Torque Vectoring Control of a Rear-Wheel Driven Hub-Motored Electric Vehicle

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Research Goals

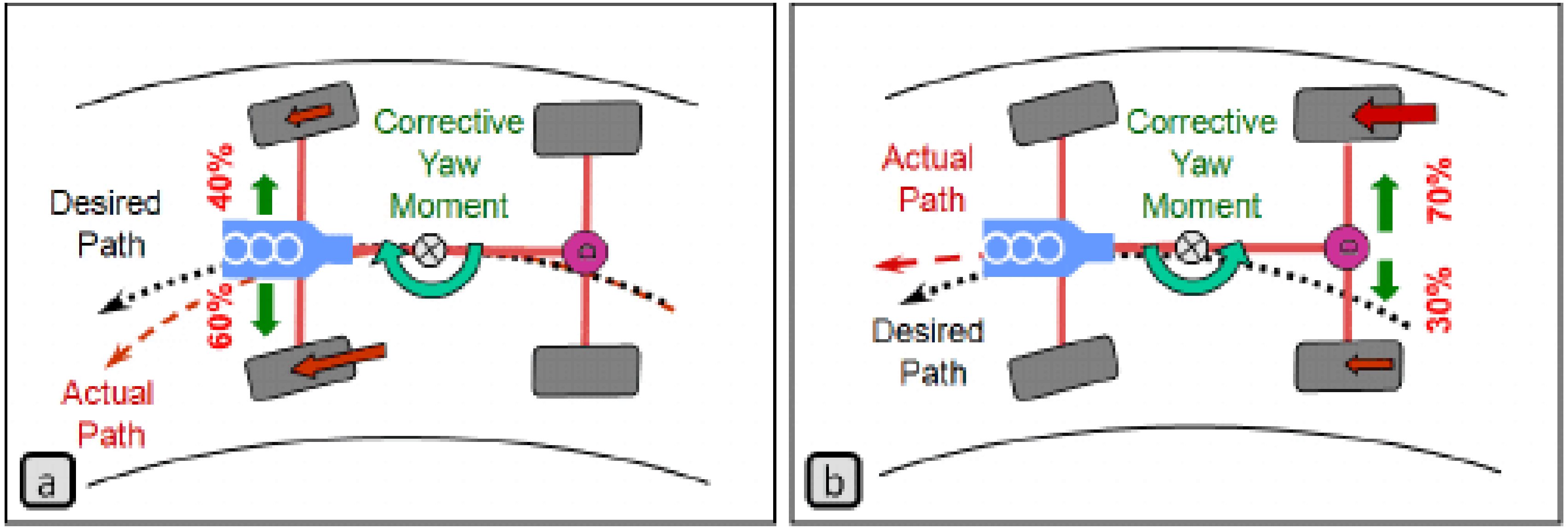
- Develop and verify an in-wheel motored rear-wheel driven electric vehicle simulation model.
- Design a torque vectoring controller for sideslip angle and yaw rate manipulation using simulation model.
- Test designed controller on the simulation environment for different cases.
- Implement designed controller on the vehicle and prove its effectiveness with real-life experiments.

Presentation Contents

- Research topic
- Description of the problem
- Simulations with MATLAB/Simulink
- Real-life experiments and verification

