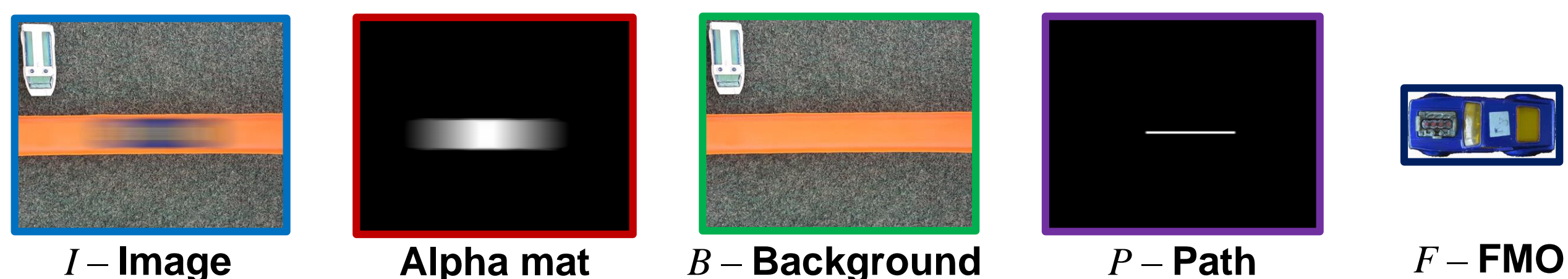


Introduction

- Definition (Fast Moving Object, FMO):** object is fast moving if its trajectory projected on the image plane is larger than its size
Note: FMO is a property of the relative motion of object w.r.t. the camera

