



Event-aided Direct Sparse Odometry

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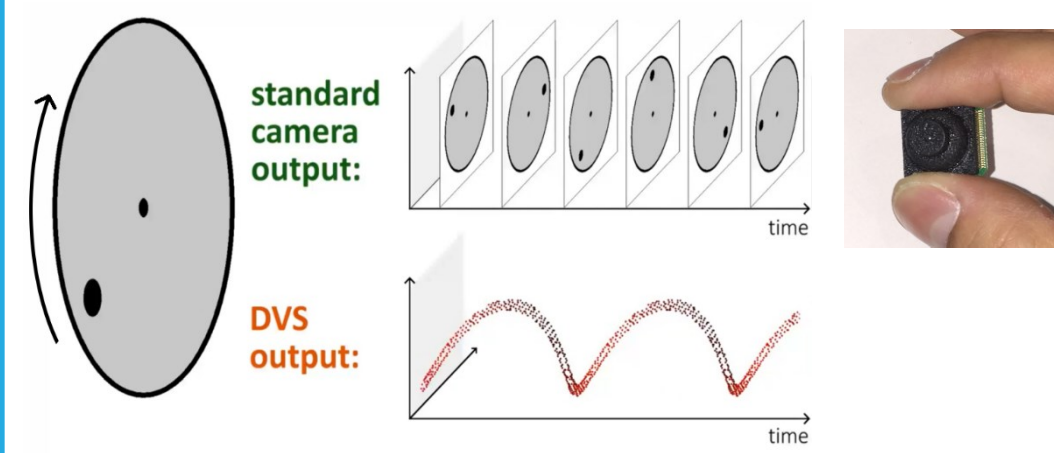


[Paper and code] <https://rpg.ifi.uzh.ch/eds>

EDS: Event-aided Direct Sparse Odometry

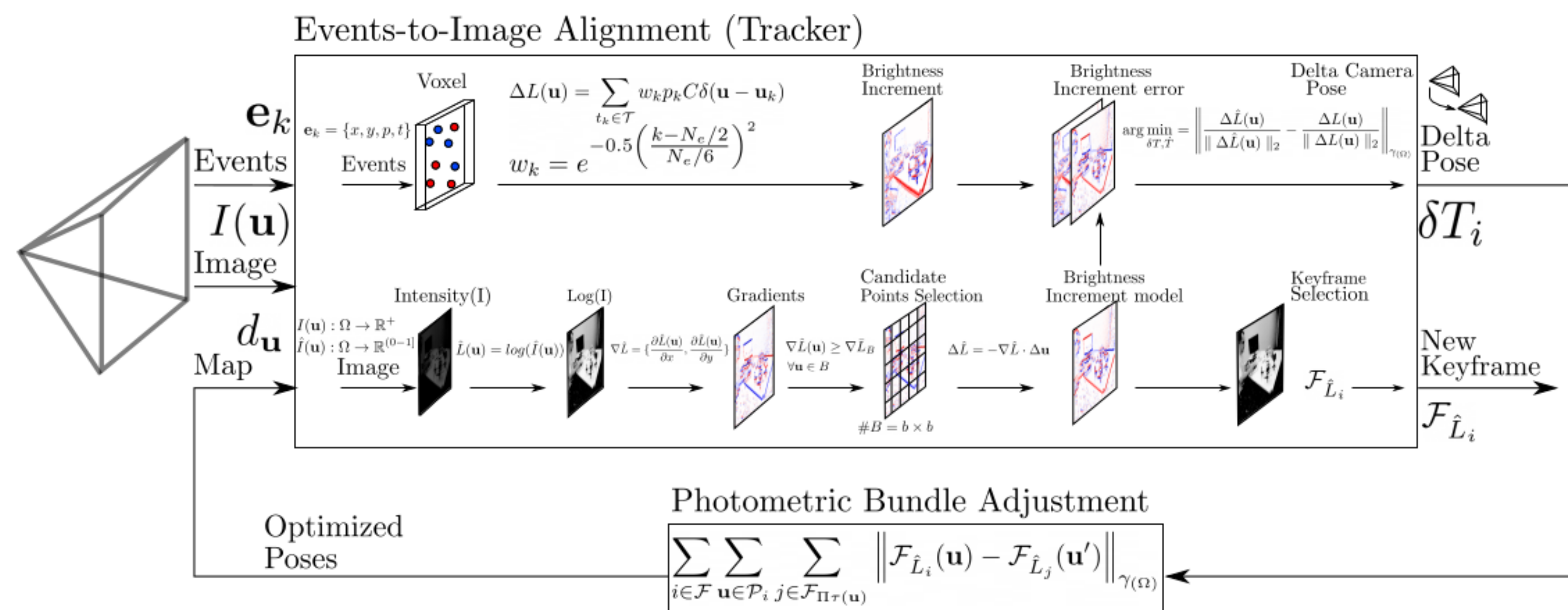
is a direct monocular visual odometry method using events and frames. Our algorithm leverages the event generation model to track the camera motion in the blind time between frames. The method formulates a direct probabilistic approach of observed brightness increments.

