A Matlab traffic Simulator for street intersections

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***Abstract*—Intelligent road intersections equipped with sensors and communication infrastructure are proposed by this work to reduce accidents at road crossings. This publication presents a simulator developed in MATLAB to understand the intersection environment. Through computational modeling of road conditions, traffic intensity, and weather conditions, it is possible to predict the effects of actions to obtain more fluidity and safety on the roads.**

Scenarios can be simulated on a computer until they are sufficiently assertive to be technically developed and included in vehicles and road infrastructure. The versatility and ease of testing scenarios are the great contribution of simulators, allowing a faster and cheaper way to obtain study results for traffic problems. Traffic management, in particular, needs new multidisciplinary approaches focusing on vehicular communications, taking advantage of wifi and optical communications. The need for more connectivity is driven by the deployment of 5G communications, the development of autonomous vehicles, and Smart Cities projects.

***Index Terms*—Traffic, Simulator, Smart city communications**

I. Introduction

Smart Cities is a cross-sectional area of research, part of the UN Agenda 2030 [1], which includes security, communications, transport, energy, environmental issues, and the digitization of public services in general.

One of the issues in the discussion of smart city is security and traffic management, especially for private vehicles. Despite the significant increase in technology in autonomous vehicles aimed at the safety of passengers and public road users, statistics have stagnated in recent years in reducing accident rates [2]. Traffic congestion in city centers and the associated environmental impact are among the main challenges posed today to researchers in the field of mobility.

This work aims to contribute to the improvement of urban mobility in terms of increasing the capacity of road infrastructures and reducing vehicle emissions. The present work is included in the domain of "Intelligent Transport Systems", namely in the simulation of vehicle traffic.

This article is divided into the following sections: Introduction in section, I; in section II describes the methodology used to prepare the article; in section III state of the art on traffic simulator), section IV presents a Matlab simulator for simulating traffic at intersections, in section V presents the first simulation results with Matlab and Conclusions in section VI.

II. Methodology

The traffic simulator at intersections presented in this article was developed in MATLAB, with the objective of evaluating the impacts on traffic of variables such as the number of vehicles in each lane; climatic conditions; vehicle's intention to go straight ahead, turn right or turn left; use of traffic lights or considering a road without traffic lights (for autonomous vehicles); considering the priorities, if there are no traffic lights.

Traffic simulation tests were performed under various conditions parameterized in a GUI[1], and the results were accumulated in a database. At the end of each processing, the system reassesses all data from the simulation history and presents graphic statistics on waiting times for vehicles in each lane, the number of vehicles that passed through the intersection, waiting time according to weather conditions, processing comparisons of vehicles with and without traffic lights.

III. State of the art

The new smart city (SC) related use case scenarios include external environments and must have a differentiated approach. Depending on weather issues, sun exposure, and obstacles cannot be avoided, such as trees, buildings, and slopes. Another point in the external scenarios is a large number of anomalous events, animals, pedestrians, and cyclists that have to share the same street safely [3]. Considering new AV use and use cases and safety, we must consider the pedestrians, bicycles, and motorcycles that share the road. As the leading cause of accidents is human error, road safety will involve solutions where everyone feels included and can safely share a lane [4]. Several simulators on the market today support traffic planning and simulation, some at the micro level and others at the macro level of a smart city. Table I refers to these simulators.

MATLAB provides the Driving Scenario Design APP to construct graphical street scenarios and generates the MATLAB/SIMULINK code that supports the development of simulators, both for academic and commercial purposes, Fig. 1.

A. Positioning issues

In the future of SC with VA, a crucial point for AVs and traffic managers is to know precisely where everyone is

[1]A GUI (graphical user interface) is a system of interactive visual components for computer software.

Reference	Simulator name	Description
[5]	Vissim Trafic Simulator	Microsimulation Urban Traffic
[6]	Paramics	Microsimulation Traffic
[7]	Aimsun	Mobility planning for cities
[8]	DYnameq	Traffic/pedestrians Simulations
[9]	AnyLogic	Traffic Simulations
[10]	TransModeler	Traffic Simulations
[11]	SUMO	Traffic Simulations
[12]	OpenTrafficSim	Micro/macro/meta-simulation

TABLE I
SIMULATORS REFERENCES.

