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CAIDM: Context Aware Intelligent Driver Model

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Abstract: Researchers present a novel approach to incorporate context awareness into the existing Intelligent Driver Model (IDM). Specifically the proposed model would like to introduce new context aware parameters to make the car following model adapted with real life scenario. Researchers would like to concentrate on the environment conditions, driver condition and the type of vehicle. The effectiveness of proposed approach is validated using mathematical calculations and graphs. One of the main improvements that will be brought about by the new proposed system is the context aware parameter. Context awareness for a system is very important as it makes it more informed about the situation where it is being put to use and hence its actions/results are custom made for that particular situation making it very accurate and apt.

Key words: Context Aware Intelligent Driver Model (CAIDM), context aware, intelligent, Driver Model, vehicle safety

INTRODUCTION

Context defines the characteristics of the situation/entity (Dey *et al*., 1998). Context awareness (Dey *et al*., 1998; Chen and Brown, 1997) in computing provides the system to sense and accordingly react based on the environment. Context aware systems lay emphasis on the acquisition of context then to abstract the required information from it and understand it and then lastly behave based on what it has learnt of the context. There are essentially three types of context:

- Location based context
- Behavior based context (Chen and Brown, 1997)
- Situation based context

The proposed model is going to be adopting the behavioral based context awareness. Researchers would be taking into consideration the various behavioral aspects of the vehicle, driver with respect to the context. There are different types of context aware modeling. Researchers propose on research on the mathematical context aware models.

The already existing car following models (Treiber *et al*., 2006) assumes that all the vehicles it is considering are of the same type and also it assumes that the vehicles are travelling in ideal environment conditions where the road surface is perfect. But in reality this is not the case, in a real time scenario there will be different type of vehicles travelling on the same road such as cars, bikes, trucks, etc. According to a survey most of the accidents on the road takes place between two types of vehicle. Thus in the proposed model the type of vehicle is considered and taken into account for calculations. Also the environment plays a very important role and it differs from time to time and place to place. So, environment is also considered in the proposed model. Lastly the state of the driver is taken into account as it plays a very huge role. The driver's state of mind such as sleepy, drunk and emotionally unstable, etc., determines the actions taken by the driver at different conditions. All the previous models do not yet consider these criteria. In this proposed model, all these criteria are being taken into consideration.

The IDM (Treiber *et al*., 2000; Kesting *et al*., 2009) Model is used to try to emulate the way a human behaves in traffic situations; this is done by model consisting of various states to describe typical responses encountered. The driving states (Triggs and Harris, 1982) are free traffic state whereby the individual vehicle can accelerate to the desired velocity. The second driving state is the Following state which is encountered in everyday traffic in which the vehicle velocity is determined by the vehicle in front of it. Lastly there is the braking state or referred to as an emergency response, this is the state when the vehicle in front comes to a halt or an object is encountered and driver in the current vehicle will attempt to stop the vehicle by using various degrees of braking

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force. It may so happen the driver is not able to visualize when to attempt to brake, the model proposes an alert to be given to the driver. The alert may so be a warning to the user as to if there is an emergency and the driver needs to apply brakes. The intensity of the warning depends on the various context aware parameters introduced. The parameters are chosen as they are the basis and play a significant role in the determination on the application of the brake by the vehicle. These factors are the vehicle response time (Hatipkarasulu, 2002), driver response time (Triggs and Harris, 1982; Hatipkarasulu, 2002) environment response time. Various vehicles have different reaction time based on their make. For demonstration researchers have assumed certain values based on different researches researchers found. The driver response time is assumed a nominal value for the calculation and environment response time is significantly determined by the grip on the road. These are the basic parameters considered by us.

RELATED WORK

Context awareness: To provide adequate service for the users, applications and services should be aware of their context and automatically adapt to their changing contexts-known as context-awareness (Chen and Brown, 1997; Kaltz *et al*., 2005). Context is very important since, it provides information about the current status of people, places, things and devices in the environment. Context is any information that can be used to characterize the situation or an entity. Context awareness means that one is able to use context information. Context aware devices may also try to make assumptions about the user's current situation. A system is context aware (Dey *et al*., 1998) if it can extract, interpret and use context information and adapt its functionality to the current context of use.

