DRIVER BEHAVIOUR MODELLING AND COGNITIVE TOOLS DEVELOPMENT IN ORDER TO ASSESS DRIVER SITUATION AWARENESS

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Abstract. The global objective of this work is to define a framework for car driving behaviour analysis according to the current driving context. The aim is to develop models, methods and cognitive engineering tools for "ecological" data (i.e. collected in real driving conditions) processing and analysis, in order to develop psychological models about the driver's "situation awareness". We present a first work consisting in implementing software solutions that enable connecting objective data to psychological theories by using the method of "experience based reasoning" coming from the field of artificial intelligence.

1 INTRODUCTION

This work is located in the intersection of Human Modelling and Artificial Intelligence Techniques applied to cognitive engineering. Its main goal is to define a theoretical and methodological framework to carry out a cognitive analysis of the car driving activity.
This analysis aims to connect the data collected in real driving situation to a description of the driver's mental processes as they are described in cognitive psychology works.
Those collected data relate both to the driver's behaviour and to the environmental context while this cognitive description stands for the driver's situation awareness. We define the driving situation awareness as a mental model built by the driver, either it is explicit or not for him. This mental model contains useful information on the situation and contains also some mechanisms making it possible to anticipate events, guide acts, and make inferences and decisions.

We take as a starting point the works of cognitive modelling and assessment of the situation awareness carried out in the LESCOT/ INRETS, and in addition work of artificial intelligence performed by the LIRIS (Computer science Laboratory in Image and Information systems / CNRS), more particularly the Musette theory (Modelling Uses and Task for Tracing Experience) (Champin & Al., 2004).

This work falls under the effort of the LESCOT to understand better the car driving activity. Within this framework, the possibility of connecting the driver's situation awareness to the driver's behaviours could have multiple uses such as to get a better understanding of the accidents or to identify needs or possibilities of assistance. We present here the first work which aims to show the feasibility of this research and its interest. This work led to a representation of the driving activity in the form of traces which includes information relating to the driver's actions, information on the vehicle and also information about the road environment. It shows how these traces can be handled by an analyst, might he be a cognitive psychologist or an ergonomist, with an aim of testing adequacy between cognitive models and driving situations.

2 THEORETICAL FRAMEWORK

2.1. EXPERIENCE BASED REASONING

2.1.1. PRINCIPLE

The theory of Experience Based Reasoning (EBR) is a theory coming from the field of Artificial Intelligence that allows modelling the mechanisms of acquisition of experience related to the realization of a task. It is placed under the paradigm of situated cognition (Clancey, 1993). Within this paradigm, cognition is seen as the index property of systems able to perceive, act, memorize and work towards a goal in an environment. Knowledge is not only seen as a set of concepts and rules but also includes the context of use, goals and evaluation of its utility according to the goal. EBR constitutes a computer solution to build situated cognitive agents. Its principle consists in solving problems arising from a new interval of time by using solutions used in similar situations met in previous intervals of time. The problem, once solved, comes to enrich the experience base of the system. This principle constitutes an extension of the Case Based Reasoning (CBR) (Aamodt and Plaza, 1994) for the cases of systems functioning in a continuous way and generating an uninterrupted data flow during the activity. We refer to this data flow by the term trace.

The EBR system thus builds a data base which is exploited on the basis of similarity measure applied to episodes (Sorlin et al., 2003). In this direction it constitutes a modelling of the experience, this is why we name it an experience base. In the various uses of this theory, the system can either (a) be used to carry out the solutions by itself (i.e., artificial cognitive systems), or (b) to assist a human agent (i.e., user assistance system), or (c) to model a human agent (i.e., cognitive modelling). In the (b) case there is interaction between the EBR system and the user. In the (c) case there is interaction between the EBR system and a third agent (analyst). We place ourselves in the (c) case. This interaction between the system and the analyst requires a common language which, in the Musette theory, is brought by the concept of Explained Task Signature (Extasi). As task signatures, Extasis provide a means of finding useful episodes in the experience base, in this way they make sense to the EBR system; because they are explained they also make sense to the analyst.

