Multi Agent Simulation of Unorganized Traffic

Praveen Paruchuri Alok Reddy Pullalarevu Kamalakar Karlapalem

International Institute of Information Technology, Gachibowli, Hyderabad, INDIA

ppraveen@gdit.iiit.net alok@gdit.iiit.net kamal@iiit.net

ABSTRACT

Traffic simulation is one of the most complex simulation projects that can be undertaken. The main issues are: modeling of autonomous behavior of drivers, modeling of their interaction, and ability to simulate the traffic and procure reliable realistic results. Organized traffic with drivers heeding to well defined traffic rules is less dynamic and erratic, than modeling unorganized traffic, wherein the drivers either do not heed to well defined traffic rules, or there are no traffic rules in place. This paper shows the viability of applying multi-agent simulation for unorganized traffic. In particular, we model the behavior of drivers, as being cautious, normal, and aggressive, and show results about average speed of vehicles in traffic, number of overtakes, and number of accidents occurring with different proportions of aggressive and cautious drivers. A multi-agent simulator with graphics interface has been implemented to visualize and evaluate the traffic flow.

Categories & Subject Descriptors

I Computing Methodologies

I.2 Artificial Intelligence

I.2.11 Distributed Artificial Intelligence

Multi agent Systems

General Terms

Design, Experimentation and Performance.

1. INTRODUCTION

Simulators have long been useful aids where the understanding of phenomena, that can be simulated, are quite difficult. Simulators help to view the same phenomena at different levels of abstraction and hence aid in easy understanding for various users who have differing knowledge of the phenomena under consideration. They are also useful where the effects of implementation of a policy are difficult to predict and the actual implementation of the policy is quite costly. The alternative is to use a simulator, find the possible outcomes and take a decision accordingly. One such useful simulator is the traffic simulator.

Different places have different traffic rules, different vehicles and different people. Therefore, traffic patterns can be expected to be different. For example, consider the typical traffic scenario in India, where at cross roads (i.e., a junction of three or more roads) there are usually no traffic lights present or at least a traffic policeman to direct the traffic. The traffic in such a situation will be understandably chaotic. Nevertheless, the fundamentals of traffic remain the same. A driver always likes to reach his destination in the best possible way. This goal of driver remains the same irrespective of the traffic being organized or unorganized.

We have checked simulators like Synchro/Sim-Traffic5 modeling traffic having two or more lanes for different directions and having traffic lights at crossovers. Such traffic is called an organized traffic. The behavior of an individual driver in such cases is, for a major part, dictated by the traffic rules imposed on them.

We are however, interested in simulating an unorganized traffic pattern. The behavior of the whole system in this case, then, depends on the interplay of different human characteristics. The overall traffic pattern is an emergent behavior of such individual interactions.

Models can be basically viewed at two levels – one at a micro level and the other at a macro level. Macro level involves modeling the general aspects of system like the average speed of all vehicles on road, vehicle density (like number of vehicles/unit stretch of road). Modeling of system from this view results in losing some of the finer aspects of the system like individual vehicle behavior based on psychological traits.

A micro simulation involves modeling each of the vehicles involved in the traffic i.e., giving each vehicle a set of its own characteristics like the vehicle length, width, maximum allowable speed and other characteristics discussed later. The overall traffic can be viewed as a collective behavior of each of the individual vehicles.

Each vehicle interacts with others in a certain way, which depends not only on the relative positions, speeds, etc. but also on the psychologies of the drivers involved. A vehicle can have a goal of maintaining a speed of 60kmph. If the vehicle just ahead of him goes at 40kmph and there is no possibility to overtake, then the following vehicle must also maintain 40kmph or less to avoid a collision, if the distance between the vehicles is less. This is one of the simplest interactions between two vehicles.

By definition, agents are a part of an environment and they can sense their environment. An agent has a goal and it can use its sensed knowledge in achieving its goal. A vehicle on the road can also be looked up as an agent because it is a part of an environment i.e., traffic, it can sense the environment by knowing other vehicles on road and how they move. A vehicle has a goal as to reach a particular destination and it can use its sensed knowledge to achieve its goal. That is, it looks at other vehicles on the road continuously and moves to reach its destination safely in the fastest possible way.

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A clear parallelism, as described above, exists between real drivers and the way agents are implemented. By definition of an agent, each driver agent can be assigned his particular behavior. The agent then behaves like the real-life driver that is modeled. The assignment of behavior is done through a set of parameters like free will speed, free will braking power, described in the simulation part (section 3) of this paper. Because of the close similarity between the driver on road and the way agents can be implemented, we have applied a multi-agent based simulation[1,2,3].