One goal of context aware systems is to acquire and utilize information on the context of a device in order to provide services that are appropriate to the particular people, place, time, event, etc.

While context-aware devices of the near future might recommend restaurants, monitor a user's health or screen phone calls, they may also save human lives by keeping drivers safe and aware of their surroundings.

Car Following Model: Microscopic models (Treiber *et al*., 2006) attempt to model the motion of individual vehicles within a system. They are typically functions of position, velocity and acceleration. Microscopic models are typically created using ordinary differential equations with each vehicle having its own equation. Because the behavior of these models is usually dictated by a lead vehicle, they are termed Car Following Models. Figure 1 and 2 show how microscopic models number vehicles in car following situations:

$$\text{Distance between two cars (d)} = Xb - Xa - L$$

Where:

Xa = Position of 1 vehicle
Xb = Position of 2 vehicle
L = Length of vehicle

Elementary equations:

$$S' = u^2/2a$$

Where:

S' = Distance travelled after braking
u = Velocity with which car is travelling
a = Deceleration

Suppose final velocity = 0 and decelerates. Compensating for the signs; S_{min} = minimum distance to keep when both vehicles come to a halt. Let reaction Time (T):

- Environment response time
- Vehicle response time
- Driver response time

$$\text{Distance travelled } S_r = T \times V(t)$$

Where:

V (t) = Velocity of vehicle 1
S_b = Braking distance

$$S = S_{min} - T \times V + \frac{V^2}{2a}$$

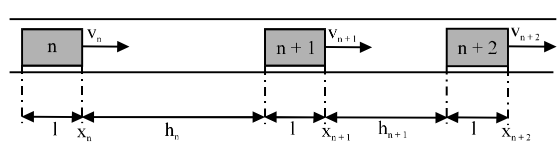

Fig. 1: Numbering vehicles in Car Following Model

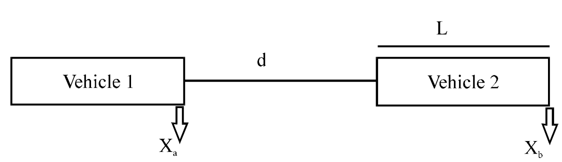

Fig. 2: Vehicles in Car Following Model

There are disadvantages that are cited (Treiber *et al*., 2006). One of the main one is that in this model the type of the vehicle is not taken into consideration. Different types of vehicle have different capabilities and hence this factor is very important.

Intelligent Driver Model: A current, state of the art model is the Intelligent Driver Model (IDM) (Treiber *et al*., 2000; Kesting *et al*., 2009). This equation was developed by Treiber, Hennecke and Helbing to improve on earlier models and was published in 2000. The model contains an acceleration strategy with a braking strategy to cover the three driving states. The IDM Model is given by:

$$\dot{v}_{IDM}(s, v, \Delta v) = a\left[1 - \left(\frac{v}{v_0}\right)^d - \left(\frac{s^*(v, \Delta v)}{s}\right)^2\right]$$

$$s^*(v, \Delta v) = s_0 + vT + \frac{v\Delta v}{2\sqrt{ab}}$$

IDM Model (Treiber *et al*., 2000; Kesting *et al*., 2009) is an acceleration function of:

s = Vehicle gap
v = Velocity
Δv = Velocity difference
v_0 = Desired velocity
v_{IDM} = IDM acceleration

The s^* term below the main function is an expansionof s^* in the numerator of the main function. In normal driving conditions, the vT term dominates. The vT term attempts to maintain a specific time gap T from the vehicle being followed. The term $v\Delta v/2ab$ dominates when approaching at high rate of speed. The model attempts to brake within the limit b but will exceed b's valueif requiredto avoid a collision.

