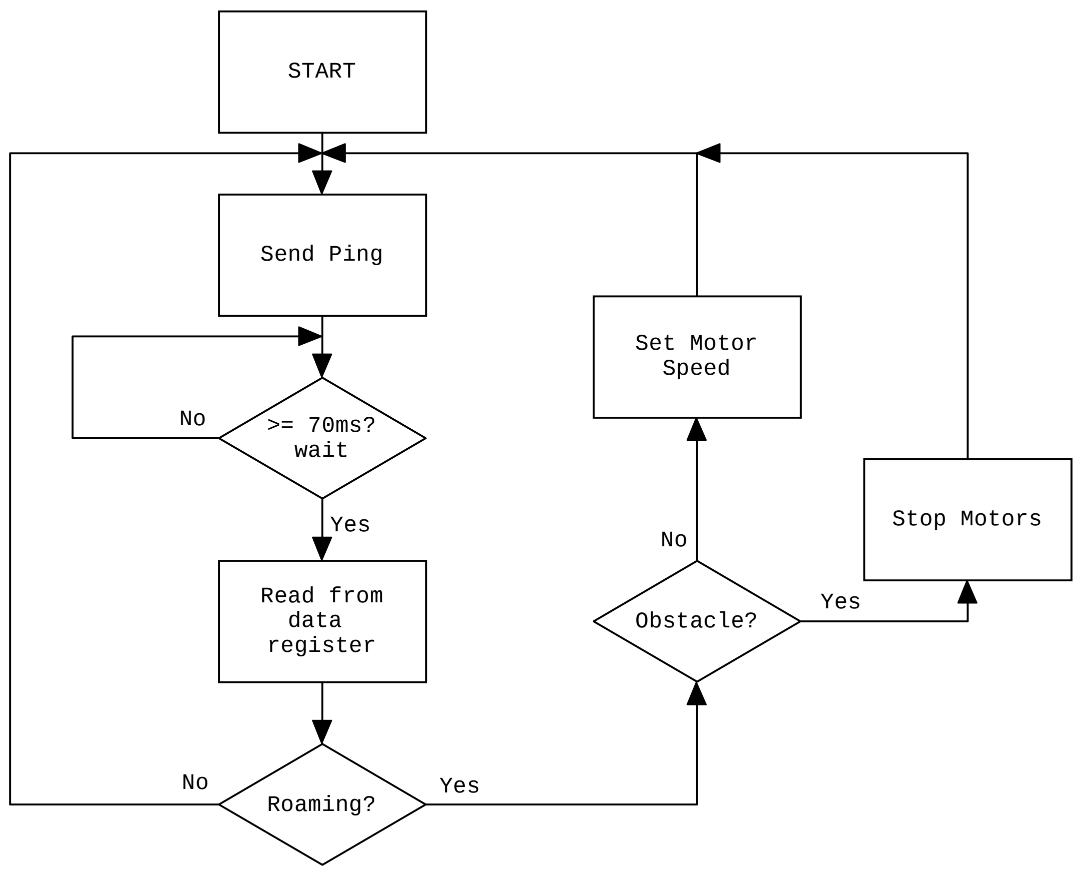

Figure 2 - Sonar Ranging Obstacle Avoidance Software Algorithm

Kanecal Kanescan Barcode Scanner

Scope

The barcode scanner is designed to read and understand Code 39 barcodes that are encoded with specific instructions. These codes act as road signs so that the robot has a rough understanding of where it is in relation to its current surroundings.

Theory

The scanner encounters and reads a valid barcode such as the following sequence:

34567

This follows the Code 39 barcode scanning format, as it is an easily obtained and freely available font and also is easily read by the barcode scanner. Other formats may be used, but the presented application assumes the use of the Code 39 format. The asterisks at the beginning and end of the numbers 34567 indicate to the scanner the start and stop points of the data. Upon a successful read by the scanner, the numbers 3, 4, 5, 6, and 7 will be serially transmitted to the microprocessor. For additional information, including wiring pinouts and a software algorithm, please refer to the final special sensor report.

Objectives

In this particular application, the barcodes will be encoded so that the robot will be able to determine its current location. Basically, the barcodes will act as road signs attached to the floor of a warehouse and will be read by the robot as it follows a line to its destination. By following the encoding scheme, it is possible for the robot to perform in a dynamic environment provided the barcodes are consistent. As a result, many different variables such as speed and next turn direction can be found "on-the-fly" by the mobile robot.

