Forecasting Approach in VANET based on vehicle collision alert

Bektache Djamel, Ghoualmi-Zine Nacira, Tolba Cherif
Laboratoire Réseaux et Systèmes
Department of computer science - University Badji-Mokhtar, Annaba
P.O. Box 12, 23000 Annaba Algeria
djamel_bektache@yahoo.com

***Abstract*— this paper deals with the forecasting of collision events in Vehicle Ad hoc Networks (VANET). Using significant parameters of each vehicle such that: position, speed, acceleration and direction, it is possible to avoid a possible collision. We present a collaborative forecasting module for VANET. The proposed module is focused on the estimation of these parameters using a kinematic model of each vehicle. As a result, each vehicle of the network could have a posterior global view of the dynamics of its network. The forecasting module is embedded in all vehicles of VANET and estimates the parameters of the subject vehicle and those of its neighbors. Estimated parameters is used beforehand to generate alerts in case potential risk. The communications between nearby vehicles (V2V communications) and the road-side infrastructure (V2I communications) is carried out by DSRC protocol (Dedicated Short Range Communication). Simulation results illustrate the estimation vehicles parameters.**

Keywords-VANET communication; DSRC; kinematic equations; estimation; road safety; forecasting module;

I. INTRODUCTION

Faced with the growing development of intelligent transportation systems (ITS) and with the arrival of the embedded telematic, the vehicles are become more and more sophisticated. Consequently, make the intelligent road and therefore both interactive and communicative constitute a new concept in advanced driver support systems. The whole of developed applications and conducted research in ITS relate to the improvement of the road safety.

In order to fulfill the main objective that is the collisions avoidance, the vehicles must exchange its significant information namely: position, velocity, steering angle or next movement etc.

The most problem faced by the drivers using the road are, especially, due to the deficiency of the communication between vehicles. The majority of accidents can be avoided if one of the drivers is alerted just-in-time before the occurrence of collision events. The question which arises is: How the drivers can detect and avoid, a priori, a possible danger. Some research does not deal really the problem of the road safety. This is seen in, the messages sent that are either messages of alarm for dangers already occurred or messages of information. Vehicle-to-vehicle communication is one of the solutions that vehicles enable to exchange the necessary information such that: position, velocity, acceleration, steering angle, etc. It is worth noting that the estimation of the same parameters is one of the solutions which allow the vehicle to detect beforehand a possible risk.

Our work intends to propose a forecasting module embedded in vehicle that contributes to reduce the road traffic collision. We present the structure of conceptual scheme for communication model in VANET taking into account the forecasting module based on estimator part of this model. This structure is focused on the estimation of the necessary vehicle parameters that may imply the traffic collision. Each vehicle of this model introduces the technical alert nearby vehicles in case when the vehicle forecast the occurrence of any risk (Estimation, Generation Risk, Decision, and Reaction). This does not mean that estimations should allow the prediction of accidents accurately, but the distinction between a high-risk situation "*collision*" and a low risk situation "*no accident*". The rest of the paper is organized as follows: in Section 2 we detail the kinematic modeling of vehicle type. The proposed conceptual scheme for a vehicular communication model is presented in Section 3. In Section 4 we show the different simulation results of the parameters estimation (estimator part). Finally, conclusion and future works are discussed in Section 5.

II. KINEMATIC MODEL OF VEHICLE

The physical systems can be represented by a kinematic or dynamic model, the first consider only the movement applied to the system, whereas the second also takes into account the forces of the masses appearing in the system [1]. In this section we will present an outline on the kinematic modeling of the vehicle parameters namely: position, velocity, steering and heading angle. Taking into account the notion of time, the kinematic model can be modeled in continuous or discrete time.

Assuming that the configuration of a mobile vehicle is represented in a fixed reference with two dimensions noted by $R(O,\vec{X},\vec{Y})$ and a mobile reference related to the movement of vehicle noted by $R'\left(O',\vec{X'},\vec{Y'}\right)$.