There are a number of drawbacks that exist in the IDM Model (Treiber *et al*., 2000; Kesting *et al*., 2009). In the present IDM Model a simple car following model is considered for one-lane situations. Due to lane changes, the input values keep on changing at a non inform rate. In which case the new distance to the vehicle in front will suddenly drop. In the proposed new CA-IDM Model, all these problems are addressed as the system is contextually aware.

PROPOSED MODEL (CAIDM)

Context aware IDM is proposed so that all the currently existing problems that are cited in the previous models are alleviated. Apart from that it also brings in many new dimensions such as the vehicle type, driver reaction and the environmental factors. In general the CAIDM concentrates on the three main areas:

Vehicle type: Car, truck, bike, etc.

Time: Environment reaction time, driver reaction time and vehicle reaction time.

Environment: Dry, rainy and icy.

Context aware parameters: In order to make the IDM context aware, researchers introduce three new parameters:

- Environment response time
- Driver response time
- Vehicle Response time

By including these three new parameters the system will provide context aware alerts to the driver. The system will use these parameters and calculate the total reaction distance and will also alert the driver when the car is entering into a critical state.

Environment response time: The environment plays a very crucial role in determining the reaction time for the vehicle. When the climate is normal then the friction co-efficient between the road and tires is high. Whereas when the climate is rainy or icy then the friction co-efficient is very low. Due to this the car will take longer to stop in such condition. Hence, researchers cannot assume same reaction time for the same vehicle in different environmental conditions. By introducing this parameter researchers make sure that the climatic conditions that are present in the scenario then are taken into consideration before the output is delivered.

Calculations: Researchers know that:

$$V^2 = U^2 + 2aS$$

where, V = 0 (vehicle needs to come to stop). Hence:

$$S' = u^2/2a$$

Here for a, we calculate by a = 9.8* ERT-factor. Researchers propose three different ERT factor value for different condition:

- For dry = 0.8
- For wet = 0.5
- For icy = 0.3

Table 1: Different ERT values under different conditions

Speed		Distance (m)			Time (sec)		
kmph	mps	Dry (0.8)	Wet (0.5)	Icy (0.3)	Dry (0.8)	Wet (0.5)	Icy (0.3)
10	2.78	0.49	0.79	1.31	0.07	0.15	0.31
20	5.56	1.97	3.15	5.25	0.21	0.39	0.75
30	8.33	4.43	7.09	11.81	0.36	0.66	1.20
40	11.11	7.87	12.60	21.00	0.52	0.93	1.67
50	13.89	12.30	19.68	32.81	0.69	1.20	2.14
60	16.67	17.72	28.34	47.24	0.86	1.48	2.60
70	19.44	24.11	38.58	64.30	1.03	1.76	3.07
80	22.22	31.49	50.39	83.98	1.20	2.04	3.54
90	25.00	39.86	63.78	106.29	1.38	2.32	4.02
100	27.78	49.21	78.74	131.23	1.55	2.60	4.49

After researchers calculate, s value we use it in the below equation and obtain t-value:

$$s = ut + at^2/2$$

Solving the quadratic equation gives us the ERT value. Table 1 provides different ERT values under different conditions.

Driver response time: The driver takes some time before he/she begins to react. During this time the car is still moving at the same speed. There is always a small time delay between the moment the driver notices the brake light and when he/she touches the brake pedal. The faster one is travelling, the further the car will travel in this time gap. According to the recent survey the biggest factor in stopping distances is the speed at which the driver reacts DRT. According to a research, an average of 1.5 sec is taken by the driver to react once he/she sees an obstacle on the way.

Reaction time: Time taken by the driver to realize that an immediate action is required to avert an accident: 0.25-0.5 sec. Time taken by the driver to move his/her foot from the accelerator pedal to the brake pedal: 0.25-0.57 sec.

