Learning-Based On-Track System Identification for Scaled autonomous racing under minute

(Reproducing and conclusion)

1 introduction

This paper uses a simple steps for identifying the tire pacjika model parameters

$$\phi \in [D_i, C_i, B_i, E_i]$$

To identifying those parameter the following steps is being followed:

1. Collect a dataset online while the car is moving using a model free controller such as pure-pursuit, the dataset collected contain the following $D \in [v_x, v_y, w, \delta]$.
2. The data collection procedure last for 30 second, after that the data is then passed to the neural network to predict the error of the current reading and next reading from the dataset.
    1. Neural network parameters [4 input layer , 8 neurons in hidden layer, 2 output layer].
    2. The activation function for the hidden layer is leaky relu to introduce non-linearity.
3. After the training finished a synthetic data is generated in the steady state with following condition:
    1. v_x is constant , and the steering is increasing linearly. The output is corrected from perviously modeled error network.
    2. The steady state required to make the below equation valid

$$\begin{aligned} \dot{v}_y &= \frac{1}{m}\left(F_{yr} + F_{yf}\cos\delta - m v_x \omega\right) \\ \dot{\omega} &= \frac{1}{I_z}\left(F_{yf} l_f \cos\delta - F_{yr} l_r\right). \end{aligned} \xrightarrow{\textbf{Steady state}} \begin{aligned} F_{yr} &= \frac{m l_f}{l_f + l_r} v_x \omega \\ F_{yf} &= \frac{m l_r}{l_f + l_r} \frac{v_x \omega}{\cos(\delta)} \end{aligned}.$$

    3. after the steady state data is generated; the pacjika tire is then estimated using linear least square regression.

2 Experiment design

The experiment used the **f1tenth low fidelity simulator** as stated int the following figure that use simple mathematical models to simulate the car behaviors, and used RVIZ (ROS Visualization) as visualization tool.

The provided parameter for the simulator is the **mass**, **inertia**, and the **vehicle dimension**.

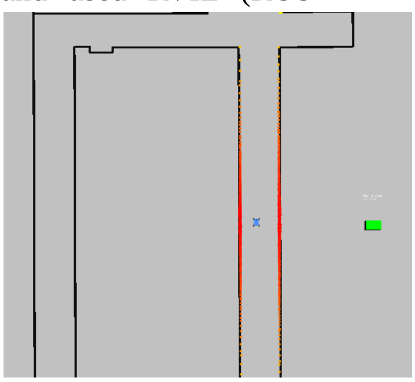

Figure 1: simulator used

Multiple given path scenarios is give to test the approach in two main scenarios , to test if the approach need to excite the v_y and ω to give good result or not:

- Zigzag path
- Smooth straight path

Not only the path is change, but also the neural network's parameters , linear velocity is changed to test the performance, and if the approach is pruned to over-fit quickly.

