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Event-based, 6-DOF Camera Tracking from Photometric Depth Maps

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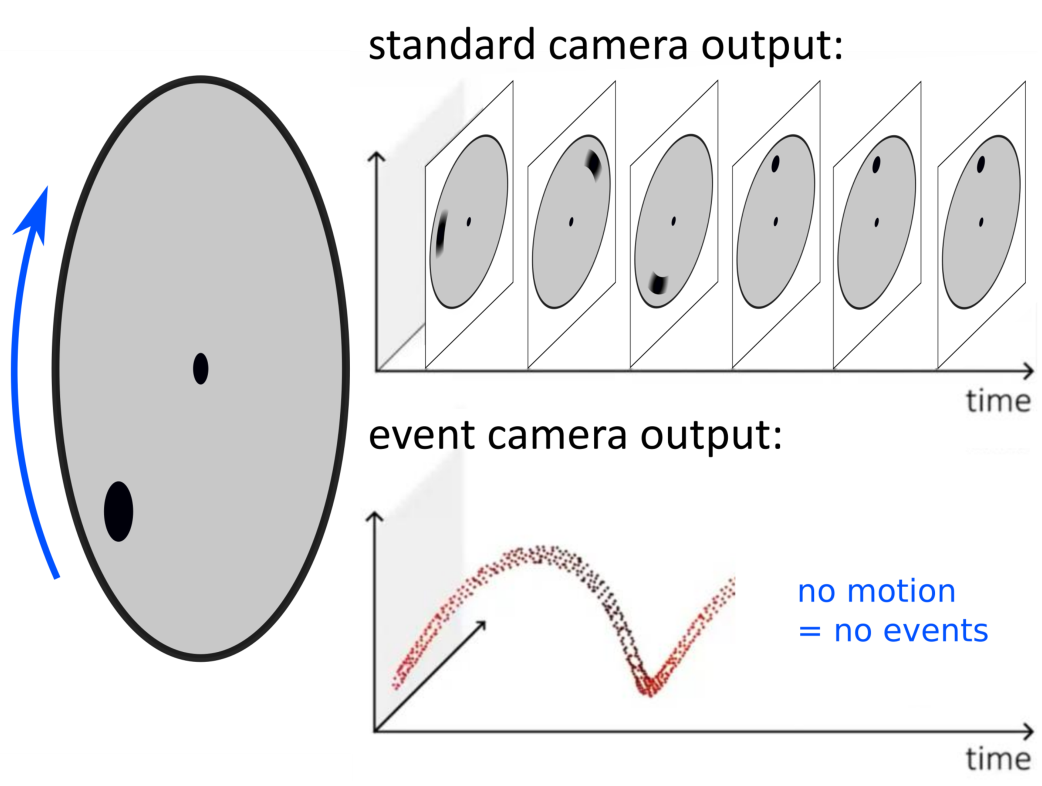
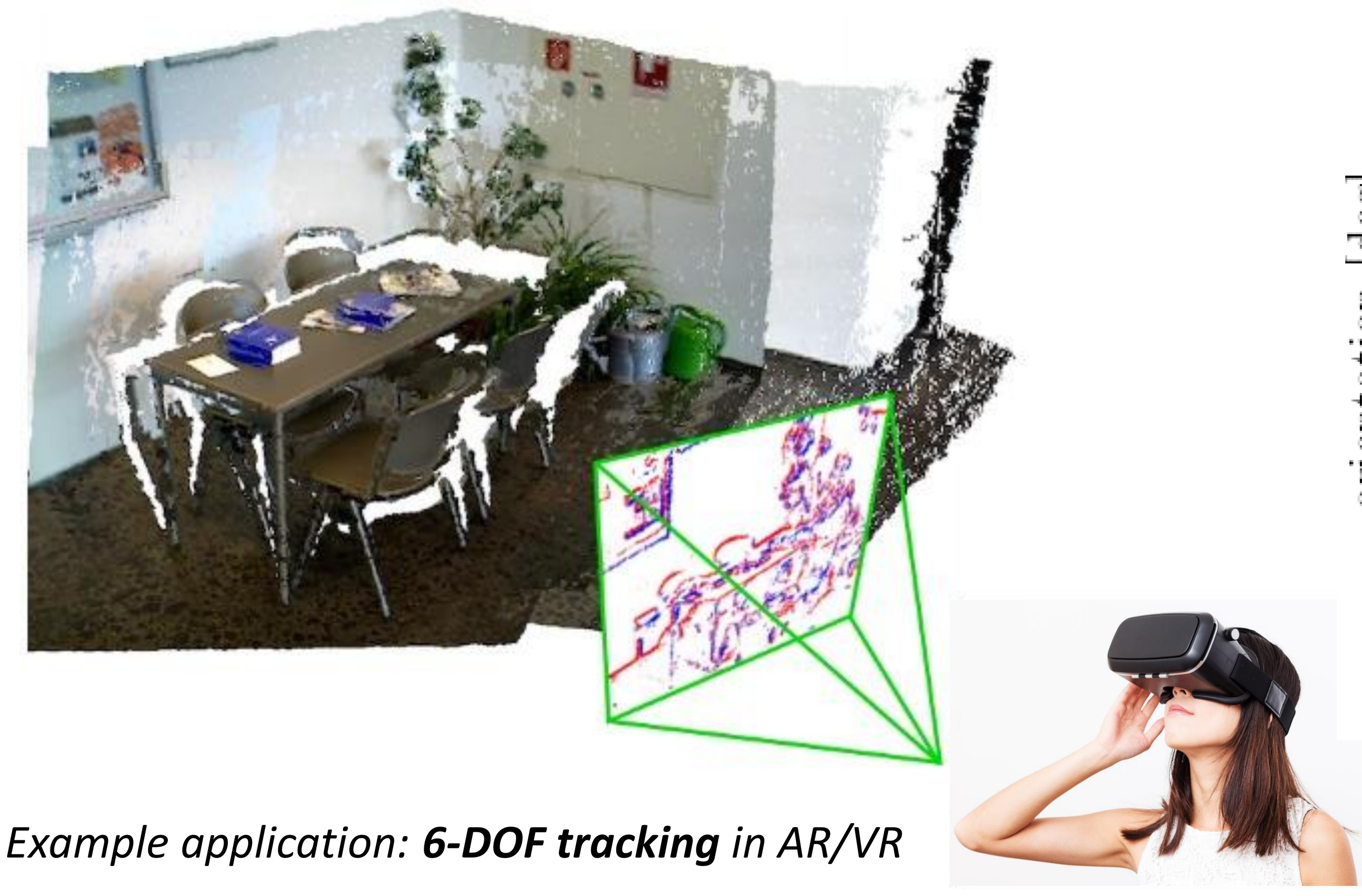
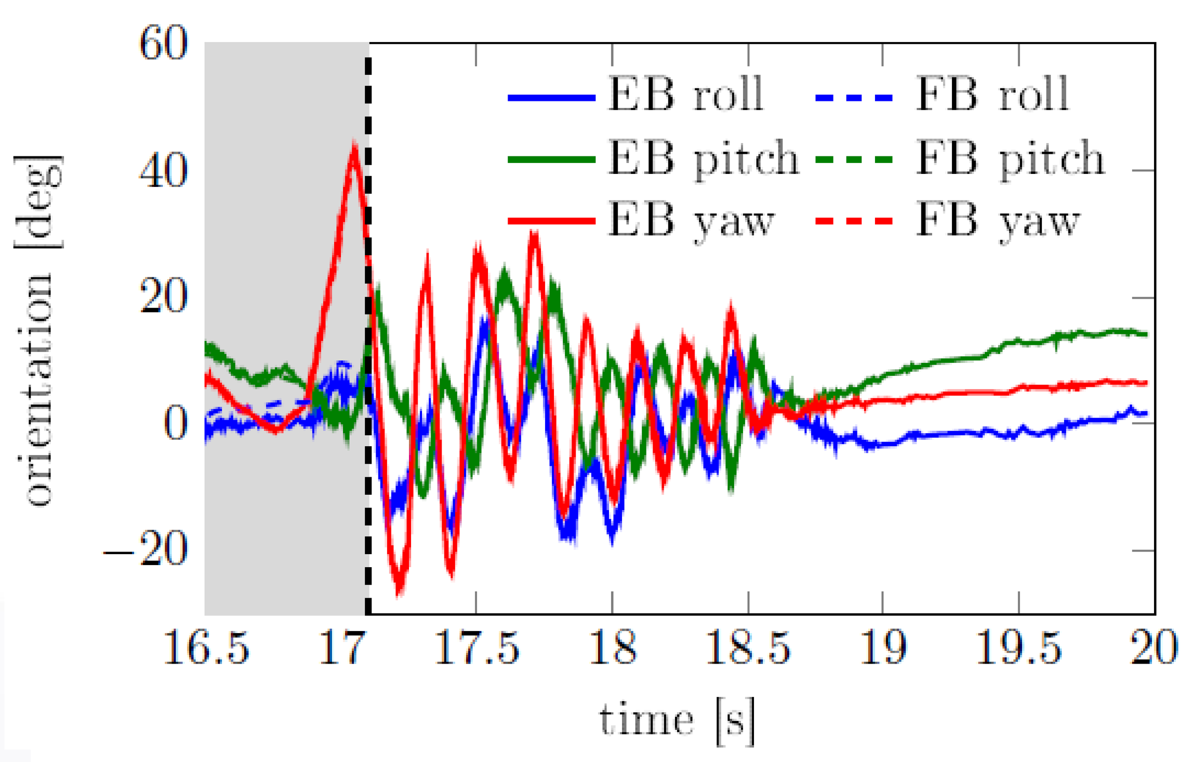


