Lab 1: Wall following report.

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Data Analysis

a) Did the bang-bang controller keep the robot at a distance bandCentre from the wall? Why is it expected that the robot will oscillate from one side of the band to the other with the bang-bang and p-type controllers?

For the design of both the bang-bang and the p-type controllers our robot followed the following logic regarding its position relevant to the wall:

- The bandCentre was set to 30 cm, with a bandwidth of 3 cm. This means that the robot would not alter its course unless it was at a distance of less than 27 cm from the wall or greater than 33 cm. We define the bandwidth area as the region between 27 cm and 33 cm.

Using this logic, the bang-bang controller constantly altered the course of the robot to keep it within the bandwidth area (27 to 33 cm from the wall). The oscillating pattern results from the fact that the robot makes no corrections when it is inside the bandwidth area, only when it is outside. This meant that the robot would typically go through the bandwidth area in a diagonal trajectory, which would then require another correction that would put it in zig-zag pattern.

In other words, the robot oscillated form one side of the band to the other because the bang-bang controller only corrected its motion once it was outside of the bandwidth area.

The same behaviour was observed when using the p-type controller, however, the robot made adjustments by increasing and decreasing the speed of the wheels by a quantity that was proportional to the size of the error (the distance from the band centre). Thus, the the motion was a lot smoother, but we could still see the zig-zag movement pattern.

Observations and Conclusion

Throughout our experimentation we noticed that the ultrasonic sensor would regularly detect false negatives; it would suddenly register the current distance as a very large number even if it had an object no more than 30 cm in front of it. This would cause our correction algorithm to suddenly increase the speed of the right wheel significantly in an attempt to bring the robot closer to the wall represented by the false negative.

This was a significant problem, specially for the p-type controller because the increase in speed is proportional to the size of the error (the measured distance from the band centre). A false negative of 255 cm (the typical false negative distance detected) would result in an enormous acceleration of the right wheel, which made it difficult for the robot to correct its trajectory. The same problem was present for the bang-bang controller, but since the speed increases are always done by a fixed amount the problems was not as severe.

In order to fix the issue of false negatives we implemented the following modifications:

- Implemented a filter algorithm for both controllers that was set to ignore distances equal to 255 cm unless they occurred more than 20 times successively. In order to do this we keep a counter that tabulates the amount of times a distance of 255 is recorded by the ultrasonic sensor. This is particularly useful for eliminating false negatives, but also to avoid gaps in the course and take left turns - the sensor would simply ignore the gap unless it was of a length that allowed it to record 255 cm as the distance 20 times.

- In the case of the p-type controller, we put a limit on the maximum speed that the right wheel could accept to prevent the robot from accelerating out of control in case the filter failed to catch a false negative.

Further improvements

1. **Mount the ultrasonic sensor on a motor to control its position relative to the movement of the robot.**

The current implementation of our robot fixed the sensor such that it looked at an angle of 45 degrees from the direction of the wheels (see figure 1 below). This allows the robot to anticipate corners so that it can successfully execute right turns. If we were to mount the sensor on a motor, then we would be able to control its position relative to the wall by having another thread adjust the angle of rotation based on the speed of the wheels. This adjustments would enable us to eliminate the zig-zag pattern that the robot follows by adjusting its trajectory to a straight line once its within the bandwidth area.

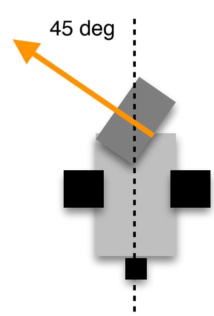

Figure 1. Sensor position on the robot. Orange arrow indicates the orientation of the sensor.

2. Use a second ultrasonic sensor to anticipate obstacles directly ahead of the robot.

A second ultrasonic sensor would allow the robot to perform better right turns when there are obstacles directly ahead it.

In the current implementation, the robot basically depends on the 45 degree angle of the ultrasonic sensor to detect concave corners. This results in successful, but the robot tends to get very close to the wall before detecting that it has to start turning, which is not the optimal scenario. A second sensor would allow us to considerably improve this motion by knowing exactly when the robot is approaching a wall.

3. Implement a gap detection algorithm to properly identify gaps in the course.

Gap detection in our implementation resulted from the combination of two factors: the position of the sensor and the false negative filter. The angled sensor allowed the robot to ignore the presence of a gap by giving it the capacity to look at obstacles ahead of its trajectory; the robot initially turns left in the presence of a gap, but then the sensor detects the wall immediately after the gap and corrects its trajectory.

The filter tells the robot to ignore distances equal to 255 cm unless they occur 20 times successively. This allows the robot to ignore the sudden increase in the distance caused by a gap for about 1 second, which is typically enough time to overcome it.

Although this combination of factors allows the robot to clear most gaps, there are still certain cases that it is not able to overcome. For example, gaps that are longer than the usual length. For this scenario it would be better to implement an algorithm that keeps the robot in a steady trajectory for a certain amount of time before relying on the measurements of the ultrasonic sensor, rather than hope that the filter will give the robot enough time to cross over a gap.