Demmel, Sebastien, Larue, Gregoire S., Rakotonirainy, Andry, & Gruyer, Dominique (2011) Using cooperative vehicle systems to collect near collision incidents events : a simulation study. In *2nd International Workshop on Traffic Data Collection & its Standardisation*, September 22-23, 2011, Brisbane, Australia.

Using cooperative vehicle systems to collect near collision incidents events: a simulation study

Sébastien Demmel, QUT & IFSTTAR, sebastien.demmel@qut.edu.au
Grégoire S. Larue, QUT, g.larue@qut.edu.au
Andry Rakotonirainy, QUT, r.andry@qut.edu.au
Dominique Gruyer, IFSTTAR, dominique.gruyer@ifsttar.fr

***Abstract*—On the road, near collision events (also close calls or near-miss incidents) largely outnumber actual crashes, yet most of them can never be recorded by current traffic data collection technologies or crashes analysis tools. The analysis of near collisions data is an important step in the process of reducing the crash rate. There have been several studies that have investigated near collisions; to our knowledge, this is the first study that uses the functionalities provided by cooperative vehicles to collect near misses information. We use the VISSIM traffic simulator and a custom C++ engine to simulate cooperative vehicles and their ability to detect near collision events. Our results showed that, within a simple simulated environment, adequate information on near collision events can be collected using the functionalities of cooperative perception systems. The relationship between the ratio of detected events and the ratio of equipped vehicle was shown to closely follow a squared law, and the largest source of non-detection was packet loss instead of packet delays and GPS imprecision.**

Keywords: Near collisions, near-misses, cooperative systems, V2V.

I. Introduction & rationale

Near collisions incidents have been demonstrated to be appropriate surrogate for injuries and fatalities resulting from actual crashes, as they reflect similar driving errors and generate extremes driving conditions [Dingus et al., 2006B]. We argue that the task of identifying crash causative factors could be supplemented with knowledge related to near collisions. The current lack of a comprehensive methodology capable of collecting, cataloguing and reporting standardised near collision incidents, severely limits the road safety practitioner's ability to develop, test and implement mitigation strategies. However collecting data about near collisions could be expensive, time-consuming and far too speculative without timely, accurate, complete, integrated and accessible data that includes location, vehicle dynamics, road geometry, environmental conditions, and related activities associated with the driving context. Indeed, even if near collision events largely outnumbers actual crashes [Heinrich, 1931], most of current vehicle data collection approaches are focused on collecting data related to actual crashes.

I.A. Definition of near collision incidents

It is important to define what a near collision incident or event refers to. Dingus *et al.* defined a near miss as "*a rapid controlled or uncontrolled acceleration, deceleration, swerve, lange change, or stopping to avoid a crash*" [Dingus et al., 1995]. However, they later refined this definition to distinguish between near crashes and relevant incidents [Dingus et al., 2006A]. A near crash is defined as "*any circumstance that requires a rapid, evasive manoeuvre by the subject vehicle, or any other vehicle, pedestrian, cyclist, or animal to avoid a crash*". On the other hand, a relevant incident is defined as "*any circumstance that requires a crash avoidance response on the part of the subject vehicle, any other vehicle, pedestrian, cyclist, or* *animal that is less severe than a rapid evasive manoeuvre but greater in severity than a ‘normal manoeuvre’ to avoid a crash*”.

More generally, a near miss can be defined as an unplanned event when two vehicles came in close proximity but did not collide, but had the potential to do so if their behaviour had been slightly different. As detailed in section III.A, this study will use a broader definition that does not make use of the emergency manoeuvre distinction, based solely on vehicles’ proximity and trajectories.

I.B. Limitations of naturalistic studies

The NHTSA “100-Car Naturalistic Driving Study” [Dingus et al., 2006B] was undertaken with the goal of obtaining data on driver performance and behaviour before a crash. A hundred vehicles were fitted with data recorders that supplied multiple data on the driver and its vehicle’s state. Similar studies have been undertaken in Europe [Trent et al., 2010] or the USA [Lee et al., 2011].

Large scale naturalistic driving studies will generate a considerable amount of data, depending on the way data are collected. NHTSA experience have shown that less than 10% of the evens that have been flagged as safety events or near collision events by automated data collection systems are actually real safety events. In order to extract these events from the whole data, a time-consuming human verification of video data is necessary. Considerable time and resources could be saved with reliable automated analysis [Lee et al., 2011].

Our understanding is that cooperative systems, using collision prevention systems, could be used to automatically distinguish between real safety events and false positive or, at least, reduce their ratio to a more manageable number. Thus, the aim of this paper is to show that cooperative systems can be used as an inexpensive approach to collect and sort data on near collisions incidents, especially if the data collection systems are linked to driving assistance systems providing safety functionalities. This would allow following the deployment rate of systems providing an immediate safety benefit and, thus, maximising their acceptability to the general public.

I.C. Paper structure

In this paper, we will present the simulation engine we developed in order to demonstrate the interest of using cooperative systems. Our simulation engine is divided in two independent parts. At first, a simulation of road traffic (a scenario) is generated with conditions appropriate for the occurrence of near collisions. Then, this scenario is run through a module that simulates V2V, extended map-building and near collisions detection.

Section II presents how scenarios are generated; section III expands on the definition of near collision event we use and mathematical background; section IV presents the functioning of our communication and extended perception simulation. Simulation results are detailed in section V and the study’s limitations are discussed in section VI. Eventually, section VII concludes this paper and gives several avenues for future research.

