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A Terminal Sliding-Mode Based Torque Distribution Control for an Individual-Wheel-Drive Vehicle

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This is a joint research project between Jilin University and University of California, Berkeley

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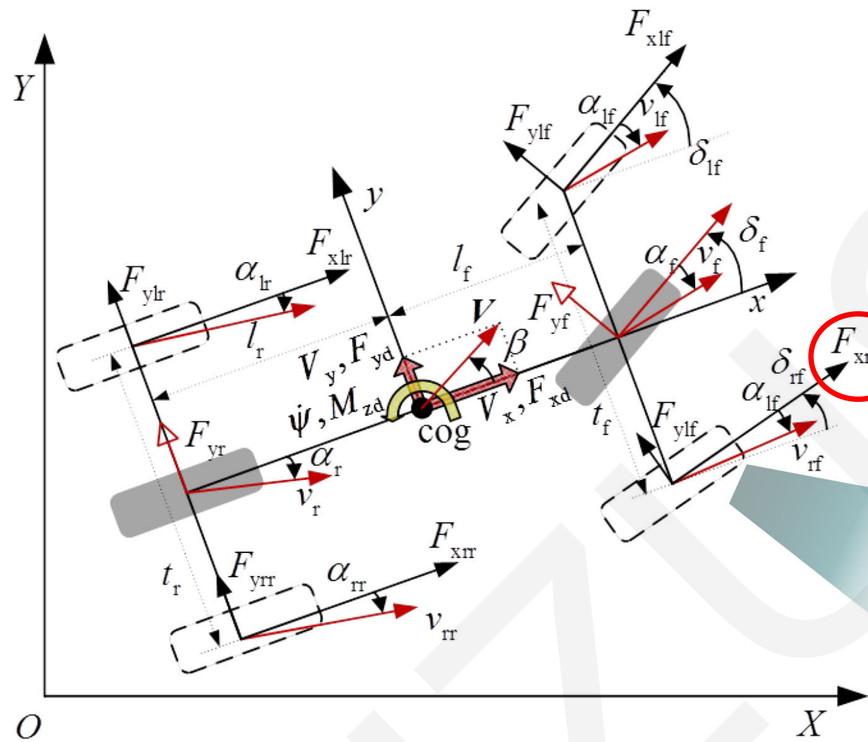
Individual-Wheel-Drive Vehicle

