REGULATING AUTONOMOUS VEHICLES: LEVERAGING SCENARIOS AND SIMULATIONS

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WHAT DO THE REGULATORS WANT?

- Regulators need to be able to assure their respective Governments that autonomous vehicles (AVs) are **safe to be brought to market**
- Regulators need to be able to reassure the public that AVs will not behave recklessly
- The level of safety needed is not yet clear; but AVs will certainly need to be safer than human-driven vehicles
- Regulators do not want to stifle innovation
CONTENT OF THIS PRESENTATION

- Need for Simulation
- Scenario-Based Testing
- Potential Approach
WHY THIS ISN’T LIKE TRADITIONAL AUTOMOTIVE SOFTWARE

• An Automated Driving System (ADS) is not like traditional automotive software
• It’s impossible to write a specification document

Example
• Level crossing with barriers down

Does the specification include:
• If there’s already a queue of vehicles at the barrier
• If there’s a lorry at the front of the queue, obscuring part of the barriers
• If the flashing lights aren’t working
• If it’s nearly (but not quite) dark
• If it’s nearly dark and there’s a grey car at the back of the queue
• …
HOW DOES THIS COMPLEXITY IMPACT TESTING?

• The ADS must respond to a large number of factors (the type & location of every actor in the scene, road type & layout, traffic signals,…)
  – Different decisions may be required for each possible combination
  – Not feasible to write an infinite number of test scripts

• Hard to separate problem into independent modules – need take everything in the environment into account when driving

Examples

Las Vegas Navya collision  Google/Waymo bus collision
SAFETY ASSURANCE: SCENARIO-BASED TESTING

• Scenarios capture key test cases for autonomous driving
• Allow focused, efficient testing of AVs
• NHTSA: “entities are encouraged to consider all known behavioural competencies in the design, test and validation of their ADS”

   Autonomous Vehicle Test & Development Symposium

HOW OUR PROPOSAL FITS IN

- Our focus is on scenarios and simulation, to help validate the behaviour of SAE Level 4/5 vehicles
- We propose physical testing of sensor processing, and simulation of scenarios
- Our approach is consistent with OICA’s 3 pillars

**Type Approval**
- Existing TA + use case tests
- Verification of sensor processing

**ADS Audit**
- Supplementary to OICA ideas: simulate many scenarios

**Real World Test Drive**
- Key part of process
- Is 60 minutes enough?
HOW DO WE USE SCENARIOS?

• Widely-recognised need for a scenario library, maintained by an independent body
  – Available to all ADS developers
  – Ensures that new, **safety-critical scenarios are shared** with everyone
  – Use common electronic formats for sharing

• A subset of scenarios would be part of the audit assessment
  – Non-audited scenarios are still useful to help ADS development

• Updates to the scenario library must have their integrity and relevance verified

• Start small, with perhaps just 100 scenarios
  – Some may require manual updates to include key information
SCENARIO APPLICABILITY

• Scenarios should cover:
  – Edge cases
  – Normal driving (international)
  – Normal driving (country-specific conventions and laws)

• Scenarios should be tagged with the list of countries they are applicable for
  – Allow easy extraction of a test suite to show compliance to laws and regulations for a specific territory

• Scenarios should be tagged with recommended or audited, normal or edge-case, …
SOURCES OF SCENARIOS

• Expert knowledge
  – TSC report “Taxonomy of Scenarios for Automated Driving”¹
  – NHTSA “Federal Automated Vehicles Policy”, September 2016²
• Pre-existing scenario repositories (CR&D, industry)
• Data recorded from sensor-equipped vehicle fleets
  – Automatic processing to extract collisions, near-misses, and other undesirable incidents
    • Use heuristics such as brake pressure applied
    • Will probably need human review
  – Existing MOVE_UK project³ is collecting a highly relevant dataset
• Real-world collisions
  – New AV collisions and near-misses (requires data recording on production vehicles)
  – Existing collision databases

PART 2

- Need for Simulation
- Scenario-Based Testing
- Potential Approach
NEED FOR VERIFICATION IN SIMULATION

“To demonstrate that fully autonomous vehicles have a fatality rate of 1.09 fatalities per 100 million miles [...] with a fleet of 100 autonomous vehicles being test-driven 24 h a day, 365 days a year at an average speed of 25 miles per hour, this would take about 12.5 years.”

