Events-to-Video:

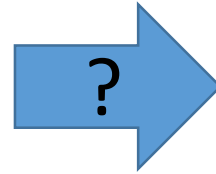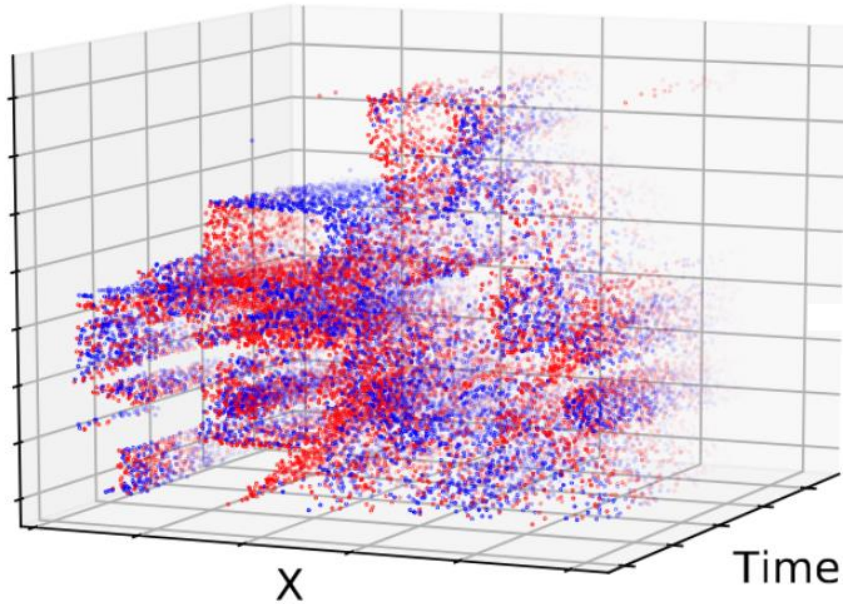# Bringing Modern Computer Vision to Event Cameras

Henri Rebecq, René Ranftl, Vladlen Koltun, Davide Scaramuzza

Rebecq et al., "Events-to-Video: Bringing Modern Computer Vision to Event Cameras", CVPR19. PDF Video.
Rebecq et al., "High Speed and High Dynamic Range Video with an Event Camera", arXiv, 2019. PDF Video Code

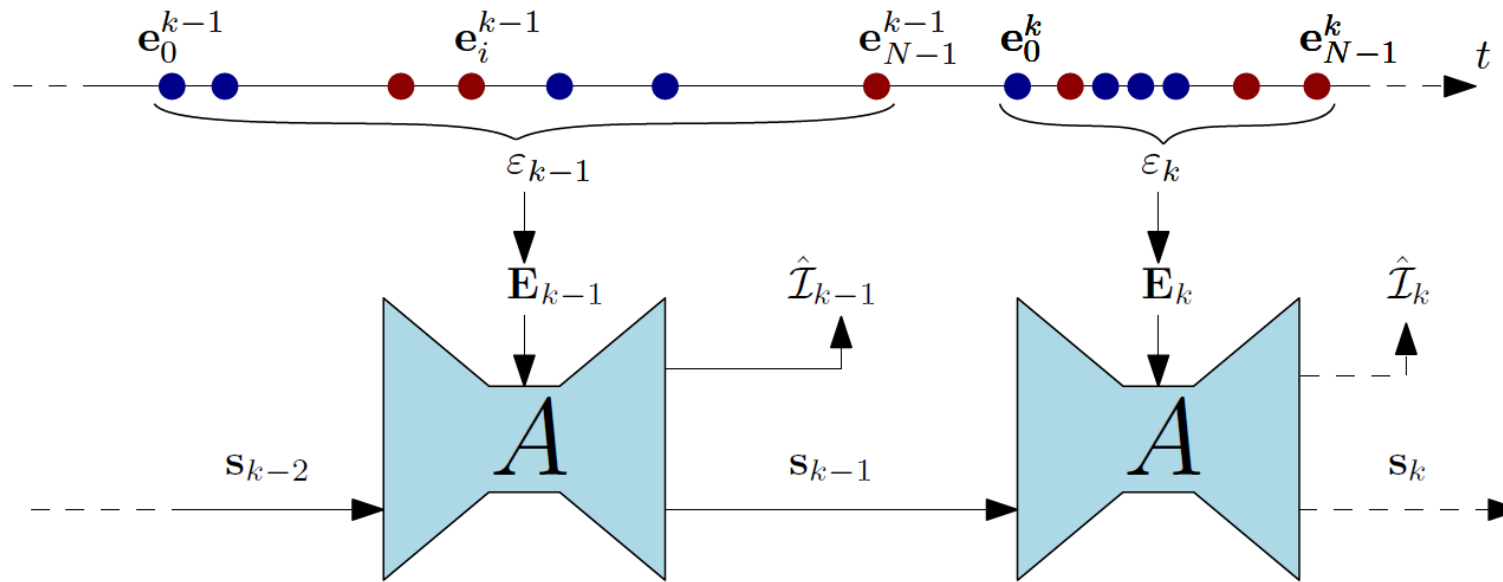# Can we turn event data into a high quality video?

