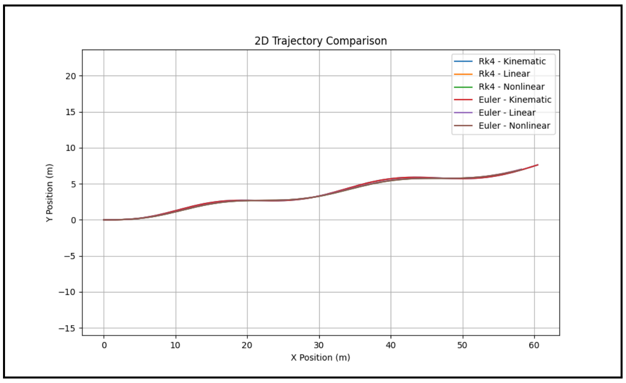
Francesco Mecatti
299822@studenti.unimore.it

Vehicle Modeling Report

Exercise 1



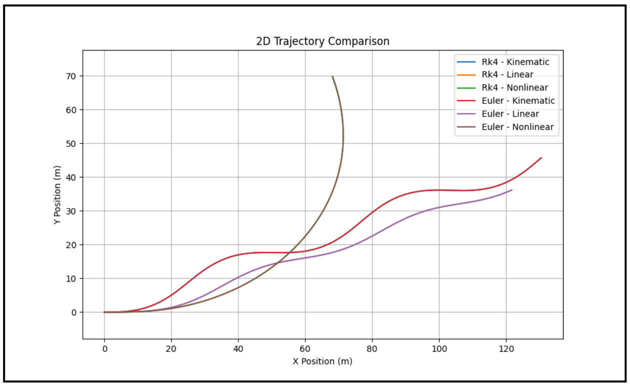
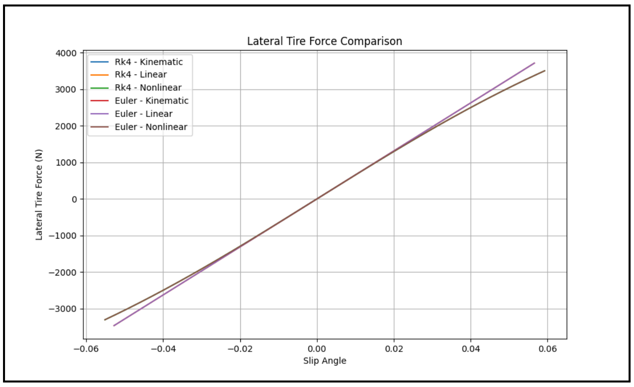


Fig. 1: V0=10m/s Trajectory Comparison *Fig. 2: V0=27m/s Trajectory Comparison*

It can be seen how, at low speed (fig. 1), all models perform almost the same. However, in fig. 2, dynamic models handling starts to be affected by the loss of front tires' lateral force, due to the higher speed: the linear model experiences a slight understeering, while the nonlinear model strongly drifts as soon as the steer starts moving right.



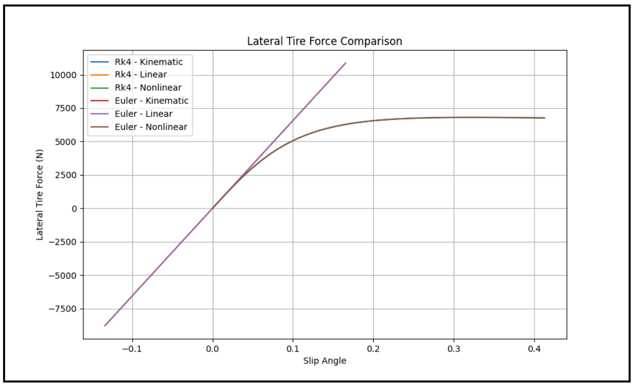


Fig.3: V0=10m/s Lateral Tire Forces *Fig.4: V0=27m/s Lateral Tire Forces*

This skidding effect is primarily caused by the lateral tire force saturation - i.e. tires model used in the simulation reaches its lateral force limit at around 0.15 rad of slip angle before plateauing - visible in fig. 4. Over that limit, tires no longer guarantee force required to perform the desired maneuver.

