Project 1

Instructions

- You need to mark which question you are answering clearly.
- You need to clearly explain all the steps of your solution for this project, including any code you wrote or any code you referenced.
- This is an individual project.
- GenAI tools can be used for coding, but not for writing the report.
- Submission is a single PDF file in Camino, but make sure you keep your code if the instructor would like to check it out.

Project Description

In the class, we recorded several robot trajectories. We will be working with these trajectories for this project.

You need to complete the following tasks.

A. Plot Data [10 %]

1) The first step is to understand the data provided. Prepare plots, include them in your report, and provide a description of what the plots show. [5%]
2) Identify points of interest in your plots and explain how you selected the points of interest. [5%]

B. Dynamic Movement Primitives [20%]

Select a trajectory (from the recorded trajectories) that you believe is a good one. Focus on the part of the trajectory that is between the pick and place of the object and ignore the remaining trajectory.

There are several implementations of DMPs available on GitHub and other code-sharing websites. There is a recent GitHub link that summarizes several implementations: https://github.com/robotic-vision-lab/Awesome-Movement-Primitives.

Based on your comfort level with programming languages, select one implementation, understand the code, and run it for the chosen trajectory. Show the following:

1) The link to the package you decided to use and screenshots from your computer show that you run the code and the DMP output. Make sure you explain the output. [10%]
2) Provide three different initial and target positions for your object and plot the DMP output for the new initial conditions. Make sure you explain your plots. [10 %]

C. Trajectory alignment [20%]

1) Apply DTW by selecting the two demonstrated complete trajectories that are the most similar. Provide the DTW library you implemented, screenshots of your results, and an explanation of which demonstrated trajectories were selected and why. [10%]
2) Identify a method for aligning multiple demonstrated trajectories or develop your own method for aligning demonstrated trajectories. Explain the method you used/developed in a mathematical way and provide screenshots of the code and the results. [10%]

D. Gaussian Mixture Model/Gaussian Mixture Regression [30%]

1) Apply GMM/GMR in your aligned data from Problem C.2. Provide details of the package you used and plots of your results. [10%]
2) Identify a method that will find the optimal number of Gaussians. You can use an already available method (e.g., BIC or https://github.com/penn-figueroa-lab/phys_gmm_python) or develop your own. Explain the method you used/developed in a mathematical way, and provide screenshots of the code, and plot the results. [10%]
3) Investigate whether GMM/GMR is better for piecewise or complete trajectories. Show your results from the piecewise trajectories vs the complete trajectories. Explain which approach is better and why. [10%]

E. Adaptation to new environments [20%]

Identify a method or develop your own method that can generate a trajectory that has different picking and placing positions of your object and avoid obstacles. Explain the method you used/developed in a mathematical way and provide screenshots of the code and the results for 3 different cases of picking and placing the position of your objects, and 1 case that includes obstacle avoidance. Discuss the limitations of your approach.

Note: You may consider working on adapting the GMM or adjusting the GMR for Problem E.