- Image formation model: $I = (1 - P * M)B + P * F$ * ... convolution

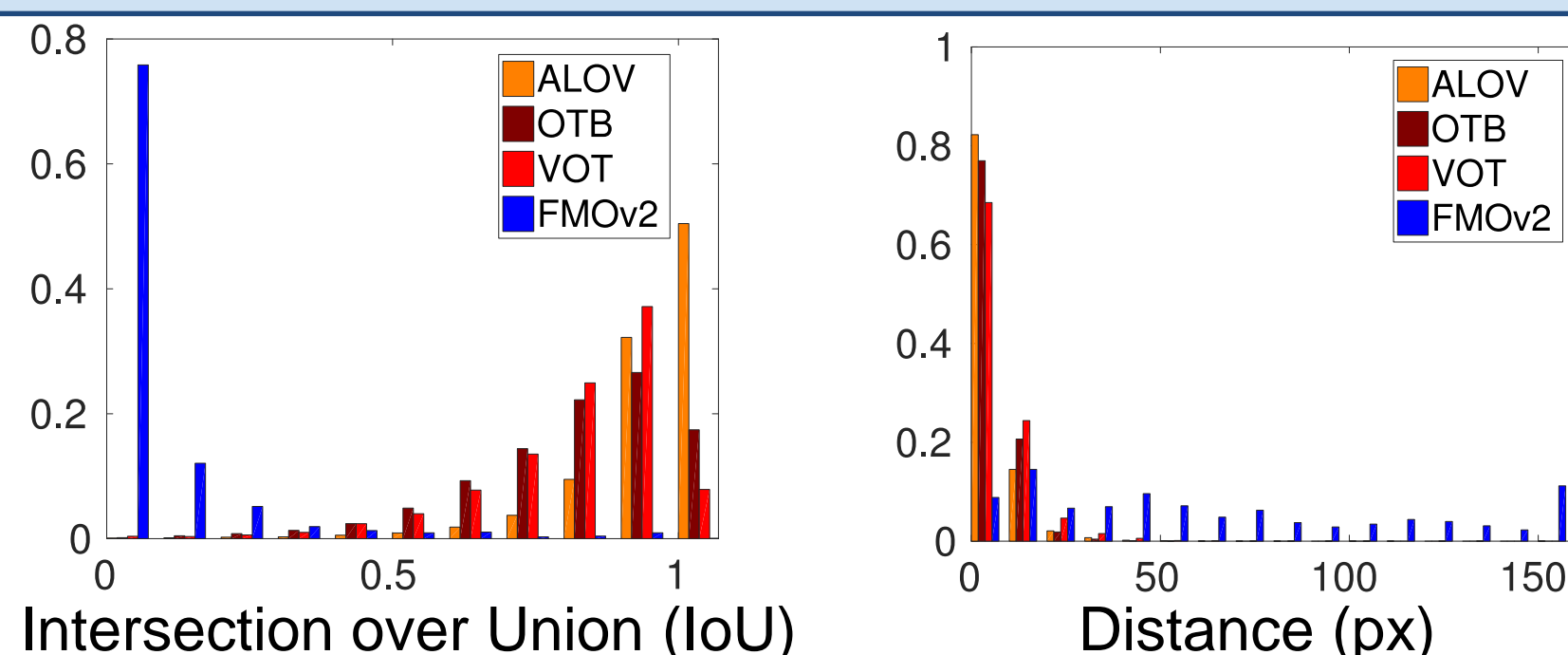


- Difference image: $\Delta = I - B = P * F - (P * M)B$
- Multiple FMOs: $\Delta = \sum P^i * F^i - (\sum P^i * M^i)B$
- Goal:** given I , recover P^i (and F^i)

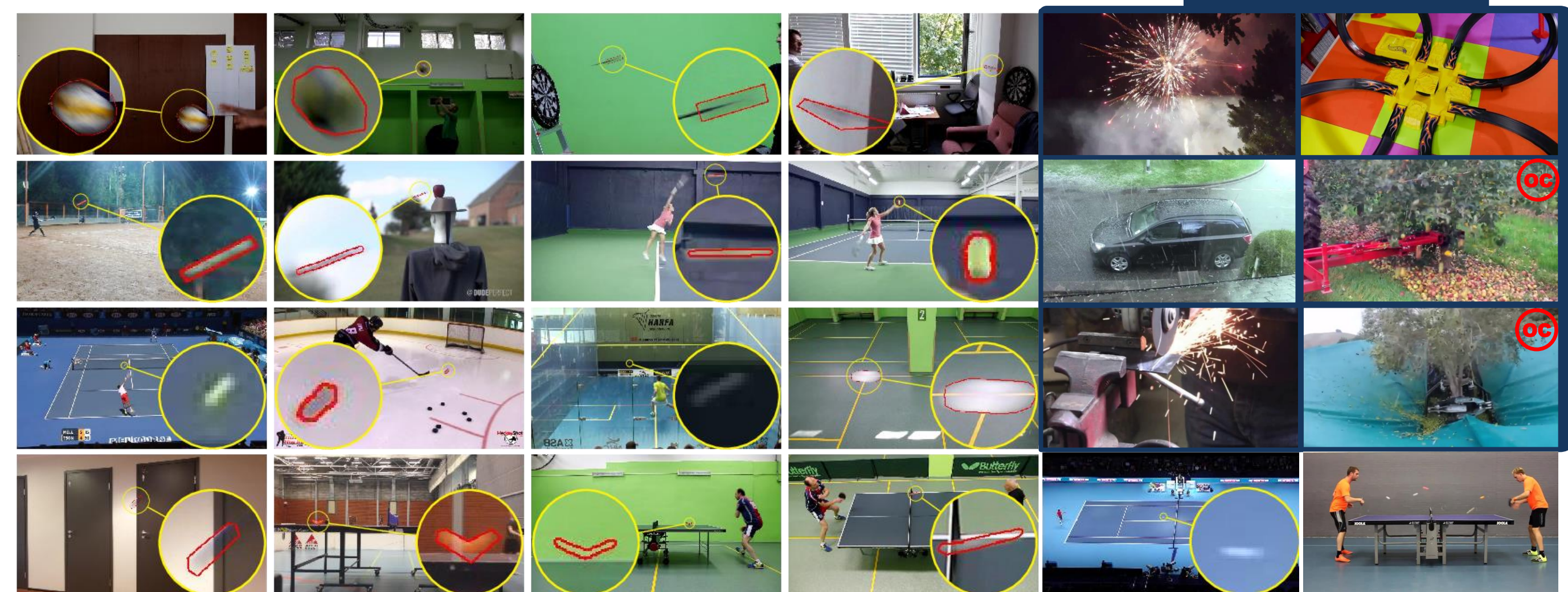
Analysis of Standard Tracking Sets: VOT [1], OTB [2], ALOV [3]

