Augmented Reality Interface Design for Autonomous Driving

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1 RESEARCH PROBLEM

During the last decades, the driving paradigm has been changed due to the introduction of the automation. Indeed, from a configuration where the driver was the sole responsible of the driving, we move to a bilateral configuration where the human agent and the technical agent share the driving task. This bilateral configuration can be observed in vehicles called autonomous ones. Considering the number of tasks delegated to the technical agent, there are several levels of automation (NHTSA, 2013). The "full automation" level means that the technical agent is the sole responsible of the driving. It will be observable in the horizon 2030. Many vehicles manufacturers and laboratories work currently on the intermediate levels of automation.

The LRA (French Acronym for Localization and Augmented Reality) project is a collaborative French project where 10 academics and industrials work together to deliverer an Augmented Reality (AR) Human Machine Interface (HMI) of an autonomous vehicle of level 3, in the National Highway Traffic and Safety Administration (NHTSA) taxonomy. This level supposes that the vehicle is able to drive alone in some particular conditions. During this period where the technical agent is in charge of the driving (also called *free* time), the human agent can do some secondary or tertiary tasks such as reading, writing, etc. The human agent is, in these periods, disconnected from the road environment and the primary task of driving. He is *out-of-the-loop*, and it is necessary to take into account two main situations. In the first one, at particular moments, he may want to verify how the technical agent works in order to know what the technical is doing and if its behavior is accurate. In the second one, at a precise time, handover will be required by the system. Consequently, the human agent has to be reengaged physically and cognitively in the driving task. He has to build a mental representation of what is going on around him in the road environment and what the technical agent is doing, in order to have a whole situation understanding of the situation. This task-specific understanding of the situation refers to *situation awareness* (Endsley, 1985). Through interface design, situation awareness has to be enhanced. In order to achieve this goal, we decided to use in information shaping, Augmented Reality, an innovative technology.

AR typically describes interfaces that overlay images of virtual objects on images of the real world. We can talk also about Augmented Reality for haptic, auditory or vestibular cues. In this research, we have decided to focus on visual cues.

There are many definitions of Augmented Reality but we have decided to choose Azuma (1997) one. He defined Augmented Reality as *any interface that has these three characteristics:*

1. combines the real and the virtual.
2. is interactive in real time.
3. is registered in 3d.

Consequently, considering the interface design in autonomous mode, we have identified three fundamental questions to design the interface:

a. In autonomous mode and in handover processing, which sufficient representation should the drivers maintain or establish? According to the Situation Awareness model defined by Endsley (1995), this question may be subdivided into three sub-questions:

(i) What should the drivers perceive?
(ii) What should they understand?
(iii) Which projection of the external environment and the system should they perform?

b. How should we design the displays?

(ii) What should be displayed?
(iii) How should that information be displayed?
(iv) When should it be displayed?
(v) With which prioritization?

c. What is the added value of Augmented Reality in the displays?

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2 OUTLINE OF OBJECTIVES

The general objective is the design of rules for Human-Machine Interface. Through the development of a specific methodology correlated to an innovative technology, Augmented Reality, we will design an adaptive interface which will ensure a safe and a comfortable driving in an automated vehicle of level 3.

In order to meet the challenges outlined above, the LRA project integrates multidisciplinary expertise from French research institutions and vehicle industrials. The involvement of the industrials creates the potentiality of a vulgarisation of the finished work. We have defined two main goals:

1) *Application of a cognitive method to derive information requirements for the driver and hierarchize them through strong rules.*
2) *Conveyance all these information in an appropriate shape by considering displays capabilities.*

To achieve these goals, we have realized a literature review at the beginning.

3 STATE OF THE ART

This chapter contains the main theoretical concepts that underlie our research work: driving task, automation, situation awareness, transparency, and Augmented Reality.

3.1 Driving Task

Michon (1985) has defined a hierarchical control structure of the driving task. This structure divided the driving task into three levels of control: strategic level, tactical level and operational level. See Figure 1. Each level has its importance in the driving task.

In the strategic level, we deal with the route that the ego vehicle intends to follow. The route is planned and the general objectives are fixed. In the tactical level, we talk about the maneuvers: passing a vehicle, entering highway, exiting highway, lane changing, overtaking. This level concerns all the maneuvers which allow to achieve short-terms maneuvers. In the last level, the longitudinal and the lateral controls are concerned.

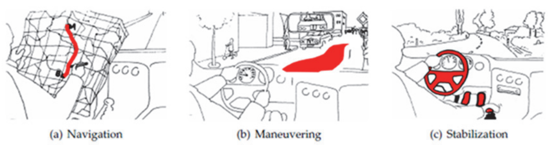

Figure 1: Three levels of control in driving.

