Proceedings of the
2007 IEEE Intelligent Vehicles Symposium
Istanbul, Turkey, June 13-15, 2007

An analysis of the lane changing manoeuvre on roads : the contribution of inter-vehicle cooperation via communication

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Abstract— **Many risky manœuvres on roads integrate a lane change action. The synchronization of the involved cars is very important in such manoeuvres. The new generation of ADAS systems based on cooperation between vehicles can offer serious perspectives to such manoeuvres. The inter-vehicle cooperation is made possible thanks to the revolution in the wireless mobile ad hoc network. In this paper we analyze the lane change process and detect its risky aspects. Regarding this analysis we propose a cooperative system that aims to estimate the risk associated to lane changing and alert the driver when possible collision with other agents on the road is detected. An experimental study of this system is performed on our fleet of experimental communicating vehicles.**

I. INTRODUCTION

The traditional standalone ADAS (Advanced Driver Assistance System) based on the on-board proprioceptive and exteroceptive sensors has shown its limitations because of the shortages and limitations of the existing sensors (camera, radar, etc). It is also impossible or uncertain to measure some parameters which are necessary to the design of new assistance systems. The new generation of cooperative systems is based on the exchange of information between vehicles. All the applications issued from the cooperation are based on the concept of the neighbor local map : a map in which rely the positions of the each neighboring vehicle in association with its exchanged data. The richer is the exchanged data the more efficient can be the new system. There is two levels of cooperation : a) a cooperation based only on the exchanged knowledge about the neighboring cars but the decision is made separately on each vehicle; b) a cooperation with interactions between vehicles and with distributed decision making. In our work, we focus on the first level which is more realistic today. The inter-vehicle cooperation concept is made possible thanks to the huge revolution on the communication systems and especially on the wireless technologies. In the last years, standards (like the 802.11) make possible the expansion of wireless local area networks essentially in indoor environments. Another work on the 802.16 standard is aiming the definition of a wireless metropolitan network. The extension of these communication systems to the vehicle domain is motivated by the need of cooperation in new ADAS applications. Many research teams worldwide are involved in the definition of such systems and this motivation will be materialized with the IEEE 802.11p standard. This standard is designed for the vehicle communication and will be ready probably on the 2008 summer. In this paper, we anticipate the standardization step by acting on the application level. We will analyze the impact of such systems on the road safety. In a very first application, we have worked on the contribution of the direct cooperation between vehicle to detect risky situation on the approach on crossroads ([1], [2]). We choose to study here the problem of lane change manœuvre. We begin our analysis by defining the lane change action, present some statistics of road accidents related to lane changing and study the impact of this manœuvre on the road safety. In Section III we present our experimental fleet of communicating vehicles. We also report some characteristics of our communication system. Using our fleet of vehicles, we experiment the collision detection system on the lane changing. The details of the studied scenarios are reported in section IV. The section V is devoted to the analysis of measured data and to the formulation of a sensible risk indicator.

This work was supported by the European Com2REACT Project

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II. LANE CHANGING

A. definition

In this paper we adopt the definition of lane changing cited in [3]: *lane changing is a deliberate and substantial shift in the lateral position of a vehicle*. By this definition we exclude all the rude manœuvres of accident avoidance and the zigzags in-between lanes. With regard to this definition, the lane changing is still a frequent driving action. In fact it constitutes an elementary action of several risky and complicated actions on roads. It could be a volunteer action as in overtaking a slower vehicle, but it can also be unavoidable like in enter/exit procedure or semi-forced when we are tailgated by a vehicle with a high speed. A lane changing example is shown on the Fig.1.

