A TRAFFIC REGULATION SYSTEM FOR THE FUTURE AUTOMATED HIGHWAY

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ABSTRACT

The contribution of this paper for the future automated highway is to carry out a traffic regulation system which allows to solve some problems of traffic congestion. The congestion of the motorway system in the peak hours involves a fall of the productivity for the conveyors, a waste of time for the motorists, an increase in the frequency and gravity of the accidents, thus a risk for the public health with the increasing of pollution due to vehicle gases. Taking in account of some characteristics of the European motorways, and mainly in France, we have noticed that there is a strong concentration of trucks on the right side way of the motorways. In the same way, it is noted that this concentration of trucks is often as convoys of trucks. This makes it possible to prove the interest of the automatic control of trucks convoys on motorway. To solve the problems of congestion, it is not only to create automatic truck convoys and to let them moving without monitoring on the motorway, but it would be necessary to regulate the traffic of the automatic truck convoys on the motorways.

Key words: Traffic regulation, automated highway, automated truck platooning

1- INTRODUCTION

The PLATOON project [7] consists in carrying out the automatic control of convoys of trucks on motorway. In this project, a vehicle can either belong to a convoy, or to be in a free state. The convoy of trucks is a set of a maximum seven vehicles, the first one is the leader and six following vehicles. The vehicle leader is driven manually, on the other hand the control of the following vehicles is in the automated state. We will call this operating mode: the platooning.

The distance between the vehicles of even convoy can be from 5 to 15 meters in the standard conditions, and from 0 to 20 meters in the extreme conditions: figure1. A truck in PLATOON project can be in three operating modes: the leader mode, following mode or free mode. Each transition from the vehicle from a mode to another represents one of principal actions of the control, supervision and traffic regulation system. These actions are:

- a creation of a new convoy,
- a fusion between two convoys,
- a in/out of vehicles in a convoy as a leader or as a follower.

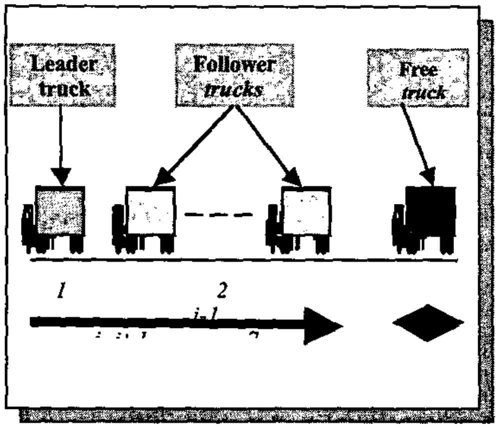

Figure1: The Platoon configuration

In the first part, we will present a traffic regulation mode which could be adapted of the current infrastructures. In the second part, we will analyse the various problems that we could meet on the automatic motorways, to be able to set up a degraded mode, which makes it possible to minimize the accident risks and to be able to regulate the traffic to decrease the delays.

2- STRUCTURE OF THE SUPERVISION SYSTEM OF THE AUTOMATIC HIGHWAY

The vehicles supervision on the automatic highway would be carried out by a system of regulation embarked in each truck. Automatic highway is a complex system with a heavy management of the whole traffic [4]. This complexity comes to the fact that the whole management of the automatic highways imposes various interactions:

- Interaction vehicle/infrastructure ;
- Interaction man/vehicle ;
- Interaction vehicle/vehicle.

This system cannot be controlled only by one system embarked in each truck, the coordination between these various interactions requires an elaboration of a hierarchical system of supervision with 4 levels of supervision: a general supervisor, supervisors of zone, supervisors of section, supervisors embarked in each truck.

2.1 THE GENERAL SUPERVISOR

This level could be an interface between the system of control (supervisors of zone, of section) and the human controllers. Information concerning the number of trucks and convoys for each section would make it possible to represent in real time, the evolution of the traffic on all the motorway network. Thus, the controllers could know constantly the traffic stat.

