Traffic Optimisation : A Machine Learning Based Approach

Sofiane LOUNICI : EURECOM - SAP

October 22, 2018

Abstract

Death on roads is a major public health issue, especially the impact of speed. Although researches has been tackling the issue for 40 years, few of them has tried to focus on Machine Learning. The goal of this study was to develop a simple traffic simulation framework to build traffic simulations. Then, by tuning the parameters studying the French government database, we try to detect an optimal speed where both the number of accidents and the global traffic speed are optimized.

1 Introduction

Speed is the main cause of deaths on roads in France, responsible for 31 % of the deaths. Moreover, it is on two-way roads without central separator that the major part of deaths occurs, with 55 % of the deaths. Hence, starting on the 1st of July 2018, the French government decided that the speed on those roads will be lowered from 90 km/h to 80 km/h. The expected impact of such action is to save between 300 and 400 hundreds of life per year. Our goals are :

- Provide an simple yet efficient model to describe an urban traffic, with highly tunable parameters;
- Study the impact of various parameters, such as speed, driver behavior, car density, shape of the road on the number of accident and also on the global fluidity of the traffic;
- Apply reinforcement learning techniques to train intelligent drivers, to see if, given a density of car, a limit speed exists to optimize our output.

2 Related Work

The work of G. Nilsson[3] and R.Elvik[1] on the Nilsson's Model were of course important in the understanding of the subject.

3 Model

Our modeling aims to be pretty simple, to give a lot of freedom to the person willing to test our model. We consider a raceway, with three lanes. N cars take part to the traffic. A car can pass another one, depending on the confidence level of the driver (see below).

Each car has a number of points, which is evolving during a simulation ; a good behavior of course increases the number of points (no accidents, no speed excess, etc..) but fast cars are encouraged also, by making the traffic more fluid. Hence, a ideal car driver need to find the balance between respecting the rules and avoiding accidents, and going as fast as it can.

We insist on rewarding the fastest cars, because in most of traffic analysis, this aspect is not taken into account. It creates a bias, because if we only want to decrease the accidents, without considering the traffic density, the analysis will always lead to a speed limitation decrease. Rewarding the fastest car will enable us to find a balance in the speed limit.

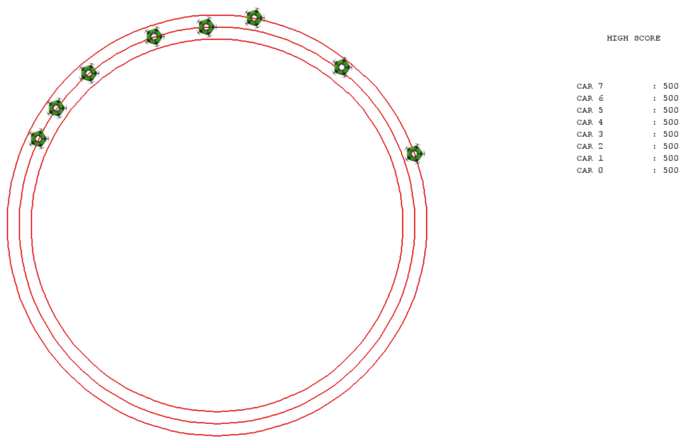

Figure 1: Environment Example

3.1 Theoretical Model

3.1.1 Car

We defined a car C, described by its parameters : $C = [speed, confidence, points]$:

- *Speed* : The given speed of the cars, which will evolved during the simulation, in km/h;
- *Confidence* : A real number in $[0, 1]$, representing the confidence level of a car driver : 1 means that we have a driver willing to take a lot of risks to get faster, passing other cars as soon as he can, and speeding up as often as possible. The confidence level can be altered by accidents, and by radar (see below);
- *Points* : Each driver is assigned a given number of points at the beginning of the simulation, a visual representation of its behavior : Avoiding accidents, driving under the speed limitations will lead to points bonus. Accidents and very slow driving will lead to a malus.

3.1.2 Environment

We defined our environment E, described by its parameters $E = [Lanes, Radars]$:

- *Lanes* : Our road is divided into multiple lanes. As usual, the faster lane is on the left and the slower lane on the right. Our cars are looping on a predefined path. At the end of each car leap, according to the average speed and the number of times a car pass another car, a car can change of lane.
- *Radars* : The average speed of a car (per leap) is stored in a variable. Radar will randomly choose cars, and evaluate their average speed to see if they are respecting the speed limit. The radar will punish cars which are not respecting the speed limitation. This control is non-periodic.