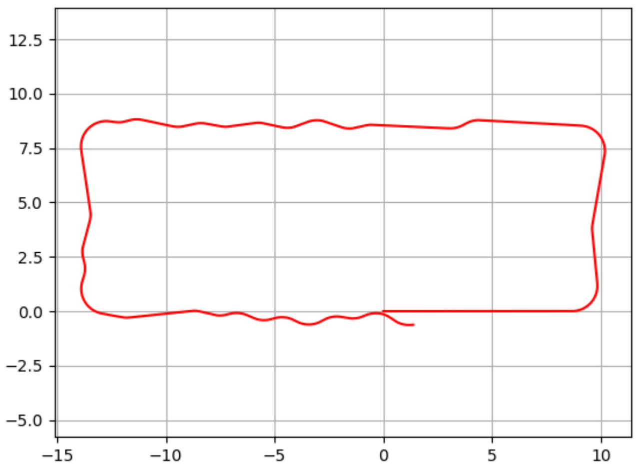

Figure 2: Zigzag path

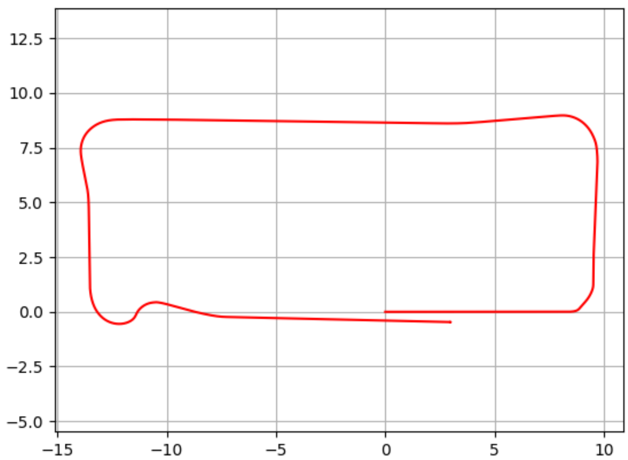

Figure 3: smooth path

3 Test Cases under default parameters

Parameter Name	Value
data_collection_duration	30 sec
num_of_iterations	6
Num_of_epochs	100
Learning_rate	0.0005
weight_decay	0.0
Linear velocity	3.0 m/sec