3.2 Automation

When the driver is responsible of the driving task, he has to lead his vehicle in each of the aforementioned levels of control. More often, we observe a delegation of one or more of functions realized by the human to one or several technical agents. Considering the number of functions delegated to the technical agent, we have many levels of automation (Sheridan, 1978). There are many taxonomies that try to classify those levels.

The most famous are: National Highway Traffic and Safety Administration (NHTSA, 2013) taxonomy, Society of Automotive Engineers (SAE) taxonomy, Sheridan and Verplanck (1978) taxonomy, Endsley and Kaber (1999) taxonomy, Gasser and Westhoff (2012) taxonomy and Riley (1989) taxonomy. As a LRA project constraint, NHTSA taxonomy was chosen but it has the disadvantage to not clearly define the functions attributed to each agent. As mentioned above, we work on an automated vehicle of level 3. As NHTSA specify, *vehicles at this level of automation enable the driver to cede full control of all safety-critical functions under certain traffic or environmental conditions and in those conditions to rely heavily on the vehicle to monitor for changes in those conditions requiring transition back to driver control. The driver is expected to be available for occasional control, but with sufficiently comfortable transition time. The vehicle is designed to ensure safe operation during the automated driving mode. An example would be an automated or self-driving car that can determine when the system is no longer able to support automation, such as from an oncoming construction area, and then signals to the driver to reengage in the driving task, providing the driver with an appropriate amount of transition time to safely regain manual control* (Marinik Bishop, Fitchett, Morgan, J. F., Trimble & Blanco, 2014).

This kind of interaction and others ones introduce Situation Awareness concept.

3.3 Situation Awareness

Situation Awareness is a term derived initially from the aviation domain. In this domain, it plays a crucial role in the design of military interface. There are numerous definitions of Situation Awareness but the most used and the widely accepted is the one from

Endsley (1995) defining it as *the perception of 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.*

The important information has to be conveyed to the driver appropriately and accurately. We assume that not all the information has to be conveyed to the driver. This introduces the *transparency* term.

3.4 Transparency

The concept of transparency can be seen in two points of view. Transparency in a form aspect, refers to the level of opacity of one particular component. There is also an aspect that deals with the quantity of information. Considering human-automation, transparency cannot, practically speaking, means that *the human knows everything about what the automation is doing* (Miller, 2014).This definition is a naïve one. Chen et al. suggested another definition for automation transparency: ... *the descriptive quality of an interface pertaining to its abilities to afford an operator's comprehension about an intelligent agent's intent, performance, future plans and reasoning process*.

Transparency could take advantage of innovative technology, such as Augmented Reality.

3.5 Augmented Reality

Many modern cars (e.g. Audi Q7, BMW M3 Berline) are equipped with Head-Up Display (HUD) technology. This technology enables Augmented Reality (AR) implementation (Tonnis, Sandor, Lange, & Bubb, 2005). Usually, AR is defined as a continuum from real to Virtual Reality (Milgram, 1994). Generally, AR in cars deals with "the problem of directing a user's attention to a point of interest (Tonnis et al., 2005). AR can "alert drivers and guide their attention to dangerous situations" (Tonnis et al., 2005). We thus assume that AR can enhance global awareness and local guidance by conveying the right information at the right moment.

4 METHODOLOGY

The figure 2 presents, step by step, the general approach employed for the design and development work we conduct. This work involves the specification and design of the interface.

4.1 First Step of the Methodology: Cognitive Work Analysis

This step involves modeling tasks and extracting information requirements for drivers. We decided to use a method that considers both technical and human aspects together: Cognitive Work Analysis (CWA) (Rasmussen, 1990). It is an integrated framework that defines the work demands of complex sociotechnical systems in terms of the constraints on actors (Rasmussen, 1986; Rasmussen, Pejtersen, & Goodstein, 1994; Vicente, 1999; Naikar, 2013). CWA is an Ecological Interface Design (EID) -based approach. In EID approach, the constraints of the system are enhanced in order to allow drivers to take effective actions and to know the impact on their actions in their goals achievement (Burns and Hajdukiewicz, 2004 cited by Salmon, Regan, Lenné, Stanton and Young, 2006).

CWA also provides information regarding the different possibilities for actions inside the system.