*Event cameras output only **brightness changes.** Output is a stream of asynchronous events.*



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

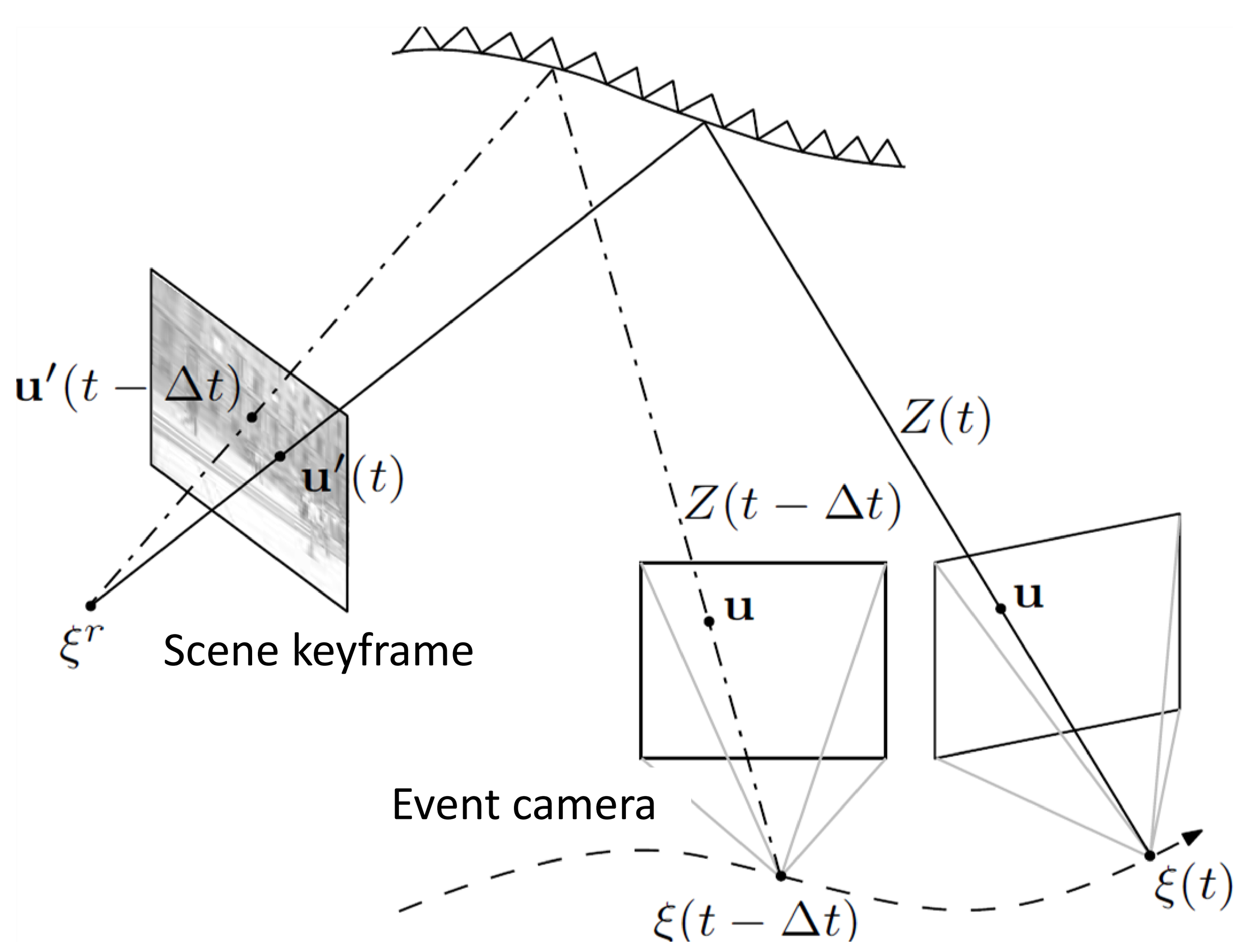


Events allow for accurate tracking even with fast motion (>500∘/sec rotation shown here)

*Event cameras have **low-latency, high dynamic range** and **no motion blur.***
How can we track their 6-DOF pose in natural scenes event-by-event?

Geometric Model

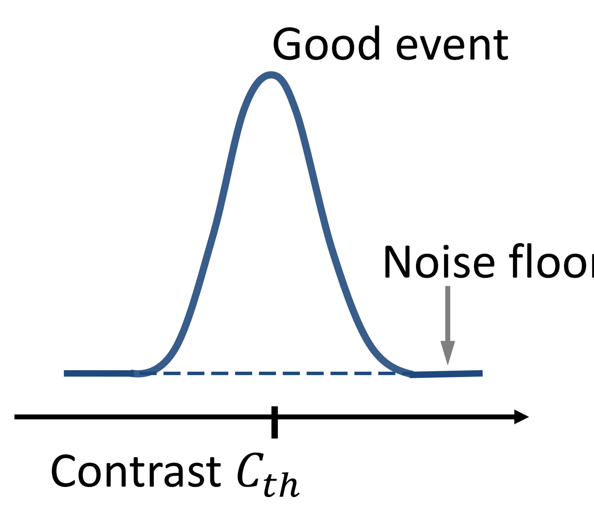
Given the events and scene, we can **solve for the pose**.
The 3D scene is represented by **keyframes** and **depth maps**.
Each event provides a brightness change observation C_{th}.



Robust Event Generation Model

Ideally, an event is generated of the brightness change is C_{th}.
Realistically, we use a **resilient mixture model**:

- Good measurement: Gaussian distribution
- Noise / outliers: Uniform distribution



$$p(o_k|s_k) = \pi_m \mathcal{N}(M(o_k, \tilde{s}_k); 0, \sigma_m^2) + (1-\pi_m)\mathcal{U}(M(o_k, \tilde{s}_k); M_{\min}, M_{\max})$$

We model the brightness change of each event using the scene information, and we use the mixture model to provide the **probability of the event being generated by the scene**.

