Simulating Formula 1 crashes in the start-section including the first turn

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Abstract – Crashes in Formula 1 are influenced by certain properties of circuits. A computer simulation model, based on the Nagel-Schreckenberg traffic model, is used to study the effects of acceleration, turn speed, distance and braking. The goal is to find unsafe conditions in a small part of a circuit. The results show that crashes occur completely at random and there is no significant factor that shows how or when a crash will happen.

1 Introduction

Formula 1 crashes are more a rule than an exception. "In the 1960s, 1 accident in every 8 in Formula One events resulted in a fatality or serious injury (defined as an injury that prevented the driver from continuing to participate in the event or subsequent events), with some years as high as 1 in 4." [7]. In the Grand Prix' [1] in 2017 only, half of the races had incidents in the part of the track including the first turn [4].

Previous research took various properties of racing into account, such as regulations and safety measurements on technical level of a car [8] to improve the safety of a driver [6]. This research extends this safety impression by looking at circuits. By taking a closer look at the start-section including the first turn in particular, we hope to find an indication that safety can be improved. The Federation Internationale De L'Automobile, FIA, which is responsible for regulations on safety for both circuits and cars state; "There should preferably be at least 250 m between the start line and the first corner." [2]. We'll have a look at measurements like this distance, braking and speed.
In some ways, Formula 1 races are similar to normal traffic flows, which can be simulated using the Nagel-Schreckenberg model [3]. This will be used as main idea for our model with as major difference that cars can crash while taking part in a simulation. Also, where in the original model a single lane is being used, we mimic the design of a Formula 1 circuit.

[1]Grand Prix (auto racing) an international race for Formula One cars first held in France in 1906 and now staged on a number of circuits around the world [name originally used for the Grand Prix de Paris];[5]

2 Methods

To obtain a view on how the amount of crashes in the first section is influenced by various factors, Monte Carlo simulations are being used. Each simulation represents a start of a Grand Prix, in which every car attempts to pass the first turn. These cars, with an average length of five metres, and a width of two, start at a grid with two sides. Every other car starts left, or right, based on the first (pole) position (predefined for every circuit), with 8 metres in between [1], on a so called grid. For our simulation we divided the total width of the circuit in five lanes, to make it possible to take over cars on both sides, as seen from both start rows.

There are 20 cars in each race. And in the simulations, every track of the 2017 Formula 1 calendar is being tested, 20 in total. The order in which the cars start, is sampled in each simulation out of all achieved qualification results in this season so far (16). By doing this, the possibilty that a driver had a bad day, or penalty can be neglected. When the driver within a team is switched during the season, this will be taken in advance.

To mimic the real world, behaviour of drivers/cars is based on the four steps used in the Nagel-Schreckenberg model:

(1) acceleration
(2) slowing down
(3) randomization
(4) car motion

As long as the point of where a car should brake isn't reached, the car accelerates (1). The numbers being used to calculate the amount of metres that is added every second, are based on a few cars [4], and define the range for all cars.

When the 'braking zone' is (nearly) reached, the negative acceleration (2) is being calculated. The number is based on the currend speed of the car together with the maximum speed that can be driven in the turn. This speed diminution will be devided over the amount of metres that's left for the turn.[4].

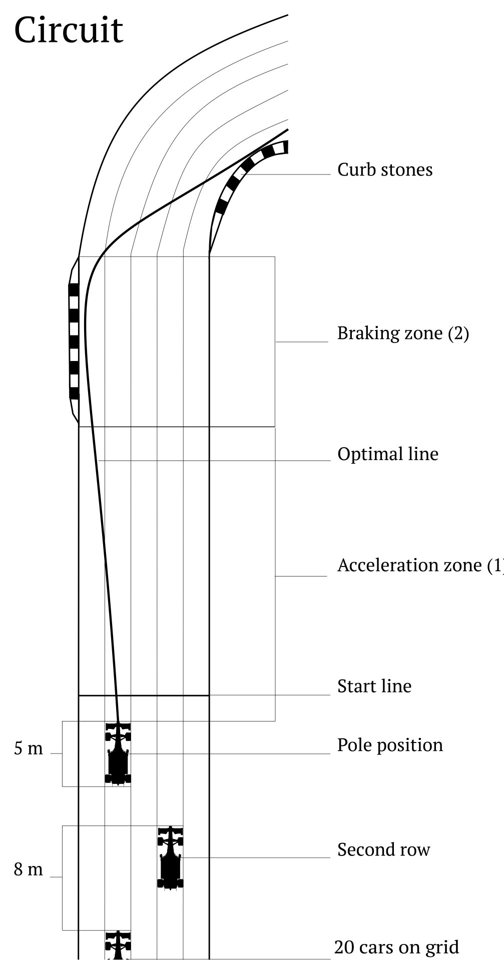

Figure 1: Model used for representation of circuits

Next to improving the distance driven, there will be attempted to move to an optimal position on the track (4). What's optimal for a car at a certain moment differs. Ideally, if a car is faster than the car in front, it will try to take over. Take overs will be done with the 'optimal row' [2] in consideration.