Another reason for selecting an agent-based approach is the distribution of control. In a pure agent based simulation the net decision that an agent makes must lie with the agent. An agent has full control over itself. This is in tune with real life scenario where a vehicle has full control over itself. In simulations using other techniques, only partial control exists for a vehicle over itself. The rest of the control lies with a central controller. The controller takes a part of the decision on behalf of the driver.

The Indian Road Traffic Simulation Project (IRTS) aims at looking at some of the finer aspects of vehicle behaviors and how various traffic patterns occur on Indian roads based on these behaviors. The realism of this simulator depends on the quality of the modeled psychological traits of drivers. In this paper, we describe the various psychological traits and their expected behaviors. The rest of the paper is structured as follows: Section 2 contains the background based on which the project was implemented. Section 3 has the actual issues involved in the implementation and it also gives some of the modeling parameters that can be changed to view various traffic patterns. Section 4 gives the evaluation of the project and presents results from various simulation experiments. Section 5 gives some conclusions of this paper.

2. BACKGROUND

The road on which simulation is done is shown in the Figure 1:

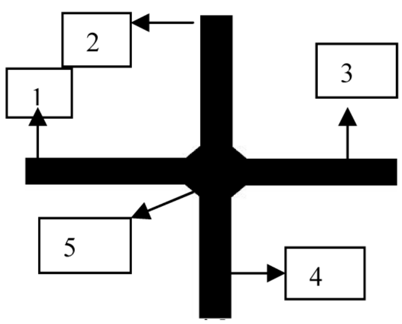

Figure 1: Road with sectors

We explain some of the terms that we use throughout this paper.

Driver/Vehicle agents: A vehicle is a thing like car and bus that moves on the road. The driver takes decisions and directs the vehicle. In the rest of this paper, we will use driver and vehicle agents interchangeably as the situation requires.

Junction: The part of the road marked 5 is called a junction where two or more roads meet in Figure 1.

Overtake: On the road, if a vehicle V1 currently present behind a vehicle V2, is present before V2 after some time, then V1 is said to have overtaken V2.

Braking power: All vehicles have a brake to decelerate. The braking power is defined in our simulator as the deceleration the brake of the vehicle can produce in meters/(second)^2.

Free will speed: The maximum speed a driver likes to maintain on the road if there are no hindrances is called his free will speed.

Gap: The distance present between any two vehicles is called the gap between the two vehicles.

Reaction time: The minimum time a driver requires, before she/he can react to a percept is called her/his reaction time.

Overtake margin: If a vehicle V1 has to overtake V2 and a vehicle V3 comes in the opposite direction, then the overtake margin is defined as the distance that must be present between V2 and V3 when V1 starts overtaking i.e., the distance between points X and Y in Figure 2.

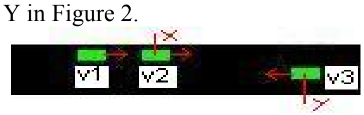

Figure 2: Distance between X and Y is the overtake margin

Traffic jam: This is a particular traffic pattern in which there is no space for any vehicle to move towards its destination and is also called a deadlock situation.

Free will braking power: Each driver has a certain comfortable deceleration that he would like to have. The braking power required for such a deceleration is called his free will braking power.

Free will acceleration: Even though a vehicle can be accelerated at a high rate each driver prefers a certain acceleration even if he is free to accelerate fully called his free will acceleration.

Each vehicle in the simulation has been modeled as an agent. For each driver to take a decision to move, she/he must communicate with all other drivers and must take her/his decisions accordingly. However, modeling such a communication system would mean that for each driver to take a decision he must process the information of all other vehicles after collecting the required information. The processing overhead involved in such an exercise could render the simulation unfit for a real time simulation like traffic.

There are some valid simplifications possible without losing the agent technology flavor. Our model involves a centralized agent plus a blackboard concept [9]. For using the blackboard concept without violating the definition of agents we model the road also, as a collection of agents. We modeled each of the sectors and the junction as agents. The work these agents do, is to sense the vehicles that pass over them. The advantages of such a model are as follows.

Each segment of the road has certain properties shared by the vehicles that go on it. There is one original flow direction and another, the opposite flow direction for vehicles on the same sector. These directions are unique for each sector except at the junction where a vehicle entering the junction must look at all the other vehicles entering it from different directions. A vehicle on any sector can have only one of the two directions assigned to that sector. Only at the junction there is no such unique flow of direction.