- No FMOs present
- Different tracking “worlds”

- [1] Kristan et al. “The visual object tracking VOT 2015 challenge results”, ICCV 2015
[2] Wu et al. “Online object tracking: A benchmark”, CVPR 2013
[3] Smeulders et al. “Visual tracking: An experimental survey”, PAMI 2014
[4] <http://cmp.felk.cvut.cz/fmo/>



FMO Annotated Public Dataset [4] and Examples



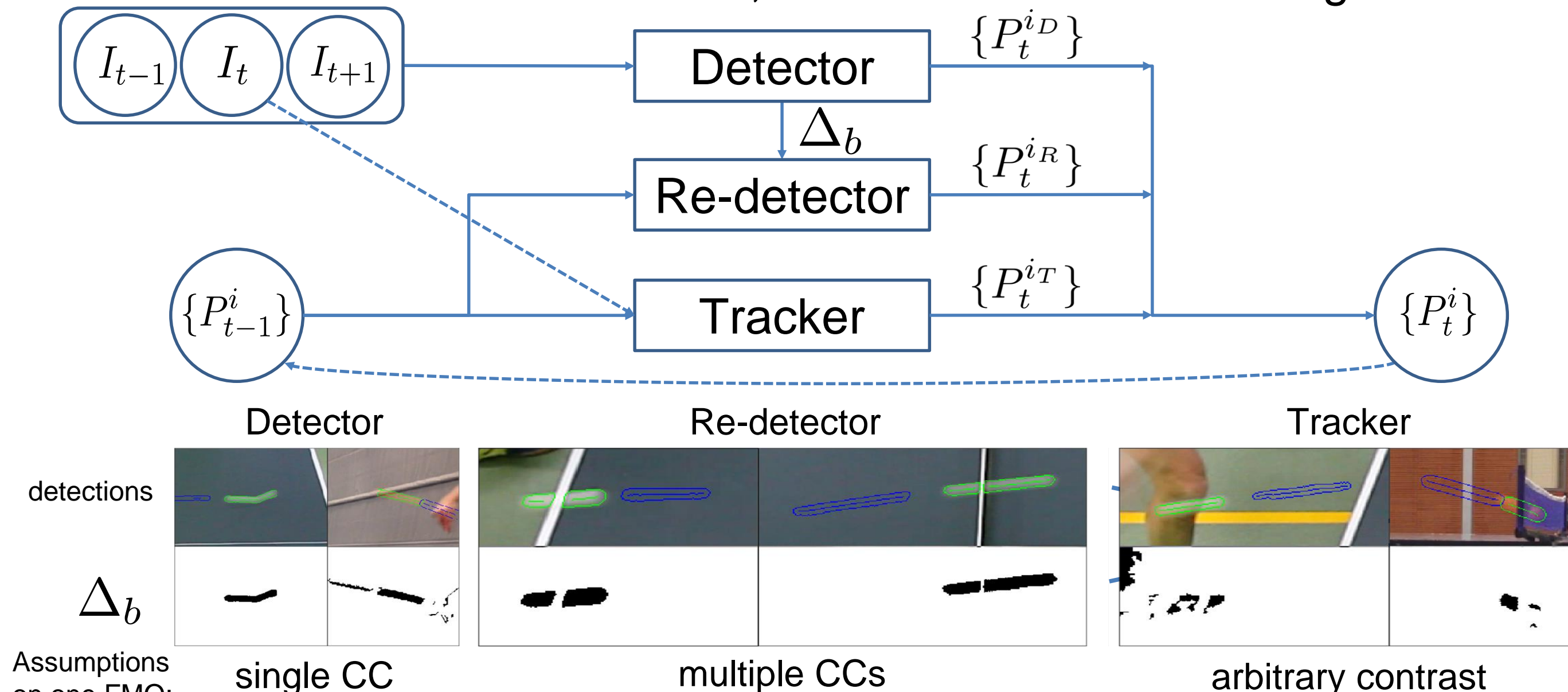
FMO Localization Algorithms

- Detection algorithm*



- Input images → background (estimated by median)
- $\Delta_b = |I - B| > \theta$ (threshold set adaptively)
- Strokey connected components
- Not a lateral motion (checked by KLT tracker)
- Not a shadow → FMOs (check of gradient fields)

- Full FMO localization: Detection, Re-detection and Tracking



* has been improved since the submission (Bc. thesis Denys Rozumnyi)

Evaluation

- Criteria: precision, recall, F-score
- SOTA trackers perform poorly

