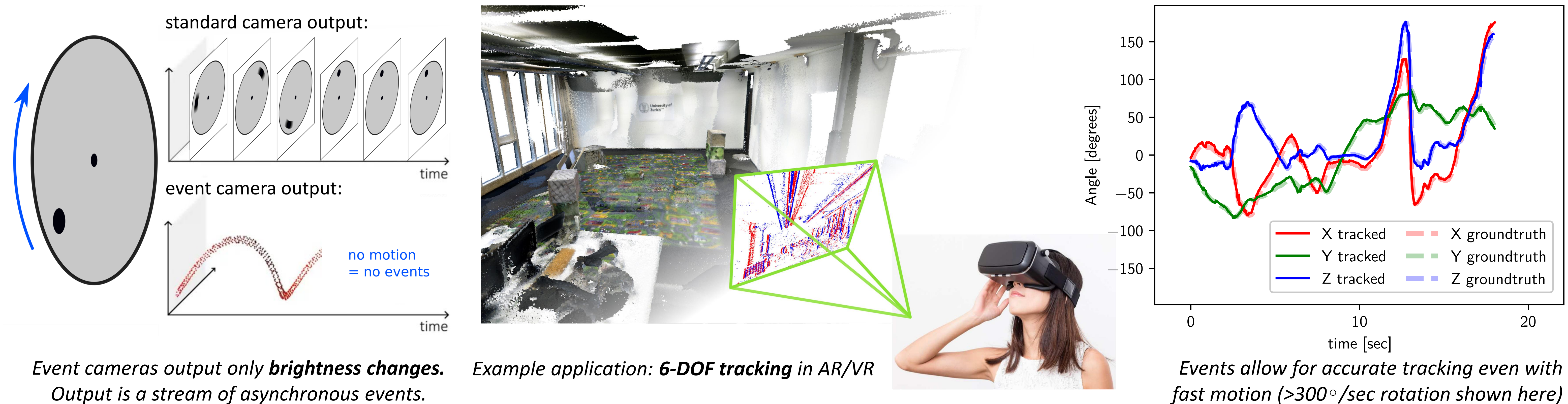# Event-based, Direct Camera Tracking from a Photometric 3D Map using Nonlinear Optimization

Samuel Bryner, Guillermo Gallego, Henri Rebecq and Davide Scaramuzza

*Event cameras output only **brightness changes.** Output is a stream of asynchronous events.*

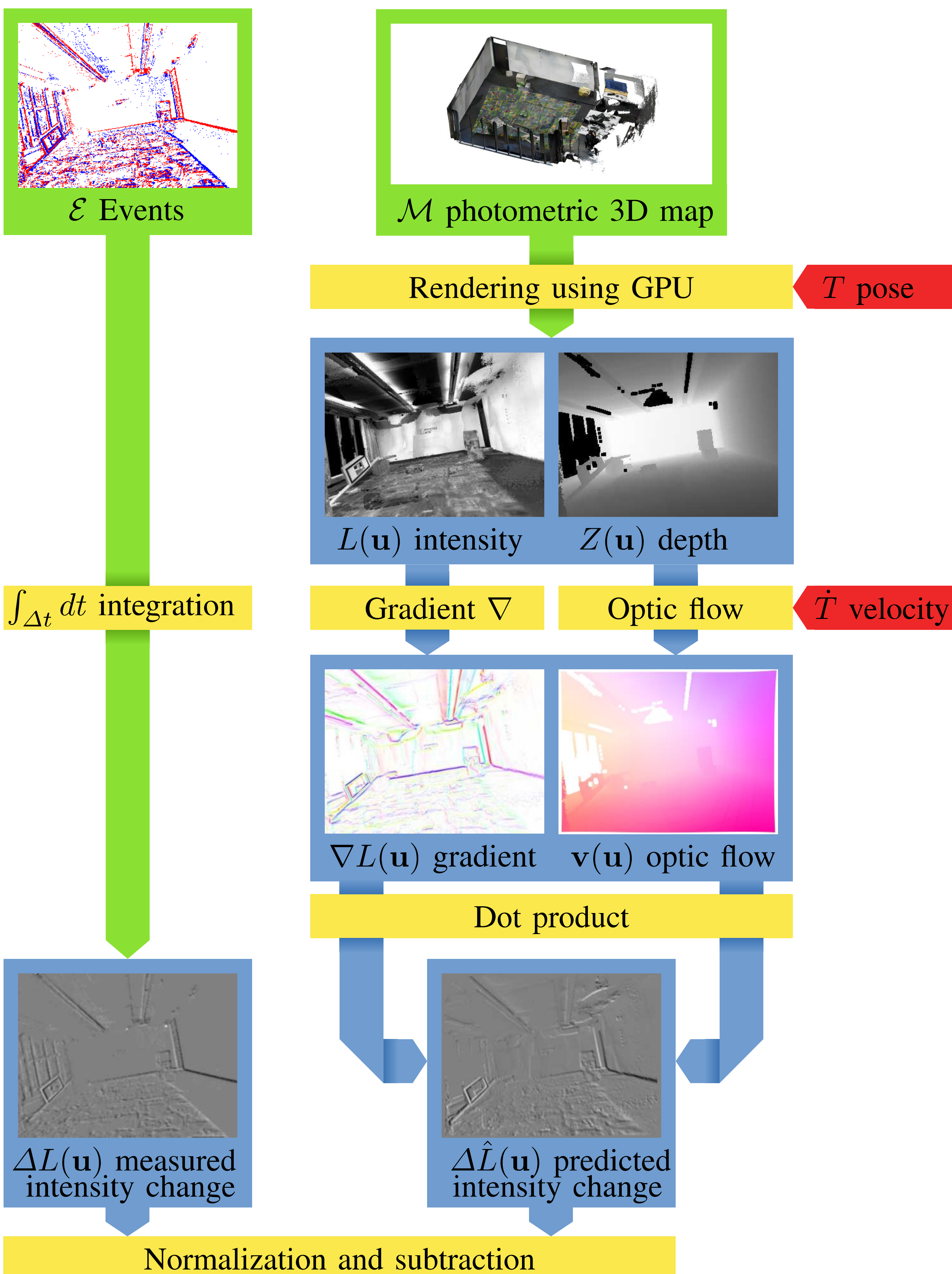*Example application: **6-DOF tracking** in AR/VR*