Most decisions a vehicle makes depend only on the vehicles present in that sector. A driver therefore can reduce his search space from four sectors and junction in the simulation to just the sector in which he is present and junction when he is near to it. This reduces the communication time for each vehicle to approximately, less than a fourth of the previous communication time. In addition, except during overtaking which occurs rather less frequently, a vehicle is usually concerned only with the vehicle before it.

If the road can sense, the next vehicle position, depending on the given vehicle position the implementation time reduces to just one communication to find the appropriate details of the required vehicle. A vehicle in such a model gives its own position to the sector and the sector detects the vehicle in front of it and gives back the required vehicle position.

The road can be viewed as a blackboard where each agent continuously updates its position and continuously monitors the vehicles it wants to. The overtaking scenario too, is simplified if the road as an agent senses the direction of flow of each vehicle. A vehicle that needs to overtake gets the information from the road, about the nearest vehicle before it in its direction, and also in the opposite direction. This allows the agent to take an appropriate overtaking decision.

The dominance effect is a striking phenomenon that will be seen at junction. In general traffic, there are some vehicles that try to push their way through even though there may not be enough space. The driver of such a vehicle is said to have a dominating nature. Similarly at junction, the dominating vehicles always try to push forward to reach their destination road. The others follow the dominating vehicle. It can happen that a large number of such dominating vehicles can make a non-dominating one wait for a long time, that is, starve.

Another issue that arises at the junction is the deadlock prevention issue. Agents must try to behave in such a way to avoid traffic jams (traffic deadlocks). Even though, each agent might try to avoid jam, due to their partial knowledge of the overall situation, a jam can still occur. The deadlock is broken by a central controller. It is similar to a police resolving a traffic jam. To simulate accidents, agents can be modeled to take wrong decisions based on certain wrong assumptions of parameters like the before_vehicle_braking_power, which we discuss later.

Figure 3 A typical traffic jam scenario

3. MULTI AGENT BASED SIMULATION

Each agent takes a decision independently and has a chance of conflicting with the decision of another agent. The decision taken depends on the traits assigned to the agent. A realistic simulation requires bringing out explicitly what decisions an agent makes when faced with such conflicting situations, which must compare with the decision a real driver makes under such circumstances

3.1 The Selfish Principle

Every driver has the aim to reach his destination. The selfish principle assumes that each driver has certain selfishness with which he likes to achieve his aim. The inclination to achieve the goal differs for different drivers. Based on the selfish principle, the different psychological traits of a driver can be coarsely classified as aggressive, normal, and cautious. An aggressive driver can be assumed to go, faster than a cautious one under similar circumstances. However, comparison between two aggressive drivers cannot be made satisfactorily based only on this coarse classification.

3.2 Fine Tuning Parameters

To analyze the finer aspects of traffic, we have fine-tuning parameters. These parameters, in our implementation include the agents free will speed, free will braking power, maximum braking power, free will acceleration, maximum acceleration, minimum gap maintained with other vehicles, overtake margin etc. The psychological traits are modeled by assigning appropriate values for these parameters.

For modeling some of these parameters we took a mean value of that parameter, based on real life situations, for each type of vehicle. Buses have a mean value free will speed different from cars. We assign the free will speed for a bus around the bus's mean speed value using a variance limit. A driver having a speed, above mean can be considered aggressive and below non-aggressive. The variance factor gives a range of values that bring out the different shades of the same trait. This distribution is called a normal distribution. Some of the above parameters have been generated using the above method and some others have fixed values modeled using real-life parameters like in Table 1(section 3.6).

We used biased distributions also, for obtaining different compositions of aggressive and non-aggressive drivers. Based on the parameters set for each agent, the agent takes its decisions. Because these parameters are different for each agent, different plans are adopted by different agents to achieve their goals. An aggressive driver always has a tendency to overtake the vehicle before him to achieve his goal. A non-aggressive driver might always give priority to safety rather than speed. The planning of a driver is therefore dependent on which factor (like speed, safety) is given greater priority.

3.3 Goals of a Driver

Goals can be modeled as two kinds: Micro and Macro goals. The macro goal is the destination that the agent needs to reach and the path it takes in reaching that goal. The micro goal involves taking a decision at each point of time, in the interest of achieving the macro goal. The micro goal can be in the form of speed with which an agent goes or a decision to overtake another vehicle or any other such decision that aids the agent in achieving the macro goal with ease. We can say, a series of micro goals taken effectively helps to achieve a macro goal.