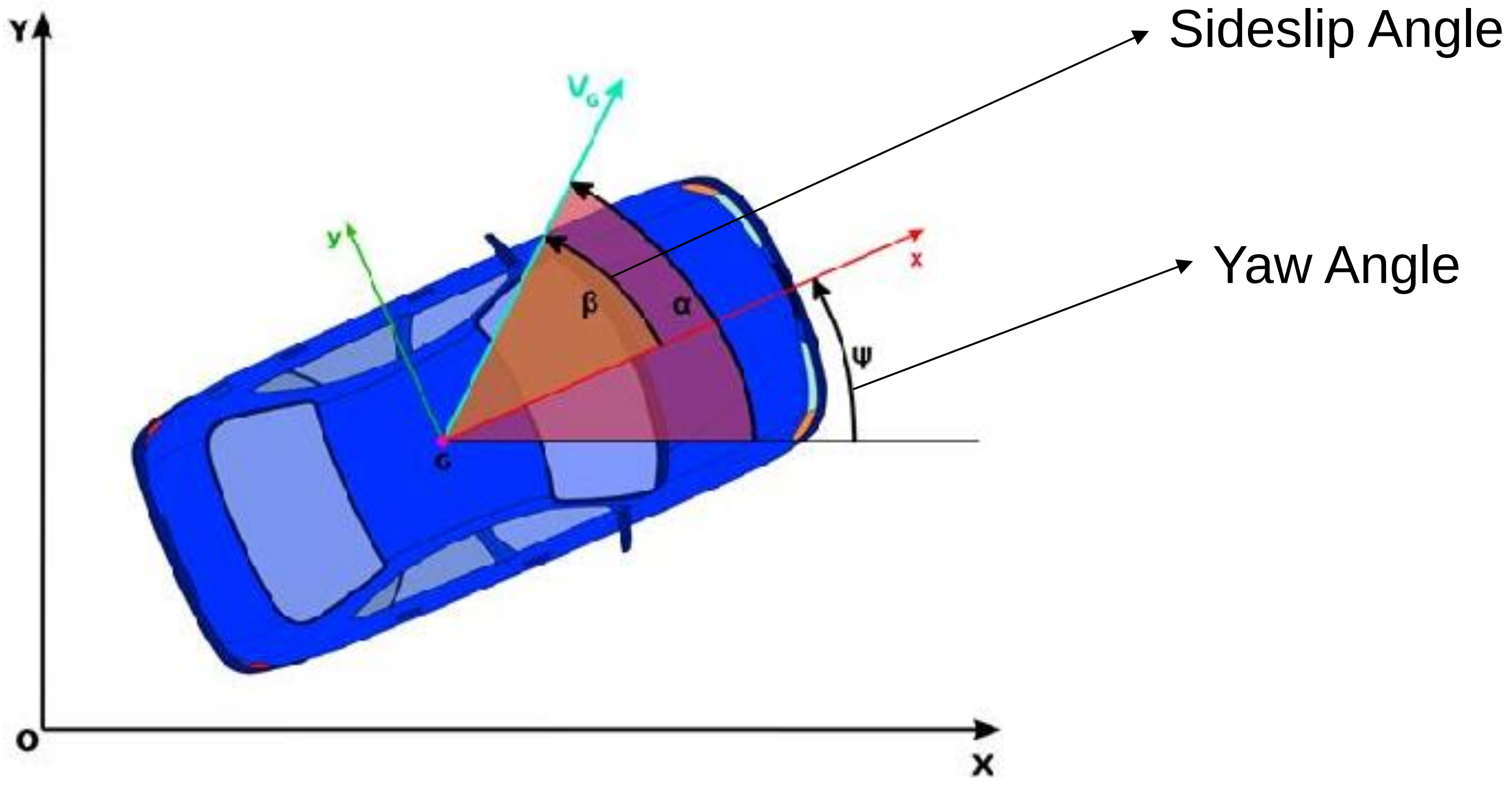
Torque Vectoring

- Torque vectoring is a technique to manipulate cornering performance and lateral stability of a vehicle.
- Torque vectoring is achieved with torque differentiation between tires of the vehicle.



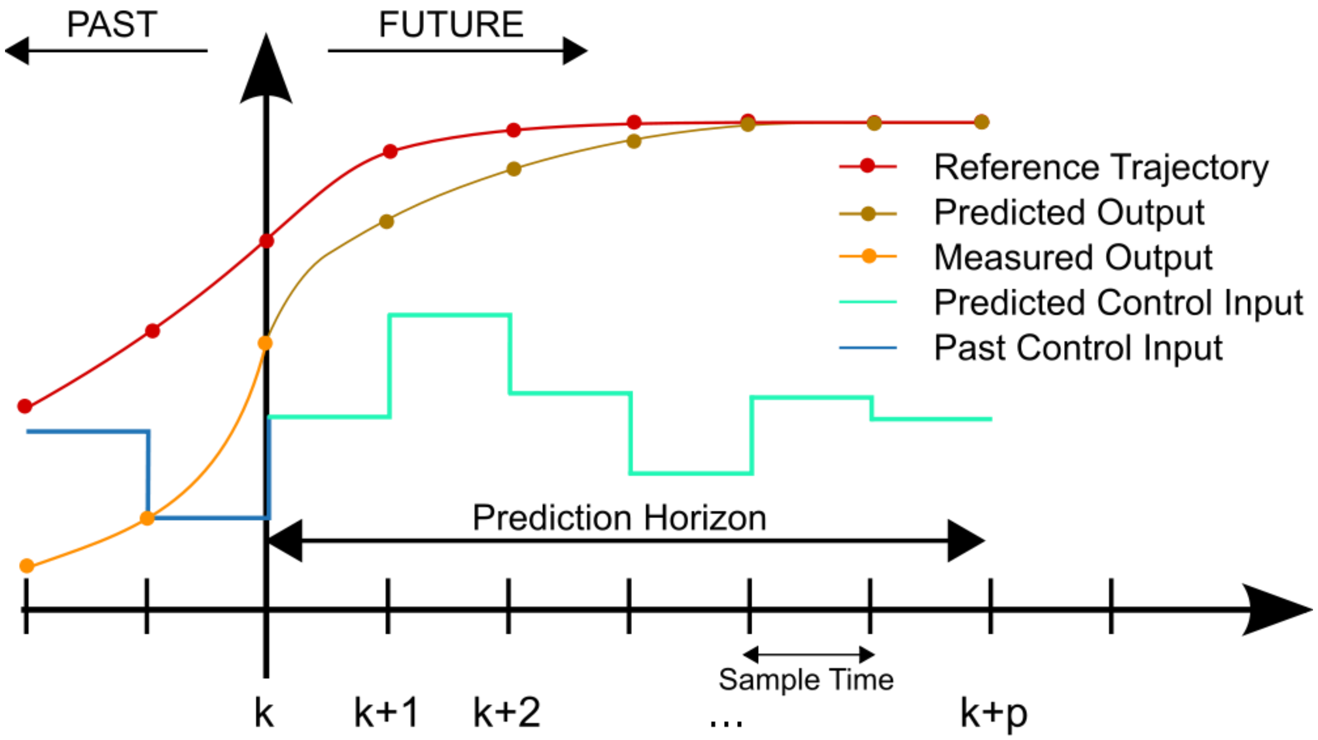
Sideslip Angle and Yaw Rate

- Sideslip angle is the angle between heading direction and actual velocity vector of the vehicle.
- Yaw angle is the angle between heading direction of the vehicle and global X axis.