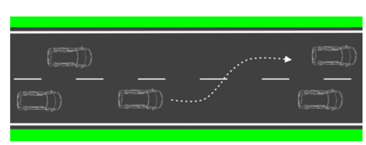

Fig. 1. Lane changing manœuvre

B. Accidents statistics

In a classical lane change manœuvre the driver try to investigate the road and estimate the speed of the other vehicles to begin lane changing. Those series of actions are typically cooperative. In fact, knowing exactly the speed of the neighboring vehicles reduce considerably the risk of accidents. The most important cause of accidents associated to lane changing involves a recognition failure by the driver. In fact, according to [8], 75% of lane changes accidents is due to this reason. According to several studies cited on [4], [5], [6], the accidents associated to a lane change manœuvre in the USA represent between 4% and 10% of the totality of the accidents in this country. On the other hand it causes 10% of the latencies on roads [3], which is probably related to the fact that this kind of accidents influences several lanes at the same time. According to [7], 78% of lane change accidents take place at a low speed (25 km/h). This low speed value reduces the requirements in terms of immediate and real time alert to the driver and let a little bit more time to avoid the accident once detected. This property supports the use of the inter-vehicle communication. If we examine the accidents nature, only 5% are pure rear-end collisions while the remaining ones are lateral collisions [6]. These statistics mean that the accidents happen mainly in the middle of the lane change procedure.

III. LANE CHANGING PROCESS

A. Lane changing stages

In order to detect the beginning of a lane change manœuvre, the vehicle observes the behavior of each close vehicle through its exchanged parameters via communication. Studying the stages of lane changing is then important to determine which parameters should we communicated and how to use them to detect the beginning of a lane change manœuvre and to model the behavior of the vehicle before, during and after the lane change. From a geometric point of view, the lane change is a modification in the lateral position of the vehicle relatively to the lanes. In [9], the procedure is divided into 3 steps regarding the positions of the vehicle relatively to the crossed line: straight trajectory on the initial lane, trajectory across the line, trajectory on the destination lane. Another classification regarding the sign of the steering angle is made in [10]: the first step is a maximum steering of the wheel and next the correction by a steering in the opposite direction. Moreover authors in [13] model the steering wheel angle during the lane change by a sine function. On the other hand, each lane change should be accompanied by a directional blinker (according to the traffic code). But according to [11], which takes care of reducing to minimum the effect of the experimentation on the natural behavior of the driver, the percentage of lane change associated in the same time to blinkers is not greater then 45% of all lane changing manœuvres. This result was in contradiction with all previous studies which give more than 85% of respect of blinkers activations at the same time as lane changing. So the blinkers are still an important indicator of lane changing but could not be considered as a sufficient and robust parameter. Some other factors could be also examined like the lateral acceleration, the wheels angles, the braking activation ...

TABLE I
BOUNDARY CONDITIONS IN A LANE CHANGE MANŒUVRE

	Longitudinal	Lateral
Position	$X_{initial} = 0$	$Y_{initial} = 0$ $Y_{final} = \Delta L$
Velocity	$\dot{X}_{initial} = \dot{X}_{final} = V$	$\dot{Y}_{initial} = \dot{Y}_{final} = 0$
Acceleration	$\ddot{X}_{initial} = \ddot{X}_{final} = 0$	$\ddot{Y}_{initial} = \ddot{Y}_{final} = 0$

B. Geometric lane change models

In order to estimate any future risk in the lane change manœuvre, we manage to predict the future positions of our vehicle during the manœuvre and to predict also the position of the other surrounding vehicles. Regarding the time critical constraint in all ADAS applications, the use of the search based or the probabilistic approaches for the trajectory planning is not advisable. Among geometric algorithms proposed in the literature, the use of polynomials seems to be a good compromise between simplicity, time computation, trajectory and curvature continuity especially in a non holonomic mobiles [12]. To obtain a realistic trajectory model of the lane change in terms of shape and curvature continuity, many researches (like [14]) choose a polynomial fifth degree function of the time on both x and y directions, standing respectively for longitudinal and lateral directions.

