IMAGE RECONSTRUCTION FROM DVS

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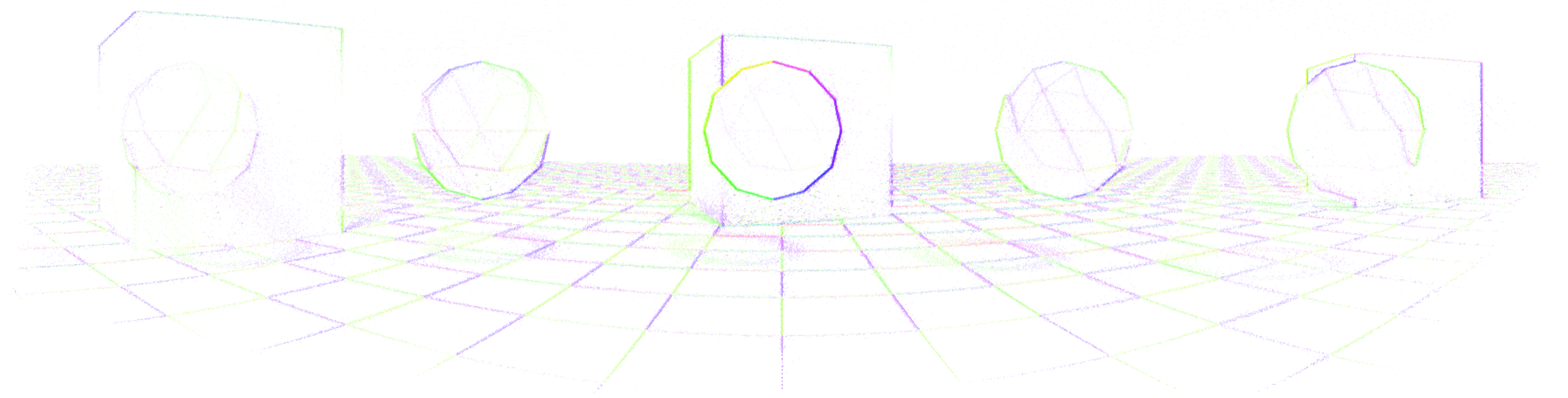
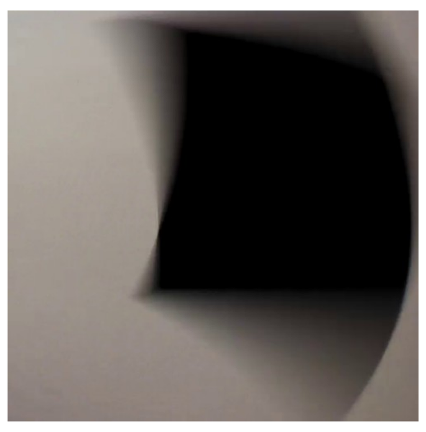
BASED ON WORK BY KIM ET AL. [1]



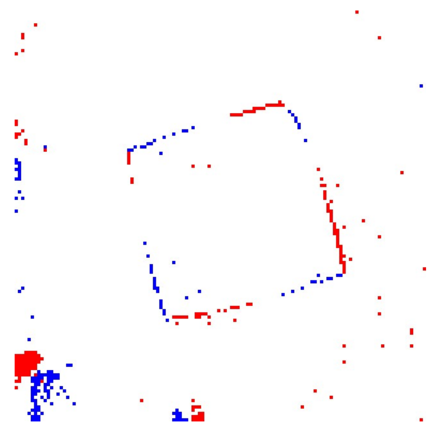
1. MOTIVATION

- increase robustness and speed of visual odometry / SLAM by replacing normal cameras with event cameras
- reduce SLAM problem to camera rotation in a static scene and reconstruction of a complete image

2. DYNAMIC VISION SENSOR



normal camera

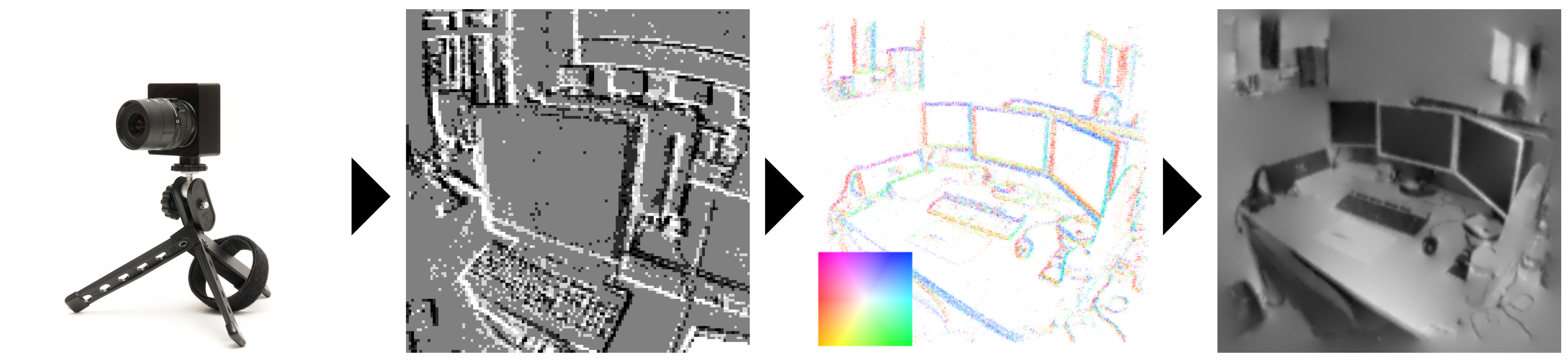


event camera (DVS)

images by [2]