3.1.3 Accident

When a car wants to pass another car, the driver needs to check if it can. We deliberately left loopholes in our model to allow accidents to happen. In our first version, we decided to not distinguish between small and deadly accidents.

3.1.4 Parameters

As supervisor, we can modify each simulation by tuning different parameters :

- *Accident Punishement* : The number of points a car should loose when at least one accident occurs in a leap

- *Speed Punishement* : The number of points a car should loose when a speed excess has been detected
- *Speed Limit*
- *Car Density*
- *Initial Speed and Lanes*

Each points punishment/reward should have an impact on the speed, and also on the confidence of the driver. Two methods were used :

A first method is to choose arbitrarily the impact on the speed. For instance, we can reward good behavior by increasing the confidence level, and accidents/speed excess with a big loss in points. It is not a very precise methods, but it is very fast to choose relevant parameters.

A second method is to do data analysis on the French government dataset on road safety, to find a link between behaviors. For instance, we can study the evolution of speed in "safe areas" and in "dangerous areas", to evaluate how much should punish or reward our drivers

3.2 Framework

The framework has been developed on Python, using Pygame for the graphics and Pandas for the data analysis.

4 Experiments

4.1 Naive Approach

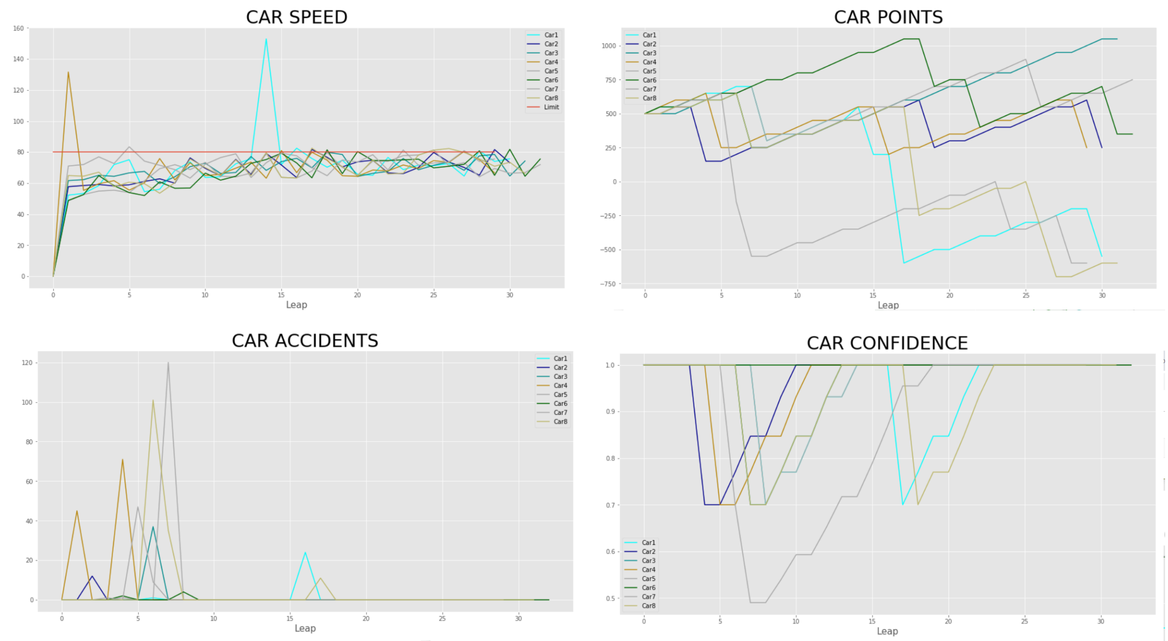

Figure 2: First Example

We choose the parameters arbitrarily, as a first approach to see if our model is valid. We run the experiment on 8 cars. Here are the parameters values :

- *Confidence* : All cars start at 1.0 (the maximum)
- *Speed Punishement* : 450 points for an accident, with 70 % of confidence left

- *Speed Reward* : 75 points for the fastest car, increase of 10 % for car without accidents.
- *Speed Limit* : 80 km/h
- *Car Density* : 8 cars
- *Lanes* : 3 lanes

As we can see, the speed of the cars tends to the limit. The punishment of the accidents seems too be efficient, because through time, the number of accidents decreases (with means that our rules to regulate the traffic are efficient).

