Improving driver's situation awareness

Juliette BREZILLON[1], Patrick BREZILLON[1], Charles TIJUS[2]

[1]104 avenue du Président Kennedy, 75016, paris, France
{Juliette.Brezillon, Patrick.Brezillon}@lip6.fr
[2]2 rue de la Liberté, 93526 St Denis, France
{tijus@univ-paris8.fr}

Abstract. Initial training, which concludes by a driving license, is insufficient because new drivers do not know how to contextualize the learned procedures into effective practices. Our goal is to improve the driver's Situation Awareness, i.e. the way in which the driver perceives events in the environment, and the projection of their status in a close future. More precisely, our concern is the way in which the driver evaluates the criticality of a situation. First, we model drivers' behavior along two approaches, that is, local and global approaches, in order to have a driver model as exhaustive as possible. Second, we model drivers in a twofold representation, a situation space (an objective representation given by a lattice) and a behavior space (a subjective representation given by a contextual graph). Scenarios connect the two representations. We present in this paper the results of a specific study on driver classification based on the two approaches.

1 Introduction

Car driving is a complex activity that needs practical experiments to be safe. Initial training ends on a driving license that is often insufficient because the young driver does not know how to contextualize the learned procedures in effective practices. As a consequence, novice drivers are proportionally more involved in accident than experienced drivers [9]. [15] estimated that up to 70 % of the novice driver's errors were attributable to inexperience. Based on 1000 novices' crashes analysis, [18] conclude that inexperience was the major factor in 42 % of these accidents. Inexperience concerns several aspects of drivers' cognition, but the main factor of novice drivers' errors is an inadequate mental representation of the driving situation.

Driver's decision making is not based on an objective state of the world, but on a mental model of the driving task and the conditions in which this task is accomplished. This mental model is a « circumstantial representation » [23] built in a working memory from perceptive information extracted in a scene, and from permanent knowledge stored in the long-term memory. This representation provides a meaningful and self-oriented interpretation of the reality, including anticipations of potential evolutions in the current driving situation. This corresponds to the driver's Situation Awareness, according to [12]'s definition of this concept: "The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future."

Moreover, this mental representation is “action-oriented” (i.e. the driver is an actor not a witness). It constitutes an Operative Image (i.e. a functionally deformed view of the reality [20]. Once built, such mental models generate perceptive expectations, guide the road environment exploration and the new information processing, orientate decision making and, lastly, determine all driving behaviors carried out by the driver [3]. Thus, mental representations are a key element of the driver’s cognition. An erroneous representation means, potentially, decision-making errors and unsafe driving actions. [2] illustrate the effect of inexperience at different levels of situation awareness, including information perception, driving situation understanding, and anticipation.

Hereafter, the paper is organized as follows. In the second part, we present the context of our work, the problem we aims to solve, and the methodology we use. In the third part, we present the tools we use along each approach (machine learning and cognitive sciences). In the fourth part, we conclude and present the data used. In the fifth part, we present the current state of the project and our results on our driver modeling. In the last part, we present the perspectives.

2 Presentation

2.1 Related works

Our work is based on the GADGET's methodology [13]. The GADGET project, acronym for "Guarding Automobile Drivers through Guidance Education and Technology", is a European project about road safety. It aims to assess traffic safety measures on driver behavior; analyze the influence of in-car safety devices, various road environments, education and training programs, safety campaigns, and legal measures (including enforcement) on driver behavior.

There are the three hierarchical levels – the strategic, tactical and operational level, and a fourth level is added concerning “goals for life and skills for living“. The levels also have been divided into three dimensions concerning knowledge/skill, risk increasing factors and self-assessment. The highest level refers to personal motives and tendencies in a broader perspective. This level is based on knowledge like lifestyle, social background, gender, age and other individual preconditions have an influence on attitudes, driving behavior and accident involvement. The idea in the hierarchical representation is that both failures and successes on a level affect the demands on lower levels. Thus driver's behavior must be analyzed on all these levels and not at the operational level only.