Scale	Description	Limit of visibility (m)	Attenuation dB/km
1	Dense fog	0 - 50	315
2	Thick fog	50 - 200	75
3	Moderate fog	200 - 500	28.9
4	Light fog	500 - 1000	18.3
5	Thin fog	1000 - 2000	13.8

TABLE II
INTERNATIONAL VISIBILITY CODE WITH METEOROLOGICAL RANGE [16]

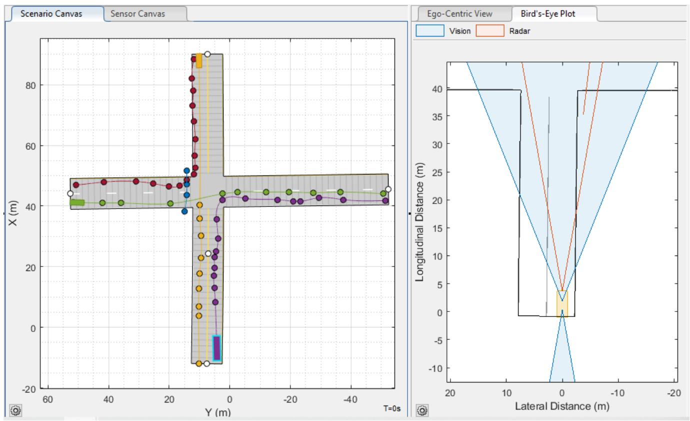

Fig. 1. APP Driving Scenario Design from MATLAB.

involved in the context of the city. We need reliable positioning information for AVs, pedestrians, and cyclists. Everyone who shares the scenario needs to be identified, not only as a point, but we need to know if it is a public transport vehicle, a priority vehicle, an AV, or a human-driven vehicle (such as a bicycle). GPS does not provide the necessary precision in urban settings. The scenario worsens in some areas of the city, hidden by buildings and other obstacles. The new technology must respond to this requirement [13]. Particularly at crossroads in the city, vehicle positioning has to be reliable to the centimeter, given the complexity of priority calculations and positioning verification of all vehicles involved.

B. Atmospheric problems and obstructions

In outdoor scenarios, the level of complexity in communications increases, considering that the environment is exposed to bad weather, such as rain, fog, and snow [14]. In the case of dense fog, visibility can be from zero to 50m, according to the international visibility table II for weather conditions and precipitation [15]. This is a road safety problem and a problem for outdoor optical communications. Some critical aspects of potential disturbances to be considered when using systems with optical communication technology are presented below [14]:

a) Fog - the first challenge of optical communications is dense fog. Rain and snow have little effect on optical technology [17].
b) Absorption occurs when water molecules suspended in the Earth's atmosphere extinguish the photons. This causes a decrease in the power density of the rays and directly affects the availability of optical systems.
c) Scattering is caused when waves collide with scatterers (particles scattered through the air). The physical size of the dispersers determines the type of scattering.
d) Physical obstructions such as large vehicles or buildings can temporarily block an optical communication system's direct line of sight. This may only cause minor interruptions, although transmissions may automatically resume.

C. Safety

Increasing complexity and the number of IoT connected to the network bring vulnerability. With the possibility of hackers breaking into the system and causing severe damage to SC management, security issues have led researchers to try solutions based on AI, Machine Learning (ML), and Blockchain [18].

D. Sustainability

Sustainability has been posed as a technical issue and environmental awareness. On the one hand, more connectivity will require more energy with more IoT on the network. Today, the production and management of energy is a susceptible problem, so projects and equipment that include green technology or reuse energy already available are privileged [19].

IV. MATLAB TRAFFIC SIMULATOR

One of the objectives of the traffic simulator is to analyze the waiting times of each vehicle to pass the intersection. Some features that influence this objective are vehicle direction, speed, weather conditions (which influence speed), the number of vehicles on the road, and whether traffic lights control the intersection.