We chose generally for O` a significant point of the platform, typically the center of the axis of the driving wheels if there exists as illustrated in figure 1. The situation of the vehicle is defined in space (M) of four dimension m = 4, chosen as follows: x, y, v, ϕ. Where x and y represent, respectively, the lateral and the longitudinal position of the mobile vehicle, v denotes the velocity of the vehicle and ϕ its steering angle [2].

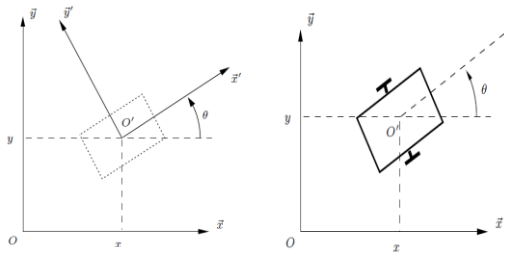

Figure 1. Location of a mobile vehicle.

The vehicle states can be represented by (x, y, v, φ, α) as shown in Figure 2.
where: x and y give the center position of the rear axle, φ is the angle between the vehicle body and the horizontal x-axis, α is the direction angle in respective of the vehicle body (the steering angle of the wheel, defining the instantaneous rotation of the vehicle center O').

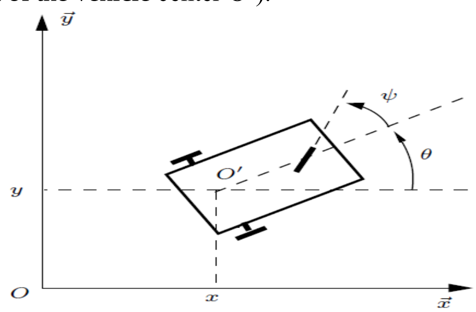

Figure 2. Presentation a vehicle parameters of tricycle type.

First, we consider the tricycle case, represented in figure 3. This vehicle has two fixed wheels on the same axis and a centered directional wheel placed on the longitudinal axis of the vehicle. The movement is provided to the vehicle by two actions: the longitudinal speed and the orientation directional wheel [2]. From this point of view, it is very close to a car. Moreover, it is for this reason that we study the tricycle, of which the interest is the application of this model in the simulation part.

By developing the components of this speed on the two axes x, y we obtain a lateral speed equal to zero due to the rolling without slip on constraints not holonomic [3].

$$-\dot{x}\ \sin\phi\ + \dot{y}\cos\phi = 0. \qquad (1)$$

We obtain also around O' a longitudinal speed of the vehicle, noted v and its speed of rotation $\dot{\phi}$ [3].

$$\dot{x}\ \cos\phi\ + \dot{y}\sin\phi = v. \qquad (2)$$

There is in effect equivalence between two representations. On the one hand, we are:

$$v = \frac{(vd + vg)}{2} = \frac{r(\dot{\varphi d} - \dot{\varphi g})}{2}. \qquad (3)$$

On the other hand, the rotation speed of the vehicle is equal to the speed of rotation around the IRC. This allows determining ω from the speeds of the wheels:

$$\omega = \dot{\phi} \qquad (4)$$

The vehicle IRC is located at the meeting of the fixed wheels axe and the directional wheel axe, as shown in the following figure: ρ can be determined geometrically from the orientation angle of the front wheel and ω can be determined from the linear velocity $\boldsymbol{v}$ of the vehicle and ρ:

$$\rho = D/\tan\alpha \qquad (5)$$
$$\omega = \frac{v}{D}\tan\alpha$$

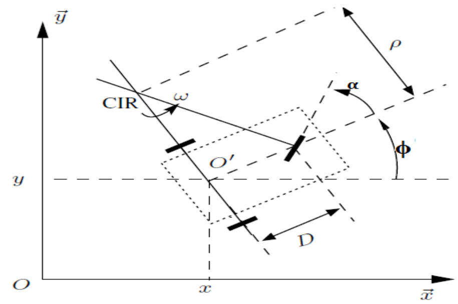

Figure 3. Modeling of Kinematic vehicle type.

