Persistent Multiple Hypothesis Tracking for Wide Area Motion Imagery

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Raphael Spraul, Christine Hartung, Tobias Schuchert
email: raphael.spraul@iosb.fraunhofer.de
**Motivation**

- Tens of square kilometers ground coverage
- Image size ~ 23,000 x 30,000 pixel
- Framerate 1 – 2 Hz
- Vehicle size 10 x 20 pixel

Persistent tracking aims at continuously tracking vehicles even if a stop occurs

Framework for persistent WAMI tracking

- **Motion Detection**
  - Images
- **Multiple Hypothesis Tracking**
  - Detections: "motion based" & "classifier based"
  - Vehicle Classifier
  - App. Descriptor
  - Collision Test
  - Images
- **Clutter Handling**
  - Clutter track
  - Valid track
  - Images
- **Tracks**
Vehicle Detection

- Motion-based vehicle detection
- Median background subtraction approach
- Neighborhood consideration
- Yields best results according to [2]

\[ D_k(x, y) = \min_{(\Delta x, \Delta y) \in N} |I_k(x, y) - I_{BG}(x + \Delta x, y + \Delta y)| \]

- Quantile thresholding
- Morphological operations

Multiple Hypothesis Tracking

- Data association with „track-oriented“ MHT approach
- Track motion estimation with Kalman filter
- Motion model: constant velocity and turn rate
- Combined track score update

\[ \Delta S_u(k) = \Delta S_{mot}(k) + \Delta S_{app}(k) \]

Motion score by Kalman filter

Appearance score by appearance descriptor
Appearance Descriptor

- Appearance Descriptor for calculating appearance scores for different track hypotheses
- Combination of
  - Local Binary Patterns (LBP)
  - Local Variance (VAR)
  - Brightness histogram (Hist)
- Hellinger distance between histograms to determine vehicle similarity
Vehicle Collision Test

- MHT produces many track hypotheses
- Using *a-priori* knowledge to reduce number of track hypotheses improves data association process
- Intersecting hypotheses result in a vehicle collision
- Vehicle collisions are excluded in standard driving behavior
Classifier-based Detections

- Median background approach does not detect stopped vehicles
- Classifier-based detections used for persistent tracking approach
- Sliding window classifier (see [3])

Clutter-Handling

- Reducing false alarms by track validation
  
  \[ \text{clutter track} : \text{non-vehicle track originated from false detections} \]

- Delete...
  
  - ... tracks with short covert total distance
  
  - ... short tracks with a high „total curvature“
  
  \[ \kappa(P) = \sum_{i} \alpha_i \]
Experimental Results

- ROI of size 1408x1408 pixels of WPAFB 2009 dataset
- 1025 frames
- 410 ground truth tracks
## Quantitative Evaluation I

<table>
<thead>
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<td>precision</td>
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<td><strong>0.770</strong></td>
<td>0.752</td>
<td>0.706</td>
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<td>0.540</td>
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N-MODA = Normalized Multiple Object Detection Accuracy  
MOTA = Multiple Object Tracking Accuracy  
S/T = Switches per Track  
B/T = Breaks per Track

## Quantitative Evaluation II

<table>
<thead>
<tr>
<th>Component</th>
<th>Test case</th>
<th>( T_1 )</th>
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Qualitative Evaluation
Conclusion and Outlook

- Novel MHT framework for persistent multi-target tracking in WAMI data that recovers missing detections with a classifier

- Extensions
  - Appearance descriptor that assesses vehicle similarities
  - Vehicle collision test for discarding wrong data associations
  - Clutter-handling to reject tracks caused by false detections

- Outlook:
  Integrate split and merge handling

Thank you for your attention!