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Autonomous Robot Platform

Introduction

Exploring a remote or dangerous location is often performed by a remotely controlled robot, such as the Mars rovers Sojourner, Spirit, and Opportunity. The problem with these is they rely on a controller stationed a long distance away, sometimes on a different planet. Furthermore, they require constant human control to accomplish any task. This is not cost effective, requiring extensive amounts of money and time. If the robots could navigate by themselves, no constant supervision would be necessary. They could also locate a desired target and map the area of interest.

Problem Description

Robots are ubiquitous in the modern world. They have been used in an immense range of applications and have proven capable of satisfying an enormous range of demands of varying complexity through individualization. While ground up custom designs often lead to high performance, they can come at a great expense. While customization is often a necessity, many robots have a common base platform of capabilities. This suggests that there is an opportunity to develop a general robotic platform with these capabilities which is cheap, easily upgraded, and readily adapted. There exists a need for a simple, adaptable robotics platform that could be used to navigate unknown, potentially hazardous, or any other scenario where you wouldn't want to necessarily send a human.

We intend to construct a platform to allow a robot to travel into an unknown, and possibly hazardous environment, and search for an exit or a particular location designated by a beacon. This system contains two parts. First, the robot needs to be able to sense, identify, and locate obstacles and targets in its environment. Secondly, the robot needs to be able to move and adjust its course according the data it gathers. Another feature would be mapping the location as well. This would be particularly useful for exploration and also would be much easier. This would require the robot to track its own motions relative to a point of reference and measure the distance to the obstacle, rather than compiling photographs and video to create a map.

This platform has several applications, such as bomb disposal, mapping a remote planet, or undersea exploration. All of these areas contain an objective where it would be difficult, hazardous or impossible for a human to venture. For a bomb threat in a building, the robot would be allowed to search the area and find the explosive device without endangering any police officers, so an existing bomb diffusing robot could be sent in to diffuse the device. For exploring the surface of a distant planet, a beacon could be dropped from orbit onto a feature of interest, and a rover equipped with our platform could be dropped in a suitable landing site, and then allowed to find the beacon. Undersea exploration would require giving the robot the ability to sense in all directions, but could easily be done.

Proposed Solution

We propose creating a robot that reads information from an infrared distance sensor, calculates the range of obstacles, and searches for paths around them. The use of stepper motors will keep track of the distance that the robot has travelled. This information can be decoded in software to determine the topology around the robot. A beacon will send a wireless signal, and three receivers on the robot can triangulate the direction to the beacon. This allows the robot to create a virtual compass pointing to the beacon and needs only simple intelligence to navigate around walls.

Locomotion for the robot is relatively simple; a stepper motor can be used to accurately control the movement of the robot. By independently controlling the left and right wheels, a wide range of movement and accurate turning can be achieved. The motors can be controlled either through a speed control circuit or a relay. Power can be supplied by a simple hobby RC battery, which would provide an ample length of time of operation.

Features to be Demonstrated

The first goal is to have a working, mobile robot that can navigate autonomously. The robot will utilize infrared distance sensors to detect its distance from a wall and will use a maze pathing algorithm to navigate its way through the maze. Ideally, some type of wireless beacon would be used, which will be described in a later section. The robot will detect direction and/or distance to the beacon and would use that information to navigate through the maze to the beacon's location.

The robot's main circuitry will consist of a micro controller based system that will take input from the wireless and infrared sensors, and distribute output to the motors, either through a speed controller or a relay. The frame of the robot will be simple, most likely made out of extruded aluminum framing and wheels.

List of features (from least complex to most complex)

1. Microcontroller circuit that can control the motion of the robot
2. Microcontroller circuit that can move the robot using input from the distance sensors
3. Navigate through obstacles without getting stuck
4. Successfully navigate through a maze without getting stuck
5. Determine direction of and/or distance to a wireless beacon
6. Successfully navigate through the maze to the beacon

Available Technologies

As mentioned, the three critical abilities of the robot platform are those of sensing nearby obstacles, navigating around those obstacles, and receiving a wireless signal from a beacon. The following sections list the available technologies that will allow the robot to function with these abilities.