Yes!

How?
What can we do with it?

Rebecq et al., Events-to-Video: Bringing Modern Computer Vision to Event Cameras, CVPR´19

Our method[1]

Overview

- Recurrent neural network (main module: Unet[2])
- Input: sequences of *event tensors* (spatio-temporal volumes of events[3])

[1] Rebecq et al., "Events-to-Video: Bringing Modern Computer Vision to Event Cameras", CVPR19. PDF Video.
[2] Ronneberger et al., U-Net: Convolutional Networks for Biomedical Image Segmentation, MICCAI'15
[3] Zhu et al., Unsupervised Event-based Learning of Optical Flow, Depth and Egomotion, CVPR'19
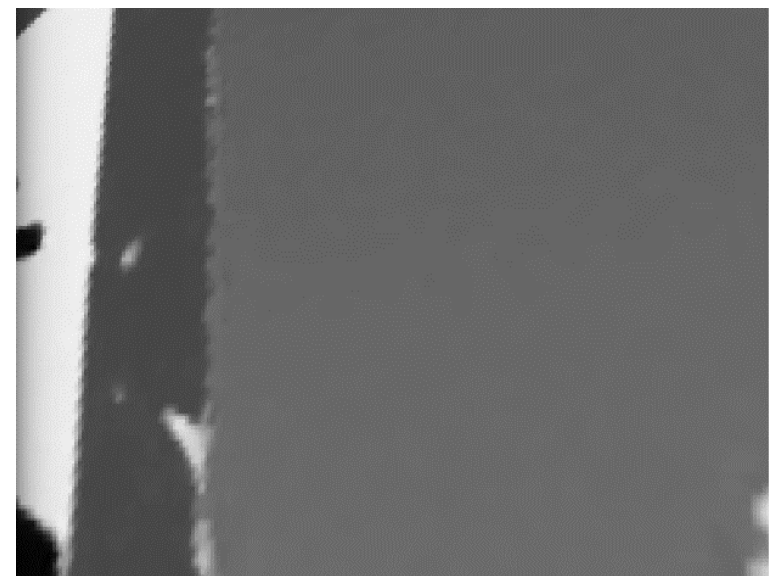
Our method[1]
Training Data

How to get aligned {events, video} pairs?

• Our method: simulate events[2] by applying random motions to real images (MS-COCO).

• 45 minutes of simulated events + ground truth videos used for training.