Model Predictive Control

- MPC (Model Predictive Control) method is selected for torque vectoring of the vehicle.
- In MPC method, a mathematical simulation model is used to simulate future responses of the system. Depending on this simulation results, optimum control input is calculated and applied to the system.



Model Predictive Control

- In MPC control algorithm, a cost function is generated with respect to the objectives and constraint of the system.
- For our case, what we are trying to control is yaw rate of the vehicle. Our manipulated variable is the torque difference between rear left and rear right tires. Our constraints are maximum torque capacity of the motors. Our cost to be minimized is the error between desired yaw rate and actual yaw rate.

$$\min \; J = \sum_{j=1}^{n_y} \sum_{i=1}^{p} \left\{ \frac{w_{i,j}^{y}}{s_j^{y}} \left[r_j\,(k+i|k) - y_j(k+i|k) \right] \right\}^2$$

Experiment Vehicle

- Experiment vehicle is a rear-wheel driven in-wheel motored electric vehicle designed and manufactured by us.

Experiment Vehicle

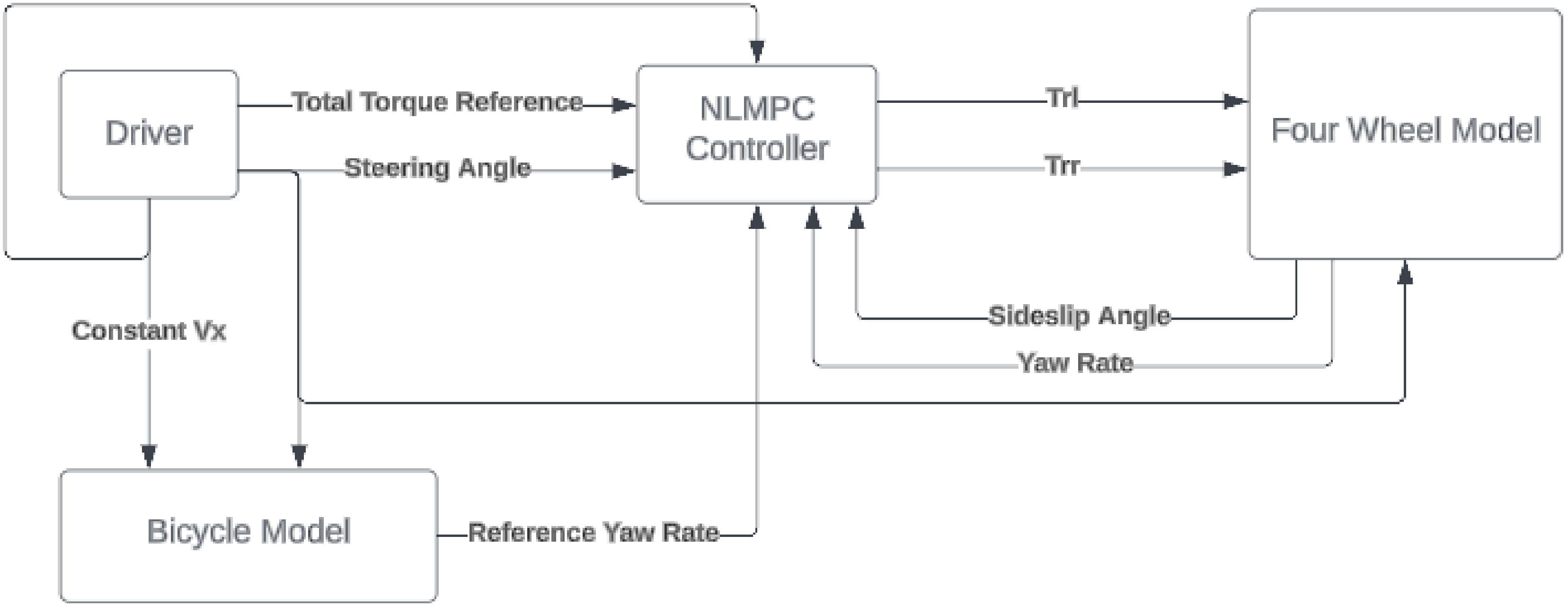
Experiments

- Different experiments are designed, simulated and executed regarding related ISO standards.