References

Vendor Name:	Kanecal
Part Number:	Kanescan
Website:	www.kanecal.com
Phone Number:	877-KANECAL
Price:	$79.00 (they offer a student price of $59.00)

Hamamatsu P5587 Photoreflector

Scope

The photoreflector is intended to be used to detect the presence of a black line (it has been experimentally found to be most successful to be using a line of black ¾" electrical tape). With one sensor it is highly difficult to track a line, but with four sensors advanced line tracking becomes possible.

Theory

When anything black is detected, the V_o output from the photoreflector becomes logic 0. All other times the output is logic 1. To achieve the most accurate and repeatable results, keep the photoreflector approximately ¼" from the line that is being tracked and at an angle of about 20-30 degrees. This setup also allows for "fake line detection" (a presence of black when there is none) to be eliminated.

Objectives

In order to track a line, certain information must be presented so that the robot can maintain on the line. By using four photoreflectors in conjunction with four external interrupt pins, it is possible for the microcontroller to take appropriate action only when there is a change in the photoreflector outputs.

References

Vendor Name:	Acroname
Part Number:	R64-P5587
Website:	www.acroname.com
Phone Number:	(720) 564-0373
Price:	$2.20

BEHAVIORS

Scanning

Since the robot spends the vast majority of its time without any barcode interpretation to do, there is only one simple interrupt behavior that needs to be implemented. When the UART receive buffer is full the microprocessor generates an interrupt and enters the UART receive interrupt routine so the data can be stored as needed by the programmer.

Lifting

The lifting behavior can occur when Kirby is inside a warehouse. In order to reach the desired height, the robot first raises or lowers the fork to either maximum (all the way up or all the way down). This maximum is discovered with the use of two bump switches acting as limits. The two switches are connected to a single ATD channel on the microprocessor and the particular pin is checked roughly every 100ms. Next, the lift motor is reversed for a certain number of seconds to allow the lifting fork to be lowered or raised to the appropriate height. This method remains an inefficient but effective way to lift objects.

Roaming and Tracking

To reach a warehouse, it is necessary for the robot to take the correct path. This is done with a combination of barcode scanning and interpretation, line tracking, and the occasional use of roaming. Most of the time, Kirby remains on the line but there are a few instances when it is not possible to do so. Such a circumstance arises when Kirby makes a 90° turn at an intersection or when turning around on the line. To ensure successful completion of the action, Kirby must roam and maintain the current heading regardless of outside influence until it encounters a sentinel condition and can return to normal tracking operations.

Avoiding

Assuming Kirby is not in the vicinity of a warehouse, it uses the sonar module in conjunction with code to avoid obstacles in its path. There are many ways to achieve successful results, but the easiest is to check the data register every 70 to 80 milliseconds as seen in figure 2 (refer to Sensors, under Devantech SRF-08 Ultrasonic Ranging Module). The specific control algorithm is integrated with the other main motor control device (the line tracker) and a decision is then made by a mediator (see figure 1 under Integrated System)

EXPERIMENTAL LAYOUT AND RESULTS

Experiments are performed for each of the robots sensors to ensure that each can work independently from one another. This is a proactive debugging strategy that saves time by eliminating the possibility of interference from the other sensors.

CONCLUSION

Overall, the project was a success and it was a great introduction to robotics in general. Initially my goal was to simply finish and wind up with a working robot; however, along the way I gained real-world experience, discovered an appreciation for how autonomous machines are built, and also began to realize my own potential as a student. All in all, I feel that I have come away with more than I set out for and I am a better person as a result. IMDL has inspired me to continue with graduate-level education and has renewed my interest in teaching. I look forward to participating and hopefully teaching a class such as this sometime in the near future.

ACKNOWLEDGEMENTS

I would like to sincerely thank the IMDL teaching assistants for all of their guidance throughout the semester. The class would have been an even greater challenge without your help. Thank you for not getting too annoyed when I felt it necessary to cut just one more circuit.

The class would not have been the full experience if it were not for my classmates’ ideas and input onto how to better the robot. Specifically, Mike Bonestroo, who spent countless hours helping me look at the bigger picture and to not get bogged down with details.

APPENDICES

Appendix A – Source Code

Due to the abundance of source code files, it will be available as a separate zip file on the course website and is included on the CD containing the electronic copies of the special sensor and final reports.