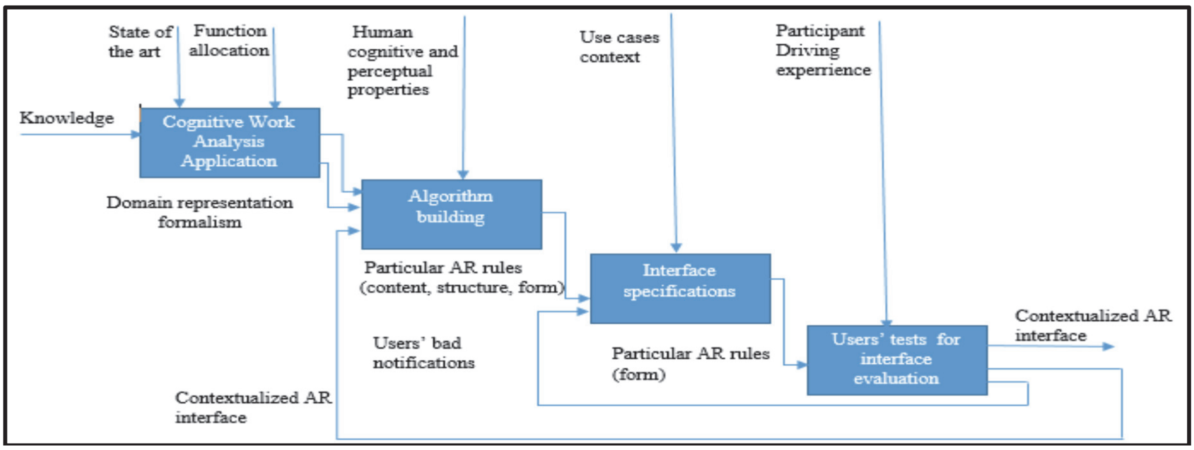

Figure 2: HMI design methodology.

This method consists of several phases of analysis: work domain analysis, task analysis, strategies analysis, organizational analysis, and skills analysis.

4.1.1 Work Domain Analysis (WDA)

It is the first phase of Cognitive Work Analysis. It focuses on analyzing the boundary conditions or constraints of a work system. Through an Abstraction Hierarchy or an Abstraction Decomposition System, the structural functions of the system are determined.

4.1.2 Control Task Analysis (ConTA)

The control task analysis *identifies the activity that is required in a work domain* (Naikar, 2013). After the definition of the constraints associated with the environment, this dimension of the CWA focuses on determining the constraints associated with *what needs to be done in the system* (Naikar, 2013). In this phase, two tools are usually used: the contextual activity template for work situations and functions modeling, and decision ladder template for control tasks modeling (Naikar, 2013).

4.1.3 Strategies Analysis (StrA)

This phase identifies *how the activity can be carried out* (Naikar, 2013). Strategies analysis deals with the constraints associated with all the possible ways to realize an activity. In fact, it is possible to have many strategies for a single activity. To represent graphically a strategy, an information flow map can be used.

4.1.4 Social Organization and Cooperation Analysis (SOCA)

This phase identifies *who can do the work and how it can be shared.* (Naikar, 2013). That means, social organization and cooperation analysis is concerned with *the constraints that the allocation, distribution, and coordination of work impose on actors* (Naikar, 2013). Work can be organized in many ways in a particular system.

4.1.5 Worker Competencies Analysis (WCA)

This phase identifies *the perceptual and cognitive capabilities of workers that are required for performing the work described in the previous phases* (Naikar, 2013).

Remark. To determine the information requirements of the driver, we need a task knowledge and the driver behaviour model towards it. That it is the reason why we focused on the first two phases of CWA. These information will help us to precisely define which data to communicate in autonomous moments of driving. Then, we assume that the rules based on these information, will help the driver to better understand the road situation, the Human-Machine Interface and the automated system. The rules that will be created, will be derived in a specific algorithm.

4.2 Second Step of the Methodology: Algorithm Building

In the second step, we suggest defining general rules to deal with the complexity and dynamics of the driving system. CWA is quite theoretical, although a method is proposed to translate the results obtained in terms of interface specifications (Burns & Hajdukiewicz, 2013). This is why we suggest building a strong structure of prioritized rules of information. Parasuraman (2000) identified four classes of functions that can be automated at different levels: information acquisition, information analysis, decision and action selection, and action implementation. Those levels, combined with the extracted CWA information, will allow us to build a matrix of salient information regarding driving management and the interaction between driver and automated system. This matrix will lead to a set of prioritized AR rules for each detailed use case, which will provide the drivers with means to deal with unanticipated and unforeseen events. These rules will help to cope with the information capabilities of the displays. Consequently, information presentation will be optimized and unnecessary information will be minimized.