$$X(t) = A_5 t^5 + A_4 t^4 + A_3 t^3 + A_2 t^2 + A_1 t + A_0$$

$$Y(t) = B_5 t^5 + B_4 t^4 + B_3 t^3 + B_2 t^2 + B_1 t + B_0$$

where A_i and B_i are the coefficients of the 5^{th} degree polynomials, and t is the time. In order to determine A_i and B_i, [15] use the boundary conditions of the initial and final positions, speeds and accelerations in both directions. For our application, the boundary conditions are given by the Table I. Where ΔL is the width of the lane, and V_0 is the longitudinal speed of the vehicle at the beginning of the manœuvre. To simplify the computations we assume that the beginning of the manœuvre will take place at $t = 0$ where $X(0) = 0$ and $Y(0) = 0$. ΔT is considered as the duration of the manœuvre. As you can see in Table I we have now 6+5 constraints for a system of 6+6 unknowns. With regard to these constraints, the solution of the equation on the Y direction is :

$$Y(t) = 6\frac{\Delta L}{\Delta T^5}t^5 - 15\frac{\Delta L}{\Delta T^4}t^4 + 10\frac{\Delta L}{\Delta T^3}t^3$$

But the system on the X direction is under determined and there is a infinity of polynomial solutions. Thus the solution could be wrote using a parameter m :

$$X(t) = \frac{3}{5}\frac{m}{\Delta T^2}t^5 - \frac{3}{2}\frac{m}{\Delta T}t^4 + mt^3 + Vt$$

According to the value of the parameters m, the shape on the x direction can have different profiles X(t). There are two kinds of curves accounting the type of the driving manœuvres:

- A lane change with a speed lower than V: we begin by decelerating until the line is crossed and then accelerate to reach the final position and speed;
- A lane change with a speed higher than V: we first accelerate to cross the line and then we decelerate to reach the speed V;

Both profiles are adapted to different given situations: the first manœuvre is suggested while preparing to exit a highway for example. The second manœuvre is suited while overtaking a slower front vehicle. The first profile corresponds in general to a right lane changing, while the second manœuvres are generally executed while passing to the left side of the road. More explicitly, the vehicle leaves the lane 1 from the position (0,0) with a constant longitudinal speed V, to the lane 2 with the position $(X_{final}, \Delta L)$ with the same constant speed. Between those two positions, the vehicle can have any profile of position, speed and acceleration with regards to these conditions:

- The lateral acceleration is lower than the limit of a comfortable acceleration $a_{Lat-max}$ (usually $4m/s^2$).
- The function $y = f(x)$ is monotone. The speed is always strictly positive and below the maximum permitted speed V_{max}.
- The longitudinal acceleration should be lower than $a_{Long-max}$ which has usually the value of $2g$, and the maximal deceleration is also lower than the braking comfort deceleration of $a_{Brake-max} = 0.8g$, where which ABS systems take over the braking control when available.
- We can also add a condition on the curvature of the trajectory : in order to obtain smooth trajectory, we will try to minimize the maximum curvature of the planned trajectory.

Lateral acceleration

According to the $Y(t)$ function, the extremum of the lateral acceleration is always lower than $a_{Lat-max}$ when :

$$\Delta T > k\sqrt{\frac{\Delta L}{a_{Lat-max}}}$$

Where $k = 2.4025$. In our typical applications we take an average lane width $\Delta L = 3.5m$ and consider the maximum lateral comfort acceleration $a_{Lat-max} = 4m/s^2$ then

$$\Delta T > 2.24sec$$

if we take a standard lateral acceleration on a lane change manœuvre of $2m/s^2$ then the minimum allowable value of ΔT becomes $3.17sec$.

In these equations we assume that ΔT is known. Obviously and in spite of the minimum threshold found, ΔT is a very complicated parameter to determine. In fact, it depends on the driving profiles of a giving driver, on the dynamics of the vehicle, on the initial speed of the vehicle, on the drivers reactivity, on the environment... In the literature, ΔT was the subject to several statistical studies. According to the review in [11], we noticed that it is hard to fix a value or a range for ΔT. We decide to fix a value to ΔT of a 5 sec which corresponds to the average of the mean values presented in the mentioned review. The risk calculated in the following sectors will depend on this choice. However we decided to be depended to this nominal value. We noticed also that ΔT is considered as the time of the manœuvre, it does not include the human perception and recognition time before the beginning of the execution of the manœuvre.

