How to Combine Reactivity and Anticipation: the Case of Conflicts Resolution in a Simulated Road Traffic

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Abstract. In this article we present the method used to solve the conflicts that can happen between agents that represent simulated drivers in a simulated road traffic. This work is part of the ARCHISIM project, which aims at both simulating a realistic traffic evolution and making the behaviour of the simulated drivers credible for a human driver placed in a driving simulator. After having categorized the types of conflicts that can happen, and the constraints that determine the choice of a solving method, we propose a method that combines reactivity and anticipation. This method is based on the works of driving psychologists who work in the INRETS institute. We offer an exprimental validation of this method with respect to real data and discuss its advantages in the perspective of largest applications.

Keywords: multi-agent simulation, traffic simulation, conflicts resolution

1. Introduction

Multi-agent simulation models are a tool which becomes more and more important for the analysis and the understanding of complex phenomena [23], mainly in human organizations (see [26]). In this article we address the particular case of a realistic road traffic simulation. This simulation is integrated in the INRETS ARCHISIM project which was created jointly by the Analysis and Regulation Department (DART) and by the driving psychology laboratory (LPC) in 1992 [16]. It has been the object of a collaboration led with the laboratory of computer science of Paris 6 (LIP6), since 1997, through a master training and a PhD thesis.

The ARCHISIM project aims at producing the global phenomenon of a road traffic by reproducing the behaviour of each driver participating to the simulation. In this model a driver is considered as an autonomous agent whose behaviour is based on the psychological studies led by the LPC [25]. These studies provide a model describing the driver's decision activity with respect his environment. The traffic produced by ARCHISIM results from the interaction of the behaviour of each agent with the regulation, the infrastructure of the road and the other users. The realism of the simulation is then a direct function of the quality of the behavioural model.

In this paper, we describe the process that we have adopted to produce a simulated traffic that could be interpreted as "realistic" by a road user. We are particularly interested in drawing a parallel between the problems that are raised by this type of simulation and the problems met in many multiagent systems, such as the choice of a conflict resolution method. The plan of the paper is as follows: first, in section 2, we describe the ARCHISIM project. Second, we introduce in section 3 the problems encountered by the designer of such a simulation, especially in the resolution of the conflicts that occur between the agents. Third, we give an overall view of the traditional methods used in DAI and their drawbacks. We then propose in section 4 a method that gracefully combines reactivity and anticipation. This method is validated experimentally in section, and we end by an overall view of the perspectives of research in this field

2. ARCHISIM

New traffic regulation possibilities are usually introduced to make the traffic surer and more comfortable. The simulation models allow to test and to evaluate these equipments without resorting to life-size tests, which are expensive and difficult to achieve. Therefore, the simulation models constitute a tool that is more and more used for traffic forecast and management, for example by local collectivities. These models can be categorised in two families:

- Macroscopic models: they describe road traffic dynamics in a global way by describing its flow, its density and its average speed. The best known in France are: *Simaut* [19], *Strada* [6] or *Meta* [20].
- Microscopic Models: they represent traffic in more details. These models deal with individual vehicles and try to focus on the interactions that occur between vehicles. They manipulate variables like the inter-vehicle time, the vehicle speed and its acceleration, and so on. In this category of models, we can mention *Casimir* [8], *Severe* [3], *Mixic* [2], or *Pharos* [21].

The analysis of a social organization such as road traffic could not be done without taking the interactions between its members into account [18]. By focusing precisely on the interactions, the microscopic models allow us to produce more realistic traffic situations than those produced by macroscopic models. However, both macroscopic and microscopic models have generally the goal to reproduce traffic flow laws identified by measure campaigns and are usually designed to solve a well-defined problem. For example, *Casimir* is designed to compare working strategies of isolated crossroads traffic lights. *Mixic* allows the study of the AICC (Autonomous Intelligent Cruse Control) impact on a number of consecutive crossroad sections.