4.3 Third Step of the Methodology: Interface Specification

The third step consists in specifying the interface practically according to the two use cases we have selected. We will define clusters of information and their modality on the interface. There, we will provide a description of how the information is required to the driver, when the vehicle is driving in autonomous mode. By giving some parameters, these information will be described. Miller (1999) has identified five parameters: scope, resolution, bandwidth, importance and control.

4.4 Fourth Step of the Methodology: Users' Tests

In the final step, we will evaluate the interface design through user testing on a simulator. All the data and specifications have to be tested. Indeed, a design can be conceptually good but practically not suitable. For that reason, we have planned three major tests to improve the whole design:

a) In the first test, we will test the interface in a full virtual windshield HUD, a pseudo HUD and other devices.

b) In the second test, the virtual HUD will have dimensions larger than the ones of a conventional HUD.

c) In the third test, the virtual HUD has the dimensions of a conventional HUD Virtual HUD is created for AR information HUD is for classic information like speed.

5 EXPECTED OUTCOME

At the end of our work, we expect an interface that adapts itself with the current situation of driving. We assume that this interface will enhance driver's understanding of the interface and the road environment. This interface will be driven by strong rules that will permit to capture pertinent information in the appropriate shape. We assume that this interface will be suitable for lane change in autonomous mode, for transition from autonomous to manual mode, and for night cruising in manual mode.

6 STAGE OF THE RESEARCH

For now, we have already realized the necessary phases of CWA in the situation of lane change, one of our use case apart from manual driving in night and transition from autonomous mode to manual mode.

6.1 Work Domain Analysis Application to Lane Change

There is a sparse literature on Work Domain Analysis on Road Driving. Some authors have realized this analysis. Stoner, Wiese and Lee (2003) have applied the Abstraction Hierarchy analysis to the driving domain. They identified information requirements for drivers. Salmon, Regan, Lenné, Stanton and Young (2006) have realized Work Domain Analysis of the road transport system in Victoria, Australia. These particular works present a general application to the whole domain of the driving, including the total system, the subsystems and the components.

There are several steps in WDA methodology.

Step 1: WDA purposes
There we consider the problem definition and the approach to address the problem. For this thesis, the purpose of WDA is related to the information requirements of driver whilst driving in an autonomous vehicle of level 3. Particularly, we pay attention to lane changing in autonomous mode, "night driving" in manual mode and transition from autonomous to manual mode.

Step 2: Project constraints identification
LRA project has many constraints that do not allow to go deeply into detail. These constraints include: the time constraint, the expertise-related constraints.
In fact, there are few experts on the project who do not have enough time to invest in this analysis. These constraints "forced" us to focus on the subsystem (driver-vehicle-road system) rather than to consider the whole system (road transportation) and each component.

Step 3: WDA boundaries
If boundaries are not clearly determined, WDA can become very large, complex and not understandable. That is why we consider highways and motorways as roads where the vehicle can drive. This choice helps to not consider potential obstacles like pedestrians.

Step 4: Constraints nature identification
Naikar and al. (2005) have identified 5 categories of work systems within a causal-intentional continuum where the focus system falls. In our work, our focus system can be from the first category "Automated systems governed by laws of nature" in autonomous mode, or between the third category "Systems governed by actors' intentions" and the fourth category "Systems governed by actors' personal objectives" in manual mode. This classification let us conclude to focus on causal constraints (Salmon et al., 2006).

Step 5: Information sources identification
To realize WDA, we mainly use documents sources of information: articles dealing with autonomous vehicles, articles dealing withlane changing, handover process and so on. Brainstorming with some experts and legislation documentation were also identified as sources of information.

Step 6: Abstraction Decomposition first construction

With our first reading, we construct our first Abstraction Decomposition Space (ADS). Ordinarily, ADS is a matrix composed of the Abstraction Hierarchy and the Decomposition Space. We just realized an Abstraction Hierarchy which is decomposed in 5 levels: functional purposes, values and priority measures, Purpose-related functions, object-related functions and physical objects. Decomposition Space is formed of total system, subsystems and different components. First, we construct a macroscopic WDA for the autonomous driving. Then, we construct a detailed WDA related to the lane changing considered as a unique system. It is this WDA that we will explained into detail in the following paragraphs.

Step 7: Abstraction Decomposition second iteration
After many reviews, we modified some elements to obtain the final WDA for the lane change.

Figure 3 presents the WDA of the autonomous vehicle. We present an overview of its structure because it is beyond the scope of this paper to present the complete ADS for the Autonomous Vehicle.