A lot of planning is involved in the whole process of achieving a macro goal in the best possible way. At each point, the best micro goal need not result in the best plan for achieving the macro goal. An example can be as follows: A vehicle v1 is at a point on the negative x-axis and moving towards the positive x-axis. A vehicle v2 is on negative y-axis and is moving to the positive y-axis. Both the vehicles have to cross the origin. Let us say vehicle v1 has realized that it cannot cross the origin before v2 can. However it has two choices. One is to go at same or greater speed and then come to stop at some safe distance from origin and the other is to proceed slowly and still have some speed at the time the vehicle crosses over. In case one the vehicle will have to again accelerate from zero speed and in case two from the speed it has. The vehicle therefore has to adopt a suitable plan taking also into consideration the vehicles that follows v2. The best micro goal would be case one because the vehicle is moving faster towards his destination. However it needn't result in the best possible way to achieve the goal of crossing the origin.

3.4 Dynamic Agents

Agents that can take decisions in an ever-changing traffic scenario like the driver agents are called dynamic agents. Agents like the sector agent are not considered dynamic because their only work is to sense the vehicles that pass over them. The dynamic nature of agents can be viewed as a combination of two parts namely reactivity and anticipation. An agent can expect certain changes to occur in its environment and can take decisions accordingly. It can so happen that this anticipation of an agent can go wrong in which case it must be reactive enough to take some corrective measures.

For example, let us consider a vehicle V1 that follows another vehicle V2 at the same speed and has no idea of the road conditions before V2. V1, therefore, has no way to know the next step of V2. But, based on the present behavior, V1 can make a reasonable assumption that V2 might continue forward with the same speed and hence can take its decision accordingly. If its anticipation goes wrong i.e., V2 decelerates suddenly, then V1 must be reactive enough to avoid a collision by suitably taking its own decision. This combination of reactivity and anticipation, dictates a vehicle in traffic and the agents in our simulation.

3.5 Communication Model

In real life, a vehicle sees another vehicle and takes a decision. In the agent paradigm, the visual communication can be modeled by selectively making certain parameters of agents, visible on the blackboard, which is the road.

We provided the position of a vehicle visible to any other vehicle. In real life, a driver makes a rough estimate of the speed of any other vehicle he wants. In our simulator, we provided the speeds of other vehicles also visible. This has been provided for computational convenience. The speed can be calculated by keeping track of previous position of any vehicle and the time gap, which is how the real driver makes his rough estimate.

3.6 Fine-Tuning Parameters

We mentioned many fine-tuning parameters. We will show how some of these parameters can be associated with the psychological traits mentioned in section 3.2. Let the maximum speed of car be 90 kmph.

Table 1 Simple classification of psychological traits based on some fine-tuning parameters

Type	Trait		
	Aggressive	Normal	Cautious
Free will speed (kmph)	≥ 75	≥ 60 && ≤ 75	≤ 60
Free will braking power (in m/sec*sec)	≥ 8	≥ 6 && ≤ 8	≤ 6
Free will accelaration (in m/sec*sec)	≥ 1.5	≥ 1 && ≤ 1.5	≤ 1

An agent does not always go at the given range of speeds, because of constraints, like a vehicle before going at lower speed. Such constraints are called "goal conflicts". Aggressive driver tends to have higher acceleration and braking rate, low optimum distance with vehicles before him and has tendency to accelerate even if the distance to his destination is small.

Consider the overtaking scenario:

Figure 4 Overtaking scenario

In the above case, vehicle 1 can overtake vehicle 2, if there is enough overtake margin. The margin depends on the speeds of all three vehicles involved and the accelerations of each of the vehicles. Apart from that, there can be some other vehicle immediately before V2 so that there is not enough gap to overtake V2. A number of such other issues decide the overtaking scenario. These are physical issues. There are other psychological issues, which can be expressed as "confidence factor" and "rush factor".

A driver might feel confident of overtaking another vehicle with a particular overtake margin. Different drivers have different confidence factors. An aggressive one has a high confidence factor whereas a cautious one has a low confidence factor. The overtaking decision depends for a major part on the confidence factors. The confidence factor is modeled as a function, based on the present speed of the vehicle, the free will speed and the expected speeds of the other vehicles involved in the overtake. An aggressive driver can expect other vehicles speed to decrease or remain constant whereas a non-aggressive one can expect others to have a higher speed than they have at the start of the overtake. The model gives the overtake margin which is then compared with the actual gap available. In our implementation, we set the confidence factor to be one if margin is less than the gap available and zero otherwise.