We postulate that the discrepancy between the theoretical training, which is validated by the driving license, and the effective training by driving alone (the learning-by-doing) is mainly due to a lack of support in the phase of contextualization of the theoretical training in real life situations, i.e. how to apply effectively general knowledge in a number of specific and particular situations.

Our third assumption is that works like GADGET methodology can be revisited at the light of the notion of context and mainly the process of contextualization.

A fourth assumption is that a decision support system would benefit of drivers’ experience by incrementally record drivers’ good and bad practices. Thus a system will be later able to identify the real driver's behavior, which determine a path in the situation space to allow the driver to return to a normal situation and correct behavior, and propose a scenario to support driver training.

[16] shows that it's better to learn from other people's errors than from their successes. Their results provide some support for the hypothesis that it is better to learn from other people's errors than from their successes. That's why we based our driver's typology on driving's errors.

2.2 The ACC Project

The work presented in this paper is ascribed in the ACC project (French acronym that stands for "Context-based Support Driving"). The project is presented at: www-poleia.lip6.fr/~jbrezillon (in French). The objective is to allow drivers to improve their situation awareness by simulation and by allowing drivers to learn from their drawbacks. More specifically, we want to help the driver to identify "pre-critical" situations, i.e. situations where it is yet possible to avoid the critical situation, to make the right decision and thus return to a normal situation instead of the critical situation.

We choose to lead our study from the viewpoint of a car driver instead of the usual observer's viewpoint. We thus focus more on drivers' behavior and his interpretation of the situation at hand than on the situation itself. We know that the analysis will be partial, incomplete and subjective and will lead to deal with a large number of contextual cues.

The three main elements are the situation, the driver's behavior and the scenario. Situations and behaviors are represented in different spaces, and scenarios connect the two spaces. Thus, a driver has a unique representation in the two spaces. A simple intermediate situation in the situation space is a normal situation. A leaf situation is a critical situation (e.g. a collision) or the last normal situation considered in a scenario. Drivers' behaviors are represented in the formalism of Contextual Graphs in which practices (i.e. scenario applications). Finally, a scenario is the crossing of a series of situations by a car driver. Scenarios are represented in the situation space by a tree structure. A node in the scenario tree corresponds to a pre-critical situation, i.e. a situation in which the driver has two options, a bad (resp. good) one leading to a critical (resp. normal) situation.

The overall organization relies on a typology of the drivers and data of real driving situations. Once the driver's position in the typology is known, a simulated scenario of real driving scenarios with driving problems is selected. Each scenario is adapted to the driver's learning through errors handling and errors feedback to improve situation's awareness.

A situation is a scene with a set of characteristics. The context of the situation (the situation dressing) defines some external variables (e.g. it is raining), which impact the situation characteristics.

We associate global methods resulting from machine learning and local methods resulting from cognitive sciences. The statistical training aims to model driver's classes whereas the latter relies on a cognitive modeling of drivers' behaviors. The global approach aims to model the driver from numerous data of low level (e.g. movement of eyes when driving). The goal is to process by generalization and abstraction to obtain more conceptual information (e.g. definition of classes of drivers based on real drivers' behaviors). The local approach aims to model each driver at the cognitive level that concerns the highest levels.

The association of the two approaches, the global and local approaches, allows a more complete modeling the driver at all the levels of the matrix proposed in the GADGET methodology. Thus we solve some problems found in literature, e.g. like some studies that analyze the driver at one level at a time, (e.g. the tactical level.)

3 The Tools

3.1 Questionnaire

We thus design the questionnaire in order to develop, organize and structure items of the GADGET matrix but respecting the hierarchical levels of the matrix. The questionnaire is online at http://www-poleia.lip6.fr/jbrezillon/questionnaire/ (in French). Advertisements for the questionnaire was targeted to associations concerned by accident, for retrieving points on the license, but also car schools, police, insurances, and automobile companies.