For example: when an accident happen, the controllers can install relief routes and transmit them to the supervisor of zone. This level would also make it possible to control the good unfolding of the devices of helps which are set up by the supervisors of zone. If necessary, the controllers could send the helps. This level could be connected to an external device giving in real time the evolution of the weather. The supervisor could transmit the exact data to each supervisor of zone to be able to anticipate the strong rains, the snow and the fog.

2.2 THE SUPERVISORS OF ZONES

We will define in the part a zone. As we can see it on figure2. The supervisors of zones could calculate the routes of the trucks entering on the automatic highway according to their destination and of information which comes from the general supervisor (work, relief routes). As we will be able to see it in the following parts, the regulation of the traffic cannot be made on the level sections because the distance is too short to be able to manage the problems due to difficulties envisaged (work, bad weather) or unforeseen difficulties (accidents). The supervisor of zone thus will have to manage the traffic and the difficulties which can occur by sending its orders to the supervisors of section, so that this we make them apply.

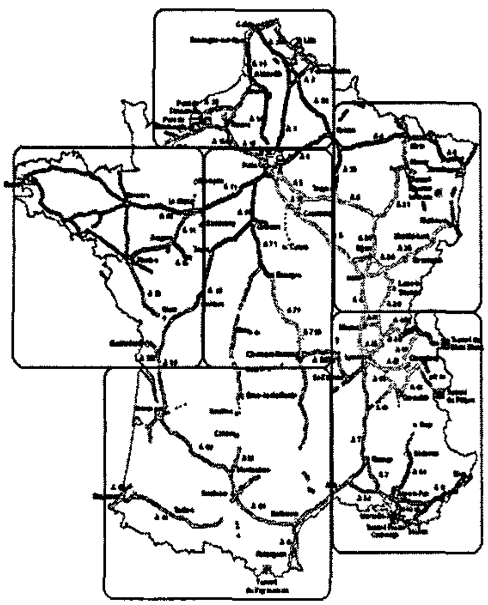

Figure2: An example for different zones of the French highway network

2.3 THE SUPERVISORS OF SECTIONS

The supervisor of section task is to control the traffic of his section and to intervene to carry out some manoeuvring (the entered, the exit, the separation, the fusion). The supervisor of section should control the distance between the convoys. He is in charge to apply the instructions coming from the supervisor of zone, with regard to the traffic: the adaptation of control in the atmospheric conditions, the shifts of speed. He can communicate directly with each truck which is on its zone. As we will see it for the management in degraded mode, the supervisor of section coordinates the resolution of the problems and transmits the necessary information to the supervisor of zone.

2.4 THE SUPERVISORS EMBARKED IN EACH TRUCK

The architecture of the embarked supervisor will be constitute by different modules. We will see the role of each module: The characteristics Module: This module could contain the characteristics of the truck which not manoeuvring in real time as the weight, the maximum speed, the maximum capacities of accelerations and of braking and the overall length of the truck. This module transmitting the necessary information to the supervisor of section by the module of communication with the supervisor of section.

The monitoring module: This module is charged to gather and control all the data. It will receive all the data coming from the sensors as well as data relating the degradation of the truck and the state of the driver. With a direct analysis or comparison, this module should be able to detect and identify the defects. The module will have to direct the information because the all modules don't need the all information. The regulation module does not receive the same information as the supervisor of section or as man/machine interface.

The traffic regulation Module: Each truck is in an operating condition (state: leader, follower or free), in each state corresponds a specific mode of traffic regulation. This module is charged to do the regulation according to state in which the truck is. For that, it needs some information which comes from the module of characteristics as well as module of monitoring. The changes of its states are ordered by the module of reconfiguration or the module of manoeuvres.
To ensure the traffic regulation, it controls the different actuators of the truck (the direction, the accelerator, the brakes). For example, in following mode, the module of regulation [1] will control the actuators to provide the function follower (space between trucks constant and ranging between 5 and 15 meters, and the same speed as the vehicle in front).