2.1.2. TRACE ENCODING

The Musette theory provides us with a means of encoding the trace in the experiment base. It defines a first level of trace called rough trace made up of a succession of observables, called objects of interest (OI). Then, it defines a second level of trace called primitive trace which consists of a succession of states and transitions embedding the OIs. OIs are of three kinds: "entities" (static facts) allowing description of states, "events" allowing description of transitions, and "relations" from entities or events to each other.

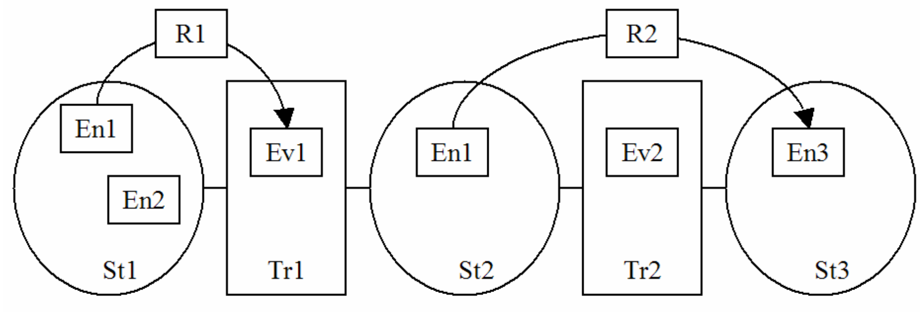


Figure 1. Primitive trace encoding

In Figure 1, states are represented by circles, transitions by rectangles, entities are labelled “En”, events are labelled “Ev” and relations are labelled “R”. The cutting into states and transitions is useful to make it possible to isolate episodes which consist of passing from one state to another through a succession of intermediate states.

2.2. MODELLING THE SITUATION AWARENESS

2.2.1. DEFINITION

The concept of Situation Awareness (SA) comes from aeronautic studies. One of its most common definitions is given by (Endsley, 1995): *The perception of the elements on the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future*.
We can say that SA is an operational representation according to the definition given to this term by (Bisseret, 1970). This definition takes the term representation in its broad sense to include at the same time descriptive and operational knowledge. Therefore, the SA can be seen as a mental model of the situation, a tool mentally built to allow simulation of the situation and realization of the implicit or explicit choices that lead to the acts. Bisseret defines the operational memory as a place of construction of the operational representation. In that sense, describing SA means describing declaratory knowledge and dynamic procedural knowledge currently activated in operational memory.

2.2.2. MODELLING

More specifically, we describe the Situation Awareness according to the car driver model developed in LESCOT (Bellet et al., 1999). This formalism is inspired by both the Frame theory (Minsky, 1975) and the Scripts theory (Schank & Abelson, 1977). It is to code the operational representation handled by the driver in the form of data structures called driving frames. Our work concerns frames of the tactical level located between the operational level (realization of the action) and the strategic level (planning of the route). The tactical frame is related to a category of road environment, it contains a local goal, a sequence of zones of displacement, a set of perceptive zones of exploration, a sequence of actions to be realized according to conditions, a set of potential events. It is related to processes of categorization, place recognition, anticipation, and decision. This modelling is the subject of a computer simulation according to UML formalism (Bellet et Al., 2003).

3 ISSUES

Most techniques used by cognitive psychologists to assess the situation awareness seek, through various experimental protocols, to allow the driver to clarify the elements he has in mind at a given moment. The protocols developed by (Bailly et al., 2003) consist of interrupting a driving situation performed under simulation, the driver then has to answer questions asked by the psychologist, or by the computer program.

Complementary to these researches, we endeavour to investigate a description of the SA embedded to an objective uninterrupted description of the driving process.

We want to superpose in only one representation of the driving activity, objective information which we can collect during the activity and further information coming from afterward explanations given by the driver or coming from cognitive psychology knowledge and assumptions. This superposition will allow the analysts to refine their models, both in their descriptive dimension and in their dynamic and active dimension. Therefore, rules of correspondence between observables and psychological explanations could be highlighted thanks to EBR methods: possibility of positioning markers in the trace, possibility of identifying states and transitions which will be able to describe supposed mental states, possibility to evaluate similarities between patterns in the trace. To do that, we initially produced a graphical chart of the driving activity. We automated, as much as possible, the systematic processing in order to obtain a sufficiently sizeable database allowing meaningful patterns to appear. Finally we worked towards producing a convivial trace handling software that could allow us to test assumptions on the explanatory bonds between the various elements of the trace. Our first work was to produce this software from simple development tools in order to validate a first version. These development tools were Matlab, Visual Basic and Excel.