This type of vehicle can move in straight line for α = 0 and theoretically turn about the point O' for α = π / 2. However, the turning radius of the directional wheel, usually limited, requires values such as $\pi/2<\alpha<\pi/2$, prohibiting the vehicle rotation on itself [3]. The kinematic model is described by:

$$\begin{pmatrix}\dot{x}\\ \dot{y}\\ \dot{\phi}\\ \dot{\alpha}\end{pmatrix} = \begin{pmatrix}\cos\phi\\ \sin\phi\\ \tan\frac{\alpha}{D}\\ 0\end{pmatrix} v_1 + \begin{pmatrix}0\\0\\0\\1\end{pmatrix} v_2 \qquad (6)$$

v_1: is the longitudinal speed of the vehicle wheels.
v_2: is the speed of the direction angle.

These equations are inspired from the kinematic model shown in figure 3, with a simple geometric reasoning, we establish the kinematic equations of this model, x and y are the estimations of lateral and longitudinal position of a vehicle respectively, v is the vehicle velocity which is always constant and ϕ represents the steering angle of the vehicle contribution to the horizontal axis X [2]. The kinematic model equations in continuous time are described as follows:

$$\frac{dx}{dt} = v(t)\cos\phi\,(\mathrm{t}) \quad , \dot{x} = v\cos\phi.$$

$$\frac{dy}{dt} = v(t)\sin\phi\,(\mathrm{t}) \quad , \dot{y} = v\sin\phi. \qquad (7)$$

$$\frac{d\phi}{dt} = v(t)\,\frac{\tan\alpha\,(t)}{D} \quad , \dot{\phi} = \frac{v}{D}\tan\alpha.$$
$$\dot{\alpha} = n.$$

The discrete form of the equations above is:

$$X_{k+1}=X_k+ V_k \cos(\phi_k)\, T$$

$$Y_{k+1}=Y_k+ V_k \sin(\phi_k)\, T$$

$$V_{k+1}= V_k T \qquad (8)$$

$$\phi_{k+1} = \phi_k + v_k \frac{\tan(\alpha)}{D} T$$

T denotes the sampling period.

III. Presentation of a Communication Model in VANET Network

Assuming a communication network (VANET) is constituted by N vehicles divided into two groups. The first group contains just only one vehicle which is the vehicle in question (SV) and the second group contains the other vehicles or neighbor vehicles (OV) [6]. In our model, each vehicle of the network is equipped by an estimator, and thus the vehicle could have a posterior global view of the dynamics of its network. The estimation of future state is carried out using an embedded forecasting system. This system estimates the parameters of its vehicle and those of its neighbors, such parameters are: position, velocity, acceleration, steering angle, or heading angle etc.

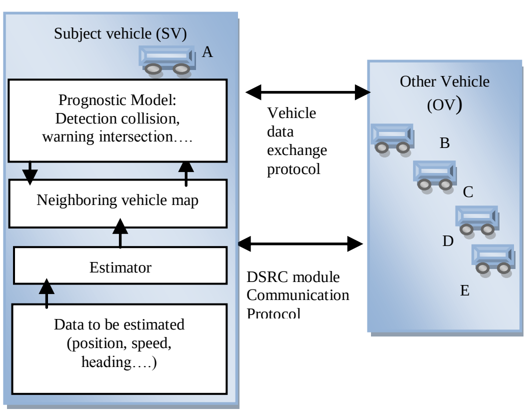

Figure4. The proposed architecture communication model in VANET

The architecture has significant common elements useful to multiple warning applications. These include:

The Neighboring Vehicle Map layer[1] in each vehicle has several functions [5]:

- It passes the GPS position, speed, and heading information produced by its Estimator to the Vehicle Data Exchange Protocol Entity for transmission to other vehicles.
- It receives the GPS position, speed, and heading messages sent by other vehicles from the Vehicle Data Exchange Protocol Entity.
- It transforms this information to relative coordinates and plots it on the Neighboring Vehicle Map.