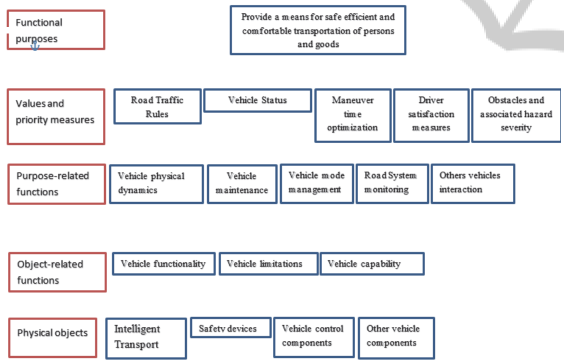

Figure 3: Autonomous vehicle Work Domain Analysis.

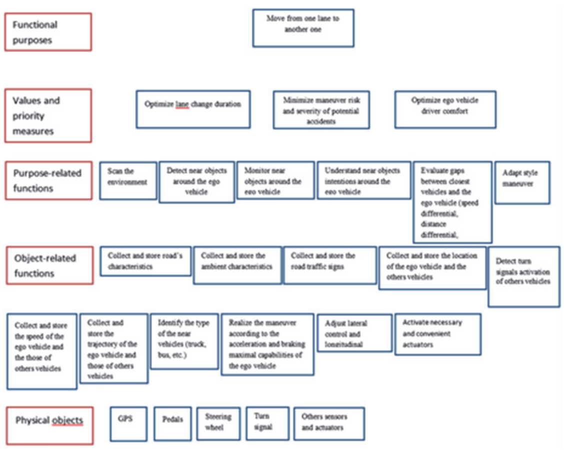

Figure 4: Work Domain Analysis of a "human" lane change system.

We insist on one particular point related to the figure 3. In the purpose related-functions, there is "Vehicles physical dynamics". Within these vehicle physical dynamics, there are speed, velocity, maneuverability, etc. Lane changing is a maneuver that autonomous vehicle can realize in any mode. Because lane changing is one of our use case, we have decided to construct a WDA for the lane change system which does not exist now. We assumed that this WDA will also help to design lane change system.

Figure 4 presents the LC WDA in manual mode.

For each level of the Abstraction Hierarchy, we give a definition and present its components.

6.1.1 Functional Purposes

Functional purposes are the *reason to be* of the system. Contrarily to goals, functional purposes are more stable over time (Burns, Vicente, 2001). Naikar suggests some questions to find them such as "Why does the system exist?", "Why is the system necessary?", "Which purposes should the system achieve?" (Naikar, 2013).

A lane change has been defined as a deliberate and substantial shift in the lateral position of a vehicle (Chovan et al., 1994). That means that the reason of a lane change is a shift, a movement from one lane to another.

6.1.2 Values and Priority Measures

Values and priority measures are the criteria that help to evaluate the system progression towards its functional purposes (Naikar, 2013). Those criteria help for system evaluation. They also allow to prioritize the elements of the below level, the purpose-related functions. To determine values and priority measures, Naikar suggests some questions like "What criteria can be used for evaluating how well the system is fulfilling its functional purposes?", "What fundamental laws, principles, or values must be respected by the system?" (Naikar, 2013).

Considering a lane change system, we have found three main values and priority measures:

a) **Optimize lane change duration:** A lane change longs between 3.5 and 8.5s with a mean of 5.8 s on the highways (Tijerna, 1997). Hetrick studies have estimated lane change duration between 3.4 and 13.6 s with of 6 s (Hetrick, 1997). We assume that a lane change system should realize the maneuver in a time interval [3.4 s; 7 s] to ensure a certain level of safety. Considering the dynamic characteristic of the road environment, a hypothesis is that more the lane change will last, more the maneuver will be dangerous.

b) **Minimize maneuver risk and severity of potential accidents:** This measure completes the first one. In fact, the danger of a lane change is not just related to its duration but also by the severity of crashes that can occur because a lack of adjustment in the maneuver. Then, a good criterion is to evaluate the number of accidents caused by the change system with an expectation of a zero accident observation.

c) **Optimize ego vehicle driver comfort:** The safety is the main aspect to consider in a lane change. When we consider also comfort aspect, it is better. In this configuration, a cognitive calculation is made in driver's head to respect the security and performance constraints. He will want to do the maneuver and be comfortable at the same time. We have already projected to evaluate comfort through a qualitative analysis of users' tests that will be carried out on the simulator.

