From Aircrafts Interactive Cockpits to Autonomous Vehicles: Are Design Principles Transferable?

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Abstract
This position paper identifies two design automation principles and discuss their applicability to the field of autonomous vehicles. The first one concerns the levels of automation while the second one focusses on the notion of allocation of tasks and functions between operators and automation. We believe that experiences in such design aspects together with dependability aspects (including operations under automation degradations) might benefit to the workshop. Our objective in attending the workshop is to bring our knowledge from the domain of safety critical interactive systems to the workshop. Beyond that we would like to assess the potential transferability of current knowledge in autonomous ground vehicles to these systems.

Author Keywords
Automation Design, Tasks description and modelling, Function allocation, Automation degradation, Function allocation.

Introduction
Designing interactive computing systems in such a way that as many functions as possible are automated has been the driving direction of research and engineering both in aviation and in computer science for many years. In the 80's many studies (e.g. [4] related to the notion of mode confusion) have demonstrated that fully automated systems are out of the grasp of current technologies and that additionally migrating functions [5] from the operator to the system might have disastrous impact on safety and usability and operationality of systems. Allocating functions to an operator or automating them, raises issues that require a complete understanding of both operations to be carried out by the operator and the behavior of the interactive system, from high-level procedures and tasks to low-level behavior of interaction techniques [2]. This position paper proposes a contribution for reasoning about automation designs using a model-based approach exploiting both task models and system models. Tasks models are meant to describe goals, tasks and actions to be performed by the operator while system models represent the entire behaviour of the interactive system. Tasks models and systems models thus represent two different views of the same world: one or several users interacting with a computing system in order to achieve their goals. In previous work we have demonstrated how these two views can be integrated at the model level and

additionally at the tool level [1]. In this position paper we present how such representations can support the assessment of alternative design options for automation and how they are positioned with respect to levels of automation as proposed by [6].

Contribution to the workshop

The design of automation in the area of safety critical interactive systems two main drivers are the automation levels and the allocation of specific operators' tasks and functions to the autonomous system.

Automation levels

Parasuraman and Riley [7] have expanded the *automation's* definition emphasizing human-machine comparison and they describe automation as a device or system that accomplishes (partially or fully) a function that was previously, or conceivably could be, carried out (partially or fully) by a human operator. This implies that automation can vary across a continuum of levels, from the lowest level of fully manual performance to the highest level of full automation and the several levels between these two extremes are illustrated in the following table.

TABLE I. LEVELS OF AUTOMATION OF DECISION AND ACTION SELECTION (EXCERPT FROM [6])

HIGH	10. The computer decides everything, acts autonomously, ignoring the human
	9. Informs the human only if it, the computer, decides to
	8. Informs the human only if asked, or
	7. Executes automatically, then necessarily informs the human, and
	6. Allows the human a restricted time to veto before automatic execution, or
	5. Executes that suggestion if the human approves, or
	4. Suggests one alternative
	3. Narrows the selection down to a few, or
	2. The computer offers a complete set of decision/action alternatives, or
LOW	1. The computer offers no assistance: human must take all decisions and actions

Even though those levels can support the understanding of automation they cannot be used as a mean for assessing the automation of a system which has to be done at a much finer grain i.e. "function" by "function". However, if a detailed description of the "functions" is provided they make it possible to support both the decision and the design process of migrating a function from the operator's activity to the system or vice versa.

Allocation of tasks and functions between operators and autonomous system

As stated in [6], automated systems can operate at specific levels within this continuum and automation can be applied not only to the output functions but also to *input* functions. Figure 1 presents the four-stage model of human information processing as introduced in [6].