When a car is in front of another car which is considered faster, it will try to defend its position by moving towards the row the car in the back is driving, in order to 'block' it.

Driving into the braking zone also means that an optimal position should be chosen to drive into the turn.

Sometimes when a car is faster, has the plan to defend or to improve its position, other cars are blocking this, or the car needs to go off the track to obtain the result. In this case the current position on track will be maintained.

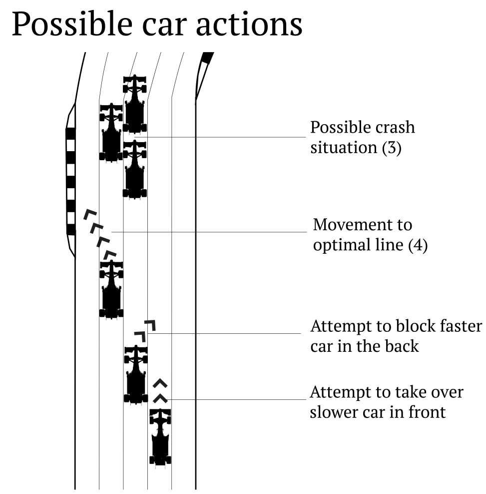

Figure 2: Model used for car actions

2.1 Crashes

Checks for crash occurences will be executed till the second in which the car has passed the point of the first turn.

A check validates if something happend between the current car, and the car in front of it. By doing this, it's possible to check if the manouvre which just was executed, either accelerating, braking or switching could be performed succesfully.

Crashes can only happen between cars that are in the same row. If a crash is near, an additional switch of rows may be performed to avoid a crash. When no positive options are left, the driver has the option to brake, or crash. A choice out of these two will be made randomly (3). If the distance between the current car and the car in front is less than zero, this will be considered as a crash.

3 Results

The results are based on simulations which are ran 10,000 times for each track. The total sum of crashes is 121,747.

[2]The opposite side of the turn is considered as being optimal. By driving there, you could maintain the top speed/accelerate as long as possible.

country	turn	mtr	brake	speed	crashes
Australia	R-L	381	100	150	7837
Austria	R-L	318	200	122	673
Azerbaijan	L-R	206	50	116	7926
Bahrain	R-L	476.4	100	70	7792
Belgium	R-L	251	150	77	2887
Brazil	L-R	334	50	109	5129
Canada	R-L	258	125	154	6334
China	R-L	324.7	50	170	7664
GBR	R-L	270	-	281	991
Hungary	R-L	576	100	85	7550
Italy	R-L	615	125	80	7393
Japan	R-L	373	10	152	1262
Malaysia	R-L	620	100	74	8849
Monaco	R-R	111	75	103	7477
Russia	R-R	205.2	-	300	2103
Spain	R-L	690.5	100	130	7211
Mexico	R-L	890	200	107	6279
Singapore	L-L	274	50	126	8724
UAE	L-R	305	50	150	9449
USA	L-R	364	100	86	8217

Table 1: Overview of grand prix, with circuit data.

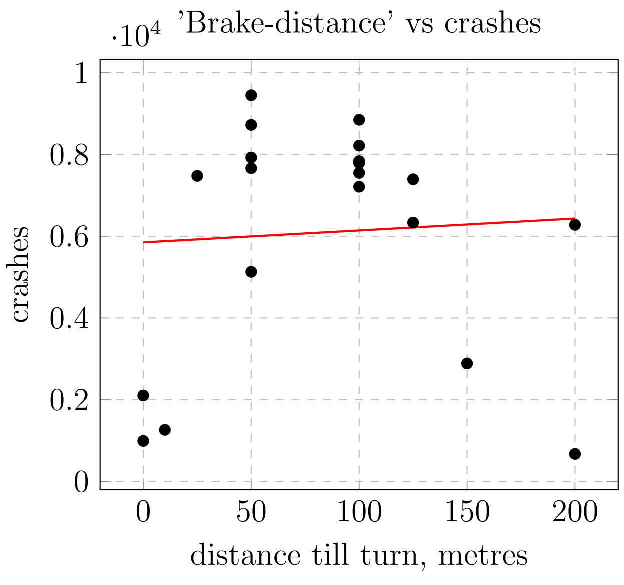

Figure 3: Distance in metres before a turn that is used on average to brake before turn one to achieve the right speed, plotted against the amount of crashes.

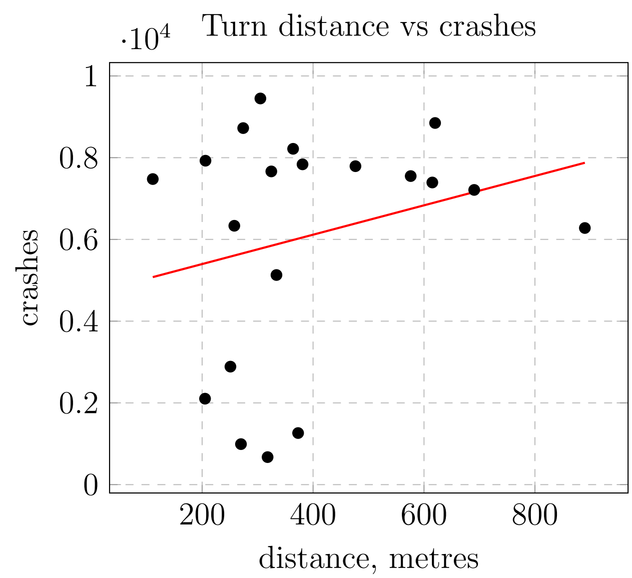

Figure 4: Distance in metres calculated from start-line till first turn, plotted against the amount of crashes.

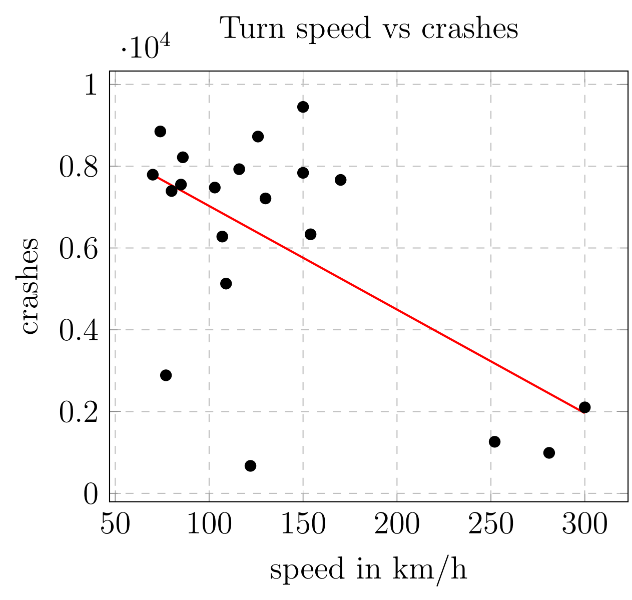

Figure 5: Maximum speed that should be driven in turn to achieve best result, plotted against crashes.

4 Discussion & conclusion

All the circuits of 2017 are listed in table 1, with the corresponding data. The last column shows the amount of crashes, computed by the simulations. The number of crashes seems divided equally over the circuits. This is in line with the real-world amount of crashes this season so far.

Figure 3 shows an almost horizontal line in the distance that is being used to brake before the turn. This indicates that the amount of metres that is shown on the track by brake-pads/distance indicators, seems right and doesn't affect the amount of crashes. The used model doesn't take the width of turns into account. Based on the 2017 circuits, it's clear that 2 or 3 cars next to each other is the maximum, instead of the 5 rows we used. Adding this constraint into future research will influence the way of braking.

According to figure 4, we see that the number of crashes increases when the distance of a turn calculated from start rises. There are numerous causes for this, high speed could be one. Putting it in perspective, you could also say that there's more metres to crash, so it's logical that the number gets higher. However, the distance of the turn doesn't say anything about the angle of a turn, which means that hard braking might be required and could cause extra danger.

The higher the speed that could be maintained in a turn, the lower the number of crashes, Figure 5 describes. This can be explained by the descreased speed differences for a car, which doesn't cause head-tail collisions in braking anymore.

By using the circuit model with 5 rows, an attempt is been made to copy the possibilities in a circuit. Though, as just said, turns have smaller widths, and also the first straight differs per circuit in general. These extra constrains could give drivers more options and could influence the total crash model. Next to circuit limitations, accelerations could be improved as well. In the simulation, we used the same number for acceleration per car for the whole season. As cars are being modified all the time, and drivers shift different every single time, it's hard to take this into account. The numbers being used are based on a selected set of cars, as no other information was available. In this, the acceleration of the first 100 metres is used, although it's clear that acceleration declines as the speed goes up.

The last major thing that influences our research is the way of seeing crashes. Wherein the model we now randomized head-tail collisions, if cars came close enough, and there weren't other options, also side-side collisons could be added.

Despite, or maybe due, all these various (missing) constraints, no hard correlations in the result can be found among speeds and (brake) distances. E.g. when a turn is far away from the start, but needs a low speed, with long braking distance, it could have the same outcome as when this turn is right after start. This tells us that we found no hard (safety) reasons why the FIA prefers to have a turn at least 250 metres.

By improving the model, with futher research, and creating a better representation of the real world it might possible to find other correlations. Some last points on weather circumstances and regulations on defending a position show that there is much left to be done. It might be a good idea to improve the study on for example all crashes on one certain circuit, and extend that, instead of trying to compare all circuits at once.

Our research set a step beyond the well-known traffic model and tries to simulate under harder conditions. This attempt wasn't perfect but indicates how the well known Nagel-Schreckenberg model can be used in more difficult situations. Also can be concluded that it's hard to tell which exact combination of properties should be used to have a first turn with few crashes.

Appendix

The supplementary online material includes a statistic hypothesis test, information about acceleration calculations and incidents overview. https://www.wisofton.nl/som.pdf

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