Persistent Multiple Hypothesis Tracking for Wide Area Motion Imagery

ICIP 2017: IEEE International Conference on Image Processing
Beijing, China
September 19th 2017

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

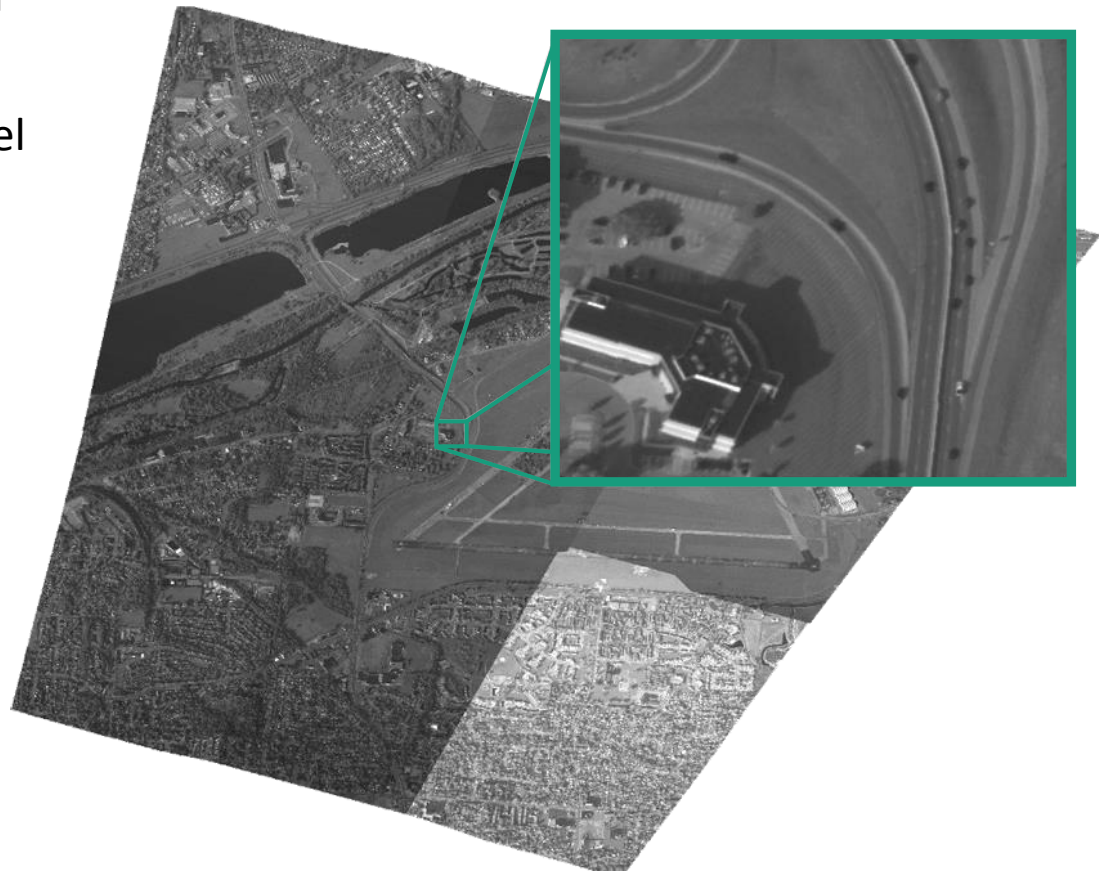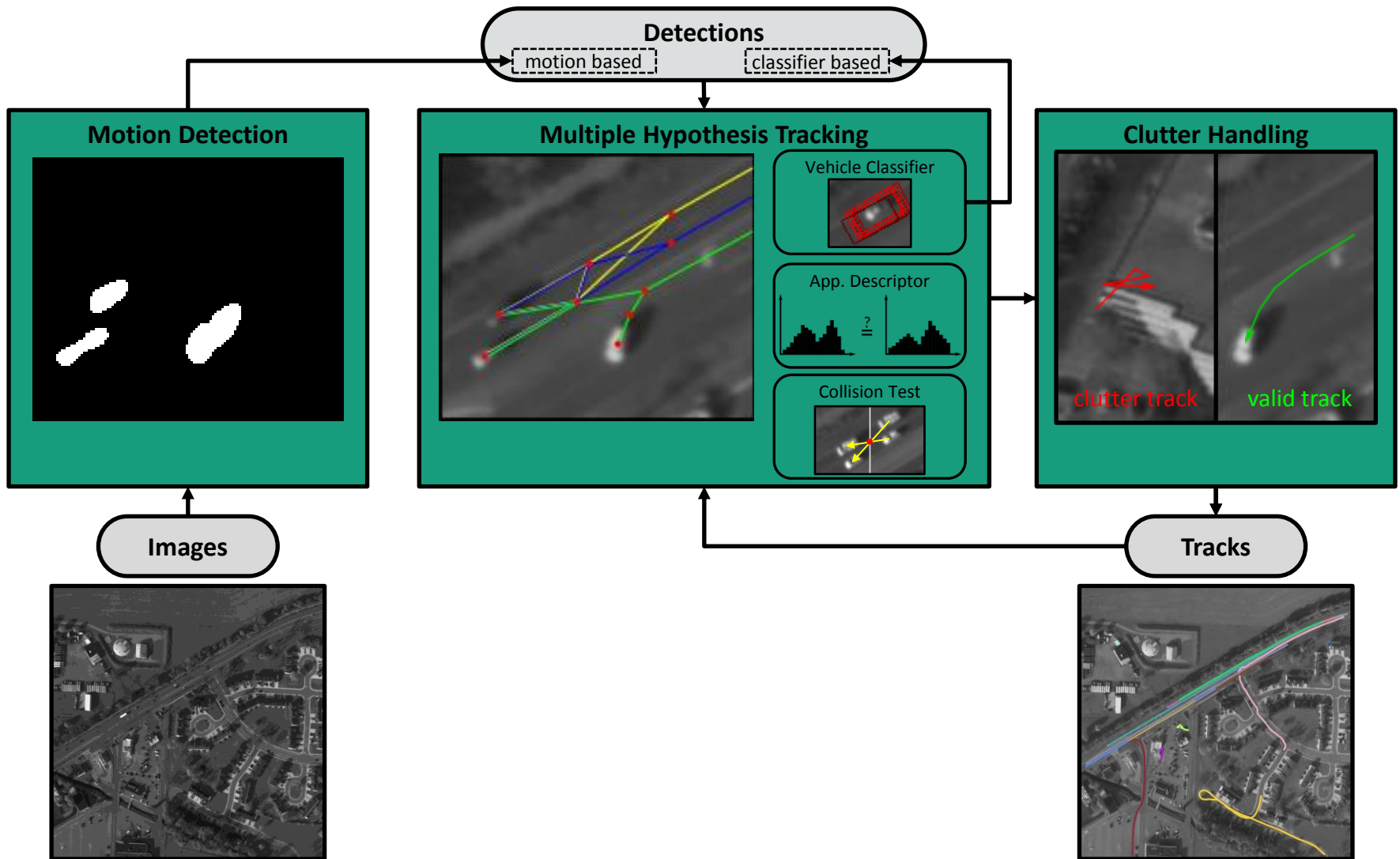Karlsruhe   Ettlingen   Ilmenau   Lemgo   Görlitz