Fig.6 shows the difference, in terms of slip angle, between the linear and nonlinear models; notice also how, in fig, 6, the slip angle is one order of magnitude higher than fig. 5. Fig. 6 further confirms that the vehicle's heading is not following the sinusoidal input anymore after roughly timestep 800, when it begins "cornering". In fact, since slip angle (front in this figure, but the same goes with rear slip angle, available in the *figures* folder) is defined as the difference between wheel's central direction and vehicle's heading, it follows that this difference grows as far as the two vectors point in two definitely opposite directions. More figures on the lateral-longitudinal velocity transfer are available in the *figures* folder.

In conclusion, while at low speeds the linear model provides a reliable estimation of vehicles lateral forces, at higher speeds the linear model results in an incorrect prediction as soon as tire friction limit is exceeded.

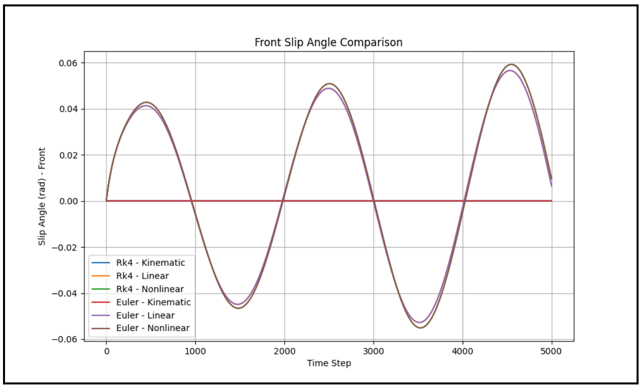


Fig. 5: V0=10m/s Front Slip Angles

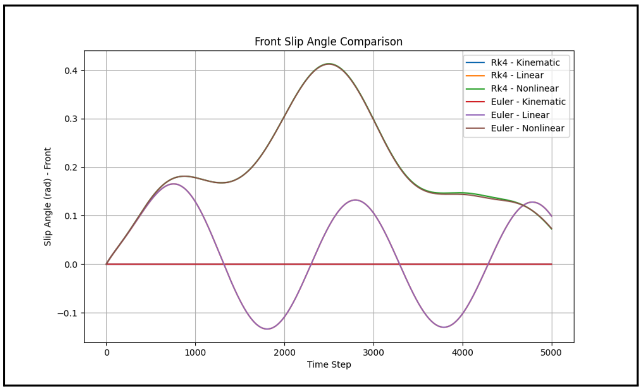


Fig. 6 V0=27m/s Front Slip Angles

Exercise 2

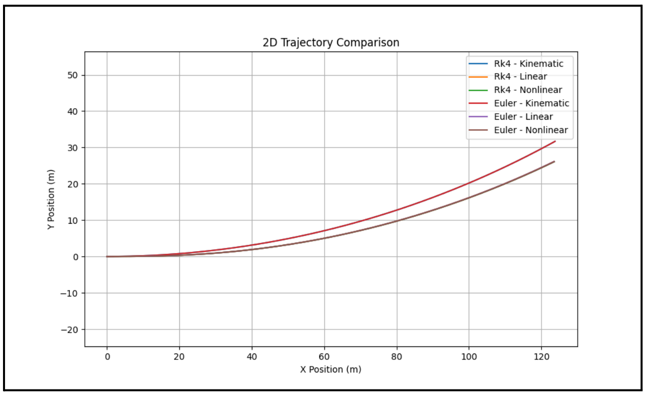


Fig. 7: 0.01 rad Constant Turn Trajectory

