VOT
visual object tracking

The Visual Object Tracking Challenge Results
VOT-RGBT 2019

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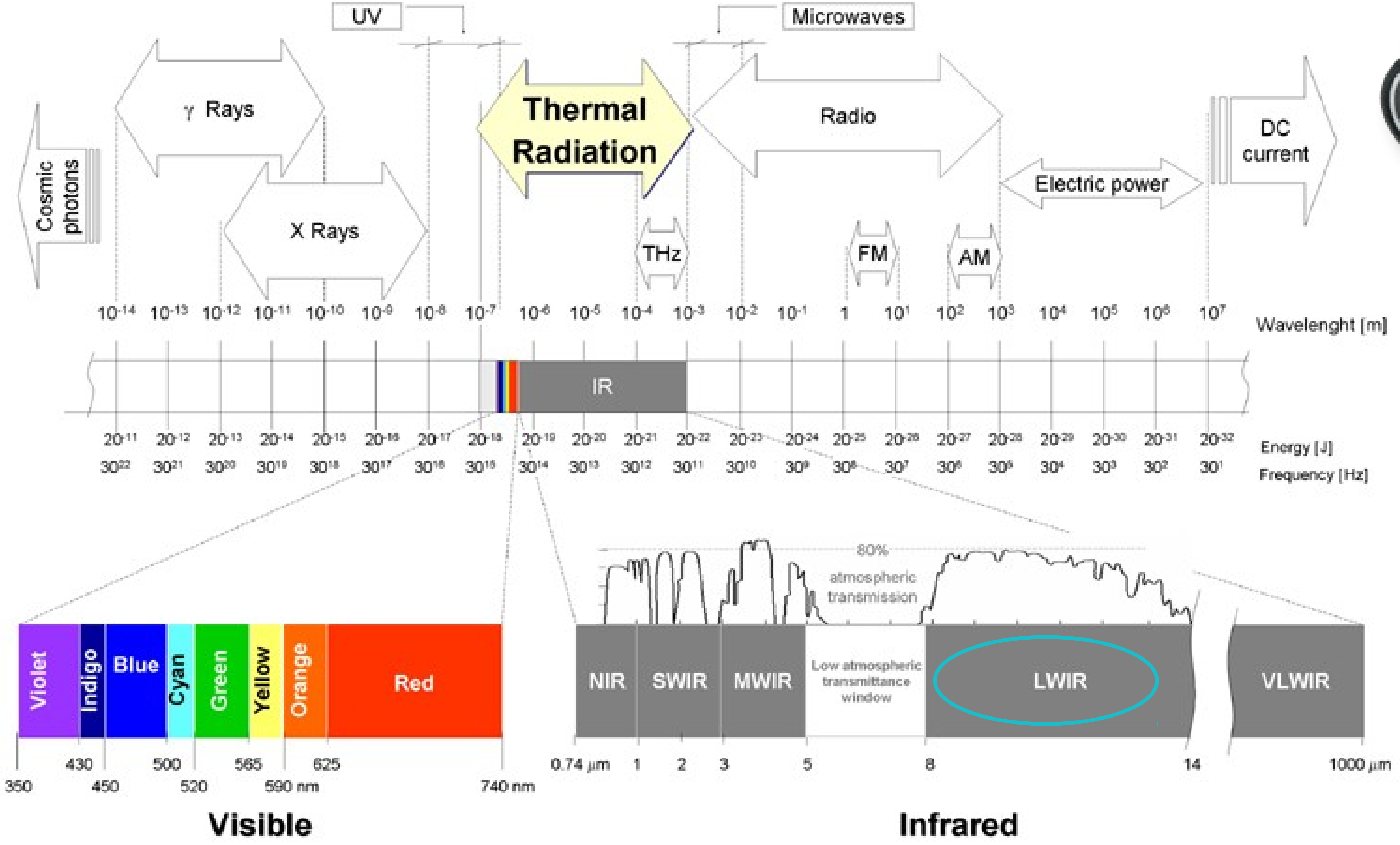
UNIVERSITY OF BIRMINGHAM

LINKÖPING UNIVERSITY

AUSTRIAN INSTITUTE OF TECHNOLOGY

Tampere University

Why adding Thermal Image Modality?