3.2 Machine learning

The process of learning based on the statistical distribution of information in a dataset is used in a class of computational models in cognitive science and psychology to describe human behavior. It is also used in computer science when using data to make predictions. We have selected two tools for their adequacy to our problem:

1. A Hidden Markov Model (HMM) is a statistical model where the system being modeled is assumed to be a Markov process with unknown parameters, and the challenge is to determine the hidden parameters from the observable parameters. The extracted model parameters can then be used to perform further analysis, for example for pattern recognition applications. In a hidden Markov model, the state is not directly visible, but variables influenced by the state are visible. Each state has a probability distribution over the possible output tokens. Therefore, the sequence of tokens generated by a HMM gives some information about the sequence of states.
2. A conditional random field (CRF) is a kind of discriminative probabilistic model most often used for the labeling or parsing of sequential data, such as natural language text or biological sequences. Similarly to a Markov random field, a CRF is an undirected graphical model in which each vertex represents a random variable whose distribution is to be inferred, and each edge represents a dependency between two random variables. In a CRF, the distribution of each discrete random variable Y in the graph is conditioned on an input sequence X.

3.3 Cognitive sciences

The methods coming from cognitive sciences considered are:

1. The STONE engine [22] is an automatic tool for structuring knowledge in a Gallois Lattice. It allows making a typology of descriptors and a typology of drivers. STONE Engine starts from input descriptors and relationships between descriptors and builds a tree of descriptors that are structured as a semantic set of dimensions. In addition, by attaching to each category what is specific to this category, the set of descriptors, which particularize each category, provide the best description of drivers of this category.
2. Contextual Graphs are a context-based formalism for representing knowledge and reasoning [6]. This formalism allows modeling the different ways in which an individual accomplishes a task. A driving situation represents the different possible scenarios for this « situation solving ». A path in this graph represents a driver's behavior in the driving situation, taking into account the different contexts considered by the user during the situation solving.

3.4 A common method: PCA

A PCA (Principal Components Analysis [1]) is a common method of machine learning and cognitive sciences. It's a technique for simplifying a dataset, by reducing multidimensional datasets to lower dimensions for analysis.

Technically speaking, PCA is a linear transformation that transforms the data to a new coordinate system such that the greatest variance by any projection of the data comes to lie on the first coordinate (called the first principal component), the second greatest variance on the second coordinate, and so on. PCA can be used for dimensionality reduction in a dataset while retaining those characteristics of the dataset that contribute most to its variance, by keeping lower-order principal components and ignoring higher-order ones. Such low-order components often contain the "most important" aspects of the data (called variables hereafter). But this is not necessarily the case, depending on the application.

4 The Data

An INRETS team at Arcueil has a simulator (embarked equipment in a car and 180-degree screen) to analyze driving situation, such as the reaction time. In terms of our approach, it is possible to simulate normal, pre-critical and critical situations.

We work now with seven associations and the French national police for the exploitation of the questionnaire on the Web. The main reasons are: large quantity of attribute for defining the driver model on several levels, it is an innovating, inexpensive, fast and effective method, it allows to collect more ecological data and offers more relevant statistical analyses, facility in finding participants and leaving the framework of the laboratory and subjects belonging to the university, a larger spectrum of subjects using Internet. Members of such associations are directly concerned by road safety, have already been involved (directly or not) in an accident, are young drivers, students, retired persons, etc.

The questionnaire is composed of 162 questions, most of them requiring a binary answer (yes or no). For the study presented in this paper, we worked on the first 166 answers, and retained as correct 419 of them. Note that the questionnaire aims to instantiate 132 variables.

5 Results

5.1 The questionnaire

Method. The questionnaire is based on the extended version of the GADGET matrix and concerns 61 variables and 162 questions. The results are based on 419 relevant answers to that questionnaire. We found 15 classes, by doing a principal composant analysis to reduce the 61 variables to 3, and we classify new data, thanks to agglomerative methods. We identify for each class the variables that represent the best the class. These variables have a specific value in a class and another value in the others classes. After, we determine in each class the variables that are related to risky behaviors. We then obtain a driver typology that is errors-based. Finally, we analyze driving behavior evolution according to the drivers' age. We wanted to know if young drivers present specific errors different from those of old drivers.