• **The network generalizes very well to real events!**
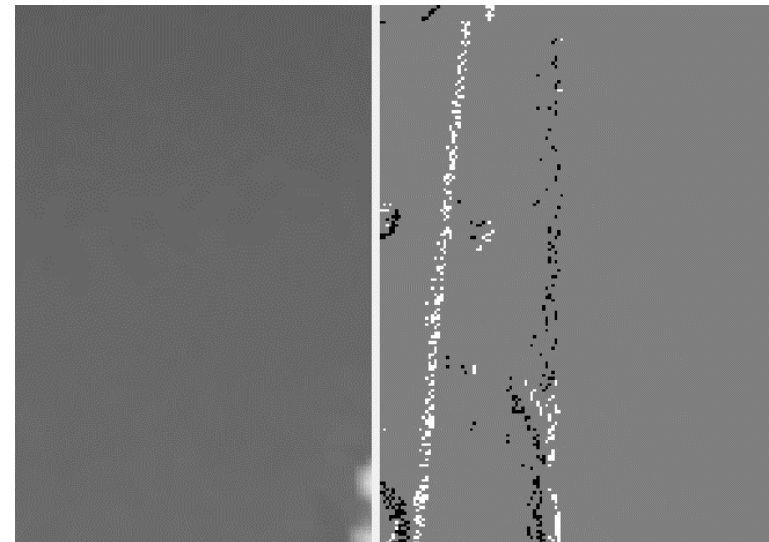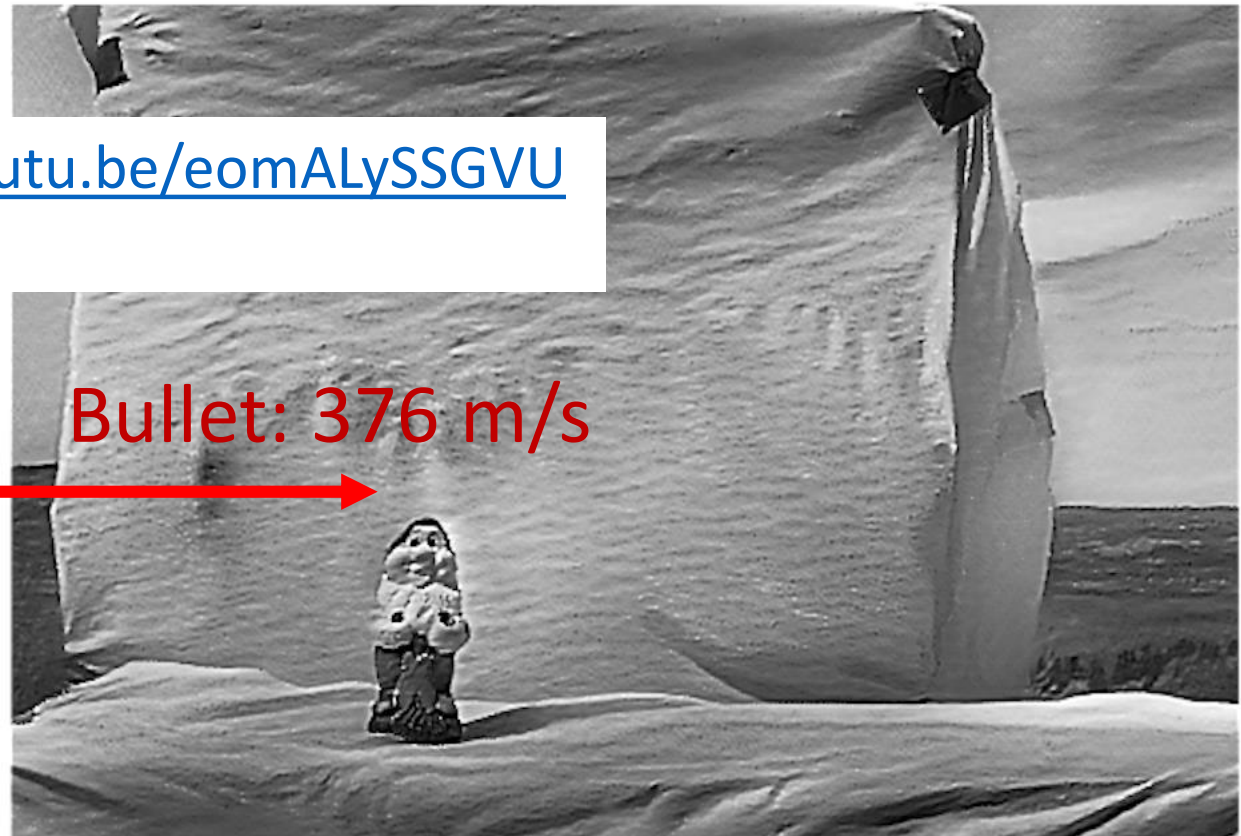

Synthetic events

Ground truth video

[1] Rebecq et al., "Events-to-Video: Bringing Modern Computer Vision to Event Cameras", CVPR19. PDF Video.
[2] Rebecq et al., ESIM: an Open Event Camera Simulator, CoRL'18 (open source)

High Framerate Video

Huawei P20 Pro (240 FPS)   Our reconstruction (5400 FPS)

https://youtu.be/eomALySSGVU

Bullet: 376 m/s

Real time

Rebecq et al., "Events-to-Video: Bringing Modern Computer Vision to Event Cameras", CVPR19. PDF Video.
Rebecq et al., "High Speed and High Dynamic Range Video with an Event Camera", arXiv, 2019. PDF Video Code

High Framerate Video

https://youtu.be/eomALySSGVU

Huawei P20 Pro (240 FPS)

