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Integration of Human Factors in an Automated Driving Supervision System

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ABSTRACT

The development of autonomous vehicles raises many questions. Although safety issues such as driver takeover of the vehicle are widely addressed, remote supervision of vehicles is still poorly investigated. The development of supervision systems could improve safety, as it has been the case in other transportation modes such as aviation and railways. Indeed, the supervision of autonomous vehicles (e.g., shuttle fleet) would enable to secure the operation by anticipating incidents (e.g., support the driver-system relationship, as an air traffic controller would do for pilots), while guaranteeing the reliability (management of system failures) and regularity of the transportation network. We present in this paper the analysis of the reference situations integrating supervision. We have integrated bus and tramway sector, and civil then military air traffic control. Completed by creativity workshops, these data will be used in our future works to design a supervision system for autonomous vehicles.

Keywords: Reference situations, Supervision, Human-factor, Autonomous vehicle, Design

INTRODUCTION

The autonomous vehicle (AV) has been a strong utopia for the evolution of mobility for the last ten years, but its deployment is constantly being postponed. Automation, which is expected to replace physical functions, freeing up time as well as manpower, is completed through artificial intelligence by providing cognitive functions such as decision making, planning, and monitoring. Parasuraman & Riley (1997) define automation as the performance by a machine agent (usually a computer) of a function that was previously performed by a human.

The present work is part of a PhD thesis started in September 2020 which, based on other sectors such as industry, aviation or railways, anticipates the implementation of anthropocentric centralized command centers for autonomous vehicles. To achieve this objective, given that our solution does not exist either technologically, or in the projected uses, alternative methods of data collection of the activity is required. We will firstly present the concepts of the literature that support our topics, then secondly, the methodological elements that we have developed. In this paper, we focus on the process of identifying the reference situations that we have studied as well as the synthesis of the elements collected.

SUPERVISION AND IMPACTS

Activity with human-machine interactions can be divided in three categories: from non-automated to fully automated, including through one or more intermediate levels (e.g., SAE levels for the AV[1]). Automation can disrupt work activity by decreasing physical tasks and increasing cognitive tasks (e.g., knowledge-workers concept; Drucker, 1999). In industrial sectors, where human presence is important for safety, Satchell (1998) considers man and machine as complementary (task sharing, control, authority, etc.). The notion of Joint Cognitive Systems appeared in the 1980s to underline "*the importance of taking into account the (joint) man-machine system to access meaningful task descriptions and this was a decisive step towards the notion of man-machine cooperation*" (Hollnagel, & Woods, 1983).

Automation is often developed to resolve the human error topics (e.g., Stanton & Marsden, 1996 for automated driving). However, the human error is a theory of action (de Beaurepaire, 1996), and represents the sign of a mismatch, a lack of compatibility between the technical, organizational, or functional characteristics of the work situation and the physical, mental, or psychosocial characteristics of the human operator (Hadj-Mabrouk & Hadj-Mabrouk, 2004). The human error is not reducible to the incapacity or incompetence to perform a task but can come from the impossibility for the operator to execute it correctly (de Terssac and Chabaud 1990).

High levels of automation can positively impact the operator by decreasing fatigue or workload, but can also generate boredom, skill erosion, decreased situational awareness, and over- or under-trust of the system (Endsley, 2017; Hoc, 2000; Wiener & Curry, 1980). At the root of these negative effects, Parasuraman and Riley (1997) point to the fact that the design and implementation of automation is typically technology centric. The cooperation human system lets appear 4 concepts emerging in the different uses: "use, misuse, disuse and abuse". "Use" characterizes the behavior of using or not automation, "Misuse" refers to over-reliance on the system while "disuse" takes shape through under-utilization of the automation. "Abuse" is "*inappropriate application of automation by designers or managers*" (p.5) because failed to consider the consequences for human performance, promoting misuse and disuse of automation.

We have identified in the literature that elements of human interaction with automation can degrade the system. In the following section, we discuss the methodology used to propose a specification to design an anthropocentric autonomous vehicle supervision center.

[1]In the field of autonomous vehicles, the SAE (Society of Automotive Engineers) defines 6 levels ranging from 0 to 5. 0 corresponds to no assistance and 5 to an autonomous vehicle without restrictions.