Results. We identify four steps in the evolution of the driving behaviors with the age (see figure 1):

- Discovering step: it's the step in which drivers discover what driving is, thus errors made at this step concern mainly a lack of competence for driving (as information overload, no evaluation of the necessity of a trip, no respect of the safety margins, etc.)
- Risk step: experience coming with driving, the driver looks then for his competences limits by taking risks, thus errors made at this step concern mainly risks (as personal driving style, the no respect to driving rules, etc.)
- Stable step: the driver has found and kept his driving style, and the errors made in this step are quite similar to the previous one.
- New driving style step: driver's competences decrease with the age; The driver becomes less and less self-confident; The errors made at this step concern the new way to drive (e.g. stressed, not realistic self-evaluation and drive for another reason than go somewhere – which appear at this step).

Figure 2 shows that there exists specific errors according to the age of the driver. Young drivers make competence errors by their lack of experience. Later, drivers make risky errors, searching their personal driving style. After, their behavior stays stable. Once older, drivers make errors because there is a shift between their previous way to driving few years ago and the current one. The main problem is a problem of information processing.

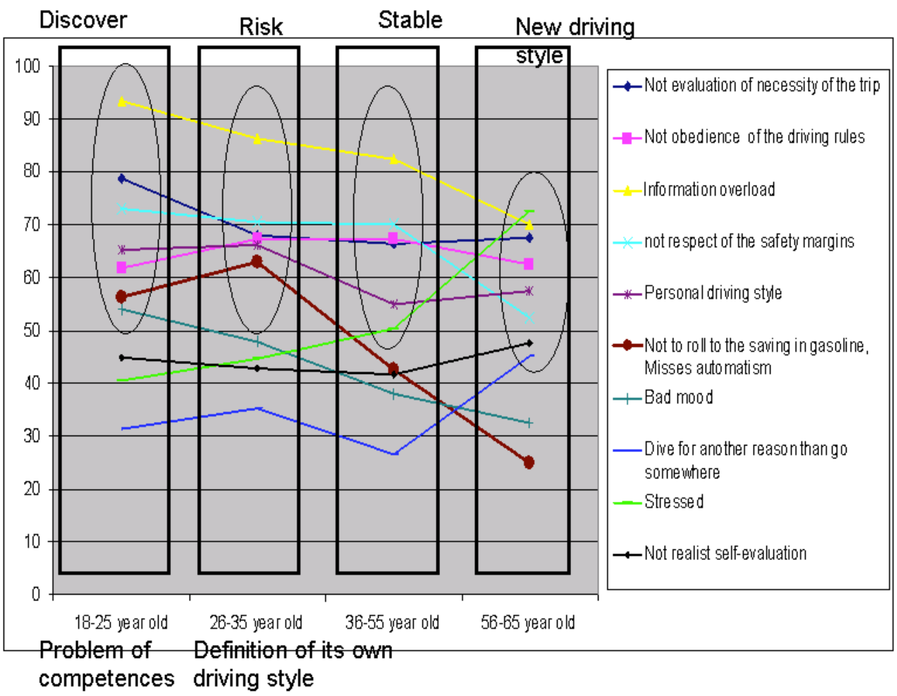


Fig.1. Evolution of the driving behavior among time

5.2 Case study

After discussion with our partners, we take a real traffic situation—a simple crossroad--and try to analyze all the driving situations that can happen. We assume only two cars arriving to the crossroad. We select the viewpoint of the driver of car A (coming from the bottom on Figure 3), and analyze all the options, first, according from where is coming the car B (from the left, the right or in front of car A), and second, according to the movement of the two cars (turn left, straight ahead, or turn right) at the crossroad. We model all the behaviors by contextual graphs (see below).

In the retained traffic situation, each road has a "give way" sign. This means that the rule is "priority to the car coming from your right."

