Vehicle-Pedestrian Near-Crash Identification with Roadside LiDAR Data

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Data for Safety Evaluation

- **Historical crash records are usually used for safety evaluation on roads.**
  - Crash data may be not available at some locations.
  - Delay in safety evaluation
- **Solution**
  - Near-crashes are then selected as a surrogate dataset for safety evaluation

The results from Guo, et al. [1] have shown that near-crashes as a crash surrogate could provide definite benefits when crash data are not available.
Near-Crash Data Collection

- **Driving Simulator**
  Driving behavior in the simulated environment is different from that in a real situation [2].

- **Naturalistic Driving Data**
  Data limited to those vehicles installed with the tracking devices.

- **Connected-Vehicles**
  Talebpour, et al. [3] developed two near-crash detection algorithms for near-crash identification in a connected vehicle environment. **Assumption: all vehicles are connected on the road.**

- **Roadside LiDAR Data**
  Fill the data gap for the transition period from unconnected vehicles to connected vehicles.
  Provide detailed trajectories of road users.
Why Vehicle-Pedestrian Near-Crash?

- Previous studies focused on vehicle-vehicle near-crash analysis (Rear-end).
- On average, a pedestrian was killed every two hours and injured every seven minutes in traffic crashes [4].
  Lack of studies related to vehicle-pedestrian near-crash analysis.
Objectives

- Develop an approach for vehicle-pedestrian near-crash identification using roadside LiDAR data
  - Use of the trajectories of vehicles and pedestrians
  - Recommend thresholds to define the risk of vehicle-pedestrian conflicts
Roadside LiDAR Data Processing

- Previous studies conducted by our team
  - Background Filtering;
  - Lane Identification;
  - Vehicle and Pedestrian Classification;
  - Vehicle Tracking.
- Detailed trajectories of vehicles and pedestrians can be obtained from the roadside LiDAR data

An example of trajectories of road users
Parameter--TDPI

▪ **Time to collision (TTC)?**

The travel-time difference between a leading vehicle and a following vehicle, which may lead to collision if these vehicles maintain their current speeds without the performance of evasive maneuvers.

▪ **Time Difference to the Point of Intersection (TDPI)**

The time difference between one vehicle and one pedestrian reaching the same point in their trajectories

\[ TDPI = \text{ABS}(\frac{T_v - T_p}{F}) \]

▪ \(T_v\) is the timestamp when the vehicle reaches the point of intersection (PI).

▪ \(T_p\) is the timestamp when the pedestrian reaches the point of intersection (PI).

▪ \(F\) is the frequency of data collection, unit: HZ.
Examples of TDPI

2.3s

148.8s
Risk Assessment with TDPI

- A controlled study in 2000 found the average driver reaction time to brake was 2.3 seconds. A few states, including California, have adopted a standard driver reaction time of 2.5 seconds [5].

- TDPI<2.5s  Near crash
- 2.5s≤TDPI≤3.5s  Crash relevant
- TDPI>3.5s  Low risk
Parameter--DSPP

- The TDPI may not identify all near-crashes in some cases, such as the driver took emergency brakes and already fully stopped before reaching PI.
- Distance between Stop Position and Pedestrian (DSPP)--The distance between one vehicle and one pedestrian when the vehicle firstly stopped before reaching the pedestrian.

\[ DSPP = \sqrt{(Xv - Xp)^2 + (Yv - Yp)^2} \]

- \( Xv \) is the X-axis of vehicle, unit: meter (s);
- \( Yv \) is the Y-axis of vehicle, unit: meter (s);
- \( Xp \) is the X-axis of pedestrian, unit: meter (s);
- \( Yp \) is the Y-axis of pedestrian, unit: meter (s).
Examples of DSPP

DSPP-11.86m (38.91ft)

https://youtu.be/QObqni4UaSI

DSPP-4.21m (13.81ft)

https://youtu.be/ovmX6ERaolI
Risk Assessment with DSPP


- The distance between yield/stop line to crosswalk (LTC) should be placed a minimum of 1.2m (4ft) in advance of the nearest crosswalk line at controlled intersection.

- Stop lines at midblock signalized locations should be placed at least 12m (40 feet) in advance of the nearest signal indication.

- If yield or stop lines are used at a crosswalk that crosses an uncontrolled multi-lane approach, the yield lines or stop lines should be placed 6.1 to 15 m (20 to 50 feet) in advance of the nearest crosswalk line.
Risk Assessment with DSPP, Cont’

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Near-Crash</th>
<th>Normal Maneuver</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intersection</td>
<td>DSPP&lt;1.2m (4ft)</td>
<td>DSPP≥1.2m (4ft)</td>
</tr>
<tr>
<td>Signalized midblock crosswalk</td>
<td>DSPP&lt;12m (40ft)</td>
<td>DSPP≥12m (40ft)</td>
</tr>
<tr>
<td>Uncontrolled midblock crosswalk</td>
<td>DSPP&lt;6.1m (20ft)</td>
<td>DSPP≥6.1m (20ft)</td>
</tr>
</tbody>
</table>
Speed-Distance Profile

- Two vehicles may have the same DSPP, indicating they stopped at the same location before the pedestrian. However, they may decrease with different decelerations before stop. Apparently, the sharply stopped vehicle is more dangerous to pedestrians.
Risk Assessment – Speed-distance Profile

- The total stopping distance can be estimated by summing the perception-reaction distance and the braking distance. For a vehicle with 15mph, the estimated stopping distance is 44ft [7].
## Risk Assessment

<table>
<thead>
<tr>
<th>Risk</th>
<th>Thresholds</th>
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<tbody>
<tr>
<td>Near Crash</td>
<td>TDPI&lt;2.5s or 0&lt;DSPP&lt;LTC or vehicle speed within area A in speed-distance profile</td>
</tr>
<tr>
<td>Crash Relevant</td>
<td>2.5s≤TDPI≤3.5s or vehicle speed within area B in speed-distance profile</td>
</tr>
<tr>
<td>Low risk</td>
<td>TDPI&gt;3.5s or DSPP≥LTC or vehicle speed within area (a) in speed-distance profile within area C in speed-distance profile</td>
</tr>
</tbody>
</table>
Case Study—UNR Campus

CONNECTED INFRASTRUCTURES WITH LIDAR
Case Study—UNR Campus

TDPI

DSPP

Low Risk
Crash Relevant
Near Crash
LTC: 6.1m
Near Crash
Low Risk

Time from the beginning of data collection (seconds)

0 500 1000 1500

TDPI (seconds)

0 500 1000 1500

DSPP (m)
Case Study—UNR Campus
Case Study—Virginia@10th St

TDPI

DSPP
Case Study—Virginia@10th St

- Near Crash
- Crash Relevant
- Low Risk
Conclusion

- Three factors: TDPI, DSSP and speed-distance profile are used to identify vehicle-pedestrian near-crashes.

- We also recommend the thresholds for crash risk assessment. The case studies showed that the crash risk can be easily estimated without waiting for historical crash records.
Discussion

- The proposed method may be very useful for before-and-after pedestrian safety assessment of one specific site, or can be used to identify the sites with highest pedestrian crash risk.
- This paper did not identify bicycle-involved near-crashes since the bicycle data were limited.
- The implementation of the proposed method relies on the accurate trajectories of vehicles and pedestrians. There are still some errors in the output of the current LiDAR data processing algorithms.
References


