SIMULATING AND ANALYZING CHAOS OF INDIAN TRAFFIC CONDITION

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ABSTRACT

Indian traffic condition is very different from that of most western countries, the most glaring difference being the variety of vehicle types vying for road space at any given instance. The diversity arises from non-standardized physical size, speed/acceleration capacity and category (public transport versus private) of the vehicles. This leads to chaos in traffic flow resulting in unintentional non-adherence to rules and not necessarily a behavior trait. Usual traffic management policies suggest enforcement of strict lane discipline, though most city roads in India have only 1.5 to 2 lanes catering to the heterogeneous traffic. In our research, we focus on studying the driver response as a function of lane discipline conditions given the vehicle diversity. A road scenario similar to the typical Indian condition is simulated in Unity3D game engine platform and functionalities of the individual vehicle type are implemented as artificial intelligent (AI) bots. These bots interact with the player/first-person driver forcing her/him to react to the emergent situations. The scenarios are: a) no-lane discipline enforced and overtaking a slow-moving leader vehicle, b) lane change possible only at certain stretches of the road and the participant driver is positioned behind a slow-moving vehicle and c) when lanes are demarcated by solid structures and the driver is stuck behind a slow-vehicle. The factors of interest to this study are driver's decision making and driving skills in each condition, the traffic disruption in each condition and the driver behavior - changing lanes without checking for clearance and self-report of anger/frustration. The scenarios are created in a virtual reality (VR) environment and the player controls the car in that simulated environment. Unity3D software was used to develop the application and Oculus/HTC Vive for VR. The player is provided with haptics (steering wheel, brakes) of a car so that he/she can physically feel that they are inside a car. Traffic sounds are added for natural effect. Experiments were done by participants with driving experience and also first time drivers.Time taken to reach the destination and the lane-change strategy was analysed for each condition. The time for no-lane demarcation condition was the least, while designated lane- change stretches required quick responses and speed-prediction skills, in the absence of which collisions were observed. The issues with a policy of lane-discipline without addressing the heterogenous traffic is highlighted. The findings from the preliminary understanding in real-life conditions and behavior in the virtual simulation led to a solution for road infrastructure model that is being discussed around the world and might be applicable for Indian city traffic.

KEYWORD

Virtual Reality, heterogenous traffic, lane, slow moving vehicles

INTRODUCTION

In India, traffic congestion in urban areas is a major problem. This could be due to any number of reasons among which are narrow roads, bottlenecks due to non-uniform road geometry, road conditions, pedestrians, heterogeneous traffic with varying speed and acceleration capacity etc. The most cited issue by drivers is the concept of lanes and and the associated (in)discipline. In addition is also driver indiscipline, as Indians regard driving as a competitive sport rather than a cooperative endeavour to reach the destination. In addition a sense of entitlement that comes from the size or type of the vehicle leads to ego-centric driving. Hence, various strategies are employed to move through the traffic by combative stances with other drivers.

Research on modelling traffic flow at a micro-macro level has been exhaustive for homogeneous traffic mostly for drivers trained to follow rules. In most of the studies, mathematical models have been used to emulate the vehicle movement programmed to follow rules of interactions, speed, acceleration, situational awareness and leader follower behaviour as noticed in real-life drivers. From these structured traffic simulations, a set of driver behaviour models have been evolved based primarily on acceleration and lane changing strategies. Most acceleration models have focused on lane-following traffic where there is a distinct lead vehicle of near equal engine capacity or vehicle type. In the non-lane (where no lanes are marked) or weak-lane discipline cases, there are multiple transient leaders and hence lateral interactions – that is, neighbouring vehicles - are considered. Also in a non-lane based vehicle model, the following vehicle is usually off-centered and hence there is a possibility of no-leadership vehicle. Heterogeneous traffic with weak-lane discipline provides interesting challenges for modellers simulating probable driver behaviour. A few studies (*1*,*2*,*3*,*4*) have looked at weak lane discipline traffic and lateral interactions. A comprehensive review (*5*) of the models for car-following and lane-changing note the advantages and shortcomings for non-regulated traffic conditions. Choudhury and Islam (*5*) consider acceleration decision-making in weak-lane discipline and present a latent leader acceleration model calibrated using the trajectory data collected from real-times roads. Their modelling results show the type of the lead vehicle and the extent of lateral overlap with the subject driver. The complexity from smaller vehicles which can manoeuvre between the larger width/chaises breaking lane discipline was explained by the continuum model (*6*).

