Challenges for Future Automated Logistics Fleet Interactions

MICHAEL GAFERT, AIT Austrian Institute of Technology GmbH, Center for Technology Experience, Austria
PETER FRÖHLICH, AIT Austrian Institute of Technology GmbH, Center for Technology Experience, Austria
ULRIKE RITZINGER, AIT Austrian Institute of Technology GmbH, Center for Energy, Austria
MATTHIAS BALDAUF, Eastern Switzerland University of Applied Sciences, Switzerland

With the deployment of automated vehicle fleets, there will be a corresponding need for managing and operating vehicles remotely. This paper introduces the challenges for the human interface of such future automated fleet management interactions. Based on an analysis of the emerging operator workplace and digitization trends in the logistics domain, key requirements for human interface characteristics for these novel systems are proposed. By means of an expert-based review of human interfaces for automated logistics fleet interaction systems, the current status with regard to the accomplishment of these requirements is analyzed. Next steps towards realizing future automated logistics fleet interactions are outlined.

CCS Concepts: • **Human-centered computing → Graphical user interfaces**; User interface management systems; Walkthrough evaluations; • **Social and professional topics → Automation**.

Additional Key Words and Phrases: fleet management, teleoperation, automation, workplace, requirements gathering

1 INTRODUCTION

The role of humans in the logistics system is evolving. Key drivers for this change are technology advancements through ongoing automation and digitalization, as well as social shifts, such as the aging population [6]. Especially, the introduction and prospective deployment of driverless vehicles is expected to have a continued strong sociotechnical impact on the logistics domain. Freight vehicles, such as forklifts, trailers, or tow trucks, are likely to be put into comprehensive large scale operation earlier than passenger transport, because controllable transport environments and standardized processes along the supply chain allow for better safety guarantees and operational efficiency [7]. Many logistics oriented companies have been or are in the process of introducing automated logistics systems. This change can be primarily observed in warehouse logistics where automated forklifts are utilized. Usually these vehicles are automatically guided vehicles (AGVs) are restricted to operation on predefined routes and cannot adapt to new environments. Sensors on the AGV can prevent hazards, but vehicles are typically not yet designed to adapt to the situation.

With the integration of more flexible driverless vehicle fleets, the human workplace will undergo a further significant transition. While the role of the driver will decrease in significance, other roles will emerge that assure qualified and responsible operation of the overall systems. The paradigm of the Logistics Operator 4.0 introduced by Cimini et al. [1] conceptualize the work role profiles implied by this shift and the required supervisory control of increasingly automated functions as well as novel human-computer interaction (HCI) features for task assistance and augmentation. While the importance of these functions is not put into question, their exact implementation still tends to be ascribed a lower

Workshop proceedings *Automation Experience at the Workplace*
In conjunction with CHI'21, May 7th, 2021, Yokohama, Japan

Website: http://everyday-automation.tech-experience.at

priority and realized in an arbitrary manner. The key question so far remains unanswered: Who will be the operator(s) for future automated logistics fleet interactions (ALFI) [6]?

We posit that answering this question about the operators and their interactions deserves explicit and systematic investigation. In this paper, we present the challenges for the human-centered design of ALFI, considering the emerging workplace requirements and required consolidations of the underlying technology. Furthermore, the gaps for the development of a future framework for designing automated logistics fleet interactions are analyzed, based on the state-of-the-art analysis of current operational systems.

2 MAPPING THE REQUIREMENTS FOR AUTOMATED FLEET INTERACTIONS

First current proponents of automated logistics fleet systems focus on single use cases and vehicle types, for example automated forklifts in a warehouse or automated trucks transporting goods between two co-located facilities. As more sectors will use automated fleets, the need for more unified concepts for ALFI will correspondingly grow. These should combine several types of remote interactions with multiple vehicles, which have so far been defined and researched separately, such as fleet management, teleoperation, process management, traffic management, and vehicle monitoring [4]. For example, fleet management systems typically offer a high level view of the system which enables the user to control the overall fleet. In future situations, a seamless transition from this high level fleet monitoring to intervention by teleoperation from an egocentric perspective may be required, in order to control singular vehicles remotely, without having to completely switch between monolithic systems that require many different control paradigms, actuators and displays. From a human-machine interaction (HMI) research perspective, ALFI should thus comprehend all possible forms of tasks and user interface components that shall enable human operators to configure, monitor and intervene in this more comprehensive notion of automated logistics fleet vehicle operations.

As Figure 1 shows, the design and deployment of HMI frameworks to support future automated fleet interactions is strongly influenced by the currently evolving human workplace environment and by the underlying technological enablers (see more details in Section 3). The underlying technology is furthermore also interacting with ALFI as only they can provide the data necessary for the interaction the users require. These systems range from route optimization over integration of legacy systems to the vehicle driving capabilities themselves (Section 4).