II. Scenarios generation with a traffic simulator

In order to generate a road traffic scenario suitable for near collisions detection, we used the VISSIM traffic simulator. Using a pre-existing traffic simulator allows saving time in design and development and, most importantly, using complex vehicular movements and behaviour models. Indeed, our aim was to allow multi-lane motion in order to avoid limiting the study to rear-end or intersections near collisions. Unfortunately, at the time of the study, we were not able to use tools that combine traffic and V2V simulators, such as SUMO, for logistical reasons. Nonetheless, a future development should be porting this study in such software.

A three kilometres-long 2 lanes straight section of freeway was created, with only one direction taken into account. Indeed, simulating both traffic directions would be redundant. A 3,000 vehicles/hours flow is injected on this section for 15 minutes; vehicles at the section's entrance are distributed exponentially. 90% of the vehicles are light vehicles; the rest is composed of lorries. Additional parameters used include "European" driving rules[1], an average looking distance of 100 metres both ahead and back, a Wiedemann 99 [Olstam et al., 2004] car following model. Drivers can suffer from temporary attention lapses with a 0.2 probability. This latter parameter was added in order to increase the number of potential near collisions by making hazardous conditions commoner. Indeed, near collisions are more likely than actual crashes (as shown in section I.A.) but they still remain uncommon occurrence over short time scales.

The simulation is updated every 0.1 second. At each timestamp, parameters from all the vehicles present on the freeway section are outputted to a file. These parameters mostly describe the vehicle's identity, position and motion.

III. Near collision definition and detection

II.A. Definition of a near collision

In order to compute the number of near collision events, we have to formally define them, as explained in section I. Within our study, we use a definition that differs from the logic used by Dingus *et al.* [Dingus et al., 1995; Dingus et al., 2006A], *inter alia*, where a near collision involves evasive manoeuvres. We use a broader definition along the line of "*any conflict between moving vehicles or situation of very close speed/distance proximity*" [Dingus et al., 2006A]. This is expressed within the simulation as the existence of a position that is projected to be occupied by two different vehicles within a time period *TTCmax* of two seconds. The Time to Collision (TTC) is classical surrogate safety measure used in traffic micro-simulations, notably with VISSIM [Eisele et al., 2004; Vanderschuren, 2007]

II.B. Detection of a near collision

The position and speed of each vehicle are known for each timestamp. The position is known for both the front and the rear of the vehicle. For each vehicle, vehicles in a 100 meters range

---

[1] Vehicles have the obligation to drive in the right-most lane (or left-most lane in the UK or Australia) when not overtaking.

are identified and potential near collisions with the focus vehicle are analysed for all vehicles within range.

The trajectories of the selected vehicles are projected up to TTC_{max} later, using the position and speed at time t. It is assumed that the speed at time t remains a good estimate of the speed during the whole time period. The position $B\,(X_b, Y_b)$ of the front of the first car at time $t + TTC_{max}$ is obtained as follows (see figure 1): from the position $A\,(X_a, Y_a)$ of the rear of the vehicle at time t , the length L of the vehicle and the speed $\overrightarrow{V}(V_{Xa}, V_{Ya})$ of the vehicle at time t

$$\begin{cases} Xb = Xa + L \cdot cos\theta + V_{Xa} \cdot TTCmax \\ Yb = Ya + L \cdot sin\theta + V_{Ya} \cdot TTCmax \end{cases}$$

with

$$\begin{cases} \overrightarrow{V} = (V_{Xa}, V_{Ya}) \\ \theta = (\overrightarrow{i}, \overrightarrow{V}) \\ L \text{ length of the vehicle} \end{cases}$$

The same calculations are done for the second vehicle (points $X\,(X_x, Y_x)$ and $Y\,(X_y, Y_y)$ in Figure 1). A near collision, as defined in III.A, occurs when there is an intersection I between the two projected trajectories. Two cases have to be studied: (i) when the trajectories are not parallel and (ii) when they are parallel.

The first case is presented in figure 1. The two directions from the two vehicles have an intersection and a near collision occurs if this intersection belongs to the projected trajectories:

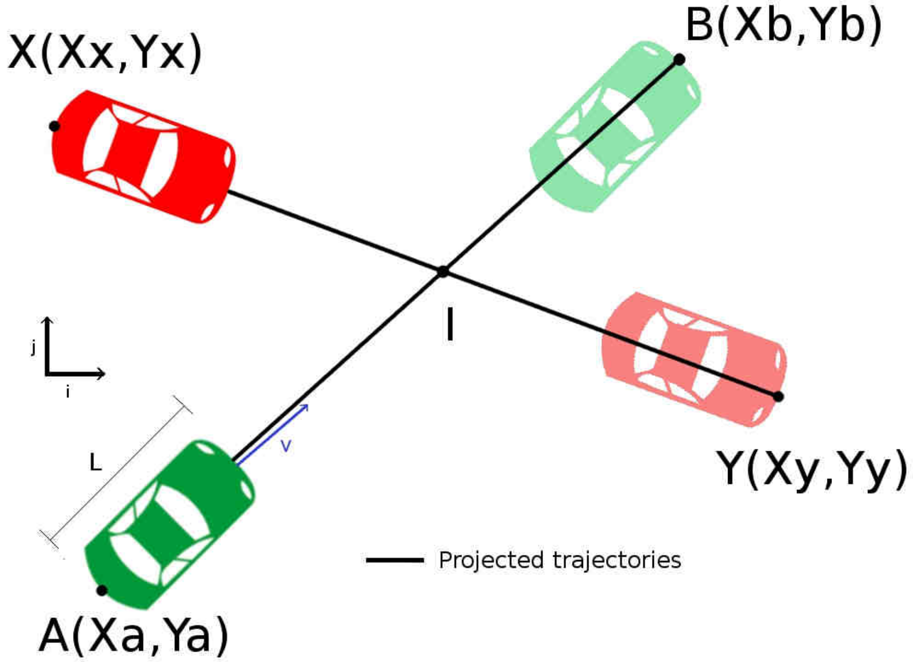
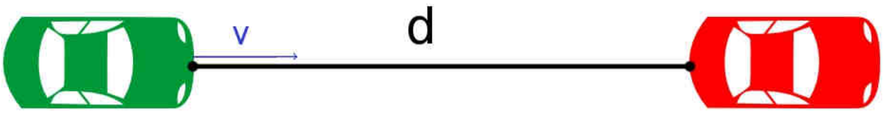


