TELEOPERATION AND REMOTE DRIVING –
REQUIREMENTS FOR SUITABILITY AND COMPETENCE OF REMOTE DRIVERS

Preliminary Results of Research Project funded by German Federal Highway Research Institute (Bundesanstalt für Straßenwesen)
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BACKGROUND & MOTIVATION

VEHICLE TELEOPERATION

CONCEPT

- Influence on the control of a vehicle by an instance that is located outside the vehicle

POTENTIAL APPLICATIONS

- In automated driving: e.g. managing and handling of unexpected/complex situations (e.g. construction site)
- In non-automated driving: e.g. delivery and hand-over of shared cars

DEFINITIONS

<table>
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<tr>
<th>Remote Driving</th>
<th>The remote driver takes control of the vehicle at the navigation, guidance and stabilization levels, whereby vehicle systems can support the remote driver in the driving task. The remote driver is responsible for safe driving.</th>
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<td>Remote Assistance</td>
<td>The remote assistant provides control-relevant recommendations/information or initiates certain driving maneuvers, whereby the vehicle control is carried out autonomously by a corresponding driving system. The autonomous driving system is responsible for safe driving.</td>
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OBJECTIVES OF RESEARCH PROJECT
SUITABILITY AND COMPETENCE OF REMOTE DRIVERS

REQUIREMENTS FOR REMOTE DRIVERS

- Remote driver is confronted with tasks that are different to driver located inside vehicle, e.g.
  - Perception and understanding of driving environment mainly video-based
  - Dealing with latency
  - Remote communication with further persons and/or passengers
  - Changed communication with other road users

→ Need for definition of **minimum requirements concerning suitability, competence and reliability of remote drivers**
  - Focus on remote driving (i.e. remote assistance is not covered within research project)
  - Focus on applications and scenarios that are likely to be feasible in near future
→ Derivation of concrete regulations for selection, training, further training and regular inspection and monitoring of remote drivers
APPROACH AND METHOD

LITERATURE REVIEW & EXPERT SURVEY

LITERATURE REVIEW

- Topics
  - Analysis of human factor challenges during remote driving
  - Overview of current remote driving workplaces
  - Suitability and capability in remote vehicle driving
  - Suitability and capability in further remote application areas (e.g. railway, aviation, shipping, unmanned ground vehicles)

EXPERT SURVEY

- Requirements for suitability, competence and reliability of remote drivers
- Sample & Organisation
  - N=13 Persons from research institutions, teleoperating companies, suppliers
  - 2-hour online interview with interview protocol approved by interviewee
HUMAN FACTOR CHALLENGES OF REMOTE DRIVING

- **Latency/Jitter**
  - Delay time that necessarily occurs during remote driving, because information (video signals, vehicle states, control signals) is transferred between teleoperator workstation and vehicle.
  - Impact on performance and efficiency (and thus also safety) of vehicle control by driver
  - Could lead to cyber sickness

- **Workload**
  - Alternation between phases of significant demand and phases of low workload
  - Latency and jitter important factors influencing workload

- **Lack of situation awareness**
  - Mental representation of the current driving situation by remote driver
  - Consists of three levels: Perception, Understanding, and Anticipation (Endsley, 1988).
  - Prerequisite for adequate control inputs and driving performance

- **Tele-Presence** (i.e. feeling of steering real vehicle in real environment)
  - Includes cognitive and emotional components
  - Feeling of presence is generated, among other things, by immersion (i.e. involvement in presented environment)
RESULTS

LITERATURE REVIEW

REMOTE DRIVER WORKPLACE

- Human-machine interface for remote driver, in order to control vehicle
- Structure similar to static driving simulators
  - Mockup:
    - Generic
    - Seat, pedals and steering wheel
    - No motion system
  - Visual system:
    - At least three screens
    - Additional views (e.g. bird's eye view) or viewing aids (e.g. display of current ego trajectory)
    - Rear views
    - Other relevant information (e.g. current latency, quality of connection)

https://ottopia.tech
https://vay.io
https://mira-mobility.com
RESULTS

LITERATURE REVIEW

STATE OF RESEARCH ON SUITABILITY AND COMPETENCE REQUIREMENTS IN REMOTE DRIVING

- No scientific publications dealing with issues related to the suitability and competence of remote drivers
- No derivation of science-based regulations for selection, training, and periodic assessments of remote drivers