The goal of ARCHISIM model is not only to produce a realistic traffic, but also to simulate a traffic composed of vehicles that behave individually in a credible way. But the "realism" with which the behaviour is simulated strongly depends on the quality of their interactions. Therefore, the choice of a multi-agent architecture gives us the possibility to model in a detailed way the interactions between the drivers, as well as their behaviour. The traffic flow laws obtained are then a consequence of the interactions of the drivers' behaviour with the regulation, the infrastructure of the road and the behaviour of the other users.

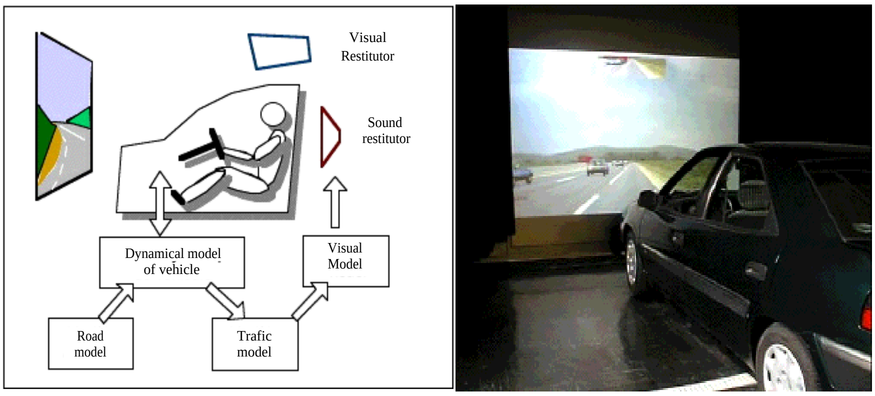

Fig. 1. Schema and view of the simulator

The modelisation of the behaviour of an artificial driver is based on the experimental driving psychology studies led by the LPC. This work makes use of a conceptual model defined by a set of rules which describe the driver decisional activities. The quality of this modelisation is a key element to the realism of the simulated road traffic situations (see figure 2).

Equally, the software architecture of the ARCHISIM model allows a simulator to participate into the simulation and thus a human driver to see and to interact with several traffic situations (see figure 1). The goal is to allow the test of "virtual" infrastructure or new equipments (driving aids, etc.) on "real" drivers, so that we could study their reactions. Consequently, the traffic situations produced by the model must give to a human operator the illusion to be in a real traffic situation, which represents a considerable challenge: the agents have to be credible and should not create unrealistic traffic situations. Eventually, ARCHISIM will then be able to [17]:

– test and refine models of behaviour;
– test man-machine interfaces on the simulator, check their compatibility with the driving task and assess their impact on the system;
– test the sensitivity of the system to various scenarios (such as, for example, the percentage of cars equipped with driving aids).

3. Description of the existing multi-agent system

Fig. 2. An example of a simulated traffic (agents: infrastructure, vehicles, etc.)

The distributed nature of traffic, the absence of any central control and the importance of behaviours in the modelisation of the driving task have naturally led us to choose a multi-agent approach in order to model this phenomenon.

In ARCHISIM, we consider that a given traffic situation is the result of interactions between heterogeneous agents: vehicles, infrastructure, road lights controller, etc. (see figure 2). Each agent is an autonomous entity, possesses its own knowledge, goal and strategy in order to perform its various tasks and to solve any conflicts which might arise with other agents. The infrastructure "transmits" information to road users and is for this reason considered as an agent. However, we note that this agent is particular because of its singleness and static status in the system. It induces behaviours through its geometric dimensions (visibility distance, lane width, etc.) without being affected by other agent behaviours.