Figure 1 – Trajectories projection

$$\begin{aligned}\text{Near collision} \quad & \Leftrightarrow I \in [AB] \;\text{ and }\; I \in [XY] \\ & \Leftrightarrow \exists\,(\alpha,\gamma) \in [0,1]^2\,,\, \overrightarrow{AI} = \alpha\overrightarrow{AB} \text{ and } \overrightarrow{XI} = \gamma\overrightarrow{XY} \\ & \Leftrightarrow \begin{cases} (Xb - Xa)\cdot\alpha + (Xx - Xy)\cdot\gamma = Xx - Xa \\ (Yb - Ya)\cdot\alpha + (Yx - Yy)\cdot\gamma = Yx - Ya \\ 0 \leq \alpha \leq 1 \\ 0 \leq \gamma \leq 1 \end{cases}\end{aligned}$$

With parallel trajectories, two different cases are possible. One car can be behind another and a near collision can occur. Otherwise the two cars can be side by side and no near collision is possible.

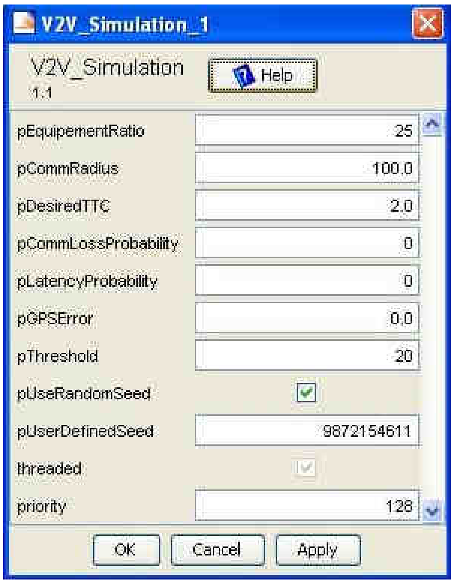
In the case of potential near collision, a near collision is recorded when the following car reaches the position of the rear of the leading vehicle within the TTC_{max} time period, which was at a distance d of the following vehicle at time t. Therefore:



$$\text{Near collision} \Leftrightarrow \frac{d}{V} < TTC_{max}, \text{ with } V \text{ speed of the following vehicle}$$

IV. Cooperative systems (V2V) simulation

The cooperative systems simulation module is based on a two components C++ program. The first component is dedicated to extracting the data from all vehicles at each time stamps and sending it to the second component where the actual vehicle-to-vehicle and extended map building simulation takes place. We will only describe how the second component functions, as the first component is trivial.



pEquipementRatio	25
pCommRadius	100.0
pDesiredTTC	2.0
pCommLossProbability	0
pLatencyProbability	0
pGPSError	0.0
pThreshold	20
pUseRandomSeed	☑
pUserDefinedSeed	9872154611
threaded	☑
priority	128

Figure 2 – Cooperative systems simulation user-set parameters

IV.A. V2V simulation

IV.A.1. Distribution of equipped vehicles

At the program's start-up, vehicles are randomly allocated cooperative perception systems. In order to simplify the code, allocation is always performed for 3,000 vehicles whatever the exact number of vehicles that is injected on the road section during the scenario as 3,000 is the maximum number. A uniformly distributed random number is generated for reach vehicle; this number is then compared to a threshold. If the random number is inferior to this threshold, the vehicle is flagged as being equipped with a cooperative perception system. The threshold is a function of the desired equipment ratio, set by the user.

The seed used to generate random numbers can be generated automatically or set manually. In the former case, it is based on the host computer's clock. The influence of using different seeds (and thus generating vastly different repartitions of equipped vehicles) at the same equipment ratio is discussed in section IV.B.

IV.A.2. Communications range

For the purpose of this study, equipped vehicles are assumed to broadcast position information every 0.1 seconds (every simulation timestamp). As typical delays [Biswas et al., 2006; Schmilz et al., 2006; Demmel et al., 2011] are in most case smaller than one simulation step, we are not taking them into account. Rarer, larger delays are still simulated as described in next section.

The communication range is determined with a classical Boolean model. Each vehicle computes the distance between itself and all other vehicles at the current timestamp; vehicles distant then less than a threshold are flagged as within communication range, vehicles distant more than the same threshold are flagged as out of range. All vehicles within range can be exchange information with the focus vehicle. Vehicles remain in direct line of sight for the whole duration of the simulation, and routing issues are not taken into account.

This is the simplest possible simulation of radio communication [Busson, 2009] and is well suited to a straight section of freeway scenario. The radio range can be set as a parameter within the simulation. The default range, which will be used for the rest of this paper, is set at 100 metres. This is about half the typical outdoor range for 802.11g transmitters; outdoor measurements performed at IFSTTAR with 2 dBi gain antennas showed ranges from 60 to 80 metres.