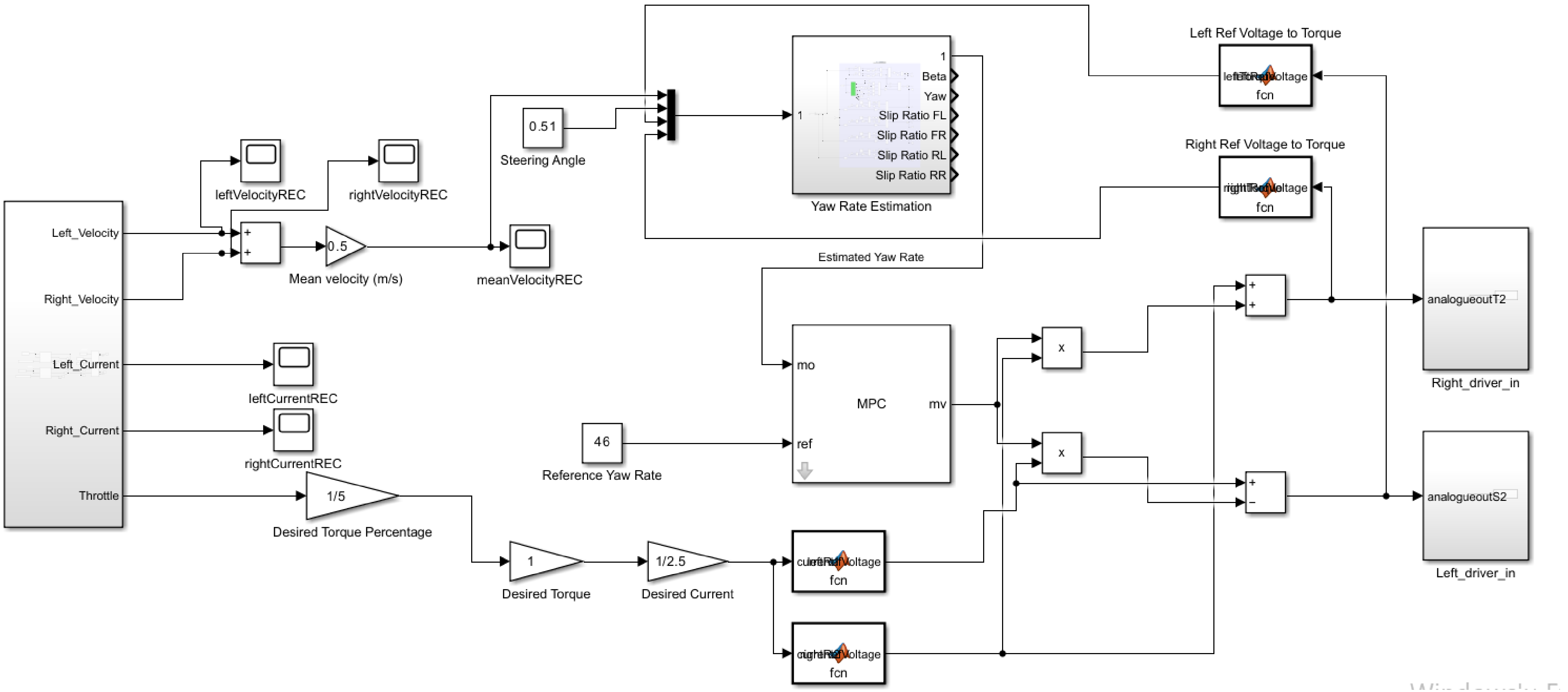
- Steady-state cornering experiment (ISO 4138) simulation and real-life experiment results are discussed in this presentation.

Simulations on MATLAB/Simulink

- Simulation model is developed in Simulink to tune the controller first.
- After that, we have evaluated performance of the controller with simulation results.