This simulator is developed using the MATLAB matrix technique. The entire system is a matrix, with a road drawn by occupying the cells in the matrix. Car movement follows the principle that it can only be moved to the next cell if it is free, and when moving, it releases its previous position. The scheme in Fig: 2 illustrates this principle.

Vehicles are randomly generated on any road, and their direction is randomly determined (go straight ahead, turn left or right). For each execution cycle (time), the simulator moves the vehicles in the predefined direction randomly when they enter the road (scenario). Each movement (a cell) represents a unit of time, which for each vehicle can be considered effective movement time or waiting time on the road. They are managed by each vehicle in the context, its position, and waiting time

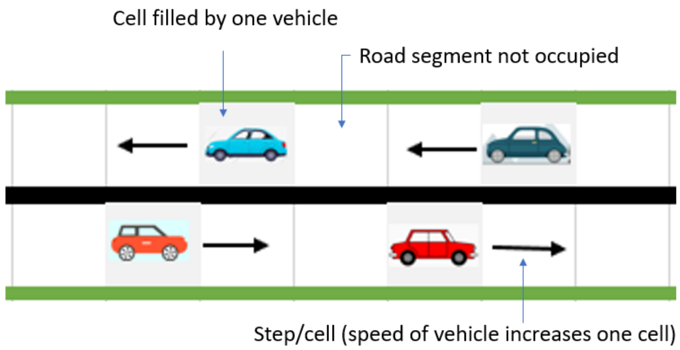

Fig. 2. Traffic simulator matrix engine.

on the road (the time in which the vehicle is stopped because there is a vehicle stopped in front of it or waiting for the traffic light). Random cars are created using the MATLAB function *rng(seconds,'multi Fibonacci')*. This initializes the random generator based on the current time (second), allowing you to get more randomness according to the computer's time. A road traffic simulator for intersecting roads was created in MATLAB to generate traffic information on roads, vehicle speed, waiting times due to changes of direction, and delays due to atmospheric issues, Fig. 4. The simulator uses a GUI

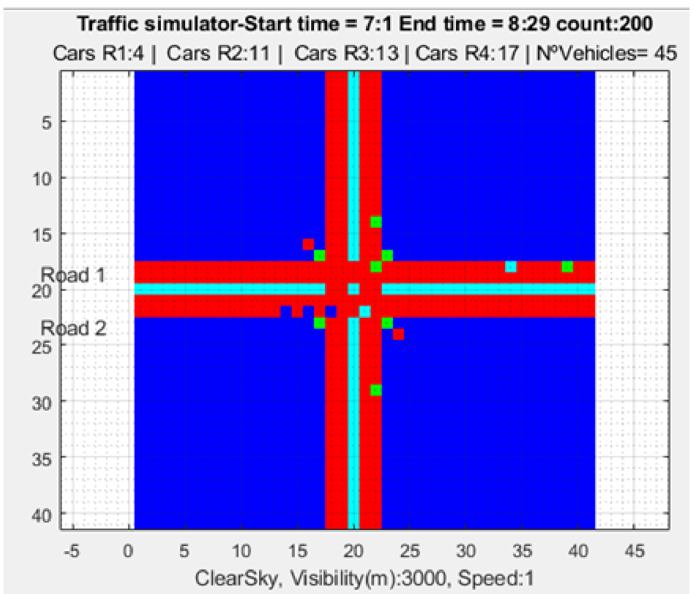

Fig. 3. Traffic simulator intersection image

to the input variables:

a) Simulation execution time;
b) Vehicle speed;
c) Generation times of new vehicles on the road with a random algorithm;
d) The maximum number of vehicles admitted;
e) Time interval for new random vehicles in the street;
f) Uses traffic lights or not;
g) Weather conditions.