The other factor involved is the "rush factor". Under normal circumstances an agent will overtake only if he is absolutely confident that he can do it. However, if there is some urgency in his reaching the goal, he might take a decision to overtake even if he is not absolutely confident. The modeling of the rush factor is done on a scale of 0.75 to 1. The rush factors are assigned different values for different agents. A rush factor of 1 is a normal rush and decreasing values imply more urgency. The rush factors are multiplied with the overtake margin. A rush factor of 0.75 implies that even a overtake margin of 0.75 times the overtake margin under normal circumstances is enough for a overtake decision. The combination of these two factors, determine the overtaking decision.

Modeling of accidents is also based on these factors. An agent might estimate his overtake margin to be too less and might realize it later but he might not be reactive enough to avoid an accident.

The dominance effect at the junction results in the “flow phenomena”. A dominating vehicle first starts going in the direction of its choice. The other vehicles, whose goal is the same, will start following the dominating vehicle. A flow of vehicles sets in the direction of the dominating vehicle until another dominating vehicle, whose goal is interrupted because of this flow of vehicles interrupts and establishes a flow in its direction. There is some time involved in the switching of the direction of flows called the “switching time”. In Fig. 5, we notice that the flow is from left to right in the top two figures. In the bottom two figures the flow is from top to bottom. The modeling and use of this dominance effect is required for unorganized traffic.

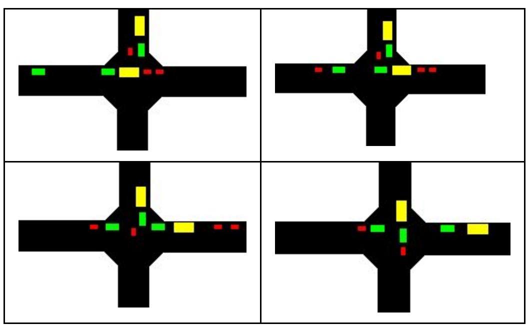

Figure 5: Illustration of Dominance Effect

3.7 Real Time Issues

Each vehicle on road continuously monitors the situation on road. On a single processor system we cannot give each vehicle a continuous monitoring facility. Each vehicle in the simulator gets a time slice to analyze the traffic situation and act accordingly. A vehicle effectively loses continuity with its environment for a certain amount of time before it can again establish a contact. This requires each vehicle to act taking the lost contact time and the changed scenario into consideration. The time slices are allotted in a round robin manner to ensure fairness.

3.8 Physics Involved

The distance traveled by a body having a constant speed in a time interval is given by: *Distance = time * speed,* where, appropriate units have to be maintained.

All decisions an agent makes regarding acceleration and deceleration are based on the following three fundamental formulae.

1. $v = u + at$
2. $s = ut + \frac{1}{2}at^2$
3.

where v is the final speed of the vehicle, u its initial speed, t the time of travel, a the acceleration of the vehicle, and s the distance traveled by the vehicle.

Here deceleration is implicit in that if acceleration is negative the vehicle decelerates. Though the basic formulae involved are the ones above there are certain modifications required, based on the kind of driver (aggressive, cautious, normal) who uses these formulae. Apart from that, the parameter called reaction time also has been taken into consideration. For showing these modifications, let us consider a vehicle following another. The question here is with what gap should a vehicle follow another vehicle. The gap to be maintained is the minimum distance, within which, our vehicle can reach the other vehicle’s speed if it decelerates suddenly.

Given the reaction time of a driver, the most aggressive driver (V1) maintains a gap with the vehicle before him (V2), given by-

$$Gap = reaction\_time * present\_vehiclespeed$$

(where reaction_time is that of vehicle V1’s driver and present_vehiclespeed is the speed of V1)

under the assumption that both vehicles are now going at same speed.

The most cautious driver maintains a gap, where,

$$Gap = reaction\_time * present\_vehiclespeed + X$$

where, $X = \frac{Vehicle\_speed^2}{2 * vehicle\_braking\_power}$

All the parameters namely reaction_time, present_vehiclespeed , Vehicle_speed and vehicle_braking_power refer to vehicle V1.

The aggressive driver assumes that his braking power is higher than that of the before vehicle whereas the cautious one assumes his brakes to be far worse than the previous vehicle brakes. A good heuristic can be:

$$Gap = reaction\_time * present\_vehiclespeed + X$$

where, $X = \frac{Vehicle\_speed^2 * (b2 - b1)}{(2 * b1 * b2)}$

Here *b1* is V1’s braking power and *b2* is expected_before_vehicle_braking_power (braking power of V2 as expected by V1). If *(b2-b1)* is less than zero the whole term will be taken zero. Modeling of *b2* is an important factor that brings out the psychological traits of various drivers. One model can be:

$$b2 = b1 * \left(\frac{mean\_speed}{free\_will\_speed}\right)$$

where, mean_speed is the mean used in the normal distribution generator to generate the various speeds and free_will_speed is the free will speed of V1.