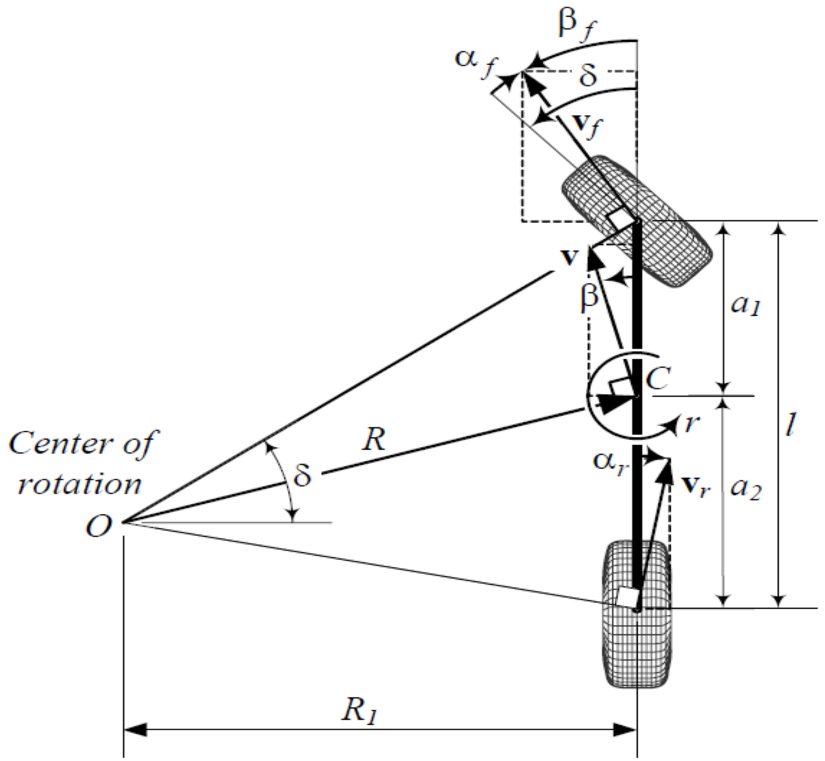


Simulations on MATLAB/Simulink



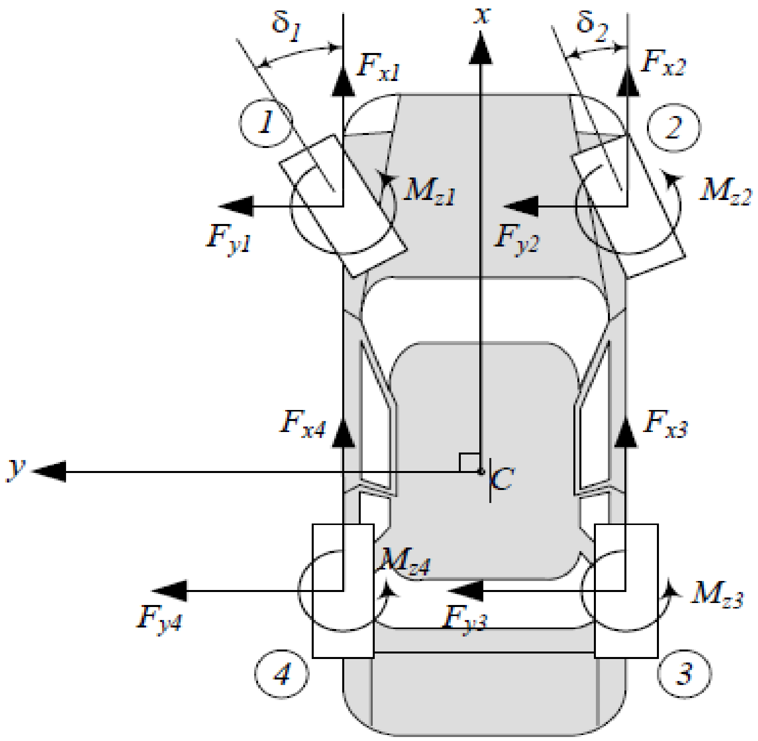
Vehicle Models: Bicycle Model

- We have developed two different vehicle models at Matlab/Simulink.
- First one is Bicycle Vehicle Model, which is a simple and ideal model for yaw rate reference generation.



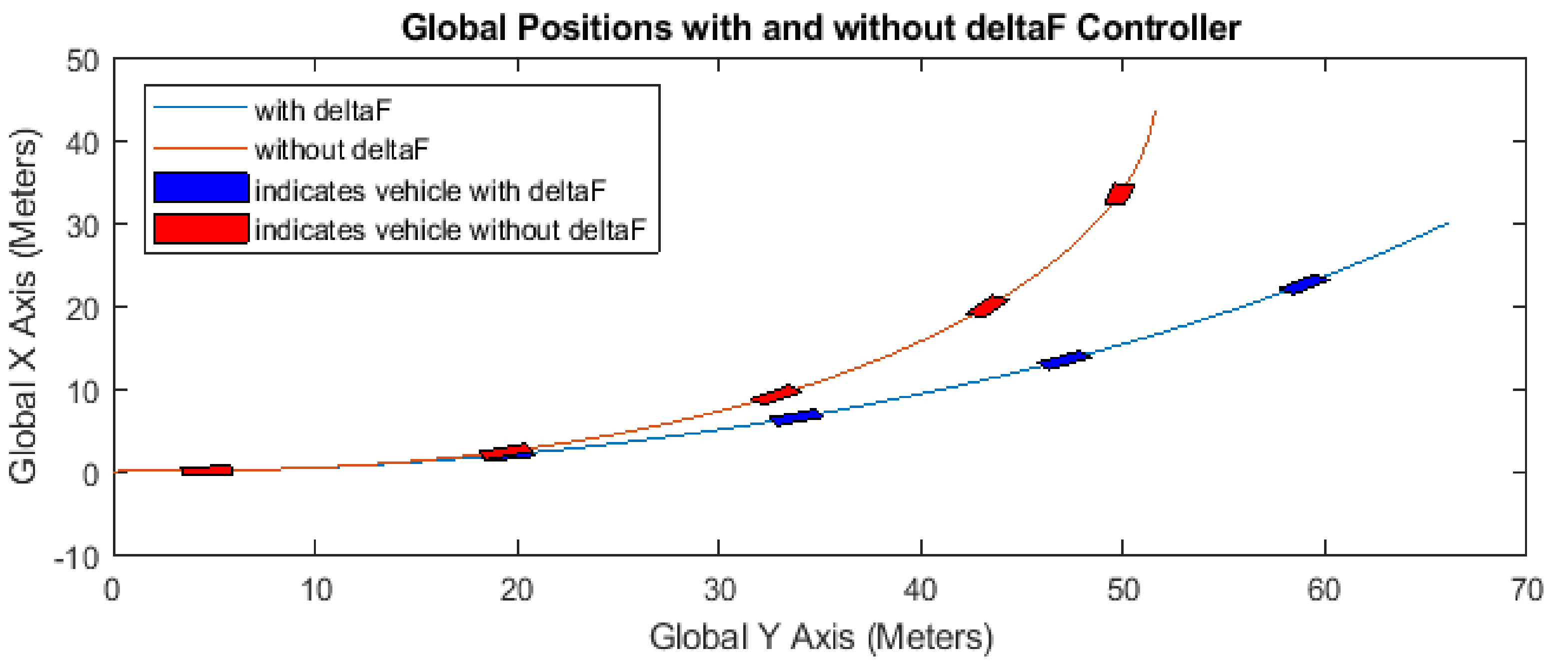
Vehicle Models: Four Wheel Model

- Second vehicle model is a more complex and realistic model which is used to make simulations on Matlab/Simulink to tune our controller and evaluate its performance in different scenarios.



