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TRAFFIC SIMULATION FOR MIXED TRAFFIC SYSTEMS

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ABSTRACT

Traffic problem is classified into single and mixed, especially in most developing countries, where motorbikes are used as the most popular transportation system. The aim of this paper is to introduce the motorbike symbol into the traffic light control system to separate cars/lorries indicator from that of motorbike. This is likely to give reliable results than if traffic simulation is developed mainly for homogeneous traffic systems. The outlines of simulation model for mixed traffic system are presented in this paper.

KEYWORDS: Simulation Model, Mixed Traffic Systems, A Traffic Simulation Program, Driver-Vehicle-units (DVUs), fuzzy control and Intersection- junction

INTRODUCTION

Traffic systems in most countries are different with those in developed ones, where motorbikes are used as a major transportation system. For example, in major cities in Cross River State, according to Cross River State vehicle register department (2010), approximately 50 thousand motorbikes were registered per 1.8 million people in comparison with 10 thousand cars. Flexibility is one of motorbike's specific characteristics of transport rules for it is not as strict as those for cars. Besides, usually on the same roads and especially intersections, many types of vehicles such as car, bus, motorbike, bicycle, truck, and primitive means of travelling together. They generate a mixed traffic system.

In addition, the development of transportation infrastructures hardly keeps pace with a growth of economy, so construction of distinct ways for them is rarely possible. Consequently, traffic problems become more serious day by day. By polluting the air, increase in fuel consumption, loss of productivity and time, delivering of goods and service are delayed. Many alternatives such as assigning different working and studying starting times for companies, offices, schools and universities, reorganizing traffic flows, and developing infrastructures have been suggested and applied, but the situation has rarely improved. One of the reasons is that they are proposed and applied in trial and error manner to the real systems without any validation. It makes the situation worse, wastes of money, time, and effort. Much research has been done and applied successfully in developed countries. When recommended, a framework for a dynamic and automatic traffic light control expert system combined with a simulation model, which is composed of six sub-models coded in Arena to help analyzing the traffic problem (Wen,2007).The model adopts inter-arrival and inter-departure time to simulate the arrivals and departures of cars on roads. Some researchers proposed the development, structure, and evaluation of traffic-control-system simulator by PIM (Parallel Inference Machine), (Takahashi,*etal,2002*). Description of a microscopic traffic model of an urban district and the analysis and problem solving traffic congestion based on actual data is its objective. There suggested models for a vehicular traffic flow based on partial differential equations and their extensions to networks of road, (Herty, *etal,* 2006) fluid dynamic traffic model is simplified and a new traffic flow model is derived based on ordinary differential equations (ODEs). Optimal problems controlled by the ODE model were considered and the optimality system was derived. Because the traffic systems in developing countries have distinct characteristics in comparison with homogeneous ones in developed countries, the aforementioned models are unlikely to give reliable results if applied. Furthermore, many of the proposed fuzzy techniques did not consider case studies of real-case traffic junctions. In this paper, we proposed a traffic light control system that can be effectively used for a mixed traffic light in the junction with multiple intersections. The system allows communications with neighboring controllers and manages phase sequences and phase lengths adaptively according to traffic density, waiting time of vehicles and congestion. Therefore, a study on developing a traffic simulation program for mixed traffic systems is presented.

OBJCETIVE

The homogeneous traffic system does not treat the motorbike separate from other vehicles such as cars and lorries. The aim of this paper is to introduce a separate light control for motorbike, cars/lorries. The objectives include reduction of the traffic congestion for mixed traffic system on the intersection road and also to provide a free

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flow of traffic for the separate transportation systems.