METHODOLOGY

In the context of long-term future design, where the situation or the needs are not well defined, it's necessary to have a projection of the future environment and to apprehend the human role. Prospective ergonomics (Brangier & Robert, 2014) is located upstream of design ergonomics and corrective ergonomics and deals primarily with the functional aspects of a project, while design ergonomics rather addresses the conceptual aspects and corrective ergonomics the operational aspects (Barré, 2015; Nelson, 2011). The "possible future activity" approach (Daniellou, 2004), permit to gets around the lack of observable situations. In this approach, Daniellou emphasizes the need to look at existing situations through "reference situations". These must have strong similarities with the project. The aim is to analyzed strengths, and weaknesses of existing systems, to build a preliminary basis for the creation of the future work situation. To design our supervision system applied to autonomous vehicles, we have identified several reference situations that can serve as a theoretical and practical foundation. This allowed us to understanding activity and more particularly to collect data on interaction between supervision operators and their system. Some of these results are presented in this manuscript. The next step: the creativity part to manage the specifications of the system, is not treated here.

Identify Reference Situations

The identification of reference situations is achieved according to the context (designing a centralized supervision center applied to autonomous vehicles) and constraints, notably given the fact that this technology is not yet mature and there is no concrete solution yet deployed on the market. We can nevertheless anticipate some possible implementations; the supervision of an autonomous public transport service (shuttles or buses), the supervision of autonomous private vehicles as well as the supervision of a car-sharing service or a robot-taxi. We also keep the possibility of still unknown applications.

Two central functions have been retained:

- **(1) The execution of supervision or monitoring tasks**. The degree of automation of the system is not discriminating in our choice, it can vary from non-existent, to average or high. The nature of the system does not have to be especially linked around mobility allowing to open the sources of data collection (industrial process, security, maintenance, etc.) .
- **(2) The execution of driving tasks or remote control**. Potentially, supervisory agents will be able to remotely take control of vehicles in case of incapacity of management by the system, we retain this function because it is associated with very specific situations.

Based on these two functions, we have identified several sectors of activity that are mainly oriented towards mobility. The mind map presented in Figure 1, gathers these 8 sectors of activity with their fields of application.

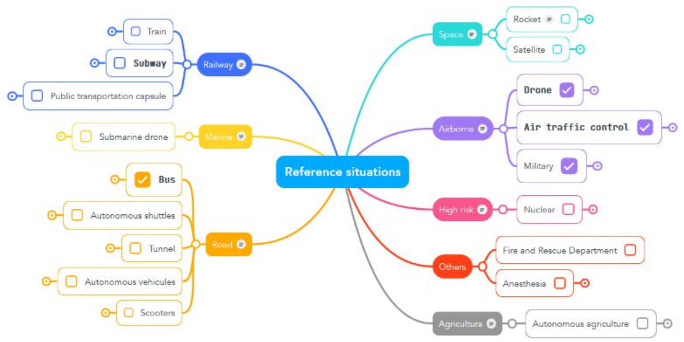

Figure 1: Activity sectors and reference situations identified around the centralized supervision of autonomous vehicles based on the functions of (1) supervision/monitoring and (2) remote driving/piloting.

Data Collection

This data collection was therefore adapted to each field, which had its own human, technical and operational specificities. At least one day was devoted to data collection on site and only one of the situations was observed by two observers.

The methodology was based on several complementary methods used in ergonomics (e.g., Guérin, Laville, Daniellou, Durrafourg & Kerguelen, 2007) and particularly the "Core Task Analysis" methodology (Norros, 2004, Leplat, 2005 and Karvonen & al., 2011). The purpose of the core task analysis is to identify the main task of a specific job. By analyzing the objective and the demands that the work impose on the workers on their daily activity but also in specific situations, it is possible to obtain the main content of the work. We structured on three main axes: observations, interviews, and critical incident analysis.

- **Open observations of the activity.** It is essential to understand the codes, the stakes, and the responsibilities of the different stakeholders. The observation of the real work allows to access the missions of the different actors and to understand the organization of the work including communications, cooperation as well as human-machine interactions.

- **Semi-structured interviews.** This method, used in addition of the observation, permits to understand the role of the human activity and to access the operators' reasoning. From an interview grid, five themes adapted from the work of Karvonen et al. (2011) on the automated metro, were discussed: the nature of work and core task, professional skills, communication and co-operation, user-interfaces, and the relationship to automation. The discussion was designed to allow free exchange on the work environment. Seven operators were interviewed for an allocated time between 20 min and 80min.

- **Critical incident analysis.** Critical incident analysis (Flanagan, 1954) offers two ways of understanding situations. It allows us to identify the undesired events that can occur in the observed context as well as the elements of initiation. It also allows the possibility of apprehending the acts of recovery set up by the concerned actors allowing or not to find a stable situation.

RESULTS

At this stage three fields (Bus & tramway supervision, Civil air control and Military air control) have been fully analyzed. A fourth exploratory field (logistics drone) is currently being studied in greater depth. Based on these elements and on a decomposition of the main functions, we were able to establish the mind map presented in Figure 2.

