Event-aided Direct Sparse Odometry

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SCAN ME

https://rpg.ifi.uzh.ch/eds

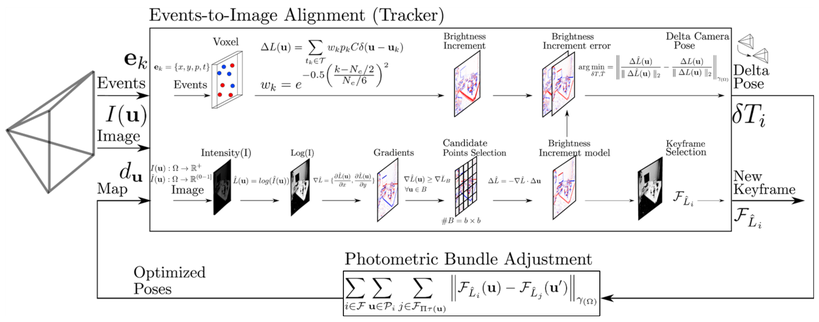
Summary

EDS is the **first** direct visual odometry method combining events & frames.

EDS leverages the event generation model to **track the camera motion in the blind time between frames**.

EDS is formulated using **brightness increments at sparse pixels**, assuming a probabilistic model that leads to an **optimization** problem.

Methodology



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

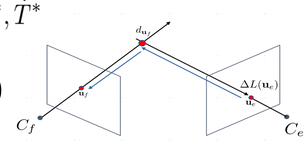
$$(\delta T^*, \dot{T}^*) = \arg\min_{\delta T, \dot{T}} \left\| \frac{\Delta\hat{L}}{\|\Delta\hat{L}\|_2} - \frac{\Delta L}{\|\Delta L\|_2} \right\|_\gamma$$

where $\Delta L(\mathbf{u}) = \sum_{t_k \in \mathcal{T}} w_k p_k C \delta(\mathbf{u} - \mathbf{u}_k)$ is the observed events

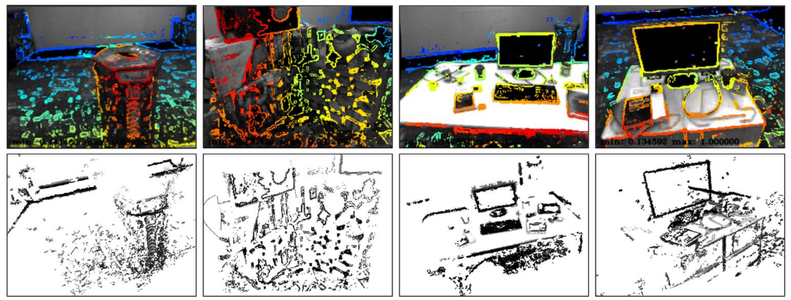
and $\Delta\hat{L}(\mathbf{u}) \approx -\nabla\hat{L}(\mathbf{u}) \cdot J(\mathbf{u}, d_\mathbf{u})\dot{T}\Delta t$ is the **E**vent **G**eneration **M**odel.

- 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 $\delta T^*, \dot{T}^*$

$$\mathbf{u}_e = \pi\left(T_{e,f}\, \pi^{-1}\left(\mathbf{u}_f, d_{\mathbf{u}_f}\right)\right)$$



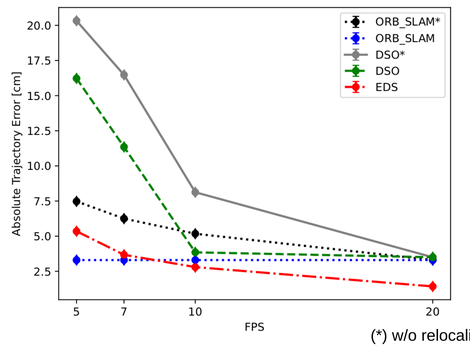
Experiments



	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**

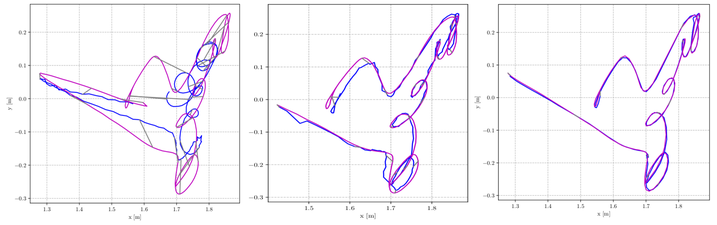
	Input	ORB-SLAM F+F	ORB-SLAM F	DSO F	DSO† F†	EDS (**Ours**) E+F
Trans. [cm]	*bin*	0.7	2.4	1.1	-	**1.1**
	boxes	1.6	3.9	**2.0**	-	2.1
	desk	1.8	3.8	10.0	1.6	**1.5**
	monitor	0.8	3.1	**0.9**	2.1	1.0
Rot. [deg]	*bin*	0.58	**0.84**	2.12	-	0.99
	boxes	4.26	2.39	2.14	-	**1.83**
	desk	2.81	2.52	63.5	**1.80**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

- Low frame rate experiments



(*) w/o relocalization or loop closure.
EDS is solely visual odometry.

- RPG Desk sequence at 20 fps



DSO ORB-SLAM EDS (ours)

Key results

- EDS produces more accurate results than previous event-based methods.
- Events improve classical photometric image alignment in frame tracking.
- EDS is more accurate than SOTA frame-based odometry methods.
- EDS opens the door to low-rate, low-power motion-tracking applications.

Sensitivity Study

- The sensitivity study shows that EDS is robust to depth noise as well as contrast sensitivity event noise.
- Robustness to depth noise is paramount for accurate camera tracking: