Automated road safety analysis using traffic conflict techniques

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Outline

- Road Safety Analysis Challenges
- Automated road safety analysis using traffic conflict techniques
  - Motivation - Safety
  - Motivation - Automated Road User Behavior Data Collection
- Applications and Case Studies
- Conclusions
Road Safety Analysis

■ The importance of reducing the social and economic costs of road collisions cannot be overstated.

■ There has been a remarkable decrease in road traffic fatalities and injuries over the last decades, especially in developed countries:
  ■ more than 50% decrease in road fatality rates despite a considerable increase in motorization (1970–2005).
  ■ Considerable research has been undertaken and advances have been made in road safety analysis.
  ■ These developments are creating a movement towards the explicit consideration of safety in transportation planning, design, and management.
Challenges

- However, associated with these advances are a series of challenges that are inhibiting or complicating the future direction of road safety.

  - Less attention has been devoted to improving our understanding of collision factors and how safety measures work.

  - Reliance on collision data is reactive and has fundamental ethical and practical issues: a significant number of collisions needs to be observed which we will subsequently strive to prevent.
Challenges (Cont.)

- These challenges may make it difficult to achieve further safety advancement and may offer an explanation to the smaller reduction (increase) in fatality rates in recent years.

- It is time to use more realistic safety analysis approaches which give better understanding of road user behavior and the collision failure mechanism.
Automated Data Collection and Safety Analysis Using Video Sensors
Motivation – Safety Analysis

- Traditional road safety analysis is a reactive approach, based on historical collision data
  - There are well-recognized availability and quality problems associated with collision data
  - Long observation periods (2-3 years)
  - Less complete understanding of the complex interaction of collision factors and how safety measures work
- A more proactive approach is needed which provides a better understanding of collision occurrence
Traffic Conflicts (near-misses)

- Shortcomings
  - Cost of data collection
  - Issues related to the reliability and accuracy of human observers

- Automation can enable the traffic conflict analysis in an accurate, objective, and cost-efficient way

Source: Hyden, 1987
Motivation - Data Collection

- Road-user movements and behavior are complex and difficult to capture manually
- A disparate mix of road users share the same road
- Manual data collection methods are more expensive, error-prone, and time consuming
Video Analysis
Real-world Coordinates Recovery
Camera Calibration
Automated Conflict Analysis

Conflict Indicators calculated for traffic event 1.

- DST: Deceleration to Safety Time
- GT: Gap Time
- TTC: Time to Collision
- PET: Post Encroachment Time

Graphs:
- DST (m/s^2) vs. Frame Number
- GT (s) vs. Frame Number
- Ped Speed (m/s) vs. Frame Number
- Veh Speed (m/s) vs. Frame Number

PET = 3.80s
Automated Conflict Analysis

Conflict Indicators calculated for traffic event 1.

DST: Deceleration to Safety Time, GT: Gap time, TTC: Time to Collision, PET: Post Encroachment Time
Cyclist-Vehicle Conflict
Examples
Cyclist-Vehicle Conflict Examples
Analysis of Collisions
Collision Probabilities

\[ P(\text{Collision}) = 0.4 \times 0.7 \times e^{-\frac{(t_1-t)^2}{2\sigma^2}} + 0.4 \times 0.3 \times e^{-\frac{(t_1-t)^2}{2\sigma^2}} \]
APPLICATIONS

- Automated Microscopic Data Collection
- Automated Violations Detection
- Safety Diagnosis
- Evasive-action Based Conflict Indicators
- Simulation-based Safety Evaluation
- Before and After Safety Evaluations
APPLICATIONS

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Classification

Classify Road-Users based on their Speed Profiles using **computer vision**

Movement Mechanisms

- Pedestrians: Ambulation
- Cyclists: Pedaling
- Vehicle: Mostly-Linear Movements
Classification

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Classification: Road-Users

Surrey Data Set 2

UBC Roundabout Data Set 3

Surrey Data Set 1

85-96% Correct Classification rate
Pedestrian Speed Heat Maps
Pedestrian Speed for Signal Indications

![Pedestrian Speed Chart]

- **Average Crossing Speed (m/s)**
- **Start Time (sec)**
  - $0 < t \leq 5$ (n=424)
  - $5 < t \leq 10$ (n=121)
  - $10 < t \leq 15$ (n=86)
  - $15 < t \leq 19$ (n=56)
  - $19 < t \leq 24$ (n=9)
  - $24 < t \leq 45$ (n=0)

