Technische Universität Berlin

EINSTEIN CENTER Digital Future

Event-based Robot Vision

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Working principle and its Consequences

- Fact: "*DVS pixels respond independently and asynchronously to relative light intensity changes*".

- Consequences (**Advantages**):

Intensity changes	Redundancy suppression Low power (efficiency) Sparse output data (low computational and storage cost)
Asynchronously	High speed (low latency, high temporal resolution, very small motion blur)
Independently	High dynamic range (HDR)

Disclaimer: we are omitting event noise

Working principle and its Consequences

- Fact: "*DVS pixels respond independently and asynchronously to relative light intensity changes*".

- Consequences (**Challenges**):

Unfamiliar output	Cannot simply apply image-based computer vision methods
Intensity changes	"Absolute" intensity is not directly available. Novel vision algorithms need to reconsider photometric aspects (edge information, log scale, polarity)
Asynchronous & Sparse	Novel vision algorithms need to reconsider space-time processing and variable data rate

Disclaimer: we are omitting event noise

Advantages

- Redundancy removal
  - “Sparsity” / Sparse output
  - Low bandwidth and storage costs
- Low power
  - Efficiency. Power savings due to sparsity
- High speed
  - Low latency (Asynchronous)
  - High temporal resolution
  - Almost no motion blur
- High Dynamic Range (HDR)

Disadvantages

- Unfamiliar output
  - No “absolute” intensity information; only log-intensity changes.
  - Cannot simply apply computer vision methods for standard cameras. Require new algorithms: “Rethink Computer Vision”.
- Low spatial resolution
  - The original DVS had 128 x128 pixels
  - Latest event cameras have 1 Mpixel
  - But: the more pixels the more events need to be processed
- Event noise. Besides, it is not fully characterized.
- Software ecosystem is not as developed as for standard cameras (e.g., there is no “OpenCV” for event cameras)
- Price. Price will drop with mass production.

Challenges

- To **unlock the potential advantages** of event cameras by designing **novel computer vision algorithms** (avoid introducing bottlenecks).
  - This means taking into account the particular characteristics of event cameras: output is asynchronous and spatially sparse, it conveys intensity changes and it is noisy.

- To **demonstrate the impact** of the resulting computer vision system to tackle…
  - …problems that are currently difficult with other sensors
  - …new problems.

Ideal vs Real event data

- Real data has quite non-uniform **noise**
- Limited speed (pixel bandwidth is finite)
- Refractory period (time after event generation when no other event is produced at the pixel)
- Sensor noise has not been fully characterized
  - It is a big challenge because it depends on multiple variables
- Noise depends on amount of incident light at the pixel
- Strong edges have trailing events (“switch bouncing”)