After 25 leaps, we can even see that the drivers confidence are at the maximum, with a small number of accidents and without speed excess.

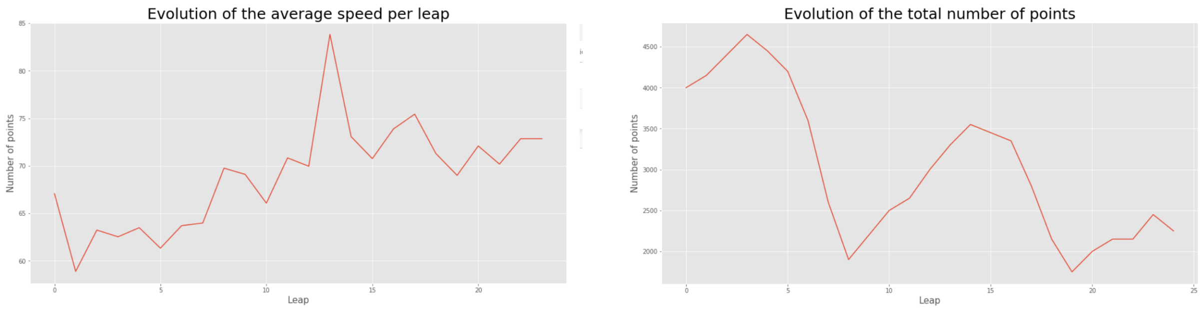

Figure 3: Points vs Speed

Although we can see that the average speed is increasing over the leaps, we can notice that the cumulated number of points per leap is going down ; it could means 2 things :

- There are still too many accidents or speed excess ; it is not the case regarding the previous chart
- The punishment for speed excess / accidents is too much high, so the global evolution of points does not reflect the behavior of the traffic.

4.2 Parameters Tuning by Data Analysis

Our analysis is based on the French government database [2] of road accidents, from 2005 to 2017. The database contains a detailed description a an accident (weather, areas, speed, accidents gravity, etc..). In our study, we focus on few parameters to improve our model, like the accident gravity.

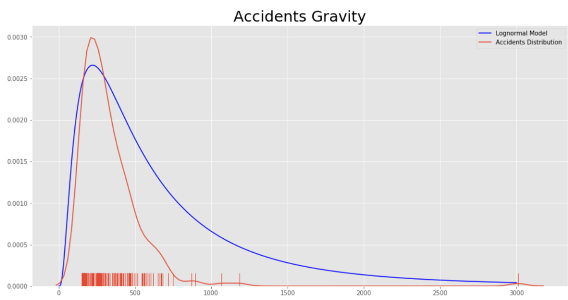

Figure 4: Accidents Modeling

We model the accident distribution gravity by a log-normal distribution, with $\sigma = 0.9$, with a $scale = 250$

$$scale * f(x, \sigma) = \frac{1}{\sqrt{2\pi}\sigma x} e^{-(\log(x)-\mu)^2/2\sigma^2}$$

Each time our model detect an accident, we run a random test on the log-normal function, to adapt the weight of the punishment on the cars points, and to the cars confidence.

4.3 More complex approach

We updated our parameters, thanks to the tuning done in the previous sections. We increased the numbers of cars to 24, and tried two speed limits : 80 km/h and 90 km/h. Here are the results :