• Using scenarios means we can focus testing on the critical and challenging cases
• Can we run enough scenarios in the real world to have reasonable confidence in the safety of AVs?

NUMBER OF SCENARIOS

Everyday scenarios (examples on right): but also
- Light aircraft landing on the road
- Smoke from a forest fire blowing across the road
- ...

Timescales for physical testing
- Assume, given one test vehicle, you can test 15 scenarios per day
- 1,000 scenarios takes over 3 months
- Waymo use a library of >20,000 scenarios

In summary, physical testing:
- Takes too long
- Costs too much
- Endangers participants
VERIFICATION IN SIMULATION: OVERVIEW

- To realise the ambition of this approach will require co-operation between ADS developers, OEMS and regulators.
- Access to executable copies of their automated driving system (ADS), with associated vehicle dynamics models, expected to be key.

Needs for Simulation:
- Allows many scenarios to be tested quickly.
SIMULATION: OTHER ACTORS

• Most scenarios will need several actors – other vehicles, pedestrians, bicycles, …

• Often these will have to react to the decisions made by the ADS. E.g.:
  – If the ADS gives way unexpectedly, a simulated human-driven vehicle might run into the back of it
  – When an ADS is attempting to merge into fast-moving traffic, actor vehicles should slow down to make space for it
PART 3

Need for Simulation

Potential Approach

Scenario-Based Testing
INTEGRATED FRAMEWORK

<table>
<thead>
<tr>
<th>Controlled test facility with a ‘Digital Twin’</th>
<th>Public Road</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type Approval Tests</td>
<td>Audit (simulation)</td>
</tr>
</tbody>
</table>

- **Perception Layer**
  - Drive a vehicle along a test route with known targets
  - Compare with ground truth

- **Scenario-Based Testing**
  - Simulation of scenarios, with randomisation

- **Real-World Test Drive**
  - Physical testing

Do the sensors give the right output?

Does the ADS make the right decision based on data received?

Does the vehicle at a system level perform appropriately?

This is a short-term goal to achieve a basic level of validation for AVs
ADS ARCHITECTURE REQUIRED FOR THIS APPROACH

- The solution presented relies on the ADS having two key modules, with a defined interface between them.
TECHNICAL CHALLENGE: SENSOR FIDELITY

- Sensor technology is rapidly evolving and maturing
- Many types of sensor exist, all are complex
- AVs use a variety of sensors that need to operate in many conditions
- Sensor simulation is computationally demanding
SENSOR PROCESSING VERIFICATION (PHYSICAL)

- Perform all sensor testing in the real world
- Use dedicated test centres, where ground truth for the movement of all actors can be measured
- Compare the ADS’s “object model” with the ground truth
  - False negatives should carry a higher weight than classification and position errors

**Benefits**
- No need for highly accurate sensor or environment modelling
- Clear and objective scoring of performance
LONGER-TERM VISION

• Longer term: Test the ADS end-to-end in simulation
  – Cheaper and faster
  – Many more vehicle types, pedestrian types, weather, object colours, etc, can be tested
• There will be a learning process as technology evolves
EVOLUTION OF REGULATORY FRAMEWORK

- Simulation allows much higher confidence to be obtained
- As the technology matures, more testing can be done in simulation
- Simulation can never completely replace physical testing
SUMMARY

• Verification of an ADS is a complex problem
• A pragmatic and effective solution is needed quickly, to support the introduction of highly automated and autonomous vehicles to the market
• Such a solution should be achieved through regulators and industry collaborating to define and meet common but evolving objectives
Thank you

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