Our modeling is based on:

- the texts of law: given the "theoretical" behavior of the driver
- a tree of situations: given the theoretical behaviors of the drivers

- the results of the questionnaire: given effective behaviors of the drivers

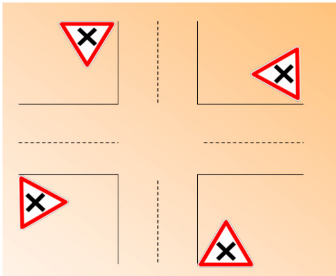


Fig. 2. The crossroad

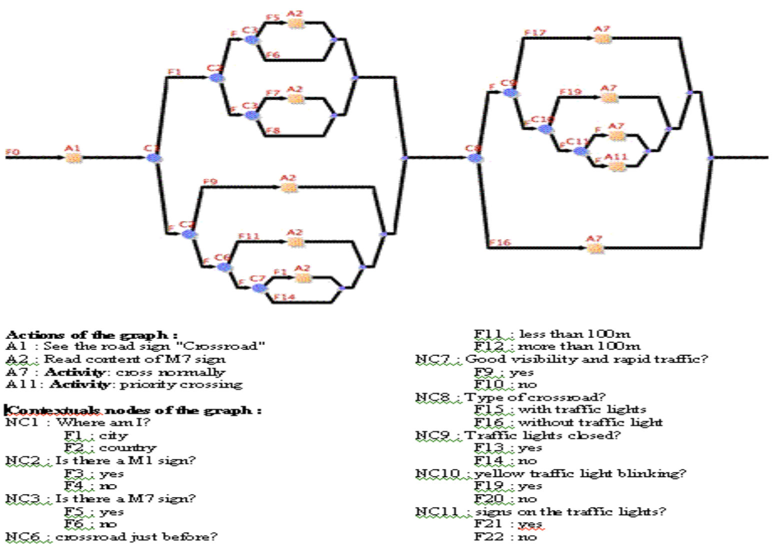
Dressing of the situation. Dressing a situation is to make its context explicit, i.e. to instantiate all the needed contextual cues. Thus, we make the following assumptions:

- The situation occurs during the day, at a normal time to drive.
- It happens in vacation, so drivers are supposed to be relaxed.
- It's not raining.
- There is no snow, or fog, or glaze in the road.
- The road is in good state.
- The car has a correct status.
- There are no pedestrian or animals that come to cross the road.
- This place that is known by the two drivers, i.e. it's not a unknown crossroad, or in a foreign country.
- The crossroad is in the countryside clearly visible by all drivers.
- The two cars can be stopped, arriving slowly, or arriving rapidly at the crossroad.
- The cars are owned by drivers.

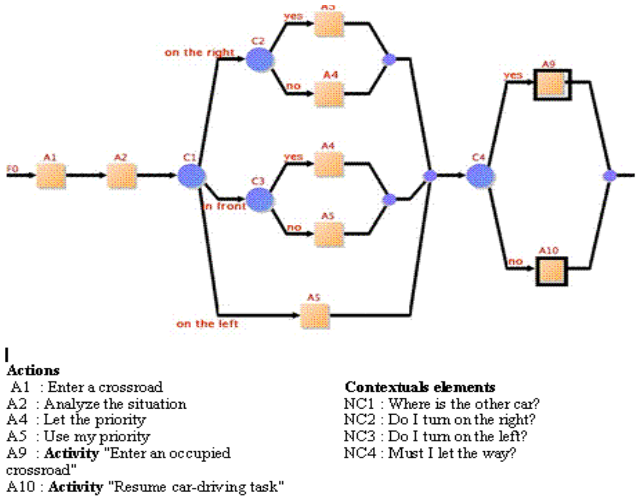
Role of context. Most of our assumptions of the previous section concern contextual elements that are often let implicit, although they are more or less related to the driving task. [7] defines context as what constrain the driving task without intervening in it explicitly. Thus context is relative to a focus (the situation in the previous section), which allows distinguishing the contextual knowledge from the external knowledge, the former being more or less related to the focus (e.g. all the known contextual cues serving for the dressing situation). For example, the contextual cue “It is raining” will be used in the driving task as “Reduce speed” (normally).

A situation typology. This crossroad can leads to 27 initial traffic situations, according from where is coming car B and where are going the two cars.