LITREATURE REVIEW

There are many factors that lead to traffic congestion such as the density of vehicles on the roads, human habits, social behavior, and traffic lights system. One major factor is due to the traffic lights system that controls the traffic at junctions. In Nigeria, software for traffic dispersal are rather ineffective during peak hours. Traffic policemen are deployed at traffic intersections everyday in order to overcome these congestions during peak hours, thus, one of the roots of the problem is due to ineffective traffic lights controllers. With effective control of the intersections, it is believed that the overall capacity and performance of urban traffic network could be resolved. There are several types of conventional methods for traffic signal control (Bart,1999), however, they fail to deal effectively with mixed, complex and time-varying traffic conditions. Currently, two types of traffic lights control are commonly installed in Nigeria and many parts of the world: the preset cycle time (PCT) and vehicle-actuated (VA). Due to the deployment of a large number of traffic police in the city during peak hours, it is evident that these types of traffic lights controllers are inadequate. Furthermore, they have been around for many decades and, thus, there is a need to research on new types of highly effective practical traffic lights controllers.(Yen, *etal* ,1995). In traffic lights control, a number of researchers have applied the fuzzy control technique in only one intersection traffic junction, were as multiple junction is not considered. Many of these approaches are not suitable for the case of successively locating traffic intersections or multiple intersections in mixed traffic systems. In urban areas, many traffic lights are located close to each other due to the proximity of a number of intersections, thus, in order to solve traffic problems effectively, the system must be able to consider neighboring controllers and also the overall traffic situations. To show the effectiveness of the proposed traffic lights controller, a simulator is developed for a mixed traffic control system and complicated traffic junction. However the simulator compares the proposed simulator program for traffic lights system to the existing types of traffic lights controllers which are available in many parts of the world. A phase is represented by drawing the traffic flow of the green lights. The capacity of the link is defined as the maximum number of cars that are able to exist between the intersections or link (Devinder, *etal,*1994).In Fig. 1, N, W, E, S stands for North, West, East and South respectively and a graphical representation showing link, cycle and phase in a traffic lights control system is given. In this paper these labels are used to identify the branch of road in each intersection.

Preset Cycle Time (PCT) Controller This type of traffic control has preset time for green, orange and red light for each phase, and the duration of each phase in one cycle is set according to its program. This preset time does not change according to the conditions of the traffic flow. The disadvantage of this method is that if there is congestion in a particular road junction, the green lights will not be extended and the next phase is continued without considering the density of the cars and motorbike at any of the junction.

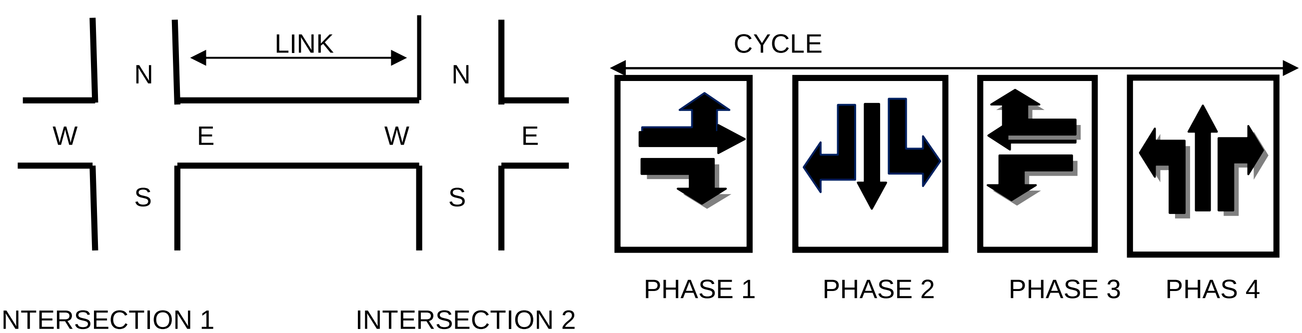

Figure 1: Graphical representations showing Link, Cycle and Phase in a typical traffic lights control system