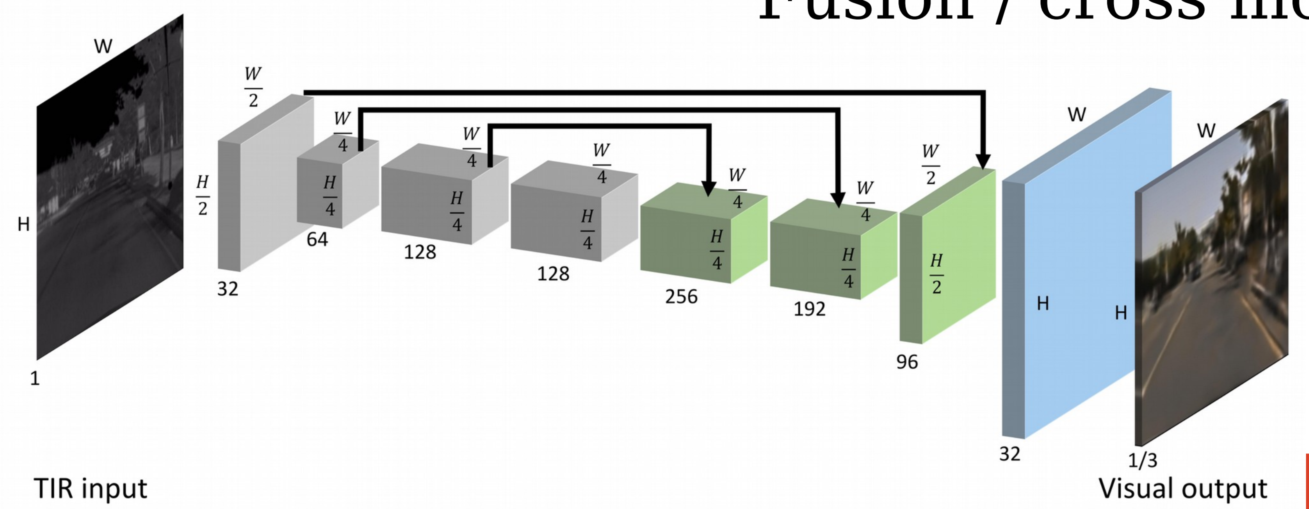
http://www.theses.ulaval.ca/2005/23016/apb.html

Applications of TIR

- Scientific research
- Security
- Fire monitoring
- Search and rescue
- Automotive safety
- Personal use
- ~~Military~~

Challenges

- Interpretation of TIR images
  - TIR2RGB
- Tracking: RGB and TIR
  - Calibration and registration
  - Understanding the similarities and complementaries (VOT-TIR)
  - Fusion / cross modality (VOT-RGBT)



Pre-VOT datasets for tracking in TIR

Name	Purpose	Resolution	#Bits	Stat/Mov
OSU Pedestrian [5]	Pedestrian detection and tracking.	360 × 240	8	Y/N
OSU Color-Thermal [6]	Pedestrian detection, tracking and thermal/visual fusion.	360 × 240	8	Y/N
Terravic Motion [7]	Detection and tracking	320 × 240	8	Y/N
LITIV [8]	Visible-infrared registration.	320 × 240	8	Y/N
ASL-TID [9]	Object (pedestrian, cat, horse) detection and tracking.	324 × 256	8/16	N/Y
BU-TIV [10]	Various visual analysis tasks. Single-object, multiple-object and multiple sensor tracking as well as motion patterns.	Up to 1024 × 1024	16	Y/N

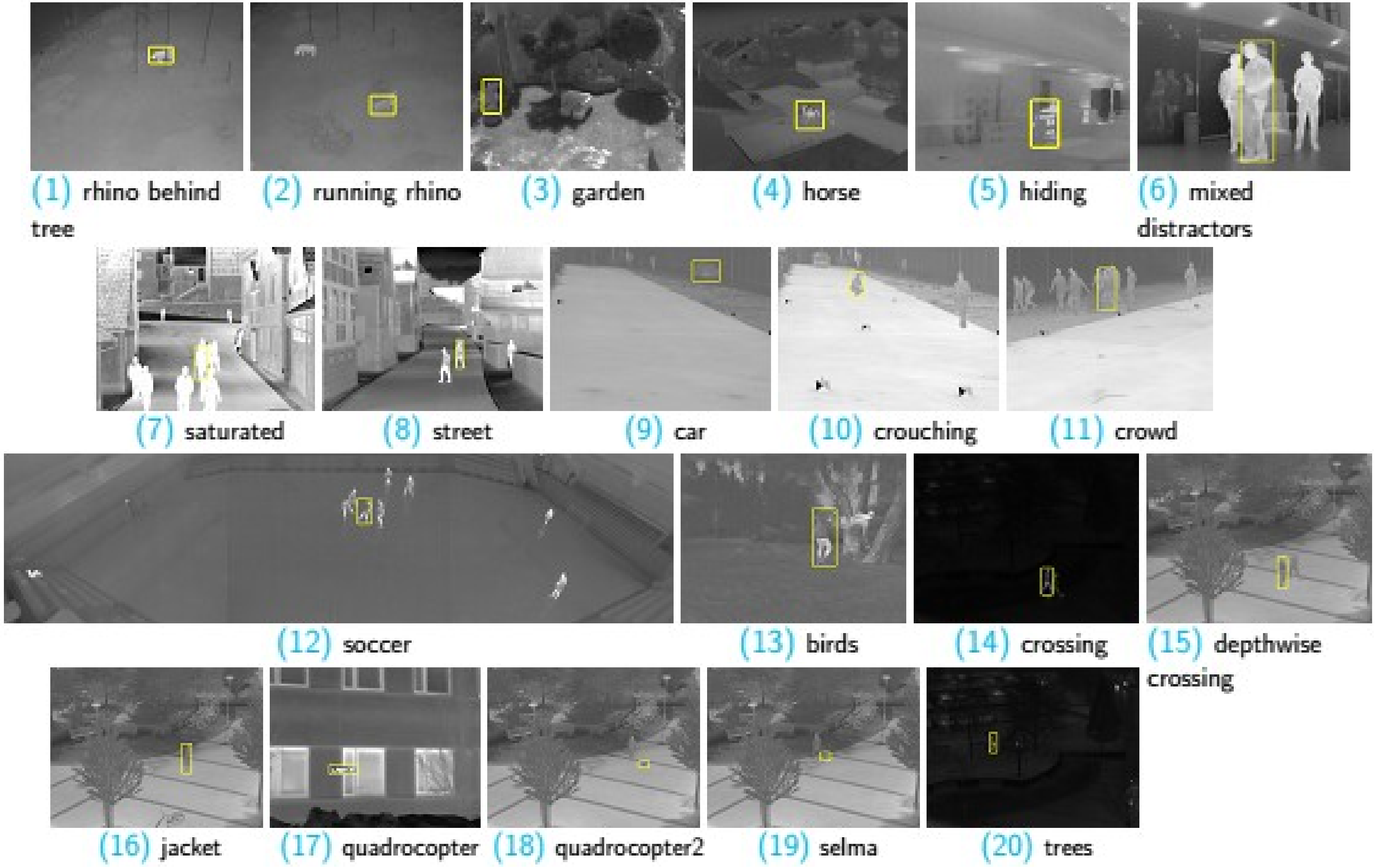
Why a separate challenge?