STATE OF THE ART RESEARCH IN RELATED APPLICATION AREAS

- Analysis of publications in different teleoperation areas, e.g. shipping, railway, aviation, unmanned ground vehicle
- Transfer knowledge to remote driving difficult, because of different characteristics of application areas (e.g. vehicle size, passengers, dynamics, complexity)
- Findings
  - Experience and regular training in real vehicle important for teleoperators’ situation awareness, perspective taking, empathy, and sense of presence
  - Additional skills include understanding of data transmission (incl. possible problems) as well as communication
  - Previous gaming experience could be helpful
  - Simulative approaches suitable for training
RESULTS

EXPERT SURVEY

DRIVER SUITABILITY AND SELECTION

- Prerequisites for remote driving trainees
  - Driving licence for (at least) teleoperated vehicle
  - Significant driving experience
  - Minimum age of about 21-30 years
  - No maximum age, but regular assessment of fitness to drive
  - Character of driver is very important for safe driving
    - Compliance with traffic regulations
    - Criterion regarding traffic register

- Compliance with traffic regulations
- Criterion regarding traffic register

- Driving experience [years]
- Minimum age [years]
- Maximum age [years]

N=13 experts
RESULTS
EXPERT SURVEY

EDUCATION AND TRAINING

- Training content, e.g.
  - Basic information concerning teleoperation
  - Technical information about teleoperation system and vehicle
  - Impact of latency/jitter and further human-factors challenges
  - Awareness for road safety and safety culture
  - Functionality and handling of teleoperator workstation
  - Driving practice (in closed-off areas and real traffic)
  - Takeover and return of vehicle control
  - Influence of operating conditions (e.g. weather)
  - Procedures in case of incidents/accidents
  - Communication with personnel and, if applicable, passengers
  - Knowledge of local traffic environment

- Estimation still difficult, but initial training to become remote driver should have a duration of at least a few weeks
  - Subsequent phase of practice under supervision (under supervision of experienced driver)

- Further training as required (e.g. for new system functions or vehicle types)
RESULTS
EXPERT SURVEY

EXAMINATION AND REGULAR FITNEES-TO-DRIVE ASSESSMENT

- Exam should complete initial training for remote drivers
  - Assessment of theoretical knowledge as well as practical driving
- As far as possible, final exam should be done by external body
- Simulative approaches could complement training and examination of remote drivers
  - Creation of controlled operational/traffic situations
  - Operating a virtual vehicle in simulated traffic environment
- Regular assessment of fitness-to-drive
  - As already mandatory for professional drivers
  - Including regular assessment of character (e.g. by checking traffic register)

SUPERVISION AND MONITORING OF DRIVER STATE

- Experts do not agree if technical systems (e.g. gaze detection) should be used to assess remote drivers’ level of attention/distraction
  - Distraction as major cause for accidents vs.
  - Training, raising awareness and organizational measures (e.g. break times)
RECOMMENDATIONS (PRELIMINARY)

SUITABILITY, COMPETENCE AND RELIABILITY OF REMOTE DRIVERS

PRIOR KNOWLEDGE/EXPERIENCE & FITNESS-TO-DRIVE

- **Driver license and driving experience**
  - **Valid driver license** corresponding to the class of the teleoperated vehicle
  - At least 3 years of active **driving experience** with same vehicle class as driven remotely

- **Minimum and maximum age**
  - **Minimum age of 21 years** (same as regulation for driver license for passenger transportation)
  - No maximum age, but regular assessment of physical, cognitive and character fitness-to-drive

- **School diploma**
  - Completed **secondary school** education
  - **Sufficient cognitive ability** to understand learning content of education for remote drivers

