DECISION MAKING AT A CROSSROAD: A NEGOTIATION OF CONTEXTS

P. Brézillon[1], J. Brézillon[2] and J.-Ch. Pomerol[3]

ABSTRACT

The initial training generally puts the driver in a supervised learning context that is not the autonomous-driving context in which decision making and responsibility are assumed by the driver alone. As a consequence, the beginner is not able to contextualize the learned procedures and transform them in effective practices, to identify and manage pre-critical situations and to evaluate the degree of danger of situations. Starting from the studies and works presented in the literature, we propose a twofold approach based on the one hand on global methods and, on the other hand, on local methods. We first represent a driver in two spaces (situations and behaviors) related through scenarios. The situation space is an objective representation by a lattice and the other one is a subjective representation by contextual graphs. Our second goal is to provide the driver with a system for a self training and self evaluation of his behavior in different pre-critical situations. This paper discusses the cognitive part of the approach and objectives on a case study.

KEY WORDS

Road safety, Decision making, Driver training, Context, Contextual graphs, Practices

INTRODUCTION

The initial training generally puts the driver in a supervised learning context that is far from the normal context of autonomous driving where decision making and responsibility are assumed by the driver alone. During the supervised training, the driver relies (heavily) on the trainer for decision making and responsibility. As a consequence, once alone, drivers (1) are not able to transform the procedures learned during their training in efficient practices, (2) are not able to evaluate the degree of danger of some behaviors (their behavior and the interpretation of others' behaviors) and of some driving situations, and (3) are not able to identify and evaluate accurately pre-critical situations to select the right option. In 30 to 60% of accidents, the information is well perceived but interpreted falsely: the responsibility of accidents is mainly due to a problem of information processing, not of information gathering.

The driving license validates the correct assimilation of theoretical knowledge (road signs, etc.) about the task of driving. Once alone, the new driver has to transform this

1 Researcher at CNRS, University Paris 6, LIP6, case 169, 8 rue du Capitaine Scott, 75015 Paris, France, Phone +331 44277008, FAX +331 44277000, patrick.brezillon@lip6.fr

2 Ph.D. student, University Paris 6, LIP6, case 169, 8 rue du Capitaine Scott, 75015 Paris, France, Phone +331 44274439, FAX +331 44277000, juliette.brezillon@lip6.fr

3 Professor, University Paris 6, LIP6, case 169, 8 rue du Capitaine Scott, 75015 Paris, France, Phone +331 44277011, FAX +331 44277000, jean-charles.pomerol@lip6.fr

theoretical knowledge into efficient practices of driving, i.e. the driver must contextualize the theoretical knowledge in order to account for specificity of the situation at hand. Our goal is to provide drivers with a support for this step of contextualization. A driver is considered along three dimensions: situation, scenario and behavior. A situation can be normal, critical or pre-critical. A scenario corresponds to the evolution of a situation for a given driver's behavior.

Situations are represented in a situation space *a la* SOAR (Laird et al., 1987). A situation is a scene with a set of characteristics. The context of the situation defines some external variables (e.g. it is raining). A situation is normal if there is no change in its characteristics (the driver keeps the same driving plan). A situation is critical if there is a definitive change for the driver in the situation or an unpredicted event in its context (the driver does not pay attention, has no time or does not know how to change the driving plan). In a pre-critical situation, the driver must identify a change in the situation or its context, or a change in his behavior (e.g. focusing temporarily on a distractive task) and make a decision adapted to this change (i.e. modifies the initial driving plan). The two outputs of such a situation are the normal situation if the driver modifies correctly the driving plan or a critical situation if the driver does not react correctly. A pre-critical situation is a kind of bifurcation point (Thom, 1977).

A scenario corresponds to a sequence of situations with their contexts. With pre-critical situations as bifurcation points, scenarios can be represented such as a scenario tree in a situation space.

Driver's behaviors are considered in a formalism called Contextual graphs that provides a uniform representation of elements of reasoning and of contexts (Brézillon, 2005). The principles of contextual-graph building for driving are the following. A contextual graph represents the different behaviors that a driver may present for managing a given driving situation. A path in this graph represents a particular driver's behavior in that driving situation for specified contexts of the driver (e.g. status = in a hurry) and of the situation (e.g. weather = rain). Such contextual elements are said instantiated because their value is explicitly considered in the decision making process, and assembled together constitute a proceduralized context (Brézillon, 2005). A driver can exhibit different behaviors for a given scenario, and the same behavior may appear in different scenarios.