Events allow for accurate tracking even with fast motion (>300∘/sec rotation shown here)

*Event cameras have **low-latency, high dynamic range** and **no motion blur.** How can we **track their 6DoF pose** robustly using only events?*

Generative Model

From a known scene, pose, and velocity we can predict events.
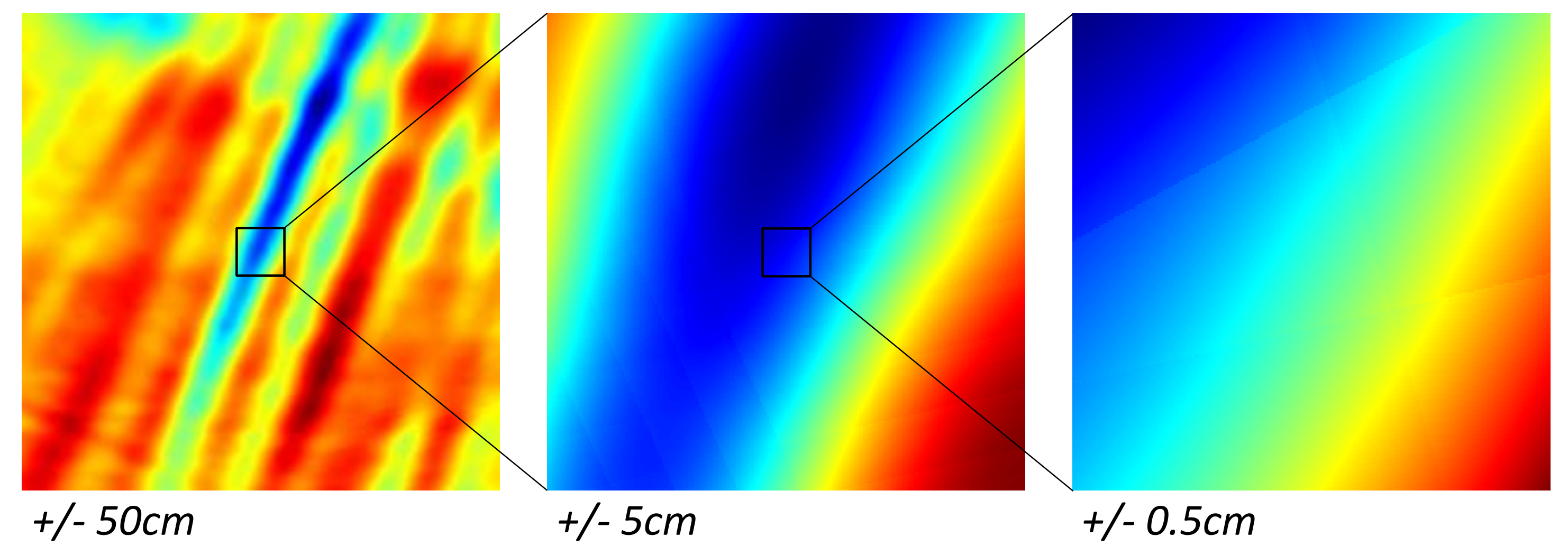Given the events and scene, we can thus solve for the pose.