METHODOLOGY/ DISCUSSION

Many unique characteristics support the differentiation of the traffic system in most developing countries from that of developed countries. The most distinctive characteristics are the transportation infrastructure and superstructure, driver-vehicle-units (DVUs) and their behaviors, and traffic flow. The DVU terminology is used to reflect the fact that movements are affected by both vehicular and driver characteristics (Jin, *et al*, 2004). A traffic system consists of a road network, DVUs, and traffic control system. For the road network including nodes intersections and arcs (roads) connecting nodes, a sub-lane notion is used for two–wheeled vehicles (bicycle, motorbike and tricycle). The road network's attributes such as the numbers of nodes and arcs, their sizes, and the numbers of lanes and sub-lanes in each road are considered in the simulation model. To reflect the DVU's behaviors, the physical,

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dynamic, and other relevant characteristics are also considered. The physical characteristics comprise the types and sizes of vehicles, while the dynamic ones consist of maximum and minimum velocities, and minimum, mean, and maximum accelerations/decelerations of vehicles. The traffic control system at intersections includes a traffic light system and traffic circle. In order to imitate the specific characteristics of the mixed traffic system, many techniques and logic models have been applied. A vehicle referring technique based on a three-dimensional coordinate system has been used to model the vehicles' locations on the mixed traffic road. Since vehicles may occupy any lateral position across the road's width, this technique can accurately represent the vehicle's movements. Vehicles are symbolized by colored rectangles of size corresponding to their real sizes. If two or more types of vehicle have the same size but different dynamic attributes, they are shown in different colors. Their locations are determined by (x, y, z) coordinates, in which the (x, y) coordinates describe the locations of vehicles on the same road, while the z-coordinate is used when an overpass system exists. Many logic models have been applied to simulate DVU behaviors, such as car-following, free acceleration, lane-changing, direction-changing, stop-run, and intersection-conflict models. The simulation model assumes that the acceleration/deceleration of the following DVU depends on its current speed, control speed, and the perception-reaction time of driver. The control speed is defined as the minimum value of vehicle's maximum speed, lane/sub-lane maximum speed, and driver's desired speed. The perception-reaction time of the driver depends on the current spacing, desired spacing between it and lead vehicle immediately in front and the status of its local leaders, When moving on the road, if the distance from, a DVU to a local leader is less than a predefined critical value(d0), it will follow its local leader with an acceleration/deceleration that is computed by equation (i),according to the car-following model. If the distance is more than the critical value, its movement is guided by the free acceleration/deceleration model, as in equation (ii).

$$a_n(t) = \alpha \frac{v_n(t-T_n)^{\beta} \; \Delta v_n(t-T_n)}{\Delta x_n(t-T_n)} \quad \ldots\ldots \quad \text{(i)}$$

where,

$$\begin{cases} \Delta v_n = v_{n-1}(t) - v_n(t) \\ \Delta x_n = x_{n-1}(t) - x_n(t) \end{cases}$$

in which, $a_n(t)$ is the acceleration/deceleration of vehicle n at time t; α, β, and γ are factors that are determined as shown in Table A. Because the value of acceleration and that of deceleration are different, each coefficient has two values. T_n is the reacting time; $v_n(t)$ is the velocity of vehicle n at time t; $x_n(t)$ is the position of vehicle n at time t; and Δv_n and Δx_n are the differences in velocity and distance, respectively, between the two vehicles.

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TABLE A:

COEFFICIENTS

Coefficient	Acceleration	Decelerate
α	8.51	13.34
β	-1.57	1.29
¥	- 0.78	1.55

$$a_n = \begin{cases} a^{+}_{max.n}: & v_n < v_{traget.n} \\ 0; & v_n = v_{target.n} \\ a^{-}_{n.n}: & v_n > v_{traget.n} \end{cases} \qquad \text{(ii)}$$