Thus, scenarios are the bridge between situations and behaviors. After a while, a contextual graph becomes a kind of corporate memory for the driving situation, because all the possible behaviors will be represented. Then, a system using this database can select an initial situation and proposes a scenario tailored to its knowledge of the user, observes the user's behavior, compares and anticipates (by simulation) the consequences of the user's behavior, analyses how the user perceives a pre-critical situation, and proposes explanations for training the user on the ground of practices, that is contextualization of procedures.

The project called "Context-based Support to Driver" (with the French acronym ACC) has the following objectives:

- Help the driver to anticipate, identify and correct pre-critical situations, when it is yet possible to avoid the critical situation and go back to a normal situation.

- Represent the triple {situation, driver's behavior, scenario} in complementary formalisms for identifying pre-critical situations.
- Propose to drivers a personalizable method of self-evaluation and self-correction of their driving practices.

Hereafter, we introduce briefly a state of the art. After, we describe the twofold approach developed in the ACC project and the chosen methodology. We discuss our position on a case study of crossroad. Finally we conclude by presenting the potentiality of our approach.

RELATED WORKS

There are a number of works on user modeling, including driver modeling. In the domain of road safety, the GADGET methodology (Keskinen, 1996; GADGET, 1999) proposes a four-layers model (life projects and aptitudes, car driving objectives and social context of the moving, tackling circulation situations, and vehicle management) and three dimensions (knowledge and capacity, factors increasing risks, and self-evaluation) (ADVANCED, 2002). Indeed, the GADGET methodology is similar to a more general hierarchical organization on people behavior at four ordered levels: policy, strategy, tactics and operational. This representation at four levels allows to clarify how a decision making is ascribed:

- At the policy level, the driver decides on general orientation (e.g. I take the car to go at a meeting) that will be then specified.
- At the strategy level, decisions are about planning of the journey, the choice of the itinerary, time schedule, etc. Checking strategic choices is realized from time to time or when an unpredicted event occurs (time constants for decision making are relatively large).
- At the tactics level, the driver deals with tasks such as how to deal with a bend, overtake a car, respect priority, etc. Time constants for decision making are shorter than at the strategy level.
- At the operational level, the driver's concern is to keep the car in the same line, control car speed, etc. Time constants for decision making at this level are the shortest among the four levels.

Choice at one level constrains choices at lower levels. Thus, decisions must be made in an increasingly short time when we go from the upper level (policy level) to the lower level (operational level). However when driving becomes familiar, the more we go down in the hierarchy, the more automatic is the behavior.

THE TWOFOLD APPROACH PROPOSED IN THE ACC PROJECT

We propose to address the problem by a double approach. A **global approach** of drivers' behavior with respect to a given task by proposing to them choices already made by other drivers with a similar profile (e.g. choice of a method, choice between alternatives) for the same task. This driver modeling considers the driver such as a "collective being" that is modeled from a set of users or user categories acting in a similar way (Blanchard et al., 2005;

Brusilovski, 2001; Pohl and Nick, 1999). Such a driver model can be described by a network of concepts and relationships between these concepts (e.g. Bayesian nets or hidden Markovian models). A **local** (or specific**) approach** considers the driver through the role played, the behavior manifested, the driving task, the situation and their occurrence contexts. Then, the driver is represented as:

- a "variable being," because the driver may have different goals and behaviors during the task accomplishment,
- a "unique being," because the driver has specific knowledge, centers of interest, preferences expressed, etc., and
- the responsible of a driving task that has been contextualized.

We have already an experience in each approach. First, we have a library of learning algorithms for the approach "variable being" and "collective being" (Blanchard et al., 2005). Second, we developed a context-based formalism for representing knowledge and reasoning called Contextual Graphs (Brézillon, 2005; Brézillon and Tijus, 2006) for modeling an individual accomplishing a task (especially used in the road-safety area (Bazire et al., 2006)).

The association with a cognitive approach allows to put the problem in a larger space, mainly concerning the representation of the driving situation the driver faces. In other terms, we try to model drivers' behaviors from a twofold viewpoint: an external view of the driver (from a driver classification, a behavior typology, etc.) and an internal view on the driver directly. Our intuition is that a post-license training of driving must rely on this double objective versus subjective approach of the driver from:

- A typology of drivers (Which type of driver am I? Which type of driver must I be?)
- A typology of situations (from normal to critical through pre-critical)
- A typology of practices (How do I drive? Which way to drive must I have?).

