Technische Universität Berlin

EINSTEIN CENTER Digital Future

Event-based Robot Vision

Prof. Dr. Guillermo Gallego
Chair: Robotic Interactive Perception

guillermo.gallego@tu-berlin.de

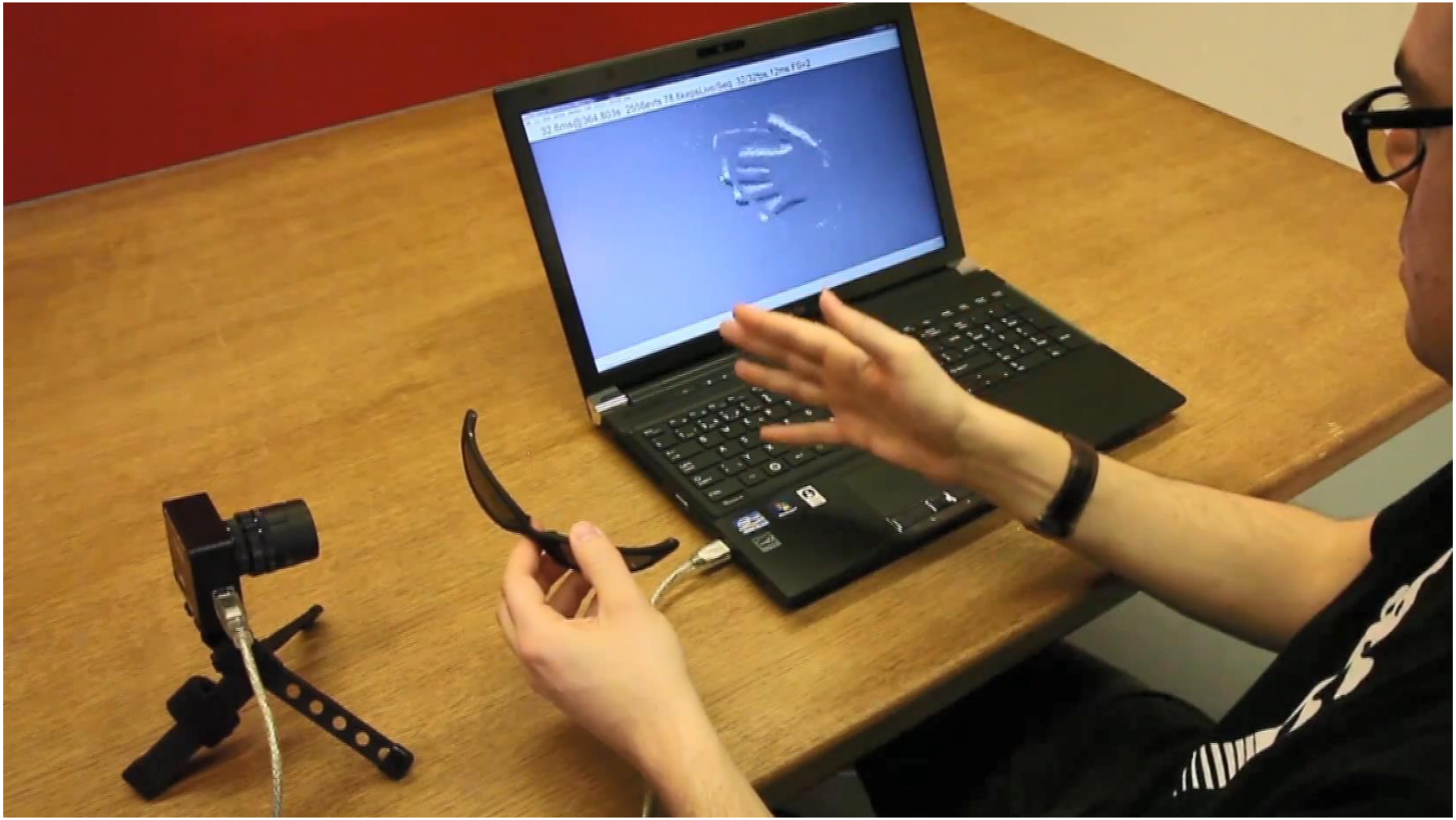
http://www.guillermogallego.es

DVS with Sunglasses. High Dynamic Range

Video: T. Delbruck. https://youtu.be/5NNoq1Gq4sc

Event camera: High Dynamic Range (HDR)