In which $a^{+}_{max,n}$ is the maximum acceleration of vehicle n, $v_{target,n}$ is the control speed of vehicle n, and $a^{-}_{n.n}$ is the normal acceleration of vehicle n. Lane/sub-lane-changing behaviors can occur when a DVU wants to move to another lane/sub-lane that allows its desired speed, or dodge obstacles, or change to a suitable lane/sub-lane before changing its direction. The lane-changing model can imitate these behaviors via a modification that enables it to simulate the different lane changing behaviors of different types of vehicles, as mentioned in the previous section. Before changing lane/sub-lane, DVUs have to look for suitable gaps. Having found such a gap, a DVU will accelerate without exceeding the maximum safe speed concerning new lead and follow vehicles. Before entering an intersection, a DVU has to check the traffic lights and change to a suitable lane/sub-lane to change its direction. The consecutive direction of a DVU such as turn-left, turn-right, or straight ahead follows a direction-changing distribution that is observed and collected from the field. Changing-lane/sub-lane activity is implemented when a DVU remains a stipulated distance from the intersection. In the case of a green traffic light, the DVU will enter the intersection; otherwise it has to decelerate to stop at the stop-line or join the queue. A stop-run logic model is applied to simulate these activities. The intersection–entering behaviors of DVUs differ remarkably depending on the presence or absence of a traffic circle. In its absence, suitable intersection–conflict models are used, in which different priorities are assigned for DVUs concerning the directions that DVUs are entering and exiting. In its presence, if the DVU takes the first exit from the traffic circle, it usually moves toward the right, otherwise, it approaches the traffic circle.

However, these aforementioned techniques and logic models are only representative ones; other techniques and logic models were also applied to simulate the characteristics of the mixed traffic system.The main function of RoadStruct-program is to convert data collected from the field into simulation data as it simulates the behaviors of the traffic system. The obtained results are recorded on two different formatted files. One is used to make reports, which are the user's expected factors, while the other is an animation file used as input data for the next program . This program supports the analysts in observing or analyzing suggested alternatives or scenarios through the animation displays.

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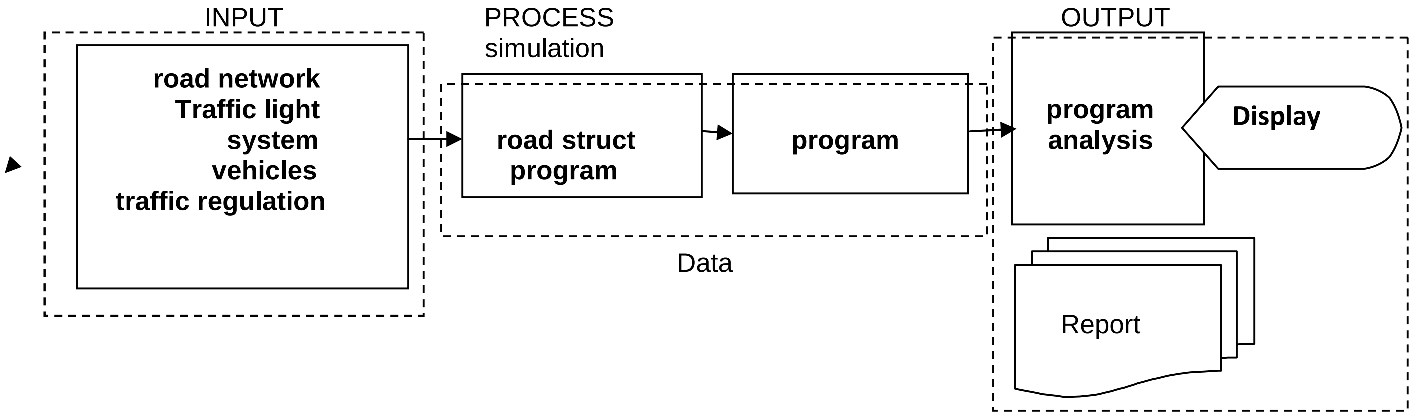

Fig 2: The sequent processes of the simulation program

Some factors or indexes such as Volume IN, Volume OUT, Average Speed, and Density Index are used to validate the simulation model and evaluate the simulation results. These factors are recorded directly or indirectly through parameters obtained from counter machines set up at all road inputs and outputs. Among these factors, Volume IN (VIij -vehicles/minute) is the average number of vehicles of type i entering the system on road j, Volume OUT (VOij -vehicles/minute) is the average number of vehicles of type i exiting the system on road j, and the Average Speed is determined through the vehicles' travelled distance and time. The density of traffic is determined by using a formula provided, (Helbing,2009).this is for the homogeneous traffic control system.