Speed

Regarding the equation of the longitudinal speed of the vehicle $\dot{X}(t)$, the extremum is obtained on the $t = 0, \frac{\Delta T}{2}, \Delta T$. We notice that $\frac{\Delta T}{2}$ is the only interesting solution. $\dot{X}(\frac{\Delta T}{2})$ is a maximum when m is positive, respectively minimum when x is negative. $\Rightarrow$

$$\dot{X}(\frac{\Delta T}{2}) < V_{max} \quad pour \quad m > 0 \Rightarrow m < \frac{16}{3}\frac{V_{max} - V_0}{\Delta T^2}$$

and

$$\dot{X}(\frac{\Delta T}{2}) > 0 \quad pour \quad m < 0 \Rightarrow m > -\frac{16}{3}\frac{V_0}{\Delta T^2}$$

$\Rightarrow$

$$-\frac{16}{3}\frac{V_0}{\Delta T^2} < m < \frac{16}{3}\frac{V_{max} - V_0}{\Delta T^2}$$

Longitudinal acceleration

Moreover, in order to satisfy the conditions on the acceleration, we compute the formula of the longitudinal acceleration:

$$\ddot{X}(t) = 12m\frac{t^3}{\Delta^2} - 18m\frac{t^2}{\Delta} + 6mt$$

this third degree function of t should satisfy the condition :

$$a_{Brake-max} < \ddot{X} < a_{Long-max}; for\, 0 < t < \Delta T$$

$\ddot{X}(t)$ has its extremum for

$$t = (1 \pm \frac{1}{\sqrt{3}})\frac{\Delta T}{2} = \alpha_{1,2}\frac{\Delta T}{2}$$

where $\alpha_1 = (1 + \frac{1}{\sqrt{3}})\, and\, \alpha_2 = (1 - \frac{1}{\sqrt{3}})$. Both solutions are in the studied interval $[0, \Delta T]$. for those values of t the acceleration have the values:

$$\ddot{X}(t) = 3m\Delta T(\frac{1}{2}\alpha_{1,2}^3 - \frac{3}{2}\alpha_{1,2}^2 + \alpha_{1,2})$$

In order to determine the type of the extremum (local minimum or maximum) we compute the expression of $\dddot{X}(t)$ at $t = \alpha_{1,2}\frac{\Delta T}{2}$

$$\dddot{X}(\alpha_{1,2}\frac{\Delta T}{2}) = \frac{36m}{\Delta T}(\alpha_{1,2} - 1)$$

if $m > 0$: α_1 correspond to a local maximum and α_2 to a local minimum. This means that in our planned trajectory we will begin by accelerating and then decelerating at the end of the manœuvre. if $m < 0$ we have the opposite behavior on the acceleration profile. Finally, if $m > 0$ then m should be:

$$m < min(\frac{a_{Longmax}}{3\Delta T(\frac{1}{2}\alpha_1^3 - \frac{3}{2}\alpha_1^2 + \alpha_1)}, \frac{a_{Brakemax}}{3\Delta T(\frac{1}{2}\alpha_2^3 - \frac{3}{2}\alpha_2^2 + \alpha_2)})$$

and when $m < 0$ then :

$$m > max(\frac{a_{Brakemax}}{3\Delta T(\frac{1}{2}\alpha_1^3 - \frac{3}{2}\alpha_1^2 + \alpha_1)}, \frac{a_{Longmax}}{3\Delta T(\frac{1}{2}\alpha_2^3 - \frac{3}{2}\alpha_2^2 + \alpha_2)})$$

usually the maximum braking deceleration is lower in absolute value than the forward acceleration. So the final interval for m is :

$$\frac{a_{Brake-max}}{3\Delta T(\frac{1}{2}\alpha_1^3-\frac{3}{2}\alpha_1^2+\alpha_1)} < m < \frac{a_{Brake-max}}{3\Delta T(\frac{1}{2}\alpha_2^3-\frac{3}{2}\alpha_2^2+\alpha_2)}$$

