Optimal Trajectory Tracking Control for Automated Guided Vehicles

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Where innovation starts

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Question

How to develop a control strategy for automated guided vehicles which tracks a pre-defined trajectory ?

Features of our strategy:

1. Generic for any kind of AGV with arbitrary number of wheels.
2. Handling severe cornering maneuver.
3. Carrying heavy load in elevated or banked road surface.

Automated Guided Vehicles

- Driver-less operation under supervisory system.
- Motion based on a pre-defined route.
- Wide range of application.

A generic framework of AGVs for various application.

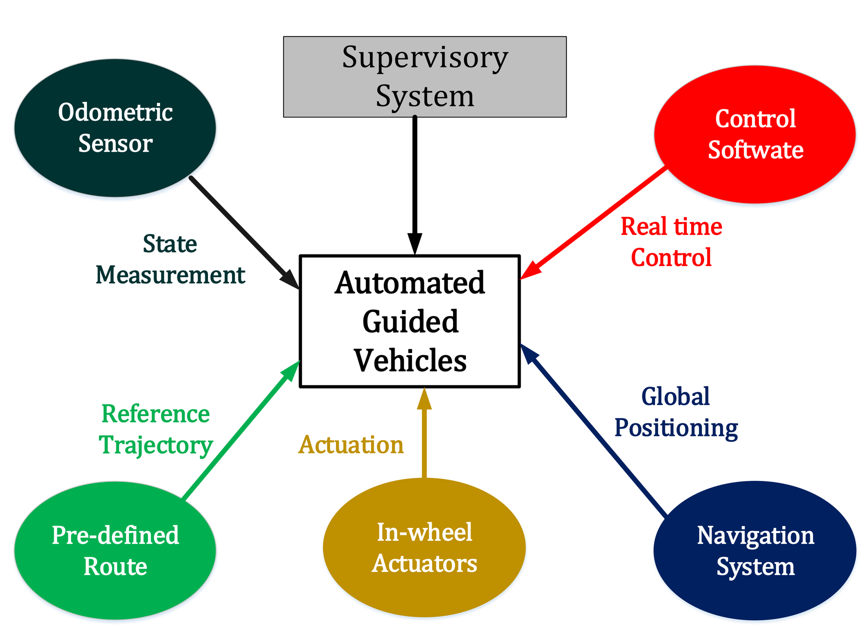


Figure 1: Architecture of AGVs

System Overview

- Exploiting multibody structure of vehicles.

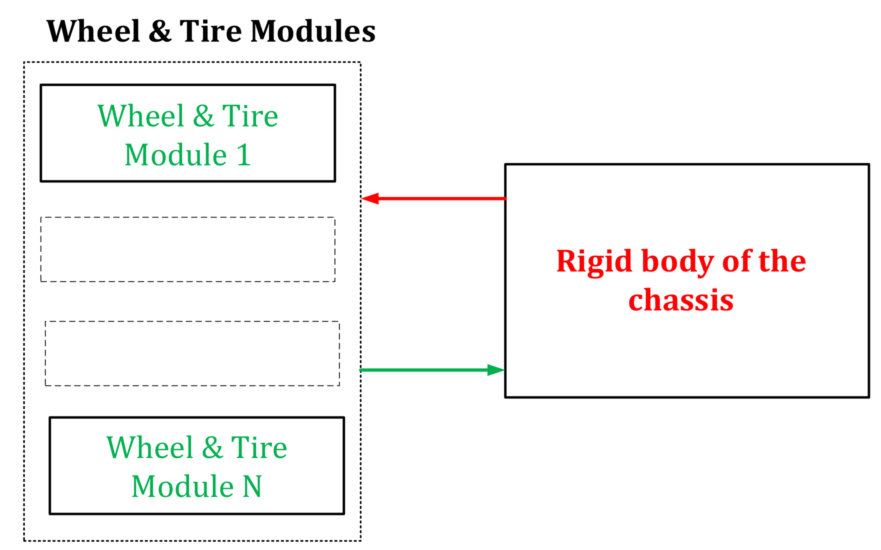
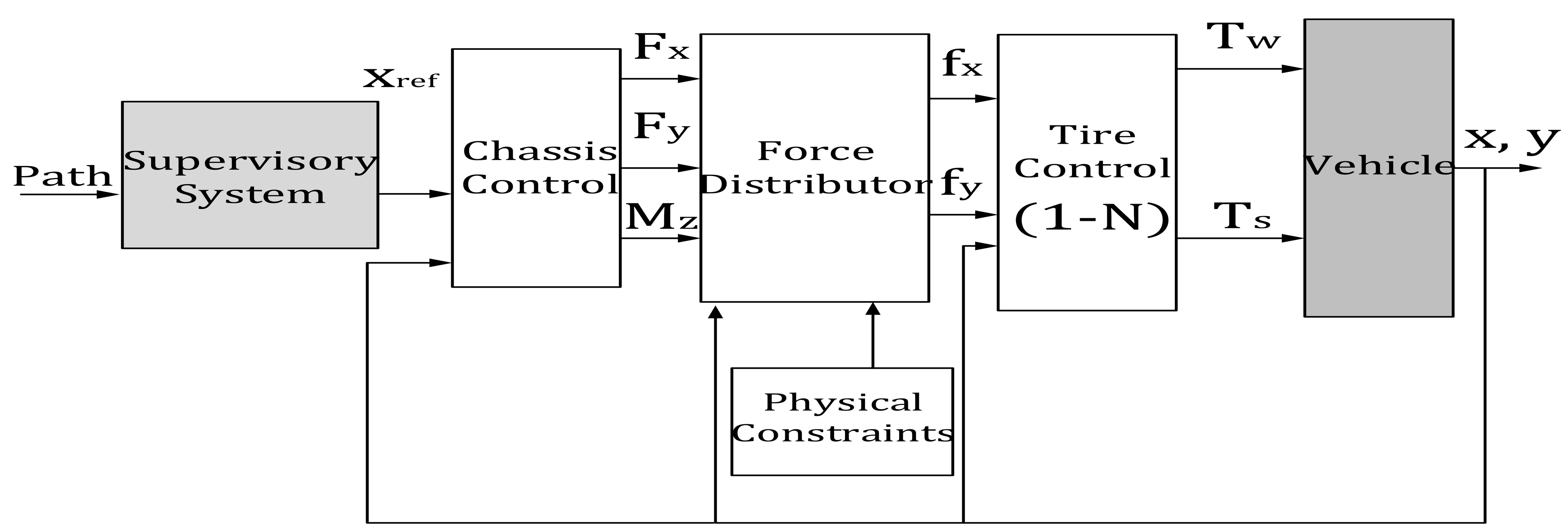