- Example detections:



F-score (in %) of the proposed method and SOTA

Sequence name	ASMS	DSST	MEEM	SRDCF	STRUCK	FMO
Average	17	1	1	1	3	32
volleyball	80	0	50	0	10	40
volleyball passing	12	6	95	88	8	0
darts	3	0	6	0	0	0
darts window	0	0	0	0	0	0
softball	0	0	0	0	0	39
archery	5	5	5	5	0	3
tennis serve side	7	0	0	0	6	56
tennis serve back	5	0	0	0	3	41
tennis court	0	0	3	3	0	41
hockey	0	0	0	0	0	7
squash	0	0	0	0	0	21
frisbee	65	0	6	6	0	75
blue ball	30	0	0	0	25	0
ping pong tampere	0	0	0	0	0	67
ping pong side	1	0	0	0	0	46
ping pong top	0	0	0	0	1	74

Appearance Reconstruction

- Minimization with priors on FMO appearance (F) and path (P)

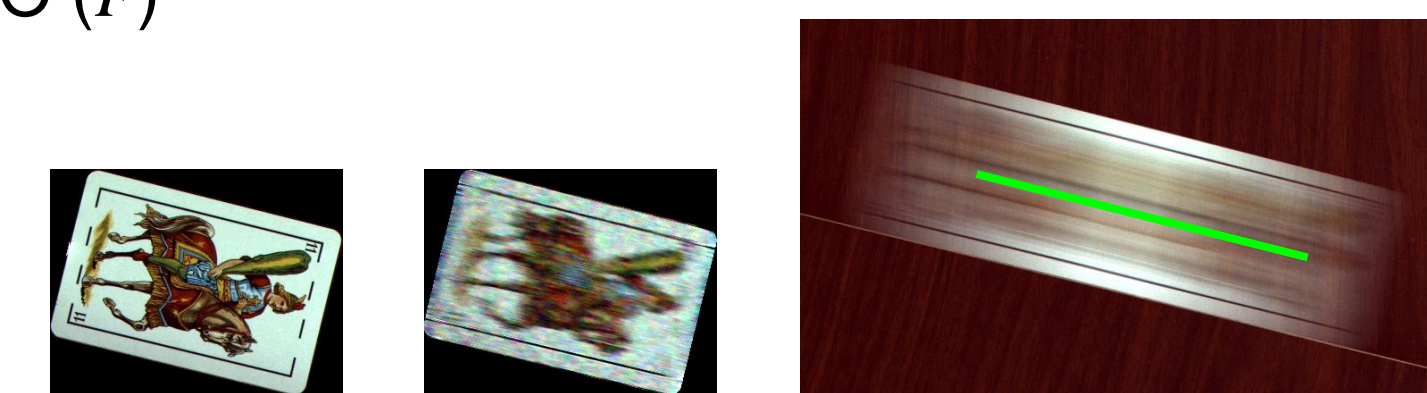
$$\min_{P, F} \|I - (1 - P * M)B - P * F\|_1 + \text{prior}(F) + \text{prior}(P)$$

- More complex than blind deconvolution:**

- mixing with background (B)
- blur (P) larger than the size of the FMO (F)