Mixed Traffic Light Architecture

Main function of this sub-program is to translate the physical traffic system information into required standard simulation data. There are required basic data including a physical road network, traffic light control system and direction system. The suitable coordinate system is used to present the physical road network shown on the road network map. The sharp, width, length, barriers, and lanes of every road are necessary information. The structure of intersections in the network is other important information, because usually there do not exist two similar intersections. Besides, the network maybe include traffic circles and similarly with intersection each circle has its own sharp, size and location on the network. The details is as follow:

1. The junction is an isolated four-way junction with Traffic coming from the north, west, south and east directions.
2. When traffic from the north moves, traffic from the West, south and east stops, when traffic from the South moves, traffic from the west, north and east Stops and when traffic from the north and south Moves traffic from east and west stops.
3. As shown in Fig. 3 there are left and right turns considered for each of side. Each side has maximum of two turns, one to right and another to left.
4. The Traffic Light controller will observe the density of the north and south traffic as one side and the west and east traffic as another side.
5. The minimum and maximum time of green light is 5 seconds and 120 seconds respectively.

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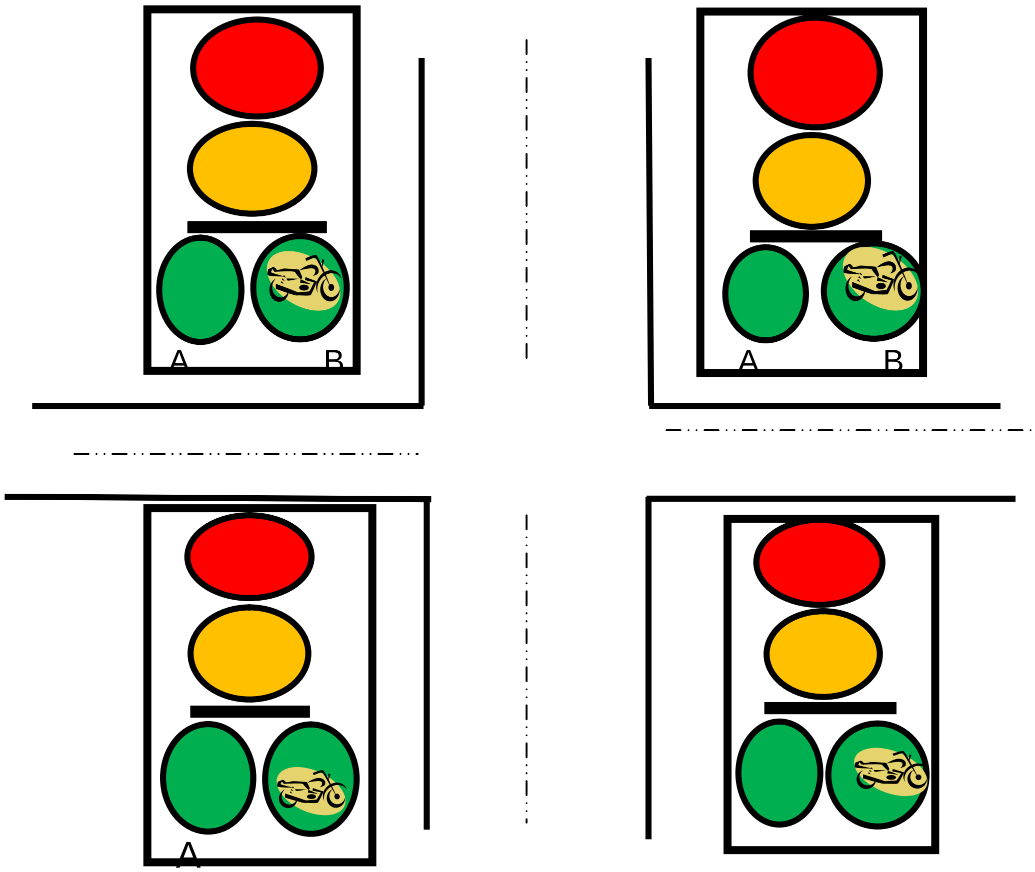