Thus, a driver accomplishing a driving task is considered such as a triple {driver, situation, practice}. Such a representation is highly contextualized. Nevertheless, our approach relies on some methodologies proposed in the literature, especially the methodology GADGET (Keskinen, 1996; Hatakka et al., 2002), the scenarios proposed in TRAINER documents and the methodology developed for the training of driving trainers (Gregersen et al., 1999). The driver would be able to tackle the following scenarios:

- Identify the type of behavior (and its associated context) in which is the driver, be able to evaluate the degree of danger of that behavior, and find a way to retrieve a normal behavior;
- Identify the situation and the driving context, evaluate the degree of danger of that situation, identify pre-critical situations and find the best way to modify his behavior in order to retrieve a normal driving situation.
- Stay vigilant on other drivers' behaviors, detect an abnormal behavior, evaluate a danger for him and adapt consequently his behavior. (Note that the danger is not perceived identically by all the drivers.)

Time constant for the driver's answer is an essential parameter in our proposal. For example, being vigilant to other drivers' behaviors is a routine task of driving (with a long time constant), while adapting his behavior to the danger presented by the other drivers may have a time constant very short (often less than one second).

Thus, the ACC project aims to:

- Synthetize the various methodologies and models available now to establish the integration of the typologies of the situations, the scenarios and the behaviors for situating a given driver.
- Develop a model of a driving situation (the driving task and a hierarchy of joint tasks) and define normal and critical situations and their frontiers (the pre-critical situations).
- Identify contexts associated with critical situations and the underlying mechanisms of contextualization of the situations.
- Represent the evolution of a driver in the three typologies and conceptualize learning such as a transfer of a category of behaviors to another one, then the transfer of a type of driver to another one.
- Develop learning and contextual mechanisms for a natural movement in the different cells of all the typologies.
- Propose the automatic generation of scenarios with the possibility of annotations taking into account the current expertise degree of drivers for their self-training.

A CASE STUDY

The case study represents the evolution of a situation for a given driver like a movement through a series of situations. We consider a discrete space of situations because we consider that a transition from one situation to another one is triggered by an event that is not plan or anticipated by the driver and implies a change in his driving plan.

Figure 1 shows a traffic situation. It is a crossroad where there are only two vehicles: a black car (C-b) and a white car (C-w). We take the viewpoint of C-b's driver. Suppose that C-b goes from the point A to the point B and that the C-w's driver wants to turn right on the road of C-b. C-b has to yield right of way to C-w. But, it can actually not yield right of way to C-w.

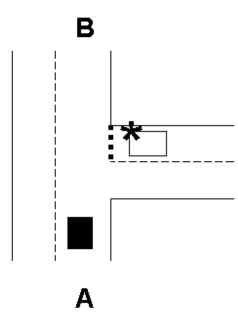

Figure 1: A traffic situation

Analysis of the different situations that can occur leads us to represent all the traffic situations that can be derived from this first traffic situation by a graph (Figure 2). The different series of situations correspond to five scenarios (numbers in Figure 2).

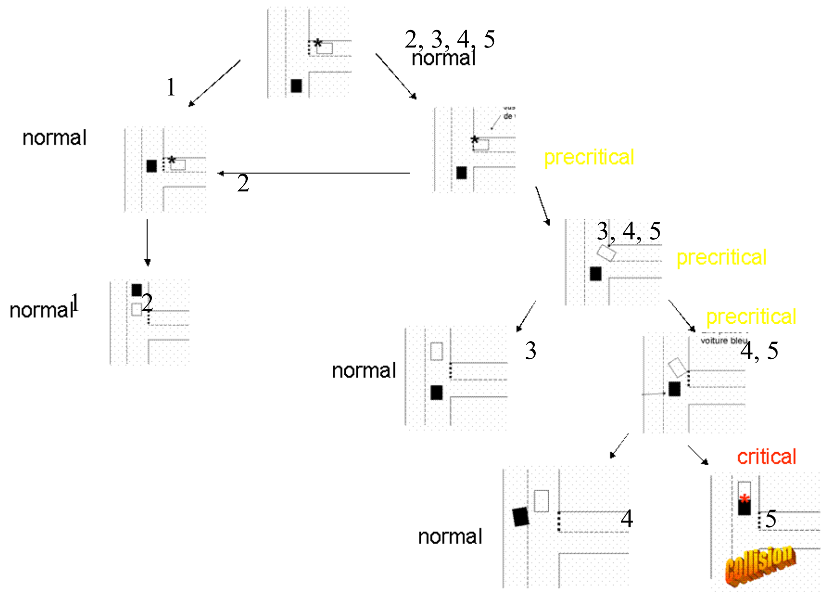

Figure 2: Graph of all the situations that can be derived from the first one

The first scenario, numbered “1” in Figure 2, corresponds to the normal situation. C-b goes ahead and C-w waits until C-b had passed and then turn right after it.

