Challenges for the Remote Operation of Vehicles
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BACKGROUND

- Vehicles can be operated from a remote location
  - First done in 1925 by radio control
  - Used in mining, agriculture, drone warfare, and dockless scooters
  - All states allow AV developers and five states can remotely operate road vehicles
  - Allows Level 4 AVs to operate at Level 5

- Questions remain for remote operation of vehicles on public roads in the United States
  - Is it legal?
  - Is it technically feasible?
  - Is it practical?

LEGAL ASPECTS

- Driver’s Physical Presence in the Vehicle
  - No state statutes expressly require physical presence of a driver as of 2014
  - Other rules imply presence
    - Unattended vehicles, abandoned vehicles, crash obligations, safety belts, driver sight, driver interference
    - Uniform Vehicle Code (basis for many state motor vehicle codes) states that
    - Other rules

- Remote Operator’s Physical Presence within the United States
  - States recognize driver’s licenses from other states
  - Driver’s licenses from foreign countries are generally recognized. Some states require an International Driver’s License

REFERENCES

- Driver’s Physical Presence in the Vehicle
- Remote Operator’s Physical Presence within the United States
- Valid driver’s license required.
- Jurisdiction not specified.
- Not specified.
- U.S. driver’s license required.
- Not specified.
- Not specified.
- Not specified.
- State laws and regulations addressing remote operation of road vehicles

MODEL

- LTE networks barely support demonstrations
  - 100ms delay
  - Field tests require more than one provider
- 5G networks supports demonstrations
  - A few successful demos
  - 10ms delay
- Large deployments might not be feasible (1)
  - Requires 20 Mbps upload rate with 99.999% probability
  - Interference becomes an issue in dense deployments
  - Could be restricted to high-velocity corridors

TECHNICAL FEASIBILITY

REMOTE OPERATION STAFFING MODEL

- Erlang C Formula
  - Used in queuing theory to predict number of operators needed to manage a call center while meeting a performance target.
  - $P_l(n, a) = \frac{a^n}{n!} \cdot \frac{e^{-a}}{1 - \frac{1}{m}}$
  - $\mu = \frac{1}{\text{Time per request}}$
  - $\lambda = \frac{1}{\text{Rate of requests}}$
  - $m = \text{Number of operators}$
  - $n = \text{Number of requests}$

STAFFING REQUIREMENTS

RESULTS

- Staffing assumptions (12-hour shifts)
  - Four days on, four days off
  - Staff needed = (Night shift + Day Shift) × 2

- Operators needed to manage all remote driving in the United States

CONCLUSIONS

- Remote operation of vehicles on public roads is somewhat common in industry, yet has received little attention from regulators and researchers.
- Remote operation is not prohibited by most state-motor vehicle codes, nor is it prohibited under most definitions of driver/operators. Other state laws imply a driver’s physical presence.
- Of five reviewed states that address remote operation in their AV laws, only one requires that a remote operator must be physically located in the United States.
- Queuing theory was used to estimate the number of remote operations needed to manage a large fleet of AVs requesting concurrent takeover. At Waymo’s 2018 disengagement rate, all driving in the United States could be managed by 4,000 to 37,000 operators working in shifts. For comparison, 4.4 million are employed as drivers in the United States.

ACKNOWLEDGEMENTS

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STATE Date Title Driver’s License Physical Location
Florida 2017 House Bill 311 U.S. driver’s license required. United States.
Arkansas 2017 Senate Bill 481 Valid driver’s license required. Not specified.
South Carolina 2017 Senate Bill 149 Valid driver’s license required. Not specified.
Utah 2017 House Bill 101 Valid driver’s license required. Not specified.

State and local laws addressing remote operation of road vehicles

REFERENCES

- VMTA. (June 2018). Virginia Government. 2017 Legislative Session. Virginia General Assembly
- VMTA. (October 2019). Virginia Government. 2019 Legislative Session. Virginia General Assembly

Erlang C model parameters

Operator Requests

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