Model of the theoretical behavior. Figure 3 shows the two successive parts of the theoretical model of drivers: (1) the analysis of the situation, and (2) the application of the decision made. Figure 3a represents the theoretical behavior of the driver that can be established from laws and the highway code. Since the crossroad has no special priority, the law defines the “theoretical” behavior as "to yield the emerging passage to the vehicles of right-hand side, by having a special vigilance and a deceleration adapted to the announced danger." There are however some restrictions. First, trams have priority, and, second, if the topology of the crossroads obliges it, a special road sign indicating the distance and/or crossroad topology is added to the road sign “Give way”. The theoretical behavior defined by the law is thus to check that the roadway which it will cross is free, to circulate with speed all the more moderate as the conditions of visibility are worse, in the event of need, to announce its approach, must engage in an intersection only if its vehicle does not risk to be immobilized and to prevent the passage of the vehicles circulating on the other ways.



a)



b)

Fig. 3. a) Theoretical behavior, b) Effective behaviors

Model of effective behaviors. Figure 3b represents the effective drivers' behaviors in the same situation from a study of drivers in real conditions. We analyzed what can happen concretely that was not planned by the law. First, the car's driver, which has not the priority, cannot respect it and enters the crossroad, because for instance, the car's driver thinks he has time to pass before the other car, or simply didn't see it. He can realize that he's making a mistake and decides to stop in the middle of the crossroad. The other car tries to avoid it. Moreover, the two car's drivers can break down. If a car's driver breakdown, the other driver will have to wait until the other starts again and leave the crossroad, or decides to overtake it. If he overtakes, the first car can start again and realize the other car is in front of him and try to avoid him.

Our approach in the study of driver's behaviors. Briefly, we use a very simple example to illustrate the interest of associating global and local methods. The crossroad has the form of a "T." The car B is coming from the right of car A but have a "Give way" sign and car A just goes straight ahead [8]. Figure 5 represents the different evolutions of this initial situation.

The first scenario ("1" in Figure 5) corresponds to the normal situation. Car-A's driver goes ahead and car-B's driver waits until car-A had passed and then turns right after it.

In the second scenario ("2" in Figure 5) car-B's driver goes ahead a little just to reach the road marking. There are several hypotheses for this. For example, the driver thinks to have time to realize his operation (turn right before car-A) but abandon the idea after a while. Another reason could be that the driver wants to see behind car-A if any other vehicle arrives. Car-A's driver reduces speed, observes car-B driver's behavior, and, as car-B does not move anymore, it crosses the road on the right, but carefully. After car-A is passed, car-B's driver turns right, and the second scenario meets the first scenario (see Figure 5).

In the third scenario ("3" in Figure 5) car-B's driver goes ahead until the mark on the pavement and decides to operate before car-A arrives. Conversely, car-A's driver has a different interpretation of the situation and anticipates that the other driver would stop at the mark on the pavement. However, car-A's driver takes care of the risk of a dangerous situation and understands quickly the purpose of car-B's driver when car-B goes ahead. Thus, car-A's driver has the time for breaking. As we assume that there is no other vehicle behind car-A, its driver can break easily without risk for eventual cars behind him. Car-A's driver break and stop (or at least reduce sufficiently its speed), let car-B's driver finish to turn, let some respectable distance between them and go ahead, after car-B.

A path may be associated with one or several scenarios. A given scenario may appear on several paths (i.e. a driver may express different behaviors at different moment in a given scenarios). It's the case in Figure 6 for scenario "5" in a circle, it's a collision that can happen for two reasons: the driver can not avoid it or the driver thinks he can avoid it but realize that practically he can not. The two representations being complementary, we can model the driver in a very complete way.

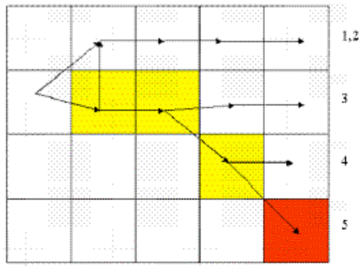


Fig. 4. The situation space

The fourth scenario supposes that, on the one hand, car-B's driver goes ahead to pass before car-A like in scenario 3, and, on the other hand, car-A's driver has a different interpretation of the situation, thinking that car-B's driver will wait before to move because car-B's driver has not the priority. Realizing that car-B's driver does not operate as expected, car-A's driver is surprised and has a short time only to react. Car-A's driver tries to break, but not enough quickly. To avoid the collision, and because there are no other vehicles than cars A and B in the area, car-A's driver decide to overtake car-B and to change lane. This decision avoids the collision of the two cars.