- **Fitness-to-drive**
  - Due to **high level of responsibility**, the remote driver should be subject to (at least) similar driving fitness requirements as for passenger transport driver license
  - Sufficient **capability to extract relevant information from screens** → specific tests
  - Certificate of good conduct and few entries in traffic register (i.e. nearly no documented traffic offences)
  - Specific physical handicaps could be handled less restrictive compared to in-vehicle drivers
RECOMMENDATIONS (PRELIMINARY)

SUITABILITY, COMPETENCE AND RELIABILITY OF REMOTE DRIVERS

INITIAL TRAINING

- Learning content according to the specifics and tasks for remote driver, e.g.
  - **Teleoperation concept**: legal basis, technology, process, vehicle control incl. takeover and return, stakeholders and roles, organization, policies and regulations, use cases, ODD and conditions for operation
  - **Teleoperator workstation**: components, technology, operation, login, integration into control center
  - **Latency/Jitter**: causes, implications, compensation
  - **Communication and video transmission**: technical background, potential problems
  - **Virtuality**: sensor information and video display, cyber sickness, immersion and tele-presence
  - **Human-factor challenges**: workload, situational awareness, implications for driving safety
  - **Communication** with other operational personnel, passengers (if any) and other road users
  - **Safety awareness** (safety and security) and assumption of perspectives regarding comfort and safety
  - **Operational design domain**: Teleoperation and driving in different traffic environments (city, country, highway) and environmental conditions (brightness, weather conditions, traffic density)
  - **Safety checks**: before departure, during the journey, after parking the vehicle
RECOMMENDATIONS (PRELIMINARY)
SUITABILITY, COMPETENCE AND RELIABILITY OF REMOTE DRIVERS

INITIAL TRAINING (CONT.)

- **Scope and approach of initial training**
  - **Theoretical** as well as **practical** learning methods
  - **Simulator** training for practicing correct behaviour in certain scenarios that can hardly be trained in reality

- **Final examination**
  - Conducted by a person who was not involved in training
  - Evaluation of **theoretical knowledge**
    - Too many errors or one safety-relevant error lead to failure of exam
  - **Practical driving** test
    - Covers essential operational and traffic situations
    - Failed if one safety-related error or repeated errors
    - Usage of driving simulator is encouraged
RECOMMENDATIONS (PRELIMINARY)
SUITABILITY, COMPETENCE AND RELIABILITY OF REMOTE DRIVERS

CONTINUOUS TRAINING AND ASSESSMENT

- Regular **fitness-to-drive assessment**
  - Remote driving **license for a limited period** (e.g. 5 years)
  - **Renewal** only if physical, cognitive, and character requirements are fulfilled
  - Concerning **older drivers**, assessment should be done at **shorter intervals**
  - Regular check for valid driver license for respective vehicle class

- Regular/continuous **training**
  - Ensures competence of personnel - especially in case of technical or operational changes
  - **Documentation** of training measures and success of participation

- Assessment **safety of driving**
  - Possible measures include real **driving accompanied by instructor/supervisor**, assessment using **driving simulator**, or check of performance using **logged driving files**
  - **Incident management** including evaluation of incidents
    - Situational causes
    - Identification of remote drivers who stand out due to frequent incidents
RECOMMENDATIONS (PRELIMINARY)
SUITABILITY, COMPETENCE AND RELIABILITY OF REMOTE DRIVERS

MONITORING OF DRIVER STATE

- Distraction warning
  - Detection of distraction using **technical system**
  - Warning if remote driver is distracted (and MRM if necessary)
  - See also: EU Regulation 2019/2144 Automotive Type Approval regarding attention monitoring systems

- Limited driving time and regular breaks
  - Remote drivers need to remain focused and attentive regardless of the time of day or workload

- Complete ban on alcohol and other intoxicating substances
  - Compliance should be checked regularly
  - **Spot checks** on alcohol and drug consumption
  - Alcolocks as an option
Thank you for your attention

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