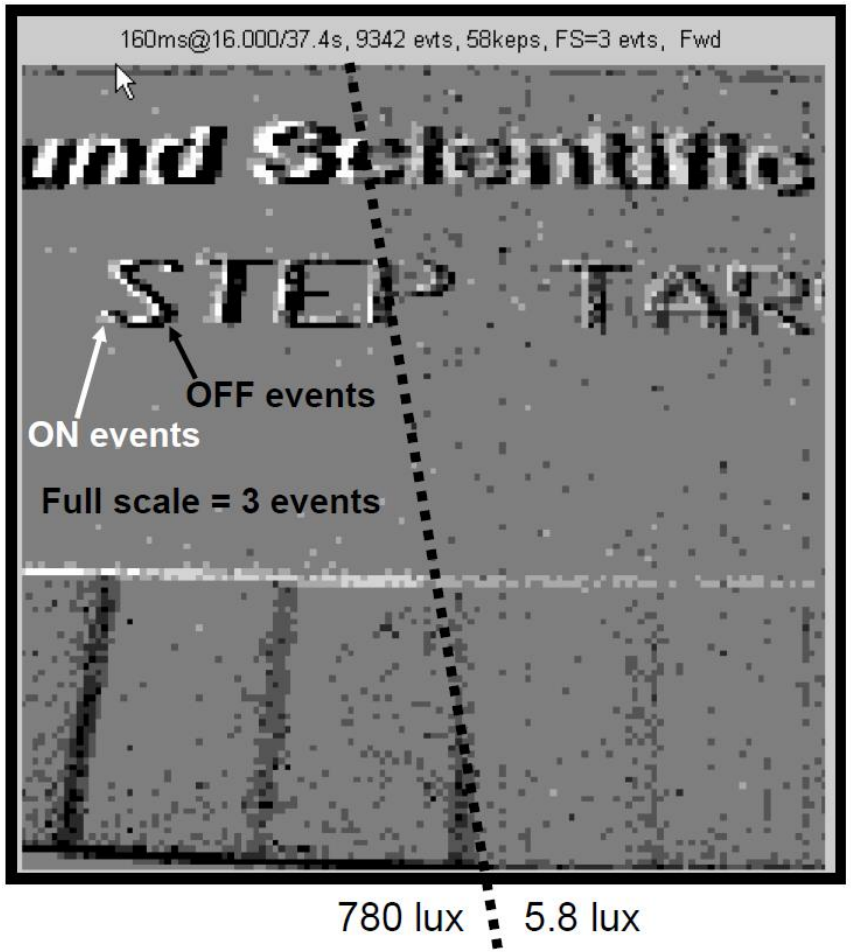
- Each pixel adapts **independently** to the light it receives and chooses its own operating point.