Tracking in TIR different from tracking in low resolution grayscale visual?

Many similarities but also interesting differences

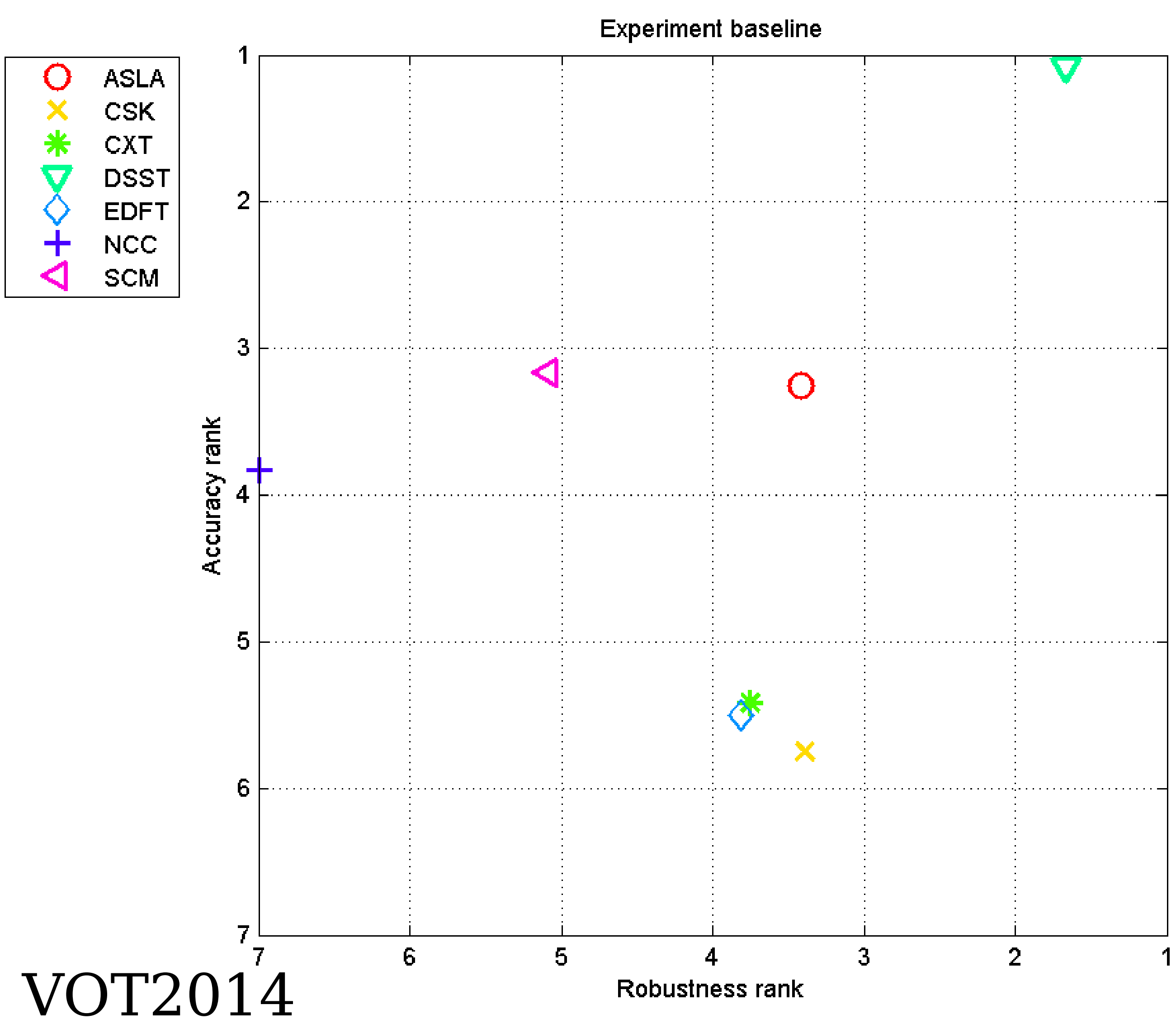
- 16-bit
- Constant values if radiometric
- Less structure/edges/texture
- No shadows
- Noise: blooming, resolution, dead pixels

