Autonomous and Intelligent Vehicles Modeling, Design and Control

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XXXIV Cycle

Research context and goals

The rapid evolution of technologies in the automotive field allows the development and realization of transport systems that are increasingly intelligent, safe, connected, and with a higher level of autonomy.

Autonomous vehicles | **Artificial Intelligence** | **Electric and Hybrid vehicles** → **RESEARCH GOALS**

- ❑ **Autonomous vehicles: modeling, design and control**
- ❑ **Design of estimation algorithms for vehicle dynamics parameters**
- ❑ **Design of estimation algorithms for the state of charge and state of health of automotive Lithium batteries**

Addressed research problems

1. Lithium batteries: State of Charge and State of Health estimation [1], [3]

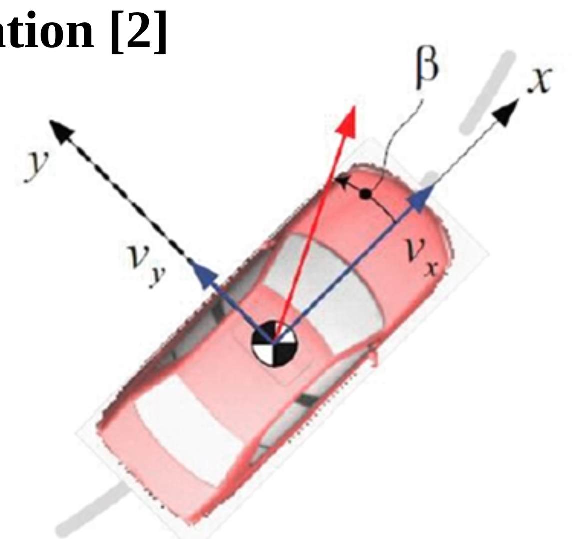
- SOC and SOH cannot be directly measured.
- The estimation system should be accurate and model-free.

NARX regression and feed-forward pattern recognition Neural Networks for SOC and SOH estimation, respectively.

2. Vehicle sideslip angle and longitudinal speed estimation [2]

- Optical sensors are very expensive.
- Common longitudinal speed estimation algorithms are inaccurate during extreme maneuvers.

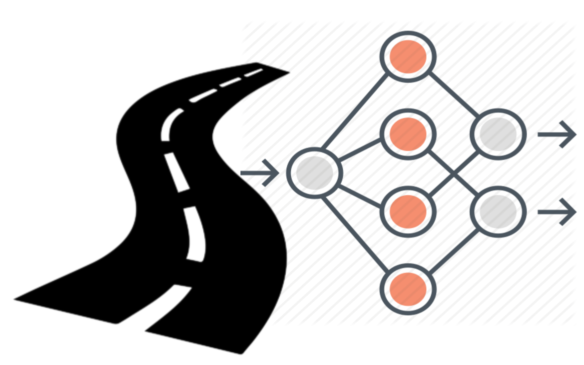
NARX regression Neural Network.



3. Road condition identification [2]

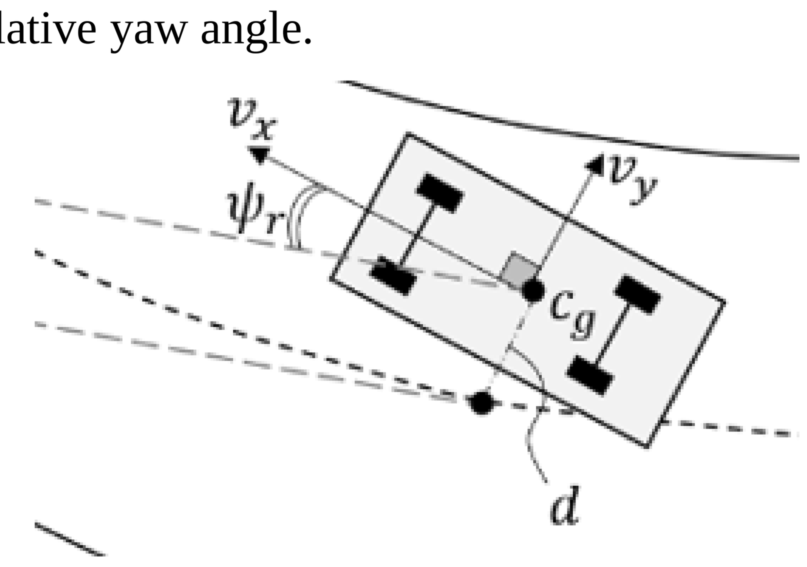
- Crucial for safety, when tuning automotive systems.

Feed-forward pattern recognition Neural Network.