Thus our architecture requires the standardization of two protocols, shown as the Vehicle Data Exchange Protocol and Communication Protocol in figure 5. Vehicles need to send position, speed, heading, and possibly other data in a format understood by all vehicles. This is the Vehicle Data Exchange Protocol (VDEP). The VDEP messages need to be sent over a communication protocol and radio standardized across vehicles. In our case this is 802.11p Dedicated Short Range Communications [5].

The position, speed and direction are important information in the inter-vehicle communication to avoid a possible collision. The estimation of the same parameters used beforehand to generate alerts to a potential risk, for this reason a forecasting module is integrated into the proposed communication model. The operation of this module is shown in the following figure:

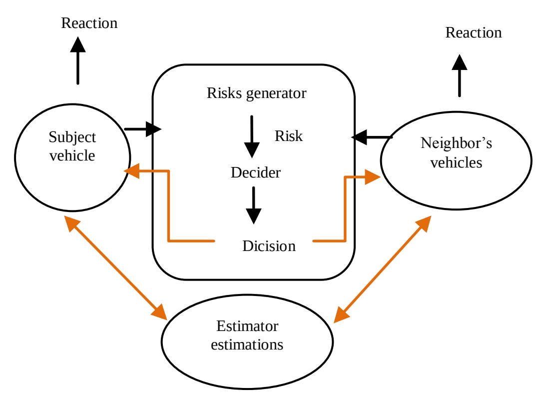

Figure5. Operation of forecasting Model

a) Generator of risks:

This generator is based on the exploitation of the estimated parameters of the subject vehicle and those of its neighbors then after analysis and comparison between these different estimations, one or more risk can be detected. Note also that there are situations where no risk can occur. Otherwise, each risk is evaluated by interpreting him the danger degree such a situation (degree of risk), this information's are transmitted to the decision maker [4].

[1] This layer is seen as a bridge between the subject vehicle and the other vehicles, it transmits and receives the estimates of the vehicles, then translates the generated risk on a display board.

b) Decision maker:

After the generation of a potential risk, according to its degree, the risk will be sent to the decision maker which generates a type and an appropriate decision as shown in the following table [4]:

Table 1. Reference Risk- Decision.

Eventual risk	Risk degree	Decision	Type of Decision
Risk 1	High Risk (collision)	Decision 1	Alert urgently
Risk 2	Middle risk	Decision 2	Alert message
Risk 3	Weak Risk (no collision)	Decision 3	Information message

IV. SIMULATION RESULTS OF PARAMETERS ESTIMATION

In this section we present the estimator simulation, and to do so we have used Matlab for kinematic equations programming. As the area research is VANET, the kinematic model chosen is a car type in discrete time presented previously (see equation 8).
If α is null (α = 0) i.e. the vehicle is moving in a straight line (there's no turning), according to the value given at steering angle φ, we distinguish five cases.

Case 1: If α = 0 and φ = 0
The vehicle is moving in a straight line to the positive x-axis as the following figure shows:
Noting that the parameters estimated are represented as:
LatP: lateral position.
LongP: longitudinal position.
StrAng: steering angle.
This notation is valid in all the following figures.

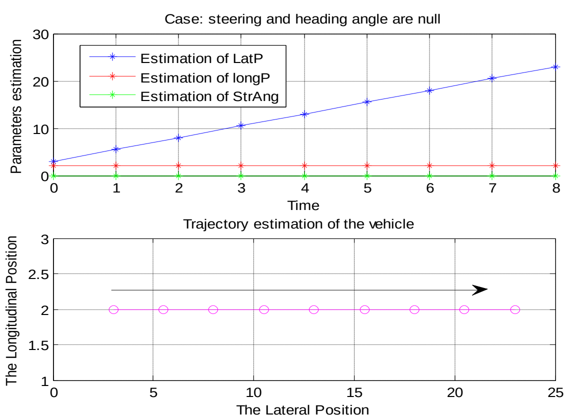

Figure 6. Estimation of parameters in the case: $\alpha = 0$ and $\varphi = 0$.