IV.A.3. Communications and sensors imperfections

Before vehicles are updated of the position and behaviours of vehicles in communication range, imperfections can be applied on the information transfer. Most issues related to lower layers of the communication architecture, such as medium access and collision control, are not simulated. Nonetheless, two parameters can be used to simulated imperfect communications: (i) a probability of message loss and (ii) a probability of latency. Additionally, an error can be added to the vehicles' position and speed as outputted by VISSIM in order to simulate the presence of GPS inaccuracies.

At each timestamp, two uniformly distributed random numbers are generated for each equipped vehicle. These numbers are tested against the threshold based on the loss and latency probabilities. Messages loss and latencies are simulated for each vehicle once, not for each individual exchange between two vehicles. As such, they represent a complete loss of remote perceptive information during one timestamp; or a delay of all remote perceptive information for one timestamp. The remote information that should have been transmitted to a "delayed" vehicle during the current timestamp is stored in a buffer to be delivered at the next timestamp, after which normal transmission resumes. Delays larger than 0.1 second (one simulation step) cannot be simulated at the moment. The probability of latency will be based on measurements we performed in a similar scenario with 802.11g, with a pessimistic average of 10% of messages showing latencies greater than 0.1 second [Demmel et al., 2011].

Non-communication related errors can also be added to the vehicles' position and speed. Contrary to communication errors, these errors are systematically present. However, they can be modified by changing a standard deviation parameter; if this value is left to zero, positioning and speed errors are effectively removed.

Positioning (GPS) and speed measurement errors are distributed normally [Taylor, 2001]. The Box-Muller transform [Box et al., 1958] is used to create three normally distributed numbers from random numbers generated with a uniform distribution. Errors applied to the position and speed are functions of the standard deviation parameter and the aforementioned normally distributed numbers. They are recomputed for each simulation step.

With all the imperfections parameters set to 0, perfect conditions will be simulated. These conditions can be used to determine the absolute number of near collision events.

IV.B. Extended perception simulation

Once vehicles have been attributed with cooperative perception systems, determined their neighbours in radio range and imperfections have been generated, the vehicles' extended map is updated. From the point of view of vehicle *i*, the extended map is an array of structure, left empty if vehicle *j* is not within radio range or updated with data relevant to vehicle *j* behaviour in the contrary. Figure 3 shows the nested structures used for the map.

```
struct mapobject{
     int m_globalID;
     float m_xFrontPos;
     float m_yFrontPos;
     float m_xRearPos;
     float m_yRearPos;
     float m_velocity;
};

struct map{
     int m_egoVehID;
     bool m_egoCar;
     bool m_egoLorry;
     mapobject m_egoVehData;
     mapobject m_remoteVehData[3000];
};

map g_currentMap[3000]
```

Figure 3 – Extended map nested structures

Maps are updated with the data extracted from the simulator modified by any imperfection, if present, first for vehicle *i*, then for all vehicles within radio range of *i*. As we always use 3,000 indices-long arrays, including nested ones, computation are quickened using only the upper half of the *ij* matrix and by determining the IDs of vehicles present on the freeway section at any *t*. Only indices bounded by _minCID and _maxCID are considered, which greatly reduces computation time. Vehicles with IDs within the above bounds but not present on the section anymore are purged from the vehicles' maps at this time too.

IV.C. Near collisions detection

Once all equipped vehicles have had their maps updated, near collision events detection can start. The mathematical aspects have already been detailed in section III.B; these equations are transposed in C++ code. Near collision detection is divided in three sequential stages, performed at each simulation time step: (i) projection of vehicle's trajectories, (ii) detection of potential and actual intersections and (iii) filtering of new events.

Projection of the vehicles position is done by simple linear extrapolation for the next TTCmax seconds (2 seconds, by default). This is performed for all vehicles present on the freeway section at the current simulation step.

Then, the program checks whether the projected trajectories intersect. Firstly, only the directions are tested with a determinant computation; then the actual projected segment are checked with the computation of α and β (see III.B for more details). If both tests pass, a near collision event is detected.

The third step is checking whether detected near collision events are new. Because of the simulation's characteristics, the same near collision event with two vehicles *i* and *j* can be detected at timestamp *t*, lost at timestamp *t+1* and detected again at timestamp *t+2*. The *t+2* detection is obviously not a new event, as only 0.2 seconds have passed since the first detection. We must thus distinguish real new events from events that are getting re-detected after a brief interruption. In order to do so, a bi-dimensional array stores the number of simulation step for which one specific near collision event between vehicles *i* and *j* have been detected. In order to be flagged as a real new event, an event has to be detected twenty times in a row (or last for 2 seconds of simulation time). This allows removing any false alarm related to small variations of direction produced by the GPS imperfections and boundary events. The number of simulation step threshold is set at 20 by default by can be set by the user. Once the filtering is done, a simple for loop counts the number of new events and add it to the running total of near collision events.

V. Simulation results

V.A. General results analysis

V.A.1. Relationship between the ratio of equipped vehicles and the number of detected near collisions

Figure 4 presents the results obtained with one scenario. For each run through the simulation module, most parameters remained identical; the main change was the equipment ratio that was incremented gradually from 5 to 100%. The seed used for equipped vehicles distribution is the same between the red and blue curves; they differ in the presence of communications and GPS imperfections. The red curve is obtained for a "perfect" situation with an errorless GPS and no communication issues; the blue curve is obtained for an imperfection environment with the following parameters: GPS standard deviation: 3.0 metres; probability of message loss: 0.01; probability of delay: 0.05. In both cases, the default parameters are used for the communication radius (100 metres), TTCMax (2.0 seconds) and the new event threshold (20).