4 ACHIEVEMENTS

4.1. GENERATION OF THE ROUGH TRACE

We used data collected from real driving situations thanks to the experimental vehicle of LESCOT. They come from three sources: values collected by sensors on the vehicle: speed, steering wheel angle, pedals insertion, visual strategies collected by a camera filming the driver, and information on the road environment coming from cartography or from a camera filming the road ahead. The following objects of interest were obtained:

Speed profile:

Speed minimums and maximums, acceleration minimums and maximums, deceleration minimums and maximums. They were obtained by detecting the zeros of the first and second derivatives of the speed curve.

Actions on the pedals:

Beginning and end of actions upon the pedals were generated by threshold detection. An OI of the “relation” type was created between every beginning of action and its corresponding end, this relation was to hold action-level data: duration of the action, distance covered, maximum pedal insertion.

Visual strategies:

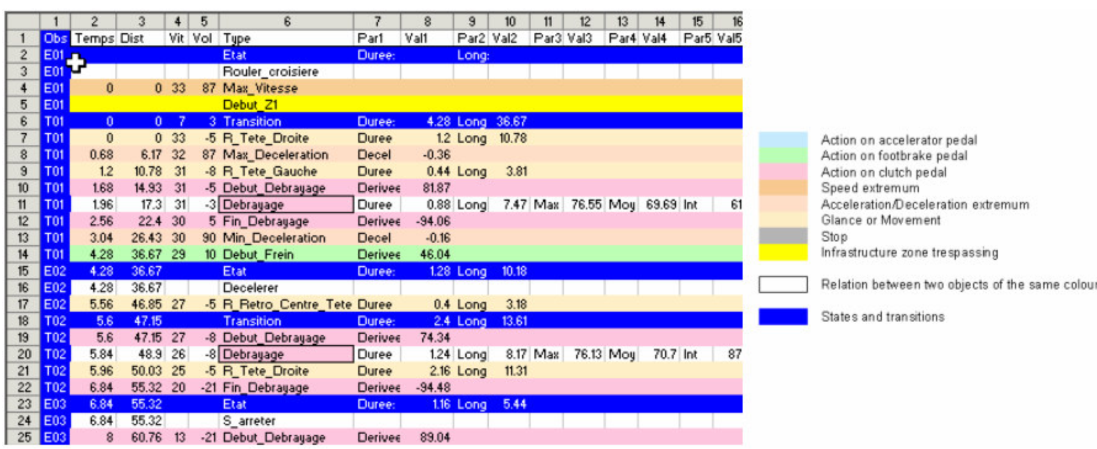
As we had no automatic sensor to record visual strategies, they were extracted by an ergonomic from the video tape recording. Labels of OIs were: Left eye, Right eye, Left head, Right head, Left body, Right body, Left wing mirror, Right wing mirror, Central rear view mirror, dashboard, and some specific glances depending on the situation, for example towards road signs.

Road infrastructure crossings:
The distance covered by the vehicle was calculated by integration of its speed. Road reference marks such as stop trespassing were positioned in the trace according to this distance. Visual reference marks recorded by the front camera were used for a more precise positioning.

The programs of generation of the rough trace were made under Matlab. The trace was visualized under Excel. Some Visual Basic Application for Excel (VBA/E) programs were written to format the trace according to colour codes relating to the various types of objects. The trace could be exported to the RDF format which is an XML standard for knowledge representation. RDF Format can be exploited with standard software query tools.

4.1.1. CONSTRUCTION OF THE PRIMITIVE TRACE

As said, the primitive trace constitutes a structuring of the rough trace for a particular use, in our case: assessment of driver's situation awareness. Accordingly, we sought to define states which corresponded to a stable instantiation of the driver's situation awareness, and transitions which marked the significant changes in this situation awareness. Moreover, some explanatory objects of interest could be inserted in the trace as entities (factual description of the situation awareness) or events (description of the factors of change of the situation awareness). This structuring of the trace must be understood as an assumption suggested by the analyst seeking to validate his coherence. To allow these tests we developed VBA/E routines which make it possible to insert states and transitions inside the rough trace in an interactive way. They make it possible to insert explanatory markers by selecting them in a drop-down list showing the objects defined in the domain ontology.