Towards VOT-TIR: Linköping Thermal InfraRed (LTIR) dataset

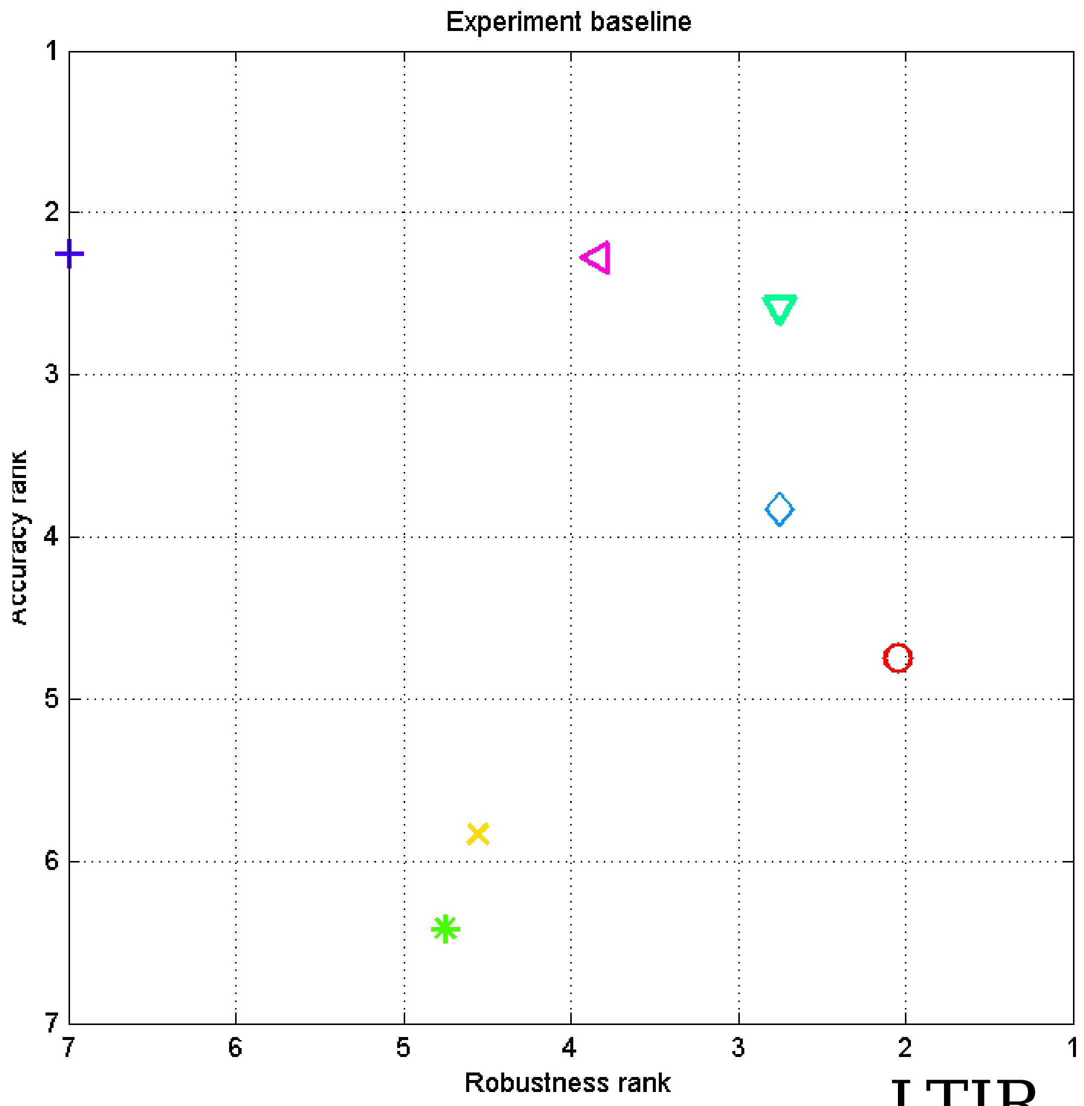


A. Berg,
J. Ahlberg,
M. Felsberg,
A Thermal Object Tracking Benchmark.
AVSS 2015.

Will it be different? Test against VOT2014

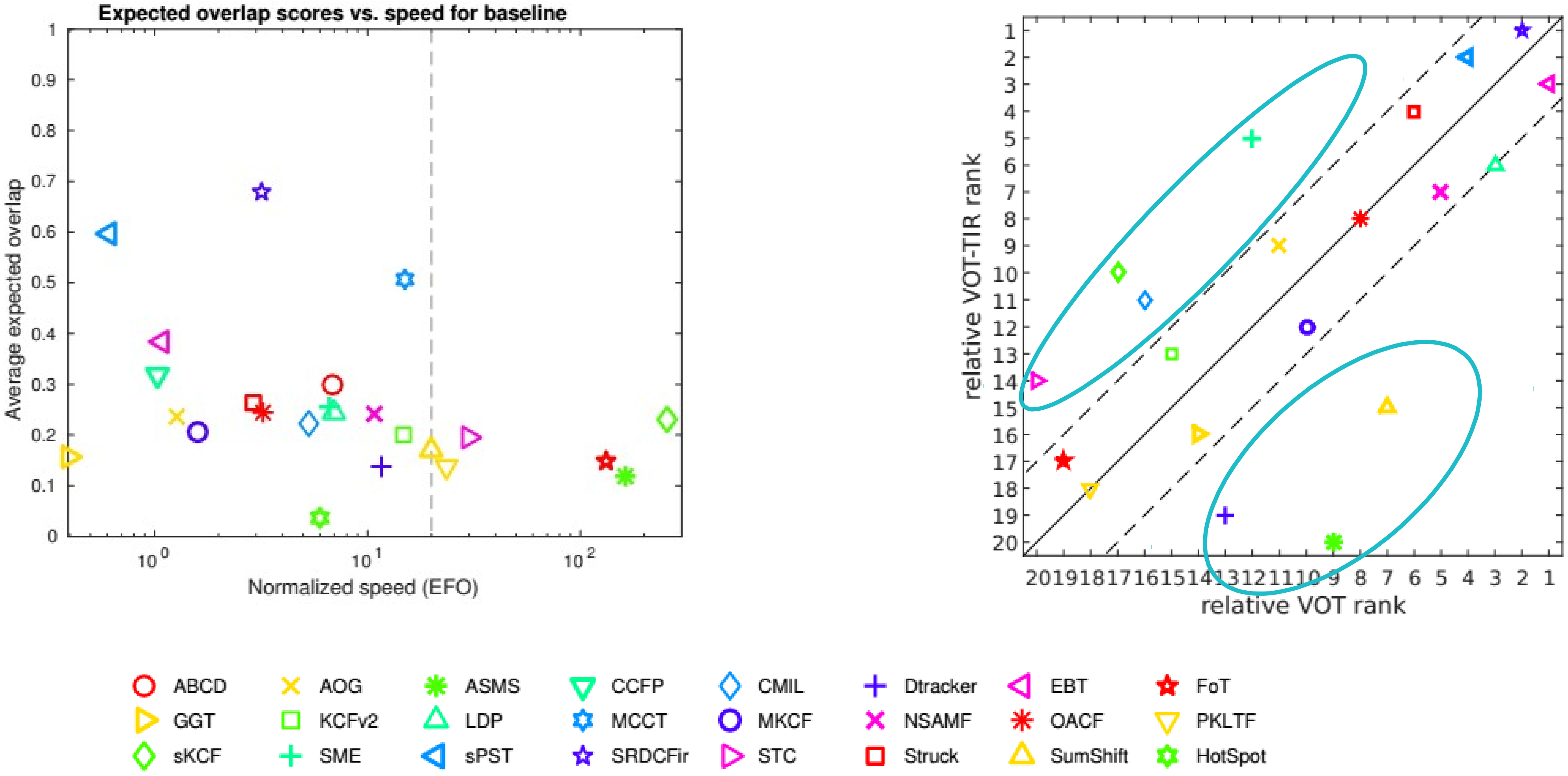


VOT2014



LTIR

