SIMULATION AND INVESTIGATION OF AUTOMATIC COORDINATION IN MULTILANE MOTORWAY

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Abstract- The primary goal of this research is to develop a simulation for a highway with automatic coordinated motorway. This simulation is performed using SimPy V.4 package in Python. This simulation is to minimize the traffic overflow, with a motorway of totally three kilometers which is around 2kilometers for the three lanes and that decreased into two lanes of about 1 Kilometer. With the support of vehicle's parameters includes such as vehicle length, acceleration, deceleration, and human driver's actions such as speed, lane change, yielding for other vehicles and some other assumptions like inter-arrival time distribution and speed limits for each lane, will simulate the model to find highest number of vehicles can be accommodated in the motorway. The vehicles such as electric cars, autonomous cars and heavy goods vehicles are the types of vehicles used in the simulation. The average travel timing is also estimated in the model simulation.

Keywords: *Simulation, vehicles, motorway, speed, time, traffic*

1 INTRODUCTION

Even after the global epidemic drastically unloading highways, information collected indicated that the amount of roadway mortality in the previous year was the maximum in much more than ten years, leading to increasing maximum speeds, road users under influence of alcohol and drugs, as well as a sharp drop in safety belt usage. Faster speeds could even cause even more major harm and considerably raise the risk of mortality as in case of a crash. Maximal traffic jams would be an inevitable part about just how civilized democracies perform. Everything just derives people's frequent efforts to gain specific objectives, which ultimately overburden local lines as well as mass transit on a frequent basis. However, someone always despises traffic jams, which continues to worsen despite efforts to alleviate it.

The Automatic coordinate highway adds significant input towards this traffic overflow dilemma by adding vehicle functionality and lessening highway disruptions. Within that simulated highway, the automobiles were mostly required to give a position, acceleration, as well as lane to accelerate in. Following that, the occurrences have been discussed and evaluated. Since it can make quality distinguish specific potential alternatives focused on an immense number of data sources, virtual world would be a useful weapon for understanding and analyzing traffic problems. These should be indicated that now the planning and design with traffic signals could have an impact on road flow performance. Throughout this research, the previously stated short term design approaches have been designed to simulate to evaluate quality metrics such as automobile driving time, channel capacity, and Carbon dioxide emissions.[4]

By a new analysis on such a conceptual structure with unsafe driving traits on Chinese highways, recurrent lane changes are perhaps the most dangerous driving actions [5]. Lane modification have been categorized either as compulsory rather than conditional based mostly on intentions. Compulsory driveway modification is however recognized as pressured and otherwise essential changing lanes. This typically happens whenever an automobile is trying to cross from left and otherwise center lane towards the right lane to make to leave the motorway, or even when intending to change direction upon having entered the motorway. Voluntary lane change is often referred to as surface lane change but rather desired lane change. It usually happens when a driver wants to develop his or her viewpoint of the operating conditions.

This Traffic congestion problem is resolved by this study by giving appropriate parameters to simulate the real time situation in-order with all the obstacles which it will face. The parameters such as speed for each lane, types of vehicles (heavy goods vehicle, electric and automatic cars), length of the vehicle, maximum acceleration and deceleration are the inputs given in the simulation environment to estimate the total number of automobiles can fit in the motorway construction. Before that, the construction of lanes is designed with three kilometers in total, three lanes with 2 kilometers and merged into the left lane to decrease into two lanes with only one kilometer. The traffic overflow, its density, average travelled time duration and inter-arrival time between two vehicles are calculated to find whether we can fit the vehicles which can coordinate itself automatically while there is traffic overcrowding.

Research Questions:

1. How much vehicle can be accommodated in the three to two merge multi lane highway?
2. What will be the average time travelling, average speed, maximum overflow, and maximum throughput, that depends on the speed?

