Localization lab and homework
Work to be done

Preparation

1. Create a folder for the lab.
2. Decompress the contents of the zip file in the folder.
3. Read the documents in the following order: the present document, then the "programs and data" document. The "Explanations about the lab" slides are fundamental to understand the equations and some parts of the code you have to provide. Remember a 2022 recording of these explanations is available in the folder where all the online lectures are.
4. Using "`ShowOdometry.m`", check the various paths corresponding to each data set. Don't forget to look at the speed data. Answer the following questions:
   a. For "loop" trajectories, the robot is brought back to (0,0). Explain why it is not the case with the path plotted by "`ShowOdometry.m`".
   b. Explain the origin of the noise in the speed and rotation speed graphs.
   Write short answers and upload the report to Aulaweb. Name the file Question4.pdf, or something like that. Make sure the file contains the names of all the group members, and their emails.

   Tip: In the sequel, you will repeatedly need to execute the following commands, in this order:
   `clear all; close all; MagnetLoc; PlotResult;`
   Type it at the command line once, as above on a single line. You then just need to recall that line using the up arrow key and hit enter. This is the simplest and fastest way to do it. Clicking on each file and the clicking on the execution button is inconvenient, and much slower.
   The "`clear all`" command is necessary because the programs use global variables in the workspace, and you want to make sure you take a fresh start each time.
   The "`close all`" command avoids having a large number of open graph windows, since PlotResults systematically opens 8 graphs.
   At some point, you may want to compare the results of two executions. In that case, use the commande line:
   `clear all; MagnetLoc; PlotResult;`
   the second time, so as not to close the windows and be able to compare graph results.
   Once these two lines are available, you pretty much never have to type any other command.
5. In this question, we do not care at all about the calculations performed by the Kalman filter. We just want to be able to run the program in order to look at some particular plots generated by "PlotResults.m". To achieve that, set all noise variances to zero in "`DefineVariances.m`" and replace the missing parts of the code by zero-valued matrices and execute the program. Depending on your Matlab version, you may get a lot of warnings from Matlab (covariance matrices are singular). Ignore them. Use figure 8 and what you know about the sensor construction to evaluate the measurement noise variance.
   Write a report with your conclusions (variances) and how you obtain them, and upload the report to Aulaweb. Do as for question 4.
6. The files "`EvolutionModel.m`" is missing (you have to write your own) and "`MagnetLoc.m`" contains missing code which you need to provide. The missing code is replaced by "***". You can use the localization book to help you in this task.
   To check your own version of "`EvolutionModel.m`", rename "`EvolutionModel.p`" so

it is not used by `ShowOdometry`, and check that you obtain the same odometry results with your own function.
Upload “`MagnetLoc.m`” in text form (this one does not need to be PDF) to Aulaweb.

7. There is another important parameter to be set: the threshold for the Mahalanobis distance (`mahaThreshold`). It is normally set by using the Matlab `chi2inv` function. You must understand what this function does and use it to determine a proper value for the threshold.
8. Once you have a measurement noise you consider reasonable, set the initial covariance matrix `Pinit`. The standard deviation `sigmaTuning` is now your tuning parameter. If the measurement noise value and initial covariance matrix have been properly set, you should be able to find a proper value for `sigmaTuning`.
Upload a report showing your methodology of tuning and results that prove that it works. The report should also contain an analysis of the results on each test. So the report here is a bit longer and has to be done with a word processor, as you will have to include some graphs.

Report

There is no report to this lab apart from the progress reports mentioned above. A specific part of the exam will evaluate your comprehension of the material. The suggested homework below will help you prepare. If you have any difficulty or question, do not hesitate to ask questions by email or ask for an appointment.

Suggested preparatory homework:

- Make sure the dimensions (number of lines and columns) of each vector and matrix is clear to you. Once the equations of any Kalman filter are given, you should be able to determine said dimensions very rapidly.
- Starting with a correctly tuned filter, test the effects of over-estimating (resp. under-estimating) each of the following parameters and make sure you understand and can explain what happens. In particular, analyze how the term $CPC^t+Q\gamma$ evolves, and how it helps understand the behavior of the Kalman filter.
    - Initial robot position variance.
    - Measurement noise variance.
    - The same test with `sigmaTuning` should be done and understood during the tuning part of the lab.
- Assuming only the `y` measurement of the magnet is used (say the designer of the program did not realize the `x` is also measured):
    - List all variables/parameters that must be changed in the program.
    - Should `sigmaTuning` be changed? Why? Make sure it is clear to you.
    - It’s possible and fast to modify MagnetLoc.m accordingly, but modifying PlotResults.m to suit this new version is a bit more involved and not required for an adequate preparation.