What is an event camera?



- Transmits brightness changes
- Outputs asynchronous events

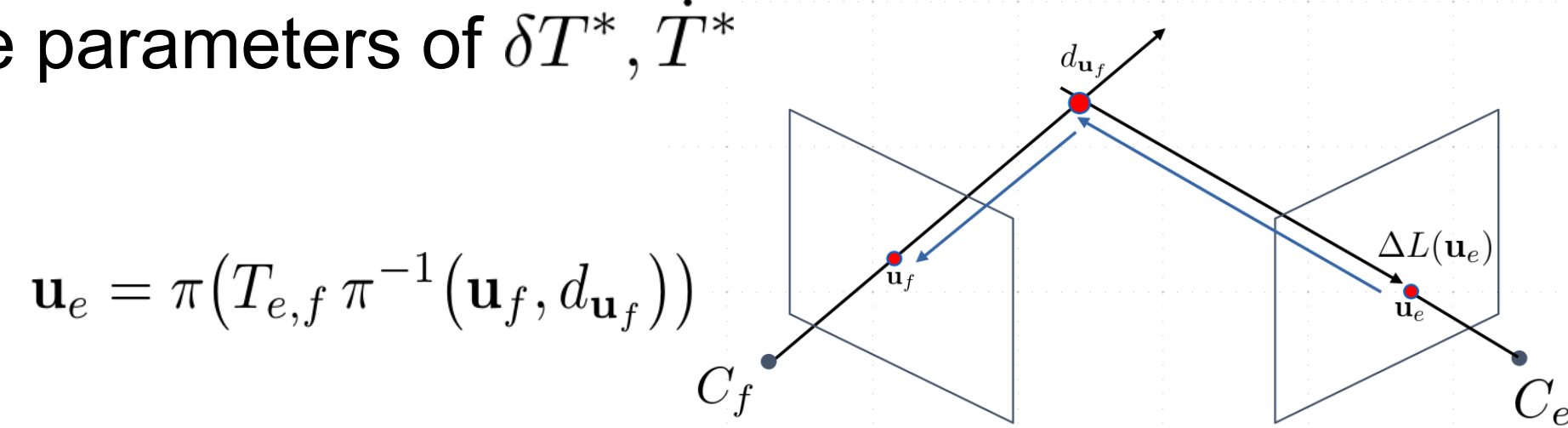
Methodology



- The camera tracking problem is a joint optimization of the normalized brightness increment error over the camera motion parameters (6DoF pose and velocity):

