The Visual Object Tracking Challenge Results VOT2017

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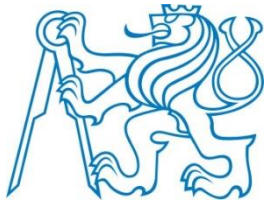

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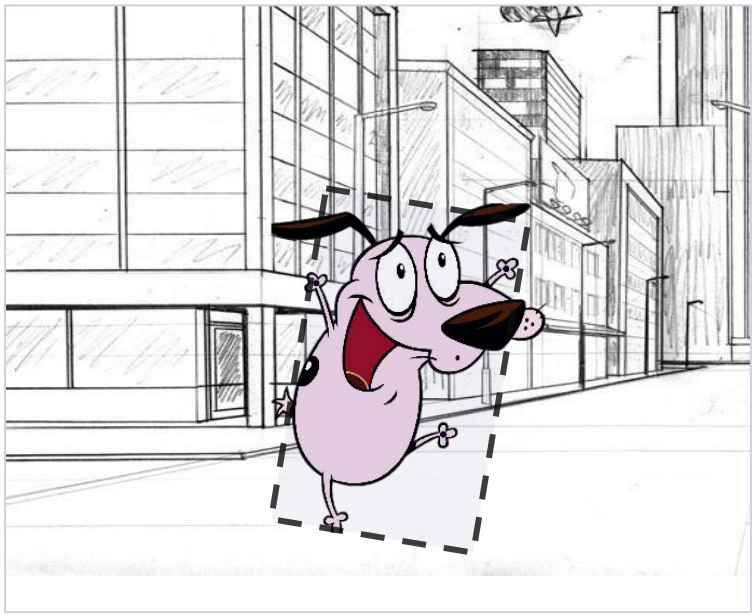
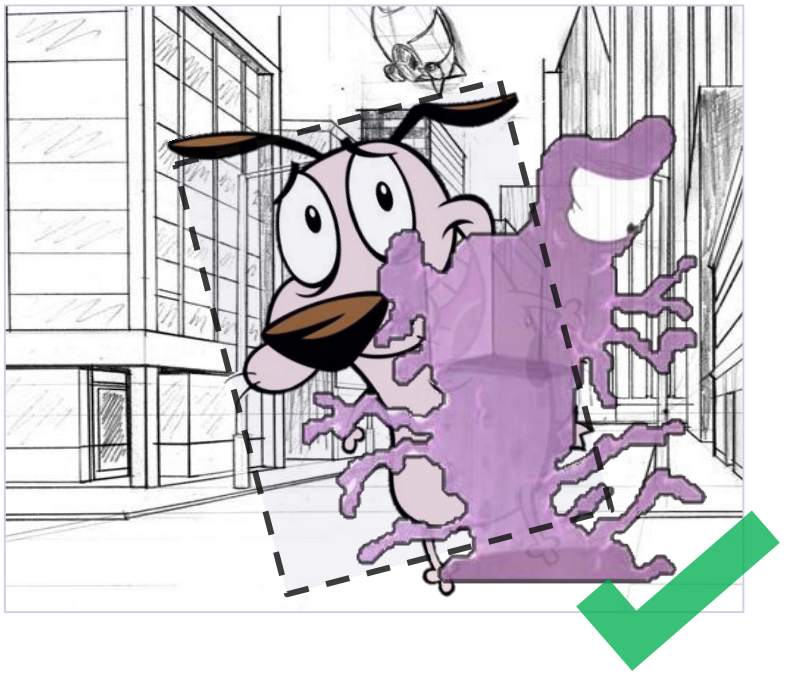
Outline

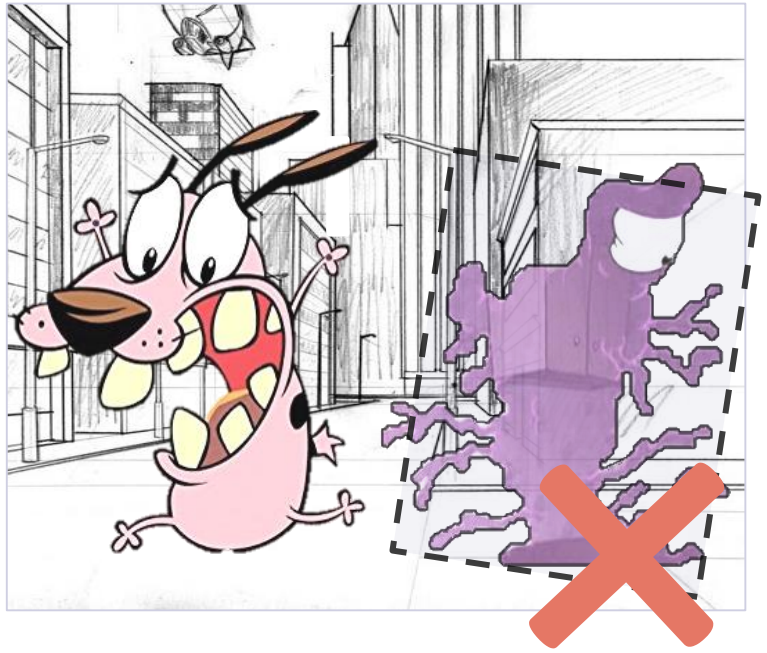
1. Scope of the VOT challenge
2. VOT2017 challenge overview and novelties introduced
3. VOT2017 results overview + winner announcement
4. Summary and outlook

Scope of the VOT2017 challenges

- Short-term, single-target, causal trackers
- No redetection: drift is considered a failure and tracker is reset







- Target state represented by a rotated bounding box

The VOT2017 evaluation system

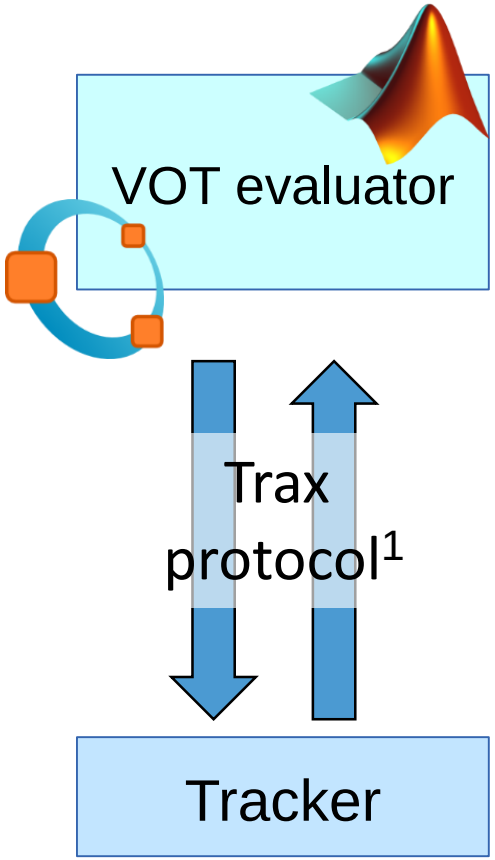
- A Matlab toolkit automatically performs a battery of standard experiments

  Currently the most advanced toolkit in visual tracking.
  https://github.com/vicoslab/vot-toolkit

- Plug and play!
  - Supports major programming languages and operating systems

- New version: Changes made to support new experiments

- Transition to the latest version of the toolkit was required (VOT2013 toolkit not supported)



[1]Luka Čehovin, TraX: The visual Tracking eXchange Protocol and Library, Neurocomputing, 2017

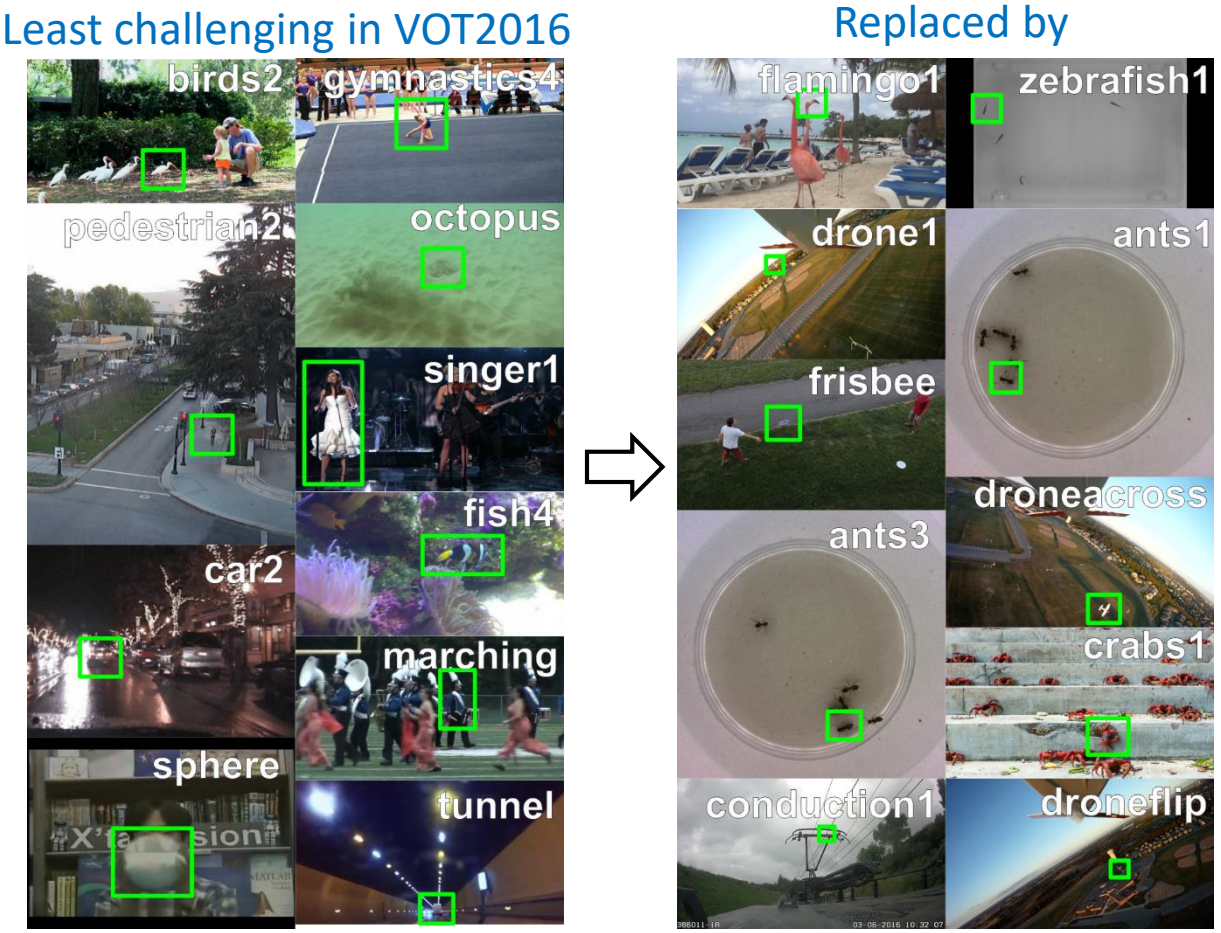
The VOT2017 dataset

- VOT approach: Keep it sufficiently small, well annotated and diverse
- Developed the VOT dataset construction methodology
- New this year two datasets: public and a sequestered

