ROLES IN THE TELEOPERATION OF HIGHLY AUTOMATED VEHICLES IN PUBLIC TRANSPORT

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1. INTRODUCTION

Teleoperation is a promising approach to boost the introduction of highly automated driving. It transfers exceptionally challenging driving tasks from the vehicle's automation to a human operator who remote-controls the automated vehicle (AV). Particularly in public transport, teleoperated driving could contribute significantly to flexible mobility solutions such as on-demand shuttle services on the "last mile" between a major hub of transport, e.g., a train station, and the final destination (Hamburger Hochbahn, 2021; RealLab Hamburg, 2020). In order to link teleoperated AVs with other means of transport and coordinate subtasks of teleoperated driving, facilities with distinct roles and responsibilities regarding the teleoperation of AVs, so-called Remote Operation Centers (ROCs), may facilitate safe and efficient AV operations embedded in public transport. Their structure und roles entailed are described in this paper. The ROCs will be responsible both for monitoring AV operations in a specified area overall and intervening in case of disturbances. Their architecture is based on the assumption that vehicles will be widely automated (SAE level 4 (Society of Automotive Engineers, 2021)), i.e., they will be operational under a plethora of Operational Design Domains (ODDs), covering most use cases. Interventions by the operator are therefore not critical for ensuring safety, as the automation will be able to conduct minimum risk maneuvers and bring itself to a safe halt without posing a threat to surrounding traffic. Rather than that, human operators will be able to extend the range of available ODDs. Thus, human intervention is optional but increases operational efficiency and passenger satisfaction.

A ROC will be comprised of the following central roles: a central manager and overseer of operations, the Remote Coordinator (RC), several operators who execute direct driving tasks, the Remote Driving Operators (RDOs), and one or more Remote System Operators (RSOs) that maintain the backend of remote-operation, and a couple of peripheral roles. Each role entails a certain set of requirements, tasks and responsibilities and requires a distinct human-machine interaction (HMI) concept for a workstation.

2. REQUIREMENTS OF ROC STAFF FROM A HUMAN FACTORS PERSPECTIVE

To design a ROC and its roles, a number of requirements regarding human factors need to be fulfilled. First, the level of the ROC staff's *situation awareness* (SA) needs to be specified. Referring to Endsley's (1995) conceptualization, while direct driving tasks are likely to focus on the perceptual level of SA, more coordinative, supervisory roles may center around the higher levels comprehension and perception. Thus, “staying on the loop” (Merat et al., 2019) may depend on the actual tasks an operator carries out. Second, sustaining attention, or *vigilance,* plays a vital role. Previous research has shown a diminishing attentional span when executing monotonous tasks (Langner & Eickhoff, 2013). Monitoring highly automated road traffic may qualify as such a task. It is therefore imperative to vary tasks and actively creative opportunities for engagement in order to shift the attentional focus, which in turn helps maintaining or restoring vigilance (Wickens et al., 2003).

Third, an optimal *task load* needs to be assured. Not only the frequency and variation of tasks is crucial but also the number of tasks that need to be fulfilled at a given point in time. Since underloading in tasks may encourage mind-wandering and therefore decrease task performance but that the same is true for overloading (Thomson et al., 2015), a medium level of task load may yield the best performance.

An example for balancing task load is the way remote-control tasks are allocated in the ROC: While the supervisory role, the RC, is responsible for indirect remote-control tasks (e.g., setting waypoints or determining trajectories) that can be accomplished relatively easily and quickly and permit simultaneous task execution, the more mentally demanding direct remote-control tasks that require full attention and do not allow for multitasking are assigned to another role, the RDO. Therefore, whenever a direct control tasks is imminent, the RC delegates it to the RDO.