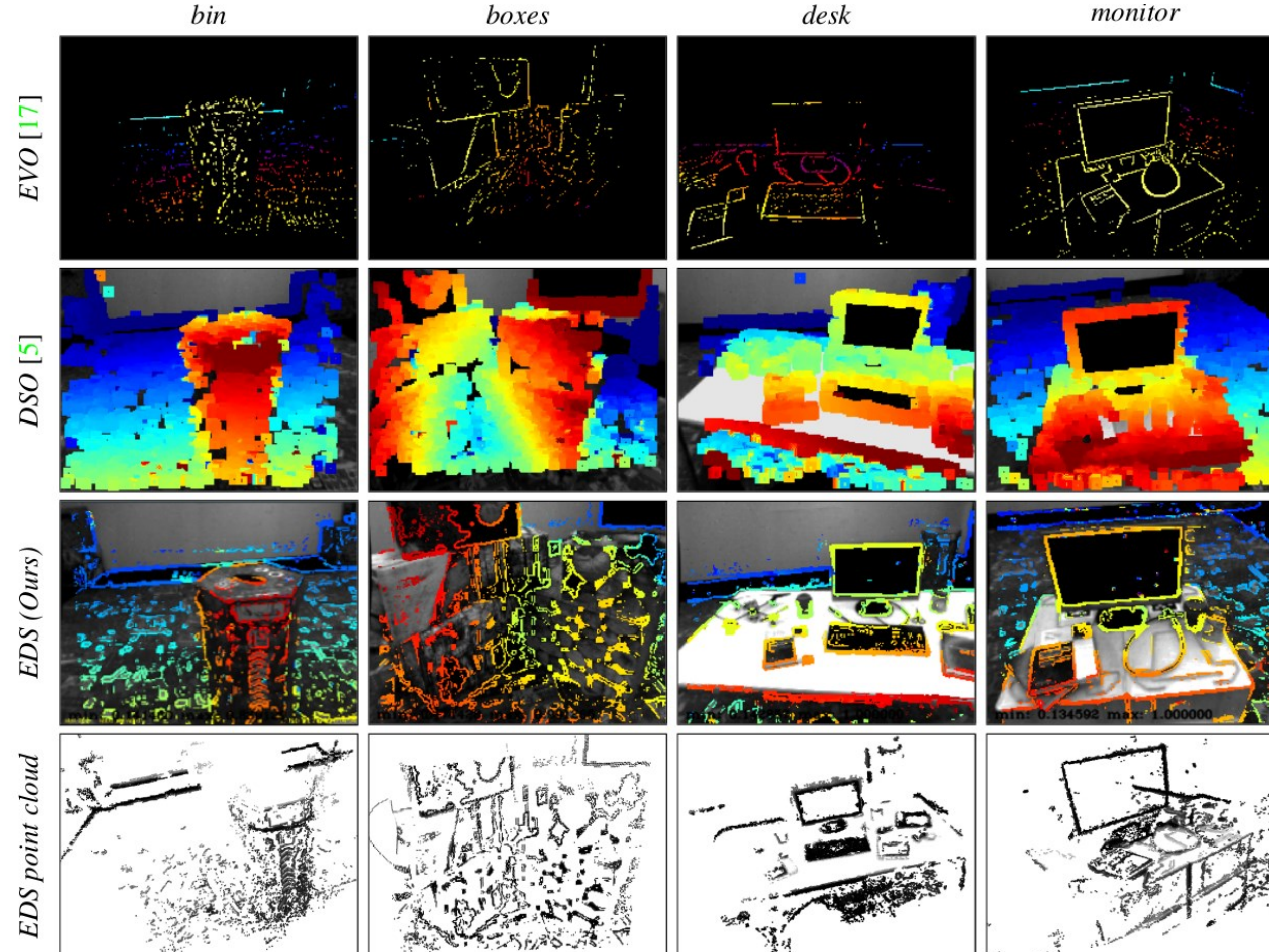
$$(\delta T^*, \dot{T}^*) = \arg \min_{\delta T, \dot{T}} \left\| \frac{\Delta \hat{L}}{\|\Delta \hat{L}\|_2} - \frac{\Delta L}{\|\Delta L\|_2} \right\|_{\gamma}$$

- $\Delta \hat{L}$ is the event generation model (EGM) and ΔL the events $\Delta \hat{L}(u) \approx -\nabla \hat{L}(u) \cdot J(u, d_u) \dot{T} \Delta t$ and $\Delta L(u) = \sum_{t_k \in T} w_k p_k C \delta(u - u_k)$
- In comparison to previous work [1,2], the optimization is done by transferring the brightness increments of a sparse set of points to the keyframe and finding the parameters of $\delta T^*, \dot{T}^*$



Experiments

- Test on sequences from the standard RPG DAVIS stereo dataset [3]