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

[1] U.S. Air Force Research Laboratory: WPAFB 2009 dataset

Fraunhofer

IOSB

Framework for persistent WAMI tracking

Detections
- motion based
- classifier based

Motion Detection

Multiple Hypothesis Tracking

Vehicle Classifier

App. Descriptor

Collision Test

Clutter Handling

clutter track   valid track

Images

Tracks

Vehicle Detection

- Motion-based vehicle detection

- Median background subtraction approach

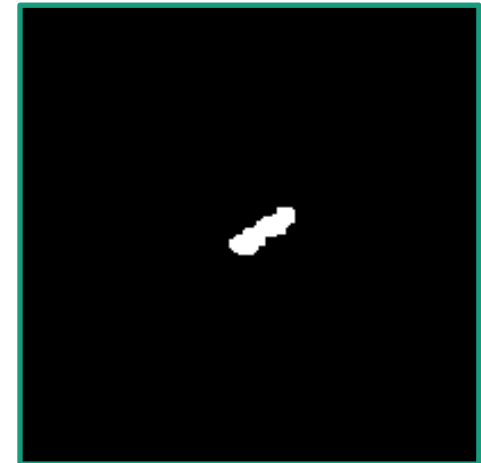- Neighborhood consideration

- Yields best results according to [2]
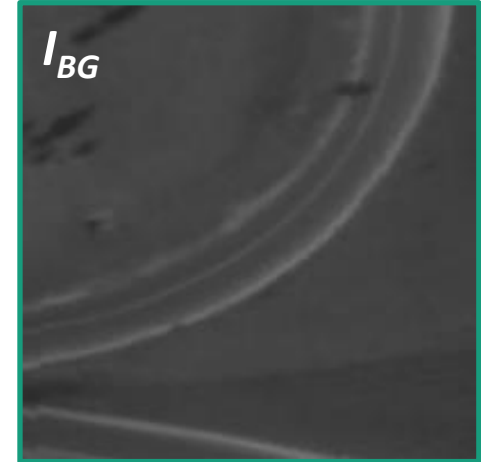
$$D_k(x, y) = \min_{(\Delta x, \Delta y) \in N} |I_k(x, y) - I_{BG}(x + \Delta x, y + \Delta y)|$$

- Quantile thresholding

- Morphological operations

D_k after quantile thresholding

D_k after morphological operations

[2] Sommer *et al.*: A survey on moving object detection for wide area motion imagery (WACVW, 2016)
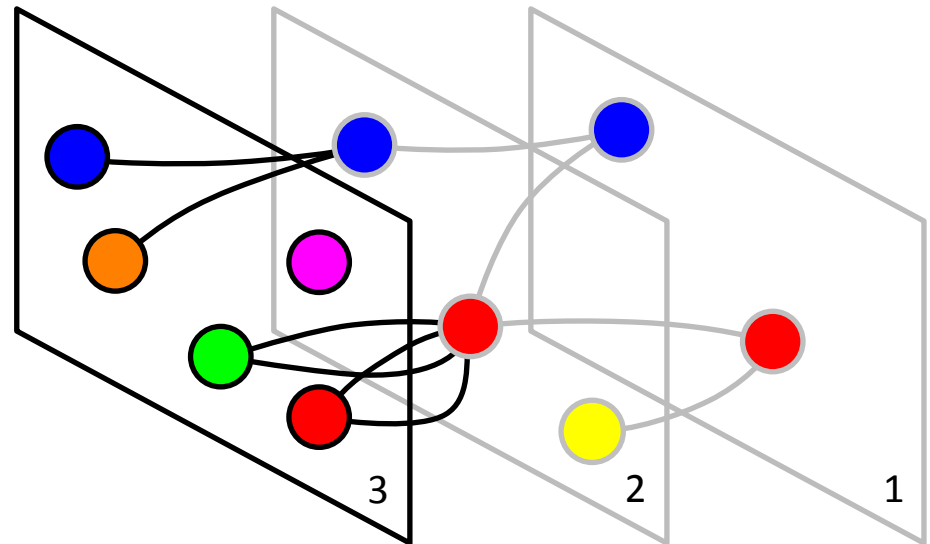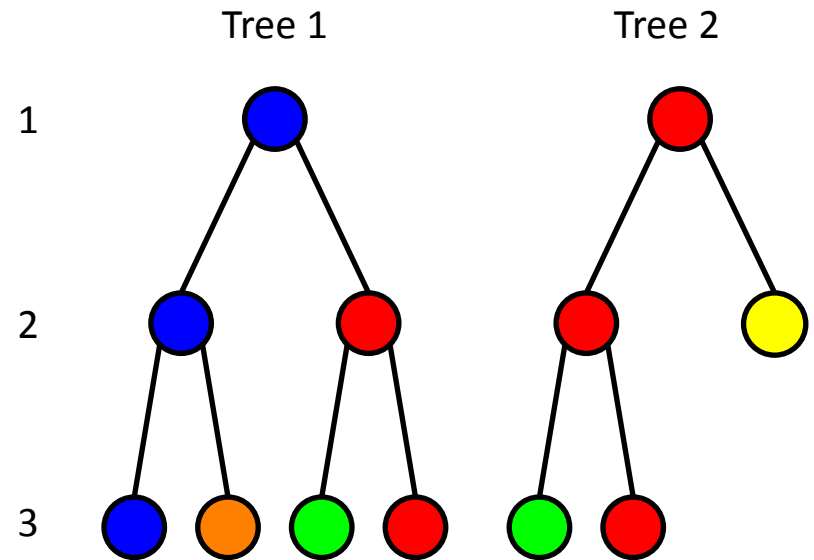
Fraunhofer