Vehicle response time: Different types of vehicles possess different braking abilities. All vehicles need some time to come to a complete stop even after applying the brakes. Cars come to a stop faster while other type of heavy vehicles such as trucks take more time to come to a complete stop. Hence, researchers introduce this VRT parameter to make the calculations more accurate and specific to the vehicle.

Architecture of the proposed model: The various vehicle reaction time of standard vehicle time are taken into consideration. The total response time and time to warn are calculated (Table 2 and 3).

Table 2: The different vehicle reaction time of standard vehicle time

Parameters	Bike	Car	Truck	Heavy truck
Vehicle reaction time	1	1.5	2.00	2.50
Total response time	3.38	3.88	4.38	4.88
Time to warn	2.62	2.12	1.62	1.12
Speed of the vehicle	60 kmph	16.67 mps	-	-
Distance the front vehicle/object	100 m	-	-	-
Environment reaction time	0.88	-	-	-
Driver response time	1.5	-	-	-

Table 3: The calculation of total response time and time to warn

Speed		Total Reaction Time (TRT) (sec) Vehicle type context			
kmph	mps	Bike	Car	Truck	Heavy truck
10	2.78	2.65	3.15	3.65	4.15
20	5.56	2.79	3.29	3.79	4.29
30	8.33	2.94	3.44	3.94	4.44
40	11.11	3.09	3.59	4.09	4.59
50	13.89	3.23	3.73	4.23	4.73
60	16.67	3.38	3.88	4.38	4.88
70	19.44	3.53	4.03	4.53	5.03
80	22.22	3.67	4.17	4.67	5.17
90	25.00	3.82	4.32	4.82	5.32
100	27.78	3.97	4.47	4.97	5.47

IMPLEMENTATION OF SYSTEM

Researchers have designed a simulation tool to explore the features of CADIM. This system is designed to provide contextual alerts to the driver in the case that the vehicle travelling in front is assumed to have come to a sudden stop. The system is responsible for informing the driver as to when to apply the brakes and how much time he has in his hand before he can apply brakes in order to avoid collision with the vehicle in front of it.

Currently in the designed system, all the values such as speed, distance, climatic conditions, etc. are manually entered but in a real time scenario all these values would be obtained with the help of sensors fitted into the vehicle (Fig. 3).