4. Lateral and longitudinal dynamics control for autonomous driving [4]

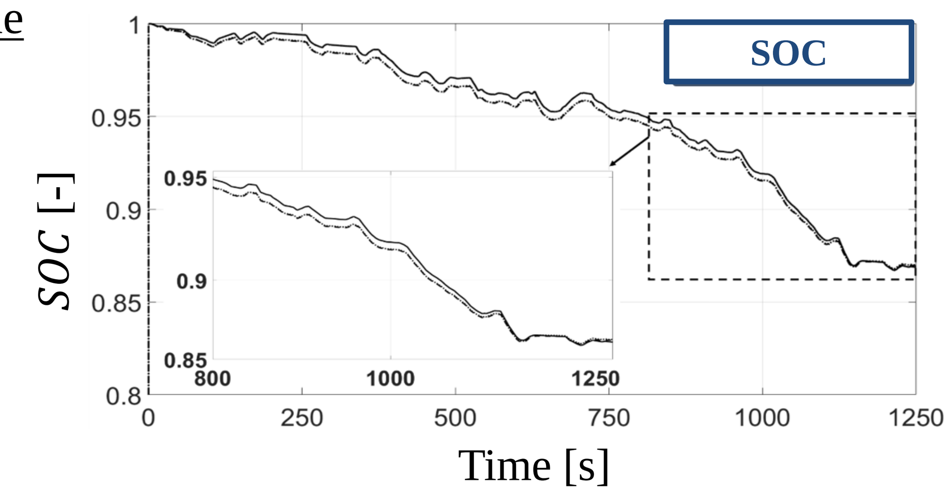
- Combined PID and MPC control technique and lane detection.
- The vehicle is considered as a 3-DoF linear kinematic bycicle model.
- The vehicle is controlled with longitudinal acceleration and steering angle.
- The control errors are lateral deviation and relative yaw angle.



Results

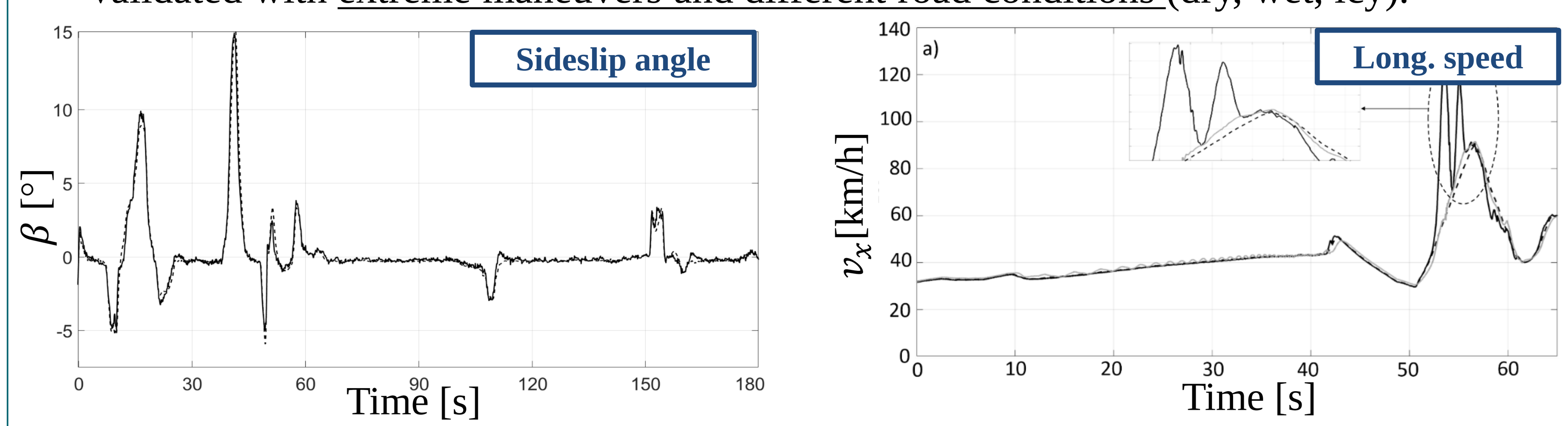
1. Lithium batteries: State of Charge and State of Health estimation [1], [3]

- SOC estimation is accurate in the experimental validation (<0.4% error).
- SOC estimation algorithm has a low computational cost.
- SOH classification algorithm validated with 98.7% accuracy.



2. Vehicle sideslip angle and longitudinal speed estimation [2]

- ANN-based estimation method is accurate during experimental validation.
- Validated with extreme maneuvers and different road conditions (dry, wet, icy).