By combining the two constraints we obtain:

$$max(\frac{a_{Brake-max}}{3\Delta T(\frac{1}{2}\alpha_1^3-\frac{3}{2}\alpha_1^2+\alpha_1)}, -\frac{16}{3}\frac{V_0}{\Delta T^2}) < m$$

and

$$m < min(\frac{a_{Brake-max}}{3\Delta T(\frac{1}{2}\alpha_2^3-\frac{3}{2}\alpha_2^2+\alpha_2)}, \frac{16}{3}\frac{V_{max}-V_0}{\Delta T^2})$$

if we take $V_{max} = 130km/h$ and $V_0 = 90km/h$ then

$$\frac{a_{Brake-max}}{3\Delta T(\frac{1}{2}\alpha_2^3-\frac{3}{2}\alpha_2^2+\alpha_2)} = -2.37$$

$$-\frac{16}{3}\frac{V_0}{\Delta T^2} = -19$$

$$\frac{16}{3}\frac{V_{max}-V_0}{\Delta T^2} = 8.5$$

We notice then the constraints on the longitudinal braking deceleration is more sharp than the condition on the maximum and minimum speed. Thus finally

$$-2.37 < m < 2.37$$

Maximum curvature

The curvature of the trajectory of the vehicle is an important parameter of a realistic trajectory planning. Thus the equation of the curvature of the curve $(X(t),Y(t))$ is complicated since it involves two fifth degree polynomials. So we have used simulation to produce curves with the described constraints. Fig. 2 shows the correspondent (x,y) curves parametrized by m. We notice clearly that the smoothest curve correspond to $m = 2.37$ which is the maximum allowed. Thus in the risk estimation computation, we will use this m value to predict the possible trajectory of our vehicle during the lane changing manœuvre. The Fig. 3 shows the shapes of the $X(t), Y(t), \dot{X}(t), \dot{Y}(t), \ddot{X}(t), \ddot{Y}(t)$ for $m = 2.37$, $V_0 = 90km/h$, and $\Delta L = 3.5m$ between $t = 0$ and $t = \Delta T = 5sec$.

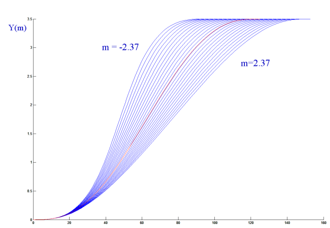

Fig. 2. The trajectory of the vehicle parametrized by $m \in [-2.37, 2.37]$

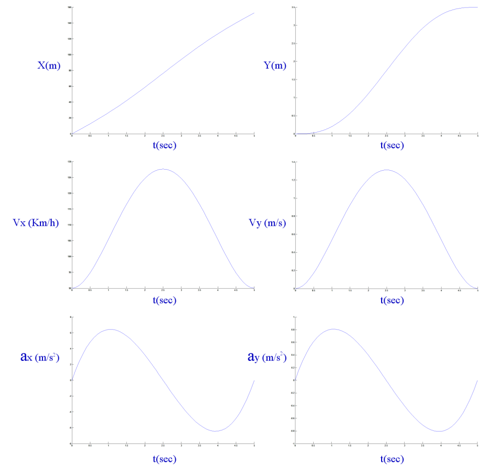

Fig. 3. Top to bottom, right to left: $X(t), Y(t), \dot{X}(t), \dot{Y}(t), \ddot{X}(t), \ddot{Y}(t)$

IV. LARA FLEET

A. Introducing intelligent prototype

LARA [1] is the name of the joint research unit between the Ecole des Mines de Paris and the INRIA [2]. The Fig. 4 shows 4 Citroen C3 of the LARA fleet. Each vehicle is equipped by a datalogger for data collection and algorithms prototyping. This datalogger, piloted by the RT-MAPS software [17], gathers in real time the information from all the sensors on the vehicle and constitutes proper time-stamped databases. The replay of a database allows to reproduce off-vehicle the same synchronized data flow as in the real experience. So the development and the test of real time applications become more efficient since the on-road tests are then repeated off-board. In order to sense its environment, each vehicle is equipped with a GPS receiver, a front looking camera and a gateway that transmits the proper vehicle information that flows on the CAN bus : braking state, lighting state, instantaneous linear speed, blinkers state, lateral acceleration, steering angle... those parameters will be next exploited in the execution of the lane changing.