- Public: refreshed VOT2016 dataset
  (for tracking community)
- Sequestered: new sequences, similar to the VOT2017 public
  (for winner identification)

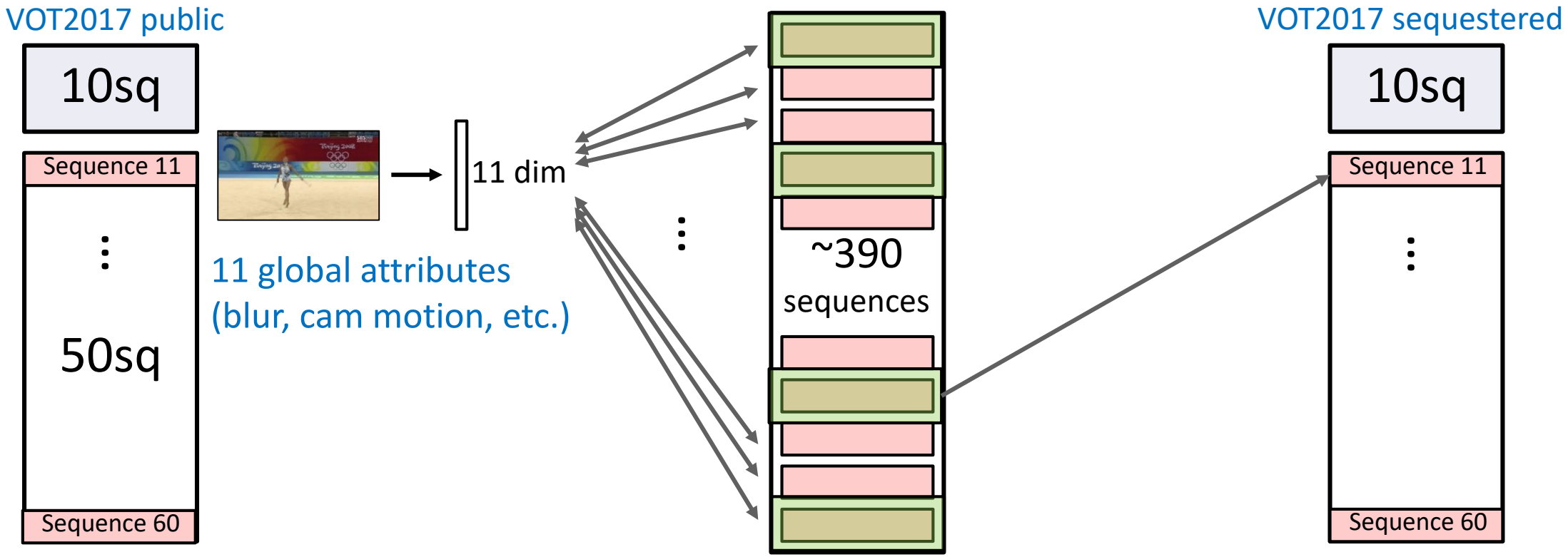
The VOT2017 public dataset

- VOT2016 dataset (60 sequences) not saturated, still challenging (refresh required only)
- Obtained 10 pairs of new sequences (not present in other benchmarks)
- Replaced 10 least challenging sequences in VOT2016 (~17%)
- VOT2016 difficulty level estimation methodology applied



The VOT2017 sequestered dataset

- Guideline: similar to the public dataset in attributes, but not easier
- 10 remaining new sequences entered the sequestered dataset
- Remaining 50 sequences selected from a pool of ~390 sequences



The VOT2017 dataset annotation

- Each image annotated by 6 attributes:

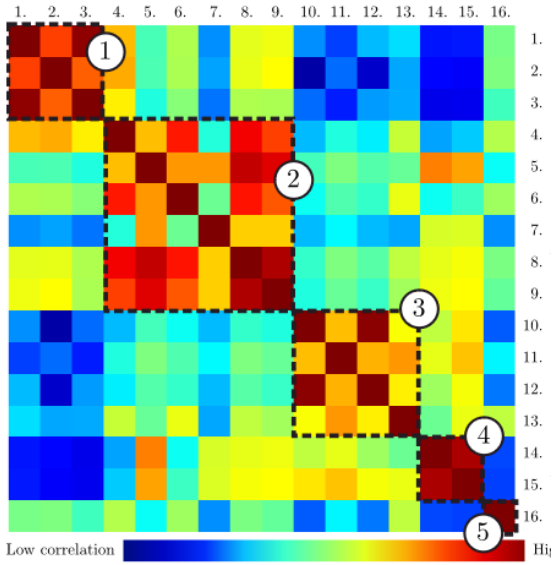
  Occlusion, Illumination change , Object motion, Object size change, Camera motion, Unassigned

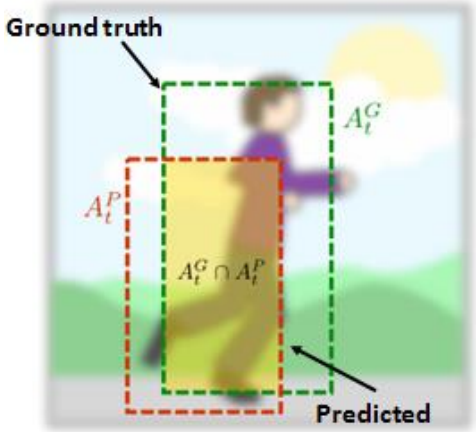
- Each image semi-automatically segmented
- A bounding box fitted automatically to segmentation mask (VOT2016 protocol)

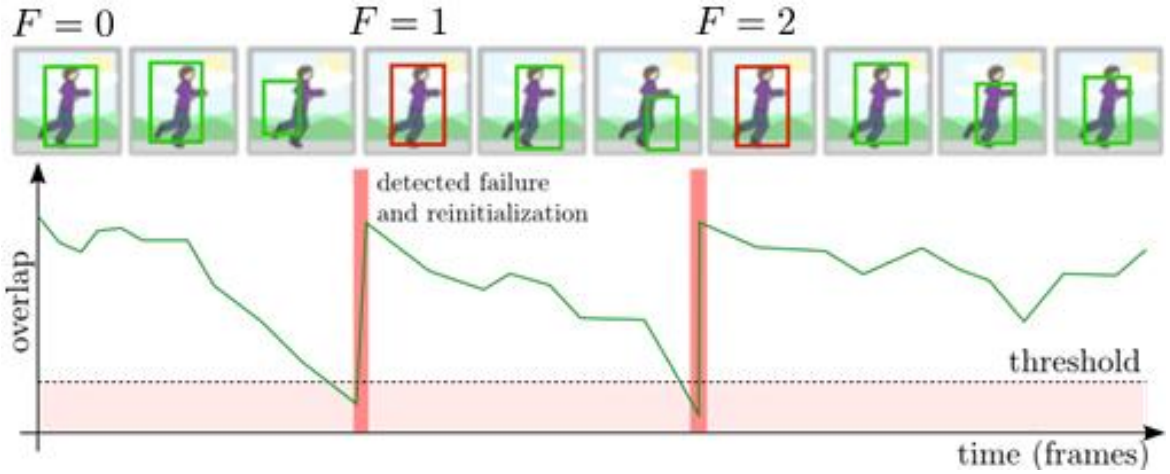
Evaluation methodology as in VOT2016

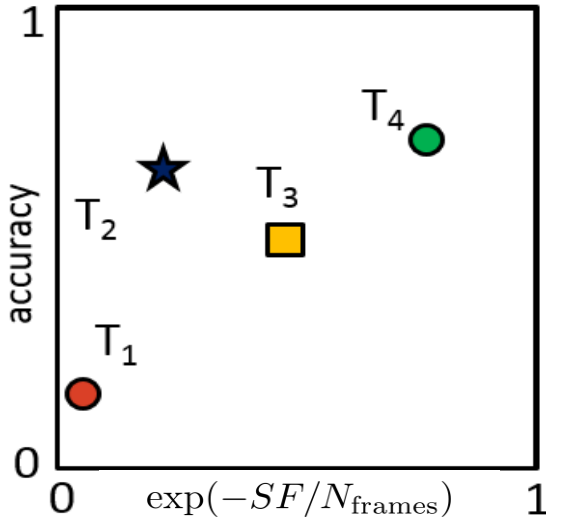
- Two weakly correlated measures[2] chosen according to[1]:
  - Robustness (number of times a is reinitialized)
  - Accuracy (average overlap while tracking)
  - + Combination of basic measures (EAO)

Performance measure correlation analysis[1]









