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

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ABSTRACT

Our global objective is to define a framework for car driving behaviour analysis in order to assess driver's situation awareness. We present models, methods and software tools inspired from the "Experience Based Reasoning" theory coming from the field of artificial intelligence. It allows a construction of a representation of the driving activity including data collected in real driving situations as well as interpretations made on the driver's mental model of the situation, and permits a refinement of psychological theories.

INTRODUCTION

This work involves both psychological theories of Human Modelling and Artificial Intelligence techniques. Its main goal is to define a theoretical and methodological framework to carry out a cognitive analysis of the car driving process. This analysis consists of connecting the data collected in a real driving situation to a description of the driver's mental processings coming from cognitive psychology studies. 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 studies 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. It shows how these traces can be handled by an analyst, whether he is a cognitive psychologist or an ergonomist, with an aim of testing adequacy between cognitive models and driving situations.

THEORETICAL FRAMEWORK

Experience based reasoning

Principle

Experience Based Reasoning (EBR) is a theory coming from the field of Artificial Intelligence. It enables a modelling of the mechanisms of experience acquisition 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. It is an extension of Case Based Reasoning (CBR) (Aamodt and Plaza, 1994) for the case 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 builds a data base which stores a description of how an agent achieved certain tasks in any situation he went through. Then it builds a solution to achieve the current task in the current situation by referring to the former occurrences of this task. The new occurrence, once achieved, comes to enrich the data base. In this way it constitutes a modelling of the experience of the agent, this is why we name this data base 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). An Extasi contains a graph of objects which constitutes a representative pattern of the execution of a task. It refers to a similarity measure making it possible to find instances of this graph in the trace (Sorlin and Al, 2003). It thus constitutes a means of recognizing episodes during which the task was carried out. Finally it contains an explanation of the task. This explanation may be a free text annotation that a human could interpret, or be a formal knowledge annotation aimed at an automated agent interpretation. Extasis thus make sense to the EBR system as well as to the analyst. As such, they can be seen as common pieces of language which can be refined during the interaction between the analyst and the system.

Trace encoding

The Musette theory provides us with a means of encoding the trace in the experience 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 a description of transitions, and "relations" bounding entities or events to each other.

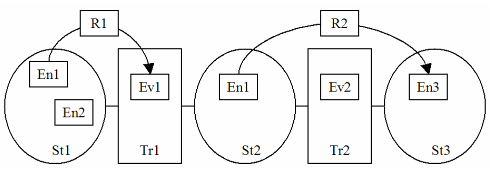


Figure 1. Primitive trace encoding

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.

Modelling the situation awareness

Definition

The concept of Situation Awareness (SA) comes from aeronautical 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 signifies describing declaratory knowledge and dynamic procedural knowledge currently activated in operational memory.

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 applies to frames of the tactical level concerning things such as lane choice, steps to complete for overtaking, tactics for intersection crossing etc. This level is located between the operational level (action realization) and the strategic level (route planning). 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 (Unified Modeling Language) formalism (Bellet et Al., 2003).

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. For example, 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 research studies, we endeavour to investigate a description of the SA embedded into an objective uninterrupted description of the driving activity. To do that we are attempting to develop a software tool able to display the trace of driving activity in a graphical way. This software allows a construction of a chart on a computer screen in an interactive manner with the goal of refining psychological models, both in their descriptive dimension and in their dynamic and active dimension. Our chart thus mixes some objective information computed from data recorded during driving activity with some further information coming from subsequent explanations given by the driver or coming from cognitive psychology assumptions. One of the steps of this analysing process is to cut the trace into meaningful states and transitions which can describe supposed mental states. Therefore, rules of correspondence between patterns of observables and psychological explanations could be highlighted with Extasis.

ACHIEVEMENTS

Generation of the rough trace

We used simple software development tools in order to validate a first version capable of generating a sufficiently sizeable database allowing meaningful patterns to appear.

Our data was collected with the experimental vehicle of LESCOT from the DECOLOVE experiment. This experiment observed the adaptive strategies carried out by the older generation to compensate proprioceptive deficiencies. It was started in 2001 and led to a collection of driving data from 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) in order to prevent variations of context between subjects, and thus allowing comparisons. The examination of this experimentation is still in hand in LESCOT.