2 LITERATURE REVIEW

As per a new analysis, regular driveway changes seem to be the most unsafe driving actions mostly on motorway throughout China. It's indeed extremely beneficial for car drivers to encounter but also start practicing driving in numerous studies have demonstrated city traffic until being revealed towards the exact road. For this study, just one lane changing framework is designed specifically for dangerous drivers. The developed framework is being used in a motoring simulation model for motorway driving lessons. The simulations show that perhaps the intensity of lane changes could be modified by altering the percentage of dangerous drivers.[5] For such system application, the 6-lane highway with additional roadways has always been built. Autonomous vehicles have been developed as well as occur at unexpected times on both three dimensions in one way. The simulation software further designates the car's size, the driver's required velocity, and even the travel speed which the motorist would then implement at obscure whenever the automobile would be triggered. The customer automobile that has stopped in the emergency lane can still be restarted as well as integrated further into flow of traffic at every time.

Among the most mutual purpose of congestion problem is to reduce traffic delays, or even to maximize throughput on such a specific existing road throughout a given timeframe, during certain hours. Emerging design approaches are centered on ramp calibration influence to maximize portions linked by on-ramps. Majority projects in vehicular environments attempt to modify the red-to-green percentages of traffic signals at motorway junctions. It is the length of the vehiclesThe findings indicated that better the proportion of reckless drivers doubles the count of changing lanes.

A snippet control system had been used to construct the lane controller for such a fully independent Smart Motor. Driveway Change is an important directional movement sequence that includes, whenever the observational velocity of the smart motor is stable, originally planned tool path or even path racecourse manipulate. It has been well acknowledged which accuracy and ride quality have become the two primary criteria for lane - changing control. A quick feet control system and just a soft lane change route must be required to accomplish those certain two outcomes. Finally, simulation model of the lane change input devices was already finalized. A finding demonstrate which smart motor can incorporate extreme accuracy under that same supervision of an organized lane change trajectory and even the LCRC regulate.[**2**]

As per results obtained, the inter-car displacement has a significant effect on both throughput and average transmission time. When evaluated by comparing to both the simplified manual-driven scenario, the assertive motoring strategy that use vibratory motorist notice used in the second, highly developed results created superior results in such constraints. After this, the results validate the integration of a proposed design as well as the maintenance of certain innovation in a massive number of vehicles to gather data for enhanced road network but also declined motor vehicle accident possibility in real-world driving circumstances.[1]

This author demonstrates an alteration to SmartCap, an event road traffic simulation platform. SmartCap has undergone two modifications. Perhaps the most essential distinction would be that the required space by automobile actions has now become velocity reliant. This enables the generation of results obtained that are somewhat conventional in compared to earlier simulations. The second challenge was to enable for irregular actions throughout the interface stream. The goal is to further properly describe actual traffic conduct.[3]

The task allocation ideal method is adopted on an image space of 12 km length. The interstate highway part is divided in to other 12 portions, that are each 1 kilometres long. People consider two cases throughout the subsequent sections: Situations 1 and 2 display attire traffic flow on another roadway and non-uniform road conditions on a two-lane motorway with such a construction zone. Inside this research, 99 car-following design is being used. Focusing mostly on calibration outputs, three essential driver behavior parameters are chosen. Therefore, the capability with all vehicles involved has been enhanced– vehicles trying to behave like even the integrated way wouldn't really consider moving in such a change sort of way, but rather would proceed at a consistent speed drive.[6]

3 METHODOLOGY

It is the section called methodology where the process before simulation is implemented. The primary objective is to find the traffic flow and how much vehicles can be fitted into the highway. The object-oriented characteristics such as inheritance and encapsulation in the Python programming is used to establish the methodology of the simulation. The process starts by creating objects and classes for different types of entities. The methodology is classified into four parts to start the simulation process.

A. Lane construction
B. Vehicle attributes
C. Vehicle aspects
D. Simulation Recording

A. Lane Construction (Class Lane)

The lanes of the motorway are constructed in the class Lane. The Lane Id will be indicated as 0 when first one is constructed and then it will be followed by 1. The lanes can be constructed by using two methods, one can be creating one single long lane and the other one is by creating into small segments of lanes. The left lane is allotted as slow lane whereas the right lane is declared as fast lane. Furthermore, the left and right lane is attached parallelly to the present lane by using the function called attachLeft and attachRight respectively in the same class. The segments are attached to the left and right lane of the current lane by using functions includes wideLeft and wideRight respectively. Enter and Leave are the two functions added to the same lane. This Class Lane is constructed in the first part of the google Colaboratory notebook.