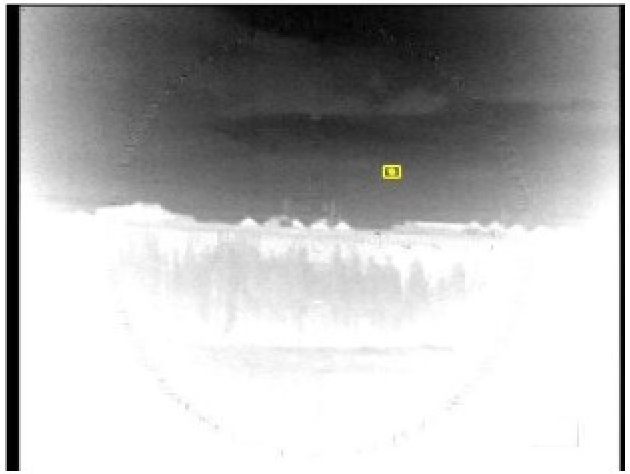
VOT2015 vs VOT-TIR2015



Modifications of LTIR

- VOT-TIR2015 was already saturated
- Call for sequences – limited success (3 new sources, too easy)
- Easiest sequences have been removed: *Crossing*, *Horse*, and *Rhino behind tree*
- New, more difficult sequences have been added: *Bird*, *Boat1*, *Boat2*, *Car2*, *Dog*, *Excavator*, *Ragged*, and *Trees2*

Beihang University



Properties

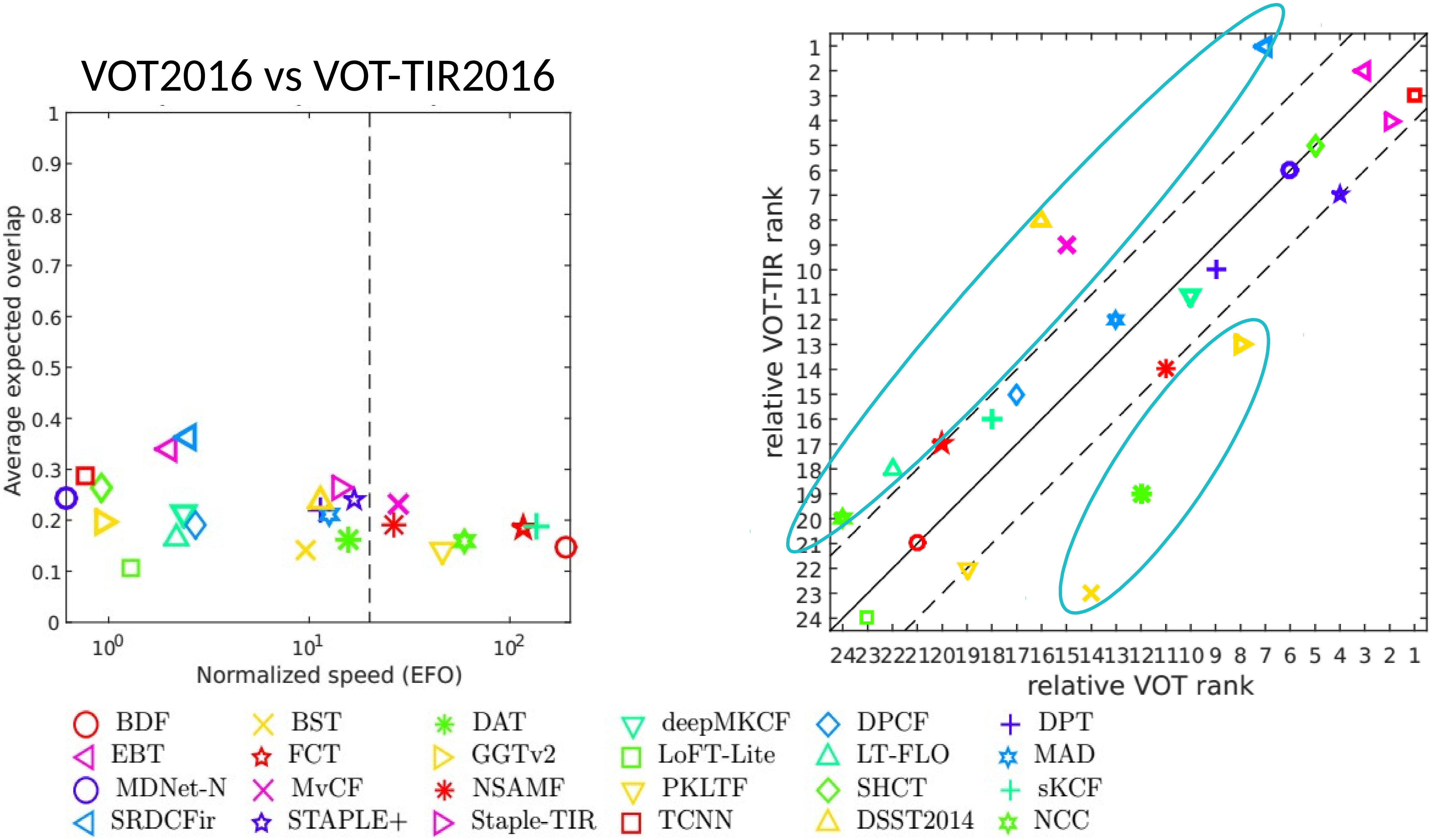
- 25 Sequences
- Average sequence length 740
- Annotations in accordance with VOT
  - Bounding-box
  - 11 global attributes (per-sequence)

