MEASURING THE SAFETY OF ADS: HOW SAFE IS SAFE ENOUGH?

Eileen Herbers

January 25, 2024
What are ADS?

Automated Driving Systems
What are ADS?
How safe is safe enough?

How do we define what is acceptably safe?
What risk do we currently accept on the road?
Do ADS reduce any of the current risk?
Do ADS create any additional risk?
SAFER THAN A HUMAN DRIVER
Total Traffic Fatalities on US Roadways by Year

How safe is safe enough?

- How do we define what is acceptably safe?
- What risk do we currently accept on the road?
- Do ADS reduce any of the current risk?
- Do ADS create any additional risk?
- Who defines what is acceptably safe?
- How is ADS safety and performance tested?
- What metrics and thresholds are used to determine safety?
- Who is at fault if ADS are involved in a crash?
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PURPOSE

Use naturalistic driving data to inform scenario selection that will be used to measure how ADS might perform in these scenarios.

Determine and analyze some scenarios in which ADS may not provide the predicted advantage of reducing or mitigating safety-critical events (SCEs).
METHODS

Naturalistic Driving Data

• Operator Factor: Fault of the other driver
• Visual Obstruction: Present

<table>
<thead>
<tr>
<th>Configuration Category</th>
<th>Number of Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Angle, Sideswipe, Merge, Cut-in</td>
<td>1325</td>
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<tr>
<td>Forward Impact</td>
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<td>Perpendicular</td>
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<tr>
<td>Head on (Initial Opposite Direction)</td>
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<tr>
<td>Backing Up</td>
<td>107</td>
</tr>
<tr>
<td>Roadside Departure</td>
<td>17</td>
</tr>
</tbody>
</table>
### METHODS

<table>
<thead>
<tr>
<th>Variable</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>T0</td>
<td>Conflict Object Identified</td>
</tr>
<tr>
<td>T1</td>
<td>Conflict Begin</td>
</tr>
<tr>
<td>T2</td>
<td>Subject Reaction Start</td>
</tr>
<tr>
<td>T3</td>
<td>Impact or Proximity Frame</td>
</tr>
</tbody>
</table>

#### Safety Surrogate Measures
- Relative Velocity
- TTC
- Minimum Required Deceleration

#### Video Review
- Validate that timestamps and values are reasonable
- Identify outlying cases
- Categorize scenarios
DRIVER REACTION

- No Reaction: 108
- Braked Only: 1193
- Braked and Steered: 795
- Steered Only: 37
- Accelerated: 4

Numbers represent the count of driver reactions in each category.
Minimum required deceleration to avoid a crash if the subject vehicle were equipped with ADS.

11.57%
Percentage of events analyzed that required a minimum required deceleration value greater than 1g
Acceleration (m/s$^2$)

Baseline Events

ADS Events that required a minimum deceleration greater than 1g
How safe is safe enough?

How do we define what is acceptably safe?

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Who is at fault if ADS are involved in a crash?
SAFER THAN A HUMAN DRIVER
CONCLUSION

• Using a small set of naturalistic data has the potential to convey important information to wide-scale ADS deployment that simulation or closed-track testing cannot.

• Human drivers are generally good at performing evasive maneuvers that require braking and steering, which requires a complex set of decisions for ADS.

• ADS may not perform as expected in:
  • High-speed turns
  • Blind turns and hills
  • Lane-change events with other vehicles
  • Scenarios with significant occlusion

• Near-crash and crash-relevant events are crucial to understanding the complex driving context
THANK YOU

SAFE-D
SAFETY THROUGH DISRUPTION

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Variables of Safety

- Harm
- Probability
- Uncertainty
- Control

Figure 1. Safety as a function of probability and uncertainty. x, y and z are levels of safety such that x > y > z.
HOW SAFETY IS CURRENTLY MEASURED

<table>
<thead>
<tr>
<th>ADAS (L1 &amp; L2)</th>
<th>ADS (L3 &amp; L4)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crash Statistics</td>
<td>Simulation</td>
</tr>
<tr>
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<tr>
<td>Closed Test-Track Testing</td>
<td>Closed Test-Track Testing</td>
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<tr>
<td>Field Testing</td>
<td></td>
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<tr>
<td>Insurance Claims</td>
<td></td>
</tr>
</tbody>
</table>
HOW SAFETY IS CURRENTLY MEASURED

Crash Rates

\[
\frac{\text{# of crashes of ADS}}{\text{# of miles driven by ADS}} < \frac{\text{# of crashes of human-driven vehicles}}{\text{# of miles driven by human drivers}}
\]
HOW DO CURRENT ADS MEASURE SAFETY?

Collision Frequency

“Cruise relied upon factors of collision frequency, primary contribution and risk of injury when comparing its AVs to the human ride-hail benchmark.”

Cruise’s “first million driverless miles resulted in only 36 collisions, of which 94% were caused by the behavior of other parties.”

• 21% other parties reversed into a stationary Cruise AV
• 26% other parties rear-ended Cruise AV often at stop signs or red lights
• 3% other parties drove the wrong way on a one-way road
• 9% other parties blowing through red lights or stop signs and made contact with a stationary Cruise AV

Insurance Claims

Waymo vehicles “reduced the frequency of bodily injury claims by 100 percent, compared to Swiss Re’s human baseline of 1.11 claims per million miles.”
Population of Crashes

- Population of crashes that could potentially be mitigated by ADAS features
- Crashes within the above population that can’t actually be mitigated by ADAS or ADS features because information is unknown
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- Crashes within the above population that can’t actually be mitigated by ADAS or ADS features because information is unknown
- Population of crashes that could potentially be mitigated by ADS
- Population of crashes that cannot be avoided by ADAS or ADS
Population of crashes that could potentially be mitigated by ADAS features

- Ex: Rear-end crashes (AEB)

Crashes within the above population that can’t actually be mitigated by ADAS or ADS features because information is unknown

- Ex: Rear-end crashes (AEB) but driver doesn’t have enough time to warnings OR car does not have enough time to brake

Population of crashes that could potentially be mitigated by ADS

- Ex: Rear-end crash, but vehicle is able to swerve

Population of crashes that cannot be avoided by ADAS or ADS

- Ex: Rear-end crash around a tight curve or over the crest of a hill

Population of crashes this research focuses on
**How to determine conflict object**

<table>
<thead>
<tr>
<th>T</th>
<th>Time point</th>
<th>Host Speed</th>
<th>Range Rate x</th>
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<tbody>
<tr>
<td>T1</td>
<td>Conflict Begin</td>
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<tr>
<td>T1.2</td>
<td>Closest radar point to conflict begin</td>
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<td>X</td>
</tr>
<tr>
<td>T2</td>
<td>Subject reaction start</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>T2.2</td>
<td>Closest radar point to subject reaction start</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>T3</td>
<td>Impact proximity frame</td>
<td>X</td>
<td></td>
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HOW TO DETERMINE CONFLICT OBJECT
# Data by Crash and Near Crash

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<tr>
<th>Configuration Category</th>
<th>Crash</th>
<th>Near Crash</th>
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<tbody>
<tr>
<td>Angle, Sideswipe, Merge, Cut-in</td>
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<tr>
<td>Forward Impact</td>
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