3. PROPOSAL FOR A ROLE MODEL IN THE ROC

The following section presents a model of the central and some peripheral roles in the ROC, taking into account the human factor requirements listed above. Each role comes with separate tasks which require diverging skills and qualifications. The role model is based on previous research on scenarios and human-machine interaction (HMI) strategies for AVs in public transport (Kettwich & Schrank, 2021; Kettwich, Schrank & Oehl, 2021), a systematic analysis of work in control centers of public transport (Kettwich & Dreßler, 2020), and the collection and systematic classification of use cases and scenarios in teleoperated driving (Kettwich, Schrank, Avsar & Oehl, 2021)

3.1 Central Roles

Three central roles are suggested. First, the *Remote Coordinator (RC)* is in charge of the ROC. It is the RC’s central responsibility to make sure all incidents are noticed, attended, resolved, and documented. Hence, his main tasks include monitoring automated driving operations, occasional remote-controlling AVs as well as managing operational disruptions. However, such disruptions are projected to be relatively rare, with the majority of time allocated to monitoring tasks. These tasks concern both the vehicle fleet, the individual vehicle, the traffic infrastructure, and the concrete traffic situations that the AV is exposed to. At fleet level, the primary objective is to obtain a comprehensive representation of the fleet’s operational status. At AV level, the focus is on monitoring the vehicle in terms of schedule compliance, i.e., avoiding early arrivals and delays, and technical functioning. Furthermore, the automation is monitored when planning and executing driving maneuvers, and when maintenance tasks are carried out. At infrastructure level, the RC monitors the electric charging and traffic infrastructure. Regarding the traffic situation, the RC monitors this, adjusts the route based on it in collaboration with other mobility operators such as bus and railway companies, to assure intermodal mobility and meet current travel demands. Regarding remote-control of the AV, the RC exerts indirect control only by determining trajectories or setting waypoints that are connected to a trajectory. Direct driving tasks are delegated to the Remote Driving Operator (RDO). In case of disruptions, the RC is responsible for accepting emergency calls and remotely supports the on-site intervention of emergency services. Incidents and their resolution are documented by the RC.

Second, the *Remote Driving Operator's (RDO)* main task is the direct remote-control of the AV using a steering wheel to turn and pedals to accelerate and brake. He is assigned tasks by the RC and is supported by a navigation system that gives directions. In the event of disruptions, the RDOs must report to the RC on duty.

Third, the *Remote System Operator (RSO)* is responsible for maintaining the operation of a fleet of AVs at a systemic level. His tasks include configuring automation software for all system components, reanalyzing video images, categorizing unclassified objects, and assisting the RC in incident analysis.

3.2 Peripheral Roles

In addition to the core roles of the ROC, numerous peripheral roles without immediate criticality for maintaining AV teleoperation are conceivable. A *Service Technician (ST)* may ensure the operation of the fleet beyond the scope of the RSO. He takes over cases that the latter cannot resolve. The ST's central responsibilities are thus to diagnose AV malfunctions, resolve them, and manually steer the AV to a safe halt or until the automated driving mode can be resumed. Further roles indirectly involved in the operation of teleoperated AVs in public transport are dispatchers that balance demand and supply of AVs, passenger service providers that support travelers with special needs, cleaning and maintenance staff that ensure sustained operability of the AV fleet, and security staff to deescalate conflicts and prevent vandalism.

4. SCOPE OF FURTHER RESEARCH

The proposed model is merely a first conceptual step to kick off a debate on how to design the work of future remote operators and the workstations they will be using from a human factors perspective. Along refinement, the following issues need to be considered in addition to the ones mentioned above: How can the ROC staff take over the driving task from the automation safely and smoothly? Does the AV need to stop completely or can the takeover take place during the ride? How long does the ROC staff need to be informed before takeover? How does latency in data transfer affect teleoperation and how can it be mitigated? Which scenarios can be effectively and efficiently resolved by the ROC and which ones should be left to the automation, such as performing minimum risk maneuvers?

A first attempt to incorporate the human factors perspective in designing ROCs is the project "U-Shift 33" (Weimer, 2019). It will largely be based on the role model described above.

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