An agent updates its knowledge by exchanging data with its environment. An important problem is to provide each agent with the informations that could change its behaviour. This leads to determine the sets of neighbouring agents that are situated in its area of perception and that change at each step of time. The first solution we could think of is that each agent sends to the others a message containing its set of observable information, namely its position on the road. Then, each receiver decides according to this position whether the agent sender is in its scope of perception or not. However, with respect to the great number of agents involved in a traffic simulation and so the great amount of communications, we can see that such a solution can not maintain an acceptable execution time. These inter-agents communications have thus been replaced by the design of a “central” process which plays the role of a "vision server". This process is the only one provided with an overall knowledge of the road network status, but it has no access to the local knowledge of agents. For ARCHISIM, a simulation consists in starting up the "central" process. Each agent present in the simulation then sends a message to this "central" process that consists of its current status (position, speed, etc.) as well as a request concerning the elements that are in its area of perception. After having received all the messages from all the agents that participate to the simulation, the "central" process computes for each agent the set of elements that are included in its perception area and sends it to each agent.

4. Main difficulties related to traffic simulation

4.1. Interaction of a set of agents

In our model, the main agents are the drivers. The quality of the simulation mainly depends on them. In ARCHISIM, each driver is an autonomous entity that possesses its own behaviour, its own goal that consists in following a given itinerary and its own knowledge described by a partial representation of its environment. We assume that the driver and the vehicle represent a single entity. We do not try to model the interactions between those two elements. A driver undergoes a set of interactions that are described by constraints imposed by the infrastructure, the regulation and the other road users. On one hand, these interactions usually represent a source of conflicts, and on the other hand, the resolution of conflicts needs other interactions. We note that in this system as in most collective systems, the notions of interactions and conflicts cannot be dissociated. These conflicts are, at the same time, the cause and the effect of interactions. Therefore, having a realistic simulation requires the use of a conflict resolution method that can be relevant in the context imposed to us by this simulation, which means complying with the models proposed by the psychologists ("credibility") and ensuring real time operations.

4.2. Nature of conflicts

In the context of road traffic we can distinguish several types of conflicts: resource conflicts, goal conflicts and commitment conflicts. Each of them is described in more details in the paragraphs below.

4.2.1. Resource conflicts

The road network is defined by a set of roads and crossroads. A road is characterized by its infrastructure (its width, its lane number, etc.). The crossroads are the place of intersections of roads. A network can also be defined as a set of sections, where a section represents a part of a road and is characterized by an infrastructure and a capacity. The capacity represents the number of vehicles on this section, which have a reasonable chance to flow out during a time interval of reference [8]. Conflicts appear when the number of vehicles willing to run on the section becomes larger than its capacity. The traffic becomes dense and conflicts arise around the traffic space. These conflicts are qualified as resource conflicts. In fact, if the space were larger, or if the number of vehicles were smaller, the conflicts would disappear. The cause of the conflicts is thus the resources available to each vehicle. In traffic situations, we distinguish two kinds of resource conflicts:

- The lane insertion conflicts, that appear for example in the case of a closing lane. A vehicle that detects that the lane on which it travels will be closed should find a gap in an adjacent lane in order to enter it. If the traffic is dense on the adjacent lane in which the vehicle would like to go, conflicts could appear between this vehicle and those on the adjacent lane. The same type of conflict appears in the case of a highway with an access road, between the vehicles on the highway and the others which are on the access road. Likewise, when a vehicle decides to change lane and that the density of the lane on which it chooses to go is very important.
- The intersection conflicts generally appear at crossroads between vehicles coming from different roads and taking different directions that intersect. These vehicles should organize themselves and share the crossroads space so that each of them could take the direction it has already chosen and avoid collisions. The problem would not arise if there were a single vehicle or if the space were large enough for all the vehicles to flow at the same time.

4.2.2. Goal conflicts

This type of conflicts appears even if the traffic on the section is not dense. They are caused by the simple presence of another vehicle. Therefore, a driver could be in conflict with another preceding vehicle, if this one runs with a speed smaller than the speed which the driver wants to reach. This type of conflict could be defined as a goal conflict. At a global level, the local objectives of each driver could not be merged in a single goal. The satisfaction of one's goal implies the dissatisfaction of the other's goal.