In overtake scenario, the most important parameter is the relative speed of the vehicles. Consider the diagram below. Let *V1* be the vehicle that likes to overtake, and *V2* the vehicle being overtaken.

Case 1:

If *V1* is moving and if *V2* were stationary, the distance that *V1* has to move on second lane would be = $g1 + g2$

Where *g1* is the distance between *V1* and *V2* at the start of

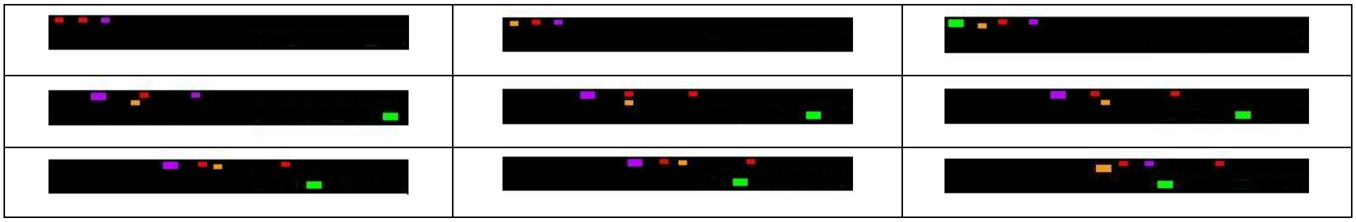

Figure 6 Snapshots showing overtaking in our simulator

overtake and *g2* the gap between *V2* and the target point of *V1*.

$|X\text{-}Y| = g1$, $|Y\text{-}T| = g2$, where *T* is the target point.

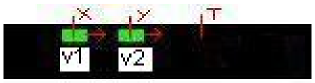

Figure 7 Two vehicle overtake

The gaps have to be calculated by using formulae given above.

Assuming *V1* moves at constant speed, time required for such overtake = $\dfrac{(g1 + g2)}{Speed\_of\_V1}$

(This formula is valid neglecting the lateral movements of the vehicle that are required for overtaking).

The effective lateral distance moved is:

$$\left(\frac{width1}{2}\right) + \left(\frac{width2}{2}\right) + (min\_horizontal\_gap)$$

Case 2:

If both vehicles are moving (as in Figure 7), let *v1* be the velocity of *V1* and *v2* the velocity of *V2*. In this case also, we assume uniform motion and the gaps are calculated according to formulae above. *(v1 > v2)* is a necessary condition for overtake to occur.

$$time\_req = \frac{g1 + g2}{(v1 - v2)}$$

where, *(v1-v2)* is relative speed .

(In this case, the target point moves. However, *g2* is the distance between *V2* and the variable target point).

Case 3:

Let us consider a vehicle *V3* that coming in the opposite direction (as in Figure 8). We assume uniform motion for all vehicles. Let *S* be the distance between *V2* and *V3* at the start of overtake by *V1*.

$|X\text{-}Y| = g1$, $|Y\text{-}T| = g2$, $|Y\text{-}Z| = S$, *T* is variable target point.

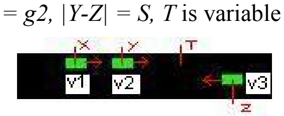

Figure 8 Three Vehicle overtake

The vehicle V3 must have a velocity v3 such that the following equation must be satisfied:

$$(S - (\frac{(g1 + g2)}{(v1 - v2)} * v3)) >= g2$$

This equation must be satisfied because of the underlying assumption that at most two vehicles can go on the road at a time because of width constraints.

The psychological traits have been incorporated into the calculation of gap. The formulae for overtaking decision involves *g1* and *g2* and hence suitable for various psychologies. An agent which has taken a decision to overtake, continuously monitors the validity of its decision. If the agent feels that the expected overtake is not possible, then it might need to change its decision while overtaking.

The speed for overtaking has two components, a forward and a side component. The net speed of the vehicle is given by:

$$Speed = \sqrt{(speed\_forward)^2 + (speed\_side)^2}$$

The above equations for overtake assume the velocity as the forward speed. The side speed determines the lateral movement. Figure 6 shows the orange vehicle overtaking the red vehicle starting with the snapshot in top left cell, and going row wise to the cell in bottom right.