The simulator has the following features:

a) The system creates random cars on the road (randomly placed on a road too);
b) Each car can go straight, turn right, or turn left (defined with different colors);
c) Near the intersection, the system calculates whether you can go to the intersection by looking at the priority roads;
d) Can configure the speed of the cars (all vehicles with the same speed are admitted);
e) We can configure the conditions of the weather, and this influences the speed of the vehicles);
f) We can configure to work with traffic light or not. Time for traffic light is configurated;

As output data, the system generates information in excel, and presents graphs and statistics of:

a) Gives the number of cars that passed on each road;
b) Processing time, and actual date ;
c) The total waiting time for each route with a traffic light and without traffic lights;
d) The total waiting time for each route by weather type;

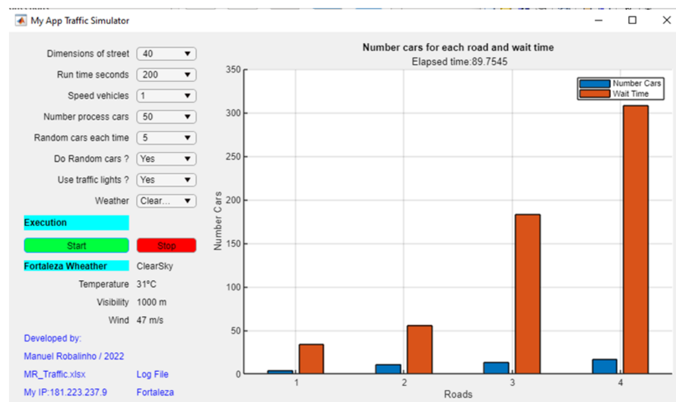

Fig. 4. GUI Traffic simulator

Upcoming improvements to the simulator include:

a) Reading of the positioning by the VLC communication of the V2I;
b) The allocation to the model of weather conditions, influencing the distance between vehicles and the VLC communication process;
c) Transposition of the simulator to Simulink flowchart.
d) Inclusion of physical properties of vehicles in the simulator, using Simulink.

A. *Algorithm*

The basic algorithm that process the simulation its presented at algorithm 1.

V. Results

The results were calculated based on 50 simulations where only the use or not of traffic lights and climatic conditions varied. As already described, changing weather conditions influence the speed of vehicles. More adverse conditions generate a lower speed in the simulator vehicles. For simulation

```
Input: Input speed vehicle (SPEED)
       Input time processing (TP)
       Input weather conditions (WC)
       Input number cars in scenario (NC)
       Input use traffic lights ? (TL)
       Input Time traffic lights (TTL)
Data: Weather table (WT)
Result: Wait time for each vehicle
scenario initialization;
while not at end of TP do
    time initialization;
    if Use Traffic Light is ON and TTF then
        compute ON to Traffic light 1 ;
        compute OFF to Traffic light 2 ;
    else
        compute OFF to Traffic light 1 ;
        compute ON to Traffic light 2 ;
    end
    while not at end of NC do
        random new car on the street;
        read position from current car (CC);
        compute new position for CC;
        if New position for NC is available AND
          Traffic Light is OFF then
            go to next new position CC;
            reset older position CC;
        else
            wait for new position to CC;
            add wait time for CC;
        end
    end
end
```

Algorithm 1: Traffic algorithm

Traffic Light	Weather	Average wait time	Percentage
NO	Clear Sky	10,77	
NO	Dense Fog	101,00	
NO	Light fog	13,50	
NO	Mild fog	14,00	
NO	Thick fog	81,33	
NO	Thin fog	17,50	
Sub total NO		28,78	5%
YES	Clear Sky	476,00	
YES	Dense Fog	260,00	
YES	Light fog	610,00	
YES	Mild fog	367,00	
YES	Thick fog	241,00	
YES	Thin fog	677,67	95%
Sub total YES		507,93	

TABLE III
SIMULATIONS RESULTS TABLE [16]

purposes, all vehicles assume the same speed in the scenario. The simulation results are presented in table III:

Based on the table III, traffic without traffic lights accounts for 5% of the total waiting time, and traffic with traffic lights accounts for 95% of the delay. Using traffic lights, we have a waiting time 17.65 times higher than traffic without traffic lights.