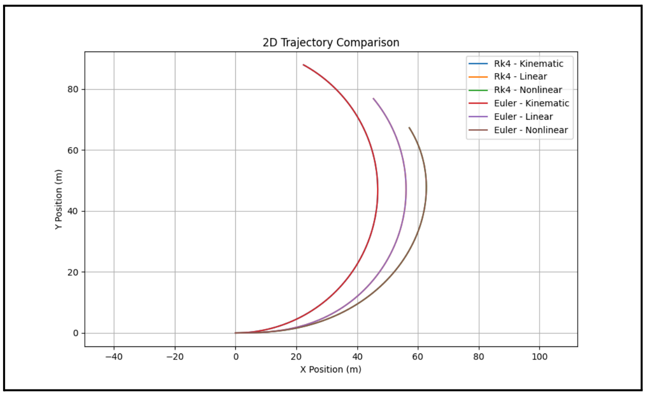


Fig. 8: 0.055 rad Constant Turn Trajectory

Once again, around lateral forces' linear region - meaning, around zero slip angle and small heading -, all the three models are pretty equivalent, but when it comes to higher headings and slip angles, major differences start emerging. In particular, it can be proved by looking at the slip angles (fig. 10) that in fig. 8 dynamic models' tires are losing some friction given the rising slip angle, contrary to the kinematic model in which slip angle is constantly zero (obviously, since it is not included in this kind of model) and therefore the path is accurately followed, resulting in a lower radius turn.

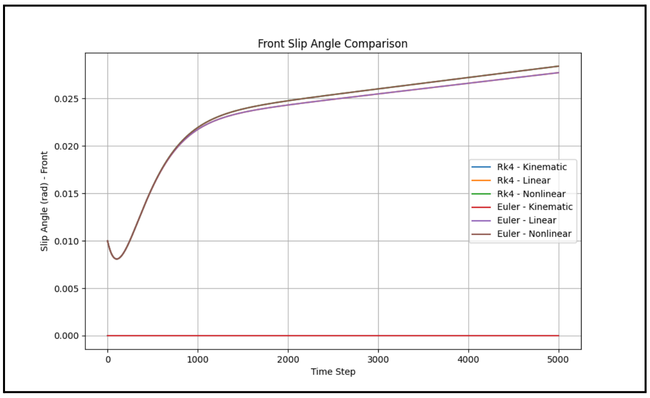


Fig. 9: 0.01r Const Turn Front Slip Angle

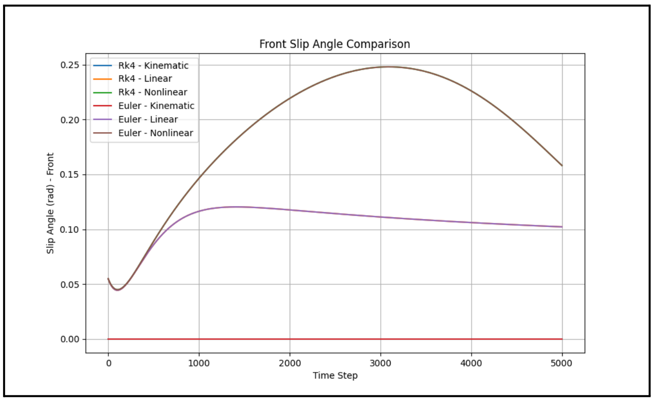


Fig. 10: 0.055r Const Turn Front Slip Angle

Fig. 8 highlights how the linear model gets wrong as the conditions move away from the operating point (heading, slip angle near zero). On top of that, the linear model uses a linear lateral tire force, which is distant to the upper bounded Pacejka curve for high slip angle values, like in this case; the curve is visible in figures 11-12.