6.1.3 Purpose-related Functions

Located in the middle of the hierarchy, the purpose-related functions refers to functions that a system must accomplish to achieve the functional purposes. They can be seen as the "uses" that physical objects and their object-related processes "put to" in a system (Miller and Vicente, 1998, p.15 cited by Naikar, 2013, p72). Those functions can also influence values and priority measures (Stanton, 2014). for a lane change system, we have identified the following functions:

a) **Scan the environment**
b) **Detect near objects around the ego vehicle**
c) **Monitor near objects around the ego vehicle**
d) **Understand near objects intentions around the ego vehicle**
e) **Evaluate gaps between closest vehicles and the ego vehicle** (speed differential, distance differential, etc.)
f) **Adapt style maneuver**

6.1.4 Object-related Functions

The object-related processes, which are highly dependent on the properties of physical objects, serve the system to achieve its purpose-related functions (Naikar, 2013). To find those processes, we can answer to some questions suggested by Naikar: "What can physical objects of relevance to the system do or afford?","What functional purposes or functional capabilities of physical objects are necessary for the system to achieve its purpose-related functions?" (Naikar, 2013, p.182).

We have extracted some object-related functions for a naturalistic lane change:

a) **Collect and store road characteristics:** Road characteristics refer to access type (freeway, highway, arterial, ramp, secondary road), road type (weaving, rural) and number of lanes.

b) **Collect and store the ambient characteristics:** Ambient characteristics; refer to the weather (rain, sun, ice snow, cold), the visibility (sun, dust, rain fog) and he time of day.

c) **Collect and store the road traffic signs and signals:** In the traffic signs, we include, speed limitation traffic signs, direction traffic sign, traffic markings and stationary cameras/police cars.

d) **Collect and store the location of the ego vehicle and the others vehicles.**

e) **Collect and store the speed of the ego vehicle and those of others vehicles.**

f) **Identify the type of the near vehicles** (truck, bus, etc.).

g) **Realize the maneuver according to the acceleration and braking maximal capabilities of the ego vehicle**.

h) **Adjust lateral control and longitudinal control of the ego vehicle.**

i) **Detect turn signals activation of others vehicles.**

6.1.5 Physical Objects

It is the level the most concrete of the hierarchy. In this level, all the physical objects present in the system are concerned. They have functional capabilities that allow the system to accomplish the object-related processes.

For our use case, we did not go deeply into the detail because the hard "part" is out the scope of our work. We have listed the main elements.

a) **Global Positioning System (GPS)**
b) **Pedals**
c) **Steering Wheel**
d) **Turn signal**
e) **Others sensors and actuators:** radar, LIDAR, Adaptive Cruise Control, Lane Departure Warning,