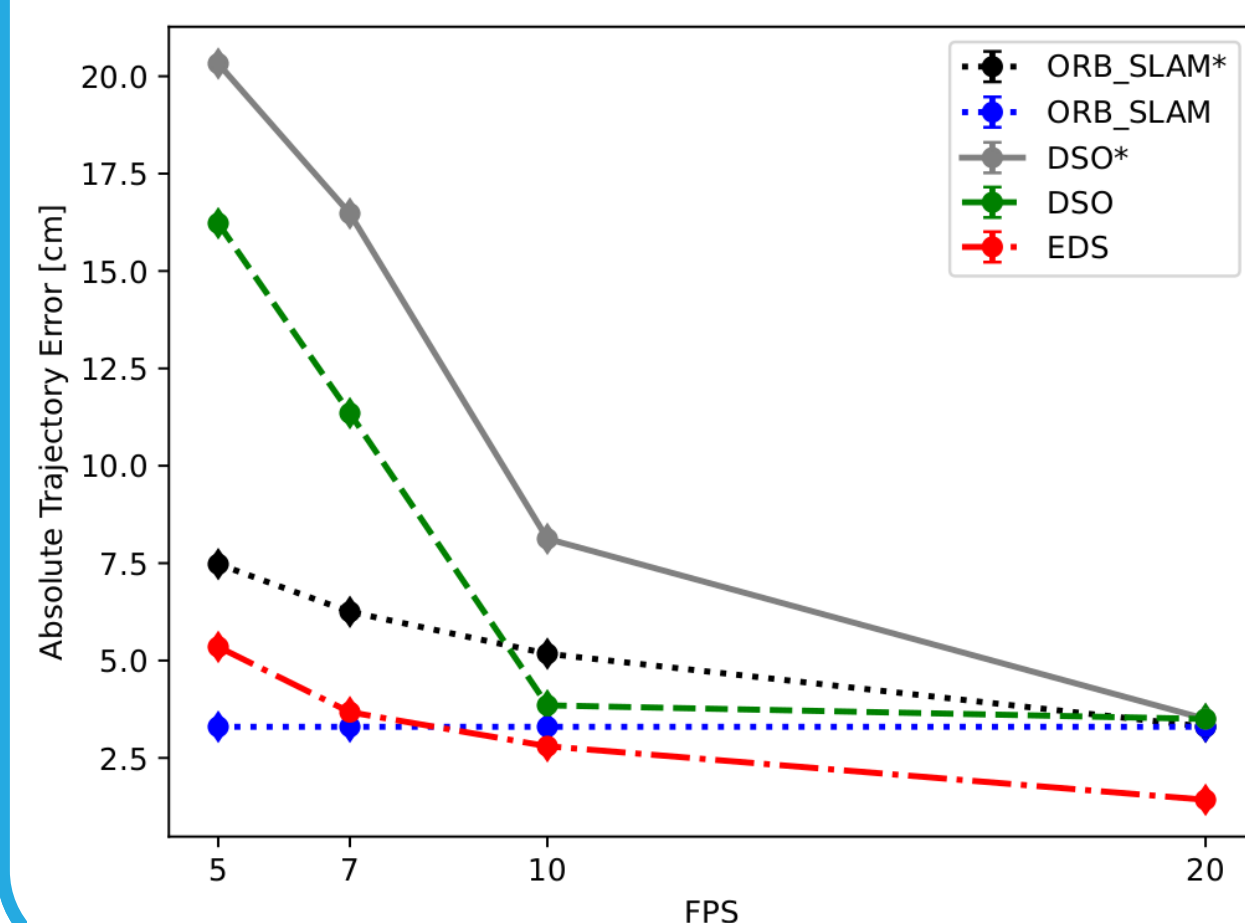


- EDS w.r.t. event-based (left) and frame-based (right) methods.