The $y = x$ and $y = \frac{x^2}{100}$ curves are also shown, respectively in black and grey. The simulated curves display a behaviour similar to a $y = x^2$ curve, which is expected. Indeed in the absence of exteroceptive sensors for a near collision event to be detected, the two concerned vehicles need to be equipped. Only events contained within the intersection of the sets of total near collision events concerning each vehicle *i* and *j* can actually be detected. Thus, the total number of detectable events is the union of all the equipped vehicle events sets intersections. Furthermore, the probability of two vehicles in a near collision event to be equipped is the square of the probability for a single vehicle to be equipped.

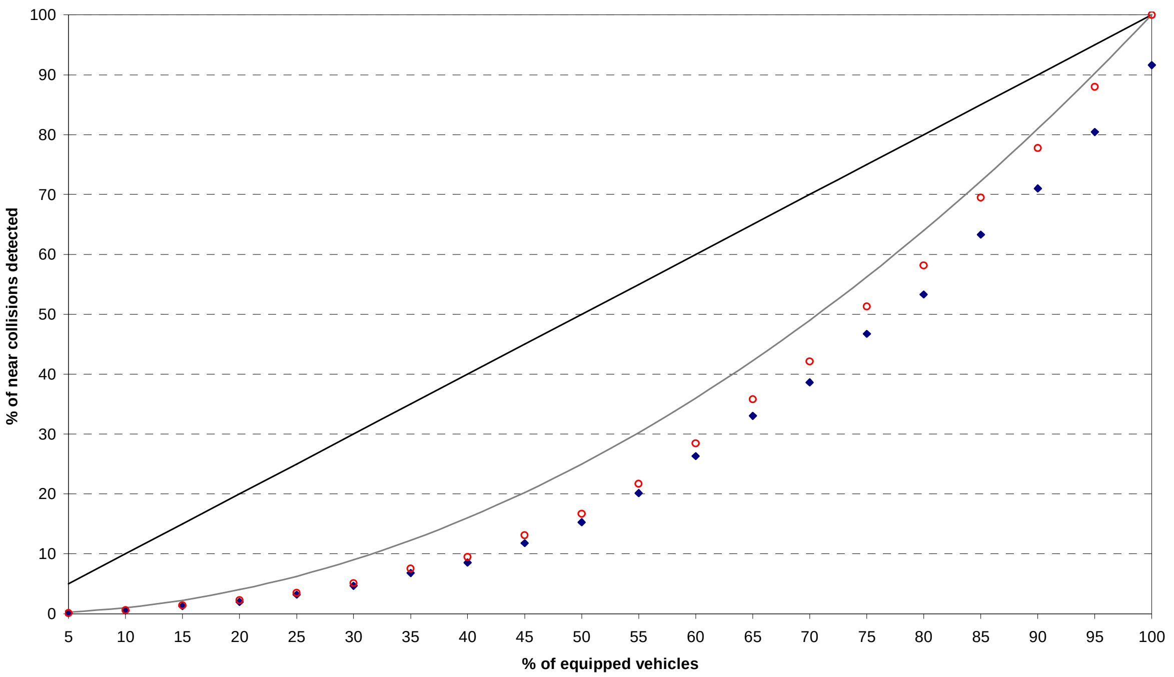


Figure 4 – Percentage of detected events versus the equipment ratio, with (blue) and without (red) imperfections.

However, the obtained curves shows that even for a perfect situation, the percentage of detected near collisions remains inferior to the $y = \frac{x^2}{100}$ curve, with the largest difference observed around 50% of equipped vehicles. At this point, we have to question whether this difference is systematic or only the produce of one specific distribution of equipped vehicles. Indeed, we can assume that some vehicles might be more "accidentogenic" than others, and if these vehicles are not equipped with cooperative perception, the near collision events they produce will not be recorded. In order to verify this, we study the influence of the equipped vehicles distribution in section V.B.

V.A.2. Communications imperfection influence

On figure 4, we can see that the communication and GPS imperfections decrease by 8.4% the number of detected events compared to a perfect situation with a 100% equipment ratio. Our results show that, in the way they are presently simulated, transmission delays have a very limited influence on the detection of near collisions. On the other hand, message loss impacts the detection considerably more. A few simulation results are shown in table I; they have been computed with a fixed seed at a 95% equipment ratio.

Table I – Events detection for varied loss and delay probabilities

Loss probability	0.05	0.10	0.15	0	0	0
Delay probability	0	0	0	0.05	0.10	0.15
Events detected	12,430	11,658	10,794	13,267	13,277	13,293
Percentage of total	84.88	79.60	73.70	90.59	90.66	90.77

The same scenario with perfect conditions yields 13,280 events, or 90.68 % of the total numbers of near collision events in this scenario. This value is very close to the ones obtained with only delayed messages, which only change by 0.18% while the delay probability increases from 0.05 to 0.15 at each simulation step. On the other hand, losing messages has a stronger influence on the detected events. With a 0.15 probability of loss (generally higher than what we can expect as short ranges [Schmilz et al., 2006]) at each timestamp, 2,486 events are also lost. Detected events decrease by 11.18% when the loss probability increases by 0.10 from 0.05 to 0.15.

With delays but no loss, increasing the delay probability actually increases the number of detected events, from a value slightly lower than the perfect case to a value slightly higher than the perfect case. Because of the new event threshold, some of the delayed messages that would otherwise have been ignored are instead counted as a new event. Thus, a limited numbers of near collisions are counted twice, as false positive. Some events are also lost, accounting for the -0.09% difference at 0.05 delay probability, but this effect is eventually counteracted by the previous one when the delay probability becomes large enough.