    Blur, dynamics change, temperature change, object motion, size change, camera motion, background clutter, aspect ratio change, object deformation, scene complexity, neutral

  - 6 local attributes (per-frame)

    Occlusion, dynamics change, motion change, size change, camera motion, neutral

VOT2016 vs VOT-TIR2016



RGBT-dataset

- RGBT234-dataset from: C. Li, X. Liang, Y. Lu, N. Zhao, and J. Tang. RGB-T object tracking: Benchmark and baseline. Pattern Recognition (96), 2019
- 234 sequences with an average length of 335 frames
- Same clustering in 11-dim attribute space, but now 60 sequences
- Local attribute illumination/dynamics change not used
- Original axis-aligend annotation has been replaced with new rotated bboxes

Issues

- Spatial accuracy (addressed by re-annotation)
- Synchronization (considered part of challenge)

Semi-automatic (re-)annotation

- Procedure described in paper #2:
  A. Berg et al. *Semi-automatic annotation of objects in visual-thermal video*.
- Step 1: semi-automatic video segmentation based on: J. Johnander et al. *A generative appearance model for end-to-end video object segmentation*. In CVPR, 2019.
- Step 2: bounding box determination: T. Vojir and J. Matas. *Pixel-wise object segmentations for the VOT 2016 dataset*. Research Report CTU–CMP–2017–01.

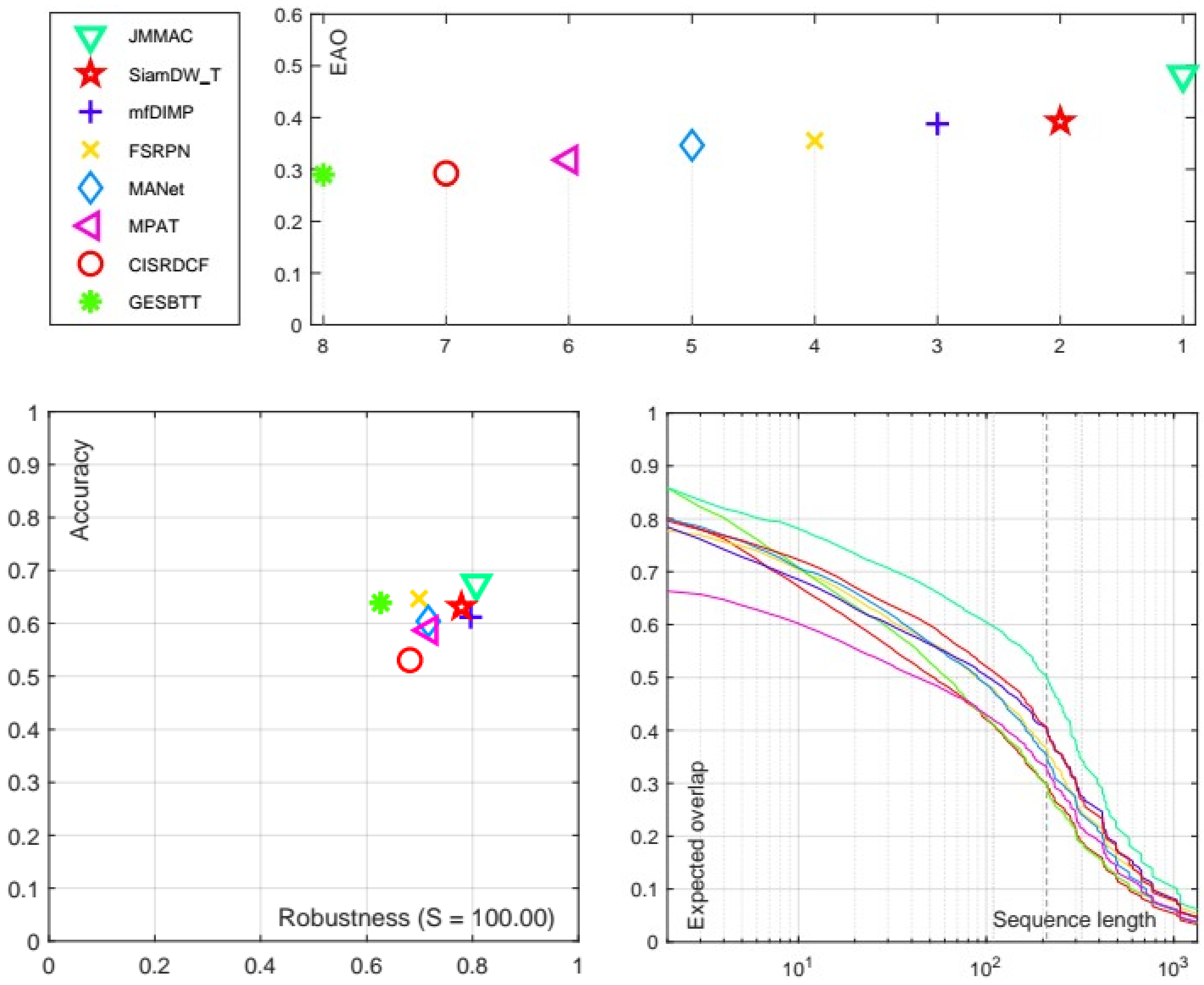
- Synchronization issue: TIR is used as reference
- Spatial accuracy: EAO RGB-TIR 0.75
- Evaluation is performed in the same way as for VOT-ST 2019
- Top-ranked trackers on the public dataset run by the committee on the sequestered dataset
- Top-ranked tracker on the sequestered dataset is the winner