Requirements from the Emerging Operator Workplace

Clarify roles: Make tasks, KPIs, responsibilities transparent and manage the variety of operational scenarios

Take account of diversity of users and multitude of work contexts

Address known human factors issues: Out of the loop syndrome, latency issues, situational awareness through missing embodiment, workload, fatigue

Enable communication: Interfacing with other organizations and handover to the next operation

Required Human Interface Characteristics

Unified design for different devices	Ubiquitous access
Adaptation to work context	Diversity-aware interface
Integrated teleoperation	Realistic representation of remote situation
Awareness and intent of the vehicles	Reliability displays for trust calibration
Quality-of-Experience	Attention management

Digital Consolidation and Interconnection

Consolidation of heterogeneous subsystems: Integration of fleets (logistics, public transport, car sharing, traffic management), support of multiple use cases and scenarios

Decision support: AI and Big Data analytics, optimization techniques

Seamless Information Flow: Real-time access to data and information from multiple sources, to allow a more responsive real-time scheduling

Fig. 1. The tension of the human interface characteristics between the emerging operator workplace environment and the underlying digital consolidation and interconnection.

3 UNDERSTANDING THE EMERGING WORKPLACE

As noted above, apart from Cimini et al. [1] overall Logistics Operator 4.0 paradigm, general role and task definitions are not yet available which could be used as a framework to describe the emerging work conditions around automated logistic fleet interactions. A comprehensive and extensible task and workflow analysis would thus be necessary as a first step. As shown in Figure 1 (top), interfaces that support these tasks should transparently map these tasks and related key performance indicators (KPIs). Furthermore, there are known human factors requirements from remote operation of automated passenger vehicles [2] that have to be considered also for the automated fleet logistics domain. This includes, reduced situational awareness, such as the 'out-of-the-loop syndrome', which should be avoided, and more time should be allowed for the take-over from automated to manual mode in case of remote operation. Designers also need to be aware of other limitations for situational awareness, important latencies (caused by network or processing capacity limits) or a missing feeling of embodiment of the controlled system (due to missing sensory information). Furthermore, there should be a balance between cognitive load, fatigue and alertness.

4 ACHIEVING DIGITAL CONSOLIDATION AND INTERCONNECTION

Current fleet management systems (FMS) are usually designed for specific use cases. Thus, the range of functions involved in FMS is broad and services are often engaged separately. But to gather an optimal performance in automated logistics fleet environments, an overall system that integrates the data from various functions is required. The challenge is to build an automated FMS which consolidates all available sources of data and information and avoids unnecessary overlaps to other systems. Furthermore it is relevant that an integrated concept allows reactions from the user interface as well as from the workplace.

Automated logistics fleet systems will comprehend many independent heterogeneous elements which are combined to one consolidated system. One large and important part of logistics transport systems are AGVs. A good overview of control algorithms and techniques with high potential are discussed for example in [3]. Such systems should handle multiple core tasks that are then optimally assigned to one or more vehicles. Thus optimization algorithms are responsible for an optimal task assignment and scheduling. To provide an optimal schedule, additional information about goods (e.g., capacities, weight) and logistic processes (e.g., time constraints) must be available. Thus, interactions and connections to other management tools are necessary, as for example to booking management tools or warehouse management tools. Other relevant tasks comprise vehicle localization, path planning, and motion planning, where real-time modifications of the planned path are considered and information from the current environment are processed (e.g., from the door status). Another important task consists in the management of vehicles, which monitors the current status of the vehicles, such as battery status, error status, or maintenance status. Other information which enhances an automated logistics fleet management are control mechanisms like traffic control or weather conditions.

The main challenge in the design of an automated logistics fleet system, which is applicable to multiple use cases, is to integrate all these elements to one consistent and general system without overlapping elements. A crucial point will be the discussion on the possibilities of the digitalization of conventional processes or the efficient integration of legacy systems. This also leads to the question of data availability and the quality of the data. Due to the above mentioned dynamic development of workplace environments and processes, it is also important to enable for a modular, open and easily extendable system architecture.

5 IDENTIFYING REQUIRED HUMAN INTERFACE CHARACTERISTICS

The requirements from the operator workplace and the digital consolidation trends pose demanding requirements for the human machine interfaces of ALFI (see an overview in Figure 1). In order to investigate the current state-of-the-art, an expert-based analysis was conducted for six HMIs of fleet management systems developed and used by automated vehicle manufacturers, shuttle service providers and logistics hub operators.

Responsive design, clean and "one size fits all" are terms commonly used when designing interfaces, but are not as common in industry applications and therefore automated logistics fleets. As legacy interfaces are renewed, these design paradigms should also be taken into account. There are already some manufacturers incorporating these elements. Interfaces should not only be designed for one user but be adaptive to new users and different environments.