V.A.3. GPS imperfections influence

Table II presents the results of simulations where imperfections are limited to GPS ones. The same seed is used for all simulations and the equipment ratio is 50%

Table II – Events detection for varied GPS imperfections

Standard deviation (m)	0	1	2	3	5	10	20
Events detected	2,863	2,635	2,609	2,572	2,570	2,439	2,308
Percentage of total	19.55	17.99	17.81	17.56	17.55	16.65	15.76

With a 5 metres standard deviation, GPS imperfections reduce by 2% the number of detected events. With a large 20 metres standard deviation, unlikely in open freeway environments, the reduction reaches only 3.79%. This shows that while GPS imperfection contributes to reducing the number of detected events, they do not contribute as much as message loss, which remains the dominating factor.

This limited effect of GPS imperfections also shows the robustness of our definition of a near collision event. With a 20 metres standard deviation, one could expect that a large number of events would not be detected because the projected trajectories do not intersect anymore. While it gives no indication on the quality of our event definition (see section VI), it shows that most of the events detected are not fringe events that would be removed by large imprecision. However, it is impossible to distinguish positive from false positive, so the proportion of false positive in the detected events in high imperfections conditions could be higher than in normal conditions.

V.B. Influence of varying distributions of equipped vehicles

Studying the influence of the equipped vehicles distribution on the number of detected events is simple: one must just modify the seed used for the random selection of equipped vehicles (see IV.A.1). Figure 5 shows the effect of different seeds on the cumulative number of detected near collisions with the same scenario, for 7 different seeds with no imperfections and a 50% equipment ratio. Although the final amount varies from 2,500 to 3,500, most of the curves follow a similar pattern. The seeds were chosen as random strings of 8+ figures. The red curve shows the most differentiation from the average, with a sharp rise between the 200th and 400th seconds compared to the other curves. This is likely the result of having a group of vehicles engaged in a high number of near collision events at this timeframe that were insufficiently equipped with the other seeds.

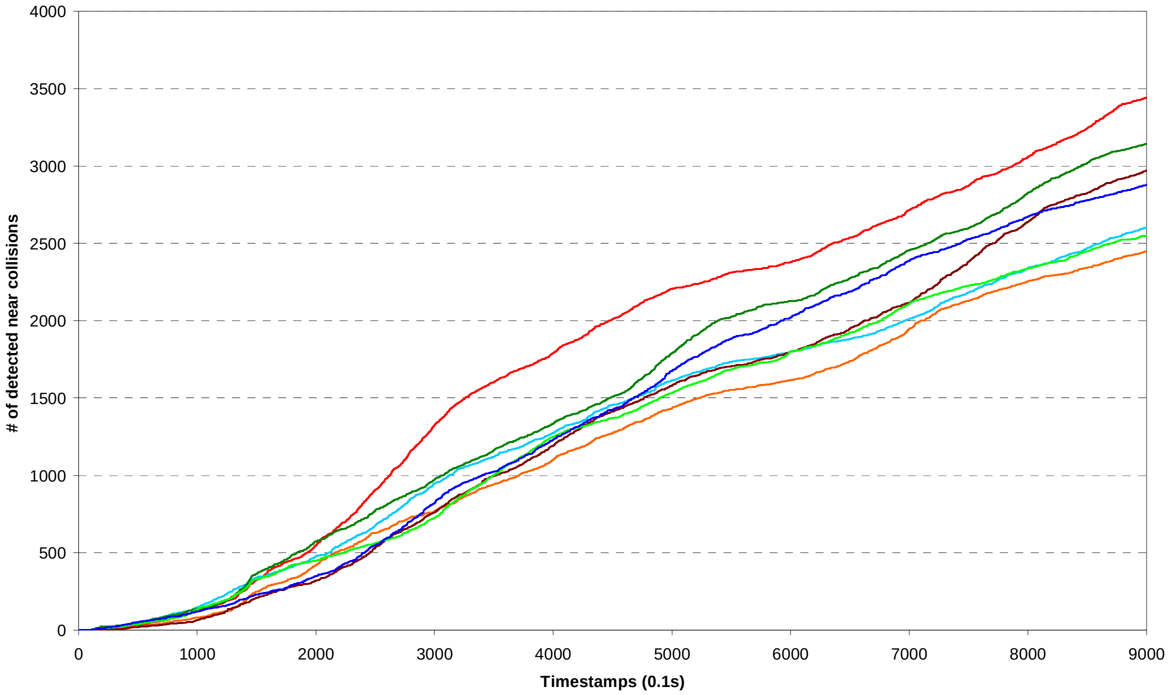


Figure 5 – Cumulative number of detected events for 7 different seeds over the same scenario

