A-RCRAFT: a Generic Framework for Automation Analysis and Design:

Application to Automotive, Tactile in vehicle Interactions

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Abstract

Automation can have a huge impact on the overall performance of the couple user/system. Function and Tasks allocation and Authority sharing are "classical" key elements exploited in the design of automation. This position paper advocates the need for dealing with additional dimensions namely Control Transitions, Resources and Responsibility. In this position paper, we discuss the benefits of embedding all those dimensions for designing automation and reasoning about automation designs. We present on a simple case study from the automotive domain how those dimensions can concretely be applied. Lastly, we discuss how they contribute to the fours Is of the workshops: Intelligibility, Intervention, Interplay and Integrity.

Author Keywords

Automation Design and Assessment; Function and Tasks allocation, Responsibility, Authority and Control Transfer.

ACM Classification Keywords

D.2.2 [Software] Design Tools and Techniques, H.5.m. Information interfaces and presentation (e.g., HCI).

Workshop proceedings *Automation Experience across Domains*
In conjunction with CHI'20, April 26th, 2020, Honolulu, HI, USA
Website: http://everyday-automation.tech-experience.at

Introduction

Currently, automation is one of the main means for supporting operators using systems with increasing complexity. Automation makes it possible for designers to transfer the burden from operators to a system. Two main aspects of automation at design time lay in describing which functions/tasks are allocated to the system and the human and who is in charge of triggering the execution of functions (authority sharing).

Because automation is more complex than that, we propose the use of additional dimension to capture aspects of automations that are not captured when focusing on Authority sharing and Functions/Tasks allocation. The dimensions of Resources, Control Transitions and Responsibility are added to compose a generic framework for automation design and assessment called A-RCRAFT.

Following sections will present successively the framework, its application to a simple case study from the automotive domain (auto flat tire repair) and how it can inform the design and evaluation of tactile interfaces on the steering wheel. Last section is devoted to the positioning of the framework with respect to Intelligibility, Interplay, Intervention and Integrity.

The A-RCRAFT Framework

We propose the A-RCRAFT framework that provides support for the analysis of automation design in terms of Allocation of: Resouces, Control Transitions, Responsibility, Authority, Functions and Tasks (A-RCRAFT). This proposal is an extension to the integration of authority and responsibility [8] to function and tasks allocation that is core in automation research and practice [9]. We identified three aspects of automation that have to be identified at design time:

- which functions are allocated to the system and which tasks are allocated to the operator (allocation of functions and tasks),
- which entity is allowed to trigger or prevent functions/tasks execution (allocation of authority)
- which entity is responsible for the outcome of the execution of the functions/tasks (allocation of responsibility) and especially, in case of incident, who will be held responsible for that undesired outcome.

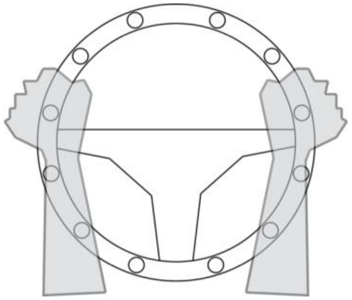
In addition, the A-RCRAFT framework integrates the allocation of resources and the allocation of control transition.

- which resource (e.g. information) is allocated to which entity in terms of production, modification or sharing with the other entity (ownership).
- how control transitions are defined and which entity can trigger them (e.g. handover and takeover activities) as defined in [4].

For example, the explicit identification and description of the A-RCRAFT enables to encompass in a single framework the various dimensions of interaction with a partly-autonomous system. This can be used, for instance, to allocate the elements of each dimension to the best player (following a kind of MABA-MABA principle [5] for functions and tasks allocation only). Existing approaches dealing with automation design usually focus on identifying functions that should be allocated to either the operator or the system as presented in [2] and [3].

Beyond that, this distribution of function and of authority can be static (identified at design time and not modifiable at operation time) or dynamic (altered at design time). Dynamicity can be also defined at design time where various distribution of functions and authority can be

Figure 1. Tactile technology on the steering wheel



considered according to, for instance, context of use. In such a case, the allocation of function could be different at night and at daytime. If this change is triggered automatically, the automation is called adaptive [7] while if the operator triggers it, it is called adaptable. between an operator and the system could change The allocation is static once deployed, which means that it can be changed several times during the design and development of the system but not at runtime. The same holds for authority that can be static or dynamic [6], adaptable or adaptive.