4.3.1 80 km/h

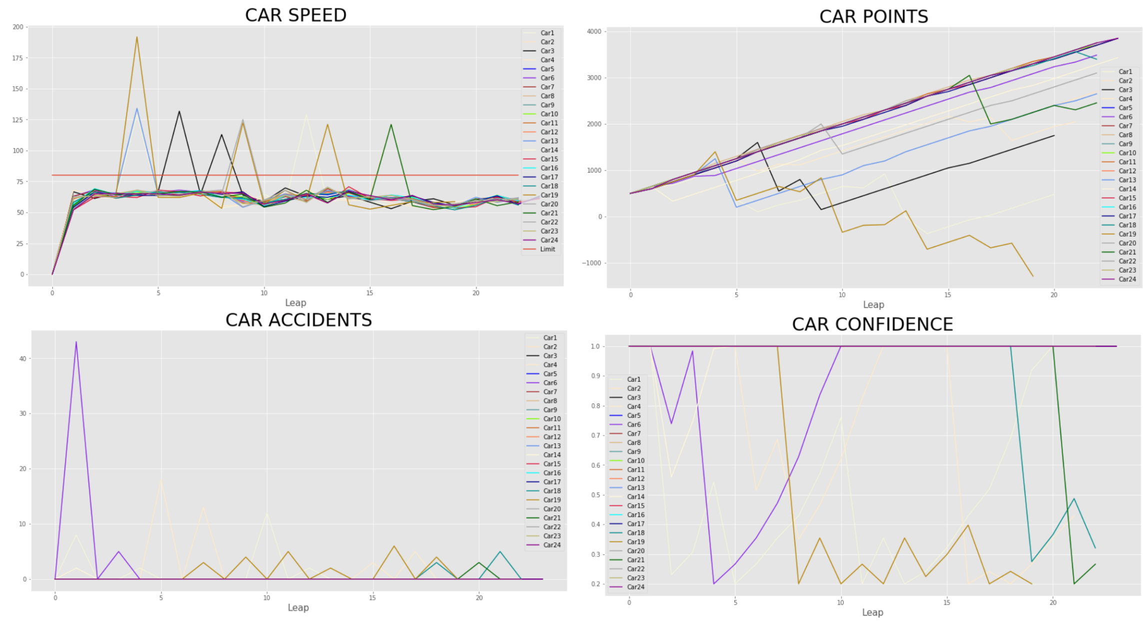

Figure 5: 80 km/h limit

We can see that, except for a few exceptions, the speed limit is well respected, the number of accidents per leap is decreasing over time, and the most important point : the number of points is increasing for most of the cars. In our experiment, we see notice that car 19 is loosing points, mainly due to accidents and speed excess, which is confirmed by the low confidence level of the driver.

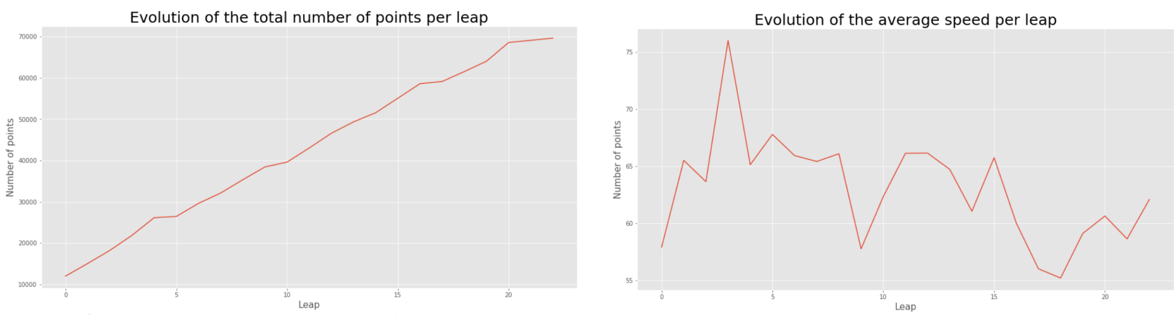

Figure 6: Points vs Speed at 80 km/h

As said before, the number of points of the cars per leap is increasing (showing a good management of the traffic). The average speed limit is slighlty decreasing, but is relatively close to the speed limit.

