A PERCEPTUAL FORWARD COLLISION WARNING MODEL USING NATURALISTIC DRIVING DATA

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**BACKGROUND**

- Early/late warnings reduce users’ acceptance and develop a mistrust due to the conflict between drivers’ expectations and the warning system \(^1,2,3\)

- The development of an efficient warning system should be based on the knowledge of unassisted driving behavior \(^4\)
OBJECTIVES

- Develop a perceptual FCW algorithm based on naturalistic driver behavior
- Compare the proposed warning distance to the warning distances of various kinematic and perceptual FCW models
BACKGROUND

- **Perceptual FCW algorithms**
  - Consider the human perceptual ability of following a lead vehicle too close address rear-end collisions
  - Usually measured by Time-to-Collision (TTC) \(^5, \, 9, \, 11\)

- **Kinematic FCW algorithms**
  - Consider vehicle kinematics (i.e., motion equations) with various assumptions on accelerations
  - Depend on following and leading vehicles speeds \(^{12-14}\)
DRIVER FOLLOWING BEHAVIOR DURING BRAKING

Data Description

Naturalistic Driving Study (NDS) Data

Position & GPS details
- Latitude & Longitude
- GPS fidelity measures

Driver behavior data
- Braking status
- Speed
- Acceleration

Radar data
- Detected vehicle type
- Relative speed
- Distance to the detected vehicle
**Driver Following Behavior During Braking**

**Car Following Identification**

<table>
<thead>
<tr>
<th>Preparing and filtering the data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifying car following events during braking</td>
</tr>
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</tr>
</tbody>
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- Braking status
- Following vehicle speed
- Headway
- Lateral distance
- Leading vehicle speed
- Azimuth change
Driver Following Behavior During Braking Incidents of Interest Selection

- Extract TTC, vehicle speed, lead vehicle speed, relative speed, and vehicle acceleration at the minimum following distance while braking.

- Select events within TTC range of 3 to 5 seconds which was assumed as the warning range \(7-9\).
where

d_{warn} = f(v_f, v_l, a_f, v_{rel})

\textbf{where}

\(d_{warn}\): minimum warning distance

\(v_f\): following vehicle speed

\(v_l\): leading vehicle speed

\(a_f\): following vehicle acceleration

\(v_{rel}\): relative speed between following and leading vehicles
# DRIVER FOLLOWING BEHAVIOR DURING BRAKING

## Perceptual FCW Model Development

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.237</td>
<td>0.003</td>
</tr>
<tr>
<td>Host vehicle acceleration (m&lt;sup&gt;2&lt;/sup&gt;/s)</td>
<td>0.122</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Host vehicle speed (m/s)</td>
<td>0.150</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Relative speed (m/s)</td>
<td>3.479</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

Model Goodness-of-fit: $R^2 = 0.916$
Six of the most commonly cited FCW algorithms\textsuperscript{9-14} were compared to the proposed model.

The warning distances were plotted against the relative speed at four levels of following (i.e. host) vehicle speeds (60, 80, 100, and 120 km/h).
RESULTS

MODEL ASSESSMENT

Warning Distance (m)

Relative Speed (km/h)

60 km/h

Kinematic FCW Algorithms
Perceptual FCW Algorithms

- Alg.1
- Alg.2
- Alg.3
- Alg.4
- Alg.5
- Alg.6
- Proposed
RESULTS
MODEL ASSESSMENT

Perceptual FCW Algorithms
Kinematic FCW Algorithms

Warning Distance (m)

Relative Speed (km/h)

Alg.1  Alg.2  Alg.3  Alg.4  Alg.5  Alg.6  Proposed

80 km/h
RESULTS
MODEL ASSESSMENT

![Graph showing warning distance vs. relative speed for various algorithms. The x-axis represents relative speed (km/h) ranging from 0 to 100 km/h, and the y-axis represents warning distance (m) ranging from 0 to 120 m. The graph compares Perceptual FCW Algorithms and Kinematic FCW Algorithms. Various lines represent different algorithms: Alg.1, Alg.2, Alg.3, Alg.4, Alg.5, Alg.6, and the proposed algorithm. At 100 km/h, the proposed algorithm offers the longest warning distance.](image-url)
**RESULTS**

**MODEL ASSESSMENT**

Perceptual FCW Algorithms

Kinematic FCW Algorithms

![Graph showing the relationship between relative speed (km/h) and warning distance (m) for different algorithms. The graph includes lines for Alg.1, Alg.2, Alg.3, Alg.4, Alg.5, Alg.6, and a proposed algorithm. The graph highlights the performance at 120 km/h.](image-url)
CONCLUSIONS

- The results of the proposed algorithm were consistent with the other perceptual algorithms.

- The warning distances varied widely between algorithms with perceptual algorithms having shorter distances compared to kinematic algorithms.
Conclusions

- The distance produced by the proposed algorithm is less than the distance produced by the perceptual algorithms which were developed based on driving simulator data (early warning)
FUTURE RESEARCH

- The variation of warning distances due to the differences in drivers’ demographics (i.e., age and gender) should be investigated.

- The impact of the proposed FCW on the network level should be assessed.
REFERENCES


Images:
QUESTIONS?

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