- **Graph Key**
  - Average + One Std. Dev.
  - Average Speed
  - Average - One Std. Dev.
Gait Analysis Extraction (Step Length and Frequency)

Walk Speed = Step Frequency \times \text{Step Length}

Eigen Components Pairing

Reconstruction
Automated Pedestrian Gender Classification

- 85 - 90% Correct pedestrian gender and age classification
Application: Pedestrian Distraction

Distraction Tracking Illustrations
Features for Classifying Distracted Pedestrians

Table 1: Features Significance

<table>
<thead>
<tr>
<th>Distraction</th>
<th>Number of Subjects</th>
<th>Walk Speed</th>
<th>Step Frequency</th>
<th>Step Length</th>
<th>Walk Ratio</th>
<th>Acceleration Autocorrelation</th>
<th>Acceleration Root Mean Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>50</td>
<td>1.63(0.19)</td>
<td>2.04(0.14)</td>
<td>0.80(0.09)</td>
<td>0.66(0.09)</td>
<td>0.26(0.16)</td>
<td>0.60(0.19)</td>
</tr>
<tr>
<td>No</td>
<td>98</td>
<td>1.7(0.19)*</td>
<td>2.06(0.15)</td>
<td>0.86(0.10)</td>
<td>0.70(0.12)</td>
<td>0.32(0.19)</td>
<td>0.53(0.16)</td>
</tr>
</tbody>
</table>

*Significant at 1%, ** significant at 5%

Maximum Correct Classification Rate (CCR) = 80%
Cyclists Speed

Average Speed Distribution throughout the Roundabout
Cyclist Speed and Helmet Use
Computer Vision System For Helmet Recognition

Step 1: Cyclist Tracking
Step 2: Head Trajectory
Step 3: Extract Features
Step 4: Supervised Learning

- helmet
- non-helmet
Step 1: Cyclist Tracking
Step 2: Cyclist Head Trajectory
Step 3: Feature Extraction

- **Color:**
  - **Reason:** Most of the helmets are colorful while the hair is usually darker.
  - **Implementation:** an RGB color histogram
Step 3: Feature Extraction

- **Texture:**
  - **Reason:** Helmets have smooth surfaces.
  - **Implementation:** intensity variation of a surface. Texton and Local Binary Pattern (LBP)

![Helmet](image1.png) ![Non-helmet](image2.png)
Is the cyclist wearing helmet or not?

Objective:
- Automatic Helmet Detection and Recognition
- Non-helmet Wearing Cyclist Retrieval System

85 % Accuracy
APPLICATIONS

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Hastings and Main Intersection
Violations Identification
Analysis of Violations
Analysis of Violations
APPLICATIONS

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Burrard and Pacific Intersection
Cyclist Conflicts Zone
Burrard and Pacific Intersection
Vehicle Conflicts Zones
Burrard and Pacific Intersection
Proposed Geometric Modifications
Burrard and Pacific Intersection
Proposed Geometric Modifications
Suggested Modifications

- Right-turn only marking
- Large Yield Signs
- Clear Crosswalk Markings
- Double Yellow Lines
- Extended solid white line
- Extended solid white line
- Advance Amber Beacons
- Suggested Countermeasures
APPLICATIONS

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Can Time Proximity Conflict Indicators Be Used in All Driving Cultures?

- Traditional conflict indicators rely on road users getting within specific temporal and spatial proximity from each other and assume that proximity is a surrogate for conflict severity.

- This assumption may not be valid in many driving environments where close interactions between road users are common.
Cairo, Egypt
**Shanghai Signalized Intersection**

### Conflicts Density

<table>
<thead>
<tr>
<th>Conflicts Type</th>
<th>Pedestrian-Vehicle</th>
<th>Pedestrian-Motorcycle</th>
<th>Pedestrian-Bicycle</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTC &lt;1.5sec</td>
<td>354</td>
<td>337</td>
<td>1016</td>
<td>1707</td>
</tr>
<tr>
<td>TTC &lt;1.5sec &amp; PET &lt;1.5sec</td>
<td>183</td>
<td>191</td>
<td>593</td>
<td>967</td>
</tr>
</tbody>
</table>

Time proximity conflict indicators such as TTC and PET do not work well in less organized traffic environments such as Shanghai.
Pedestrian Walking Behaviour

Sudden Running
Pedestrian Walking Behaviour

Sudden Stopping
Application Example

- TTC <1.5sec (1707 event)
- Rate of Change step freq>0.7 & Jerk>8 (121 event)
- TTC <1.5sec & PET<1.5sec (979 event)
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Before-and-After Safety Studies

- **Duration** (1-3 years before as well as after treatment)
- **Current statistical techniques** have shortcomings
- **Paradoxical situation**!