The Auto Flat Tire Repair Example

Description of the example

Cars can now embed an auto-repair functionality of flat tire thanks to a special kind of tire. In the described example, we use the tire developed by Continental [10]. That tire automatically seals punctures (up to 5mm in diameter) using an embedded glue. If the hole is too big, we consider that the car is able to trigger a warning towards the driver. Otherwise, the driver will be informed of the flat tire detection (warning) that will disappear if the repair is successful.

A-RCRAFT view on flat tire example

The addition of an auto-detect-and-repair flat tire system changes significantly how flat tire management is performed. A-RCRAFT allows to make explicit the impact allocating the 5 dimensions to the driver or to the system:

- Allocation of Resources related to the autonomous system (detection and repair). In that case all the information about detection and repair is allocated to the autonomous system.
- Allocation of Tasks and Functions: detection and system-repair are allocated to the system. Decision to perform a manual repair is left to the driver in case the flat tire alarm is remains displayed.
- Allocation of Authority is entirely to the system, which can trigger actions based on sensors information. The driver is only informed by means of the warning.
- Allocation of Responsibility. According to the law, the responsibility remains to the driver who is responsible to ensure the operational status of the vehicle (enforced on a regular basis by technical controls).
- Allocation of Control Transitions. At any time the driver can take over the auto detect and repair system (looking at the tire and deciding to start a manual repair). The system cannot prevent such takeovers. The current description of the example does not provide enough information about the possible takeover or explicit handover from the system (for instance in case of impossibility to repair). It is important to note that Control Transitions can be computed from a description encompassing Authority and functions/tasks allocation but it is an important concept that is explicitly considered at design time as argued in [16].

The Tactile Technology for UI of RCRAFT

To illustrate how the RCRAFT elements can be integrated into a cockpit user interface using the auto flat tire repair example, we describe a prototype capable of conveying information (notifying system failures to drivers) through the steering wheel using tactile feedback. As the NHTSA [11] recommends to keep both hands on the steering wheel while driving, drivers are likely to receive any tactile notification from the steering wheel. The prototype includes a dozen of pairs of Peratech SP200-05 force sensors [12] and electroactive polymer piezoelectric actuators [13] embedded around a steering wheel (see **Figure 1**). While the force sensors allow the detection of pressure and the identification of the position of the hands, the printed actuators provide localized tactile stimulations around the steering wheel. The actuators are driven by a TI-DRV2667 chip and a 5V/2A power supply. An ATmega32u4 micro-controller is used to read data from the force sensors.

A tactile message is created by combining three bursts of a signal, generated with a sinusoidal wave of 230Hz and lasting for 240ms, into a pulse with an interval of 120ms. This combination of parameters was selected according to previous studies on tactile perception on the steering wheel [14, 15]. A custom software was developed to send the haptic signal to the actuators and to coordinate both pressure/location input and tactile output.

Application of A-RCRAFT to the design of a tactile User Interface

Design A: As soon as the system detects a loss in pressure (tire failure), it locates the drivers' hands on the steering wheel and generates a continuous pulse delivered by the actuators at the location of the hands. When the flat tire is repaired, the pulse is stopped.

Design B: Other design options would be to notify first the driver about the failure and then notify again differently if repair is successful with a long pulse and repeated pulse every 5 seconds to notify the driver the control transition until manual repair is undertaken.

In Design B, the Information flow is used to represent both the status of the flat tire and the status of the automation. Design B is more transparent [1] even though the allocation of function and tasks remain the same. Authority, Responsibility and Control Transitions remain the same in both cases even though regulators might alter this responsibility in case of tire failure following an auto-repair. Functions to disengage auto-repair (as this is available for passenger Airbags) might also provide drivers with higher authority over automation.

Connection to Intelligibility, Interplay, Intervention and Integrity

Intelligibility: the tactile interaction technique in designs A and B brings the issue of learning and training as the meaning of those interactions cannot be inferred.

Interplay: the issue of non-experts is particular in automotive. Indeed, every driver has to be trained and follows a standardized training program. As stated above, in alternative designs, the driver might be more involved in decision making (e.g. when to trigger auto-repair).

Intervention: here again, the case study does not offer intervention to the driver as the system is fully autonomous. The alternatives presented would allow more intervention keep the driver in loop who can bring non-sensed information to the system.

Integrity: the case study already demonstrates that the driver cannot trust the automation as the system is only able to operate in the case of limited damage on the tire. Trust will be built based on experience while interacting with it. However, as flat tire events are seldom it is likely that drivers' level of trust will remain high due to no interaction with that system also known as the Black Swan effect from highly improbable events [17].

Acknowledgements

Some of the authors are funded under European Union's Horizon 2020 research and innovation programme under grant agreement No 761112 (PRESTIGE)

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