IOSB

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

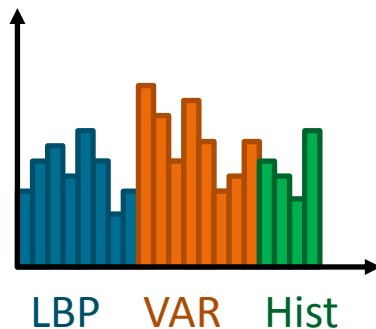$$\Delta S_u(k) = \Delta S_{mot}(k) + \Delta S_{app}(k)$$

Motion score by Kalman filter

Appearance score by appearance descriptor

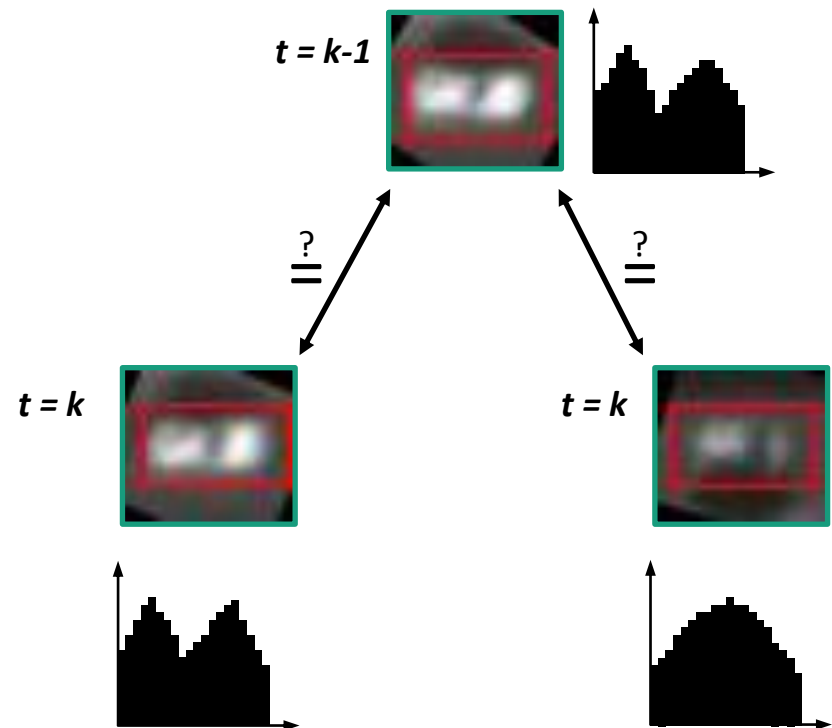**Fraunhofer**

IOSB

Appearance Descriptor

- Appearance Descriptor for calculating appearance scores for different track hypotheses

- Combination of

  - Local Binary Patterns (LBP)

  - Local Variance (VAR)

  - Brightness histogram (Hist)