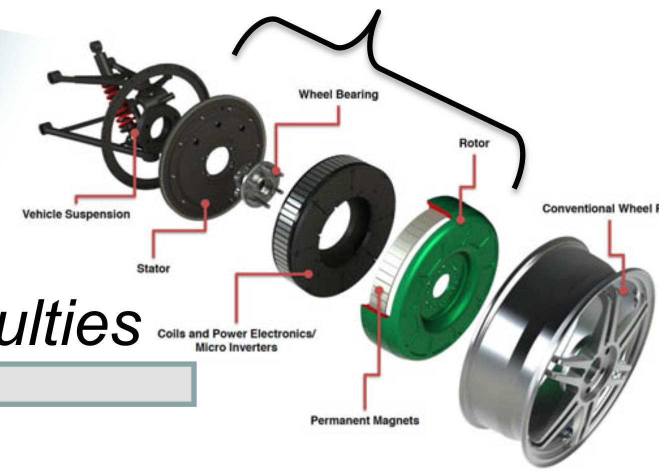


Improve **maneuverability** and **controllability** of the IWD vehicles

Merits

F_{xij} can be controlled independently

4 In-Wheel Electric Motors
Torque can be positive or negative

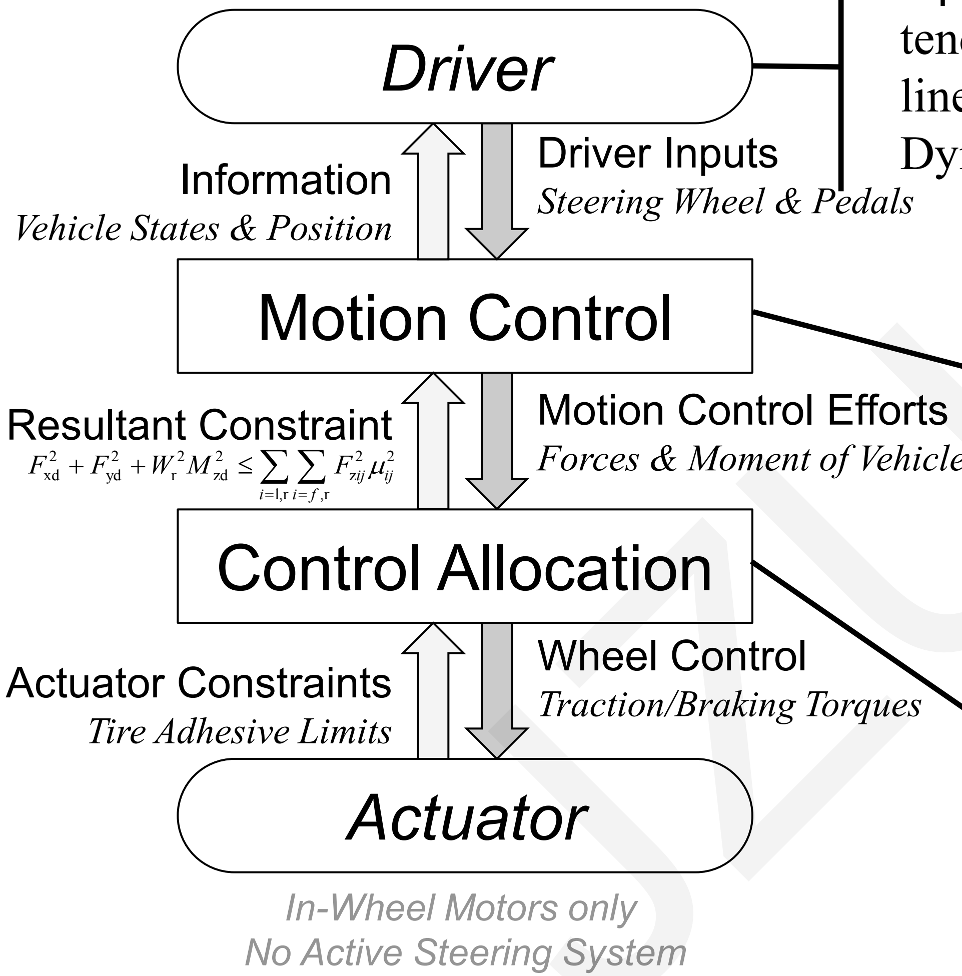


Difficulties

How to **coordinate** the individual traction and braking actions of the four wheels?

Fig. 1. Individual-Wheel-Drive Vehicle.

Global Chassis Control System



Optimal Preview Acceleration (OPA) Model tends to maneuver the vehicle according to its linear response. Guo. & Guan., Vehicle System Dynamics, 22(3-4), 141-184 (1993).

GCC task #1
where the nonlinearity of the vehicle dynamics is usually handled by Sliding Mode Control (SMC) and terminal SMC (TSMC) is a very promising technique.

GCC task #2
where optimization algorithms are used but with high computational complexity. The pseudo-inverse method is efficient but cannot consider the actuator constraints

(Result) ⇧⇩ (Target)

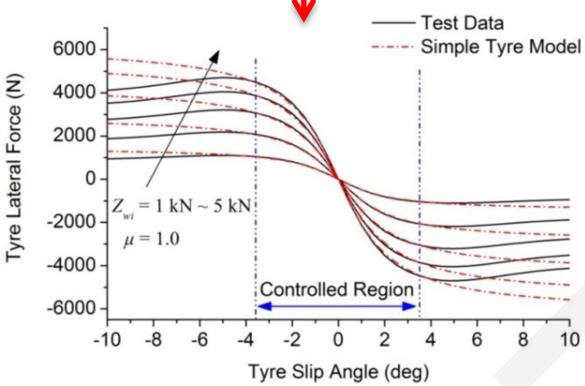
Fig. 2. Hierarchical architecture of Global Chassis Control (GCC) system.