One of the manufacturers took this principle further and designed their system for ”ubiquitous controllability”, with a consistent conceptual design for desktop computers, mobile devices, touchscreens on and near the vehicle. However, what has so far been neglected by current systems is the adaptation to the diversity of users (e.g. regarding qualification level and age).

The analyzed systems were each tailored for the purpose of one single use case. Some systems focus on presenting the results of the automation in terms of KPIs (Is there money saved in the process and the output increased?). Others support the investigation of the actual vehicle (with regard to the current state, such as battery charging or failures). A third type of systems highlights the logistical process (e.g., what will be transported, where will it be transported and when?). No single system provided all necessary elements to enable a user wide interface which can be built on modular elements to enable an interface which fits the requirements of each user best. Future fleet management systems should provide spatial resolution as well as low level vehicle status information, dashboards for managers, and teleoperation possibilities built directly into the system.

Fleet management and teleoperation are regarded as separate issues, as the teleoperation driver needs special training and a driver's license. For example in the case of transporting goods on a public road a truck driver's license is needed. The current solution for connecting fleet- and teleoperation is by manually sending a teleoperation task from the fleet management to an always occupied teleoperation stand. The teleoperator is waiting at the teleoperation stand for new tasks and controls the vehicle if requested. Although this is a good separation of concerns, some context might be missing for the teleoperator to complete the required task as efficiently as possible. This includes the current position of the vehicle, the current load, why it failed and where it needs to go. To provide a more seamless hand over of the teleoperation task, the teleoperation and fleet management could be combined into a dedicated remote operator, who can, in case of a failure, also take over the control of the vehicle. It should be discussed in later work what method is more feasible. In any case, the workplace requirement of realistic simulation of the remote situation should be realized for situations in which teleoperation is required.

An aspect so far less regarded is the communication of the vehicle's awareness and intent, as well as their reliability, in order to calibrate operators' trust in the system capabilities. Another aspect that needs to be considered when realizing the above recommendation of integrating more spatial resolution and maps is a satisfactory Quality of Experience. Furthermore, with the increasing number of vehicles, more sophisticated attention management will be necessary, in order not to overload operators.

6 CONCLUSIONS

The above considerations highlight the need for a systematic user-centered investigation of automated logistics fleet interactions. The next step in our research is to perform a task analysis, based on contextual interviews of current fleet managers, teleoperators and experts in the human factors of logistics and transport. Once the data has been analyzed, requirements can be gathered to generate design patterns [5]. Patterns are a collection of solutions for interface design challenges which reoccur across the domain. These patterns can then be used to create a unified experience allowing for a better experience across all interaction categories for automated vehicle fleets.

ACKNOWLEDGMENTS

This work is part of the project AWARD, which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101006817. The content of this paper reflects only the author's view. Neither the European Commission nor CINEA is responsible for any use that may be made of the information it contains.

REFERENCES

[1] Chiara Cimini, Alexandra Lagorio, David Romero, Sergio Cavalieri, and Johan Stahre. 2020. Smart Logistics and The Logistics Operator 4.0. *IFAC-PapersOnLine* 53, 2 (2020), 10615–10620. https://doi.org/10.1016/j.ifacol.2020.12.2818 21th IFAC World Congress.

[2] Mutzenich Clare, Durant Szonya, Shaun Helman, and Polly Dalton. 2021. Updating our understanding of situation awareness in relation to remote operators of autonomous vehicles. *Cognitive Research* 6, 1 (2021).

[3] M. De Ryck, M. Versteyhe, and F. Debrouwere. 2020. Automated guided vehicle systems, state-of-the-art control algorithms and techniques. *Journal of Manufacturing Systems* 54 (2020), 152–173. https://doi.org/10.1016/j.jmsy.2019.12.002

[4] J. Feiler, S. Hoffmann, and D. F. Diermeyer. 2020. Concept of a Control Center for an Automated Vehicle Fleet. In *2020 IEEE 23rd International Conference on Intelligent Transportation Systems (ITSC)*. 1–6. https://doi.org/10.1109/ITSC45102.2020.9294411

[5] Alexander Mirnig, Tim Kaiser, Artur Lupp, Nicole Perterer, Alexander Meschtscherjakov, Thomas Grah, and Manfred Tscheligi. 2016. Automotive user experience design patterns: an approach and pattern examples. *International Journal On Advances in Intelligent Systems* 9 (2016), 275–286.

[6] Fabio Sgarbossa, Eric H Grosse, W Patrick Neumann, Daria Battini, and Christoph H Glock. 2020. Human factors in production and logistics systems of the future. *Annual Reviews in Control* (2020).

[7] Bram Van Meldert and Liesje De Boeck. 2016. Introducing autonomous vehicles in logistics: a review from a broad perspective. *FEB Research Report KBI_1618* (2016).