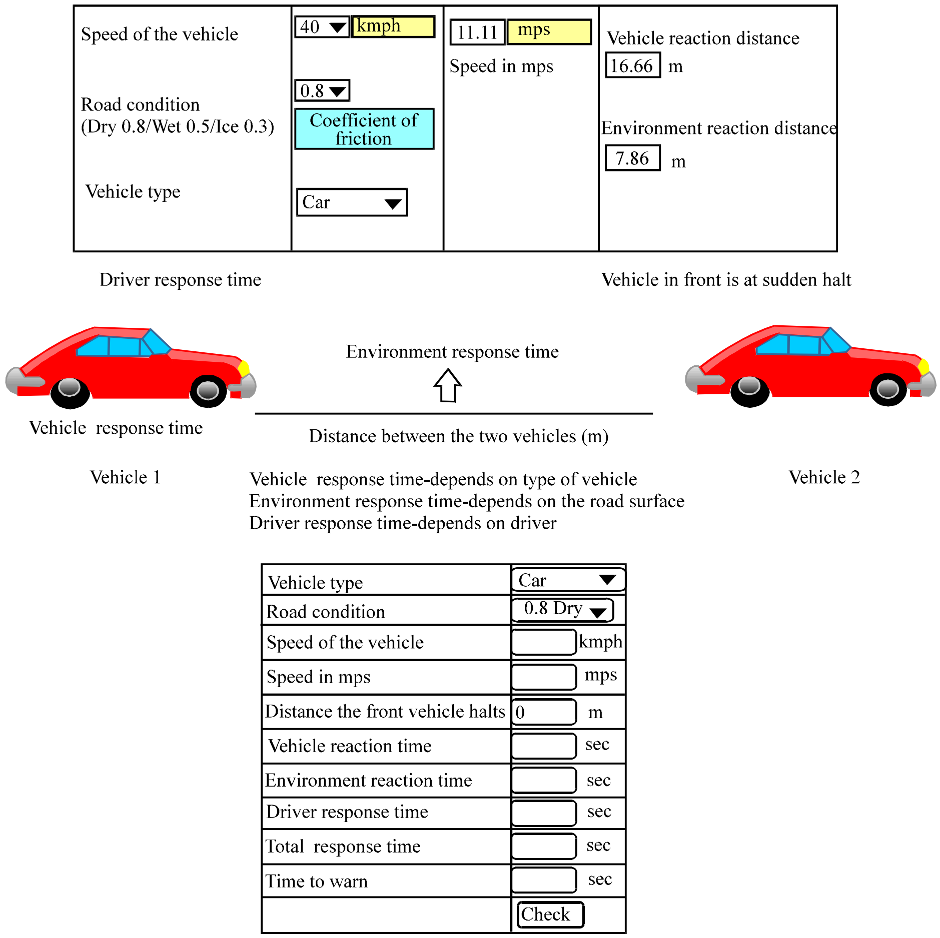

Fig. 3: Designed system

RESULTS AND DISCUSSION

Table 4 and Fig. 4 show the various different total reaction distances that different vehicles take on an ideal weather conditions. As it is can be clearly seen from the graph as the vehicle gets more heavier it requires more total reaction time, i.e., even after applying brakes, a considerable amount of time is taken for heavier vehicles to come to a complete stop. Researchers assume that the vehicle travelling in front is at a distance of 100 m.

Table 4 shows the different TRTs required by different vehicles on a wet road condition when its raining. Researchers assume that the vehicle in front is travelling at a distance of 100 m. As it can be inferred by comparing Fig. 5 and 2, it is very evident that vehicles take longer time to respond on normal surfaces at to rainy/slippery road surfaces. Now we consider the vehicle to be a car and then look how different speeds lead to different TRTs. Researchers assume that the vehicle in front is travelling with a gap of 50 m (Table 5).

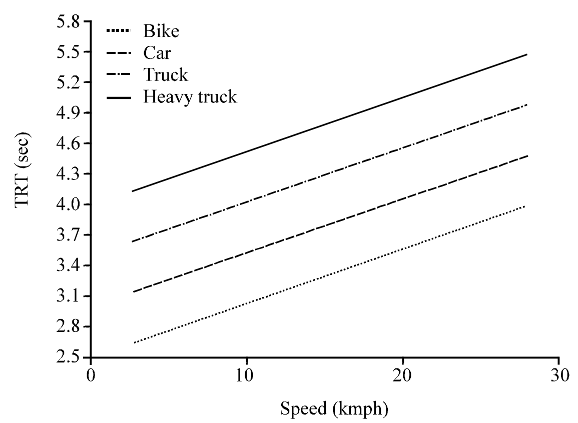

Fig. 4: Various total reaction distances that different vehicles take on an ideal weather condition

Greater the speed, more is the total reaction time. This rule applies in all types of weather conditions (Fig. 6). Now researchers would like to demonstrate the

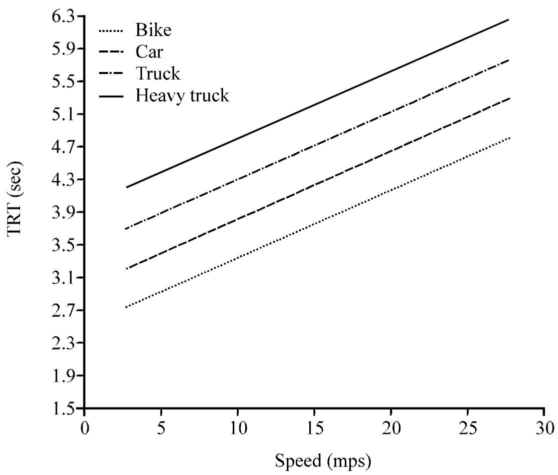

Fig. 5: Vehicle take longer time to respond on horn and surfaces at to rainy/slippery road surface