LBP   VAR   Hist

- Hellinger distance between histograms to determine vehicle similarity

$t = k-1$

$t = k$ $t = k$

Fraunhofer

IOSB

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

Invalid pair of track hypotheses
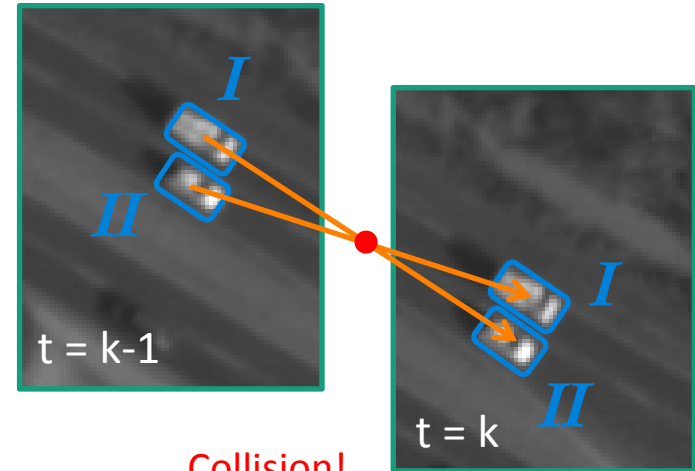
Collision!
=> Track hypotheses are in conflict!

Valid pair of track hypotheses

Fraunhofer
IOSB
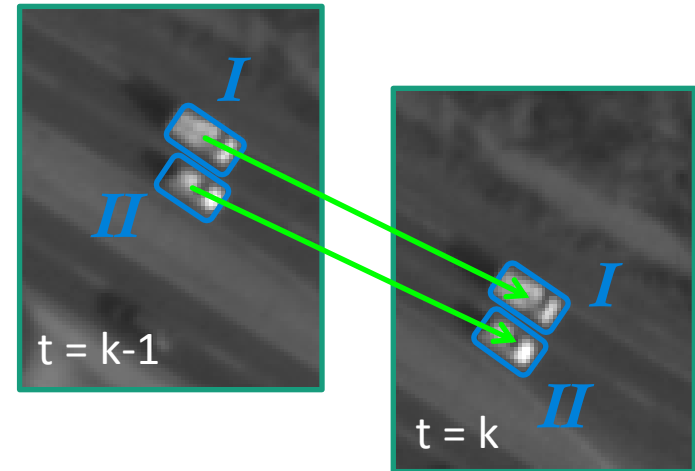
Classifier-based Detections

- Median background approach does not detect stopped vehicles

- Classifier-based detections used for persistent tracking approach

- Sliding window classifier (see [3])

dfv

1.0

0.0
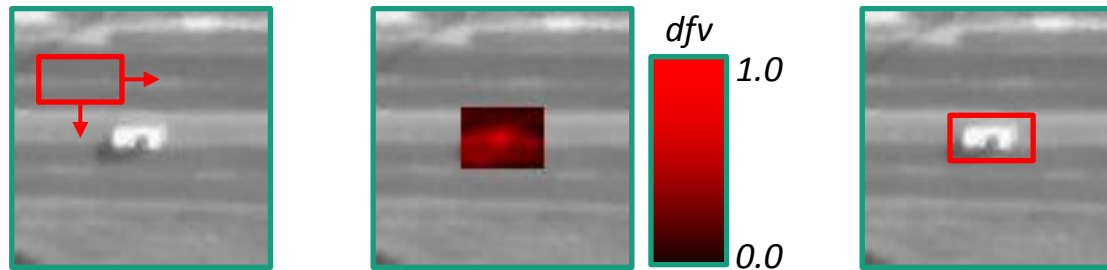
- Classifier-based vehicle detection if track slows down

- Reducing search space by using vehicle position and orientation from Kalman filter

[3] Teutsch *et al.*: Robust detection of moving vehicles in wide area motion imagery (CVPRW, 2016)

Clutter-Handling

- Reducing false alarms by track validation

  clutter track := *non-vehicle track originated from false detections*

- Delete…

  - … tracks with short covert total distance

  - … short tracks with a high „total curvature"