Simulation Results

- Simulation results show that designed torque vectoring controller has ability to manipulate yaw rate and sideslip angle of the vehicle depending on given reference.



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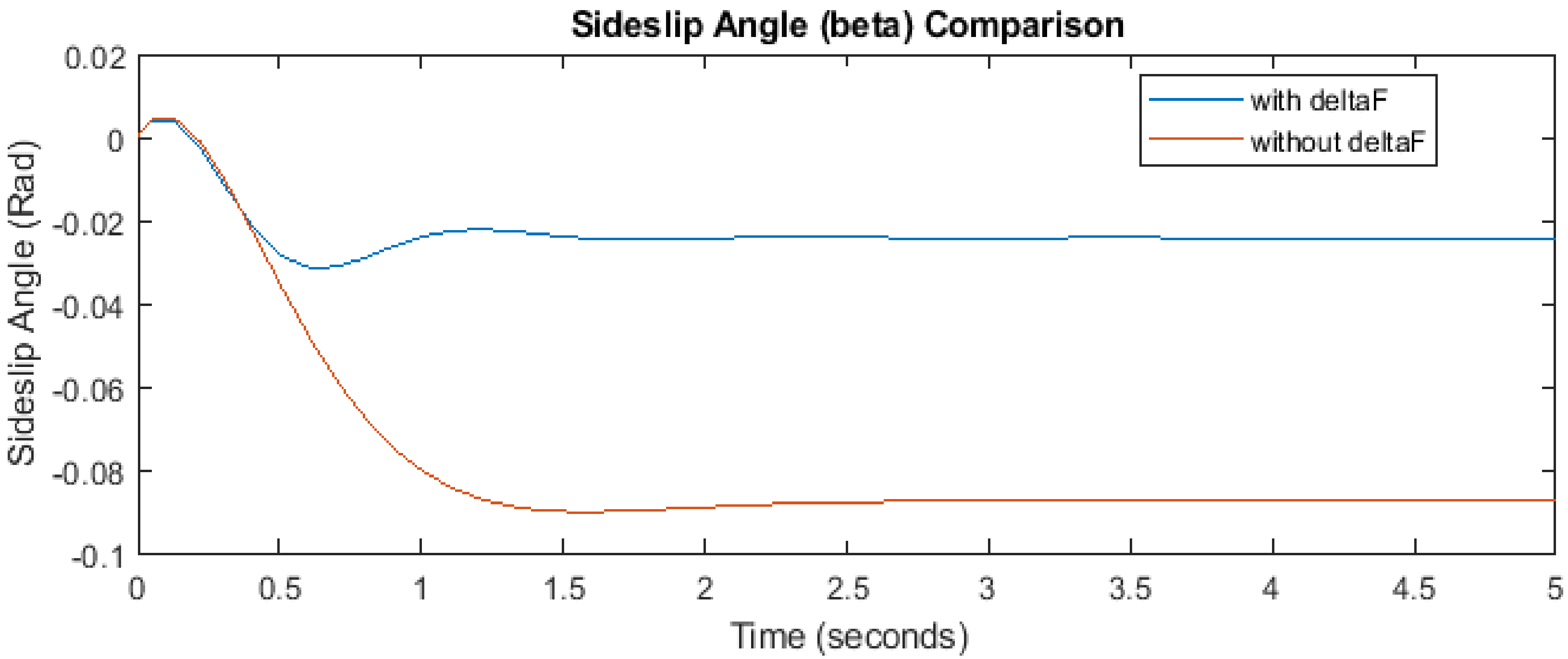
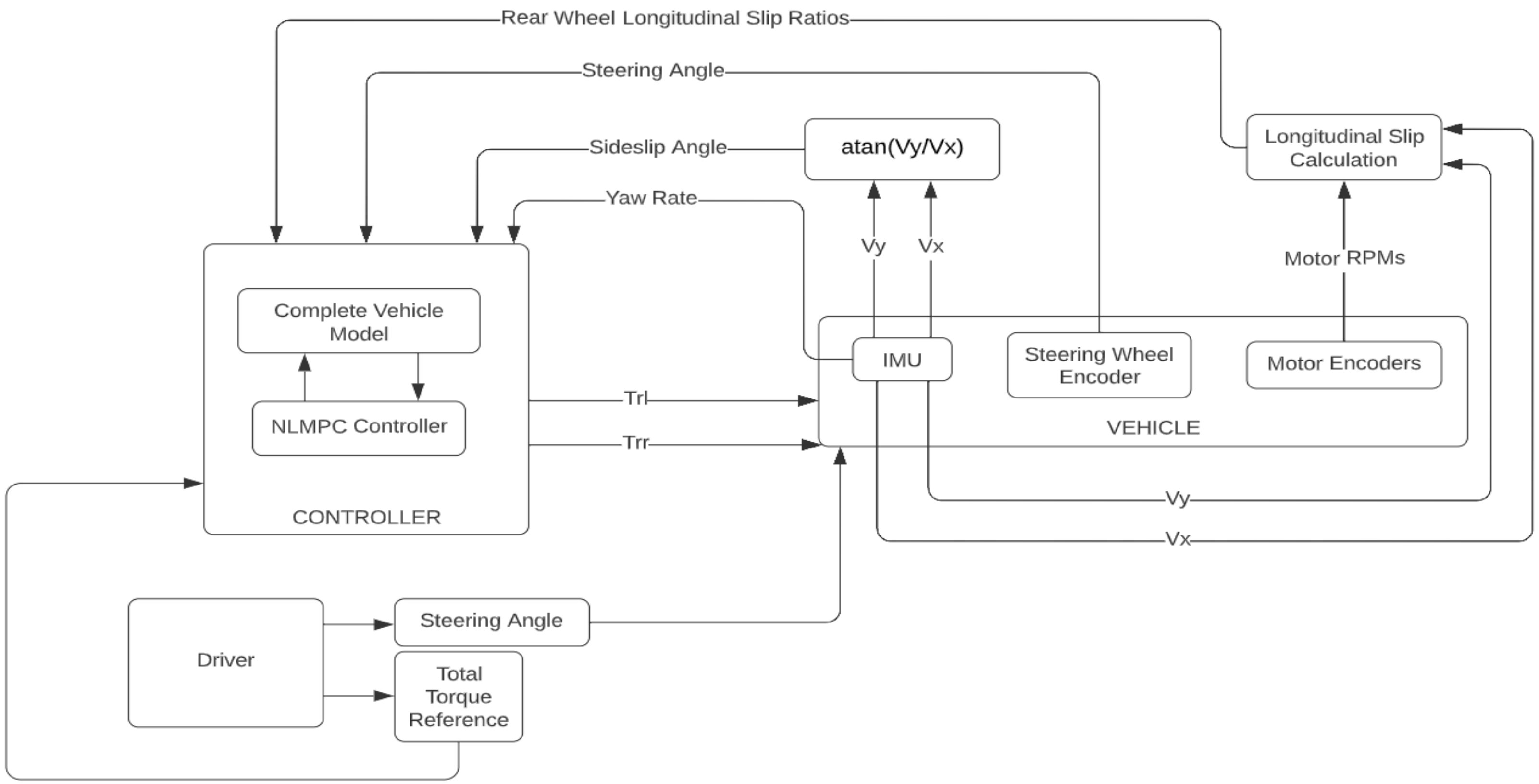
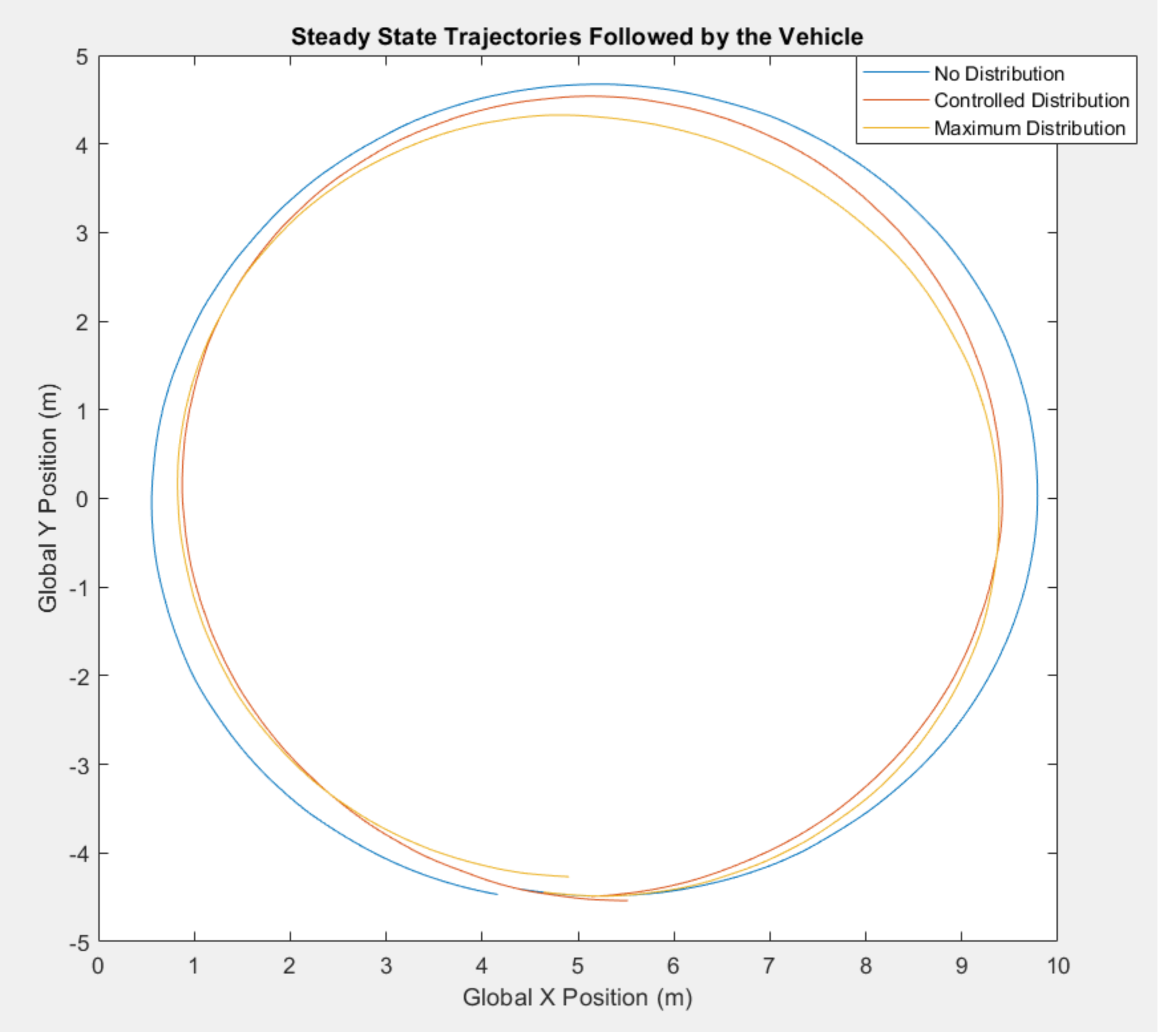