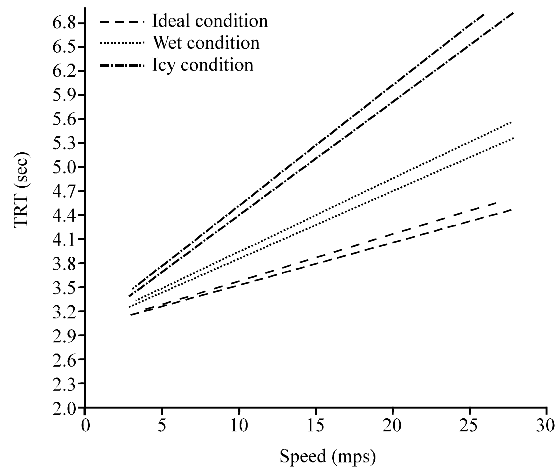

Fig. 6: Greater the speed, more is the total reaction time

Table 4: Different TRTs required by different vehicles on a wet road condition when its raining

Speed		TRT-Wet condition (sec)			
kmph	mps	Bike	Car	Truck	Heavy truck
10	2.78	2.74	3.24	3.74	4.24
20	5.56	2.97	3.47	3.97	4.47
30	8.33	3.20	3.70	4.20	4.70
40	11.11	3.44	3.94	4.44	4.94
50	13.89	3.67	4.17	4.67	5.17
60	16.67	3.91	4.41	4.91	5.41
70	19.44	4.14	4.64	5.14	5.64
80	22.22	4.38	4.88	5.38	5.88
90	25.00	4.61	5.11	5.61	6.11
100	27.78	4.85	5.35	5.85	6.35

Table 5: Different speeds lead to different TRTs

Speed		Total reaction time (sec)		
kmph	mps	Dry (0.8)	Wet (0.5)	Icy (0.3)
10	2.78	3.15	3.24	3.39
20	5.56	3.29	3.47	3.78
30	8.33	3.44	3.70	4.17
40	11.11	3.59	3.94	4.57
50	13.89	3.73	4.17	4.96
60	16.67	3.88	4.41	5.35
70	19.44	4.03	4.64	5.74
80	22.22	4.17	4.88	6.13
90	25.00	4.32	5.11	6.52
100	27.78	4.47	5.35	6.91

total time remaining to hit the brake against different speeds on a car in different weather conditions. Again we assume that the vehicle travelling in front is at a distance of 100 m (Table 6).

The lines that go below the X-axis into the negative axis shows that the car is travelling way to fast and it is bound to collide with the front vehicle. As the weather changes from ideal to icy, time remaining for the driver to react gets smaller and smaller (Fig. 7).

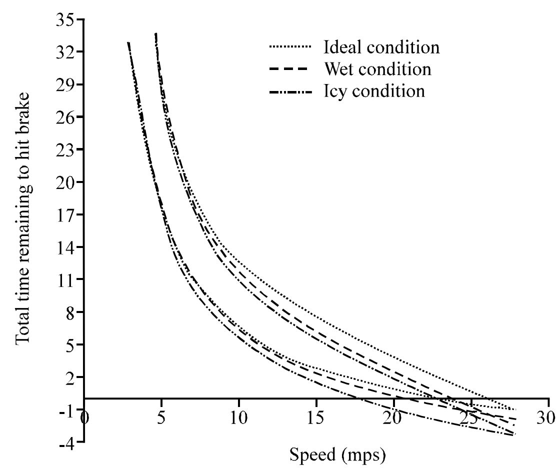

Fig. 7: Weather changes from ideal to icy

Table 6: Demonstration of the total time remaining to hit the brake against different speeds on a car in different weather conditions

Speed		Total reaction time (sec)		
kmph	mps	Dry (0.8)	Wet (0.5)	Icy (0.3)
10	2.78	32.82	32.73	32.57
20	5.56	14.69	14.51	14.20
30	8.33	8.56	8.30	7.83
40	11.11	5.41	5.06	4.43
50	13.89	3.46	3.02	2.24
60	16.67	2.11	1.58	0.65
70	19.44	1.11	0.50	-0.59
80	22.22	0.32	-0.37	-1.63
90	25.00	-0.32	-1.11	-2.52
100	27.78	-0.86	-1.74	-3.31

Now, researchers calculate the distance required by a car to come to a complete stop at various different speeds under different climatic conditions. From the Table 7, it can be seen how the climate plays a major role (Fig. 8).