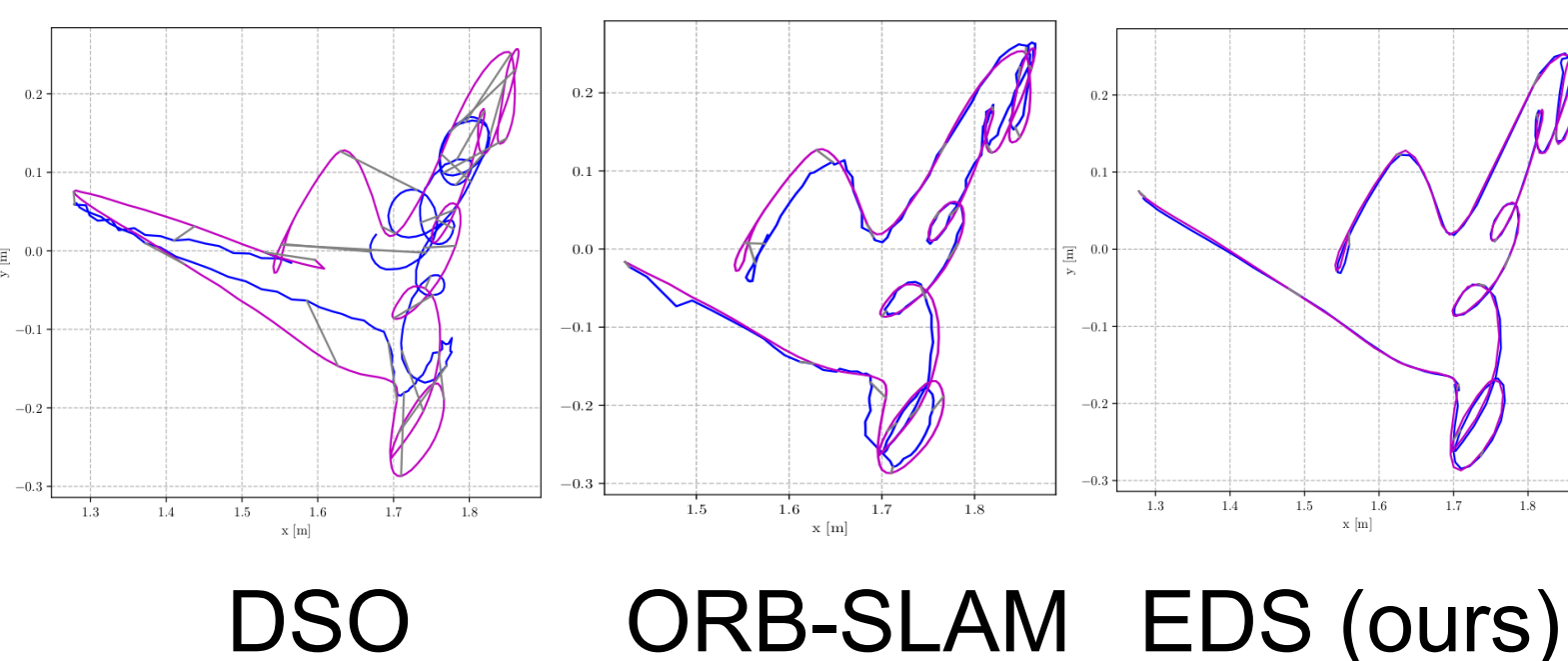
Input	ESVO E+E	USLAM E+F+I	EVO E	EDS (Ours) E+F
Trans. [cm]				
bin	2.8	7.7	13.2*	1.1
boxes	5.8	9.5	14.2*	2.1
desk	3.2	9.8	5.2	1.5
monitor	3.3	6.5	7.8	1.0
Rot. [deg]				
bin	7.61	7.18	50.26*	0.99
boxes	9.46	8.84	170.36*	1.83
desk	7.25	32.46	8.25	1.87
monitor	2.74	7.01	7.77	0.60

Input	ORB-SLAM F+F	ORB-SLAM F	DSO F	DSO [†] F [†]	EDS (Ours) E+F
Trans. [cm]					
bin	0.7	2.4	1.1	-	1.1
boxes	1.6	3.9	2.0	-	2.1
desk	1.8	3.8	10.0	1.6	1.5
monitor	0.8	3.1	0.9	2.1	1.0
Rot. [deg]					
bin	0.58	0.84	2.12	-	0.99
boxes	4.26	2.39	2.14	-	1.83
desk	2.81	2.52	63.5	1.80	1.87
monitor	3.70	1.77	0.33	1.54	0.60