4.2.3. Commitment conflicts

The driver could also be in conflict with a vehicle running ahead, which switches on its indicator at instant t and switches it off at instant t+1. The fact that the vehicle switches on its indicator implies that it is ready to leave the lane. The vehicle that is behind will take decisions on this basis, which it will cancel at instant t+1. This type of conflicts could be qualified as commitment conflicts. The promise made by the vehicle that switched on its indicator is not kept. All of the anticipations made by the other agents on this basis have to be canceled.

Some conflicts are predictable and can be avoided. In reality, they are usually solved by the use of constraints that are imposed by the infrastructure and the regulation. In fact, the Highway Code and the road equipments such as road lights and traffic signs impose hard constraints to the driver when he is driving on the road. Likewise, the highway was designed in a way that the flows that move in opposite directions are separated. This allows avoiding collisions that might occur between these two flows. These constraints are introduced into our model. They consist in a set of individual behaviour rules that aim to avoid collision between the two flows. In a multi-agent context, this resolution method is called coordination by regulation or social norms (see for example [9] who works on the emergence of social norms in an agent population, and shows the interest of introducing such constraints in a multi-agent system).

However, other conflicts exist that cannot be solved by this method. Sometimes, the application of the regulation leads to blocked situations. For example, in the case of a cross-shaped crossroad, on which a vehicle is placed at the end of each of the four roads: if drivers apply the left priority rule, none of them would decide to enter the intersection and all of them would be blocked. In practice, the driver uses his perception of the environment in order to make his decisions and to solve such situations. The driver agents should do so in order to have an individual and a collective behaviour that is realistic. Just like in reality, they should find a solution that satisfies most of the constraints imposed by the regulation, the infrastructure and the road traffic, without perhaps respecting all of them. In this article we are mainly interested in this type of conflicts, and in the methods allowing solving them.

5. Constraints for conflicts resolution

The psychological studies of driving led by the LPC [25], which inspired us during the design of the behavioural model, underlines the importance of the anticipation for the driver. In fact, the driver takes the forecasting duration of the interaction into account when reacting to it. He does not, simply, react to instantaneous variations of the data describing it. So if he predicts that the duration of the interaction will not be too long, he can decide to adapt and stay on his lane. Else he can try to eliminate this interaction. Therefore, the adopted method for conflict resolution should allow the driver agents to anticipate the traffic evolution, so that they could have a credible behaviour.

On the other hand, because of the dynamical character of the traffic, it is quite difficult to predict it accurately. For this reason, we need a quick and adaptive conflict resolution method in order to allow the simulated driver to react in real time, i.e. as quickly as a real driver. Given the constraints imposed upon the agent driver (mobility, movement, etc.), we are in fact close to the design of reactive robots, for example those participating to the soccer competitions [4]. However, we stress that, contratrily to robotics, where the goal of a robot is to find an optimal solution to the problem it is facing, we try to reproduce in ARCHISIM a human behaviour that does not usually correspond to an optimal solution. An other difference is that the method chosen needs to satisfy three constraints at the same time: implement the anticipation mechanisms described by the psychologists, combine these mechanisms with a strong reactivity, and combine these two behavioural models in order to obtain credible driver agents.

6. Solving conflicts between driver agents

6.1. Distributed AI traditional methods

6.1.1. Reactive systems

The numerous reactive coordination methods used for solving conflicts, have proved themselves efficient in the domain of highly dynamical multi-agent systems. These methods are based on the use of several essential techniques [18]. Among these techniques, the most used is the one based on symmetrical force fields, which allows to define attractive and repulsive behaviours. It is applied in the area of air traffic control [30], simulation of collective animals behaviour [23, 11], or in the field of collective robotics [13].

Adding coordination actions, which allow the agents to help one another, can also ensure solving conflicts. For instance, to design autonomous aircraft controlling their traffic [10], each aircraft-agent can be aware of the team tactics and of its role in this tactics. Coordination between agents is then obtained thanks to the observation of actions of team members with respect to a set of common tactics. Another example of coordination, similarly dealing with programs of controls between reactive agents, is given by [5].

