

OpenLapSim

The Open Source Lap Time Simulator Software

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Abstract

The aim of this project is to build a structure for an open source Lap Time Simulator software, which can give an understanding of the main functionality of such a tool.

The software as it is can be used for preliminary study related to race car and help to compare some of the main trade off of setup configurations or design (aero, power, mass, grip), but as an community project can be further developed to a more advanced tool.

Intro

The *OpenLapSim* is a quasi-static Lap Time Simulator for a point mass vehicle, with aerodynamics forces, engine map, gear ratio and tire friction ellipse, written in Python.

The program simulates the maximum performance (accelerations) of the given vehicle-setup on all the sections of the circuit, giving the fastest lap time and highest speed trace over the lap the car could theoretically give.

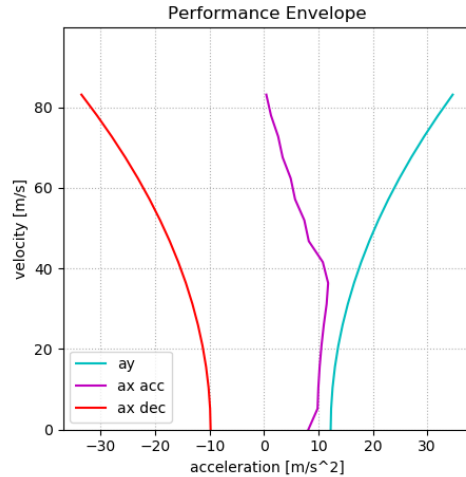
Methodology

For the development of this Software has been used Python 3.7 and Spyder as IDE, which allows to easily visualize the variable space (explorer). Python is a free programming language very powerful for mathematical modelling. The libraries used are NumPy, SciPy and Matplotlib.

Theory

The structure of the Lap time simulator is divided mainly in two components: the Performance Envelope calculator and the Lap time Simulator for the speed trace calculator.

The *Performance Envelope* is also called GGK diagram [1] and describes the maximum accelerations of the vehicle on the axis of velocity, from 0 to max speed, for positive (a_x acc), negative (a_x dec), which is braking phase and lateral direction (a_y).



To calculate it the program uses the setup parameters (defined by the user) and calculates the forces equilibrium for both longitudinal and lateral directions for each point of the speed vector as following:

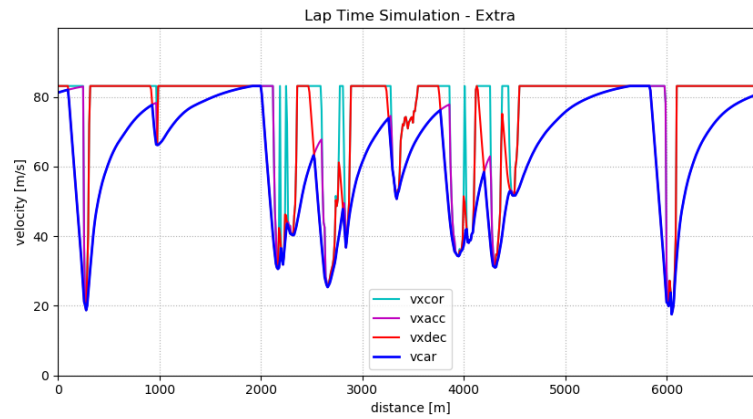
The *Lap Time Simulator* uses both the result from the previous routine and the track file.

The TrackFile.txt is a two columns matrix which contains the distance [m] and curvature ($1/\text{CornerRadius}$) of the circuit.

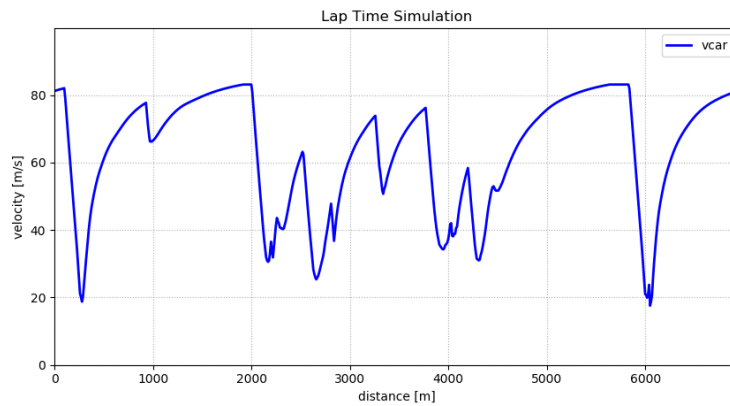
This routine calculates for each segment of the circuit (row of the track file) the maximum lateral acceleration the car could do based on the GGK diagram, and then integrates it over the distance to compute the fastest speed trace on the circuit [2].

The same calculation is computed for the longitudinal, in both acceleration (positive) and deceleration (negative) phases. On the Long calculation we have to consider the amount of lateral acceleration you have, which means it is a “combination” of acceleration and we are moving out from the maximum pure longitudinal point of the GGK.

In this tool the combined performance between long and lateral acceleration is calculated with the equation of the ellipse (simple ellipse of adherence).



At the end for each segment of the circuit it is taken the minimum value between the three speed traces calculated.



Software Guide

The structure of the folder *OpenLapSim* is as following:

- 📄 LapSimCalc.py
- 📄 PerfEnvCalc.py
- 📄 PostProc.py
- 📄 RunOpenLapSim.py
- 📄 SetupFile.py
- 📄 TrackFile.txt

The file needed to run the simulation is *RunOpenLapSim.py* where the user needs to specify two files: *SetupFile.py* and *TrackFile.txt*

```

-----
Select Files
-----
"""
# TrackFile.txt
TrackFile = 'TrackFile.txt'

# SetupFile.py
from SetupFile import*

```

On the SetupFile.py the user can modify the parameters of the vehicle as needed, while the TrackFile is a txt file with distance in meters and curcature (1/R) of the specific circuit.

Still on the RunOpenLapSim.py, below the selection the are the objects instantiation for the PerfEnv (pE) the LpSim (l1 and l2 for first and second iteration), and finally the PostProc (pP) for plotting and data print.

When run the RunOpenLapSim you should see on the console these lines:

```

PerfEnvCalc completed
LapSimCalc completed
LapSimCalc completed
PostProc completed
-----
LapTime: 121.836 [s]
TopSpeed: 299.2 [Km/h]
-----

```

Conclusion

This Project does not want to be an advanced tool for simulation given the large amount of assumption and simplifications. It is anyway a ready to use tool which can be furthermore developed and an education software. It is important to remember that the simulation results are both a combination of model approximation and correctness of the input data, especially in a Formula type car, where aerodynamics and tire frictions coefficient heavily modify the results.

Links

The source code is available on GitHub and is licensed under GNU General Public License: <https://github.com/dstrassera>

References

- [1] W. F. Milliken, D. L. Milliken, *Race Car Vehicle Dynamics*. Warrendale, Pa: SAE, 1995
- [2] J. Hakewill, *Lap Time Simulation*. 2000 [Online], available: http://www.jameshakewill.com/Lap_Time_Simulation.pdf