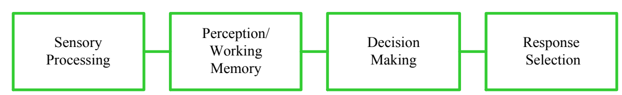

Figure 1: Simple four-stages model of human information processing

The first stage refers to the acquisition and recording of multiple forms of information. The second one involves conscious perception, and manipulation of processed and retrieved information in working memory. The third stage is where decisions are accomplished by cognitive processes and the last one contains the implementation of a response or action consistent with decision made in the previous stage.

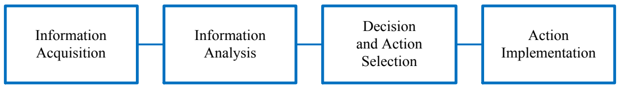

Figure 2: Four classes of system functions (that can be automated)

This model of human information processing has a similar counterpart in system's functions as shown in Figure 2 and then provide support for analyzing migration of tasks into functions in the system or migration of system functions into user tasks. Each of stage of the model of human information processing can be automated to different degrees. For instance, the *sensory processing* stage (in Figure 1) could be migrated to the *information acquisition* stage (in Figure 2) by developing hardware sensors. The second stage in the human model could be automated by developing inferential algorithms (as for instance in recommender systems). The third stage involves selection from several alternatives which can be easily implemented in algorithms. The final stage called *action implementation* refers to the execution of the choice, an example of automation of this stage can be found in [3]. Automation of this stage may involve different levels of machine execution and could even replace physical effectors (e. g. hand or voice) of the operator [8].

Discussions for the workshop

Based on these principles design issues can be raised and the following questions could trigger discussions at the workshop:

- How automation surprises can impact user experience of drivers/operators?
- How design decisions may influence safety and more precisely incidents and accidents (for instance the rear-end accidents with autonomous vehicles)?
- Would it be possible to dynamically migrate between levels of automation (from fully manual to fully autonomous behavior) and how would this influence user experience, usability and safety?
- Would it be relevant (in order to increase user experience of drivers) to migrate functions according to the classes of functions presented in Figure 1 and Figure 2 (i.e. human stage of information processing and classes of system functions)?
- How is it possible to evaluate theoretically the designs addressing the issues above without going for in-depth experiments involving large numbers of users.

Authors' background

The authors have been working for more than 20 years in the area of the design and evaluation of safety critical interactive systems. More precisely they have developed notations, tools and techniques to support in a common framework properties such as Usability, Reliability and Dependability. These contributions have been applied to several industrial projects such as the design of collaborative environments to manage collision risks between satellite and space objects, Air

Traffic Management automation with tools such as AMAN (Arrival Manager) and more precisely how automation degradation of such advisory tools can deeply impact safety and operations. More information can be found at: http://www.irit.fr/recherches/ICS/projectsummary/projects.html.

Philippe Palanque is Professor in Computer Science at University of Toulouse 3. He has worked on research projects to improve interactive Ground Segment Systems at the Centre National d'Études Spatiales (CNES) for more than 10 years and is also involved in the development of software architectures and user interface modeling for interactive cockpits in large civil aircraft (funded by Airbus). He is also involved in the research network HALA! (Higher Automation Levels in Aviation) funded by SESAR program which targets at building the future European air traffic management system. As for conferences he is a member of the program committee of conferences in these domains such as SAFECOMP 2013, DSN 2014 (44th conference on Dependable Systems and Networks) and was co-chair of CHI 2014 (32nd conference on Human Factors in Computing Systems) and research papers co-chair of INTERACT 2015.

Célia Martinie is Assistant Professor in Computer Science at University of Toulouse 3. She has been working on task modeling techniques for the design and development of interactive systems since the beginning of her PhD in 2009. Prior to that, she worked in the mobile industry (Motorola) during 8 years, and has contributed to the design and development of user interfaces for mobile devices. She is the principal investigator of the projects related to the design and development of the operators goals and tasks description HAMSTERS and its associated tools. She applied the task modeling approaches to a variety of systems including satellite ground segments, interactive cockpits of large civil aircrafts and air traffic control workstations.

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