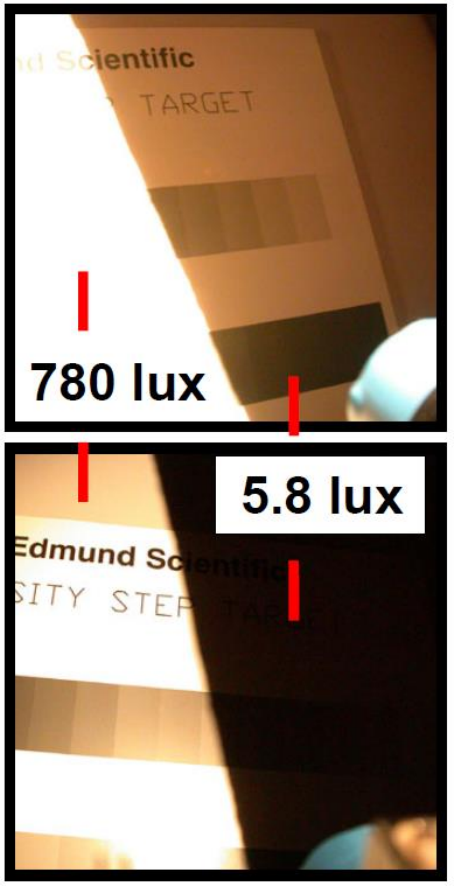


Video: Dynamic Vision Sensor https://youtu.be/QxJ-RTbpNXw

Using a light meter and a density step target

- A more quantitative approach



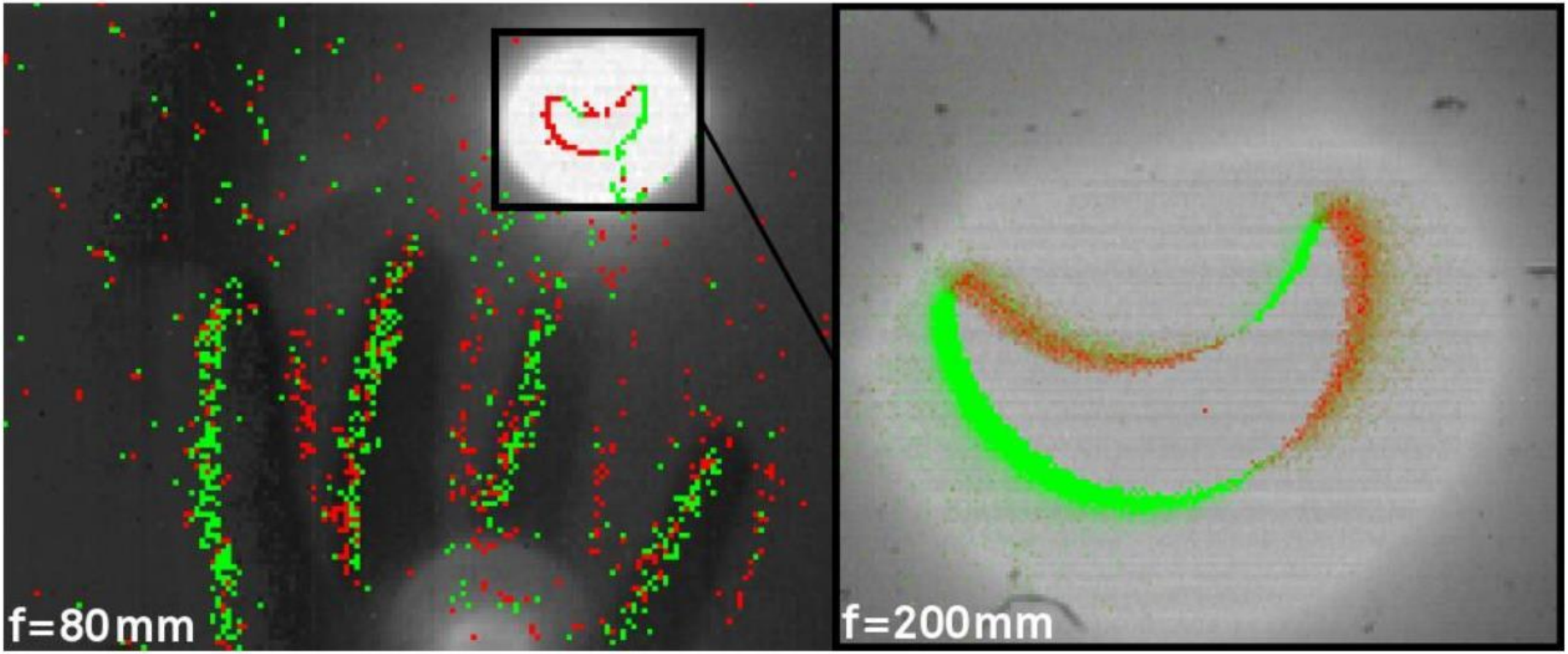


Edmund 0.1 density chart
Illumination ratio=135:1

Lichtsteiner et al., *A 128×128 120dB 30mW Asynchronous Vision Sensor that Responds to Relative Intensity Change*, ISSCC 2006.