6.2 Control Task Analysis Application to Lane Change

Control Task Analysis can be seen as an analysis of

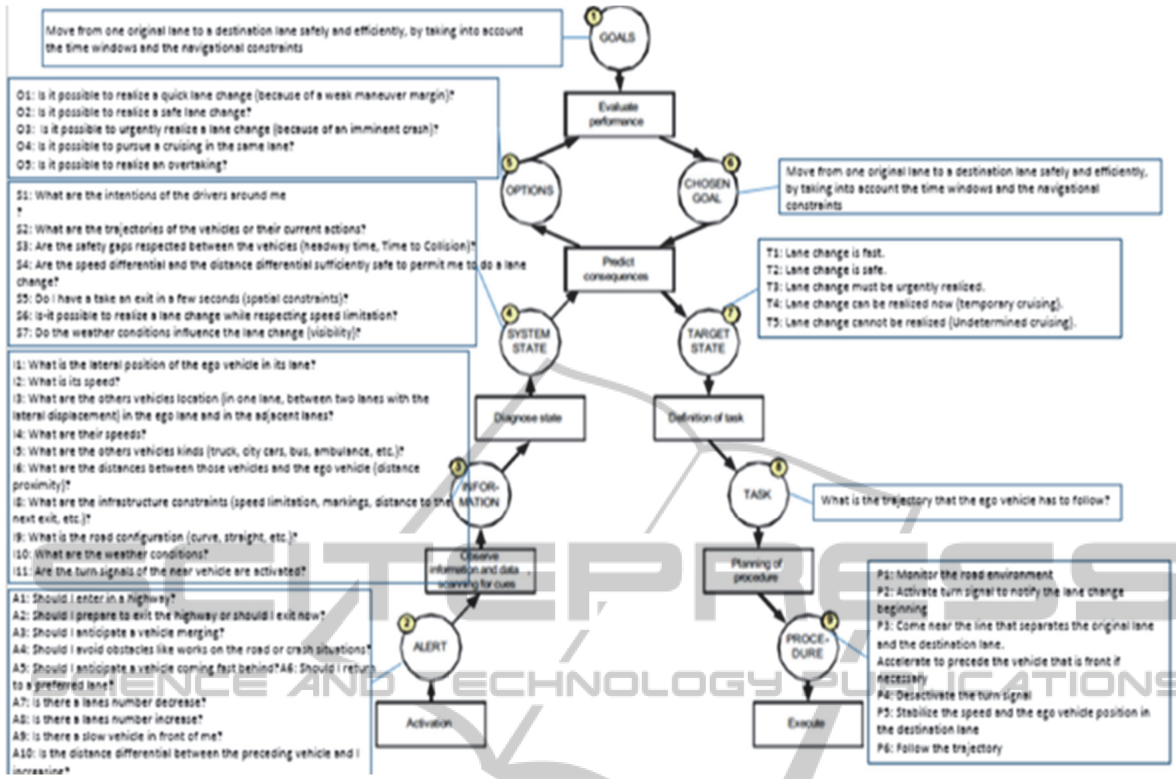

Figure 5: Decision ladder template applied to lane change system.

the activity in terms of decision making. It does not answer the question related to how the activity should be realized nor the question of who is accomplishing the activity. Like we have said before, there are many activities that can occurred in a particular work domain. There, we will analyze the lane change activity from the beginning to the end.

6.2.1 The Decision Ladder Template

The decision ladder is comprised with annotations that come from Rasmussen and Vicente papers (Rasmussen, 1976; Vicente, 1999). It is composed of rectangles and ovals. Rectangles are the boxes of information processing. Ovals are knowledge states which can be either the inputs either the outputs of the rectangles. The writings near the oval are formulated like questions to show actors reasoning (Elix and Naikar, 2008). The ladder must not to be linearly read. The result of the lane change decision ladder is represented in figure 5.

6.2.1.1 Goals

At the top of the ladder, the first state of knowledge is the one of goals. This state consists in the system goals definition. It is slightly similar to the first level of Abstraction Hierarchy, the functional purposes. Literature advises the following formulation for this circle "Goal that begins with a verb + constraints" (Elix and Naikar, 2008; Jenkins, Stanton, Walker and Rafferty, 2009).

For the lane change system, we formulate the goal as **move from one original lane to a destination lane safely and efficiently, by taking into account the time windows and the navigational constraints.**

6.2.1.2 Alert

After the goals definition, we consider the circle at the bottom of the left branch of the ladder: the alert. The alert refers to all the elements that can trigger an event.

In our case, it refers to all the causes that can trigger a lane change. According to Lee, Olsen, Wierwille and Naranjo, the following question can be asked to determine the alert (Lee, Olsen, Wierwille, 2004; Naranjo, 2008; Olsen, 2003).

A1: Should I enter in a highway?

A2: Should I prepare to exit the highway or should I exit now?

A3: Should I anticipate a vehicle merging?

A4: Should I avoid obstacles like works on the road or crash situations?
A5: Should I anticipate a vehicle coming fast behind?
A6: Should I return to a preferred lane?
A7: Is there a lanes number decrease?
A8: Is there a lanes number increase?
A9: Is there a slow vehicle in front of me?
A10: Is the distance differential between the preceding vehicle and I increasing?

6.2.1.3 Information

There we find all the information necessary to evaluate the alert. For example, Stanton and Bossell (2014), while studying how a submarine returns to periscope depth, enumerated in the information level, the surface constraints, weather constraints, etc.

We have formulated questions to grasp the necessary information.

I1: What is the lateral position of the ego vehicle in its lane?
I2: What is its speed?
I3: What are the others vehicles location (in one lane, between two lanes with the lateral displacement) in the ego lane and in the adjacent lanes?
I4: What are their speeds?
I5: What are the others vehicles kinds (truck, city cars, bus, ambulance, etc.)?
I6: What are the distances between those vehicles and the ego vehicle (distance proximity)?
I8: What are the infrastructure constraints (speed limitation, markings, distance to the next exit, etc.)?
I9: What is the road configuration (curve, straight, etc.)?
I10: What are the weather conditions?
I11: Are the turn signals of the near vehicle are activated?

6.2.1.4 System States

Analysis and fusion of information allow knowing the state in which the system is (Jenkins et al., 2009). Because of the diversity of information in terms of nature, quantity and understanding, there are several system states.

Lane change can be realized or not, depending of the relations between the subject vehicle also called ego vehicle and the others.

S1: What are the intentions of the drivers around me?
S2: What are the trajectories of the vehicles or their current actions?
S3: Are the safety gaps respected between the ego vehicle and the others ones?
S4: Are the speed differential and the distance differential sufficiently safe to permit me to do a lane change?
S5: Do I have to take an exit in a few seconds (Spatial constraints)?
S6: Is it possible to realize a lane change while respecting speed limitation?
S7: Do the weather conditions influence the lane change (visibility)?