3.9 Graphics Involved

The visual display requires a mapping from meters in real numbers to pixels in integers. We maintained a carry over distance for representing the fractional part. The mapping from pixels to meters if the distance moved by an object is d meters is given by (d * pixels_per_meter).

The parameter pixels_per_meter is an important parameter, modeling of which is a challenging task. We have to show a good length of road in simulation so that complex phenomena can occur, at the same time not hampering the visual display of vehicle movement. Another important parameter is the refresh rate, which determines the quality of the simulator and depends on the computational complexity. We have to adjust the vehicle density to get good refresh rates.

3.10 Implementation Details

C++ with qt graphical interface developed on Linux platform.

3.11 Procedures Used

Random number generator and normal distribution generator have been used. We also used biased random number generators to set certain percentages. The junction modeling involves certain deadlock avoidance and deadlock resolving issues. In appendix, we present the vehicle agent procedure.

4. EVALUATION

The aim of the simulator is to evaluate different traffic patterns that might occur under different circumstances. We therefore provide the flexibility to change some parameters to see the various patterns that can be generated. Some general parameters that can be changed are the vehicle density (number of vehicles per unit stretch of road), sector widths and lengths, vehicle length and widths, the mean speed value for different kinds of vehicles, definition of aggressive driver speed, the percentage of aggressive drivers on road etc.

The visual part involves showing the road with the vehicles moving. A snapshot of the road has been presented in section 2 of this paper. The various vehicle movements like constant speed, acceleration, deceleration and overtaking are presented in the Figure 6 and 9. The vehicle-color pairs used are: car - green, bus - yellow and scooter - red, accelerating vehicle - violet, decelerating vehicle – white and overtaking vehicle – orange.

Figure 9: Sector showing vehicles in various modes

The simulation can be evaluated from a statistical point. We present the effects on the average speed and the average simulation time as a function of the percentage of aggressive drivers present in the scenario.

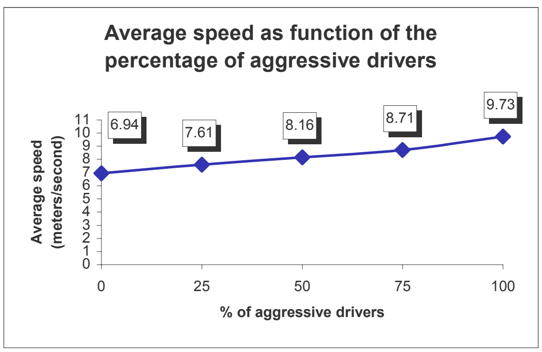

Figure 10. average speed vs % of aggresiveness

The average speed is the average of all vehicle speeds over the total simulation. The total simulation time in seconds for above as % aggressive vs simulation time are : 98 , 91 , 85, 79 & 71 seconds respectively .This is in tune with the diagram above because as the average speed increases the total time for the simulation for the same stretch of road decreases .

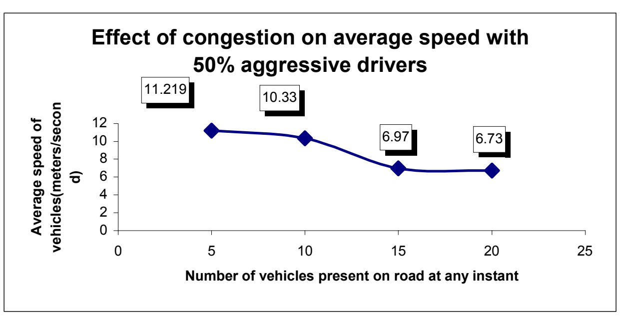

Figure 11 Effects of Congestion plotted

From fig 11 we can clearly see that as the number of vehicles on road increase the average speed of the vehicles over the whole simulation decreases called the congestion effect.

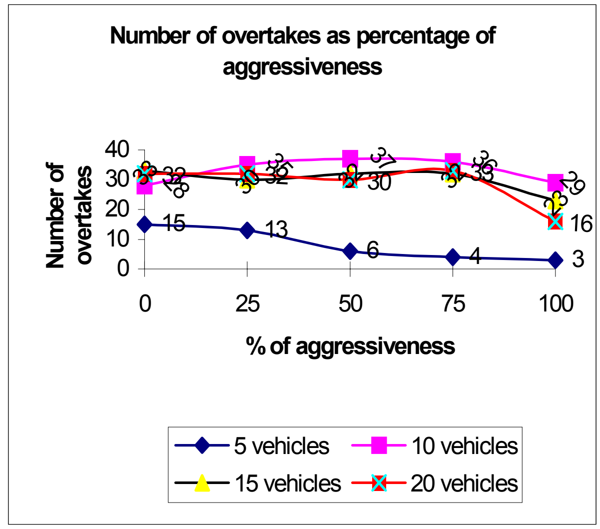

Figure 12 Plot showing number of overtakes as function of aggressiveness for different maximum number of vehicles allowed