All these approaches, which are designed to be used in dynamic and unpredictable contexts, do not necessarily fit the road traffic case. In fact, their assumptions are mainly to act in reaction to the events perceived by the agent. The perception-action loop must be as short as possible, the agent can not extract too much information from its environment, nor can it anticipate in the future. And it is contradictory with the fact that driving psychologists stress the importance of anticipation even in highly perturbed contexts. The microscopic traffic simulation model, *Mitsim* [29], is a good example of the non-appropriation of a purely reactive method. This model applies a method for solving conflicts based upon the pursuit law (the vehicle acceleration is computed according to the speed of the preceding car). The decision to change lane only depends on the state of the neighbouring traffic. This limited piece of information, necessary for reactivity, induces very short-term anticipations, and produces unrealistic behaviours. Figure 3 illustrates a case of malfunction of this method.

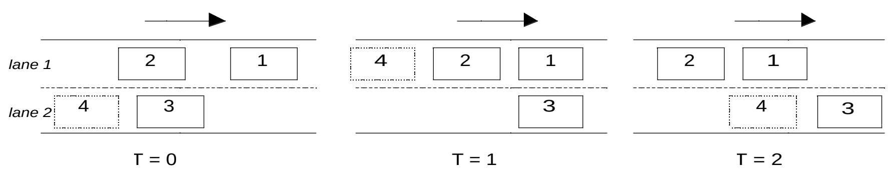

Fig. 3. The vehicles, numbered from 1 to 4, have respectively a speed of 60, 100, 80 and 90km/h. Vehicle 4 wants to reach 120km/h. At t=0, the speed of vehicle 2 is higher than that of vehicle 3. Then, vehicle 4 changes lane in order to accelerate. But, some times later, at t= 1, vehicle 2 is forced by the speed of vehicle 1. After evaluating the speed of vehicles 2 and 3 once more, vehicle 4 decides to go back to lane 2. The unuseful lane changing could be avoided if vehicle 4 anticipated in the long term, considering vehicle 1. It is what a human driver would do in this situation (according to the experiments lead by psychologists).

Furthermore, it can be difficult to escape from a conflict situation when the agents are not able to anticipate. For instance, a traffic jam around a crossroad can become so heavy that it is impossible to get rid of. This is a quite rare situation in reality and it should be so in a realistic simulation (see the example of the traffic jam formation by very simple driver-agents in [22]).

6.1.2. Planning systems

Other techniques proposed in the literature, such as planning techniques, allow solving this problem by giving the agents a very high capacity to anticipate. Yet, they need some kind of communication between the agents, and also important possibilities of representation. Therefore, they are usually unable to deal with unpredictable or very complex situations in a short term (see [1]).

In this kind of systems, each agent defines a plan in which it describes the different actions it has to do at long or at short term, regarding the present status of its environment and the status it wants to reach. Given the great number of driver agents which a road traffic simulation involves, we could expect numerous plan revisions and thus a very slow individual execution time. This would prevent the agent from acting or reacting in a real time.

Moreover, if the frequency of modifications of data describing the environment is high (higher than the frequency of plan generation), the use of a planning method not only becomes inefficient, but also useless (if the agent generates plans without using them). For instance, the use of a planning technique in order to microscopically simulate a crossroad in the city of Saint-Quentin [28] allows to reproduce in a realistic way the flows which take place on the crossroads. However, the computing time becomes very important when the number of vehicles is more than one hundred.

We can conclude that, on one hand, the conflicts resolution methods which allow to react in real time in a dynamic environment, are usually not able to anticipate at a long or average term and that, on the other hand, the methods that are able to anticipate cannot cope with strongly dynamical systems. Therefore, a conflict resolution method used in the context of road traffic can be efficient only if it allows to make a good compromise between these two antagonistic criteria. It must combine reactivity and anticipation.