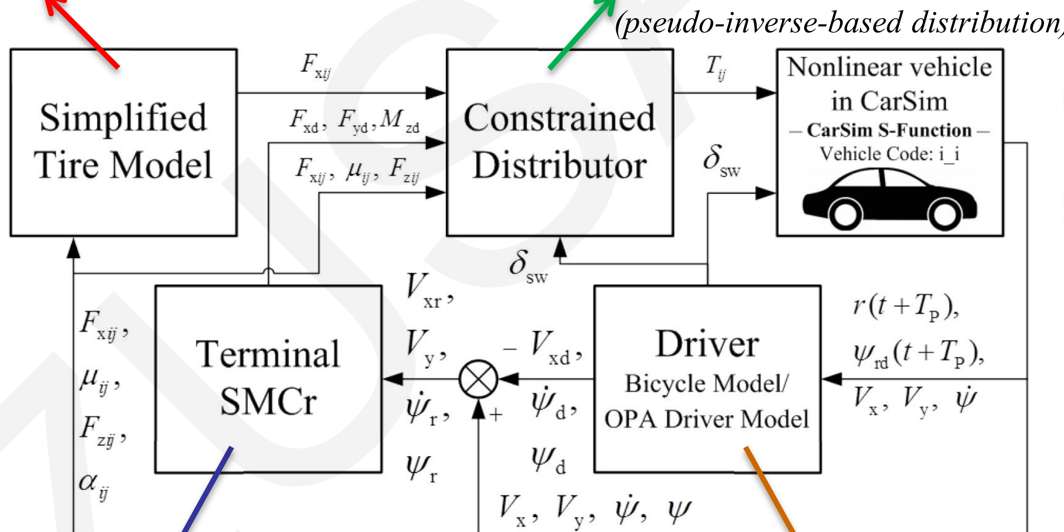
Torque Distribution Controller

Sakai et al., Electrical Engineering in Japan, 138(1), 79-89 (2002).
where the fitting constant is changed.

Normal: Achieve Long., Lat. & Yaw Efforts
Emergency: Achieve Long. & Yaw Efforts
Extreme: Achieve Yaw Effort Only

Improve Fitting Accuracy





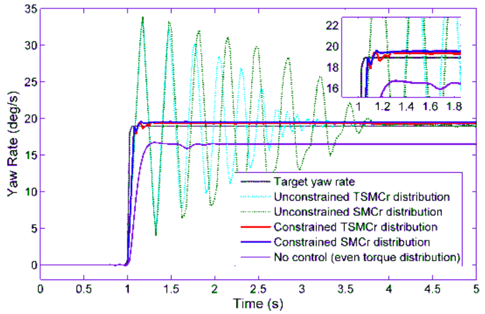
Global Fast TSMC: Longitudinal Control & Lateral Control
Nonsingular TSMC: Yaw Control

Longitudinal: Given Speed Profiles
Lateral & Yaw: 2-DOF Bicycle Model & OPA Driver Model

Fig. 3. Structure of proposed torque distribution controller.

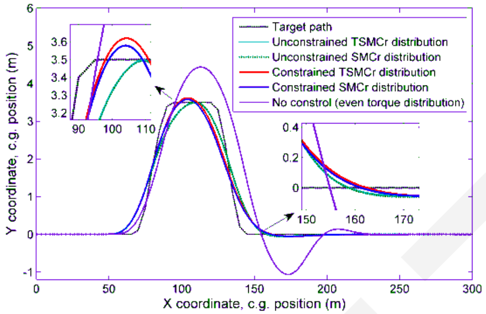
Simulation Results

1. Open-loop step-steer maneuver @ 80 km/h (yaw responsiveness)



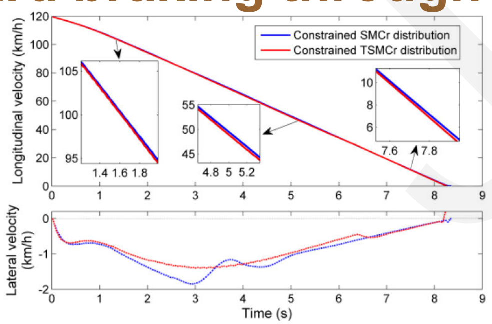
The handling characteristics of the vehicle are altered from understeering to neutral steering so the vehicle is more easy to drive. TSMC controller provides the fastest yaw response with the minimum tracking error while the constrained distributor can maintain the vehicle stability.

2. Closed-loop double-lane-change @ 100 km/h (lateral responsiveness)



The constrained TSMC controller has the best tracking performance for a given trajectory and gives the best handling quality by increasing maneuverability with the least steering effort by the OPA driver.

3. Hard braking through a *μ*-split surface (longitudinal responsiveness)



The constrained distributor is able to balance the trade-off between the lateral stability and the braking efficiency. The vehicle with constrained TSMC controller has the shortest braking time with the least lateral deviations which hence results in the shortest braking distance.

Conclusions

- **Due to the fast and finite time convergence, and the high steady-state precision, TSMC provides more improved control effects than SMC does**
- **The constrained distribution approach also significantly improves vehicle stability and handling performance.**
- **On an overall evaluation, the constrained TSMC based controller meets the design requirements and shows the best performance among all schemes during our study.**

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