B. Vehicle attributes (Class Vehicle)

The Vehicle attributes are defined in the class Vehicles. The vehicle Id is created as O and then it will be added by next one. The situations such as overtaking, emergency braking and crashing are added in the same class. It starts by declaring

initialization to velocity, acceleration and start position. The overtaking function is developed in the class vehicle. It is created by using two conditions. First, it will check the distance of front side and back side if the distance is higher than the minimum fixed Left and right Lane are indication to move the vehicle to the next lane.value. Second one is check there is no vehicle in the next lane (nearby one). The adjustvelocity function adjust the velocity accordingly when the vehicle runs. ChangeLane function is used to change the lane when vehicles come close to avoid from crashing the vehicles. This Second part of the google colobaratory is Class Vehicle.

C. Vehicle aspects (Class Surround)

The vehicle aspects are added in the class surround to give access to the left, right, front, and back. The left and right indicates to move aside respectively. The frontLeft, frontRight, backLeft and backRight are the indiacation to move into the next lane from the present one. This Class Surround is the Third part of the google Colaboratory notebook.

D. Simulation Recording (Class Recording)

The Class Recorder is used to run all the events such as crashing, overtaking, braking, changeLane occurs during simulation. After the running, the process of simulation is stored in the separate pandas dataframe. The various events occurring in the class Recorder are mentioned below.

A. Emergency Braking:
It is the situation of braking when it happens during the simulation, it will be recorded.

B. Crash:
Crashing is recorded when any vehicles crash during the run in the simulation.

C. Enter:
Enter is the event when vehicle enters the lane, it will be recorded.

D. Leave:
Leave is the event which happened when a vehicle leaves the lane, this will be recorded during the simulation run.

E. End:
End is recorded when the simulation has come to end.

4 SIMULATION MODEL

The Simulation is the replication of the real-world events in virtual technology. This project is self-organizing vehicles created by using simulation process. It runs for various times to estimate the optimal simulation result. In this research, Throughput will be estimated along with traffic flow(volume), traffic density, average speed and average total travelling time. An environment is created using simPy.environment. The classes and functions are combined all together in a single environment using env.process. The simulation runs using env.run, all the events runs from the declared start and stop time. No events will run after the stop time, it will be ended.

The model of simulation is built by using the four sections below:

4.1. Model for the Motorway section

The model started by creating the lanes, before running the vehicles and drivers' behaviors to run the simulation. In this case, three kilometers of Lanes are developed by having two kilometers of three lanes and only on kilometer of two lanes. This is implemented using merge lane and the support of on-Ramp.

First, the left lane with 1000 kilometer is being created. Then, another 1000 is extended (which is l1), followed by another 1000 kilometer which is l2. The left lane of 3000Km is created into three segments. The right lane is created by using widenRight function same as the left lane. The on-Ramp is started from first segment by 1000 kilometers, which does not allow to change the lane and merge lane with 1000 kilometers are created. Further, ramp lane connected with right lane and the merge lane merges with Right and left lane. This can be seen in the Jupiter notebook and for the reference the code can be seen below in the Figure-1.

```
# Vehicles on the Motorway
N = 65
IAT =15

rec = Recorder(0, 1600, 1)

l = Lane(rec, 1000,speedLimit=60)
l1 = Lane(rec, 1000,speedLimit=60)
l2= Lane(rec,1000)
l.extend(l1)
l.extend(l2)
r = l.widenRight()


onRamp = Lane(rec, 1000)
mergeLane = Lane(rec, 1000, merge='R')
onRamp.extend(mergeLane)

l1.attachLeft(mergeLane)
l1.left = None  # don't move from the Motorway onto the on-ramp/merge lane
print(onRamp)
print(l)
print(r)
```