6.2. Proposed method for conflict resolution

According to the studies led by the LPC [25], the space around the vehicle that constitutes the area of control of the driver can be split into several sectors distinguished according to their location (front, rear, left side, right side) and their proximity (very near, near, far). The driver makes his decisions on the basis of an analysis of the traffic condition in these areas. His aim is to minimize the present and future conflicts.

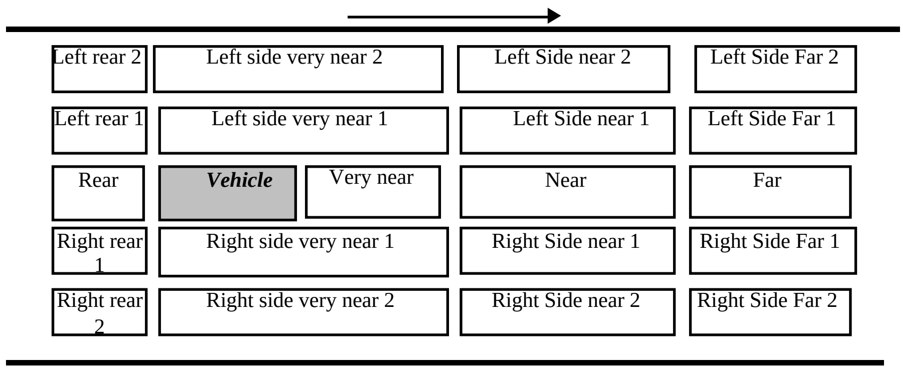

Fig. 4. The areas of perception of a simulated driver

Thus, the idea is to model the perception area of each simulated driver as a set of areas covering the field of control of a real driver (see figure 4). The decisions made by the agent driver are based on the characteristics of these areas: their infrastructure, the regulations, and the behaviour of the drivers in these areas. These characteristics are described with two parameters:

- The first is the typical interval, that measures the distribution of the speeds of the vehicles running on that area and thus the traffic stability of the area. In other words, the typical interval describes a part of the drivers' behaviour. It answers to the question whether the road users of that area have a stable behaviour or not. A high typical interval value would mean that the traffic is not stable. This would discourage the agent driver from going to that area.
- The second parameter is the area's speed. A high speed value means that the traffic on that area is fluid and encourages the agent driver to go there. This speed is computed by the agent as shown below :
  - We assume that each agent driver possesses a preferential speed which it aims to reach.
  - The speed of an area is then equal to the speed of the slower vehicle running in the area if the latter is smaller than the preferential speed of the agent driver. Otherwise its speed is equal to the agent's preferential speed.
  - However, it sometimes occurs that the geometrical dimensions of the area or the road equipements situated in the area (red light, speed limitation) impose a smaller speed than the one computed above. In that case, the area's speed will be equal to the one imposed by the road's equipements or by the area's

infrastructure. For example, if an area comprises a lane closing, its speed will be equal to zero.

At each new step of the simulation, the agent driver takes information about these areas and assigns to each of them their values of stability and speed. Accordingly to these data, it decides on the actions he will undertake. The decision rules it uses are « simple ». For example in the case of file driving where the decision consists in staying or not on the same lane, the driver agent proceeds as shown below:

- Remind that, according to the psychological studies on which we are basing our work, a human driver takes the forecasting duration of the interaction into account. Likewise, an agent driver starts by assessing the duration of the interaction it is experiencing. If the duration is short it decides to adapt and to stay on its lane. For instance if the disturbing vehicle switches on its indicator, an agent driver estimates the duration of the interaction as short, since the disturbing vehicle would leave the lane soon.
- Otherwise, it associates to each of the lanes (straight-ahead, left, right) a benefit that it computes with an assessment function. This function uses the characteristics (speed and stability) of the near, very near and distant areas as parameters. The lane, which the driver will choose to drive on, is the one with the highest benefit value.