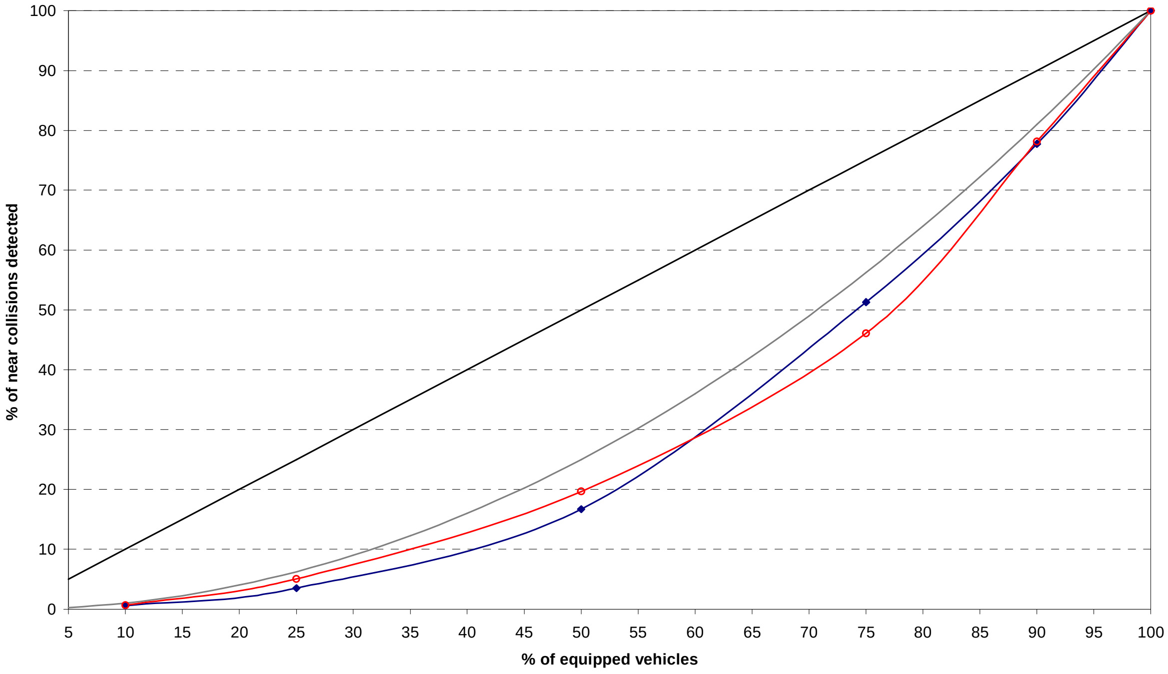


Figure 6 – Percentage of detected events versus the equipment ratio, with 2 different seeds (no imperfections)

Figure 6 shows the percentage of detected events relatively to the equipment ratio, for two different seeds. Both curves remain under the $y = \frac{x^2}{100}$ curve shown in grey. While their different with the said reference curve varies depending on the equipment ratio, both curves ultimately converge toward the final, absolute value. This is confirmed by figure 7, which display the envelope of half a dozen curves obtained with different seeds. The lower envelop, in red, has its largest difference (~11%) from $\frac{x^2}{100}$ at 75% of equipped vehicles. The high envelop follows $\frac{x^2}{100}$ much more closely, with a maximum difference of only 3%. The seed used to generate this curve is likely to be close to the seed required for obtaining the optimal detection of near collisions events for that specific traffic scenario.

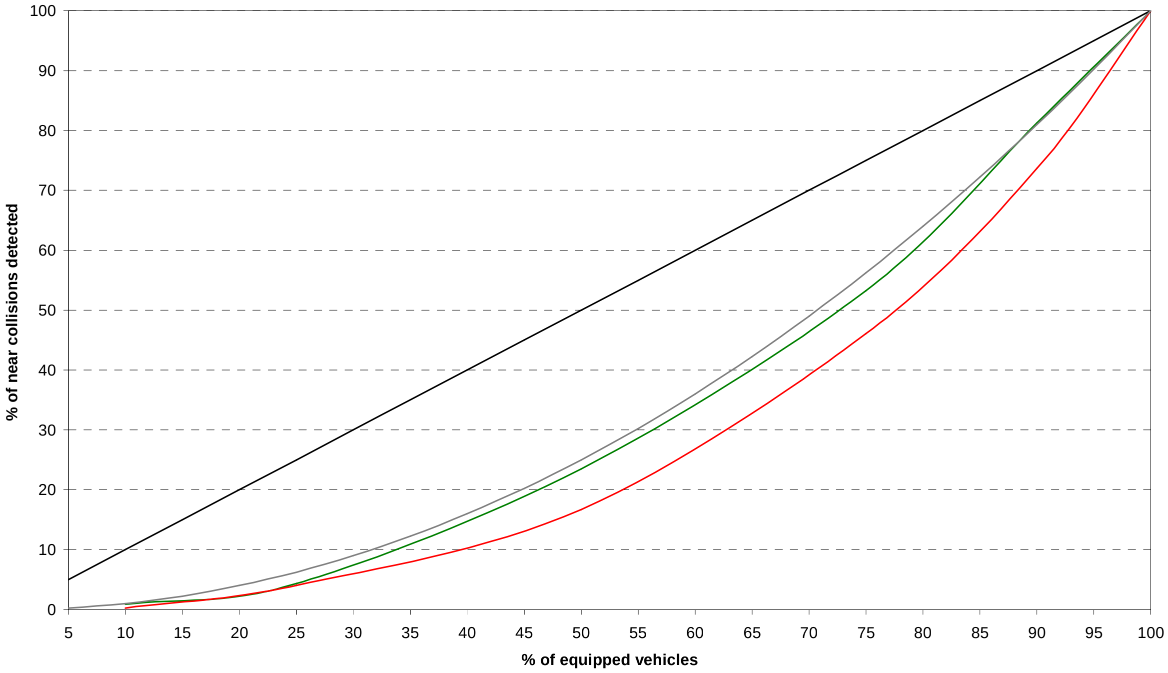


Figure 7 – Percentage of detected events versus the equipment ratio, maximum and minimum envelope

VI. Limitations

One obvious limitation of this study relates to the assumptions taken with the radio communications, which are purportedly kept relatively simple. Nonetheless, the present assumptions have not hindered the system from performing as expected. Other limitations are related to VISSIM's characteristics and the detection of false positive.

It is important to note that VISSIM is not able to simulate crashes. When the simulator's parameters are pushed to the extremes (with very large traffic densities or high attention lapses) vehicles might overlap each other. However, these events are not recorded by the simulator and the concerned vehicles will continue their motion unimpaired as if the overlapping was inexistent. Even if they could be detected through *a posteriori* examination, as they do not impact the traffic flow, they cannot be used to represent realistic crashes. Nonetheless, braking events leading to near collision conditions are within the simulator's scope.