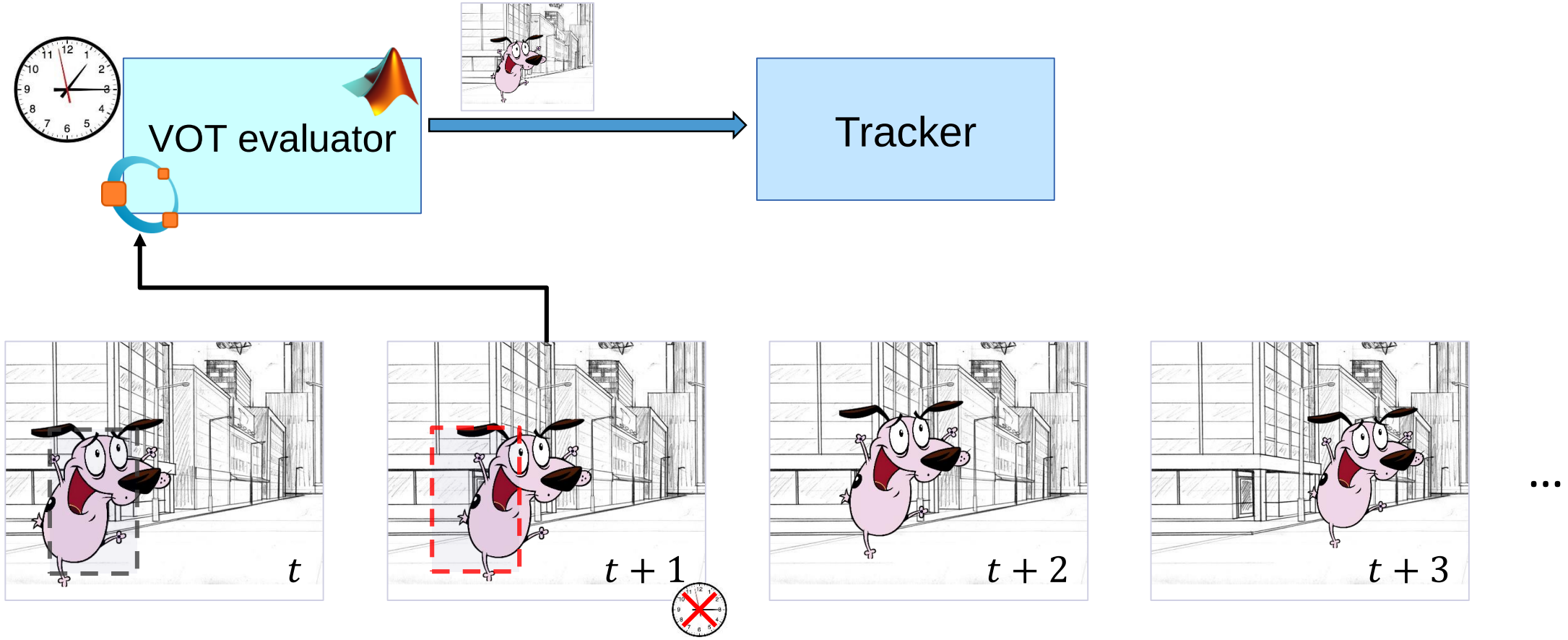
[1]Čehovin, Leonardis, Kristan. *Visual object tracking performance measures revisited*, IEEETIP 2016
[2]Kristan et al., A Novel Performance Evaluation Methodology for Single-Target Trackers, IEEETPAMI 2016

The VOT2017 main challenges

- VOT2017 baseline challenge
  - Experiment with resets upon drifts (VOT standard)
  - Experiments without resets (OTB standard)

- New challenge: VOT2017-realtime challenge
  - Since 2015 efforts made towards stressing the importance of speed
  - Introduction of EFO measure
  - But speed does not directly translate to performance in realtime scenario

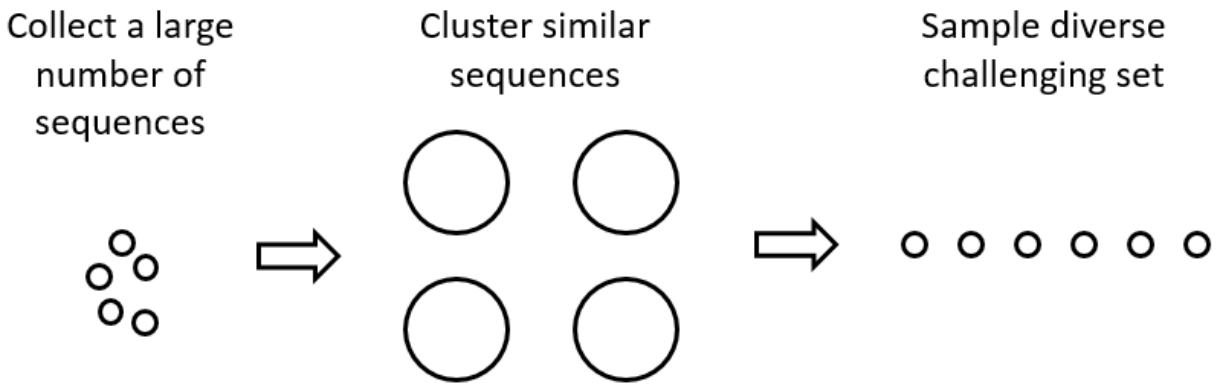
VOT2017-realtime challenge (NEW)



- Tracker required to produce the output faster than frame-rate
- The VOT reset-based methodology used

VOT-TIR2017 challenge

- Task: tracking with thermal videos
- VOT-TIR2016 has not been saturated, therefore in 2017 re-opened
- Follows VOT2013 selection and annotation approach:
  - Small (25 sequences) but diverse dataset according to VOT methodology



  - Derived from Linköping Thermal InfraRed (LTIR) dataset[1]
  - Annotation according to VOT methodology (illumination change becomes dynamics)

[1]A. Berg, J. Ahlberg, M. Felsberg, *A Thermal Object Tracking Benchmark*. AVSS 2015.

VOT2017 participation + winner requirements

- Different parameters don't make a different tracker
- Realtime experiment – running on a single machine

Results paper coauthorship:

- Sufficiently well performing tracker (NCC)
- Agree to publish the code online at VOT2017 page

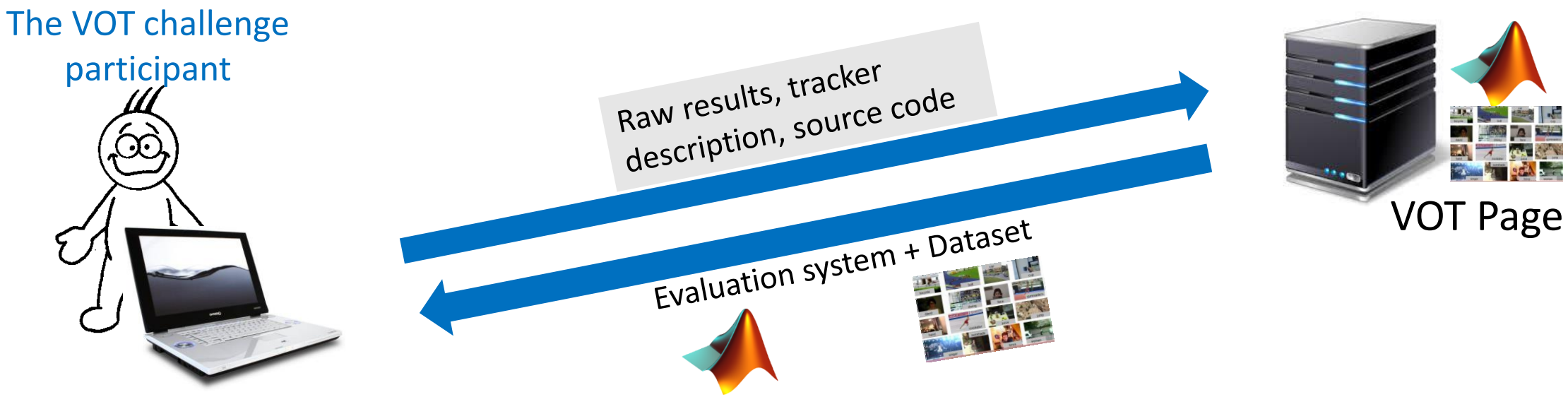
Additional constraint for winners:

- Best-performing tracker *not submitted by the organizers*
- Training on tracking benchmarks prohibited
- VOT2017: Top performance on VOT2017-sequestered dataset
- VOT-TIR2016: Significant improvement compared to 2016

The VOT 2017 workshop

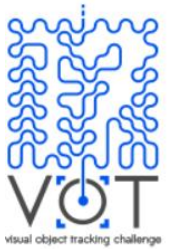
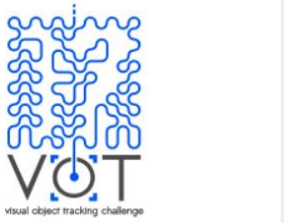
VOT2017 MAIN CHALLENGE PARTICIPATION AND SUBMITTED TRACKERS

VOT2017 participation



- Participants download the toolkit and the VOT2017 dataset
- Toolkit automatically performs all experiments
- Submission of raw results + tracker code required
- Top ten trackers re-run by VOT committee on the sequestered dataset

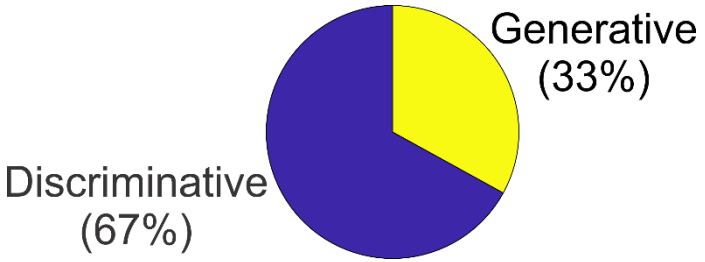
Evolution of VOT submitted trackers

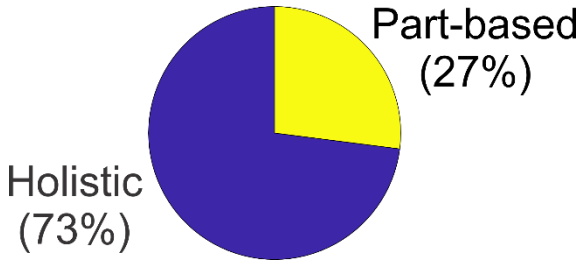
	2013	2014	2015	2016	2017
# Submissions	27	38	62	70	51
Submitted trackers design types	Many diverse trackers submitted	8 Discriminative (sSVM, DCF) 11 Generative 6 Part-based [many diverse]	16 DCF [many diverse] 3 CNN-based	14 CNN-based 27 use DCF [many diverse]	
Top performing	**Discriminative** **Generative** Part-based Holistic	**3 DCF**, Holistic 1 Part-based	**2 CNN-based** 1 sSVM-based 1 Part-based	**CF+CNN** **CNN**, **DCF**	

Kristan et al., "The Visual Object Tracking VOT2013 challenge results," ICCV Workshops 2013
Kristan et al., "The Visual Object Tracking VOT2014 challenge results," ECCV Workshops 2014
Kristan et al., "The Visual Object Tracking VOT2015 challenge results", ICCV Workshops 2015
Kristan et al., "The Visual Object Tracking VOT2016 challenge results", ECCV Workshops 2016
Kristan et al., "The Visual Object Tracking VOT2017 challenge results", ICCV Workshops 2017
Kristan et al., "A Novel Performance Evaluation Methodology for Single-Target Trackers", IEEE TPAMI 2016

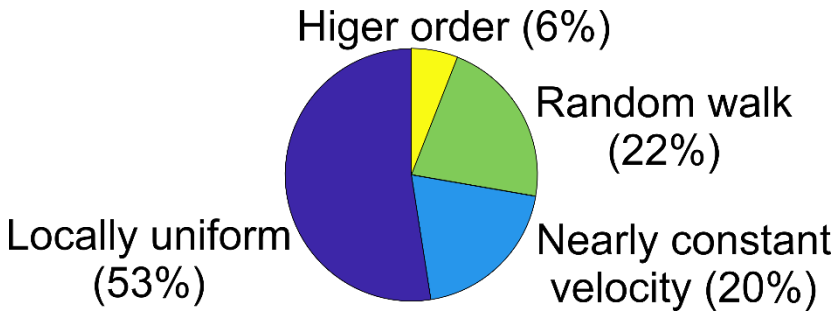
VOT2017: 51 trackers tested

Visual model:





Motion model:



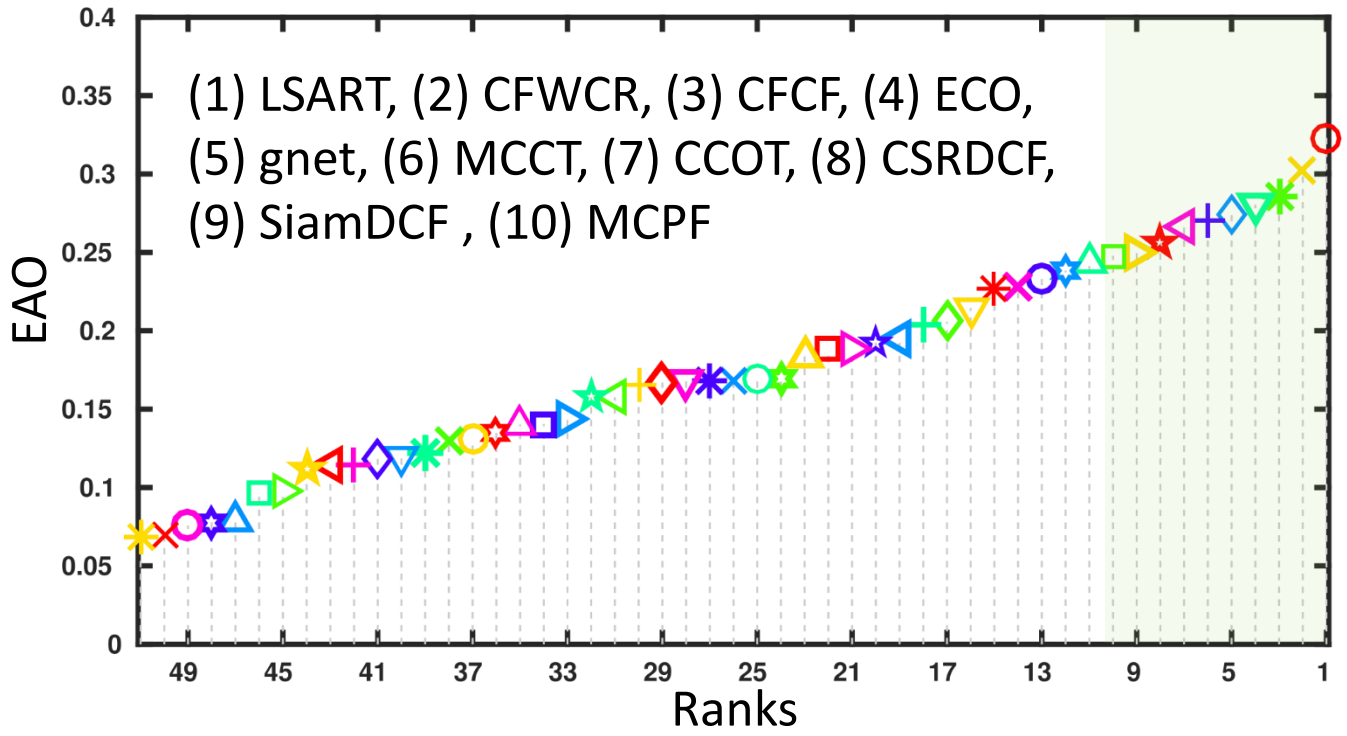
- Discriminative correlation filters (49%)
- Deep convolutional neural nets (31%)
- Mean-shift-based (10%)
- Structured SVM (4%)
- Combination of trackers (3%)

The VOT 2017 workshop

VOT2017 MAIN CHALLENGE RESULTS

VOT2017 results on public dataset

- **Tracking approach:** All apply DCF on top of multi-dim features
- **Features:** All CNN (+handcrafted), except CSRDCF (HoG+Colornames)
  - Most CNN trained for detection, except CFCF and SiamDCF (trained for localization)
- **Design:** most are holistic, except LSART (channels specialize to different parts on target)



VOT2017 results on public dataset

- Top trackers are among the most robust trackers

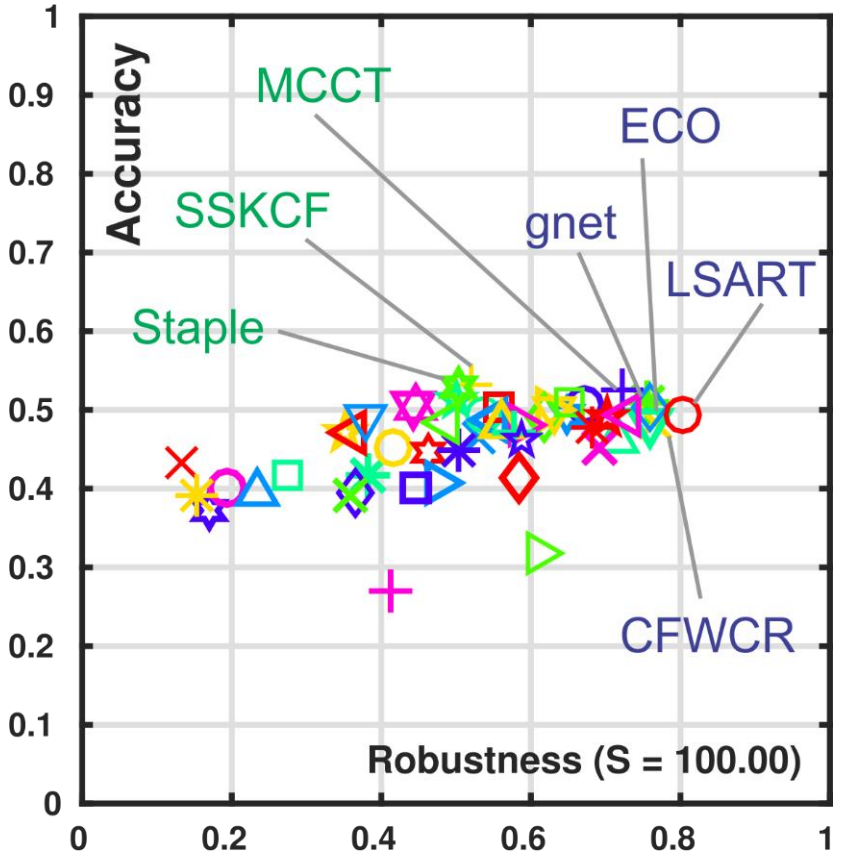
  (1) LSART, (2) CFWCR, (3) ECO, (4) gnet

- Top in accuracy:

  (1) SSKCF, (2) Staple, (3) MCCT

- Per-attribute analysis:

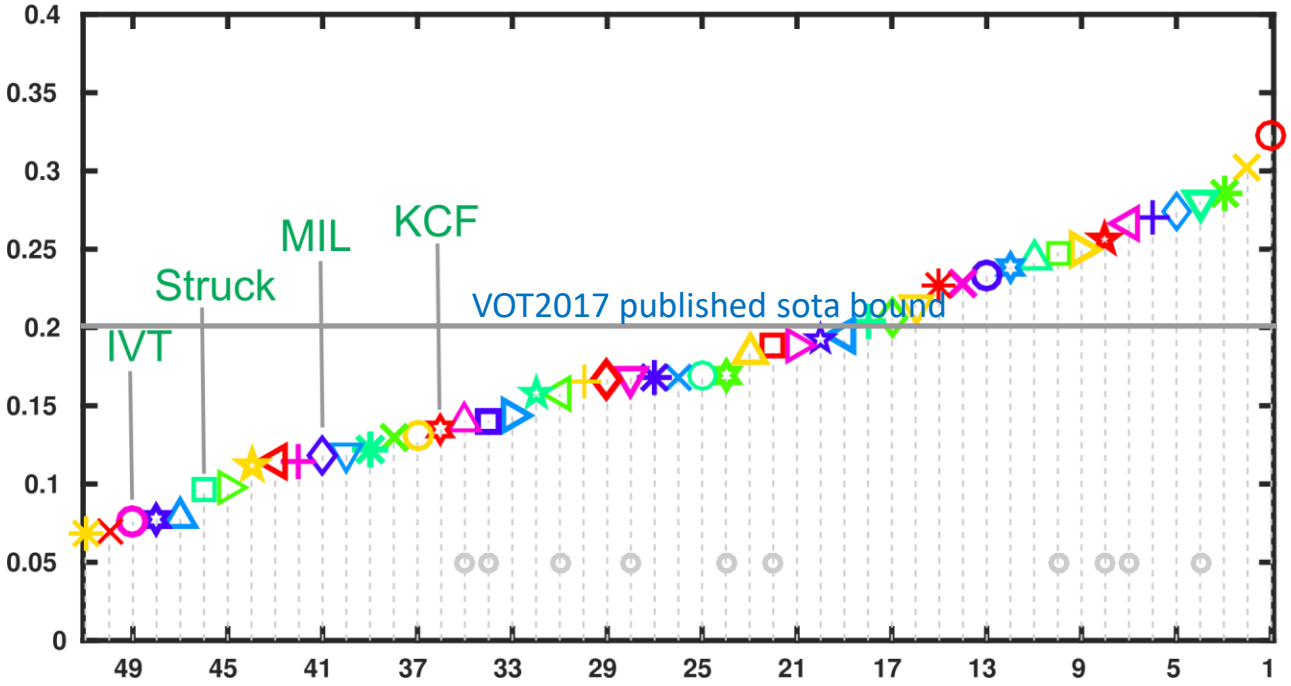
	cam. mot.	ill. ch.	mot. ch.	occl.	scal. ch.
Accuracy	0.48	0.46	0.45 ③	0.39 ①	0.41 ②
Robustness	0.84	1.16 ②	0.97 ③	1.19 ①	0.69