These same rules could be qualified as being reactive and anticipative at the same time. As a matter of fact, a driver agent operates in a reactive manner since its reactions only depend on its perception of the environment. The information concerning its behaviour is found in perception. To obtain these information, it does not needs to communicate with other agents nor to memorize them. Thus its reactions are fast and allow it to cope with a highly dynamical system such as road traffic.

This method also allows it to anticipate. Indeed, the agent reacts not only to the characteristics of the near areas but also on the basis of the characteristics of the distant areas. Thus it forecasts the traffic evolution by looking at distant areas and anticipating long term conflicts. Consequently, it is able to take the required decisions to avoid them. For example if the traffic is free in a near area and if an accident occurs in a distant area on its lane, the agent driver can expect the speeds to slow down and will try to avoid this interaction. In practice, the assessment function will return a low benefit value for the lane ahead and a high benefit value for the other lanes. The agent driver will choose the lane with the highest benefit value and will decide to change lane.

The distinction of the areas, according to their proximity, allows to categorize the types of actions to undertake into reactive actions and anticipating actions. This is possible because of the similarity existing in road traffic between “foreseeing” in space and “foreseeing” in time. It certainly explains that this method cannot be generalized for any multi-agent problem, but only for a class of problems still to be determined with the same space-time characteristics. The scientific interest of this method is that this idea is now accepted in many areas of human psychology. For instance, the works of psychologists on the decision making in collective sports [24], assert that once the cognitive effort of visual determination of significant visual signs has been done (which corresponds to the "experience" of the driver through a discreetization of his active perception), the implementation of simple and stereotyped rules applied to these pieces of information allows to obtain a behaviour combining anticipation and reactivity in an elegant and efficient manner. This approach is the one we already proposed in other contexts (cf. [12]), with the difference that it allows us to obtain behaviours interpreted as "credible" by the users of the simulator. The following section illustrates this point in the particular case of driving in file.

6.3. Example : driving in file

In this example our objective was to improve the realism of the decision of lane changing, already existing in ARCHISIM, but in a poorly realistic way. It was purely reactive and, thus, showed no anticipation. To make this decision – changing or keeping lane – the agent driver must take the traffic condition not only in its near environment but also in a more distant environment into account. When the anticipations are only of short duration, which means that the traffic conditions are only taken from the near environment, the emerging behaviours are often unrealistic. We observe, in particular, a high mobility between lanes (see 3.1.1).

To validate our model at an individual level, we have applied the method of conflict anticipation to many different scenarios, which have been carefully observed by the psychologists. They have concluded that the realism of the behaviour at an individual level was greatly improved [15]. For instance, in the scenario presented at the paragraph 3.1.1, the vehicle number four does not change lane and stays on the same one.

Having a behaviour that is valid at an individual level, we wondered whether this could also lead to a valid collective behaviour. For this reason, we tested whether the traffic produced by the model complied with the general laws of traffic flow. Thus, we made a comparison between the results obtained from our simulation model and the laws described in [7]. The experiments have demonstrated that our model reproduces these laws [15].

Since, in this example, our objective was to improve the realism of the decision of lane changing, we have also validated the choice of the lane by the simulated drivers. We have based our validation on the works achieved by the Transport Engineering Department of the University of Napoli 2 (Italy) and the Faculty of Engineering of University of Reggio Calabria (Italy) [27]. On the basis of real data, the latter have described laws representing the distribution of the flow on each lane as a function of the total flow. They have also pointed out laws describing the relation between the average speed on a lane and the total flow. Both of these laws are considered in the context of a two lanes and a three lanes highway. Through the superposition of the curves obtained by simulation in ARCHISIM, and the corresponding laws [15] (see figure 5), we have been able to verify that the traffic produced by our model complied with the laws and that the assignment of flow on each lane appeared as "realistic".

