Semi-Automated Analysis of Bicycle and Motorized Vehicle Trajectories at Urban Intersections using “Traffic Intelligence”

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Presentation at the Workshop:
Comparison of Surrogate Measures of Safety Extracted from Video Data
2014 TRB Annual Meeting

January 12th, 2014
Agenda

1. Introduction to Research Problem
2. Data Collection
3. Data Analysis
   - “Traffic Intelligence”
   - Grouping Features: Hypotheses Based on Position
   - Connecting Divided Trajectories
   - Resulting Dataset
   - Evaluation
4. Bicycle Modeling Applications
5. Conclusion
Introduction to Research Problem

Motivation

1. Increase in bicycle traffic = increased impact of bicycles on traffic flow
   
   Goal: Improve and develop models of bicycle movement and interaction that can be integrated into existing microscopic traffic simulation tools

2. Continuing concerns with bicyclist safety
   
   Goal: Increase understanding of bicyclist behavior at urban intersections in order to be able to design for bicyclist safety

3. Development of bicycle targeted driver assistance systems in UR:BAN
   
   Goal: Provide modelling basis for the evaluation of these systems in the future
Introduction to Research Problem

How will we accomplish these goals?

1. Assessment of the state-of-the-art in modeling bicycle behavior
   
   Outcomes:
   
   - At the **operational level** several models exist but little work has been done to **calibrate** or **validate** these models
   
   - At the **tactical level** only a handful of models exist, but
     
     • **Lack of information** concerning how bicyclists make tactical choices
     
     • Not implemented in any commercially available simulation tool

2. Collection and analysis of video data from urban intersections

3. Analysis of the operational and tactical behavior

4. Provision of data for calibration of operational models

5. Extension of operational models and development of tactical models

6. Assessment of developed models
Data Collection

Requirements for Data Collection System

- Flexibility – possibility to install the system at many intersections
- Wide Range – information from the intersection and approaches
- Low Cost

System

Camera: GoPro Hero3 Black Edition
- Wide angle lens
- Desired output format (.mp4)
- Small, easy to install and control
- Wifi remote control

64 GB micro SD = 7 hours recording time (1920x1080, 25 FPS)
Battery pack (capacity: 13 000 mAh, > 14 hours)
Theft-proof mounting container/tripod
Data Collection

Selection of Research Intersections

Three research intersections in Munich were selected with:

- different traffic and geometric characteristics (traffic volume, number of lanes, etc.)
- different combinations of bicycle infrastructure (three categories)
- a possibility for camera mounting

<table>
<thead>
<tr>
<th>Marsstraße-Seidlstraße</th>
<th>Karlstraße-Luisenstraße</th>
<th>Arcisstraße-Theresienstraße</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bicycle Infrastructure:</strong></td>
<td><strong>Bicycle Infrastructure:</strong></td>
<td><strong>Bicycle Infrastructure:</strong></td>
</tr>
<tr>
<td>• Bicycle lane in roadway</td>
<td>• Separated bicycle lane</td>
<td>• Bicycle lane in roadway</td>
</tr>
<tr>
<td>• Separated bicycle lane</td>
<td>• Mixed traffic</td>
<td>• Mixed traffic</td>
</tr>
<tr>
<td><strong>Traffic volume:</strong> High</td>
<td><strong>Traffic volume:</strong> Low</td>
<td><strong>Traffic volume:</strong> Moderate</td>
</tr>
</tbody>
</table>
Data Analysis

Semi-Automated Video Analysis

• Large amount of data (62.5 hours, more to come) → semi-automated analysis approach needed
• “Traffic Intelligence" selected (open source)

Challenges for our Research Purpose:

1. Calibration for mixed traffic streams
   • Different physical and dynamic characteristics

2. Classification of road users as cars, bicycles and pedestrians
   • Not implemented directly in the C++ code currently
   • Road users are differentiated based on average speed
     – low traveling speed of all road users at intersections

3. Complete trajectory data across intersection
   • Discontinuities caused by start-and-stops and obstructive objects
   • Tactical behavior analysis

Data Analysis

Challenges 1 and 2: Feature Separation - Hypothesis based on position

- Touch-at-any-instant polygons – areas only touched by pedestrians and bicycles
- Touch-in-all-instances polygons – bicycle lanes
Data Analysis

Challenges 1 and 2: Creating Road User Hypotheses

The features in the separated databases are grouped using specified parameter sets:

- Under segmentation is preferred to over segmentation

### Parameter/Value

<table>
<thead>
<tr>
<th></th>
<th>Arcisstraße</th>
<th>Luisenstraße</th>
<th>Seidlstraße</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum number of frames to consider a feature</td>
<td>40/45</td>
<td>40/40</td>
<td>40/30</td>
</tr>
<tr>
<td>Connection distance (distance at first instant) [m]</td>
<td>0.8/1.9</td>
<td>0.8/2.1</td>
<td>0.8/2.0</td>
</tr>
<tr>
<td>Segmentation distance (difference in max and min distance) [m]</td>
<td>0.4/0.7</td>
<td>0.5/0.6</td>
<td>0.5/0.5</td>
</tr>
<tr>
<td>Maximum distance [m]</td>
<td>0.8/1.9</td>
<td>0.8/2.1</td>
<td>0.8/2.0</td>
</tr>
<tr>
<td>Minimum cosine of the angle between the velocity vectors [m]</td>
<td>0.65/0.70</td>
<td>0.6/0.65</td>
<td>0.6/0.7</td>
</tr>
<tr>
<td>Minimum average number of features to create a hypothesis [m]</td>
<td>1/5</td>
<td>1/3</td>
<td>1/3</td>
</tr>
</tbody>
</table>

Classification

- Vehicles in the motorized vehicles database are “cars”
- Max speed is used to differentiate bicycles and pedestrians in the other database (9 km/h)
Data Analysis

Challenge 3: Connecting Divided Trajectories

Problem:
1. Only moving features are tracked → When a road user stops moving, it is no longer tracked and is assigned a new object id when it restarts.
2. When a road user passes under or behind an obstruction it is assigned a new id.