Submitted tracker

- 10 trackers in total, 8 unique submissions with code
  - 5 ST_1, 3 ST_0
  - 7 uniform dynamic model, 1 random walk
  - 4 trackers based on discriminative correlation filters: CISRDCF, GESBTT, JMMAC, and mfDiMP
  - 4 trackers based on multiple CNNs: MANet, mfDiMP, MPAT, and SiamDW_T
  - 4 trackers make use of Siamese CNNs: FSRPN, mfDiMP, MPAT, and SiamDW_T
  - 2 trackers apply a Kalman filter: GESBTT and JMMAC
  - 1 tracker makes use of optical flow: GESBTT
  - 1 tracker makes use of ransac: JMMAC
  - 5 trackers use combinations of several features
  - 6 trackers use CNN features
  - 3 trackers use hand-crafted features
  - 2 trackers use keypoints
  - 2 trackers use grayscale features

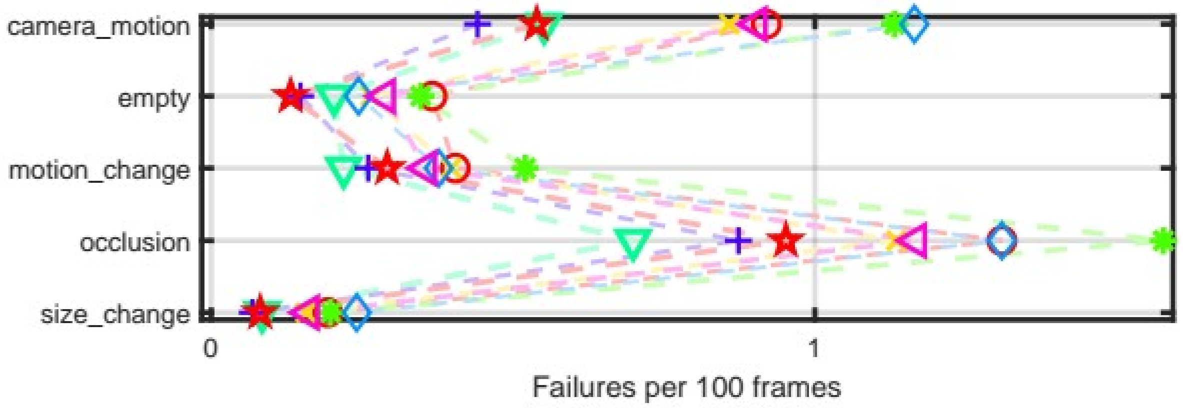
Results on public dataset

- All top-5 trackers use CNN features
- Respectively 3 out of these 5 trackers use
  - DCFs
  - Multiple CNNs
  - Siamese CNNs
  - JMMAC is working significantly better than the other two DCF-based trackers – RANSAC reason?



Further results

- EAO is stronger correlation to robustness than accuracy
- Robustness is most challenging for occlusion and camera motion
- Changed order for sequestered dataset



	Tracker	EAO	A	R
1.	mfDiMP	0.2347 ①	0.6133	0.3160 ①
2.	SiamDW_T	0.2143 ②	0.6515 ②	0.2714 ②
3.	MANet	0.2041 ③	0.5784	0.2592 ③
4.	JMMAC	0.2037	0.6337 ③	0.2441
5.	FSRPN	0.1873	0.6561 ①	0.1755

VOT-ST2019 Winners

Winners of the VOT-RGBT 2019 challenge:

mfDiMP by: L. Zhang, A. Gonzalez-Garcia, J. van de Weijer

"Multi-modal fusion for end-to-end RGB-T tracking"

(The talk up next!)

Summary

- CNN-features dominating
- The ranking changes on sequestered dataset
- Overall performance decreases on sequestered dataset
- Robustness most important
- Occlusion and camera motion largest challenges
- For the future:
  - Attract more participants
  - Measure the effect of spatial missalignment and synchronization errors?
  - Potential other changes in the evaluation system

Thanks

- The VOT2019 committee


M. Kristan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- Everyone who participated or contributed

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- VOT2019 sponsor:

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