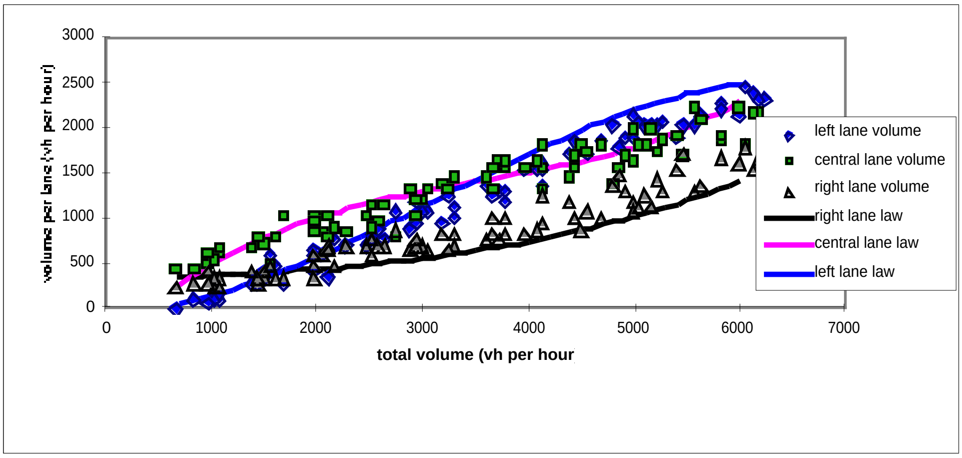

Fig. 5. Volume distribution on a three lanes highway. The laws represented on the curve were obtained through the interpolation of real data and describe the distribution of the flow according to the total flow in the case of a three lanes highway. The data represented in the form of point clouds were obtained from the application of our model to the same scenario.

The lane choice analysis gives us a global validation of the changing lane decision. However, the volume distribution can be statistically correct, whereas the number of changing decisions that leads to this distribution is not. Therefore, it will be interesting to lead a more accurate validation based on the number of lane changing decisions. The only difficulty is that actual data about this criterion does not yet exist. That is why we are engaged in a cooperation with our Italian partners, during which they will eventually provide us with laws about individual lane changes.

7. Conclusion and perspectives

The objective of ARCHISIM model is to produce realistic traffic situations by reproducing the behaviour of the drivers and putting these simulated drivers in interaction in an artificial environment. The traffic produced results from the interactions between these artificial agents (in the context described by the road infrastructure and the regulations). Yet, contrary to most of the existing models, ARCHISIM also allows to introduce in the system a real driver in a driving simulator, who receives the images of the simulated traffic. The global "realism" of a simulation (in terms of measurable data) has then to be associated with an individual "realism", (each agent being a “credible” driver for a human driver). It is under this double constraint (a constraint also strong in the design of "avatars" in virtual worlds, for example) that the agents behaviours were designed. In particular a great care was given to the mechanisms of conflicts resolution implemented by the agents, as none of the methods used in DAI was really satisfying: either because of their weak realism (reactive methods) or because they necessitated too much computation time (planning) or because they were inadequate for a very dynamic environment (planning again). The solution chosen has been inspired by the works of driving psychologists and relies on the characteristics of the road traffic, in which seeing far in space allows to make projections in time with a weak error margin. In that way we have been able to combine the design of reactive behaviours depending on a discreetization of the perception with a potentiality of anticipation, which is the implementation of the same reactive behaviour applied to distant areas. Furthermore, this solution allows us to obtain very realistic behaviour for the driving agents and has been successfully validated, with respect to a realistic traffic, in the particluar case of driving in file.

Our perspectives for the next two years are as follows:

- Refining the individual decision rules so that they will eventually be able to deal with even more complex road situations such as highway ramps, crossroads etc.
- launching a more complete set of empirical and perhaps theoretical validations (based, for example, on the number of lane changing decisions, etc.),
- generalizing this type of method to other multi-agent systems where it is crucial to combine reactivity, anticipation, real time decision-making and “credibility”. The design of artificial agents evolving in virtual reality environments together with humans or the design of robots colonies immerged in human collectivities [14] seem to be interesting problems in that respect.

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