6.2.1.5 Options

Towards a system state, many actions can be carried out to achieve the purpose of the system. The number of actions to realize are deeply related to the system state. We assume that less complex a system will be, less action will need to be realized. Jenkins suggests to formulate the elements at this level by: “Is it possible…?” (Jenkins, 2009).

O1: Is it possible to realize a quick lane change (because of a weak maneuver margin)?
O2: Is it possible to realize a safe lane change?
O3: Is it possible to urgently realize a lane change (because of an imminent crash)?
O4: Is it possible to pursue a cruising in the same lane?
O5: Is it possible to realize an overtaking?

6.2.1.6 Chosen Goal

As we mentioned before, a system can have one or many goals. But at a particular time, just one goal can be elicited because of the environment constraints (Elix, Naikar, 2008 cited by Jenkins et al., 2009).

In our case, the chosen goal is the same that the goal because there is only one goal: “move from one original lane to a destination lane safely and efficiently, by taking into account the time windows and the navigational constraints.”

6.2.1.7 Target State

When an option is chosen, it becomes the target state. The target state can be formulated by “Is (option) can be adopted?” (Jenkins et al., 2009).

T1: Lane change is fast.
T2: Lane change is safe.
T3: Lane change must be urgently realized.
T4: Lane change can be realized now (temporary cruising).
T5: Lane change cannot be realized (Undetermined cruising).

6.2.1.8 Task

It is the task and a group of tasks to realize in order to achieve the goal(s).

In the lane change system, the main task is to define the trajectory and follow it.

6.2.1.9 Procedure

It is the procedure that has to be conducted in order to realize the tasks.

P1: Monitor the road environment.
P2: Activate turn signal to notify the lane change, beginning.
P3: Come near the line that separates the original lane and the destination lane.
Accelerate to precede the vehicle that is front if necessary.
P4: Deactivate the turn signal.
P5: Stabilize the speed and the ego vehicle position in the destination lane.
P6: Follow the trajectory.
This procedure can be reiterated if necessary.

6.3 Information Requirements for Interface Design

The information that is presented by an interface should be the appropriate information in the appropriate shape. Then the question of form of the information and its quantity are critical for drivers' situation awareness and workload.

The WDA and the CTA help us to extract information requirements independently of the autonomous system. The categories of information based on those analyses are listed below:

- For the ego vehicle
    - Vehicle condition: fuel level
    - Vehicle component conditions: if they work well or not
    - Current location and desired end point
    - Own dynamics: speed, velocity, lateral displacement
- For the others vehicle
    - heir type
    - Their location
    - Their relative proximity with the ego vehicle in terms of speed, distance or time
    - Their intentions
    - Their actions
- For the infrastructure
    - Road signage presentation
    - Road type
    - Infrastructure related Warning
    - Lane width

There are also information requirements related to the automated system and the ego vehicle driver. Considering that autonomous mode should be enjoyable time where the driver will have access to the information he wants to have access to, driver should know for example, how long he has to plan its leisure activity. It is also necessary to check driver vigilance especially when the transition from autonomous to manual mode will be required. Other information should be conveyed:

- For the automated system
    - Its intentions
    - Its current action
    - Its comprehension of road rules
    - Its road perception
    - Remaining time in autonomous mode
- For the ego vehicle driver
    - Its distraction level
    - Its protection information: information related to the seatbelt lock or unlock, hands on steering wheel or not, feet on pedals or not.

Some Intelligent Transport Systems provide those information but for some, not in their entirety. Consequently, the next step will be to determine which information will be design in Augmented Reality.

Comments. At this stage of the work, we have realized the most critical part of the work. We have spent much time to do it but it was really important to have a convenient work. Now we are ready to go into the prioritization and rules levels for a first users' test in December.

7 CONCLUSIONS

To design an interface, precise and adequate information are timely needed, especially in autonomous mode for driving. In this paper, we have described our methodology for interface design. We have finished the first step of Cognitive Work Analysis to capture information needs in lane change and associate them with our use cases.

We are thinking on information representation and the level of transparency of the interface. This methodology, derived from a cognitive approach, will lead to a set of rigorous rules. Those rules will allow at specific time specific components to appear either in Augmented Reality form or not. Acknowledgements. The thoughts expressed here are the work of the authors, but related work has been supported by French government in conformance with the PIA (French acronym for Program of FUTURE Investments) within IRT (French acronym for Technologic Research Institute) SystemX.

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