Our reconstruction (5400 FPS)

100 x slow motion

Rebecq et al., "Events-to-Video: Bringing Modern Computer Vision to Event Cameras", CVPR19. PDF Video.
Rebecq et al., "High Speed and High Dynamic Range Video with an Event Camera", arXiv, 2019. PDF Video Code

High Framerate Video

https://youtu.be/eomALySSGVU

Water balloon

Apple iPad (120 FPS)

Our reconstruction (4800 FPS)

* different sequences, recorded in identical conditions

Real time

Rebecq et al., "Events-to-Video: Bringing Modern Computer Vision to Event Cameras", CVPR19. PDF Video.
Rebecq et al., "High Speed and High Dynamic Range Video with an Event Camera", arXiv, 2019. PDF Video Code

High Framerate Video

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Rebecq et al., "Events-to-Video: Bringing Modern Computer Vision to Event Cameras", CVPR19. PDF Video.
Rebecq et al., "High Speed and High Dynamic Range Video with an Event Camera", arXiv, 2019. PDF Video Code

HDR Video

Selfie Video

https://youtu.be/eomALySSGVU

Events

Our reconstruction

Phone camera

Rebecq et al., "Events-to-Video: Bringing Modern Computer Vision to Event Cameras", CVPR19. PDF Video.
Rebecq et al., "High Speed and High Dynamic Range Video with an Event Camera", arXiv, 2019. PDF Video Code

HDR Video
Driving out of a tunnel

▶ YouTube   https://youtu.be/eomALySSGVU
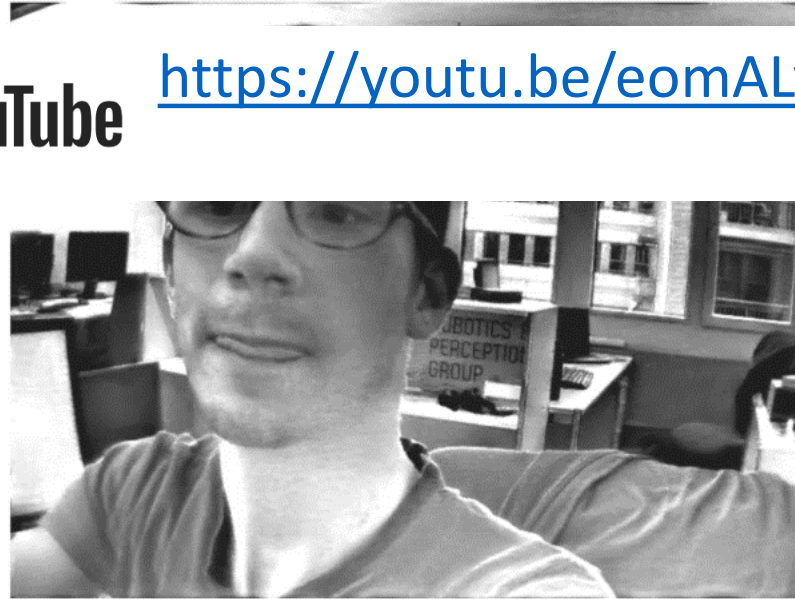
Events   **Our reconstruction**   **Phone camera**

Rebecq et al., "Events-to-Video: Bringing Modern Computer Vision to Event Cameras", CVPR19. PDF Video.
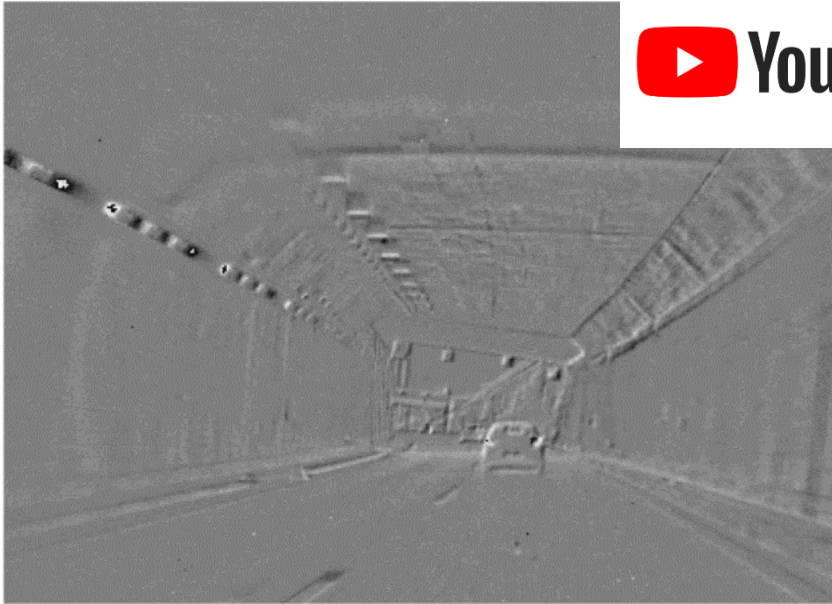Rebecq et al., "High Speed and High Dynamic Range Video with an Event Camera", arXiv, 2019. PDF Video Code