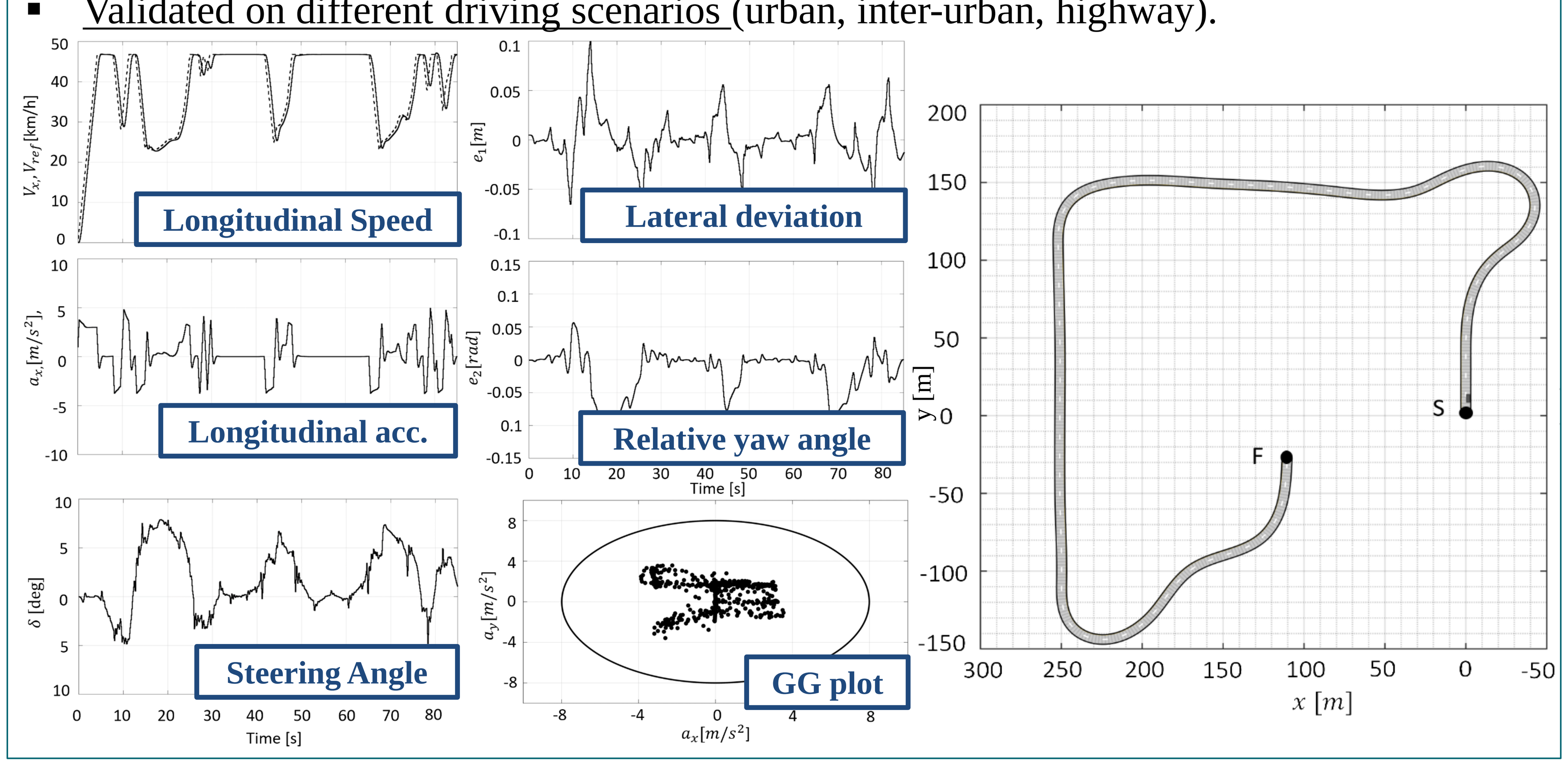


3. Road condition identification [2]

- 99.5% classification accuracy (dry, wet or icy road) in the experimental validation.
- Fast classification output refresh rate (10Hz).

4. Lateral and longitudinal dynamics control for autonomous driving [4]

- The method maximizes the vehicle longitudinal speed.
- Respecting the vehicle dynamics constraints.
- Validated on different driving scenarios (urban, inter-urban, highway).



Future work

- ❑ **Experimental validation of perception and control algorithms on a real sport electric vehicle** (Formula Student)
- ❑ **Improve lateral and longitudinal control**
- ❑ **Design optimal trajectory planning** algortithms

Selected Publications (2019)

[1] Bonfitto, A., Feraco, S., Tonoli, A., Amati, N., & Monti, F. (2019). "Estimation Accuracy and Computational Cost Analysis of Artificial Neural Networks for State of Charge Estimation in Lithium Batteries." *Batteries*, *5*(2), 47.

[2] Bonfitto, A., Feraco, S., Tonoli, A., & Amati, N. (2019). "Combined regression and classification artificial neural networks for sideslip angle estimation and road condition identification." *Vehicle System Dynamics*, 1-22.

[3] Bonfitto, A., Ezemobi, E., Amati, N., Feraco, S., Tonoli, A., & Hegde, S. (2019, July). "State of Health Estimation of Lithium Batteries for Automotive Applications with Artificial Neural Networks." In *2019 AEIT International Conference of Electrical and Electronic Technologies for Automotive (AEIT AUTOMOTIVE)* (pp. 1-5). IEEE.

[4] Feraco, S., Bonfitto A., Amati N., Tonoli A. (2019). "Combined Lane Keeping and Longitudinal Speed Control For Autonomous Driving". *In Proceedings of the ASME IDETC-CIE 2019, 21st International Conference on Advanced Vehicle Technologies (AVT).*