A review (*7*) of the various microscopic driving models and the applicability to Indian traffic types states that these models do not consider all the complexities of (in)homogeneous traffic and the dynamic strategies drivers apply. A simulation (*8*) modelled for European traffic was modified for Asian traffic and it was found that traffic-jam density depends on the surface area of the vehicles as well as mix of vehicles. They applied their model to a real-time situation of a traffic junction in India. Other studies include one on modelling the traffic stream with no lane discipline (*9*) and a non-lane based microscopic modelling under heterogeneous traffic conditions (*10*) to know how vehicles move in heterogeneous conditions. Important aspect to study is the behaviour of the drivers in mixed traffic conditions (*11*).

The models proposed by these studies suggest how better lane discipline translates to lower congestion but does not consider issues from mandatory lane discipline in the mixed traffic seen on Indian roads. The Indian roads at any time has buses, trucks, 3-wheeler public and goods vehicles, 2-wheeler motorbikes or scooters, cars of different engine capacity, non-motorised push-carts/bicycle, pedestrians and animals. To follow lane discipline is impossible in India as there is inconsistency in the each vehicle's capacity and power. There are situations where fast moving vehicles are forced to follow slow-moving vehicle. If there is dense and fast traffic on both sides of the fast moving vehicle, then the vehicle is stuck as it cannot overtake and is forced regulate its slow-down. With constraints imposed by the heterogeneity lane rules would lead to higher traffic congestion. In the study reported in this paper, we demonstrate the issues with lanes discipline policy.

Most of the studies collected real-time traffic flow using video shoots and on-car video cameras to obtain driving trajectory data to verify the mathematical models. The data is extracted using image analysis but covers, at any time, only a few hundred meters of the road distance, while driving behaviours need to be studied for longer driving duration to understand all complex integrated movements or causality. While robust, the models would be either extremely theoretical or the setup is non-repeatable and not controlled by the researcher. For real-time experiments, the dynamics are volatile and hence driver-behaviour is subjective, rendering it difficult to evolve models.

Driving simulators are important tools which can provide the immersive environment for a driver, while allowing the researcher to manipulate the situations (*12*)(*13*). To qualitatively measure real-time driver behaviour, verification of the parameters used in the various models requires controlled conditions and ways to collect perceptive data from the drivers. Traffic simulators are mid-way solutions used by researchers both for training and to understand driver behaviour in controlled situations. One such microscopic behaviour-based traffic simulator is the VISSIM (software package developed by PTV Planning Transport Verkehr AG in Karlsruhe, Germany) to analyse traffic flows. The simulator has a fundamental 3D UI and based on mathematical equations, it can calculate the position of each vehicle in the 0.1-1s range. Objects like vehicles and pedestrians can be assembled in the initial conditions and simulation run.

For this study keeping in view the conditions to be tested, a controlled experimental setup on the virtual simulations emulating real-life traffic situations is implemented using the Unity3D game engine and presented on virtual reality glasses (Oculus rift). Naturalistic traffic noise and individual vehicle sounds with effects were the auditory inputs to the participants. The participant decisions on discretionary lane change to overtake an immediate lead vehicle, which is a slow-moving car/autorickshaw, were recorded and the time taken to reach the destination. They are one of three conditions: a) no lanes, b) designated lane changing stretches and c) barricaded lanes. In the first condition, where there is no mandatory lane discipline, the driver can make an estimate of the distance between the vehicle in the next lane and overtake the slow vehicle. In the second condition, the driver can only change lanes at designated stretches in a gap between fast moving traffic in the neighbouring lanes. This is a complex maneuver as the vehicles in the two lanes are speeding. Hence the driver should estimate the gap between his/her vehicle and the preceding fast moving vehicle in the target lane, between his/her vehicle and the vehicle speeding from behind in the target lane, and making these estimates while all along being aware of the gap between the slow-moving vehicle in its own lane. In the third scenario, the driver just has to follow the slow-vehicle, creating a long traffic queue and increasing frustration. The goal is to find out the efficacy of having strict lane discipline for designated per-vehicle type, in Indian heterogeneous traffic conditions and the time cost and anger/rage of the driver stuck behind a slow-moving vehicle.

METHODOLOGY

Participants

For this experiment, the participant age group ranged between 19 years to 25 years, with the following breakup: 2 people were of 19 age group, 4 of 20 years, 8 of 22 years, 12 people of 23 year age group and 4 people of 25 years old. Out of these people, 56.7 % people knew how to drive and around 36.7 % were female gender.