Data came 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 computed 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 analyst 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:

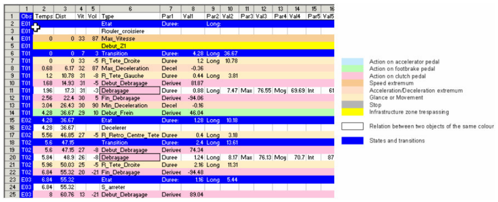
The distance covered by the vehicle was calculated by integration of its speed. Road reference marks such as stop passing were positioned in the trace according to this distance. Visual reference marks recorded by the front camera were used for a more precise positioning.

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 XML files in the RDF format which is a standard for knowledge representation. RDF Format can be exploited with standard software query tools.

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. Figure 2 shows states and transitions (in dark blue) and explanatory objects of interest (in white) manually inserted along a trace made up of different kinds of automatically computed observables.

This interaction is facilitated by VBA/E routines which automatically calculate values tied to states and transitions (duration, covered distance) and let the analyst select explanatory markers from a drop-down list showing pre-defined labels.



	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						
24	E03	6.84	55.32			S_arreter										
25	E03	8	60.76	13	-21	Debut_Debrayage	Derivee	89.04								

🟦 Action on accelerator pedal
🟩 Action on footbrake pedal
🟥 Action on clutch pedal
🟧 Speed extremum
▨ Acceleration/Deceleration extremum
▨ Glance or Movement
▩ Stop
🟨 Infrastructure zone trespassing

☐ Relation between two objects of the same colour

🟦 States and transitions

Figure 2. A primitive trace displayed under Excel

CURRENT REACHED LEVEL

Rough trace

We generated a set of rough traces including 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 rough 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.

For example, an intersection crossing is described by about fifty observables which can be printed on only one A4 page. Once the colour codes have been learned, these printouts become very readable and permit us to quickly identify differences between various cases. Some interesting observations could be done such as the fact that the older generation changed down the gears less to stop at an intersection compared to the younger generation, or that speed profiles of the older generation were less regular compared to those of the younger generation: they had more extremums of acceleration and deceleration. These observations could easily be confirmed by a counting of the objects of interest.

Impact on the driving tactical frames

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

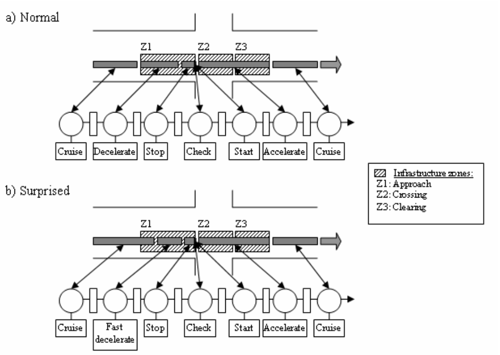


Figure 3. Normal vs Surprised Operational Subschema

This representation allowed 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 upon the approach zone (Z1) of the infrastructure, followed by a "Fast decelerate" state characterized by a value of deceleration higher than in the normal subschema.

CONCLUSION

While most studies on situation awareness focus upon a snapshot of the situation, our work concerns the whole driving process analysis. This is how we seek to describe the mechanisms of inference carried out by the driver, and the procedural side of situation awareness. Our approach is based on the work of an analyst (who could be the driver himself) assisted by software able to display a certain abstraction of a recorded driving sequence. This abstraction leads to a representation of the driver's behaviour and of its supposed underlying cognitive processes that can be built in an interactive and iterative manner. In a more general prospect, this work should lead to a better understanding of how representations can emerge from sequences of actions, whether it is for an external analyst or for the subject himself.

We now want to continue in this direction by fully exploiting 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 analyst. A great deal of work remains to be done to make the trace display more graphical and to produce a robust software tool which can be used by non computer specialists. Moreover, mechanisms making it possible to create and exploit explained task signatures remain to be implemented. Therefore, connections between experience stored in memory, and current pieces of information, and driver's actions could be investigated.

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