The fifth and last scenario is a variant of the fourth scenario. Car-A's driver tries to break, but not enough quickly. Car-A's driver has no time to change of lane (or can not do it) and a collision of the two cars thus happens.

The situation space. Figure 4 represents the previous behaviors in a situation space. Each cell is a driving situation and a path in that space corresponds to a scenario that can happen. White cells represent normal situation, grey cells pre-critical situations and the dark cell a critical situation (the collision). The distinction of the different types of situations is always relative to a given driver's viewpoint.

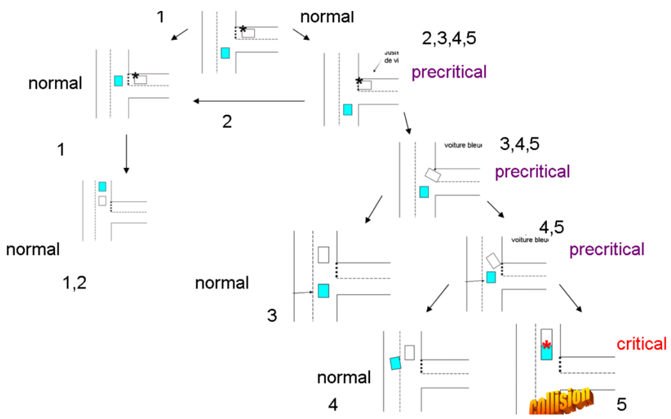
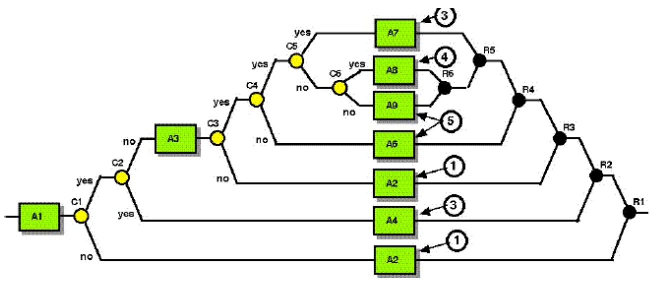


Fig. 5. The entire traffic situation

The behaviors space. Figure 6 represents some real behaviors of drivers in the contextual graphs. A path in the contextual graph corresponds to a driver's behavior.



Contextual element	
C1	Car coming on the right?
C2	Has the other car priority?
C3	Is the other car coming on my road?
C4	Can I avoid the other car?
C5	Is it sufficient to brake?
C6	Can I overtake the other car on the left?

Action	Definition
A1	Detect a crossroad
A2	Keep the same behavior
A3	Keep the same behavior and be careful
A4	Let the other car going ahead
A6	Announce my coming to the other car
A7	Brake to reduce speed
A8	Overtake the other car
A9	Brake strongly

Fig. 6. The behavior space

6 Conclusion and Perspectives

Driver modeling is an important domain that interests a number of administrations (for a uniform road security in European countries, for the police for interpreting correctly drivers' behaviors, for associations wishing to introduce some changes in the laws, etc.). Our contribution brings at least three new insights on this hot topic. First, we propose a "driver-based" classification of drivers and not an arbitrary classification. Second, we propose an open modeling in the sense that it is possible to incrementally acquire new behaviors of drivers. Third, we use good and bad practices for driver's self-learning, bad practices being mainly used by the system for identifying what is doing a given driver, and how to help him to correct his behavior.

Our goal is now to refine scenarios, unify the various representations, integrate the behaviors with the situation space, develop a tool for 3D simulation based on the situation space, confront the model to an about sixty drivers, and validate our model in real conditions.

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