Simulation and Virtual Reality Display

The hardware setups includes a high-end desktop with a graphics card, Oculus Rift virtual reality glasses, headphones and a game steering wheel with brake/accelerator controls. The simulation of the road was coded on Unity 3D game engine. The scenario is a 360-degree view of a 3 lane road with rule-based artificial intelligence (AI) bots of trucks, buses, cars and autos. These AI bots are programmed with vehicle type, pre-determined constant speed, that is, a truck will be moving slower than a car. In the left lane heavier vehicles are positioned while the participant's car is the middle lane and right lane also have car-bots. The two wheelers are mixed in between the lanes as is usually the condition on Indian roads. A rigid-body collision detection is made to simulate collision between the vehicles, both in terms of AI bots and the driver controlled car. In the left most lane, the heavy vehicles move and on the right side of the participant, cars are moving. The immediate lead vehicle is a slow moving three-wheeler auto rickshaw.

The setup is designed to give the participant a first-person driver perspective (Figure 1a) . The participant can control the car with the steering wheel, along with the accelerator and hand-brakes. They can hear all the noises around them with the stereophonic sound. Three scenarios are presented and studied for this experiment. All the participants are tested on these scenarios and their interactive responses and time taken to reach the designation are recorded. A timer is displayed on the screen for reference. Before the main experiment, all participants were allowed to get accustomed with the VR environment and control gear. A questionnaire was also given to record immersiveness and irritation for following the slow-moving leader vehicle.

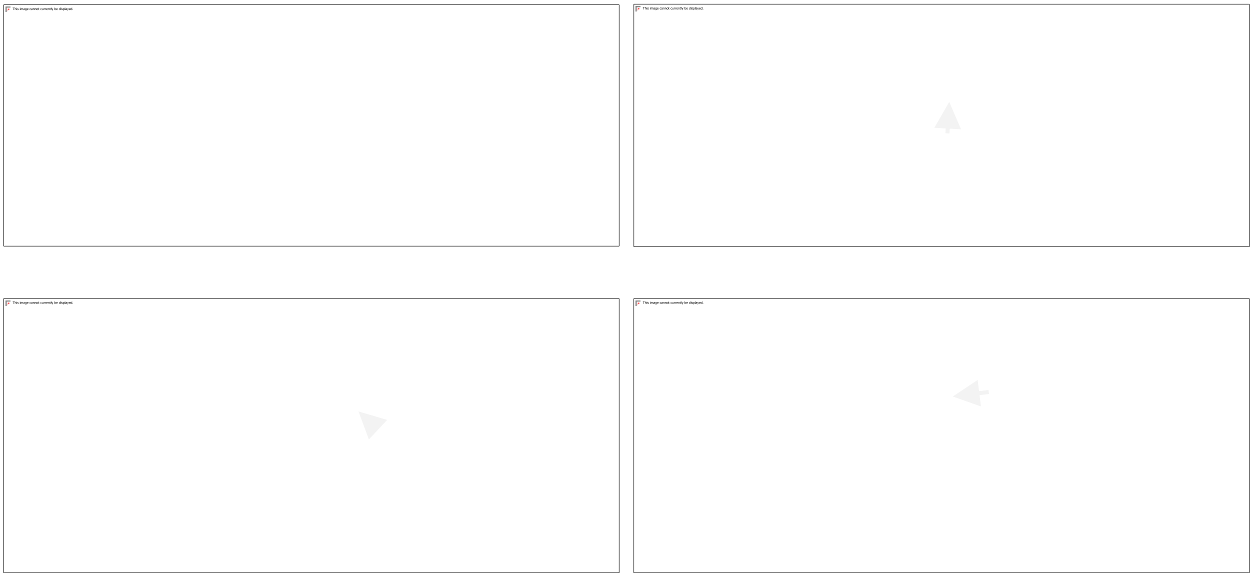

FIGURE 1 (a) First-person-view of the road where the participant is the driver, (b)Road without lane barriers, (c) Road with half lane barrier, (d) Road with full lane barrier.

Scenarios

Scenario 1

In the first scenario, a slow-moving autorickshaw is in front of the participant's car. Both are in the same middle lane. There are heavy vehicles which are moving on the left lane and cars which are moving on the right side of this lane. The participant can overtake from either side. The participant has to cover a half kilometer cover to reach the end point and then the timer will stop. (Figure 1b)

Scenario 2

In the next scenario, the participants can overtake or change lanes only at designated stretches. In the simulator, physical barricades were placed to indicate no-lane-change stretch. The driver can estimate the speed of the vehicles on the two side lanes and shift to the corresponding lane in the stretch of the road where it is allowed. The timing for reaching the end point is recorded (Figure 1c). The slow moving vehicle is marked by a white arrow.

Scenario 3

In the last scenario, the car is forced to follow the autorickshaw for the whole journey and the time is recorded (Figure 1d). As all the participants are following the same slowly-moving auto rickshaw for the entire road, their timings are almost same, but this condition was introduced to specifically gauge the frustration or anger levels of the driver.