This representation allows us to identify 7 major components of supervision, that are linked together and need to be whole considered. These links are represented by the green arrows on the Figure 2. It is impossible for us to deal with all the headings in this document, so we will discuss the most salient elements.

The institutions we met have a strong safety culture; clearly stated component of the different situations observed. We find these elements both in the operators' communications and in the management of incidents/accidents. They are managed in such a way as to understand the complexity of situations to propose adjustments in the procedures to limit their occurrence. For example, the air traffic control domain records all communications, HMI data and operator actions to allow a complete analysis after a non-common event to identify the faulty elements. The quality and safety investigation office ensures numerous communications about events requiring reinforced vigilance to allow collective appropriation. Indeed, a supervision "service" is intended to improve the system by guaranteeing the management of unforeseen events. We noted a difference in that with the bus and tramway sectors. For one, this is done in the form of a sector breakdown (air domain) and for the other in a global form - end-to-end (road transport domain). We also recognize two categories of modality for performing the supervision task: "proactive supervision" and "reactive supervision". We attribute the proactive supervision to the aviation sector because the supervisor (also called "controller") has a central place in the system with the role of realizing the interface of coordination and cooperation between the aircraft present in its defined area. Conversely, in the bus and tramway supervision sector, supervisors (also called "regulators") anticipate many phenomena but have the vocation to resolve conflicting situations, that is what we consider "reactive supervision". Finally, we find a higher degree of safety, or at least a more "regulated" one, in the airline sector.

The organization of these two sectors also differs in the constitution of the workstations. The bus and tramway supervision area is organized with one agent per workstation, while the air transport area is organized by "booth" of two agents: a controller and a planner.

They have a similarity on the software. It's centered on a real-time visualization of the evolution of the traffic activity. Some specifications such as user interface or menus adapted to each sector to allow a good awareness of the situation and tend towards the best decisions.

The issue of task allocation is present in the airline sector and has been discussed in the public transportation sector. The air sector has an automatic preventive alarm of aircraft crossing. When the trajectory projection calculates a penetration of the horizontal and vertical separation, the system triggers

Figure 2: Mind map of the main functions and components of the supervision activity resulting from the analysis of the reference situations.

a first alert to request an action from the controller. In this case the system is not able to propose different maneuver choices; it only reports the anomaly. Within the bus & tramway supervision, the supervisors underline the interest of the deployment of an aid from the software aiming at repositioning correctly the tramway drivers following an incident which required the implementation of an interruption of a given portion.

Supervision of systems always presents the human agent in the loop of control, so the system is vulnerable to the failures of the human factor. The notions of understanding, trust, situational awareness, but also the human's capacities, training or even fatigue are involved in the human-system relationship. The human's cognitive capacities limit him in the workload he can assume. We find an example of considering the human factor within the civil aviation field concerning the management of sectors. It has been determined, over an hour, a defined number of aircraft that a "control cabin" (2 agents) can assume in consideration of the specificities of the situation and if this is reached, then the sectors are subdivided. This action will allow a distribution of the workload with another team and will make it possible to maintain working conditions which encourage a framework favorable to air safety. In the land transport sector there is no formal workload distribution strategy. This is due to the absence of variability in the quantity of vehicles to be regulated over time. The overload of the agents, caused by the simultaneous occurrence of several disruptive events, is solved informally with the support of the other agent (bus or tramway supervisor).

CONCLUSION

To understand the position of the human operator in the supervision, we tried to integrate as many reference situations as possible, from the closest to our target system, such as the supervision of buses and tramways, to the most distant, such as the supervision of a nuclear power plant. Currently, we could analyzed the bus and tramway sector, as well as the civil and military air traffic control. Thus, out of all the reference situations identified, we were able to carry out observation and comparison of the activity of these three.

Although the macro function of the supervisor is to bring a global vision of the direct situation to the pilots/drivers, we note that the supervisor takes a different place depending on the sector of activity. This is already reflected in the names of these agents: we speak of "supervisor" or "regulator" for the bus/tramway supervisor, whereas we speak of "controllers" in the airline sector. This reflects the incident and deviation management role of the former and the proactive control role of the latter.

From these data collections, as an extension of the state of the literature review, we extract crucial information about the organization, functioning and vigilances of supervision in these different sectors. Each of them has its own specificities but presents an overlapping structuring that brings essential elements to the projection of a centralized supervision center for the application to an automated driving supervision system.

This data collection needs to be adapted to the specificities of the target system. To propose a first specification for the system designer for this application, we will focus on the conversion levers of these data for our system: needs, functions, and solutions. We will proceed by setting up creativity workshops to position itself in a prospective ergonomics approach.

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