Fig. 4. The full equiped four Citroen C3 of the LARA fleet

B. Inter-vehicle communication

As explained in [1] we equipped the vehicles with communication devices in order to exploit the domain of the cooperative driving. In the absence of adequate materials, we have chosen to adopt the WiFi technology. Our aim is to

[1]LA Route Automatise for The Automated Road

[2]The French National Institute for Research on computer science and control

TABLE II

THE REAL COMMUNICATIONS DEVICES CAPACITIES

Transmission power	32 mW
Maximum communications range	350 m
Maximum bandwidth	7 Mbps
Maximum absolute speed	120 km/h

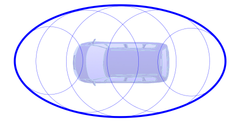

Fig. 5. The uncertainty ellipse modelled by a series of circles

design applications based on communication and to evaluate the efficiency of such cooperation on road safety. We use Dlink 802.11g+ access points with an 8 db antenna. These devices are controlled in real time by RT-MAPS through a specially designed sniffer based on the Pcap library [16]. The role of the sniffer is to assure the communication without the use of an inadequate communication protocol. Table II gives some results of the real capacities of the used materials. Those results are obtained on board the vehicle in real experiences made especially in this aim (for more details see [1], [2]).

C. Geometric vehicle model

The risk of collision during lane changing is directly related to the distance between the vehicles. In our application the positions of vehicles are given by the position of the respective on-board GPS receiver. Since reducing the vehicle to a point is not a realistic solution, we propose a geometric model of the vehicle around the position returned by the GPS. On the other hand the measure of the distance between vehicles is basically performed in a 2D space which justifies a 2D model representation of the vehicle. We begin by proposing a first approximation by a rectangle framing the vehicle. The dimensions of the rectangle are 3.8 x 1.6 m for the C3 vehicles. However the position of the vehicle given by the GPS receiver includes some uncertainty on the x and y axes. Thus the vehicle position will belong to an elliptical uncertainty area. The ellipse will be extended in both direction by the dimensions of the framing rectangle. But it is quite complicated to use rectangles or ellipses in the computation of distances. We took as a starting point the collision detection in the 3D mesh environments where we model the object with its framing outer circle (or sphere) and compute distances between those framing circles. Thus we model the vehicle by a framing circle containing the extended circle. With this model we exaggerate the dimensions of the vehicle and so for the risk of collision. So when two framing circles enter into collision, this means that two vehicles are close. We refine the model of the vehicle by a series of circles distributed along the principal axis of the extended rectangle. This model is more accurate and gives a more realistic distance measure. The search of the intersection is then performed by computing the distance between circles of each model. These models are represented in Fig.5.

V. EXPERIMENTAL STUDIES

The problem of lane changing is composed of three steps:

1) the detection of the drivers intention of lane changing
2) trajectory prediction for the vehicle performing the lane changing as well as the surrounding vehicles supposed in a straight trajectory
3) prediction of a possible collision involving our car and the risk estimation of this collision.

We can formulate the problem as following: the most risky situation is when a vehicle is immediately preceded and followed by two vehicles tries to perform a lane change while inserting between the vehicles circulating on a adjacent lane. The computation of the collision risk with each vehicle is performed in a separated algorithm. ideally (obviously) it is necessary to combine somehow the four calculations to optimize the global risk indicator. Moreover, we simplified the problem by considering the problem of lane changing without collisions as a simple logical combination of four separate collision detection between our vehicle and the four respective concerned vehicles (if they exist in the neighborhood). While studying each case separately, we notice that there are four risky configurations to study:

- Front vehicle in the departure lane
- Rear vehicle in the departure lane
- Front vehicle in the destination lane
- Rear vehicle in the destination lane