The reconfiguration module: This module is charged to reconfigure the system of control when a defect happen. The defects are identified by the module of monitoring which sends the nature of the defect (for example: loss a velocity pick-up). The module of reconfiguration will deduce the type of the defect. According to the nature of the defect, the module of reconfiguration will reconfigure the system, by ordering with the module of the manoeuvres to do some specific manoeuvres of the degraded mode, or by ordering with the regulation module to change the state of the operation (mode switch-over following degraded).

The manoeuvres module: This module is charged to make apply to the module of the traffic regulation, the manoeuvres which are ordered to it by the module of reconfiguration or the supervisor by the module of communication. The manoeuvres in question are those which are carried out when the truck is in the automatic mode of control [5] (following, following assisting, following range); in normal mode there is separation (before the exit). These manoeuvres can be carried out by changing parameters of the regulation. For example, separation is done by increasing the distance between two trucks, modifying the distance between trucks. The module of manoeuvres can change the mode of control from the following mode to the manual control mode.

The communication module between the vehicles: This module is used to exchange information between the trucks of the same convoy. It can be used as connections to bring to the monitoring module the missing data. This communication is very significant during the treatment of certain defects which require help of several trucks of the convoy.

The communication module between the vehicle and the supervisor of section: This module exchanges information with the supervisor of section. As for the preceding module, it can convey missing data. It transmits the orders of the supervisor to the module of manoeuvres for the following mode, and to the driver by the interface of the vehicle.

Interface Vehicle/Driver: This module ensures the connection between the driver and the embarked supervisor [6]. The state of the driver is sent to the module of monitoring, we could imagine systems making it possible to control the state of the driver by this interface.

3. THE SAFETY SPACE BETWEEN TRUCKS AND BETWEEN CONVOYS

According to the traffic, the space between two groups of tracks can vary. we will fix a limit lower than this space, we will call it " the safety space ", and that the drivers will have to respect. we mentioned previously, that he would be preferable to avoid the abrupt decelerations, to have a good fluidity of the traffic. On the current motorways, the vehicles are sometimes brought to slow down abruptly on the level of the entries in the highway [2][3]. However, if we want not to have decelerations in the zones where the trucks enter, we need a space sufficiently large to put the new truck. Moreover, it would be necessary to envisage a space to carry out the manoeuvres separation. Indeed the separation of two trucks from even convoy requires an increase in the distance between these trucks called D. While taking the case where all the trucks from even convoy should separate at the same time (for example when they all leave to the same exit), we would have a distance to add of 6 D. With this space, the manoeuvres of exit for a truck will not create decelerations for the following convoys. Lastly, it is necessary to take completely in account the distance necessary to a convoy to stop, to avoid the collision risks if the convoy in front is stops. This space is given between 70 and 100 meters.

3. CONCLUSION

This work is an introduction to the management of flow of trucks on an automatic motorway. It sets up a regulation in normal mode, based on the distribution of the trucks in convoys and the space management between convoys, according to the level of density of traffic. This would make it possible to keep a fluid traffic and to avoid the significant decelerations. The mode of supervision presented is a system arranged hierarchically, at various levels of supervision. One defined precise enough roles for each level without returning in technical details to explain real operation. The fact of decentralizing part of the management of the traffic on the level of the sections makes it possible to better be able to manage each truck individually.

The supervisors of sections are charged to do a different traffic regulations according to the state of the traffic flow (weak, normal or high). When the traffic normal is raised, we will control spaces between the convoys so that the traffic keeps a good fluidity, in spite of an increase in the number of vehicles. The distance between two convoys will be controlled to reach the maximum capacity of the highway respecting the criteria of safety. In weak traffic, we will respect the safety distance between two convoys. The procedures presented for the realization of the current manoeuvres (entry, exit) show some limit system due to the behaviours of the drivers.

In the model presented, we confined ourselves with the traffic regulation of the convoys of trucks without taking in account the cars t. It will thus be necessary to evaluate in which measurements the traffic of the cars will influence and will modify the traffic regulation installation for the trucks, and to see whether we can apply a traffic regulation similar to the convoys of cars.

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