- F arbitrary (~1min)

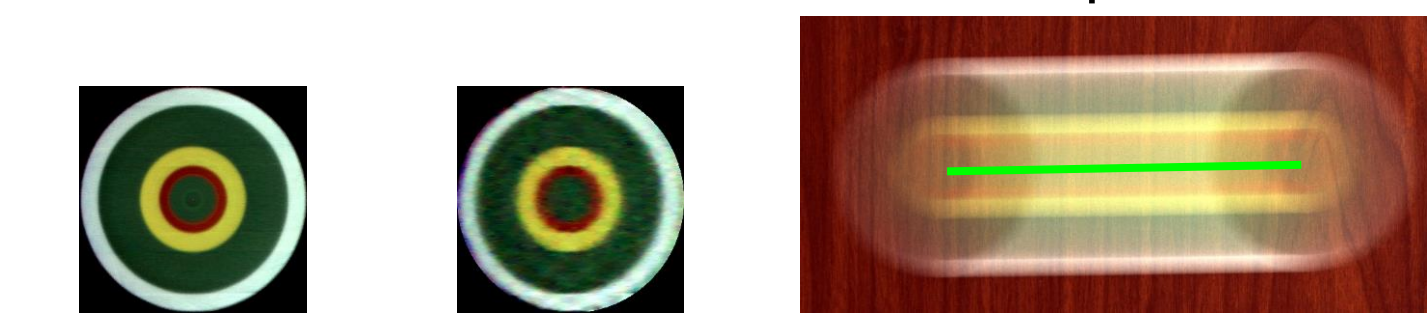
- P from tracker assumed correct
- prior(F): standard total variation



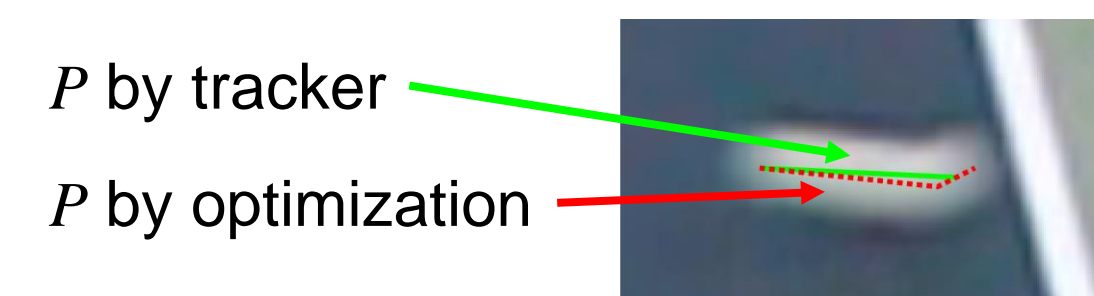
no motion estimated F input I

- F simplified (~1s)

- estimation of F and improved P
- prior(P): polyline
- prior(F): circular symmetry (demo)



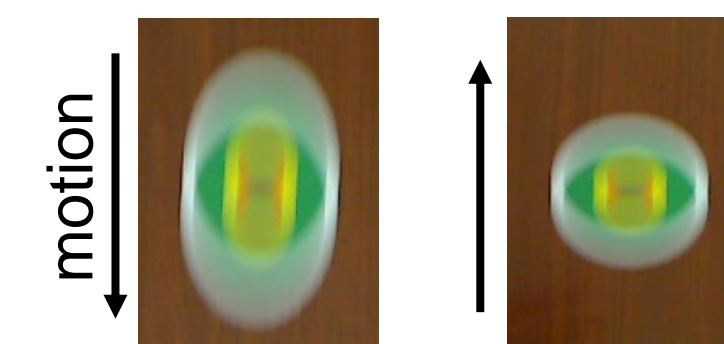
- prior(F): single-color sphere (table tennis)
- estimation of F (color, radius) and improved P