Case 2: α = 0 and φ = π / 2
The vehicle moves in a straight line to the positive Y-axis

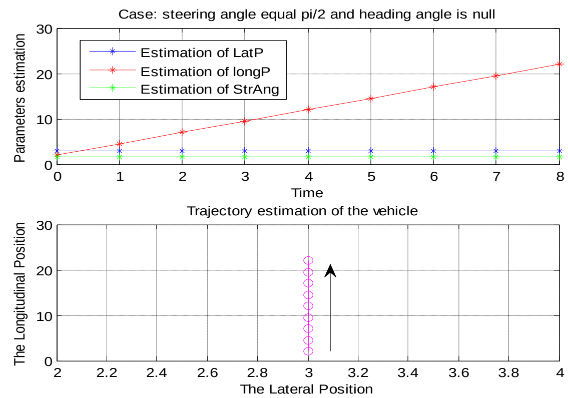

Figure 7. Estimation of parameters in the case: $\alpha = 0$ and $\varphi = \pi/2$

Case 3: α = 0 and φ = π
The vehicle moves in a straight line to the negative X-axis

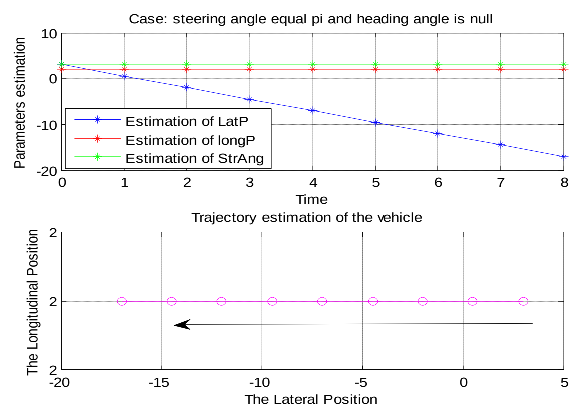

Figure 8. Estimation of parameters in the case: $\alpha = 0$ and $\varphi = \pi$.

Cas 4 : α=0 et φ=- π /2
The vehicle moves in a straight line to the negative Y-axis

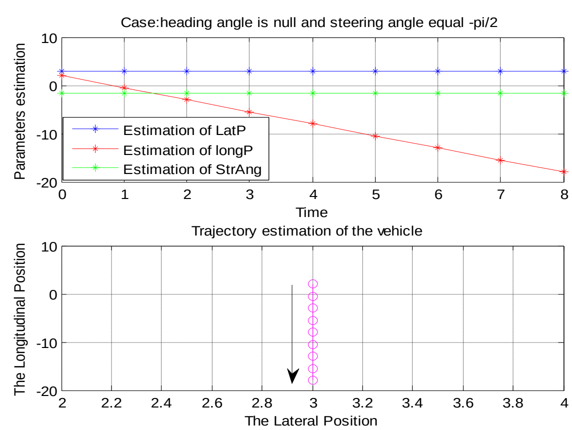

Figure 9. Estimation of parameters in the case: $\alpha = 0$ and $\varphi = -\pi/2$.

Case 5: α = 0 and φ = π /5

The vehicle moves in straight line with a fixe steering equal to 36°.