In the same data on the table III, there is a marked waiting time based on weather conditions. With clear weather, an average delay of 10.77, and with dense fog an average delay of 101.00. (a ratio of 9.38 plus delay)

Traffic simulator MATLAB tests identify greater complexity in vehicles that are going to turn left, as they need to cross more lanes, so it will take longer to obtain lane availability in congested traffic lanes, Fig. 3. Therefore, accurate positioning information is critical in traffic management, and the need for communication of this positioning between the V2V and V2I must be efficient.

Considering the little space in which vehicles transit during an intersection, assessing the greatest risks in crossing roads (if the vehicle intends to turn left or right), and taking into account the atmospheric conditions, it is easily inferred that We need a very assertive communication of the positioning of each vehicle (with an error of less than one meter) and that is a communication with a minimum error.

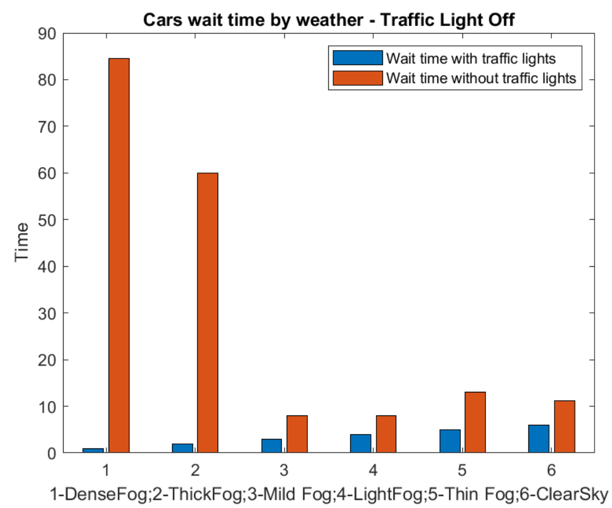

Fig. 5. Statistic about Wait time in weather conditions

From the graph in Fig. 5, we can see that weather conditions have a lot of influence on the flow of traffic. Bad weather, especially foggy weather, causes many stops in vehicles and a lower speed that causes congestion. The simulations also show a great influence on traffic in the use of traffic lights, regardless of weather conditions. Although the traffic light times for the roads can be adjusted, the impact compared to use without traffic lights is very relevant in the simulations carried out. From the graph in Fig. 6, we can see the impact of using traffic lights on the road, as it is the factor that causes greater congestion at road crossings.

VI. CONCLUSIONS

The simulator presented was able to perform mass simulations for various traffic scenarios at a road crossing. The data generated made it possible to obtain statistics on the behavior of the traffic, taking into account the direction of the traffic of

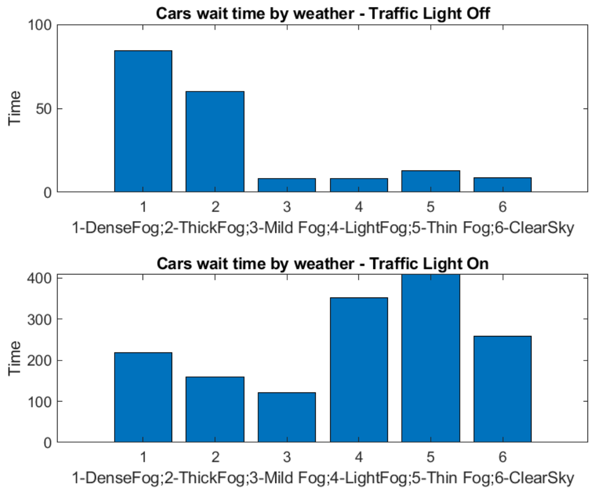

Fig. 6. Statistic about Wait time in weather conditions and traffic lights

the vehicles, the weather conditions, the speed, the number of vehicles on the road, and the use or not of traffic lights.

Thus, it is expected that ideas will be presented for the challenges of sharing a road with pedestrians, cyclists, and motorcyclists and using technologies that allow the use of AV, given that it proved to be the most interesting scenario in these simulations.

At the city level, one of the main traffic issues is the intersections. In this context, presenting viable solutions that allow a crossing without traffic lights and coordinate automatically is a great challenge.

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