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Obs	Temps	Dist	Vit	Vol	Type	Par1	Val1	Par2	Val2	Par3	Val3	Par4	Val4	Par5	Val5
2	E01					Etat	Duree:		Long:							
3	E01					Rouler_croisiere										
4	E01	0	0	33	87	Max_Vitesse										
5	E01					Debut_Z1										
6	T01	0	0	7	3	Transition	Duree:	4.28	Long	36.67						
7	T01	0	0	33	-5	R_Tete_Droite	Duree	1.2	Long	10.78						
8	T01	0.68	6.17	32	87	Max_Deceleration	Decel	-0.36								
9	T01	1.2	10.78	31	-8	R_Tete_Gauche	Duree	0.44	Long	3.81						
10	T01	1.68	14.93	31	-5	Debut_Debrayage	Derivee	81.87								
11	T01	1.96	17.3	31	-3	Debrayage	Duree	0.88	Long	7.47	Max	76.55	Moy	69.69	Int	61
12	T01	2.56	22.4	30	5	Fin_Debrayage	Derivee	-94.06								
13	T01	3.04	26.43	30	90	Min_Deceleration	Decel	-0.16								
14	T01	4.28	36.67	29	10	Debut_Frein	Derivee	46.04								
15	E02	4.28	36.67			Etat	Duree:	1.28	Long	10.18						
16	E02	4.28	36.67			Decelerer										
17	E02	5.56	46.85	27	-5	R_Retro_Centre_Tete	Duree	0.4	Long	3.18						
18	T02	5.6	47.15			Transition	Duree:	2.4	Long	13.61						
19	T02	5.6	47.15	27	-8	Debut_Debrayage	Derivee	74.34								
20	T02	5.84	48.9	26	-8	Debrayage	Duree	1.24	Long	8.17	Max	76.13	Moy	70.7	Int	87
21	T02	5.96	50.03	25	-5	R_Tete_Droite	Duree	2.16	Long	11.31						
22	T02	6.84	55.32	20	-21	Fin_Debrayage	Derivee	-94.48								
23	E03	6.84	55.32			Etat	Duree:	1.16	Long	5.44						
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Figure 2. A primitive trace visualised under Excel

5 RESULTS

5.1. ROUGH TRACES

An important set of rough traces were generated from data collected on the occasion of the DECOLOVE experimentation. This experimentation was to observe the adaptive strategies carried out by the older generation to compensate proprioceptive deficiencies. It was started in 2001 and led to collect driving data of thirty two subjects on a real course of approximately 5 km. The course

was performed in a protected site (campus of the University of Luminy, Marseilles), thus it allows comparisons between subjects. The examination of this experimentation is still in hand in LESCOT.
We generated a set of traces including the vehicle data of all the subjects and all the courses, that is to say a total of approximately 160 km traversed. We also generated a set of traces including the visual strategies collected on certain sequences of the course representing a total of approximately 30 km made up of significant moments (intersection crossing, going beyond, conflict with another vehicle). These traces had a utility by themselves because they helped with the interpretation of this experimentation. Some observations could be made such as the fact that older generation changed down the gears less to stop at an intersection compared to the younger generation, or than speed profiles of the older generation were less regular compared to those of younger generation: they had more extremum of acceleration and deceleration.

5.2. IMPACT ON THE DRIVING FRAMES

The creation of the primitive traces led us to widen the tactical frame to a finer granularity level. We called this level the operational subschema level.