3.1 Zigzag Path

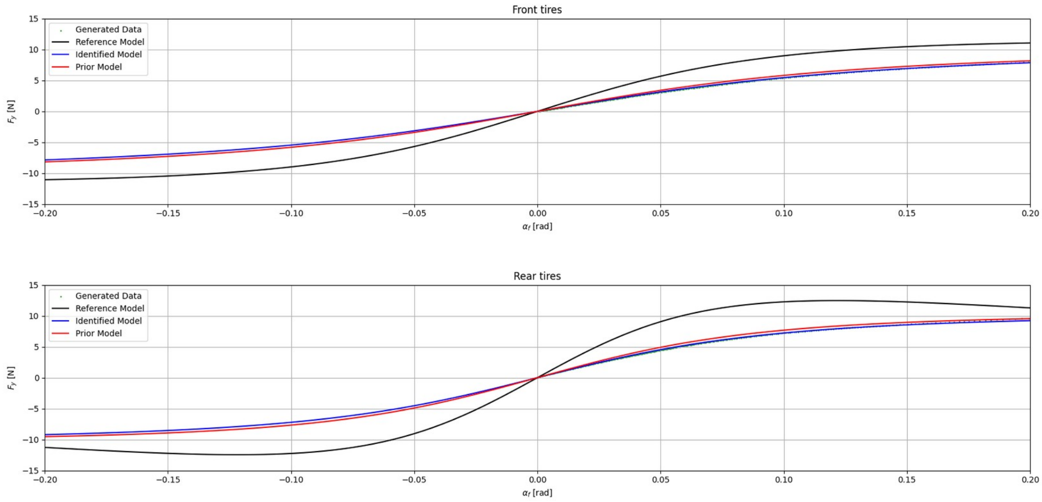

Figure 4: benchmarking of predicted tire forces and ground truth on zigzag path

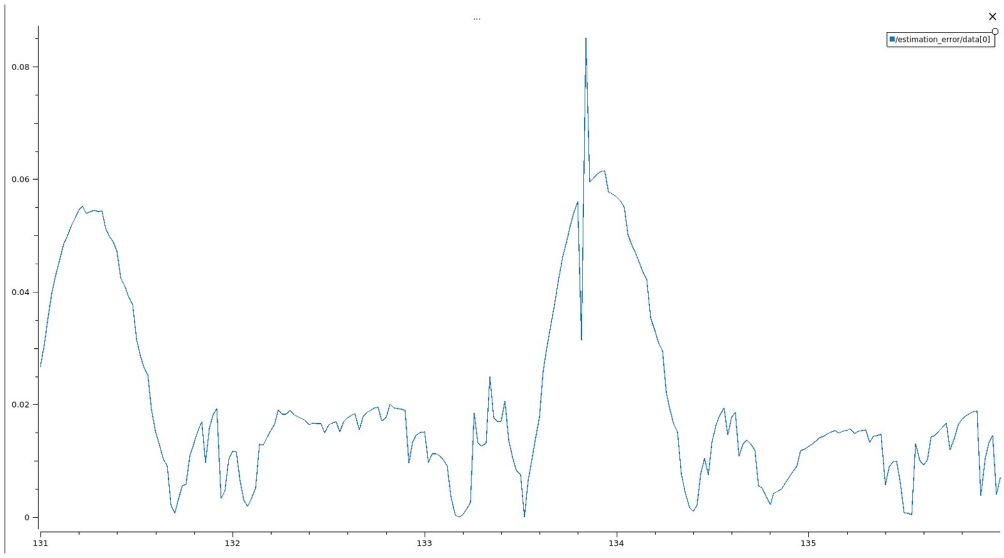

Figure 5: estimated error between estimated vy and vy obtained from sensor

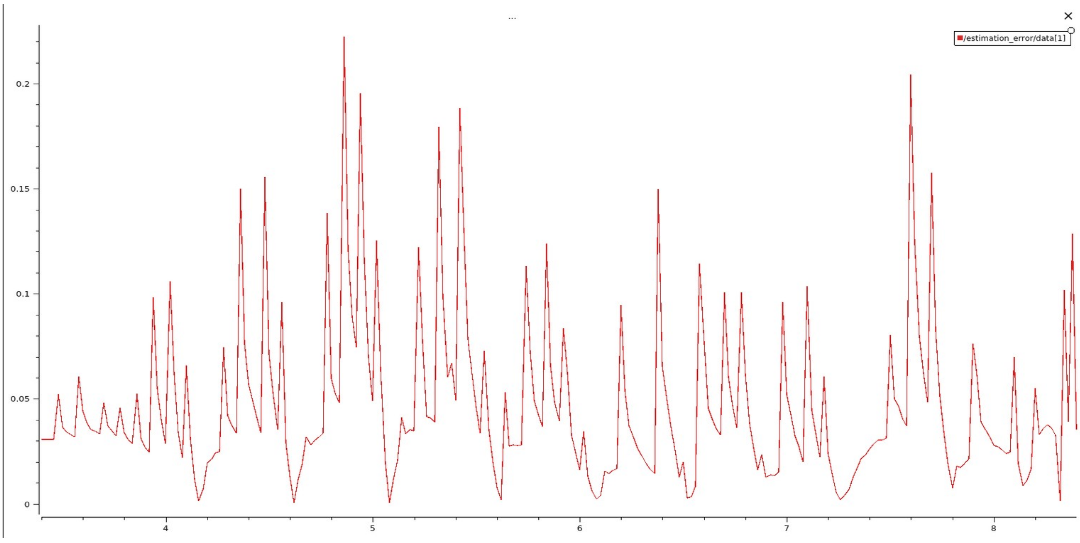

Figure 6: estimated error between estimated w_z and w_z obtained from sensor

3.2 Smooth Path

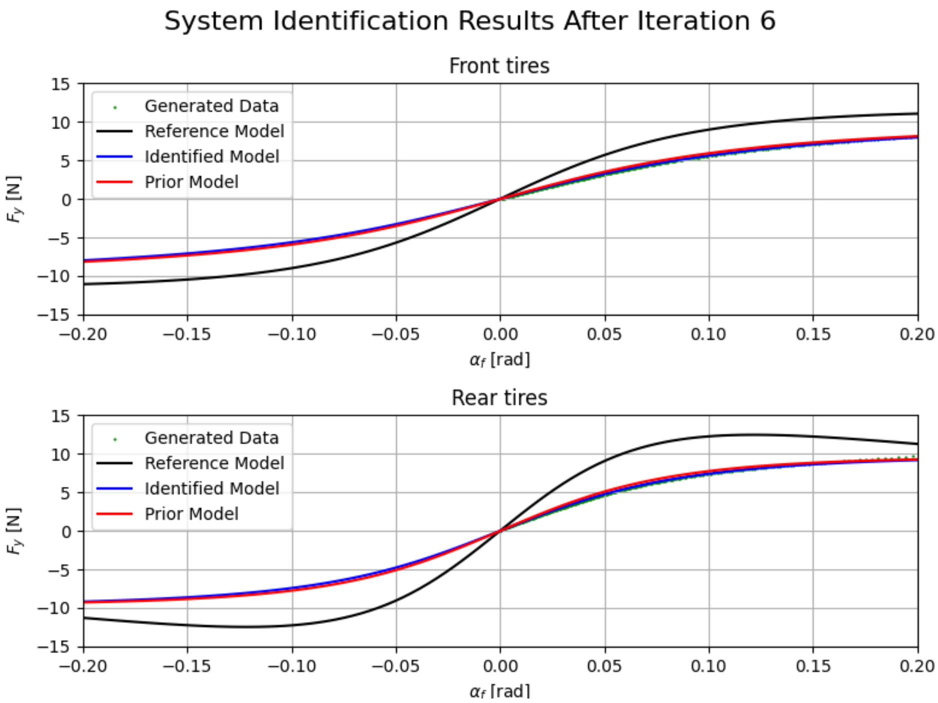

Figure 7: benchmarking of predicted tire forces and ground truth on smooth path

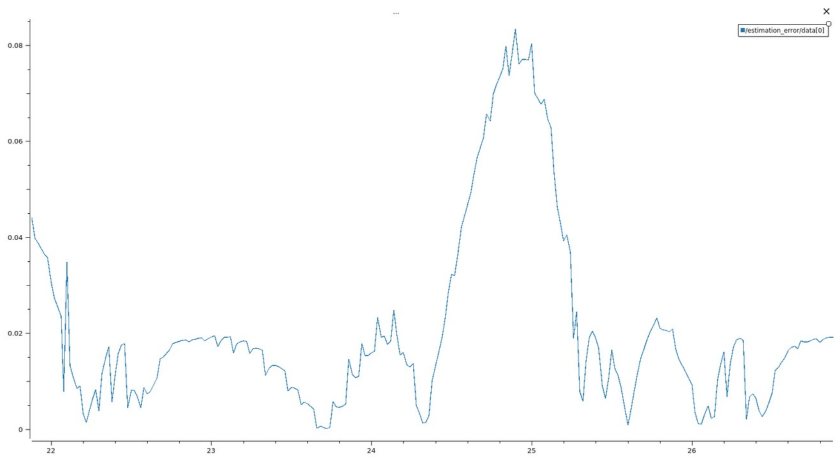

Figure 8: estimated error between estimated vy and vy obtained from sensor in smooth path

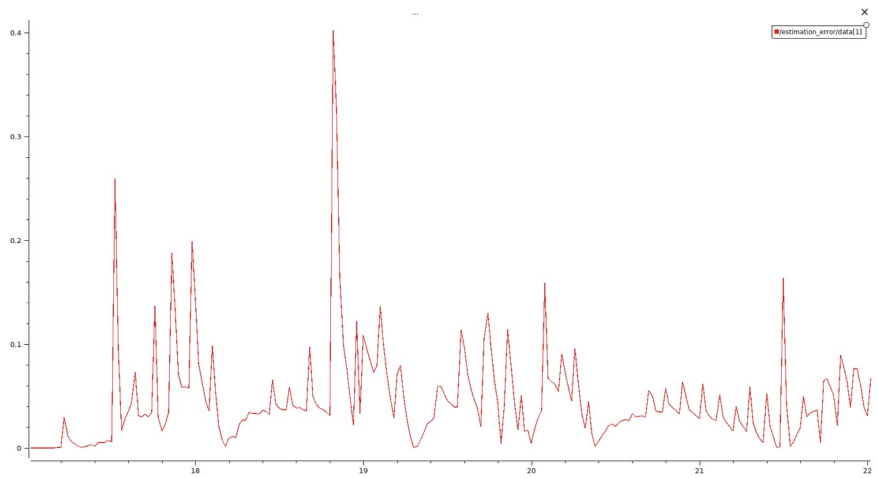

Figure 9: estimated error between estimated wz and wz obtained from sensor in smooth path

4 Initial Conclusion

- The approach depend on one step prediction when benchmarking which is not a reliable option to test the algorithm

$$\mathrm{v}_{prev} = v_{prev_{sensor}}$$
$$v_{estimated} = v_{prev} + a_{estimated}\Delta t$$

- The approach is very prune to over fit on the generated data on steady state method

- The V_y error increase at sharp corners that can lead to slippage in the car if we use

- Dependencies on low fidelity simulator such as f1 10^{th} simulator that use simple mathematical solver

- The system prune to low speed driving (the speed must be above 2.5 m/sec) and collision in identification phase.

5 Suggested next steps

- Test the same approach on IPG
- Implement MPC with identified parameter to see the how the approach affect the car behavior
- Add LSTM as suggested by the author to the architecture and see the results
- Change the regression type in the phase of identification of the pacjika tire model