Figure 2: Separation of multibody dynamics



Force Distribution

Force distribution to each wheel.

Cost Functional:

$$J(f) = f^T W f$$

Wheel Position:

$$M\ f = F_d^k,$$

Friction Limit:

$$G\ f \leq h.$$

Chassis Control

Obtain desired F_x, F_y and M_z for $x_{\text{ref}}(t)$

Cost Functional:

$$J(x_b{}^*, x_{\text{ref}}, u_b) = e^T(t_{k+1})\ Q_f\ e(t_{k+1})$$
$$+ \int_{t_k}^{t_{k+1}} [e^T(t) Q e(t) + u_b^T(t) R u_b(t)] dt$$

Feedback:

$$A^T K + KA - K\ B\ R^{-1} B^T K + Q = 0,$$

Feedforward:

$$\dot{r}_b(t) = -[A^T - K\ B R^{-1} B^T] r_b(t) + Q x_{\text{ref}}(t),$$
$$r_b(t_{k+1}) = -Q_f x_{\text{ref}}(t_{k+1})$$

Control input:

$$u_{b,\text{opt}}(t) = -R^{-1} B^T [K\ x_b(t) + r_b(t)]$$

Tire Control

Obtain desired F_x, F_y and M_z for $x_{\text{ref}}(t)$

Nonlinear dynamics of Wheel & tire:

$$\dot{x}_w = f_w(x_w) + g_w u_w,\ \ y_w = h(x_w)$$

Diffeomorphic Transformation:

$$\xi = \Phi(x_w),\ \ \dot{\xi} = b(\xi) + A(\xi) u_w$$

State Feedback Structure:

$$u_w = A^{-1}(\xi)[v - b(\xi)]$$

Virtual Control input:

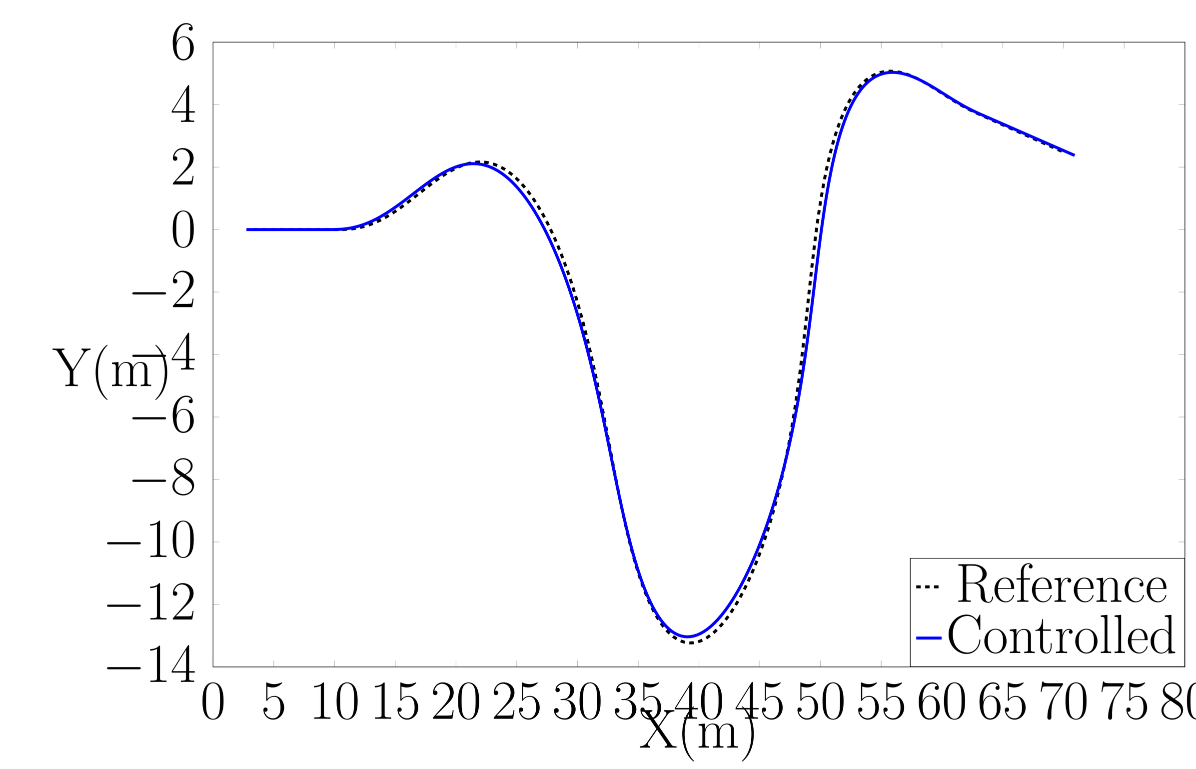
$$\dot{\xi} = I\ \xi + b v_w$$

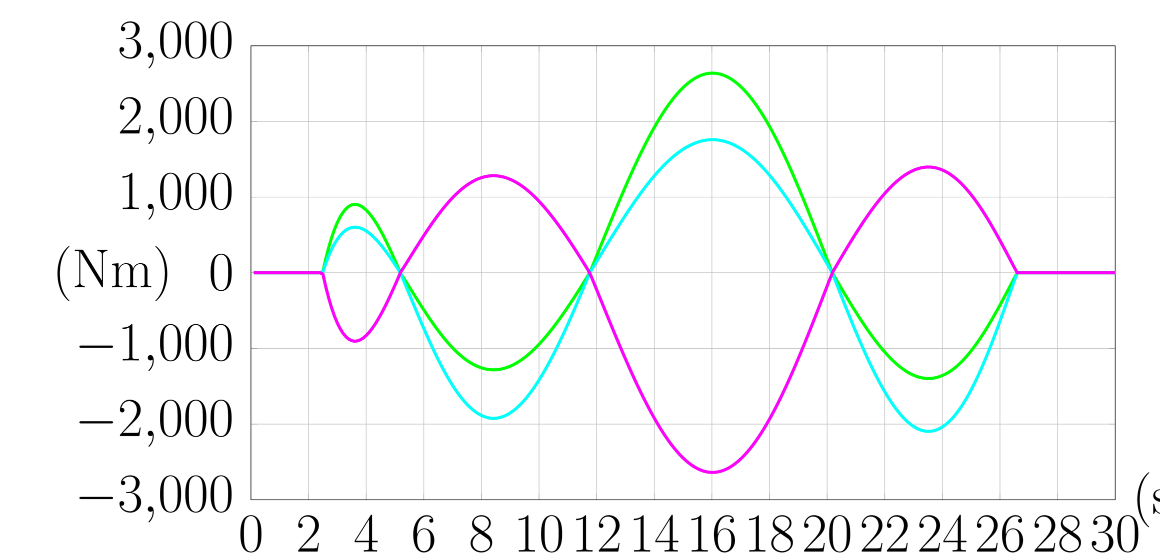
Design v_w with linear control technique.

Closed loop nonlinear system is exponentially stable.

Simulation Results

Six wheeled vehicle with all wheels to be controllable.





Conclusions

- A three-stage cascade control scheme which separates the dynamics of chassis from each wheel and tire.
- The design is generic in the sense of incorporating multiple wheel & tire modules.
- Incorporating steering torque as control variable allows for handling large steering angle.

Future Recommendations

- Observer based control design in case of limited sensor measurements.
- Addressing robustness issue regarding model-plant mismatch, other uncertainties.
- Including actuator limits.