Sensors:

Since the robot need only avoid immediate obstacles, equipping each of the four sides with a short range sensor will provide the robot with enough of a view of its surroundings to navigate properly. Short range sensing can be achieved at relatively low cost by using infrared sensors, as proved by the following potential sensor, GP2Y0A21YK, made by Sharp. This sensor outputs an analog voltage which correlates to the distance the infrared signal traveled before reflection. It operates effectively through a range of 10cm to 80cm and consistently for targets with varying reflectivity, as shown in Fig. 5. Additionally, its implementation into the design is relatively simple as it operates without the need for external control circuitry.

Navigation:

Within the ability to navigate effectively, there are three main considerations: providing power and a mechanism for movement, providing a means to quantify and track the previous movements of the robot, and providing a means for steering by rotating the robot.

The robot will be built on a platform mounted to four wheels. Since the robot should be relatively small in size, it will likely need to be supplied with only several watts of power. To effectively maintain a regulated voltage of 5V for the board, the battery should supply above 5V. 7.2V supplies are widely available and should be both affordable and effective.

Quantifying the movements of the robot can be achieved through the use of a stepper motor, which increments rotations of the axis by a fixed angle. Once the step size is know, distance measurements are obtained by simply counting the steps taken in each direction. A sufficient solution can likely be found among the 57BYGH motor series. This series offers options, which are low cost, light weight, low current and still capable of providing sufficient power for the application.

The steering functionality can be met through the use of tank drive, in which the set of two wheels on each side of the robot is connected by a belt to its own stepper motor. Steering is accomplished by independently varying the power supplied to each side of the robot by modulating the voltage supplied to each stepper motor. Preassembled stepper motors are available; however, judging from the complexity of the sample speed controller diagram below, we believe it is well within our abilities to design and use our own circuit if the need arises.

Wireless Link:

Ideally, a wireless connection would provide the robot with information about its absolute position relative to the beacon; however, determining distance based on a wireless signal is a complex and inaccurate process, and that it is likely beyond the scope of this project. However, a useful connection can still be created with the simpler goals of providing the robot a guiding direction as it navigates its surroundings and alerting the robot when it has reached its target (the beacon).

Tracking the direction of the beacon signal can be accomplished by placing three electromagnetic sensors on the robot in a triangle formation and measuring the difference in time between the reception of a pulsed beacon signal at each sensor. This eliminates the need to accurately measure the signal strength and eliminates errors due to signal strength fluctuations.

The pulsed wireless signal from the beacon can easily be made strong enough so that it is sufficiently above ambient noise strength when the robot is within close proximity to the beacon. A set point can be defined such that when the wireless signal is consistently at or above the set strength, the robot is alerted that it has reached its target and will discontinue its search.

Engineering Content

The main challenges for designing the robot will be the algorithm for navigating the maze, finding the direction to the beacon, and determining the locations of obstacles. All of these are primarily signal processing problems that will be addressed in the software.

Many algorithms for maze navigation have been developed, with varying levels of complexity. The simplest is simply following along an obstacle until the robot finds a clear path towards the beacon, and would be fairly simple implement in code. More complex algorithms, such as marking specific locations and determining shortest paths, can be implemented for more complex topologies.

Determining the beacon direction will require either multiple sensors or a set movement pattern to get multiple data points. Using the time or signal strength between the points, the distance and possibly distance can be triangulated using basic mathematics. Since for the demonstration the distance will be small, the difference in signal strength will be small as well; though it remains an option for determining distance to the beacon.

Determining the locations of obstacles is the simplest; each of the infrared sensors can tell the distance to an obstacle. The distance and relative location to the robot can be tracked giving a topology of the surrounding area.

Conclusions

In conclusion, it is very feasible to design and build a simple, adaptable robotics platform that has the ability to navigate and maneuver through known, unknown and/or potentially hazardous environments autonomously. There exists current technology in the form of microchips, motors, sensors and wireless applications that will be customized and integrated together to create a platform that could potentially be mass produced and/or adapted for a huge range of applications. At the end of the project, the goal is to be able to demonstrate a working robot that can autonomously navigate through a maze or unknown environment to locate a wireless beacon placed in an unknown location.