Recent NHTSA Lane Keeping Support Research

Taylor Manahan
Transportation Research Center Inc.

Garrick Forkenbrock
NHTSA
Presentation Overview

• What is LKS?
• 2016 Test Objectives and Methods
  – Evaluate contemporary systems
  – European NCAP and NHTSA procedures
  – Develop test maneuver automation using a steering robot
  – Results and observations
  – Problems associated with a steering robot
  – Future Plans for LKS Research
What is LKS?

- Lane keeping support (LKS)
  - Momentarily applies a steering torque and/or a braking input
  - Used to help restore lane position
  - Automated Vehicle SAE Level 0
- LKS is not Lane Centering Control (LCC)
  - LCC continuously applies steering inputs
  - Used to maintain lane position in the center of the lane
  - Automated Vehicle SAE Level 1
2016 Research Objectives

• Use a steering robot to improve test accuracy and repeatability
  – Evaluate consequences associated with a steering robot
• Assess the Euro NCAP and 2016 NHTSA (experimental) LKS test methods
• Evaluate LKS system responses of contemporary vehicles
  – Ability to recover from an imminent lane departure
  – Observe whether the first LKS response causes a secondary departure
    • Secondary departures may result from the LKS correction of the initial lane departure
    • NHTSA doesn’t want to correct one safety problem only to introduce another
2010 NHTSA Lane Keeping Support Procedure

- A supplement within NHTSA’s Lane Departure Warning (LDW) NCAP test procedure
- Historically used driver based steering control
- Includes two lateral velocity categories
  - **Low** - 0.1 to 0.6 m/s with a target lateral velocity of 0.5 m/s
  - **Iteratively Increased** - Increase in lateral velocity from 0.6 m/s to a magnitude where LKS can no longer prevent a lane departure from occurring

<table>
<thead>
<tr>
<th>Lateral Velocity</th>
<th>Line Type</th>
<th>Departure Direction</th>
<th>Number of Trials</th>
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<td>Low</td>
<td>Solid</td>
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<tr>
<td></td>
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<td>R</td>
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<td>L</td>
<td>10</td>
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<tr>
<td></td>
<td></td>
<td>R</td>
<td>10</td>
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</table>
2016 NHTSA Experimental LKS Procedure
(used for work described in this presentation)

- Differs from 2010 LKS test procedure in the following ways:
  - Modelled after European NCAP LKS procedure
  - Automated using steering controller robot
  - Achieves lateral velocity by travelling partially through curved radius (R=1200 m)
  - Utilizes two-part baseline tests to determine steering control release point
  - Performed at multiple lateral velocities
    - 0.1 m/s to 1.0 m/s iteratively increased by 0.1 m/s
2016 Test Matrix

**Two test types**
- European NCAP
- 2016 NHTSA (experimental)

**Three vehicles:**
- 2017 Audi A4
- 2017 Volvo S90
- 2017 Mercedes E300 (Brake-based)

### Lateral Velocity

<table>
<thead>
<tr>
<th>Lateral Velocity</th>
<th>Test Type</th>
<th>Departure Direction</th>
<th>Number of Trials</th>
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<td></td>
<td></td>
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<tr>
<td></td>
<td></td>
<td>R</td>
<td>3</td>
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2016 Test Scenario

- Vehicle initially driven in a straight line
- Transitioned to a curved path (R = 1200 m) until desired heading angle is achieved using closed loop control
- Vehicle path straightened
- At a time based on a baseline output
  - Steering enters open loop control - vehicle path straightens
  - Constant throttle position is maintained

Potential secondary lane departure

Lateral velocity established

Steering control released then LKS reaction occurs

Departure = >0.4 m (1.3 ft) past lane line
2016 Results

- Comment regarding additional tests performed with the Mercedes E300
  - Method 1: Constant throttle position after open loop control point
  - Method 2: Released throttle after open loop control point
- Key to results charts
  - No highlight (white/light blue): No tests resulted in a departure
  - Yellow: At least one, but not all tests resulted in a departure
  - Red: All tests resulted in a departure
- Red line indicates the cut-off lateral velocity for the European NCAP LKS test procedure
- “n/a” indicates no secondary departure possible because an initial recovery did not occur
- NOTE: European NCAP ratings do not consider secondary lane departures
## Results – Initial Lane Departures

<table>
<thead>
<tr>
<th>Initial Lateral Velocity (m/s)</th>
<th>Audi A4</th>
<th>Mercedes E300</th>
<th>Volvo S90*</th>
<th>Audi A4</th>
<th>Mercedes E300</th>
<th>Volvo S90*</th>
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<td>Held</td>
<td>Released</td>
<td></td>
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*Volvo S90 testing has not been fully completed at this time
# Results – Secondary Lane Departures

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<tr>
<th>Initial Lateral Velocity (m/s)</th>
<th>NHTSA</th>
<th></th>
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Testing Results Observations

• Discrepancies between Euro NCAP and NHTSA test scenarios’ results
  – Higher lateral velocities
  – Secondary lane departures

• Steering robot: influence on vehicle performance
  – Drag from motor affecting LKS capabilities
  – Primarily for secondary departures, but possibly even initial departures
Effect of Steering Robot on Lateral Response

- Steering robot is needed to insure test accuracy and repeatability, however...
- Vehicle response can be affected
LKS Test Performance Without Steering Robot
LKS Test Performance With Steering Robot
Effect Of Steering Robot Installation On Lateral Response

- Audi A4
- Volvo S90

Graphs showing the effect of steering robot installation on lateral response for Audi A4 and Volvo S90.
Summary

• 2016 LKS testing
  – LKS test maneuvers were performed using steering and braking controller robots to achieve highly repeatable steering and throttle inputs
    • Compared to driver-based inputs, test accuracy and repeatability was improved
    • Discovered use of steering controller may confound the ability accurately examine LKS system performance
  – Gained experience with the European NCAP test procedure
• Anticipated NHTSA LKS testing for 2017
  – Complete the evaluation initiated during 2016
  – Identify a way to reduce the effect of using robotic steering control
THANK YOU!

TAYLOR MANAHAN
TRANSPORTATION RESEARCH CENTER, INC.
taylor.manahan.ctr@dot.gov