Homework/Project 4: Path Following Model

Due Date and Place: Please check the syllabus and Carmen for submission deadline (online submission in Carmen)

Philosophy: Learning by doing, also called experiential learning, is a proven and effective method of teaching. It is expected that students taking the course will master path planning, tuning a path tracking controller and the lateral direction automation and control unit topics like path following modelling, designing paths to be followed by the controller and manipulating the given Simulink models and using m-file programming for emergency lane maneuver.

Related Unit: Unit 6

Homework/Project Aims: The aims are to apply the methods learned in Unit 6 on lateral automation/control, to conduct a simulation study using the given path following model, study the impact of velocity and preview length and to design the lane maneuver for tracking. Model data to be used is provided. The equations required to write the script are present in the Unit 6 lectures.

Project Background: You will be using your first path following model by working with the given Simulink model that does a double lane change maneuver. You can later change the path model to a clothoid or polynomials and change the controller with more detailed ones like MPC, sliding mode control etc.

Format: Prepare your report using powerpoint. You should have a cover page and a final page. Please use the provided template. Convert your powerpoint report to pdf before submitting online. Cut and paste any Simulink diagrams and Matlab m files into your report. Also add your Matlab and Simulink files with an explanation of how to use them in a readme.txt file. Submit two files in Carmen: your pdf report and a zip file containing your Matlab/Simulink and readme.txt files.

Software: Matlab and Simulink will be used in this homework assignment. .

Homework/Project Statement:

Consider the given Simulink and Matlab m-file path following model of a mid-sized passenger vehicle. The following m files are provided for the simulation:

1. Path_following_SS.m – Includes Vehicle parameters & State Space model parameters calculation.
2. Bezier_curve.m – A function for obtaining the X & Y points by fitting a Bezier curve given the control points.
3. Double_lane_change_bezier_func_mcode_v2.m: This has the calculation of the double lane change path using Bezier curves. This provides the Road curvature (rho) as the output of the mfile.
4. Path_following_model_w_dbl_lane_change.slx: This is the path following model with the State space vehicle model, PID controller, trajectory calculation, road curvature input.
5. Path_following_sim_file.m: This is the file that will simulate the Simulink model after executing the m files above. This file will also plot the results.

All vehicle parameters have been provided within the Matlab m-files in parameter assignments. Please contact your TA for any clarification of parameter/values you may need.

Controller Tuning

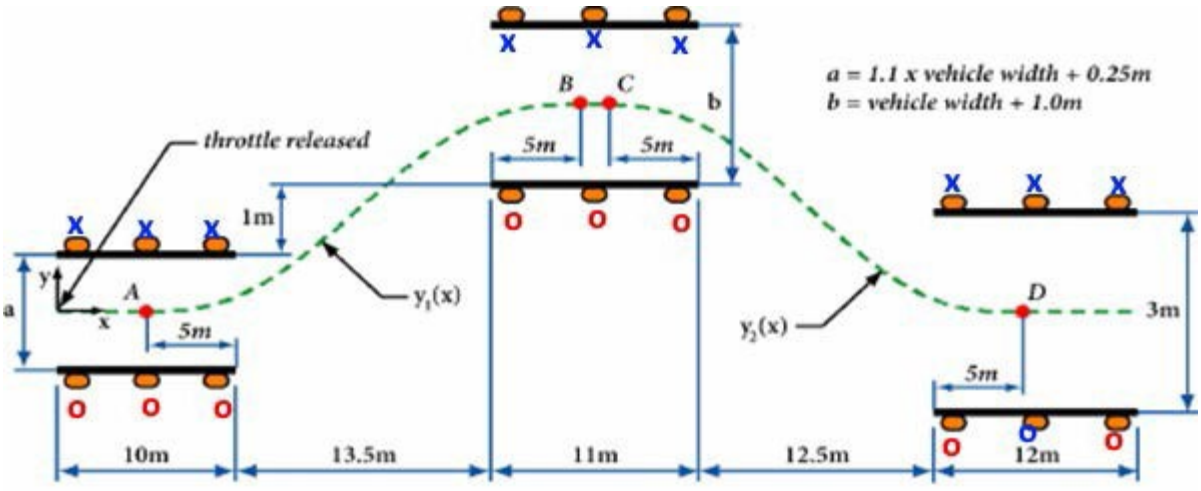
- Consider the path following model for a double lane change maneuver that is provided, with the controller. The controller is not tuned (very slow). Tune the PID controller that is present in the model to follow the path more accurately. *(20 points)*
  - You need to create a Simulink file with the controller and the plant model blocks alone to tune the controller. You can use the reference parameters for controller tuning as a desired bandwidth of 10 rad/s and a desired phase margin of 60°. (You can set these parameters in the PID tune block).
  - You are free to refine your controller parameters depending on your path following performance.
  - You can set other parameters as given below
    - Velocity of the vehicle (V) = 5 m/s
    - Preview length (l_s) = 2 m
- For the tuned controller, change the velocity to 1,10,20 & 40m/s (with l_s = 2m) and simulate with input road curvature as "Both pulse" given in the Pulse input block. Plot Steering angle, road curvature disturbance and error. Comment on these plots. (*15 points*)
- For the tuned controller, for V = 20 m/s, change l_s = 2,5,10,20,40 m and simulate with input road curvature as "Both pulse" given in the Pulse input block. Plot Steering angle, road curvature disturbance and error. Comment on these plots. (*15 points*)

Simulate Double lane change maneuver

- After tuning the controller, Use those values in the model for the double lane change maneuver and simulate the model, for V=5m/s and l_s =2m.
- You can see that the path is not being followed. In order for the vehicle to follow the path, the road curvature has to be smooth. To make the curvature smooth, modify the lower bound array points in the Bezier curve points (p_lb_pts) to make the curve smoother in the file double_lane_change_bezier_func_mcode_v2.m. Simulate the double lane change model to ensure the path is being followed. Plot the X-Y path error, steering angle, road curvature and error. Comment on your results. (*50 points*)
  - Hint:
    - The transition point of the curves (one curve ends & second curve starts) are the one that create a slope change. Changing the location will modify the slope drastically.
    - Use the slope of the road curvature as your measure to figure out the location of the points. Use diff(rho_new) command to plot the differentiation of the road curvature (a.k.a slope)

Challenge Question: Emergency Lane change maneuver (**Extra:** *25 points*)

- Create an m-file from the double lane change maneuver, and change the control points (p_lb_pts in code) to **Red 'o'** (in the picture) to reflect the ISO 3888-2 Emergency lane change maneuver.



- Fit the curve that is similar to the green dotted line. You can use any curve fit method (Bezier is one option)
- Check the X-Y points in the X-Y plot for your path shape.
- Change the Path_following_simfile.m to include your m-file corresponding to the emergency_path_maneuver, and run the model.
- Plot the X-Y path error, steering angle, road curvature and error.
- If your vehicle path has error (not able to track the reference path), try to make the curve smoother.
- Hints:
  - If your vehicle is not following the path, check the road curvature. If there are sharp changes, then the vehicle model will not be able to follow the path, and this error will accumulate for the rest of the path.
  - Check the Road curvature & slope of the road curvature (see the discontinuities, drastic slope changes).
  - If the slope changes are drastic then the path following model will not be able to follow your reference path.