In terms of risk estimation, the treatment of the four cases is appreciably the same but the proposed solutions could be different. In this paper, we focus on the study the risk estimation procedure regardless the specific case. The experience was conducted in Paris region by two communicating LARA vehicles. Vehicle 1 is preparing to perform a lane change, it computes its future trajectory, it predicts the future positions of the vehicle 2 regarding its exchanged data and it calculates in real time if there is a possible collision between the two vehicles. Fig. 6 shows the GPS positions of our two communicating vehicles. In this experience, the vehicle-1 is performing the lane change (represented with red dots) while receiving the positions of the vehicule-2 (represented by blue dots) and calculating the risk of the manœuvre of lane changing based on their respective positions. In this example vehicle-1 is changing its lane to join the lane of the vehicle-2.

VI. RISK ESTIMATION

The aim of our system is to estimate the risk related to the lane change manœuvre when decided by the driver (vehicle-1). Once the blinkers are activated, the system performs the computations described above in order to determine the coming trajectory of the vehicle. On the other hand, the dynamic profiles of neighboring vehicles are known thanks

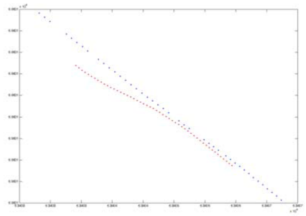

Fig. 6. The GPS positions of the Vehicle-1 (red dots) during a lane change manoeuvre while receiving at the same time the GPs positions of the Vehicle- 2 (blue dots)

to communication media sending corresponding information. The position of a neighboring vehicle (vehicle-2) coming from the adjacent lane can be expressed in the vehicles reference frame as:

$$x_2(t) = x_2(0) + V_2 t$$

$$y_2(t) = \Delta L$$

Where V2 is the instantaneous speed of vehicle-2 when the blinkers of vehicle-1 were activated. Notice that we assume here a constant velocity of the upcoming vehicle-2. Under these conditions, a collision is possible when the distance between both vehicles is below a certain threshold which is defined by the sum of the radii of the respective outer circles:

$$d = \sqrt[2]{(x(t) \cdot .x_2(t))^2 + (y(t) \cdot y_2(t))^2} < (r_1 + r_2)$$

Where r_1 and r_2 are the respective outer circles radii and (x(t),y(t)) are the coordinates of vehicle-1 as expressed by the fifth degree polynomials. In case a collision is detected a coarse to fine method is performed using the circles series model (described in Fig. 5). Any combination of circles intersections between vehicle-1 and vehicle-2 confirms the detected collision which occurs at a given time t_0. In practice, the calculations are performed in the temporal horizon of $[0, 2.T]$ as in the interval $[\Delta T, 2.T]$ the trajectory of vehicle-1 is assumed linear with the speed V_0. Three levels of risk assessment are defined : if $t_0 < \Delta T$ then the lane change should be forbidden as the collision could happen during the manœuvre and the driver should be alerted with a maximum risk indicator. If $\Delta T < t_0 < 2.T$ then the manœuvre is allowed but a middle level warning is communicated to the driver because the risk of collision still exists. If no intersection was detected then the driver will receive a green light alert to execute his safe manœuvre.

VII. CONCLUSION

In this paper we have exposed our approach of using the intervehicle communication in the aim to assist the driver during a lane change manœuvre. We have proposed a polynomial model of the lane change process. This model allows us to predict the trajectory of the vehicle during the lane changing and thus to compute the risk of collision with neighboring vehicles. The proposed model is assuming that the time of the manœuvre is constant which is not truly realistic. An amelioration of the algorithm could propose a calculation of this time based on the speed of the vehicle or based on a more realistic database of lane changing. This model has also the inconvenient of being perfectly symmetric. Naturally we never proceed symmetrically between the middle of the two adjacent lanes. However this study relies on real test performed on our intelligent vehicle. These tests show that our model can match with the real data on road. The risk is then computed in three levels and communicated to the driver. The role of our system is to help the driver during the manœuvre by judging the lane changing safe or risky. Our future work aims to validate this study on more scenarios with multiple vehicles.

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