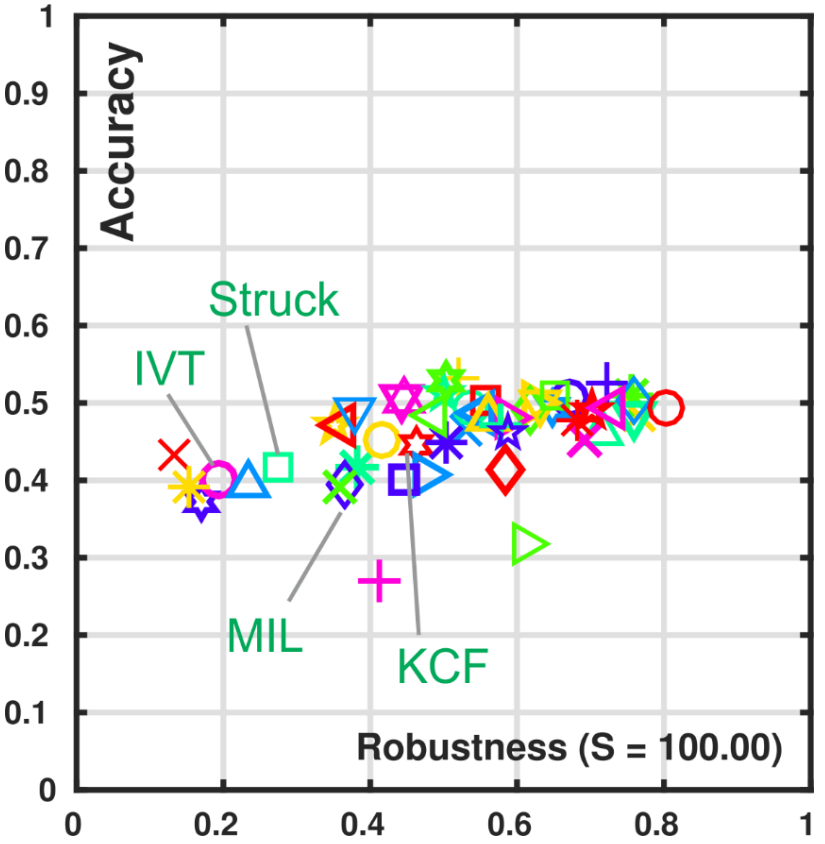
- Most failures due to: Occlusion
- Mostly affects accuracy: Occlusion + Scale change

VOT2017 results on public dataset

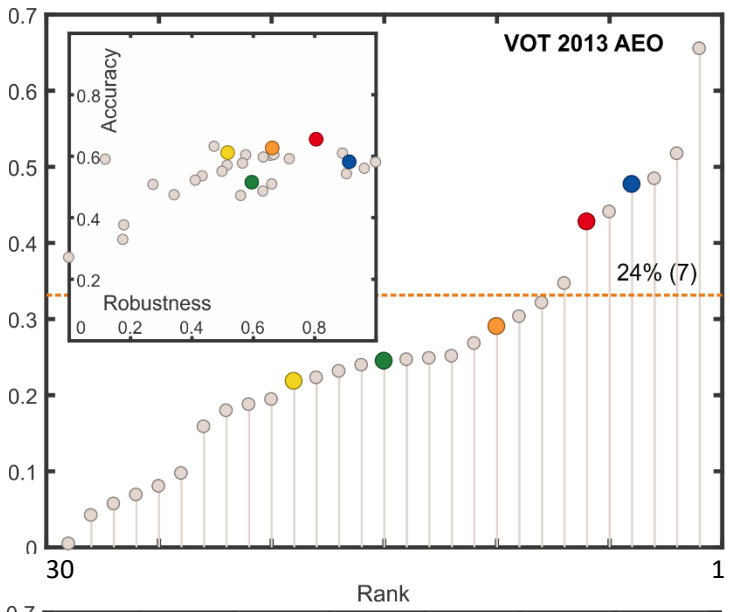
- Baselines ranked at the very tail of the benchmark
- 10 trackers published at major CV venues (2016>)
  - Their average performance: VOT2017 sota bound
  - Over 35% submissions exceed this bound

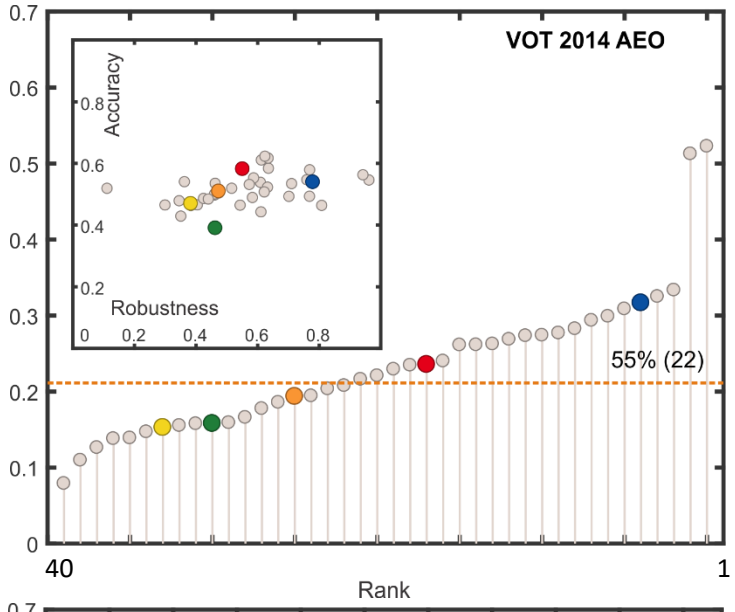


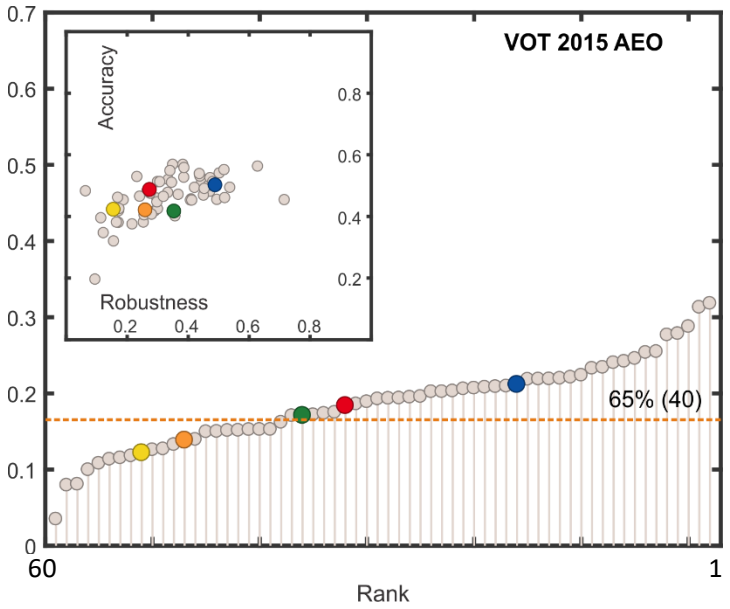
Most submissions are highly advanced trackers!

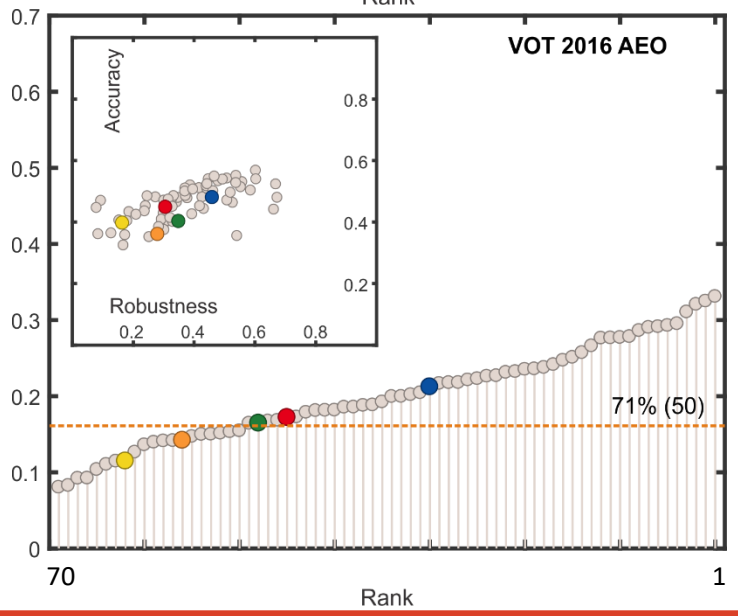


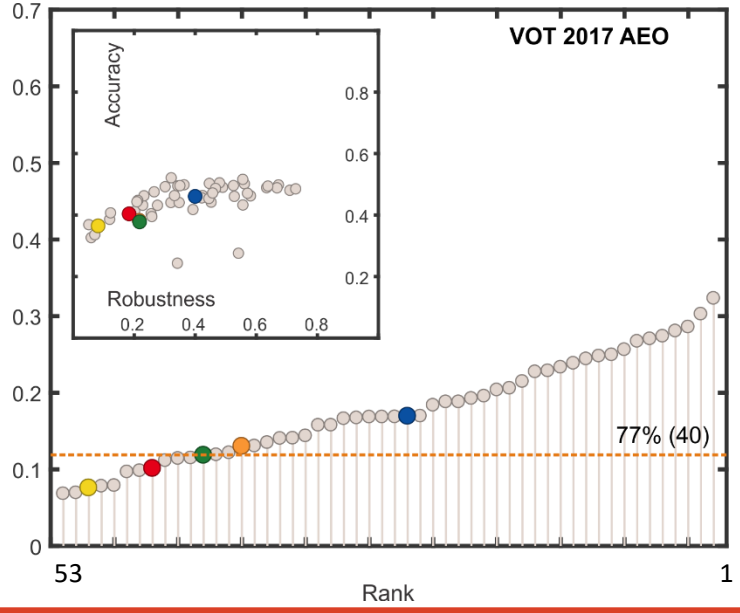
VOT submitted trackers quality over the years











The submitted trackers are:

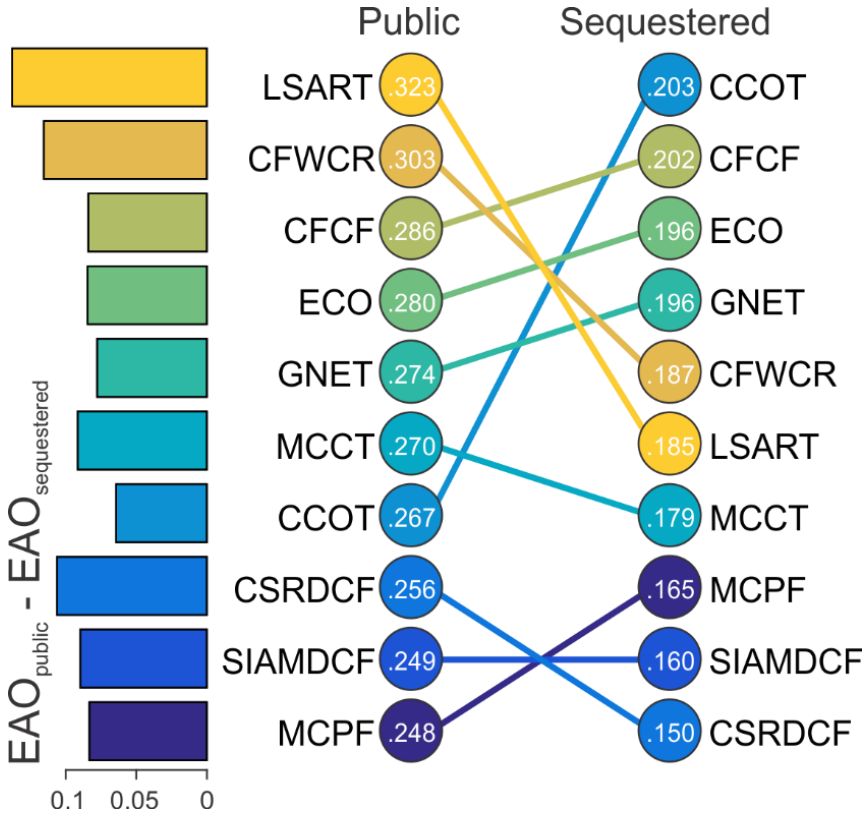
... getting more accurate

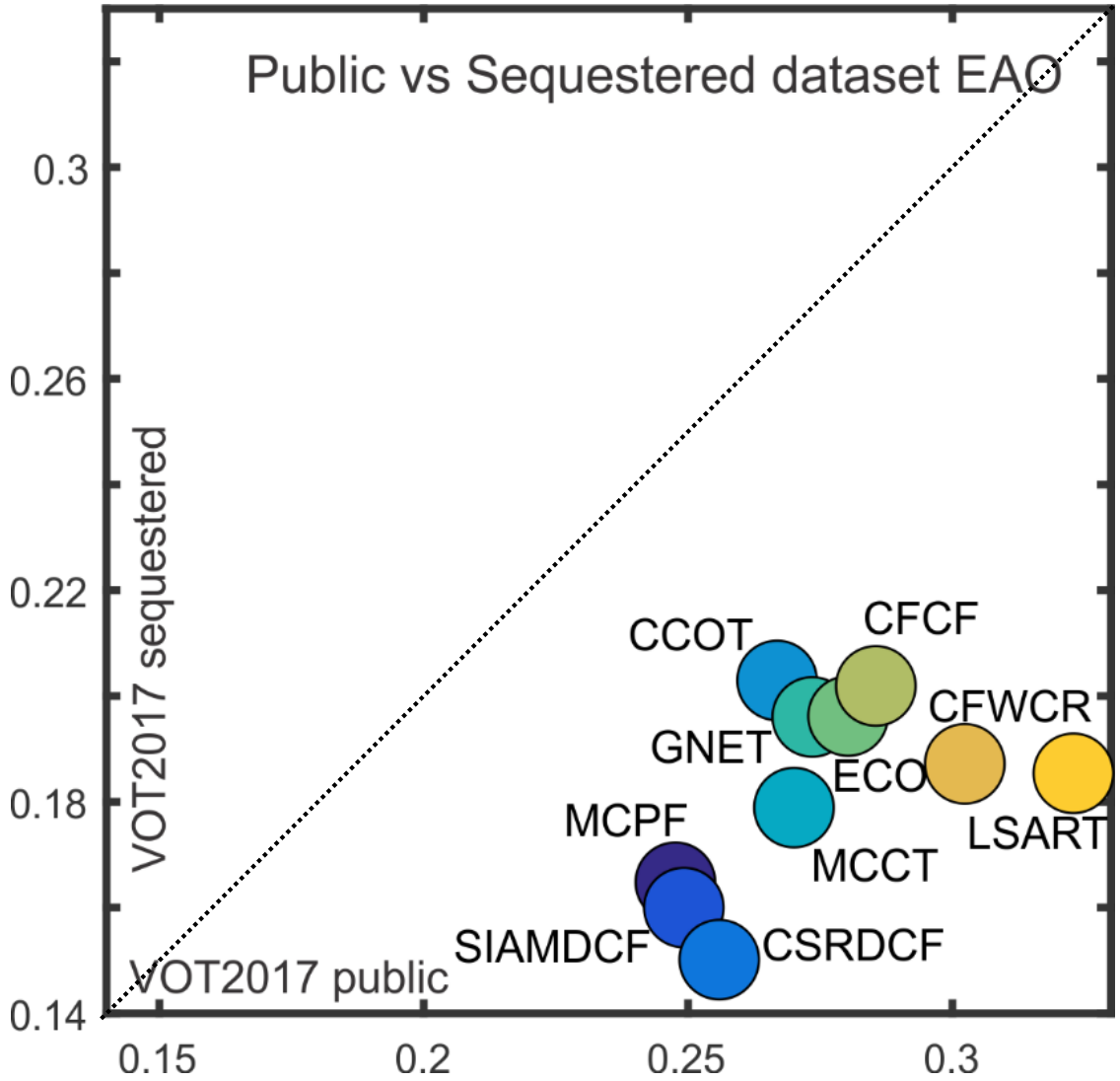
... getting more robust

... increasingly exceeding baselines

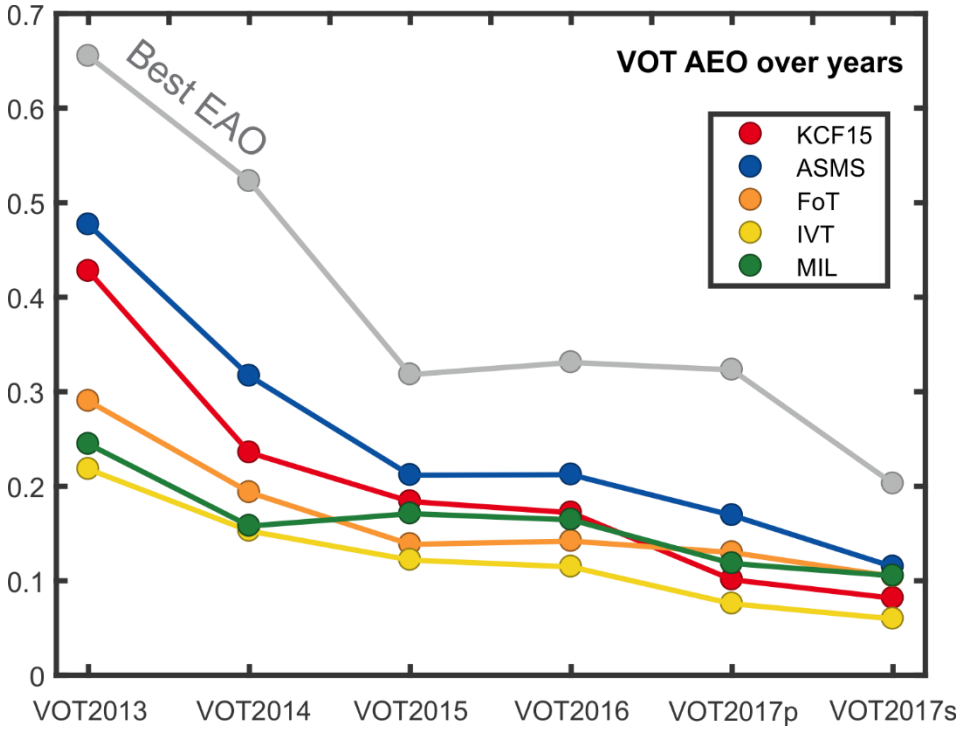
VOT2017 results on sequestered dataset

- Fairly stable ranks
- Greatest change: LSART
- Smallest change: CCOT





The VOT datasets tracking difficulty



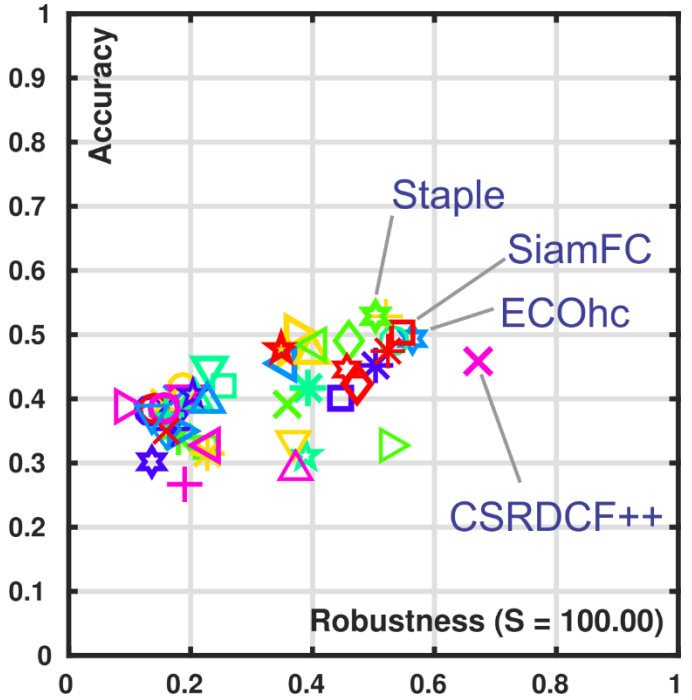
Dataset increasingly more challenging
Top performance stabilized on public dataset