4.3.2 90 km/h

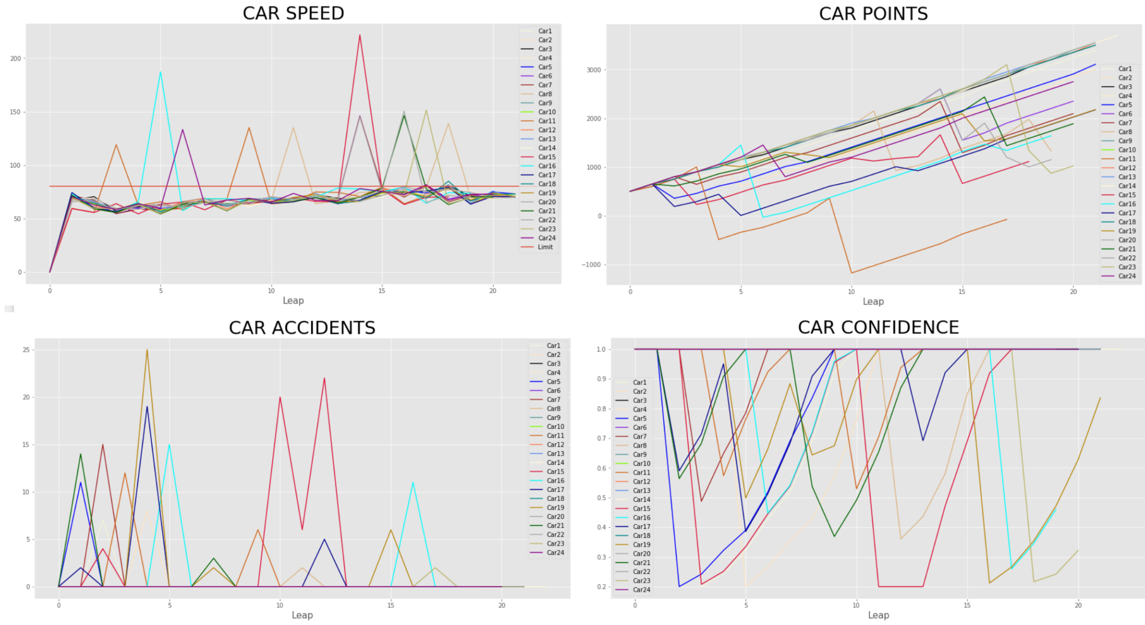

Figure 7: 80 km/h limit

In the 90 km/h, we can clearly note that more cars cross the speed limit ; furthermore, it not isolated phenomenons, it is regularly repeated. We can also notice that there is still a important number of accidents at the end of the simulation (contrary to the 80 km/h case), impacting directly the drivers confidence.

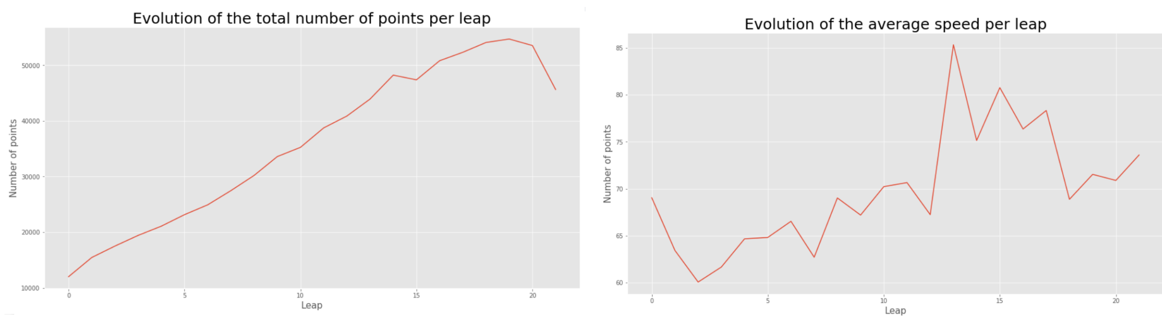

Figure 8: Points vs Speed at 80 km/h

In spite of the accidents, the global number of points is rising, meaning that most of cars are respecting the rules, and the accidents are not deadly. It is interesting that the average speed is slightly increasing, around 75 km/h.

5 Conclusion

Our study showed a simulation model for traffic optimization, with highly tunable parameters, to enhance our understanding of traffic. We especially studied the impact of the reduction of speed limitation from 80 km/h to 90 km/h, and saw that, although it improved a little bit how fluid the traffic is, it doesn't balance the number of accidents who remained high.

References

[1] R. Elvik. Speed and road accidents: An evaluation of the power model. *Institute of Transport Economics, Oslo.*, 2004.

[2] French Governement. Unknown title, 2018.

[3] G Nillson. Traffic safety dimensions and the power model to describe the effect of speed on safety. *Lund Institute of Technology*, 2004.