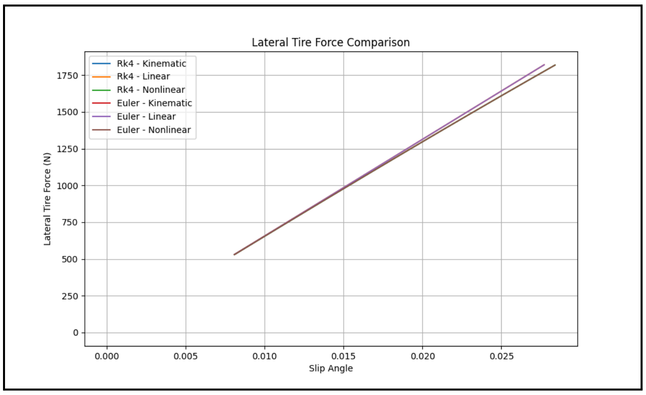


Fig. 11: 0.01r Const Turn Lat. Tire Forces

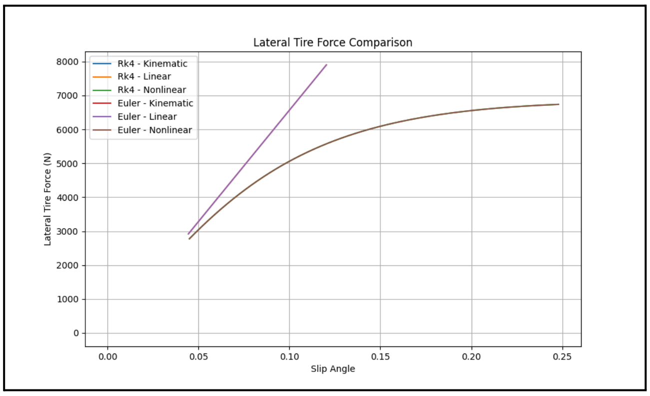


Fig. 12: 0.055r Const Turn Lat. Tire Forces

Exercise 3

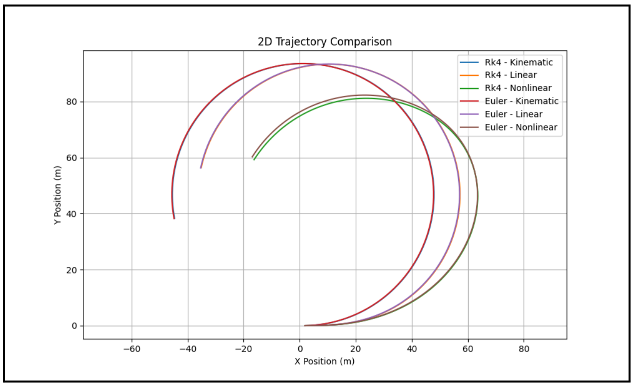


Fig. 13: 0.08s Time Quanta Traj.

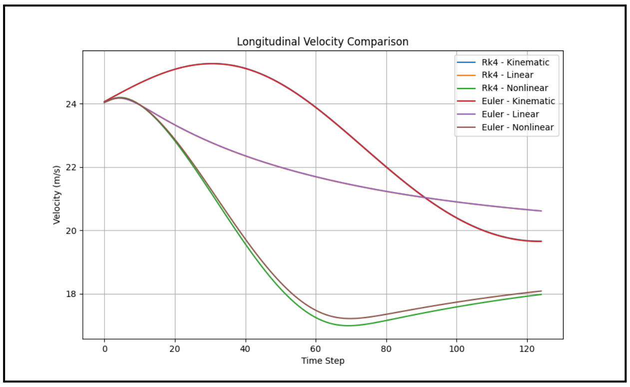


Fig. 14: 0.08s Time Quanta Long. Vel.

By increasing the time quanta of the simulation, we are making each simulation step much coarser. This has an impact primarily on the computation of the derivative, during the temporal integration phase. In particular, by increasing the time quanta, we are basically saying that the solver has to make a longer “prediction” while computing the derivative of a given function. It follows that the error will especially accumulate in the neighbours of the points where slope rapidly changes, like it can be seen in the local minimum of fig. 14.

Additionally, it can also be noticed that the derivation error mainly affects the nonlinear model, since it is arguably harder to approximate a nonlinear function with a finite difference method than a linear one. This is especially true for slip and lateral force formulas, which are, in one case, approximated with a linear relationship, while in the other case with bounded functions. What can happen is therefore that the lower or the upper bound is exceeded by the derivative if the “step length” is too high.