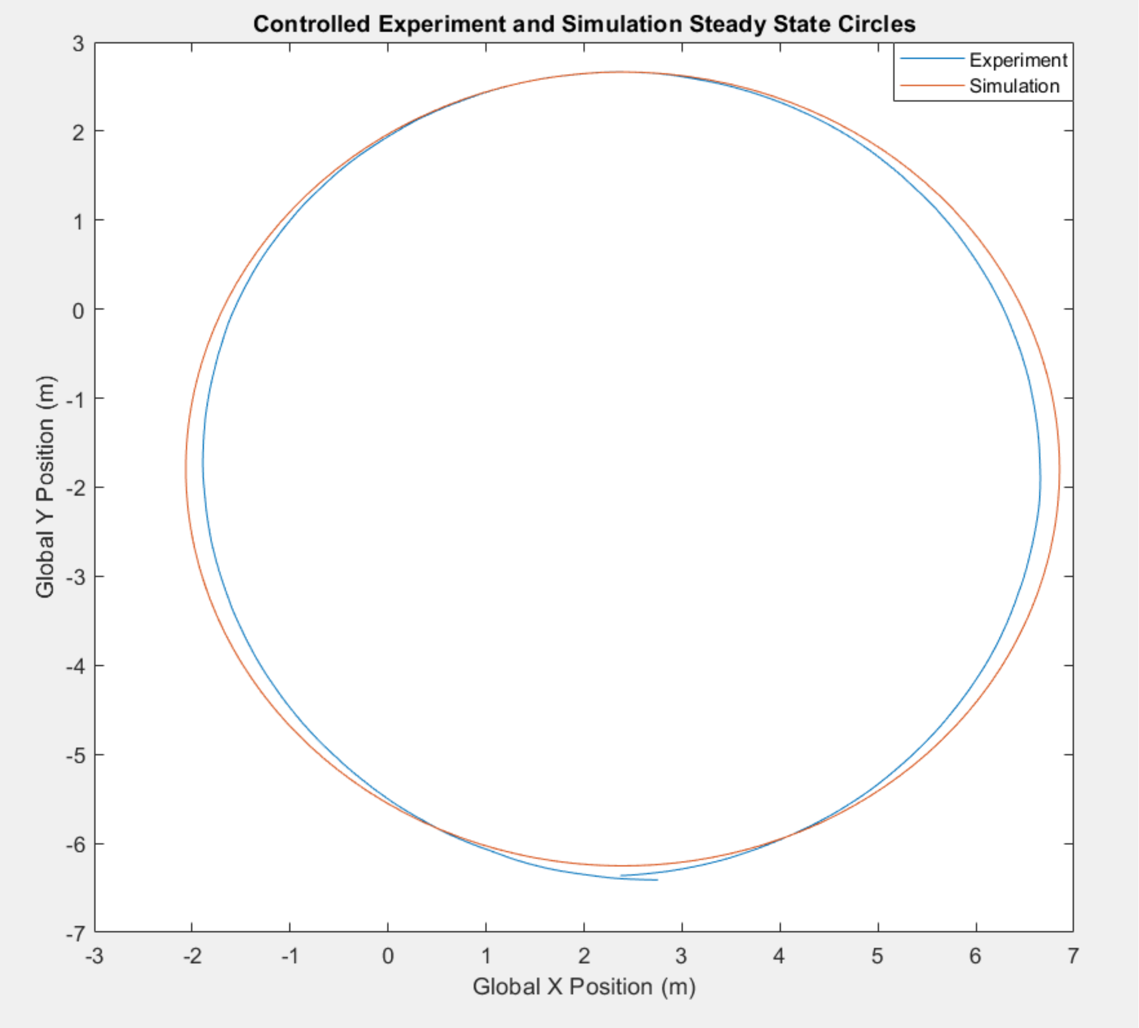
Experiment Results

- Tuned control algorithm is uploaded to the main controller hardware (MicroAutoBox 3) using Simulink for real life experiments.
- Experiments are made using related ISO 4138 standard (steady-state cornering experiments).



Experiment Results





MATLAB/Simulink Perspective of The Project

- MATLAB/Simulink allowed us to make our simulations a lot faster and easier. Without the use of Simulink, we would need to write thousands line of code for our simulations.
- Designing and tuning our controller was also easier with Simulink thanks to ready-to-use controller designing and tuning toolboxes.
- Our control hardware (MicroAutoBox 3) is programmable via Simulink with additional toolboxes, which made us easily use this hardware without the need to write every line of the firmware.

Thank you

Q&A – 5min

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