- a DVS delivers **instantaneous changes** in image brightness ("events") instead of periodic full frames
- practically no motion blur
- very high dynamic range
- drastically reduced bandwith incurs significantly lower computational costs

3. CORE ALGORITHM

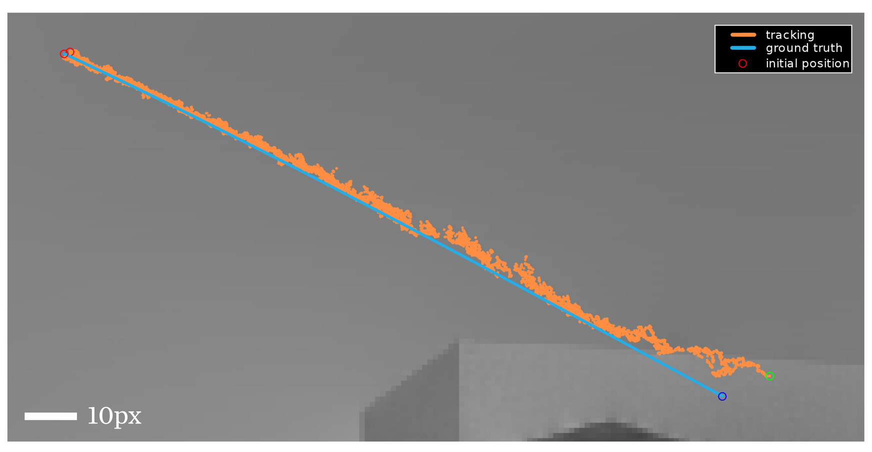


Jointly track the global rotational motion of a camera and estimate the gradients of the scene around it. The gradient map is then upgraded to a full image-like mosaic.
Each of these components essentially believes that the current estimate from the other is correct.

ASSUMPTIONS

- a change in brightness is caused by a movement of the camera (static scene)
- only rotation, no translation and therefore no parallax displacement

MOVEMENT TRACKING



- rotation tracking with particle filter and constant position motion model
- for every event, compare intensity at event position for every possible camera rotation to intensity at (assumed) position of last event:

$$z := \log(M(\mathbf{p}^t)) - \log(M(\mathbf{p}^{t-1}))$$

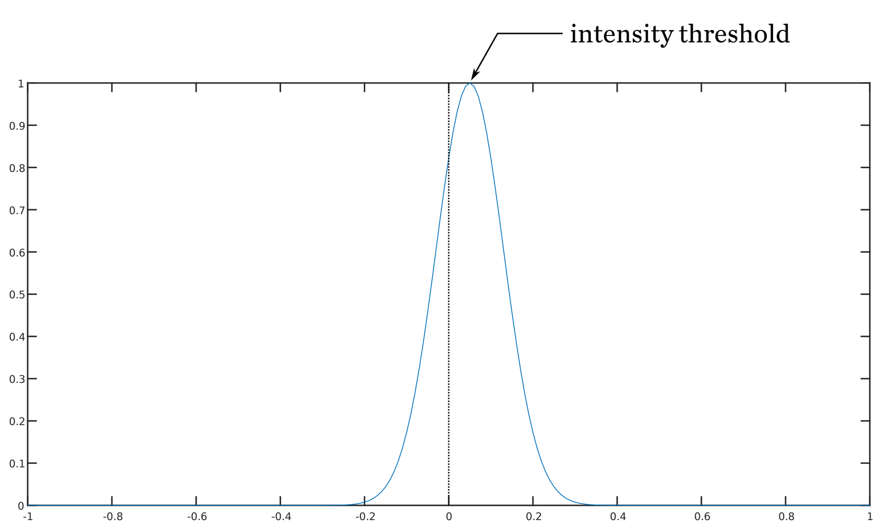
the closer the intensity change to the camera's threshold the more likely is the proposed movement

- bootstrap: start with a small known patch at the center. See also initialization in section 5.