Solution – Logical Connection:
1. If a trajectory ends in the middle of the video frame
   • a search for trajectories that start in a defined circumference is carried out.

2. If two trajectories run parallel to each other after a cut-off
   • The distance between the objects and the time overlap is tested and the objects are combined.
Data Analysis

Resulting Dataset
X and Y coordinates and speed for each car, bicycle and pedestrian in each frame
## Data Analysis

### Evaluation

<table>
<thead>
<tr>
<th>Road User/Intersection</th>
<th>Total Number</th>
<th>Total Tracked (%)</th>
<th>Over Grouping # of instances (%)</th>
<th>Correctly Classified of those tracked (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Motorized Vehicles:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arcisstraße</td>
<td>57</td>
<td>41 (72%)</td>
<td>2 (7.0%)</td>
<td>39 (95%)</td>
</tr>
<tr>
<td>Luisenstraße</td>
<td>36</td>
<td>33 (92%)</td>
<td>1 (5.5%)</td>
<td>30 (91%)</td>
</tr>
<tr>
<td>Seidlstraße</td>
<td>111</td>
<td>95 (86%)</td>
<td>2 (3.6%)</td>
<td>92 (97%)</td>
</tr>
<tr>
<td><strong>Bicycles:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arcisstraße</td>
<td>25</td>
<td>18 (72%)</td>
<td>0 (0.0%)</td>
<td>5 (28%)</td>
</tr>
<tr>
<td>Luisenstraße</td>
<td>25</td>
<td>19 (76%)</td>
<td>1 (8.0%)</td>
<td>11 (58%)</td>
</tr>
<tr>
<td>Seidlstraße</td>
<td>30</td>
<td>24 (80%)</td>
<td>0 (0.0%)</td>
<td>23 (96%)</td>
</tr>
<tr>
<td><strong>Pedestrians:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arcisstraße</td>
<td>14</td>
<td>13 (93%)</td>
<td>-</td>
<td>8 (62%)</td>
</tr>
<tr>
<td>Luisenstraße</td>
<td>23</td>
<td>18 (78%)</td>
<td>-</td>
<td>14 (78%)</td>
</tr>
<tr>
<td>Seidlstraße</td>
<td>17</td>
<td>13 (76%)</td>
<td>-</td>
<td>8 (62%)</td>
</tr>
</tbody>
</table>
Bicycle Modeling Applications

Data for the Validation and Calibration of Existing Models

Common parameters for existing models (operational)

- Speed and acceleration profiles
- Lateral and longitudinal spacing (moving and queuing)
- Density (moving and queuing)
- Duration and flow of the dissipation of bicycle queues
- Positioning in the lane
- ….

Measurable from trajectory database, but first:

- Accuracy (position, speed, acceleration) must be tested more thoroughly
- Trajectory smoothing approach must be implemented
Bicycle Modeling Applications

Extension of Current Models
E.g. Avoidance of complete stops, riding on the sidewalk or in the wrong direction on a bicycle lane, crossing red lights

Development of Tactical Models
E.g. Modeling “route choices” of bicyclists across intersections

- Derive influential parameters from literature and video observation (signal phase, geometry of intersection, traffic flow (macroscopic))
- Use trajectories and situational information as “revealed preference” data for discrete choice modeling based on utility of the option

\[ U_{iq} = V_{iq} + \varepsilon_{iq} \]
\[ V_{iq} = \sum_{k=1}^{K} \beta_{iq} X_{ikq} \]
\[ P_i = \frac{\exp(V_i)}{\sum_{j=1}^{J} \exp(V_j)} \]
Conclusions

• Automated video data processing at busy intersections with many different types of road users is possible but is not easy and **does not yield perfect results**.

• Program created to assist manual correction of the database (4-9 minutes per 1 minute of video).

• Improve differentiation between pedestrians and bicycles
  – Examine correlations between number of features/feature density and road user type
  – Look at other dynamic characteristics such as acceleration
  – Develop Fuzzy Logic approach

• Manually corrected output is useful for the analysis of bicycle behavior (operational and tactical)
References


3. Li M, Shi F, Chen D. Analyze bicycle-car mixed flow by social force model for collision risk evaluation.

Acknowledgements

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Thank you for your attention!

Comments, questions, suggestions?
Bicycle Modeling Applications

Development of Tactical Models

Modeling “route choices” of bicyclists across intersections

Define possible “routes” for different maneuvers

Eg. Left hand turn
   1. Direct turn with motorized traffic
   2. Indirect turn
   3. Wrong way with available light
   4. ?

- Derive influential parameters (signal phase, geometry of intersection, traffic flow (macroscopic) from literature and video observation
- Use trajectories and situational information as “revealed preference” data for discrete choice modeling based on utility of the option

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