P by tracker
 P by optimization

- Beyond convolution

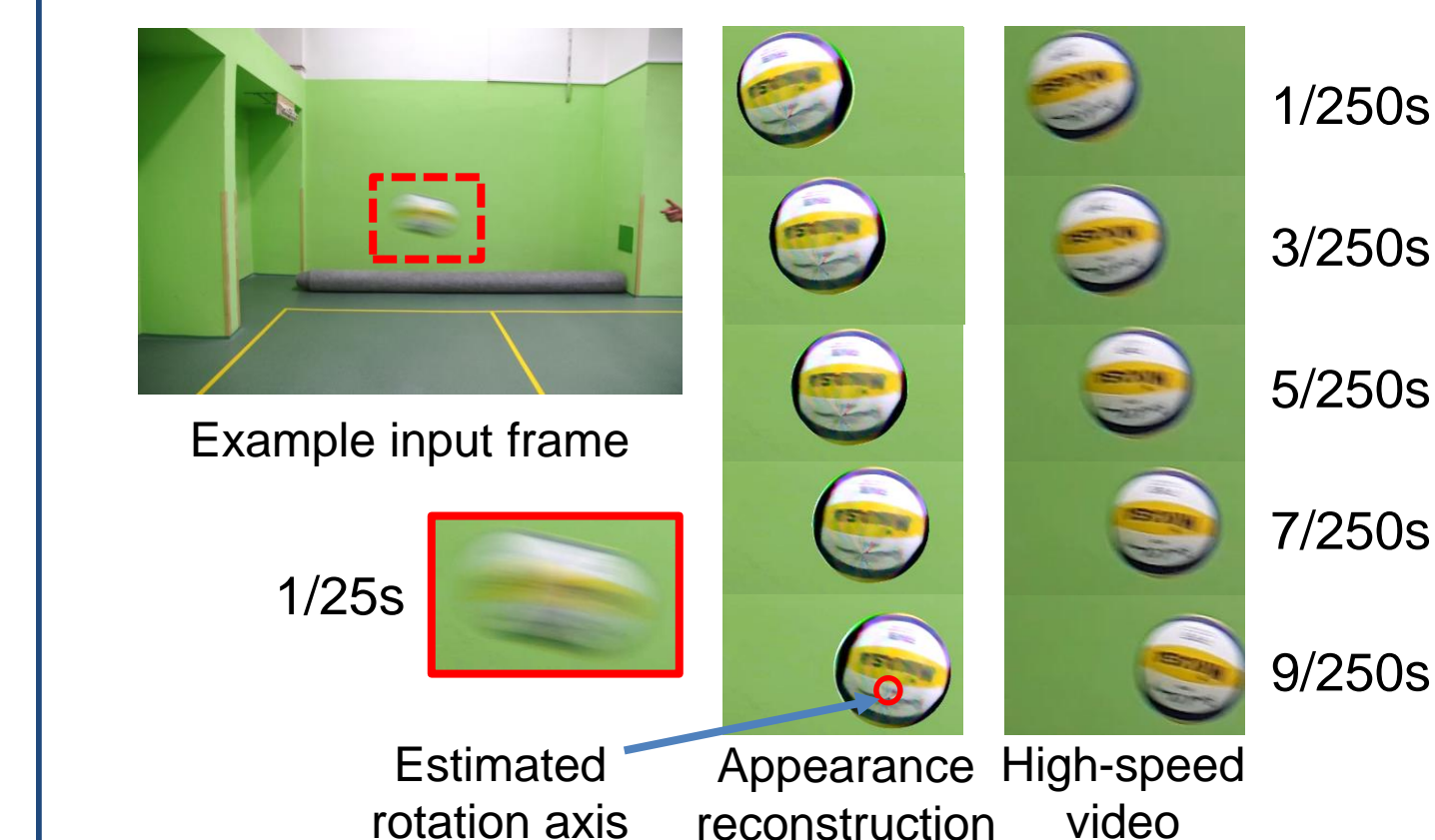
- rotating FMO → grid search over rotation axis and speed
- rolling shutter → complicated space-variant blur



motion

Applications

- Temporal super-resolution 25 fps vs 250 fps
- Angular velocity



- Object counting
- Projected translational velocity vs radar