High Dynamic Range Scene

- Ability to see very bright and very dark scenes, simultaneously
- Image of the solar eclipse (March 2015) captured by a DAVIS

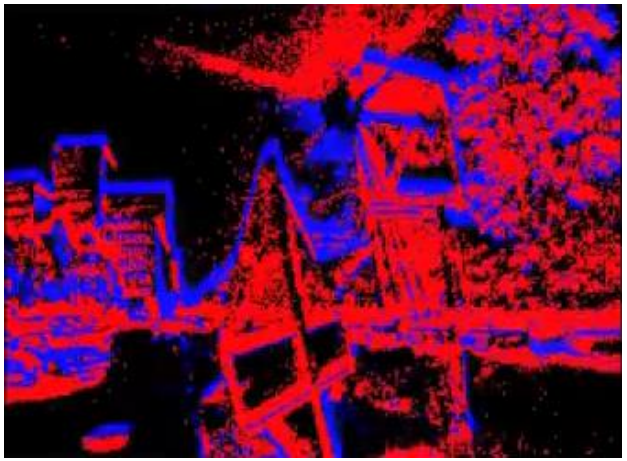


Video credit: M. Osswald, T. Delbruck and S. Bamford. https://youtu.be/hQI7e1TpXmA

Visual Odometry in High Dynamic Range Scenes

Standard camera

Event camera



SLAM output:
Camera pose and 3D map

Rebecq et al., *EVO: A Geometric Approach to Event-based 6-DOF Parallel Tracking and Mapping in Real-time*, RAL'18. https://youtu.be/bYqD2qZJlxE

Automotive Applications

- High Dynamic Range (HDR)

