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MOBILE ROBOTS - Laboratory 3

Reports 1 and 2

Premise

Unfortunately, we have no specifications on the sensor range. However, we experimentally assume that the sensor can roughly detect magnetic fields at +- 170mm of distance. This conclusion was drawn by running the “*line1magnet*” experiment. In fact, when a measurement is taken, at least 4 couples of magnets are detected (*Figure 1*). That implies a magnet couple at roughly the same position of the sensors, one at ±55mm, one at ±110mm, one at ±165mm.
These considerations started to get us thinking about how to approach and answer the issues in this lab.

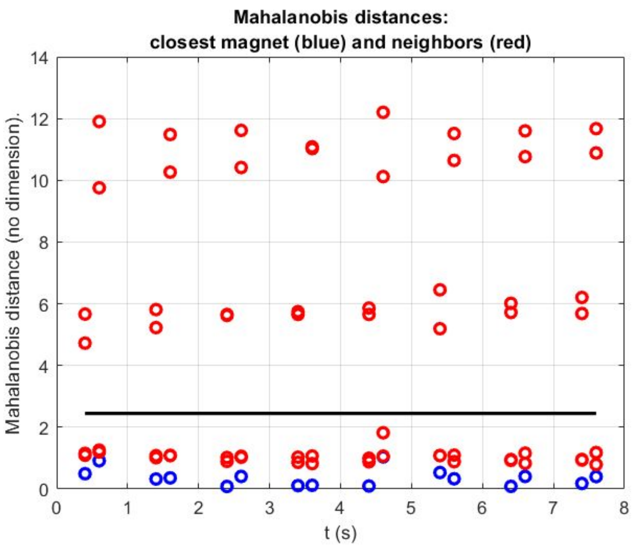

Figure 1

PART 1

- **Point 1** Starting with the "*line1magnet*", and by multiplying the X measurement uncertainty by a factor of 10, we increase the uncertainty of the ellipse on the X measurement direction. This forces the uncertainty ellipse to "enlarge" or "elongate" over the X direction. This means that the overall measurement vector does not allow to distinguish among the magnets on the x-direction, while it is able to determine the correct closest magnet on the y-direction. As a result, another couple of magnets (one in front and one in the back) has a Mahalanobis distance below the threshold, as we can see in *Figure 1*, and is therefore considered to be correct. We can deduce the uncertainty ellipse to be at least 55mm (as it can capture the next magnet-set from the measurement) but smaller than 110mm as the 2nd magnet couple is above the Mahalanobis threshold. Lastly, we need to point out that the robot is moving on a straight line parallel to the arrangement of the magnets.

- **Point 2** As for the previous case ("*line45degrees*"), the X measurement is unreliable, and the discussion about the uncertainty ellipse still applies; the robot is once again moving on a straight line. However, in this case, we are moving along a line rotated by 45° with respect to the absolute reference frame. Therefore, in this case, the y-component of the measurement vector gives information about both the x and y-axis of the absolute reference frame, allowing to determine the correct closest magnet in both directions of the "grid". In fact, we can see that only the correct magnets are under the threshold (*Figure 2*).

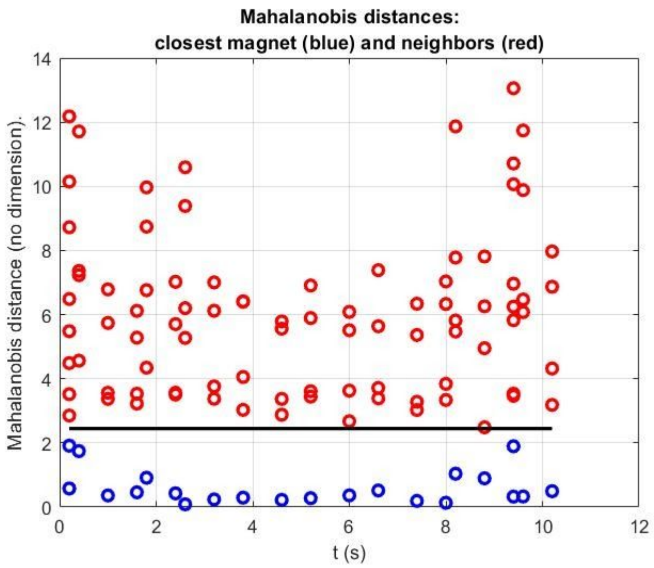

Figure 2

- **Point 3** In this last part, with the "*twoloops*", we noticed that for some positions of the robot, a greater number of red magnets are below the threshold, and we set out to discover when this happens. First of all, we see that the robot moves in a combination of straight lines and rotations. By inspection, in *Figure 3*, we saw that at around *5s*, *20s*, and *32s*, the robot only has "blue magnets" below the Mahalanobis threshold. At those times, the measurements are not "confused" and the robot can safely distinguish between magnets. By looking at the other graphs, and inspecting the robot position and motion in those time instants, we clearly see that it is moving, roughly over a diagonal straight line and it is not rotating. This clearly tells us that when the robot is rotating, the measurements are untrustworthy due to the large uncertainty component. When it is moving on a straight line, the same line of reasoning applies as in the previous point 2.

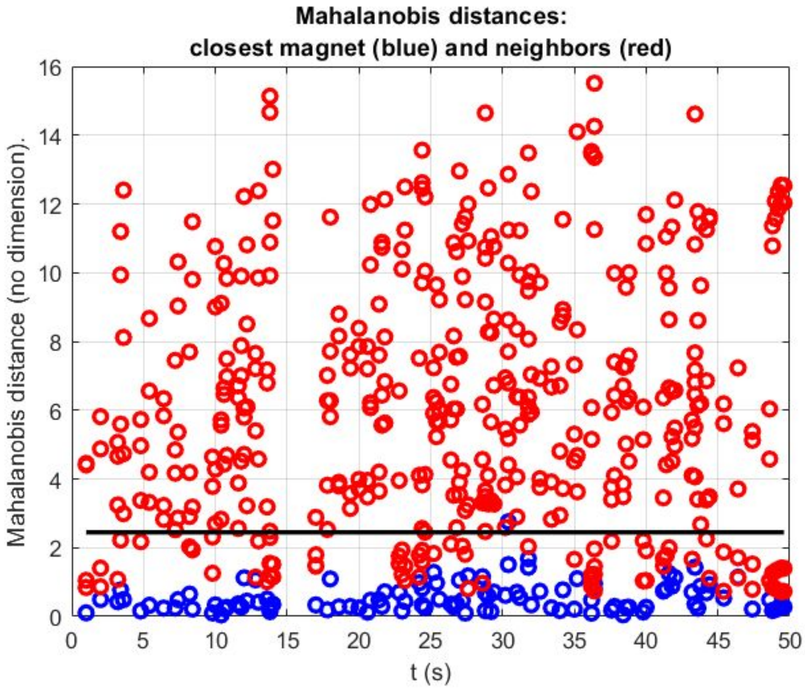

Figure 3

Brief Conclusions

In general, with high uncertainty on the X, there are problems in identifying the magnets when the robot is moving in a horizontal and vertical straight direction, as well as when it is rotating. When it is moving on a diagonal straight line, in general, it is possible to distinguish properly the magnets as there is a trustworthy Y measurement correcting the measurements and properly separating the red magnets from the blue ones.

PART 2

- **Point 1** From *Figure 4* we can notice that the uncertainty in the x-coordinate is increasing in an unbounded way. This is due to the fact that σ_x keeps increasing because of the odometry error and the high uncertainty on the X-measurement, which does not allow to reduce σ_x in the estimation phase (→low filter-gain). This means that the robot is not able to correctly localize itself along the x-axis, and the situation will become worse and worse as the robot keeps moving.

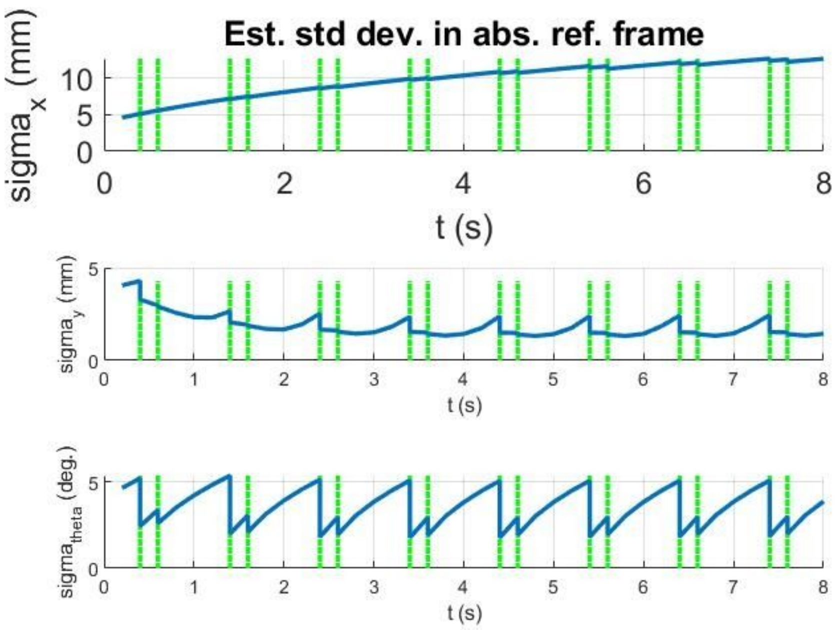

Figure 4

- **Point 2** Even though it is possible to distinguish the magnets thanks to the Y measurement, σ_x is still unsatisfactory: as for the previous case, it increases and will eventually diverge. This means that, even though in the first part of the motion (visible in the analysis) the robot is able to determine the correct magnet, we can imagine that at some point it will no longer be able to do it. The next step consists in comparing the standard deviations in the absolute reference frame (*Figure 5*) with the standard deviations in the robot reference frame (*Figure 6*). This is due to what was already discussed in part 1: in the robot reference frame, σ_y is correctly decreasing (because we trust y measurements), while in the absolute reference frame it seems that it is going to diverge, just like σ_x. This mathematical behavior is related to the transformation between the two reference frames: doing such transformation, the error on σ_x will negatively impact on the σ_y.

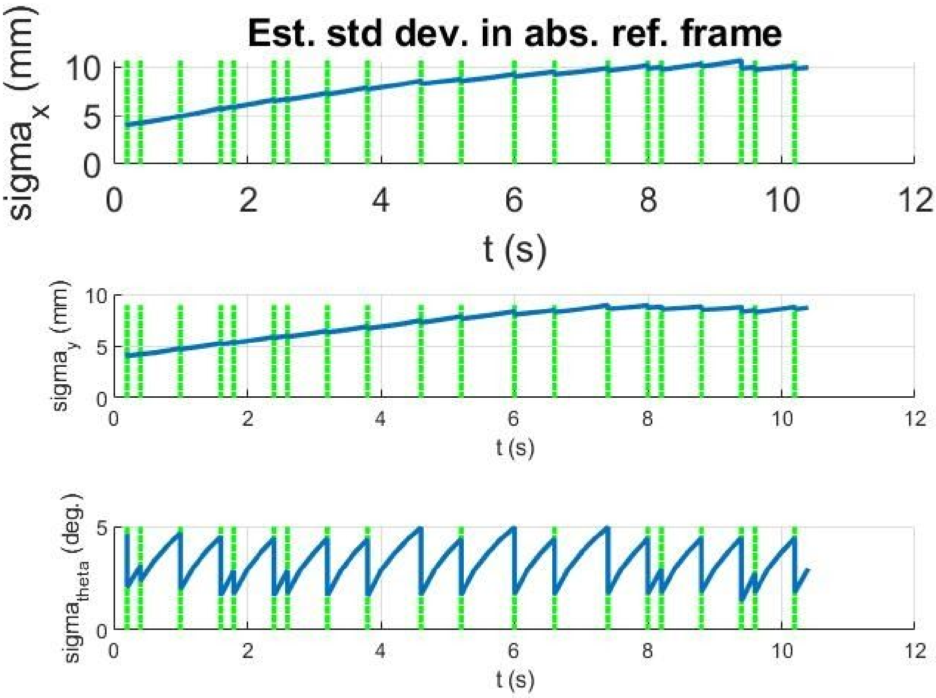

Figure 5

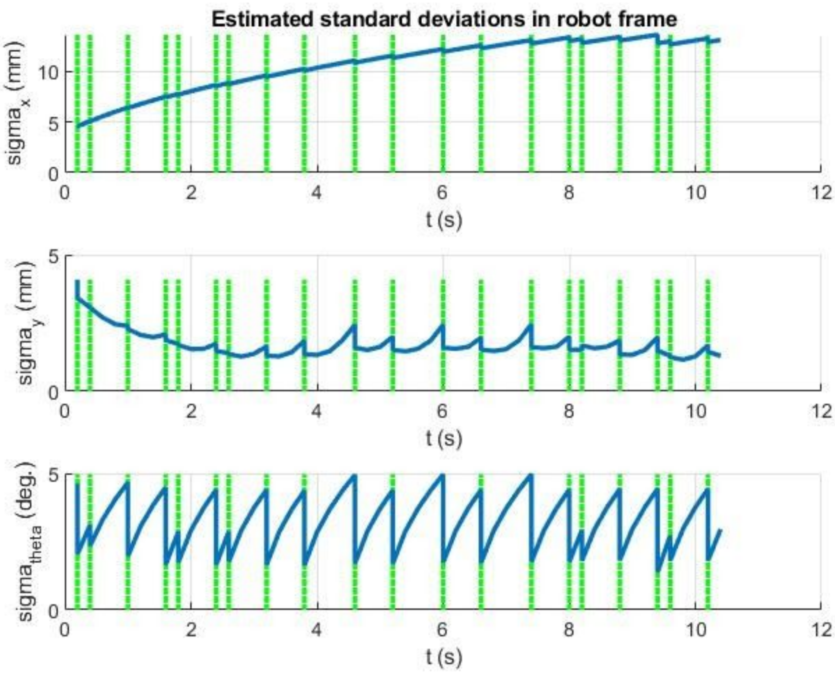

Figure 6

PART 3

In this part we compared the uncertainties evolutions for the datasets *“line1magnet”*, *“diagonal45degrees”* and *“twoloops”*. In general, when the robot moves on straight lines ($\omega = 0$), we have seen that σ_x diverges even if the magnets are correctly distinguished (*Figure 4,5,6)*. In “two loops”, instead, the robot performs rotations as well and we notice that the variance is bounded and generally decreases when the robot is rotating (even though, in this kind of motions, a larger number of neighbor magnets are under threshold and are therefore considered to be correct). Therefore, the empirical results show that when rotation speed increases, the standard deviation on the X position σ_x in general decreases, and inversely the opposite. This is why σ_x remains bounded in *“twoloops”* (there are rotations), while it tends to infinity in *“line1magnet”* and *“diagonal45degrees”* as there we have $\omega = 0$.