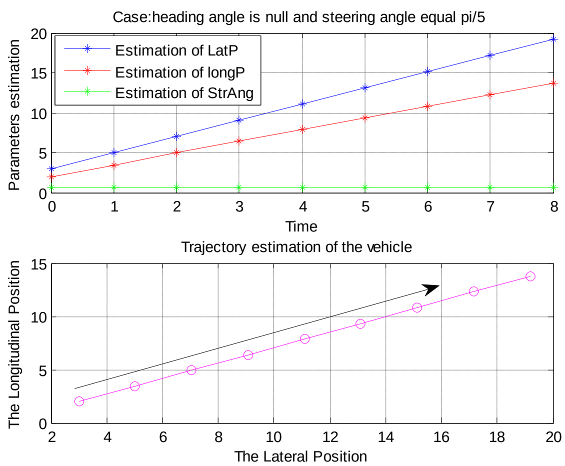

Figure 10. Estimation of parameters in the case: α =0 and φ=π/5.

Case 1: X=0, Y=0, α=π/20, φ =0 and v=25

If α is not null, the steering of the wheel influences on the angle ***φ*** and thus influence also on displacement of the vehicle, we will take α like a fixed constant.

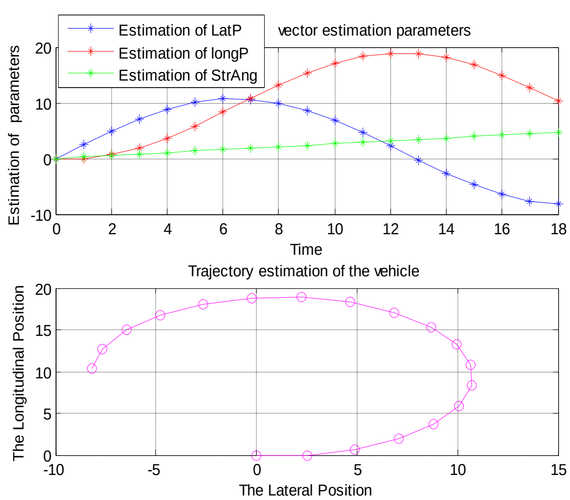

Figure 11. Estimation of trajectory and vehicle parametres (α is fixed).

V. CONCLUSION AND PERSPECTIVE

In this article we have detailed kinematic modeling of vehicle type, than we are focused on the movement estimation of the vehicle by the programming of the kinematic model equations. Our contribution treats a suggested scheme, this architecture is based on the estimation of some important parameters in the inter-vehicle communication as: position, velocity, and direction. This model allows to each vehicle to have an estimation of the future state network, this estimate is calculated by an embedded estimator in each vehicle. The estimator output is an input of a forecasting module that detects the potential risk presence, chooses an appropriate decision and transmits it to nearby vehicles. To implement our architecture, we started with the simulation of the estimator using the kinematic equations of vehicle type.

Our future work is to extend our simulation model for all network nodes, i.e. implement both the estimator of all neighboring nodes and the communications protocol ensuring transmission of the calculated estimations at real time.

REFERENCES

[1] J.Marina and C.Marti, "Position Estimation and control of an autonomous vehicles", Master thesis, EPFL1 , ETSEIB2, Lausanne ,Switzerland;30/06/2005.

[2] B.Bayle « Robotique Mobile » , chapter lessons, école nationale superieur de physiquede strasbourg 2010-2011.

[3] I.Abuhadrous, « système embarqué temps réel de localisation et de modélisation 3D par fusion multi-capteurs », Phd thesis, école des Mines de Paris,2005.

[4] D.Bektache, C.Tolba, N.Ghoualmi « Apllication et Modélisatiopn de la Communication Véhicule à Véhicule pour la Sécurité Routière », RSACS '11 ,INTITIC Oran, 2011.

[5] R. Sengupta, S. Rezaei, S. E. Shladover, J. A. Misener, S. Dickey, H. Krishnan, "Cooperative Collision Warning Systems: Concept Definition and Experimental Implementation," Journal of Intelligent Transportation Systems, vol.11,No.3, pp. 143-155, 2007.

[6] S.Rezaei, R. Sengupta, H. Krishnan, X. Guan, R. Bhatia, "Tracking the Position of Neighboring Vehicles Using Wireless Communications," Journal of Transportation Research Part C: Emerging Technologies, Vol. 18 , issue 3, pp. 335–350, 2010.