Fig. 3: Traffic Light Control Structure

The traffic light control system presented by its location on the network at intersections and direction system used to guide the vehicles when travelling on the roads as well as make decisions at the intersections or limits the moving spaces as controlling data of any network. The green light time is adjusted and divided into two, for each of the option A (for cars) and B (for motorbikes) to show one after the other within the specified time interval. A model of this program can be expressed in mathematical form as a function window controlling the processes on the road network by using the DUMMY VARIABLES MODEL. This model is flexible to handle a variety of interesting problem of this nature.

Dummy Variables Model can be represented as below;

Let $Y=\beta_{0\,+}\,\beta_1X_1+\beta_2X_2+\beta_3(X_3+X_4)$

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3D_1+\beta_4D_0 \quad (1)$$

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3D_0+\beta_4D_0 \quad (2)$$

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_4D_1 \quad (4)$$

$$Y=\beta_0+\beta_1X_1+\beta_2X_2+\beta_3D_1 \quad (3)$$

where,
Y = Dependent variable
β = is the slope of the intercept
X_1 = Independent variable Red light
X_2 = Independent variable Amber light
D_1 = Dummy variable that the Green light is either 40 or 80 seconds respectively as being assigned to bikes or cars

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This model helps in the simulation program to give a free flow of traffic at the intersection Junction that will control the movement of motorbikes and vehicles on the road traffic light control system.

CONCLUSIONS

The research paper is geared toward introducing motorbike symbol into the traffic light control system to separate cars/lorries indicator from that of motorbike. This will definitely lead to the reduction on the traffic congestion for mixed traffic system on the intersection road. Also, provide a free flow of traffic for the separate transportation systems.

REFERENCES

Bart De Schutter., 1999. “Optimal Traffic light Control for A Single Intersection”, Proceedings of the American Control Conference, San Diego, California, June 1999.

Devinder, Kaur., Elisa, Konga and Esa, Konga., 1994. “Fuzzy Traffic Light Controller”, Circuits and Systems 1994, Proceedings of the 37th Midwest Symposium 1507-1510. 2, August, 1994.

Helbing, D and Mazloumian, A., 2009. "Operation regimes and slower-is-faster effect in the control of traffic intersections." The European Physical Journal B - Condensed Matter and Complex Systems 70, (2): 257-274.

Jin, Lei and Ozguner, U., 2004. "Combined decentralized multi-destination dynamic routing and real-time traffic light control for congested traffic networks." In Decision and Control, 2004. Proceedings of the 38th IEEE Conference on.

Herty, M., Klar, A and Singh, A. K., 2006. “An ODE traffic network model” Journal of Computational and Applied Mathematics, 203, Elsevier, 419-436. Available: www.elsevier.com.

Takahashi, M., Nakanishi, T., Miyoshi, I and Fujikura, T., 2002. “An evaluation of the road traffic system simulator PIMTRACS by PIM”, Mathematic and Computers in Simulation, Vol. 59, Elsevier, pp.45-56.Available: www.elsevier.com.

Wen, W., 2007. “A dynamic and automatic traffic light control expert system solving the road congestion problem”, Expert Systems with Applications, Elsevier, Available: www.elsevier.com.

Yen, J., Lagari, R., and Zadeh, L., Eds. 1995. “Industrial Applications of Fuzzy Logic and Intelligent Systems”, IEEE Press, USA.

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