Figure-1

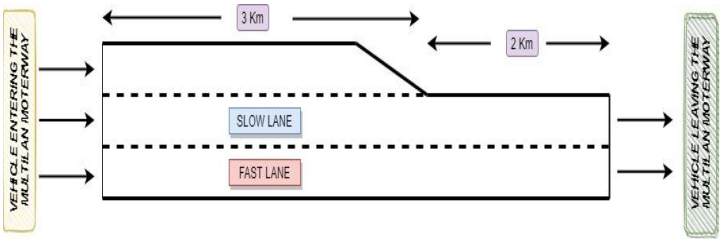

Figure-2

Speed limit is given for all the lanes as 60. This first step of the research is to develop three to two lane motorways. It is being created by using on-ramp. The Figure-2 is the lane pictorial representation.

4.2 Model for vehicles and drivers

The vehicles are the significant part to check the simulation. The vehicles of three types such as Tesla, FamilyCar and Heavy goods vehicles are used to accommodate the motorway. The parameters are given to all the types of vehicles according to its attributes. Family car is the fuel car, its braking speed is -4.0 m/s², Coast is -0.9m/s² and max acceleration is 3.2 m/s². For Tesla, it is electric car, brake speed is -8.0m/s², coast is -1.8 m/s² and max acceleration is 4.6m/s². The heavy good vehicles are larger and bigger in size and weight, its brake is -10.2 m/s² , coast is -2.5m/s² and max acceleration is 1.2 m/s². Even though diesel vehicles have higher velocity than electric cars, it has higher acceleration. This can be seen in the Figure-3.

Human behaviors depend on choosing lane and using interarrival time. The lane can be chosen by driver between the three lanes randomly by using weightage given. In the estimation of inter-arrival time, uniform distribution is used.

```
if vehicleType=='FamilyCar':
    self.a_brake = -4.0 # [m/s²]   Tesla: -8.0 # [m/s²]
    self.a_coast = -0.9 # [m/s²]   Tesla: -1.8 # [m/s²]
    self.a_max =    3.2 # [m/s²]   Tesla:  4.6 # [m/s²]
                    # Note: 2.5m/s² corresponds to 0-100km/h om 11s
    self.length = 8 # [m]  Length of the vehicle
    self.absolute_speed_time_tolerance = 2 # [s]
    self.relative_speed_time_tolerance = 5 # [s]
    self.far_away_in_front = 200 # [m]
    self.far_away_in_back = 80 # [m]
    self.min_action_time = 0.5 # [s]

    self.lane_change_time = 3 # [s]
    self.min_speed_diff = 2 # [m/s]

elif vehicleType=='Tesla':
    self.a_brake = -8.0 # [m/s²]   Tesla: -8.0 # [m/s²]
    self.a_coast = -1.8 # [m/s²]   Tesla: -1.8 # [m/s²]
    self.a_max =    4.6 # [m/s²]   Tesla:  4.6 # [m/s²]
                    # Note: 2.5m/s² corresponds to 0-100km/h om 11s
    self.length = 4 # [m]  Length of the vehicle
    self.absolute_speed_time_tolerance = 2 # [s]
    self.relative_speed_time_tolerance = 5 # [s]
    self.far_away_in_front = 200 # [m]
    self.far_away_in_back = 80 # [m]
    self.min_action_time = 0.5 # [s]

    self.lane_change_time = 3 # [s]
    self.min_speed_diff = 2 # [m/s]

elif vehicleType=='HGV':
    self.a_brake = -10.2 # [m/s²]   Tesla: -8.0 # [m/s²]
    self.a_coast = -2.5 # [m/s²]   Tesla: -1.8 # [m/s²]
    self.a_max =    1.2 # [m/s²]   Tesla:  4.6 # [m/s²]
                    # Note: 2.5m/s² corresponds to 0-100km/h om 11s
    self.length = 12 # [m]  Length of the vehicle
    self.absolute_speed_time_tolerance = 2 # [s]
    self.relative_speed_time_tolerance = 5 # [s]
    self.far_away_in_front = 400 # [m]
    self.far_away_in_back = 100 # [m]
    self.min_action_time = 1 # [s]

    self.lane_change_time = 5 # [s]
    self.min_speed_diff = 4 # [m/s]

else:
    raise ValueError('Unknown VehicleType:' +vehicleType)
```

Figure-3

The drivers' behavior such as crashing, overtaking, velocity acceleration is being checking for every simulation run. Crashing occurs if a vehicle does not have enough time to overtake another vehicle.