The safety analyst, for the sake of methodological correctness, strives to observe events that ought to be prevented
Before/After Evaluation of Pedestrian Scramble
Motion Patterns
Results - (Spatial Conflict Density no./m²)

Pre-Scramble

Post-Scramble
Before-and-After Conflict Indicators

Histogram of Before-and-After TTC

Histogram of Before-and-After DST

Histogram of Before-and-After PET

Histogram of Before-and-After GT
## Conflict Severity Analysis

<table>
<thead>
<tr>
<th>CONFLICT TYPE</th>
<th>FILTERING SPECIFICATION ( (k) )</th>
<th>BEFORE TREATMENT</th>
<th>AFTER TREATMENT</th>
<th>B/A RATIO</th>
<th>IMPLIED REDUCTION IN CONFLICTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration (hrs)</td>
<td>N/A</td>
<td>2.19 merging and 3.25 rear-end</td>
<td>6.37 merging and 6.83 rear-end</td>
<td>-</td>
<td>NA</td>
</tr>
<tr>
<td>Maximum Theoretical Exposure (millions)(^2)</td>
<td>N/A</td>
<td>3.72 merging and 2.33 rear-end</td>
<td>23.26 merging and 3.68 rear-end</td>
<td>-</td>
<td>NA</td>
</tr>
<tr>
<td>Merging SI Rate</td>
<td>5</td>
<td>1.1399e-004</td>
<td>4.1768e-006</td>
<td>27.29</td>
<td>96%</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>9.1363e-005</td>
<td>3.4317e-006</td>
<td>26.62</td>
<td>96%</td>
</tr>
<tr>
<td>Rear-end SI Rate</td>
<td>5</td>
<td>2.8716e-005</td>
<td>2.3093e-005</td>
<td>1.24</td>
<td>20%</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>2.4232e-005</td>
<td>1.6991e-005</td>
<td>1.43</td>
<td>30%</td>
</tr>
<tr>
<td>All Conflicts SI rate</td>
<td>5</td>
<td>8.1091e-005</td>
<td>6.7632e-006</td>
<td>11.99</td>
<td>92%</td>
</tr>
<tr>
<td></td>
<td>10</td>
<td>6.5463e-005</td>
<td>5.2856e-006</td>
<td>12.39</td>
<td>92%</td>
</tr>
</tbody>
</table>
Evaluating Cycle Safety Treatment

- Several treatments were implemented:
Conflict Examples - Before
Results

Conflict distribution in the before period

Conflict distribution in the after period (Day 2)
Urban Smart Channels

- Smart Channels offer safety benefits to vehicles (better merging view) and pedestrians (shorter pedestrian crossing distance)
Penticton, BC - Before/After Analysis of Right-turn Treatment

- Three intersections in Penticton BC + 1 control site
Penticton, BC - Before/After Analysis of Right-turn Treatment
## Comparison with Collision-based FB B/A Evaluation

<table>
<thead>
<tr>
<th>Intersection/Severity</th>
<th>Traffic Conflicts (Average Hourly Conflicts)</th>
<th>Collisions (on 4-month basis)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1 – Channel/Green</td>
<td>33%</td>
<td>34.2%&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T2 – Channel/Warren</td>
<td>57%</td>
<td>60.3%&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>T3 – Channel/Duncan</td>
<td>55%</td>
<td>48.1%&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Overall</td>
<td>51%</td>
<td>56.3%&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total Severity</td>
<td>Conflict Severity: 41%</td>
<td>PDO: 59.2%&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>F+I: 48.8%&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
Locations of Projects

Calgary
Edmonton
New York
Italy
Shanghai

Vancouver

Oakland, CA
Kentucky

Cairo

Kuwait city

Doha

Mecca
Automated Safety Analysis - Conclusion

- **A new approach to road safety analysis**
  - Proactive, generic and low cost approach
  - Collection of microscopic exposure and behavior data
  - Provides better understanding of driver behavior especially collision avoidance mechanisms
  - Diagnostic approach
  - Overcomes the problems with the traffic conflict technique (high cost and reliability of observers)
Thank You