An Autonomous Self-Parking Vehicle

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Abstract

Several automotive manufacturers (e.g., BMW and Lexus) have initiated the concept of a "self-parking car" whereby a driver positions their automobile into a location that can be maneuvered into a parking spot under automated control. This project demonstrates an experimental effort to expand on this concept by providing additional automated parallel-parking capabilities, such as self-discovery of parking spaces and coordinated avoidance of objects.

The prototype vehicle is a NXT Robot, which includes a processor, Bluetooth wireless, three motors, and several sensors. The robot uses two ultrasonic sensors to detect surrounding objects. A light sensor identifies the lines that demarcate parking spaces. These sensors are coordinated to ensure that: 1) the road is clear, 2) there is an empty space of the street, and, 3) the empty space is legal (e.g., not a driveway).

The robot fulfilled all of the goals of the project, but with a few compromises. Due to the limitations of NXT, it was difficult to create a front-wheel steering system resembling a real automobile. The prototype has two front wheels with rubber tires, but the back wheels are plastic to enable easier movement along the driving surface. The robot's turning radius is dramatically less than a standard automobile. However, the project successfully demonstrated the ability to sense and interpret data in a real-world situation. The opportunities for broad impact are significant. Future extensions may include a vehicle that circles the block to await the driver's return, or a fully automated modular transit system consisting of smart cars.

Vehicle Construction

The robot constructed for this project contained the following configuration:

- **Two ultrasonic distance sensors**

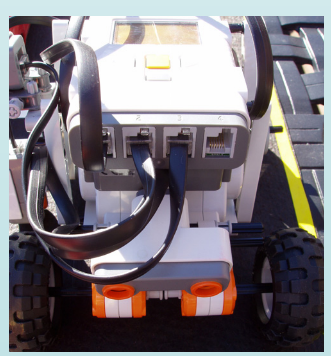
  One mounted in the front to detect obstacles to forward travel, and one mounted on the side to detect cars that are already parked

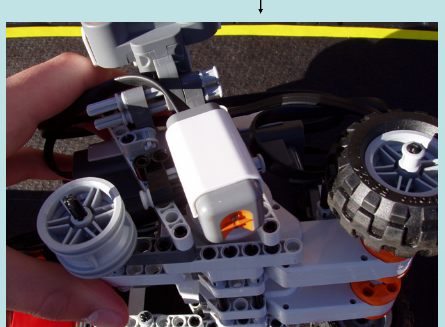
- **Two Motors**

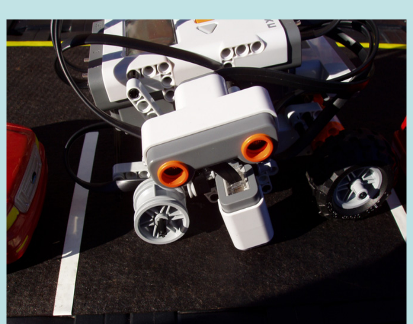
  To provide the propelling force for the robot

- **One light-reflectivity sensor**

  Mounted on the side in order to detect the white lines that indicate a legal parking space







Project Objectives

This project uses the Lego Mindstorms NXT robotics kit to construct a prototype proof-of-concept autonomous self-parking vehicle. Recently, both Lexus and BMW released cars with the ability to parallel park; however, the abilities of their cars are very limited, and only work in best-case scenarios, when this ability is the least needed. This project intends to improve upon their weaknesses in the following areas:

- **Forward obstacle detection**

  The ability to determine whether the road ahead is clear

- **Space detection**

  The ability to find an open parking space on its own

- **Legality determination**

  The ability to decide whether a space between parked cars is a legal, marked parking space or a driving area

Background: NXT and Robot C

The vehicle was constructed using the Lego Mindstorms NXT Robotics System. The NXT has impressive capabilities, including Bluetooth connectivity; light, reflectivity, ultrasonic distance, sound, and touch sensors; three servo motors; a 32 bit processor; and 256 Kbytes of Flash memory. The robot was made available to consumers in July 2006.

All of the code for controlling the robot was written using the Robot C language, which is a C-based programming language developed by Carnegie Mellon University specifically for use with the Mindstorms robots. It includes a library of robot-specific methods, such as reading sensor data and controlling the motors.

NXT Peripherals

Software Control

All of the code for this project was written using Robot C. A fragment of the code is shown below.

```
while (SensorValue[sonarFrontSensor] > 50 && !canPark) {

   while(SensorValue[lightSensor] < 30) {
      motor[motorRight] = 100;
      motor[motorLeft] = 100;
   }

   if(SensorValue[sonarSideSensor] < PARKWIDTH) {
      firstEmpty = false;
   }
```

This loop moves the robot as long as the following conditions are true:

- there is enough space in front, and

- it hasn't already found a space.

This drives forward until the robot encounters the first line of a parking space.

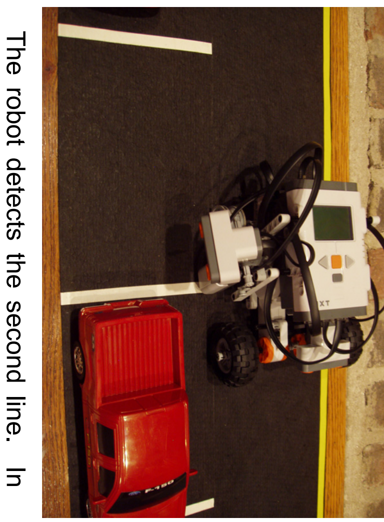
This code determines if the space to the side of the robot is smaller than the width of a parking space. If so, then the boolean firstEmpty, which indicates whether or not the front of the space is empty, is set to false. This is repeated later in the code for other parts of the space.

Outcome

The robot can successfully navigate a street situation in order to find an empty, legal parallel parking place. Although it still has occasional difficulties, these are not major and could be solved with additional refinement of hardware and code. The only true difficulty with this arrangement is that due to the limitations of the NXT system, it was very challenging to create a true wheel-rotating steering system that is common to automobiles.

This project points to the feasibility of future exploration of automated travel. For example, imagine a robotic car that may not need to park when its owner is only expected to be gone a few minutes; instead, it might merely circle around the block until its owner messages it to come back. Even further in the future, perhaps all transit will be entirely automated, including parking garages. Less effort, fewer collisions… What's to lose?

The robot detects the first line.



The robot detects the second line. In the intermediate stage, it has checked to be sure the space is clear.

The robot backs into position.

Parking successfully completed.