Driving out of a tunnel

Rebecq et al., PAMI 2020

https://youtu.be/eomALySSGVU

Response in Low Light Conditions

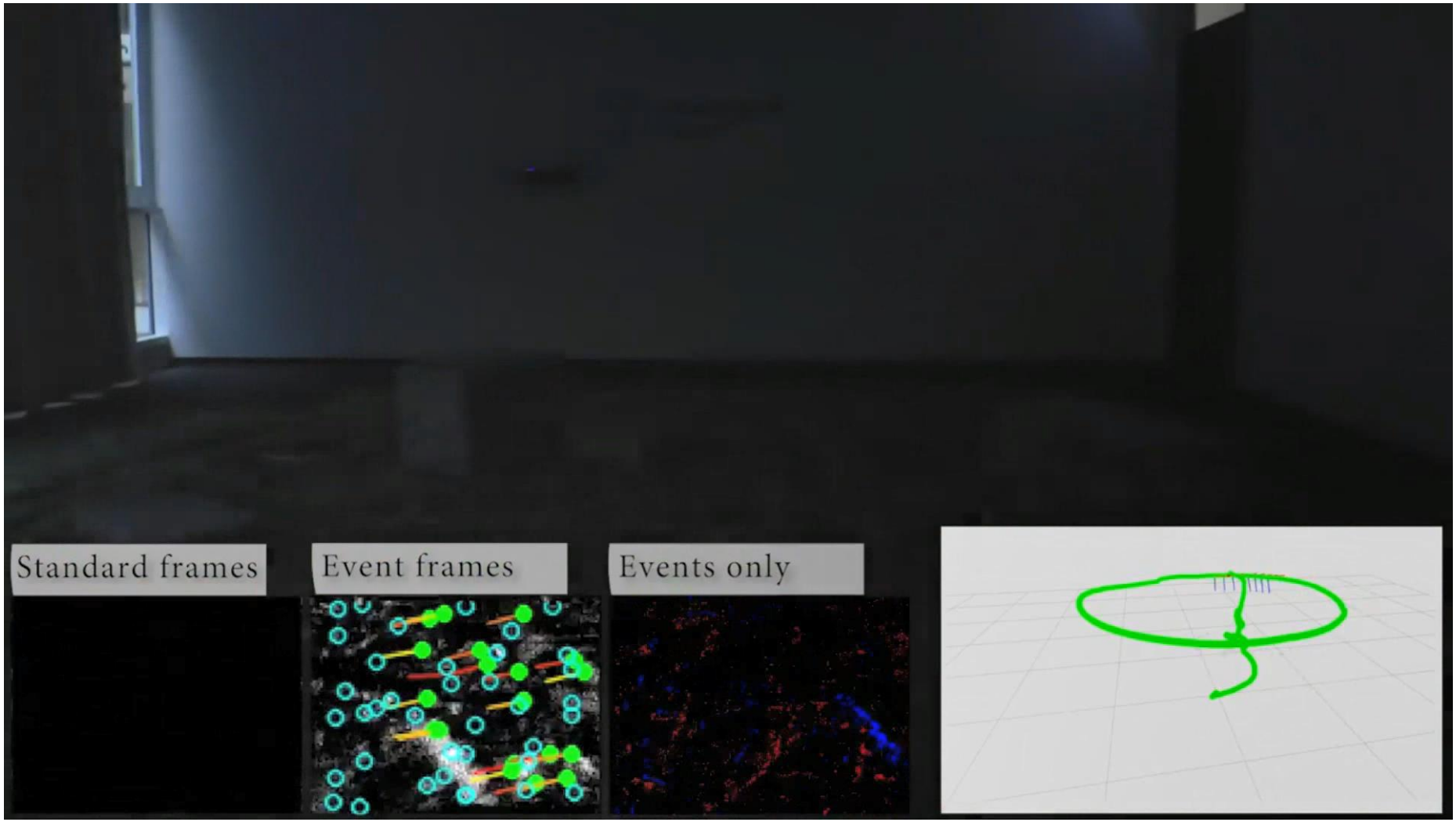
- Moving black text on white background under 3/4 moon (**< 0.1 lux**) illumination (180 ms, 8200 events)
- Minimal motion blur!

Video: https://youtu.be/-OrnWXDJ0WI

Lichtsteiner et al., *A 128x128 120dB 15µs latency asynchronous temporal contrast vision sensor*, IEEE J. Solid-State Circuits, 2008.

Robot in Difficult Illumination Conditions

- Tightly coupled sensor fusion, fully onboard processing



Rosinol et al., *Ultimate SLAM? Combining Events, Images, and IMU for Robust Visual SLAM*…, RAL 2018. https://youtu.be/jIvJuWdmemE

Discussion

- Understand the reasons that enable HDR:
  - Every pixel has its own operating point (There is no global shutter)
  - Pixel intensity is measured in logarithmic scale

- Investigate:
  - How is dynamic range measured?
  - Trade-off between dynamic range and contrast sensitivity (survey paper IEEE TPAMI 2020, Section 2.4).

References

Reading:

- Look at **experiments** that show the HDR capabilities of the camera (and the resulting vision system). Often, they are qualitative, comparing with a standard frame-based camera.
  - Lichtsteiner et al., *A 128x128 120dB 15μs latency asynchronous temporal contrast vision sensor*, IEEE J. Solid-State Circuits, 2008. (quantitative)
  - Kim et al., *Simultaneous Mosaicing and Tracking with an Event Camera*, BMVC 2014.
  - Bardow et al., *Simultaneous Optical Flow and Intensity Estimation from an Event Camera*, CVPR 2016. YouTube
  - Rebecq et al., *EVO: A Geometric Approach to Event-based 6-DOF Parallel Tracking and Mapping in Real-time*, RA-L 2016. Youtube
  - Rebecq et al., *High Speed and High Dynamic Range Video with an Event Camera*, PAMI 2020. YouTube