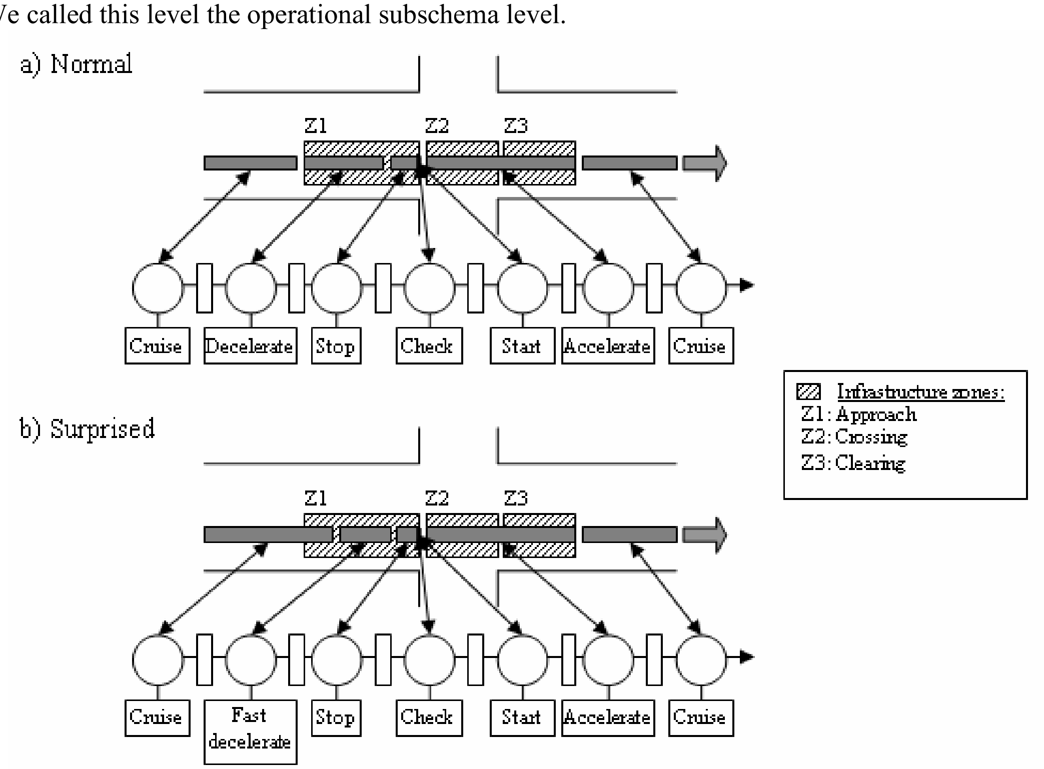

Figure 3. Normal vs Surprised Operational Subschema

This representation allows us to describe tiny differences between situations. Figure 3 shows how we can represent a "surprised driver" subschema that is characterized by an initial "Cruise" state which encroaches on the approach zone (Z1) of the infrastructure, followed by a "strongly decelerate" state characterized by a value of deceleration higher than in the normal subschema. From future developments we want to implement search functionalities which enable us to find patterns in the primitive trace likely to match with this kind of cognitive model, according to criteria specified.

6 CONCLUSION

We brought a new mode of representation of the driving activity: rough traces and primitive traces. This mode of representation makes it possible to show next to each other, on one hand, the objectively observable facts of the situation such as the driver's actions or the events occurring in the environment, and on the other hand the interpretations made on the driver's mental model of the situation. We brought with these traces a support of analysis and expertise of the activity, usable by the ergonomists and the experts in cognitive modelling. The analysis is facilitated by a visual display and possibilities of interactive handling. We showed how these traces allowed an investigation of the driver's mental states and cognitive processes. Therefore they constitute an element of confirmation or invalidation of the cognitive theories. We also showed that these traces made it possible to emphasize some particularities that are specific to some individual or to some situation. Beyond this tool for analysis, we brought a formalism of recording the driving activity in a knowledge base. This knowledge base constitutes an implicit experience capitalization, this is to say it does not contain rules or concepts explaining car driving, but it contains knowledge likely to be exploited in situation by methods of EBR.

We now want to continue this work with an aim of completely exploiting the possibilities offered by EBR. Our first results led us to imagine various levels of primitive trace: a level made up of small states and transitions not necessarily significant but which could be generated automatically and which could constitute the entrance point usable by the analysts. A great deal of work remains to be done to produce a robust software tool which can be used by non computer specialists. Moreover it remains to implement the mechanisms making it possible to create and to exploit explained task signatures; it is an important thing to make in order to fully exploit the contributions of the Experience Based Reasoning.

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