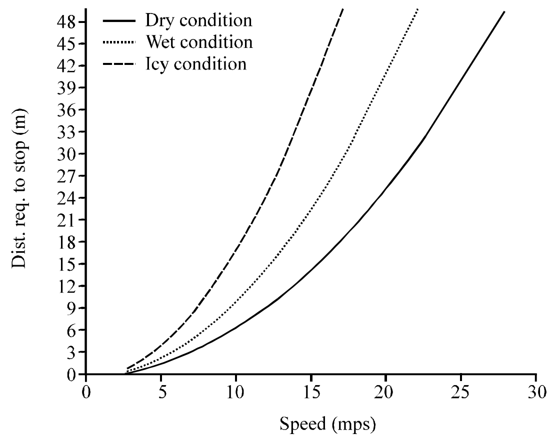

Fig. 8: Different climatic conditions

Table 7: Role of different climatic conditions

Speed		Distance required to stop (m)		
kmph	mps	Dry (0.8)	Wet (0.5)	Icy (0.3)
10	2.78	0.49	0.79	1.31
20	5.56	1.97	3.15	5.25
30	8.33	4.43	7.09	11.81
40	11.11	7.87	12.60	21.00
50	13.89	12.30	19.68	32.81
60	16.67	17.72	28.34	47.24
70	19.44	24.11	38.58	64.30
80	22.22	31.49	50.39	83.98
90	25.00	39.86	63.78	106.29
100	27.78	49.21	78.74	131.23

Table 8: Comparison between the already existing IDM Model and the proposed context aware IDM

Models	Velocity	Distance	Time	ERT	VRT	DRT
IDM	√	√	√	×	×	×
CA-IDM	√	√	√	√	√	√

Comparison between IDM and context aware IDM: Researchers briefly provide a summarized comparison between the already existing IDM Model and the proposed context aware IDM. In the Table 8 researchers have outlined the different parameters that are taken into consideration by the two different models (Table 8).

Now researchers conduct a performance evaluation test using the two different models on a real time incident. Researchers assume that a car is travelling in ideal condition and the vehicle in front of it is at a distance of 100 m now we calculate the distance that is required for the car to a complete stop (Fig. 9). The dotted line shows the result of the simulation and it is clearly visible that it is very close the CA-IDM line rather than the IDM. Hence, it is quiet clear that the result obtained from CA-IDM is far more accurate and realistic as when compared with the IDM Model.

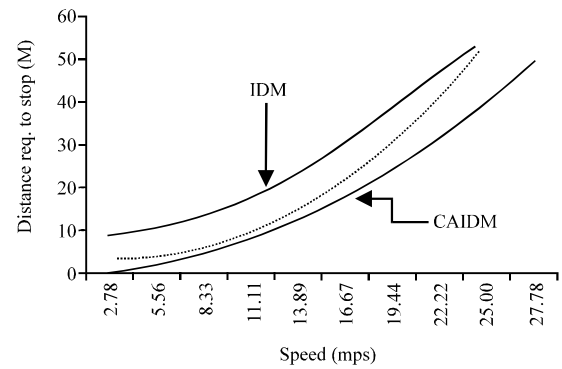

Fig. 9: Performance evaluation test

CONCLUSION

The proposed model is thus far more accurate and apt as it is contextually aware of the situation where it is working. This makes the system more reliable and subsequently it provides appropriate contextual alerts to the driver when it detects an obstacle in the front.

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