Downstream applications

Can we apply off-the-shelf computer vision algorithms to video reconstructions?

Downstream applications (object detection)

https://youtu.be/eomALySSGVU

Events

Our reconstruction + object detections (YOLOv3)

Rebecq et al., "Events-to-Video: Bringing Modern Computer Vision to Event Cameras", CVPR19. PDF Video.
Rebecq et al., "High Speed and High Dynamic Range Video with an Event Camera", arXiv, 2019. PDF Video Code

Downstream applications (monocular depth)

Events   Our reconstruction   Monocular depth

https://youtu.be/eomALySSGVU

[1] Li et al., MegaDepth: Learning Single-View Depth Prediction from Internet Photos, CVPR´18
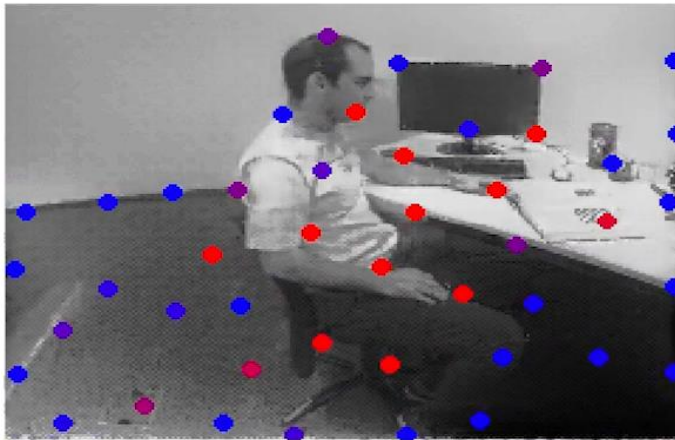
Rebecq et al., "Events-to-Video: Bringing Modern Computer Vision to Event Cameras", CVPR19. PDF Video.
Rebecq et al., "High Speed and High Dynamic Range Video with an Event Camera", arXiv, 2019. PDF Video Code

Downstream applications (visual odometry)

Events

Our reconstruction
+ tracked features

https://youtu.be/eomALySSGVU

▶ YouTube

VINS-Mono running on our reconstruction
from events

Rebecq et al., "Events-to-Video: Bringing Modern Computer Vision to Event Cameras", CVPR19. PDF Video.
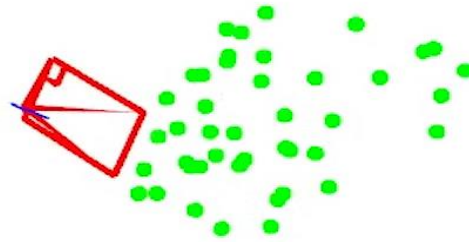Rebecq et al., "High Speed and High Dynamic Range Video with an Event Camera", arXiv, 2019. PDF Video Code

Conclusions

- Videos reconstructed from events are on par with conventional cameras!
  - ✓ High framerate
  - ✓ High dynamic range

- Sim2Real transfer works for event data! Potential application to many other tasks.

- Off-the-shelf computer vision algorithms work very well on the reconstructions.

- Event sensors are getting mature (higher resolution and quality).

Rebecq et al., Events-to-Video: Bringing Modern Computer Vision to Event Cameras, CVPR´19

Live demo at the workshop!

Reconstruction code + pretrained models available at:

http://rpg.ifi.uzh.ch/E2VID

Many event datasets available at:

https://github.com/uzh-rpg/event-based_vision_resources#datasets

Our event camera simulator ESIM available at:

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

Thank you!

Huawei P20 Pro (240 FPS)   Our reconstruction (5400 FPS)

Rebecq et al., Events-to-Video: Bringing Modern Computer Vision to Event Cameras, CVPR´19