In the second scenario (“2” in Figure 2), C-w goes ahead a little just to reach the road marking. There are several hypotheses for the white’s car driver goes ahead a little. For example, the C-w’s driver thinks to have time to realize the operation (turn right before C-b) but abandon the idea rapidly. Another reason could be that the driver wants to see behind C-b if any other vehicle arrives. The C-b’s driver reduces speed, observes C-w, and, if C-w does not move anymore, decides to maintain his driving plan but being careful. After, C-w turns right, and the second scenario meets the first scenario (see Figure 2).

In the third scenario (“3” in Figure 2), C-w goes ahead until the mark on the pavement and decides to operate before C-b arrives. Conversely, the C-b’s driver had a different interpretation of the situation and anticipated that the other driver would stop at the road mark. However, C-b’s driver takes care of potentiality of the situation and the risk of a critical situation and understands quickly the purpose of C-w’s driver when C-w goes ahead. Thus, the C-b’s driver has time for breaking. As we assume that there is no other vehicle in the situation, C-b’s driver can break easily without risk for other cars behind him. C-b breaks and stops (or at least reduce sufficiently its speed), let C-w finishes to turn, let some safe distance between them and go ahead, after C-w.

The fourth scenario supposes that, on the one hand, C-w goes ahead to pass before C-b like in scenario 3, and, on the other hand, C-b’s driver has yet a different interpretation of the modified situation, thinking that C-w's driver will wait before to move because he has not the priority. Realizing that C-w's driver does not operate as expected, C-b's driver is surprised and has a short time only to react. C-b's driver tries to break, but not enough quickly. To avoid the collision, and because there are no other vehicles in the area, C-b's driver decide to overtake C-w 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. C-b's driver tries to break, but not enough quickly and has no time to change of lane (or can not do it) and a collision of the two cars thus happens.

Figure 3 provides a representation of the different situations and scenarios identified in Figure 2. There is one critical situation (we do not consider the different types of collision and consequences) and three pre-critical situations (in grey and corresponding to scenarios 2, 3, 4), which leads to five scenarios.

In a pre-critical situation, the driver has to identify the problem and make a decision in a very short time. For example, on the pre-critical situation in which C-w's driver attempts to pass before C-b, if C-b driver's attention is correct, this situation would lead to a normal traffic situation, otherwise this situation leads to a critical situation.

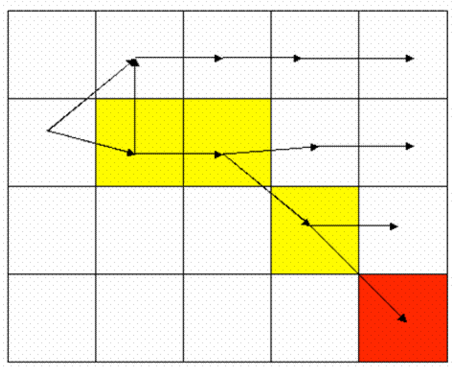

Figure 3: The five scenarios at their different steps (white squares represent normal situations, in grey are pre-critical situations and in dark the critical situation) in the situation space

This type of representation is close from system rules-bases, like the state space in SOAR [Laird et al., 1987]. The SOAR system is proposed as a unified theory of cognition, which is able to account for grist of phenomenon tentative. Its architecture is a problem solver (each cognitive task is seen as a solver problem). SOAR is a production system developed to support an explicit symbolic approach in problem solving. In this approach, known under the name Problem-Space Computational Model), an initial state is transformed in a final state by applying a set of operators associated with this state. The sets of states and of operators exercisable to a problem constitute its space-problem. As in SOAR, the representation in Figure 3 shows that each cell of the table is a state representing one traffic situation.

Figure 4 presents the five scenarios in Figure 3 in the contextual-graphs formalism.