RESULTS

We conducted the experiment with 30 participants. Out of these, 17 of them have experience driving. The task was explained to the participants and all the controls were described. As virtual reality glasses are a novel experience, enough time was given for accommodation. Instructions were given to mention any discomfort or vertigo sensations. The steering wheel rotation is transferred as control to the vehicle being driven in the virtual world by the participant. The lane changes and the time taken by each participant to reach the finish line for each scenario was recorded.

The average time for each scenario was calculated with all the participants (Table 1). A 2-sample T-test was applied to look at statistical significance for the timings from the first two scenarios with 95% confidence level. The p value comes out to be less than 0.0001. By conventional criteria, the difference is considered to be extremely statistically significant. The standard error of difference is 3.875.

TABLE 1 The average time taken by the 30 participants to navigate through the simulation for each scenarios presented in the experiment.

Conditions	Average time to reach destination
Scenario 1 (no lane)	38.7 sec
Scenario 2 (specific stretch for lane change)	334 sec
Scenario 3 (physical barricades for lanes)	645 sec

The irritation levels of the participants for being stuck behind a slow-moving vehicle was distributed as follows. The anger and irritation level was measured on a scale from 1 to 5 (1 being least and 5 maximum). 10 % people were in the least irritation with scoring 1 on the rating scale. 20% of people rated 2 on the scale, 36.7 % people scored a 3 while the remaining 33.3 % people rated it of 4 level irritation.

DISCUSSION

Most of the traffic problems on Indian roads have been attributed to either poor lane discipline by drivers or narrow roads. A policy that is loosely followed is to segregate the traffic on utility, type of vehicle and engine capacity. The rightmost lane is usually for fast moving 4-wheelers/cars, the leftmost for public transport buses/trucks and the middle lane is for a mix of all other types found on Indian roads. While these are logical models to impose with no feasible plans to homogenize the vehicle types, urban roads with limited real estate to expand requires alternate plans. The comparative analysis of the three scenarios to understand the inadequacy of lane-discipline policy imposed by traffic management in terms of time to reach destination (an important parameter for a driver) highlights the issues with imposition of mandatory lane discipline in Indian traffic. Travel information shows that slow-moving traffic can lead to traffic jams and increase time spent in traffic. This leads to driver irritation/anger as observed from the rating data, wherein nearly 70% scored above ⅗ on the level of irritation experienced.

We do not advocate the removal of the lane rule, as the absence of it would lead to accidents and confusion, rather it is to suggest the need for alternate mechanisms.The cost-effectiveness of dedicated lane versus general-purpose lanes for US roadways has been discussed in a white paper by Richard Poole (*14*), with focus on the issues with dedicated lanes which would lead to congestions due to slow-moving traffic and but for safety purposes advocates a separate lane for cars only. Arasan & Vedagiri (*15*) promotes the need for a bus-only lane, to increase the volume capacity of the road and also increase use of public transport by citizens due to increase in speed in these lanes. While the argument on optimal number of lanes, the need for dedicated lanes and imposition of lane discipline continues, solutions or models need to consider the complexity of traffic management in countries like India. The most important factor to evaluate is the cost of road widening in congested cities in terms of social upheavals due to land acquisitions, real estate prices and ever increasing population. Traffic segregation based on utility and type is required but only by balancing the socio-economic factors. Hence, we propose the double-decker lane system for cities (example model Figure 2). The initial costs would be higher but can be a

long-term solution. Such a model has been proposed in Chengdu, China and the highway 409 by the Ontario government. A 3-tier 2-lane segregated road above ground structure or with 1-tier underground (based on soil conditions) would divide the traffic. The ground lane accommodating the public transport heavy vehicles and three-wheelers , the middle floor lane carries cars and top floor dedicated to 2-wheelers. Further models and simulations from transport engineers, environmentalists, urban planners and traffic engineers are required to analyse the feasibility.

Virtual driving simulators with haptic feedback have some limitations especially in their ability to represent the real-traffic parameters for the immersive experience. A study towards this (*16*) compared the reaction time in the virtual simulator and in real driving experiment and found the results were near similar for both conditions with reactions times in the virtual simulator being just slightly better than in the real-driving experiment, as expected. In the simulator implemented for this study, the 360 degree view in the virtual reality glasses, the auditory input supported by the haptic feedback from the steering wheel and driving in first-person view added to the immersiveness. But, it should be acknowledged that some behaviours in the virtual world might be more aggressive than in real-life as the fear of physical harm is not accounted for. One limitation in the simulation is the interface, a real-car body with actual steering wheel and accelerator/brake system and sync real-time hand movement with the virtual animation. Ongoing embodiments to the simulation include emergent behaviour of the AI bots, feedback system to the driver and integration of the hardware controls.

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