Legend:
- Input data
- Intermediate results
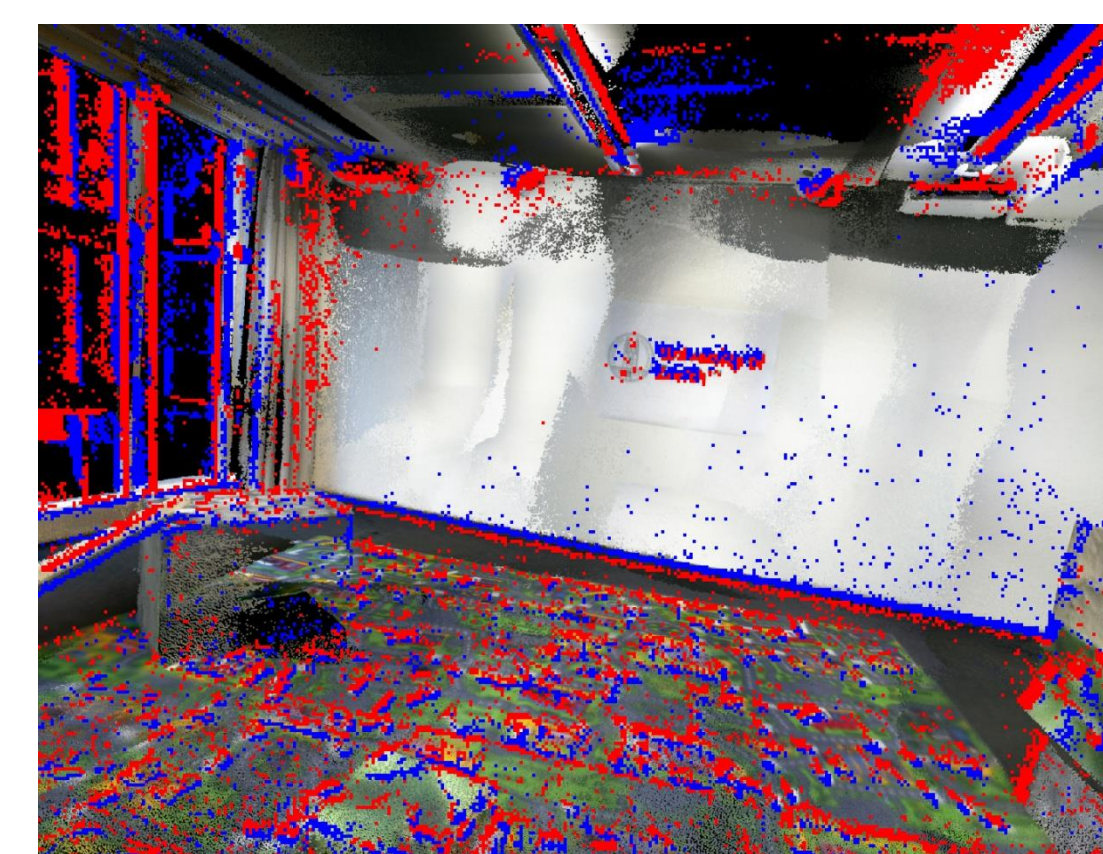- Operation
- Optimization parameters

$\mathcal{E}$ Events

$\mathcal{M}$ photometric 3D map

Rendering using GPU — T pose

$L(\mathbf{u})$ intensity $Z(\mathbf{u})$ depth

$\int_{\Delta t} dt$ integration

Gradient ∇ Optic flow — $\dot{T}$ velocity

$\nabla L(\mathbf{u})$ gradient $\mathbf{v}(\mathbf{u})$ optic flow

Dot product

$\Delta L(\mathbf{u})$ measured intensity change

$\Delta \hat{L}(\mathbf{u})$ predicted intensity change

Normalization and subtraction

Non-Linear Optimization

$$\min_{T,\dot{T}} \|\Delta L(\mathbf{u}) - \Delta \hat{L}(\mathbf{u}; T, \dot{T})\|^2_{\mathcal{L}^2(\Omega)}$$

measured   *predicted intensity change*

+/- 50cm   +/- 5cm   +/- 0.5cm

Visualization of error function (translation along image plane, i.e. x and y)

Results

Real events aligned to 3D map

		Gallego et al., PAMI'18			This Work		
	Length	Position		Orientation	Position		Orientation
	[s]	[cm]	[%]	[∘]	[cm]	[%]	[∘]
Boxes 1	23.3	5.08	2.69	2.51	4.74	2.52	1.86
Boxes 2	26.7	4.04	2.15	2.18	4.46	2.38	2.10
Boxes 3	33.7	5.47	2.90	2.82	5.05	2.68	2.39
Pipe 1	29.8	10.96	4.04	2.90	10.23	3.77	2.13
Pipe 2	22.2	15.26	5.34	4.68	11.29	3.95	4.02

Comparison of RMS pose errors to state-of-the-art

Open-Source Dataset

All the data used can be found at:

http://rpg.ifi.uzh.ch/direct_event_camera_tracking/

Sponsors