RECONSTRUCTION

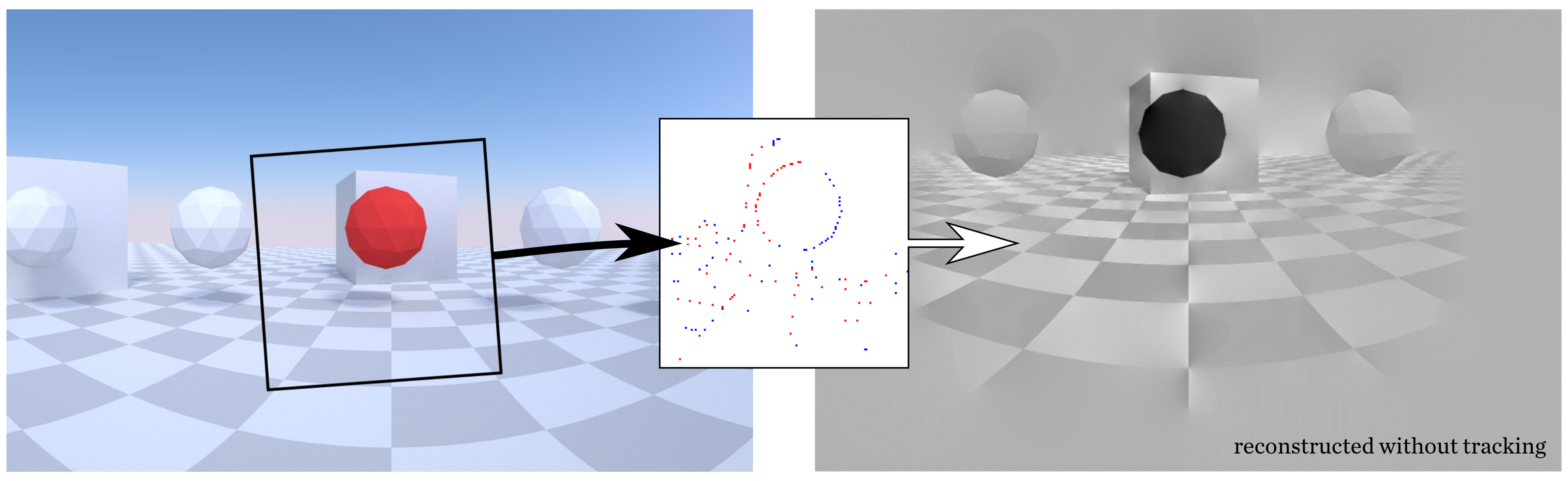
Use movement between current and last event of the pixel to estimate gradient (intensity change) at event pixel.

- extended Kalmann filter reduces noise in the image
- Poisson-solver computes grayscale image from gradients.



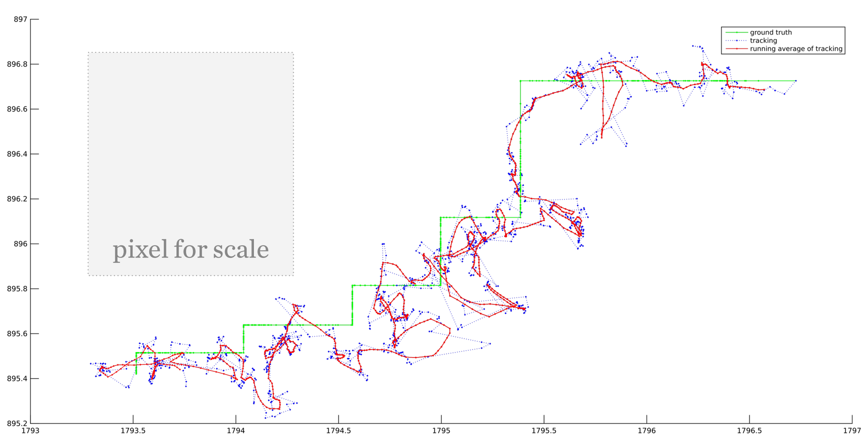
likelihood function for intensity change

4. SIMULATION



The full system is implemented in simulation. Both tracking and image reconstruction can either work with ground truth data or results from the other component.

TRACKING RESULTS



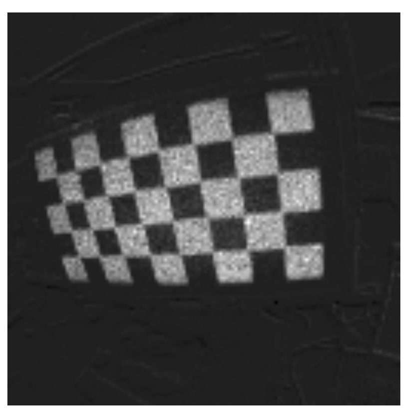
- locally very noisy (a few pixels)

⇒ many events necessary

- sensitive to motion parameters
- no way of detecting or correcting lost tracking

5. REAL DATA

CALIBRATION



- flickering display of normal checkerboard pattern as proposed in [2]
- standard camera calibration toolbox

INITIALIZATION

- integration over events when removing a dark cover results in an initial image patch
- another possibilty: the 2nd generation DVS is able to take full pictures

6. CONCLUSION

A dynamic vision sensor is a feasible option for rotational motion tracking. With some optimizations the system is conceiveably real-time capable - especially when combined with other sensors such as an IMU. This might even lead to full 3D-SLAM with a dynamic vision sensor.

7. REFERENCES

[1] H. Kim, A. Handa, R. Benosman, S. Ieng, A. Davison, 2014 "Simultaneous Mosaicing and Tracking with an Event Camera"

[2] E. Mueggler, B. Huber, D. Scaramuzza, IROS 2014 "Event-based, 6-DOF Pose Tracking for High-Speed Maneuvers"

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