4.3. Traffic Generation

This is the part where four estimations will be estimate by using numerous values. This will help to find which values of the variables affects the simulation results.

A. Traffic flow or traffic volume:
   Traffic flow is the flow of the vehicles in the motorway, which is calculated by taking difference between the vehicle that enters the lane and which leaves the lane in the highway.

B. Throughput:
   Throughput is the aggregation volume between one direction lanes and the time. In this scenario, throughput is calculated by the difference between the last vehicle which leaves the lane and the first vehicle that leaves the lane.

C. Average speed:
   Average Speed is the calculation of the ratio of total lane length and total travelling time of the vehicle. After that, average will be taken by using the number of cars selected.

D. Traffic density:
   Traffic density is the ratio of throughput and the average total travelling time taken for the highway.

E. Average Total Travelling time:
   Average total travelling time is the mean of the total time travelled by the vehicles all through the motorway. In this scenario, all the vehicles total time which passes through the highway from the enter lane to the leave lane is being calculated. Then, the average time will be estimated according to the total number of vehicles selected while simulation.

Further, the additional parameters of vehicles are changed various values to simulate the different results.

A. Far away in front:
   Far away in front is the minimum distance to maintain. It is taken as 200 in our case.

B. Far away in back:
   Far away in back is the minimum distance to maintain. It is being taken as 80 for this case.

C. Min action time:
   It is the minimum time difference to initiate overtaking. It is taken as 0.5 for every vehicle.

D. Lane change time:
   It is the maximum time taken to change the lane. It is taken as 3 for all the vehicles.

E. Min speed diff:
   It is the minimum speed difference to initiate overtaking. It is taken as 2 for all the three vehicles.

F. Length of the vehicles:
   The vehicle's length has given separately. Tesla is taken as 4meters, Family Car is chosen as 8meters and Heavy Goods Vehicle is chosen as 12 meters.
   The traffic mix of vehicles are Tesla, Family Car and Heavy Goods vehicles. The tesla, heavy goods vehicles and Family car are given as 25%, 15% and 60% respectively in the multilane highways.

4.4. Data Collection

The model process is recorded by using recorder function. It comprises of a various parameter to verify the simulation run. This recorder data is saved into separate pandas Dataframe file.

5 RESULTS AND INTERPRETATION

The simulation has run numerous times to give optimum result depends on the parameters includes like, average travel time, density, flow, mean speed, and throughput.

A. SIMULATION 1:

For this simulation, we used 90 vehicles for N, inter-arrival time is fixed to 40 seconds, and the simulation stop time has made as 1800secs. It can be seen in the Figure-4.

- N= 90
- IAT=40
- Stop time=1800

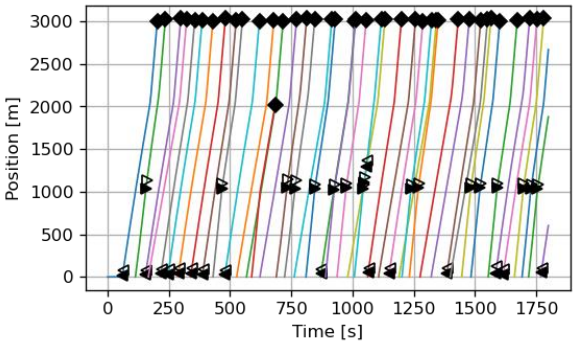

Figure-4.

Interpretation1:

The Position-Time graph shows that there is a vehicle which does not ended at the end. Because of lower inter-arrival time. By using these inputs, throughput has obtained about 91 cars/hour, while density, average speed, Traffic flow, and average time travel are 3.22m/s, 72m/s, 73cars/hr and 31 secs.

B. SIMULATION 2:

In this simulation, N=70 that is 70 vehicles are allotted in the motorway with inter-arrival time of 25 secs is given. The stop time for simulation has given as 1800 secs.