Probabilistic Approach

Bayesian filter:

$$\underbrace{q(s_k; \eta_k)}_{\text{Posterior}} \approx C\, \underbrace{p(o_k|s_k)}_{\text{Likelihood}}\, \underbrace{q(s_k; \eta_{k-1})}_{\text{Prior}}$$

State vector: current pose, poses and sensor parameters:

$$s = (\boldsymbol{\xi}_c, \boldsymbol{\xi}_i, \boldsymbol{\xi}_j, C_{\text{th}}, \pi_m, \sigma_m^2)$$

Approximate the posterior distribution in the exponential family, and **minimize** the Kull-back-Leibler divergence to yield the **filter equations**:

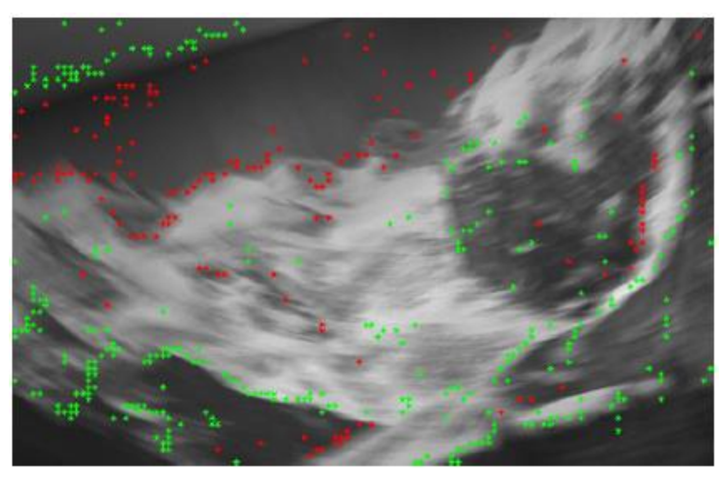
Gain: $K_k = P_k J_k^\top (J_k P_k J_k^\top + \sigma_m^2)^{-1}$

Weight: $w_k = \dfrac{\pi_m \mathcal{N}(\bar{M}_k; 0, \sigma_m^2)}{\pi_m \mathcal{N}(\bar{M}_k; 0, \sigma_m^2) + (1-\pi_m)\mathcal{U}}$

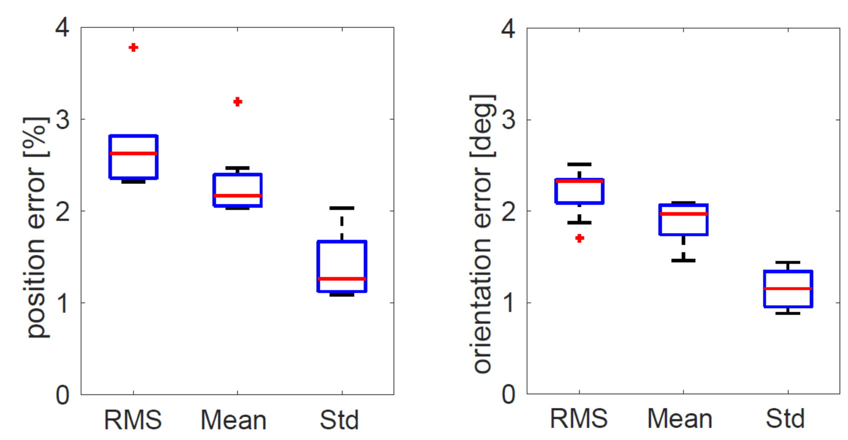
Pose: $\boldsymbol{\xi}_{k+1} = \boldsymbol{\xi}_k + w_k K_k \bar{M}_k$

Covar: $P_{k+1} = (\mathbb{1} - w_k K_k J_k) P_k,$

Results



Events on frame. High-speed motion



Accuracy evaluation: rocks sequences. Ground truth from mocap system.

Video:

Dataset:

Sponsors

robotics Swiss National Centre of Competence in Research
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