CPE 470/670 Report #01
Lab 03: Tunnel Navigation

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Hardware and Software Design

Hardware

The design of the robot was a wide, low-centered one, generally with all pieces either parallel or orthogonal to the floor. The robot featured two driving wheels and a trailing caster wheel to allow for adequate mobility to accomplish the task of turning sharply as it navigated the tunnel. The flat, design of the robot allowed for easy attachment of the various sensor devices, and helped to eliminate the difficulty of aiming sensors too high or too low.

Three sensors were used: two ultrasonic range-finding sensors and an RF reader. The ultrasonic sensors were attached to arms that projected from the front of the robot, parallel to the floor, and the sensors were positioned such that their “view” would be parallel to the floor and so that they were facing 45 degrees away from the midline of the robot, each facing outward on their respective sides. The RF reader was attached to the chassis of the robot on the rear-right, such that the sensor was only a few millimeters above the floor, facing the ground.

Overall, this hardware design made for a robot that could sense obstacles that were in front of the robot, but to the side, turn easily to avoid most obstacles, and sense RF nodes on the ground provided the RF sensor passed either close enough or slowly enough by the RF node.

Software

The software design of the robot was simple. Three tasks (or processes/threads) were used to manage the robot’s behavior. These were: the movement task, the sonar task, and the RF task.

The primary task, the movement task, was responsible for managing the robot, and therefore all outward behavior. The movement task was responsible for causing the robot to proceed forward, sway left or right to avoid an obstacle, or make a U-turn at the end of the tunnel. These decisions were all made based on the state of the environment as perceived by the sensor tasks, which were relayed by global flags or status variables.

The sonar task was responsible for detecting the walls of the tunnel and determining if they were near enough to necessitate avoidance. This task continually collected distance readings from both sensors, took the difference between the distances, and if the difference was above appropriately chosen thresholds, the task would signal that a turn was necessary. Note that positive and negative thresholds were chosen to determine which direction of turn was necessary.

The RF task was solely responsible for detecting the presence of the RF card strip to indicate that the end of the tunnel was near. This task would signal to the robot that it was time to make a U-turn once the RF strip had been passed.

Problems Encountered During Implementation and Their Solutions

Physical Design

The first difficulty encountered during the implementation of the robot was the physical design. The design that we had started with was a more upright design, which had more than enough mobility to effectively complete the task, but was ill suited for attaching many sensors, or attaching them at appropriate orientations.

The solution was to redesign the robot, attempting various configurations. In redesigning the robot, some designs which were too bulky were attempted, some were unable to turn adequately, and others did not have enough utility/attachment space for sensors. Eventually a suitable design was reached that was agile and suitable for attaching sensors. The solution that was reached eschewed a 4-driving wheel design, as our experience with such designs did not afford the robot much agility. The low, flat design described previously was, used to gain the much needed utility space on the robot. Combining these two findings made for a robot that was suitable for the task.

RF Sensor

The RF sensor was somewhat difficult to work with given that it did not detect RF nodes as readily as might be desired. This could have been due to either the sensor not being given a lot of distance between it and the ground, since the RF sensor did not seem to perform well at detecting RF signals laterally, or because the sensor was not given appropriate time to detect the RF nodes, which is entirely possible given that by nature, passive RF nodes require more time to be detected.

To solve this problem (or at least make reasonable improvement), it was decided to simply slow the robot's driving speed down. While this was not necessarily the best move for a competition that required speed, it was ideal for producing a robot that could reliably, even if not perfectly, detect RF signals. The option of positioning the sensor further from the floor to give a larger area of sensing was not chosen due to the fact that in exploration of the sensors capabilities, detection performance rapidly declined as space between the sensor and the node increased.

Algorithm Design

To solve the original problem several algorithms were consider. One such algorithm was to follow the walls of the maze in and out. This algorithm was rejected because following the wall accurately and quickly was not quick enough compare to our other solution. Another algorithm was to stop the robot, ping for ranges, and then determine the optimum path. This solution was also rejected because stopping our robot, processing calculating an optimal, and then going introduces unnecessary delays during each action. These delays could be reduced but they will not be zero and because the problem is time sensitive so it was not worth experimenting with. Our last solution was to read the distance from both sensors. This would give a distance of how far the robot is from each side of the maze. These numbers could then be used to find the middle of the maze and direct the robot to stay in that middle. Eventually, this method was refined such that the difference between each distance was computed and the robot would only change courses if it is outside some tolerance. This was the solution used because it allowed the robot to go through the maze smoothly and fast provided that the sensors are effective.

Unsolved Problems

Inability to Detect Obstacles Directly in Front of the Robot

Due to the perpendicular positioning of the ultrasonic sensors, they did not detect obstacles directly in front of the robot. This was problematic because when the RF sensor failed to indicate the RF strip, the robot was unable to know that it needed to turn around in order to egress from the tunnel. We had not considered this to be a problem because, due to a misinterpretation of the rules (described below), we had assumed that it was ok to rely on the RF sensor to detect the end of the tunnel. While the RF sensor should have detected the end of the tunnel, the ultrasonic sensors should have been relied on for the primary perception of the robot's environment.

Misinterpretation of the Rules
The team did experience some confusion concerning the rules. It was thought that the RF strip at the end of the tunnel was meant to signal when a U-turn should be made, not simply indicate that the robot should still search for the end of the tunnel or ignore it completely. Only in discussing things with the other groups shortly before the start of the competition was it realized that the robot should use obstacle avoidance sensing to detect the end of the tunnel. For this reason the robot relied on detection of the RF strip to make its U-turn. Given the imperfect nature of the RF detection, this led to a disqualification in the competition, as a missed RF detection made for the lack of a U-turn. However, the robot was able to demonstrate that it could easily reach the end of the tunnel and return in future runs.

This problem could have been easily remedied, it was just the result of rule misinterpretation.

Turning
While not a barrier to completing the given task, the robot did spend too much time in a "turn mode" at the cost of performance. Rather than proceeding straight ahead, the robot spent much of its time weaving, even in open space with no walls to avoid. This was likely due to an ill-tuned algorithm. In a sense though, this may have hidden the ultrasonic sensor placement because the robot's over-turning masked its inability to sense obstacles directly in front of itself.

This problem likely could have been solved, but its low priority in terms of barriers to completing the task prevented this problem from receiving any attention before the competition/demonstration.