- N= 70
- IAT=25
- Stop time=1800

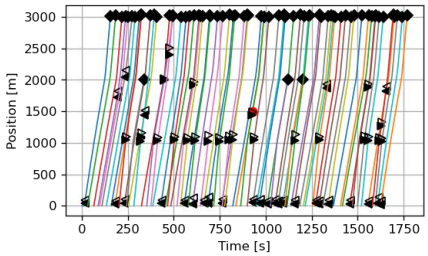

Figure-5

Interpretation2:

The position-time graph explains that one of the vehicles has not reached the end because the time has ended. It shows that the inter-arrival time is lesser for 60 vehicles. By using these inputs, throughput has obtained about 156 cars/hour, while density, average speed, Traffic flow, and average time travel are 5 m/s, 65 m/s, 137cars/hr and 46 secs.

C. SIMULATION 3:

In this simulation, 60 vehicles are used to run in the highway with inter-arrival time of 20 sec, with random variable distribution.

- N=60
- IAT=20
- STOP TIME= 1400

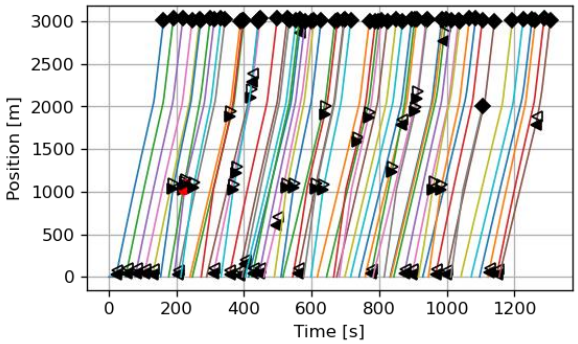

Figure-6

Interpretation 3:

The Figure 6 is the graph of the Position – Time. It explains there is no crashes in the graph. By using these inputs, maximum throughput has obtained about 182 cars/hour, while density, average speed, Traffic flow, and average time travel are 6 m/s, 66cars/hr, 152 m/s, and 50 secs.

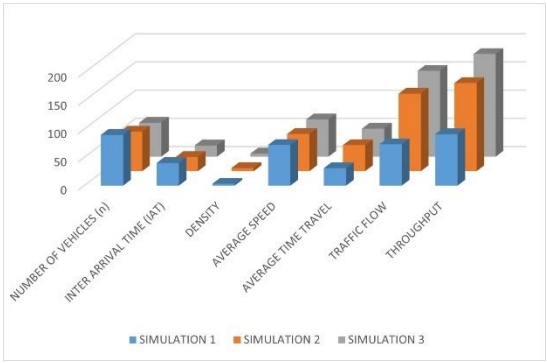

Figure-7

This Figure-7 shows the pictorial view of the three simulation results and it can be found that simulation 3 is optimum one. The figure-8 represents the parameters value in a table representation for analysis.

NO OF SIMULATION	SIMULATION 1	SIMULATION 2	SIMULATION 3
NUMBER OF VEHICLES (n)	90	70	60
INTER ARRIVAL TIME (IAT)	40	25	20
DENSITY	3.227455485	5.454700855	5.530959752
AVERAGE SPEED	71.9904155	65.85451295	66.05936577
AVERAGE TIME TRAVEL	30.93875	46.09	49.695
TRAFFIC FLOW	73.27093708	137.3350151	152.2781568
THROUGHPUT	91.25475285	156.133829	181.9713564

Figure-8

6 REFLECTIONS AND FUTURE WORKS

The traffic overcrowding is the major issue in most of the cities. This real-life problem can be resolved by simulations. In this research, the attributes of vehicles and actions of driver's were used to simulate the process. The different parameters have simulated numerous times and maximum throughput is being reported. The simulation which has chosen as optimum model

has obtained maximum throughput is 182 cars/hour and average travel time is 50 secs. These values shows the real – time case of multilane motorway very closely. In future, attributes such as lane changing and automatic speed limit change can be implemented to get better model to help minimize the overcrowding traffic.

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