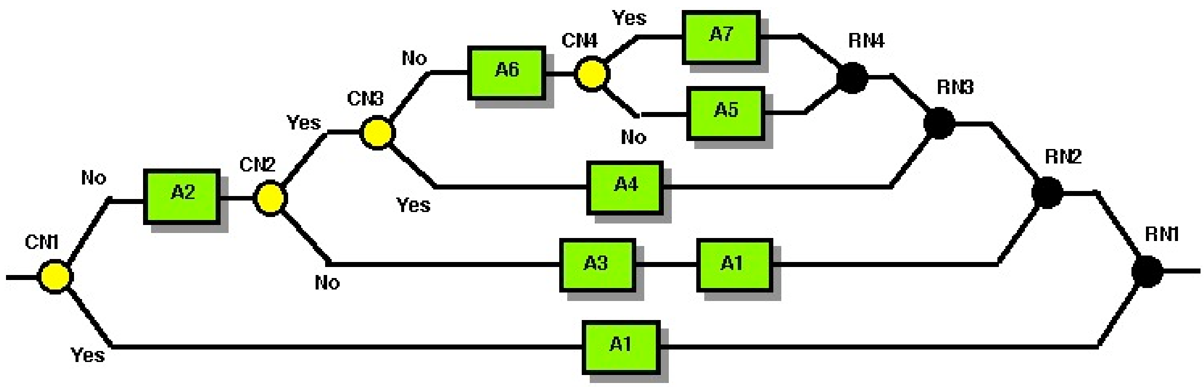

Figure 4: Contextual graph of the traffic situation with the five scenarios in Figures 2 and 3. Elements are defined in Table 1.

Table 1 : Contextual elements and actions while negotiating a crossroad of Figure 4 (CN, RN and A stand for contextual and recombination nodes, and action)

Contextual element	
CN1-RN1	Is the white car stopping?
CN2-RN2	Is the white car going ahead?
CN3-RN3	Can I let the white car going ahead?
CN4-RN4	Can I overtake the white car on the left?

Action	Definition
A1	Keep the same behavior
A2	Interpret the behavior of the other car's driver
A3	Note that the white car's driver stop at the road mark
A4	Brake enough to let it going ahead
A5	Change of lane and overtake
A6	Evaluate the situation
A7	Try to brake strongly

Figure 4 represents in terms of contextual graphs what's happens in Figure 2 in terms of driver's behaviors of C-b instead of situations encountered. Real behaviors observed for drivers will introduce differences between the two representations corresponding to the introduction of new practices in the contextual graph representation (Figure 4). For example, the driver may interpret (action A6 in Figure 4) wrongly the situation after an overestimation the speed of the white car and thus reach it too quickly. Other behaviors may deviate from the initial scenario. Thus, this initial contextual graph may evolve and represent different behaviors for a given scenario, and the same behavior may be encountered in different scenarios.

CONCLUSION

The literature underlines generally that the initial training is not sufficient because the beginner does not know how to contextualize the learned procedures in effective practices. Starting from previous work, we choose a twofold approach, a global approach and a local approach. This allows to consider driver's behavior along the four dimensions, namely policy, strategy, tactics and operation.

Concretely, we describe scenarios in two representation formalisms. The first one is a situation space in which we describe how a situation may evolve, and the different scenarios related. The second one is a context-based formalism for representing drivers' behaviors that can be associated with the different scenarios. The two representations are complementary and will guide us in determining the types of data we need for our global and local approaches. We present our position on the example of a crossroad with two cars and show that five scenarios could be developed, each scenario being associated eventually to several drivers' behaviors due to diverging interpretations of the drivers concerned.

Contextual graphs can be enriched incrementally when more complex scenarios are concerned. For example, scenarios will be built from combination of elementary situations like in Figure 5.

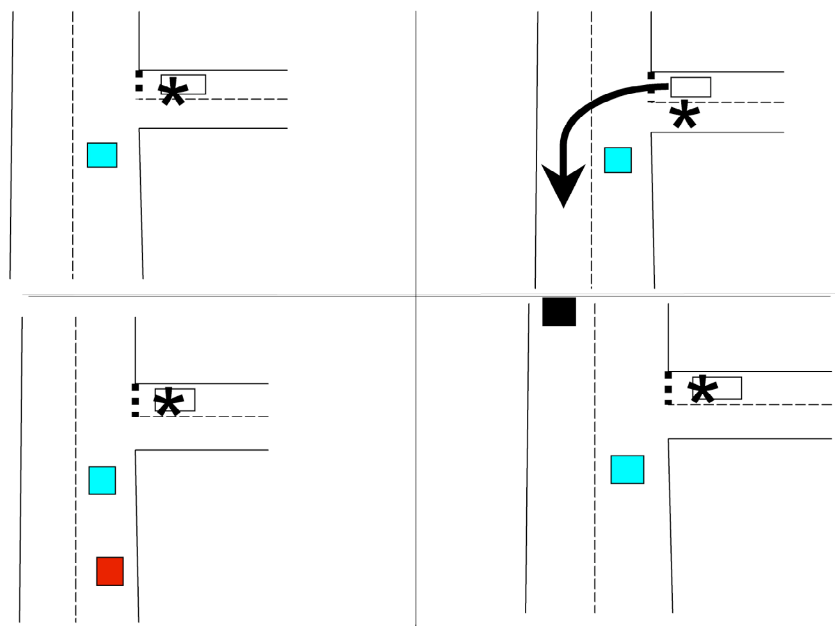

Figure 5: Variants of the initial situation presented in Figure 1

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