Another limitation of this study is that some of the near collision incidents detected using cooperative systems might be false positive. In the present framework, we cannot verify whether the detected events are real near collisions only transitory situations that will quickly move away from near collision conditions. Further research is required to evaluate the effects of the different parameters on the detections' accuracy. Research should also try to assess whether detection of near collision incidents using cooperative systems are recorded accurately in terms of time. Such study could help in designing active cooperative systems that would be more efficient in reducing likelihood of crashes on the road.

VII. Conclusion

In this paper, we have presented a novel cooperative vehicle system simulation to detect near collisions events. Our approach alleviates the limitations of naturalistic driving and driving simulator experiments. Our results have shown that this approach is feasible and can produce useful results, albeit more work will be necessary to allow more realistic simulations.

We have shown that without exteroceptive sensors, the relationship between the equipment ratio and the number of near collisions detected follows a square curve. We have determined that with the present parameters, the number of detected events always remains under the "optimal" squared curve. We also showed that the distribution of equipped vehicle within the traffic flow is the biggest influence factor. Nonetheless, communications imperfections can have a significant influence too, as message loss was show to decrease the number of detected events by up to 10%. GPS imperfections and message delay were shown to have a less significant effect, although they might increase the proportion of false positive in the detected events.

Future research will concern expanding the communication simulation in order to reach a more realistic depiction of radio technologies and protocols used in the ITS field. This could take the form of creating a more realistic simulation module or transferring the current scenario to combined traffic-V2V simulators such as SUMO. Another aspect will be the introduction of exteroceptive sensors. With the current work, vehicles require information from other vehicles to perceive their environment. If they are fitted with exteroceptive sensors, such as radars or laserscanners, vehicles can perceive themselves at least a part of their immediate environment and detect near collision events that would be impossible to detect otherwise (unless all vehicles were equipped for communicating their position). We expect that curves such as shown in figures 4, 6 and 7 will have a more linear behaviour when exteroceptive sensors are included and should tend toward the theoretical number of near-miss that can be detected. Furthermore, the system will need to be modified in order to distinguish actual incidents from false positive. Eventually, the present system can be used over more complex road networks (e.g. intersections) without modifications.

Acknowledgement

This research is supported by the Commonwealth of Australia through the Cooperative Research Centre for Advanced Automotive Technology (AutoCRC).

References

Biswas, S.; Tatchikou, R.; Dion, F. "Vehicle-to-vehicle wireless communication protocols for enhancing highway traffic safety", Communications Magazine, IEEE , vol.44, no.1, pp. 74-82, Jan. 2006.

Box, G. and Muller M., "A Note on the Generation of Random Normal Deviates", in The Annals of Mathematical Statistics, Vol. 29, No. 2 pp. 610–611, 1958.

Busson, A., “Performance evaluation of broadcast protocols in VANET: a point process approach”, in Proceedings of the 6th ACM symposium on Performance evaluation of wireless ad hoc, sensor, and ubiquitous networks, Tenerife, Canary Islands, Spain, pp. 108-115, 2009.

Demmel, S., Gruyer, D., Besnier, J., Ben Jemaa, I., Pechberti, S., Rakotonirainy, A. “Collision warning dissemination in vehicles strings: an empirical measurement”, in Proceedings of the IEEE 2011 Intelligent Vehicles Symposium, Baden-Baden, Germany, pp. 454-459, 2011.

Dingus, T., McGehee, D., Hulse, M., Jahns, S., Manakkal, N., Mollenhauer, M., Fleishman, R., “Travtek Evaluation Task C3-Camera Car Study”, Report No. FHWA-RD-94-076, U.S. DoT, 1995.

Dingus, T., Neale, V., Klauer, S., Petersen, A., Carroll, R. “The development of a naturalistic data collection system to perform critical incident analysis: An investigation of safety and fatigue issues in long-haul trucking”, in Accident Analysis & Prevention, Volume 38, Issue 6, Pages 1127-1136, November 2006.

Dingus, T. A., et al., “The 100-Car Naturalistic Driving Study, Phase Ii – Results of the 100-Car Field Experiment”, Technical Report DOT HS 810 593, U.S. DoT, 2006.

Eisele, W., Frawley, W. “Estimaing the impact of access management with micro-simulation: lessons learned”, in Proceedings of the 6th National Conference on Access Management, Kansas City, USA, 2004.

Heinrich HW, “Industrial accident prevention: a scientific approach”, McGraw-Hill, 1931.

Lee, S.E., et al., “Naturalistic assessment of novice teenage crash experience”, in Accident Analysis & Prevention, 2011.

Olstam, J. and Tapani A., “Comparison of Car-following models”, VTI Publication M960A, 2004.

Schmilz, R.; Leiggener, A.; Festag, A.; Eggert, L.; Effelsberg, W.; , "Analysis of Path Characteristics and Transport Protocol Design in Vehicular Ad Hoc Networks," Vehicular Technology Conference, 2006. VTC 2006-Spring. IEEE 63rd , vol.2, no., pp.528-532, 7-10 May 2006.

Taylor, George “Road Reduction Filtering for GPS-GIS Navigation”, in Transactions in GIS (1361-1682), 5 (3), p. 193, 2001.

Trent, V., Bärgman, J. and Hurtig, S. (2010) “Sweden-Michigan Naturalistic Field Operational Test (SeMiFOT) Phase 1: Final Report”, SAFER REPORT 2010:02, Gothenburg, May 2010.

Vanderschuren, M. “Safety improvements through Intelligent Transport Systems: a South African case study based on microscopic simulation modelling”, in Accident Analysis & Prevention, Volume 40, Issue 2, Pages 807-817, 2008.