An Autonomous Robot Designed to Navigate a Maze and Extinguish a Small Fire

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Abstract

This paper outlines the design of the construction and programming aspects of building an autonomous robot capable of navigating a maze, locating a small flame, extinguishing it, and exiting the maze. This robot must be completely autonomous, using no external input to dictate its actions. The robot must also be able to navigate a maze with one correct path from entrance to exit completely. While navigating the maze, the robot must detect a small, lit candle embedded in the floor of the maze. When it detects this candle, it must extinguish the flame, and move on to exit the maze. The first part of this paper will detail the mechanical design of the robot. The second part will cover the design of the various sensors that enable the robot to detect its environment and the electronics that drive them. The third part will detail the programming of the artificial intelligence which will allow the robot to act according to its situation.

Part I: Mechanical Design

In order to navigate a maze, the robot must contain several mechanical subsystems which allow the robot to move through the world. The mechanical design of the robot must also be able to completely support the components which drive the mechanical and electronic subsystems.

There are four major subsystems in the robot's mechanical design: propulsion, electronics support, mechanical support, and the base frame.

The base frame of the robot will be constructed out of a circular plastic disk. This frame material was chosen due to its ease of use in the assembly process. Plastics are easy to drill, cut, and shape. For their weight, certain varieties of plastic are capable of supporting large amounts of weight rigidly.

The base was chosen to be circular for ease of navigation. In order to navigate a maze with hallways of width 5 units, a robot with a circular base needs to have at most a radius of 2.5 units. A robot with a square base in the same maze, would need a side length of 5 units also. The surface area of the circular robot would be 19.635 units, and the surface area of the square base would be 25 units. Although the square base has a larger surface area which can be used to mount more components, the circular base has one major advantage. In order to navigate the halls in the maze, the square robot must be aligned perfectly with the side wall, or else it will get stuck. The sharp corners on the square robot are also prone to snagging on outcroppings and getting stuck in corners. However, the circular base can navigate the hallways at any orientation and still fit (Fig. 1.1). The circular base also prevents the robot from getting stuck in a corner. If a robot with a square base moves into a corner, in order to turn, the robot must first back up into a spot where the edges won't get caught and then turn. The circular base only needs to turn in place.

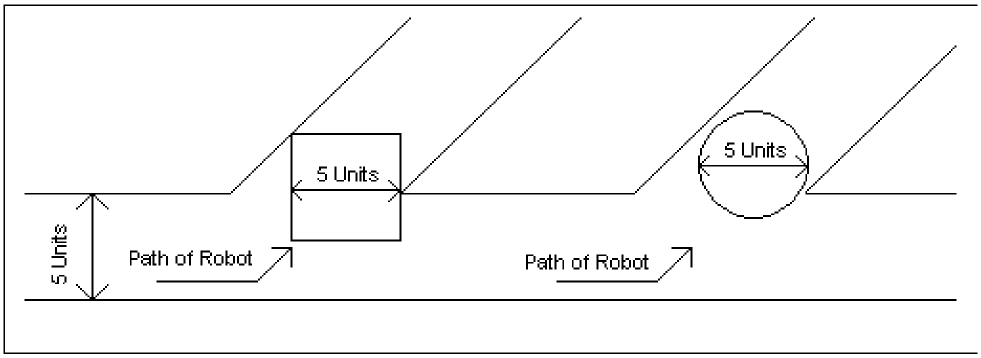

Fig. 1.1 A circular base can fit into smaller passages than a square base without precise reorientation

In order to combat the smaller amount of surface space that the circular base contains, the components will be mounted in a layered support system. The basic propulsion systems will be mounted on the base platter, with the control electronics and sensors mounted on disks mounted above the primary base. This will provide a way for subsystems to be mounted and removed easily without interfering with the other systems.

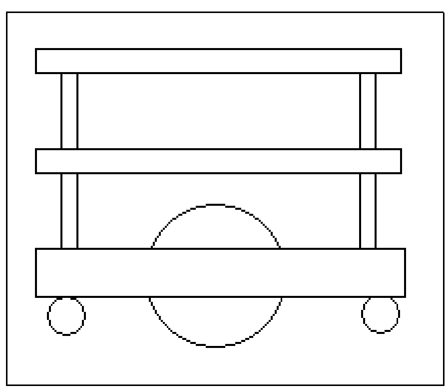

Fig 1.2 A layered mounting system provides a way to easily add and remove subsystems independently.

The propulsion system is the subsystem which is essential to the functionality of the final robot. The propulsion system contains the parts that work to make the robot physically move through space. The two main components in this system are the wheels and the motors.

The wheels of the robot need to both support the weight of the other components and provide enough traction to propel the robot without slipping. Wheels are made out of several different materials which are each suited for different environments. Inflatable tires are generally large, and fairly light. Since they are filled with a non rigid substance, inflatable tires absorb more irregularities in the environment than a solid wheel. However, inflatable tires are prone to rupturing in environments with sharp objects. Solid molded wheels are better suited for harsher environments because they cannot break. However, since they are solid, the wheels do not compress, and thus provide less traction than inflatable wheels.

Since the robot will not be that large, most wheel designs would not have a problem with propelling the robot. Since weight is a potential issue in the construction of the robot, a wheel which is light and durable is preferable to a heavier wheel. Due to this factor, small foam molded model aircraft wheels will be used. These wheels generally have a solid plastic hub which will allow for easy mounting to the motors.

Fig 1.3 Small, lightweight, foam molded model aircraft wheels (Image courtesy TowerHobbies.com)

For motors, several options are available. Three major types of motors are used in hobby robotics: stepper motors, continuous motors, and servo motors. In a stepper motor, applying power to the leads causes the motor to rotate a set amount of degrees. In order to obtain continuous rotation, electricity must be pulsed to the several different leads of the motor in sequence.

Stepper motors are often used in applications that require precise positioning of components. However, this precision comes with the added difficulty of control. A stepper motor controller is needed to correctly sequence the application of power that allows the motor to turn the designated amount.

Continuous motors are by far the most common of the three major types of motors. Anything from an electric car to a blender operates using a continuous motor. When power is applied to the leads of a continuous motor, the shaft rotates until power is taken away. Continuous motors are the easiest to control, but they have no positional feedback. The only way to know how far the motor has gone is to estimate it using time or use an odometry system.

Servo motors are a continuous motor with a additional feedback line. Servo motors are commonly used in model aircraft and cars to accurately position the steering and control surfaces. Servo motors use a potentiometer to detect how far the servo has rotated when power is applied. In normal function, servo motors have limit switches which limit the amount of rotation the motor can obtain. While this is good for precise positioning of control surfaces on a model airplane, it keeps the servo for rotating a full 360º. Servos can be modified to suit 360º rotation at the cost of losing the positional feedback. The advantage of modifying a servo for continuous rotation is the fact that servos contain built in gears that are contained in a nice package.

Fig 1.4 A servo motor