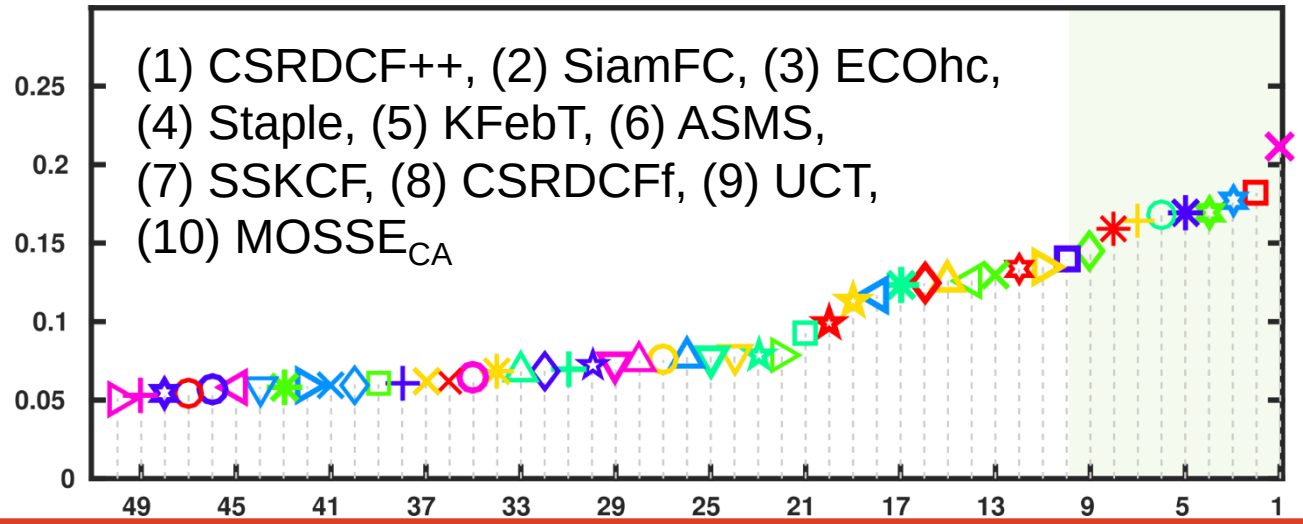
The VOT 2017 workshop

VOT-REALTIME RESULTS

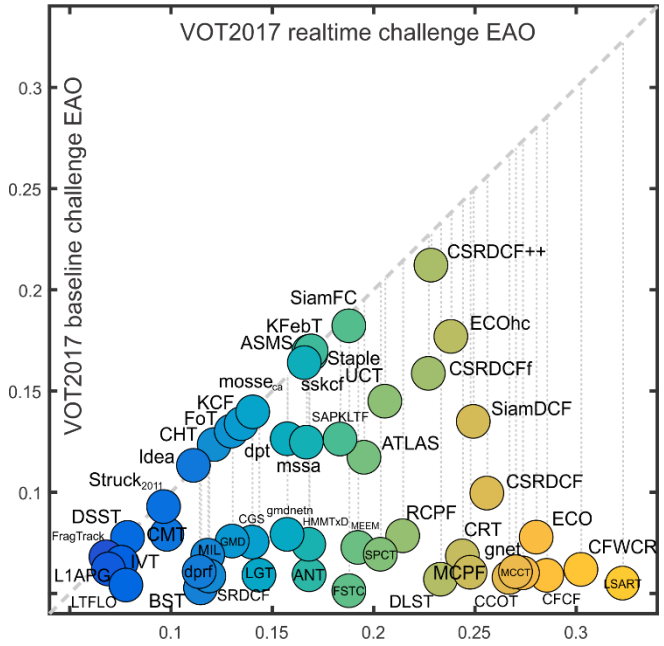
VOT2017-realtime results on public dataset

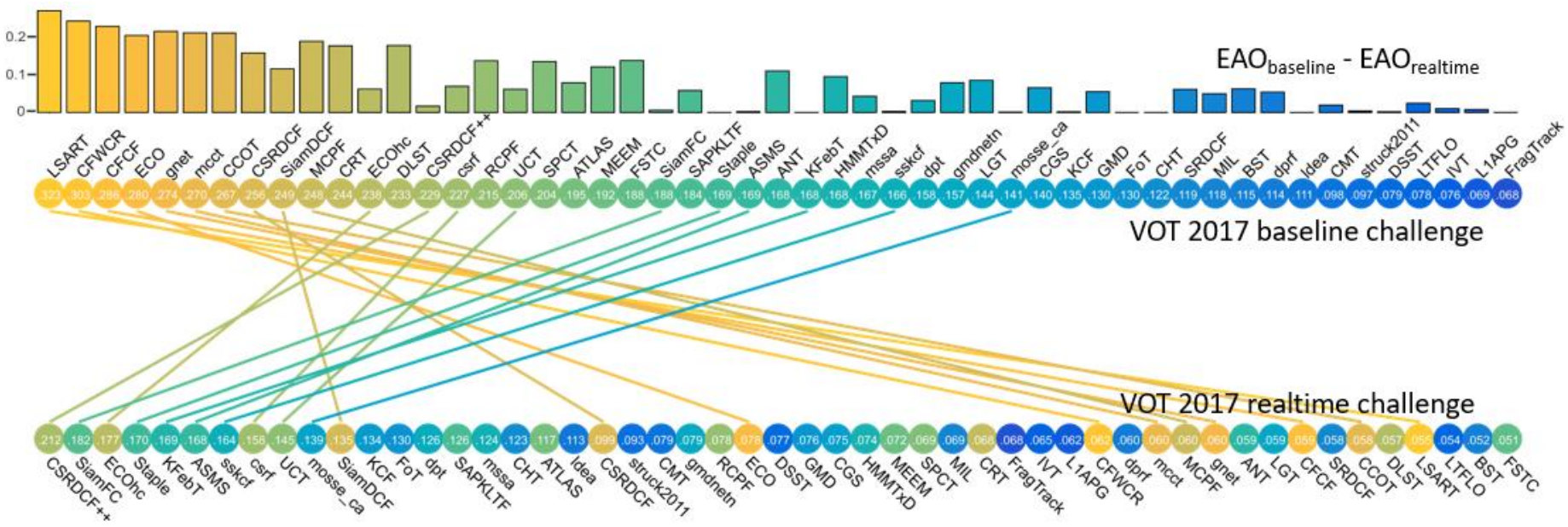
- **Tracking approach:** All apply DCF except from ASMS (scale-adaptive MS), SiamFC and UCT (CNN correlation)
- **Features:** Handcrafted, some apply CNN
  - SiamFC pretrained for template correlation
  - SiamDCF: pretrained for CF localization
  - UCT: CNN trained online
- Implementation/hardware:
  - Most: Matlab, C++ feature extraction
  - CSRDCF++: C++/CPU
  - ECOhc: Matlab, C++/CPU
  - SiamFC: Matlab, C++/GPU





Realtime vs Baseline experiment





- Most of the top baseline performers drop with real-time constraint
- The drop is smaller for real-time trackers on baseline challenge
- Some achieve top real-time performance AND perform well on the baseline

The VOT 2017 workshop

VOT-TIR CHALLENGE AND RESULTS

(Main organizer: Michael Felsberg)

VOT-TIR2017: 10 trackers tested

VOT-TIR2016 re-opened:

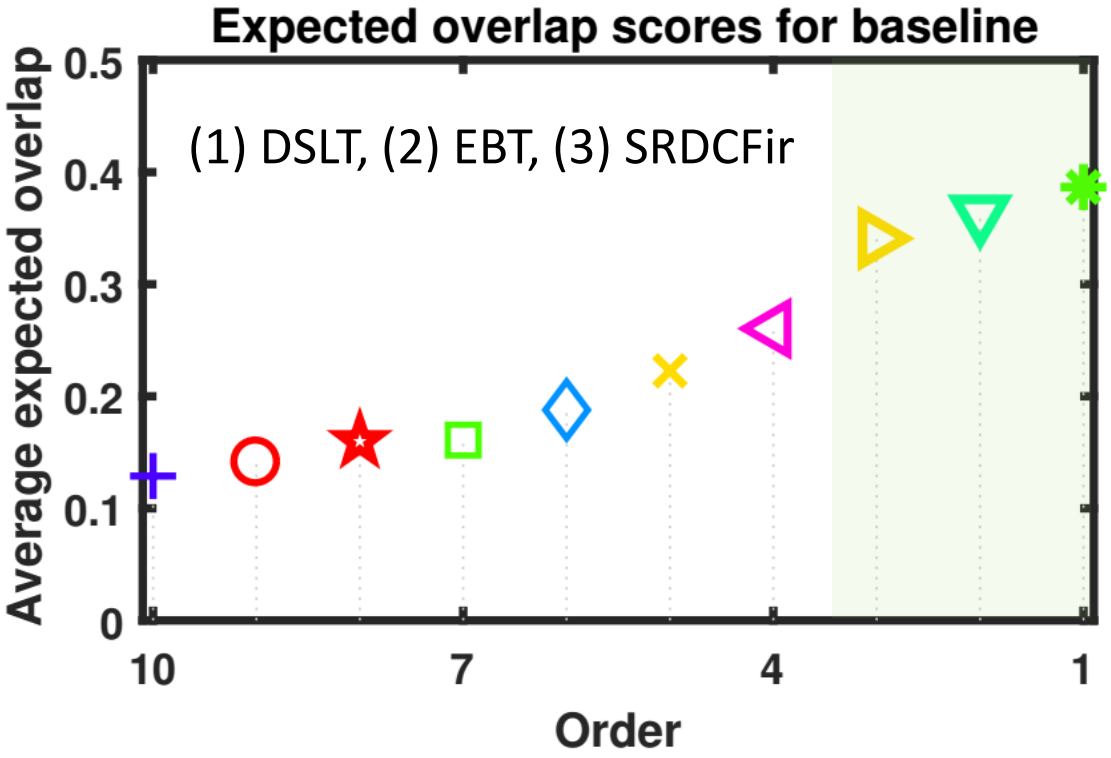
- Winner VOT-TIR2016 (EBT) not significantly better than top-performer 2015 (SRDCFir)
- Both added by the VOT-TIR2017 committee
- Also by committee: ECO

7+1 new submissions:

- Discriminative correlation filters (4)
- Deep convolutional neural nets (2)
- Mean-shift-based (1)
- (Structured) SVM (2)
- Combination of trackers (2)

VOT-TIR2017 results

- **Requirement:** Winner needs to perform better than EBT/SRDCFir
- **Tracking approach:** two main paradigms
  - EBT: object proposals (SVM)
  - SRDCF: DCF-based
  - DSLT: Struck-based (SVM)
- **Features:**
  - EBT: edges
  - SRDCFir: HOG, intensity, motion mask
  - DSLT: HOG and optical flow



VOT-TIR2017 results

- Top trackers are among the most robust trackers

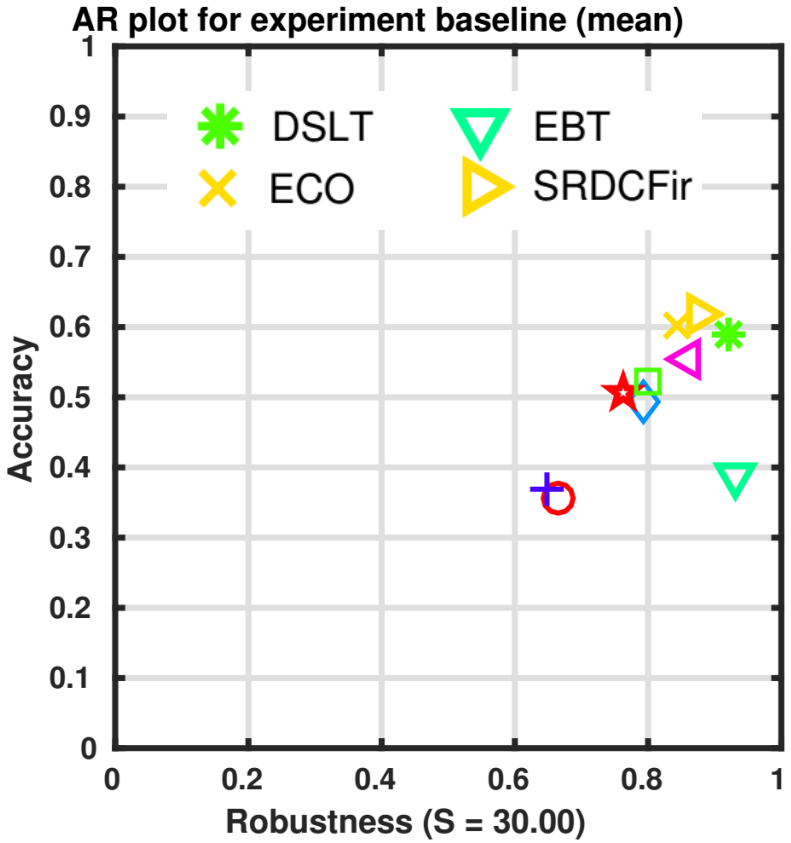
  (1) EBT, (2) DSLT, (3) SRDCFir

- Top in accuracy:

  (1) SRDCFir, (2) ECO, (3) DSLT

- Per-attribute analysis:

	cam. mot.	dyn. ch.	empty	mot. ch.	occl.	size ch.
Accuracy	0.51 ③	0.49 ①	0.54	0.49 ②	0.59	0.52
Robustness	0.72 ③	1.23 ①	0.82 ②	0.31	0.58	0.42



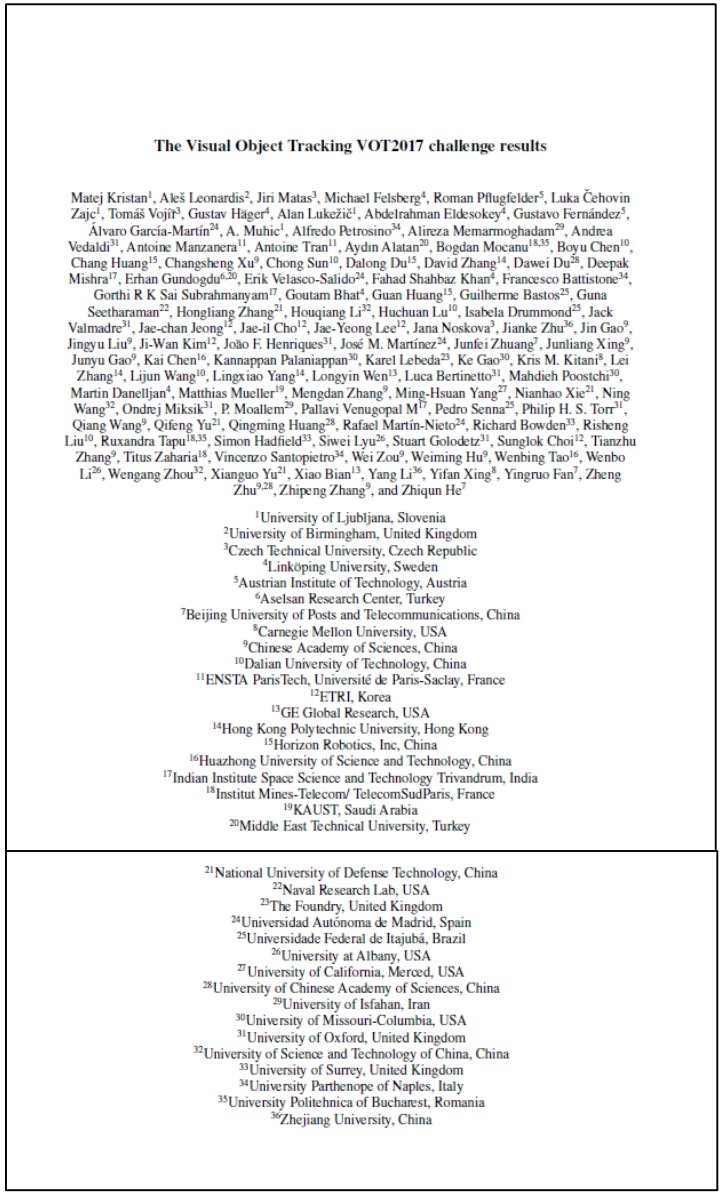
- Most failures due to: Dynamics change
- Mostly affects accuracy: Dynamics change

VOT2017 challenges Summary

- VOT2017 baseline:
  - Emergence of deep features trained for localization (seem to perform very well)
  - Correlation approaches (wide sense) perform best
  - Sequestered dataset more challenging than public
- VOT2017-realtime:
  - Best performance: fully convolutional deep approaches and discriminative CFs
  - Some of the fastest trackers also rank among best on baseline
- VOT-TIR2017:
  - Deep features are not (yet) significant for achieving sota performance
  - Motion features seem to be essential for robust tracking
  - Best performance by SVM-based approaches

VOT2017 online resources

- Results in 104 coauthor paper
- Available at http://www.votchallenge.net/vot2017
- Presentations + papers + Dataset + Evaluation kit
- Guidelines on how to evaluate your trackers on VOT2017 and produce graphs for your papers
  (directly comparable to 51 trackers!)
- VOT is open source:
  - All toolkits and protocols on Github
  - VOT2017: ~36 tracker source code
  - VOT2016: 39 tracker source code



The Visual Object Tracking VOT2017 challenge results

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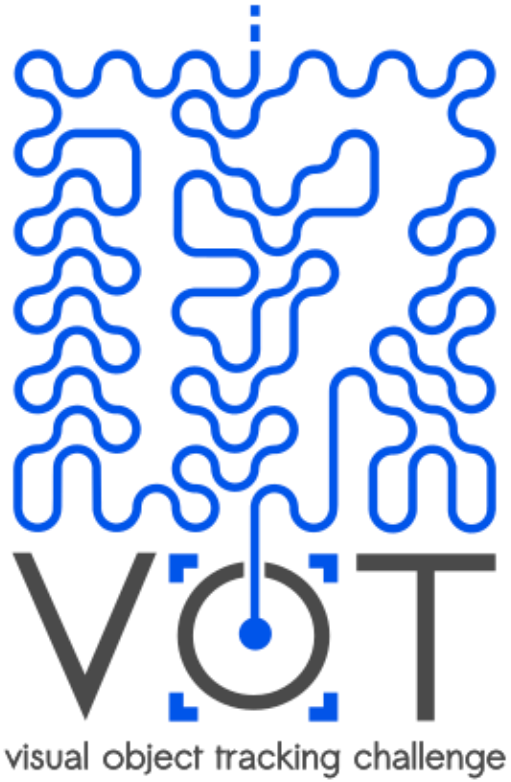
VOT2017 awards:

Winners of the VOT2017 main challenge:

CFCF by: Erhan Gundogdu, Aydin Alatan

“Convolutional Features for Correlation Filters”
Presentation next



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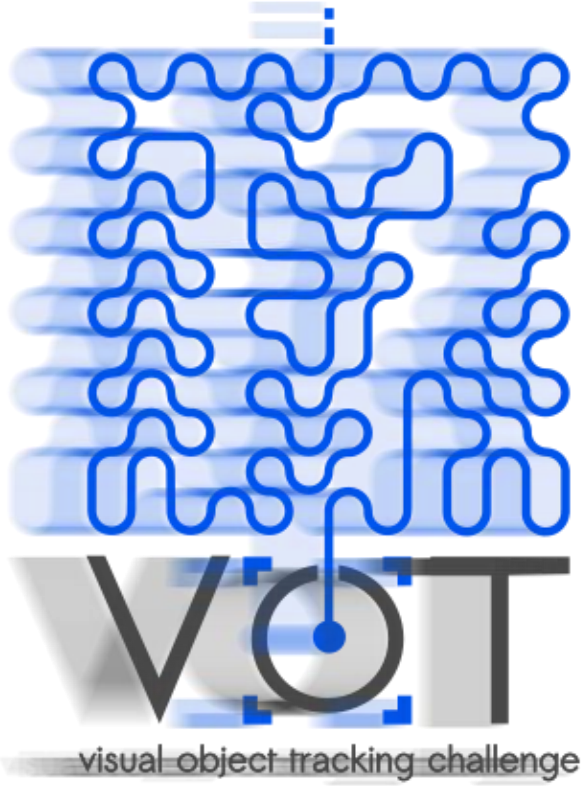
VOT2017 awards:

Winners of the VOT2017 realtime challenge:

SiamFC by: Luca Bertinetto, Joao Henriques, Jack Valmadre, Andrea Vedaldi, Philip Torr

“Fully Convolutional Siamese Network”



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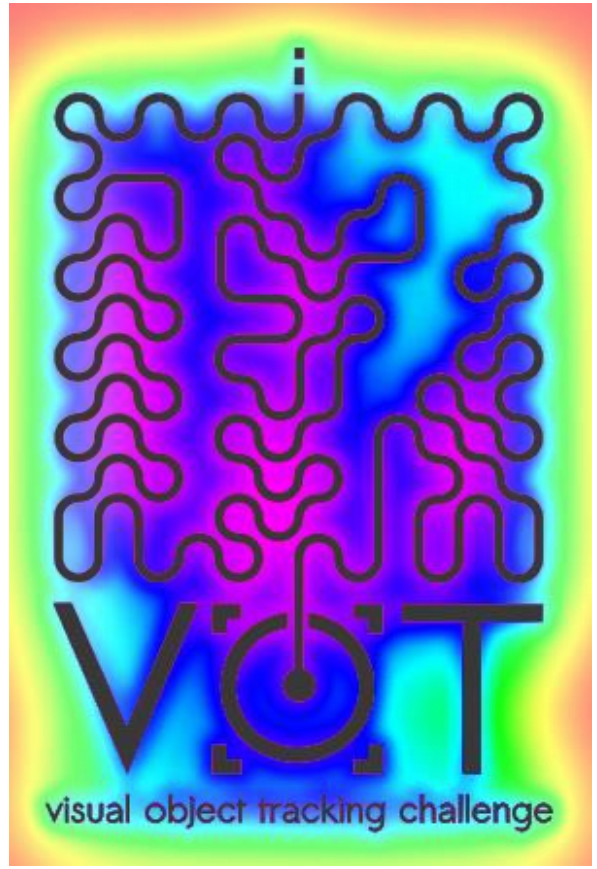
VOT2017 awards:

Winners of the VOT-TIR2017 challenge:

DSLT by: Xianguo Yu, Qifeng Yu, Hongliang Zhang, Nianhao Xie

“Dense Structural Learning based Tracker”



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Thanks

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