    $$\kappa(P) = \sum_i \alpha_i$$

roof of a high building

P

α_1 α_2 α_3
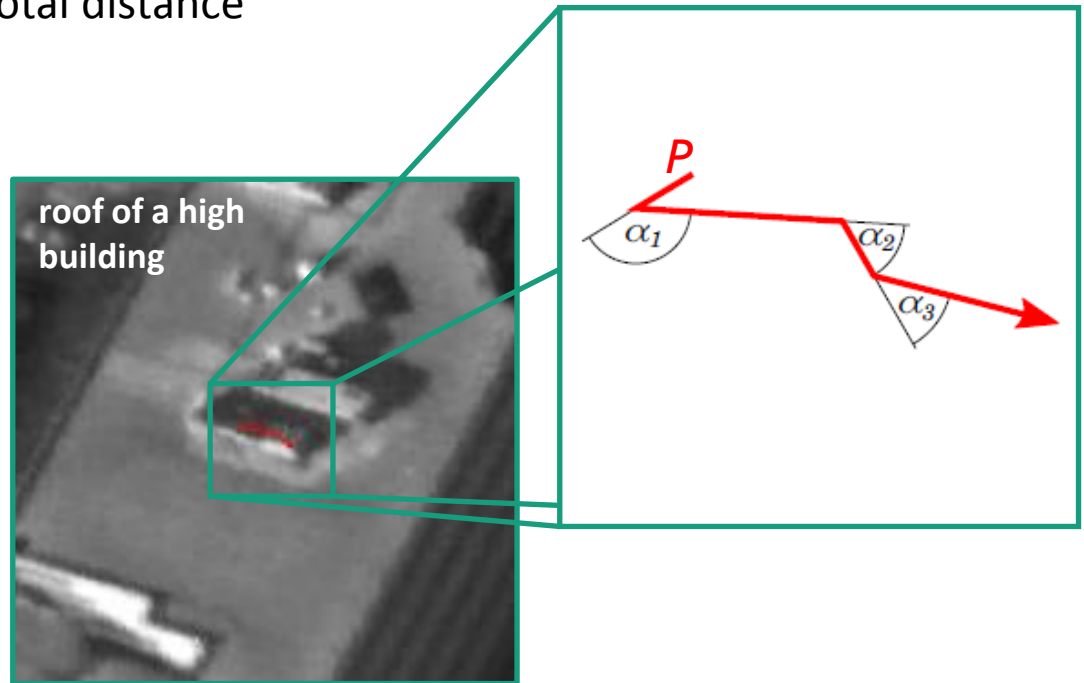
Experimental Results

- ROI of size 1408x1408 pixels of WPAFB 2009 dataset

- 1025 frames

- 410 ground truth tracks

Fraunhofer

IOSB

Quantitative Evaluation I

Method / Metric	Proposed	Literature				
		Chen [4]	Chen [5]	Prokaj [6]	Prokaj [7]	Reilly [8]
precision	0.932	**0.990**	0.987	0.960	0.985	0.940
recall	**0.657**	0.606	0.550	0.539	0.504	0.573
f-score	**0.770**	0.752	0.706	0.690	0.667	0.712
N-MODA	**0.609**	0.600	0.543	0.516	0.497	0.536
S/T	0.373	**0.015**	0.200	0.237	0.249	0.851
B/T	1.005	**0.317**	0.500	1.022	1.515	1.293
MOTA	**0.602**	0.599	0.540	0.512	0.493	0.522

N-MODA = Normalized Multiple Object Detection Accuracy S/T = Switches per Track
MOTA = Multiple Object Tracking Accuracy B/T = Breaks per Track

[4] Chen *et al.*: Exploring Local Context for Multi-target Tracking in Wide Area Aerial Surveillance (WACV, 2017)
[5] Chen *et al.*: Motion Propagation Detection Association for Multi-target Tracking in Wide Area Aerial Surveillance (AVSS, 2015)
[6] Prokaj *et al.*: Persistent Tracking for Wide Area Aerial Surveillance (CVPR, 2014)
[7] Prokaj *et al.*: Inferring tracklets for multi-object tracking (CVPRW, 2011)
[8] Reilly *et al.*: Detection and Tracking of Large Number of Targets in Wide Area Surveillance (ECCV, 2010)

Fraunhofer
IOSB

Quantitative Evaluation II

Test case / Component	T_1	T_2	T_3	T_4	T_5
Appearance descriptor	+	−	+	+	+
Vehicle collision test	+	+	−	+	+
Classifier based detections	+	+	+	−	+
Clutter handling	+	+	+	+	−
MOTA	**0.602**	0.565	0.582	0.543	0.289

Qualitative Evaluation

Fraunhofer
IOSB

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!