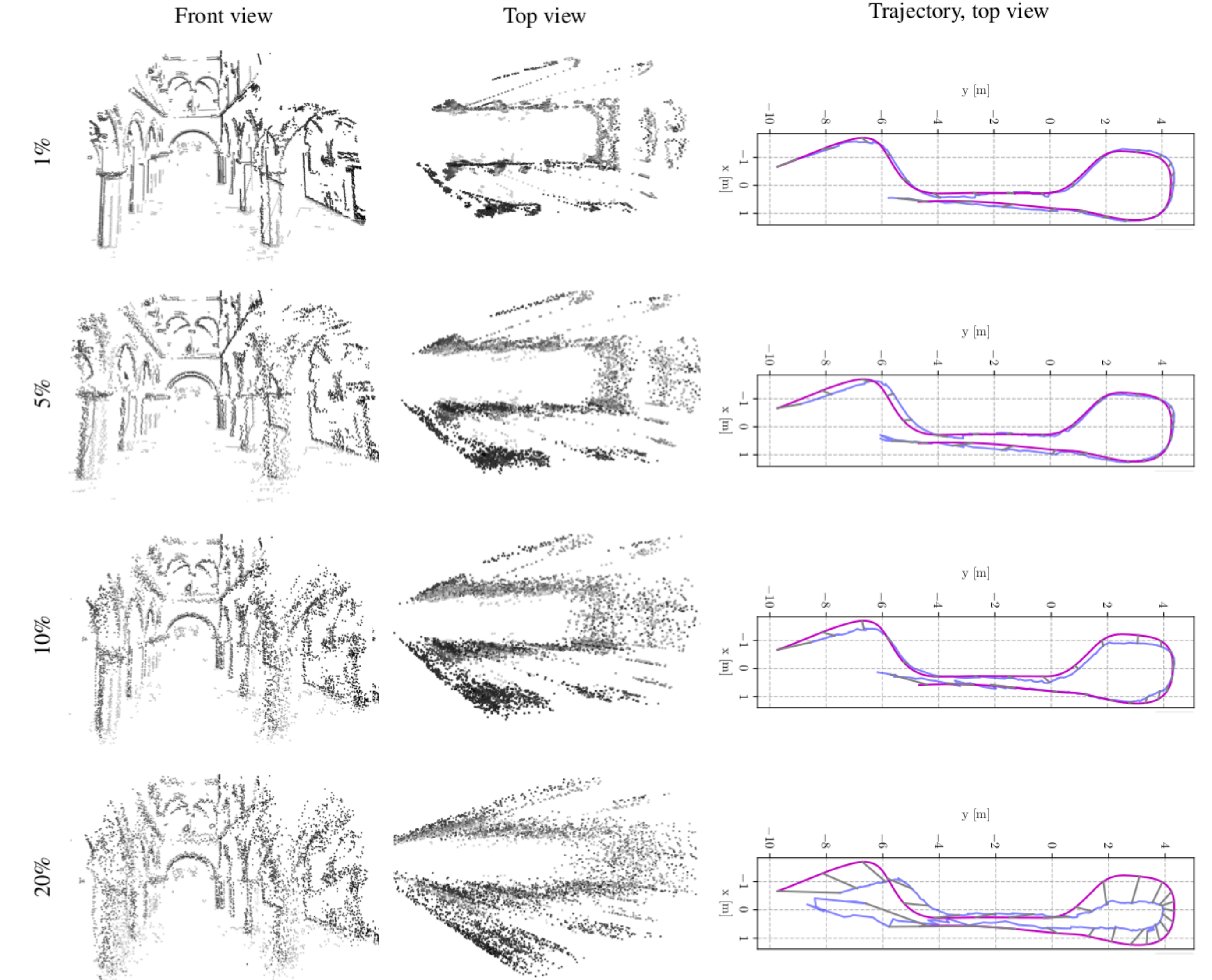
- Low frame rate experiments



- RPG Desk sequence at 20 fps



Sensitivity Study



Conclusion

- EDS is the first direct visual odometry method combining events & frames.
- EDS produces more accurate results than previous event-based methods.
- Events improve classical photometric image alignment in frame tracking.
- EDS opens the door to low-power motion-tracking applications.

References

- [1] Samuel Bryner, Guillermo Gallego, Henri Rebecq, and Davide Scaramuzza, "Event-based, direct camera tracking from a photometric 3D map using nonlinear optimization," in IEEE Int. Conf. Robot. Autom. (ICRA), 2019.
- [2] Daniel Gehrig, Henri Rebecq, Guillermo Gallego, and Davide Scaramuzza, "EKL: Asynchronous photometric feature tracking using events and frames," Int. Journal of Computer Vision, 2019.
- [3] Yi Zhou, Guillermo Gallego, Henri Rebecq, Laurent Kneip, Hongdong Li, and Davide Scaramuzza, "Semi-dense 3D reconstruction with a stereo event camera," in European Conf. in Computer Vision (ECCV), 2018.