The graph plotting the number of overtakes as percentage of aggressiveness, represents the number of overtakes that we obtained by allowing hundred vehicles to cross a 320m stretch of road in our simulator. The four plots are obtained by fixing the maximum number of vehicles allowed on the road at any instant. We see as the aggressiveness increases beyond certain percent the number of overtakes in general decrease. We put forth the following explanation without any proof. As drivers become more aggressive, not only do their tendency to overtake increases but also the tendency to allow other vehicles to overtake decreases. We therefore argue in favor of the results obtained. We also notice that if the maximum number of vehicles are ten or more there is no considerable difference in the number of overtakes. Its probably due to congestion.

In figure 13, we present the data obtained when an external user modifies the vehicle parameters in the simulator. In our case we kept a refresh rate which implies for every nth time all the vehicles get a chance to take a decision the program sets the third vehicle speed to 0. This results in some accidents. We show a plot of the number of accidents obtained as a function of the maximum number of vehicles present on road at a particular instant for the different total number of vehicles simulated.

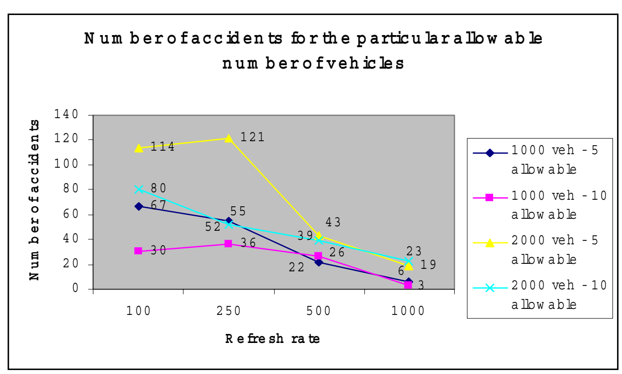

Figure 13. Number of accidents as function of vehicle density

5. CONCLUSIONS AND PERSPECTIVES

The objective of this work is to produce a realistic traffic situation by reproducing the behavior of drivers. These drivers interact among themselves and the produced traffic is an emergent behavior of such interactions. However the traffic is simulated with single lane for each direction and also without traffic lights at junction. This brings out an unorganized traffic with the traffic patterns dictated as the collective behavior of various agents rather than by some traffic rules. The simulation also allows the user to specify his own psychology and view himself as a part of the whole simulation.

Effort has been put in for designing the various decision taking capabilities appropriately. Various parameters have been chosen from real life examples and care has been taken to model appropriate behaviors based on these parameters. This project will be extended to include more realistic effects like human beings crossing road, visibility ranges under fog, and other severe weather conditions.

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APPENDIX: Vehicle Agent Function

```
Vehicle Agent {
Make_appr_move()
If (not nearest vehicle to junction in the sector)
If (not isovertaking())
        Get_my_sector().get_before_veh_position_insamedir(get_my_id(),get_my_dir)
        Get_prev_vehicle_speed(prev_veh_id);
        If (my_speed < prev_speed)
                Calcgap();
                If (gap < my_min_gap_for_acc) Gowithconstantspeed(); Else Gowithaccelaration()
        Else
                Calcgap(); Guess_before_vehicle_braking_power(); Generate_my_optimal_gaptobemaintained();
                If (gap < my_optimal_gap) Generate_optimal_speed(); Apply_brakes_toobtain_optimalspeed();
                Else If (gap > overtake_decision_gap)
                        If (currentspeed < free_will_speed) gowithacceleration(); Else Gowithconstantspeed();
                   Else Mysector.getvehicleposition_inoppdirection();
               If (my_free_will_speed > current_speed * increase_factor)
                  If (all 3 vehicles can go on road at the same time ) Overtake();
                                        Else
                                                Calc_req_overtakemargin();
                                                Calc_present_gap_available();
                                                If (presentgap > overtake_margin)
                                                        Overtake();
                                                Else
                                                        Handle_no-overtake();
                                Else
                                        Handle_no_overtake();
Else
        Check_for_validity_of_overtake_decision()
        If (valid())
                Continue_overtake()
        Else
                go_back_to_prev_relative_position()
}
```