Bandwidth-Limited Sensing with Neuromorphic Cameras
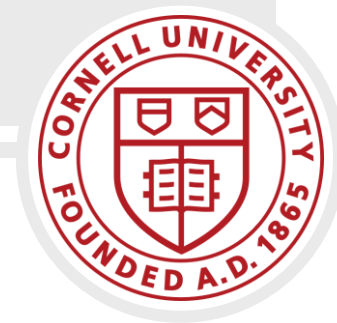
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Characteristics of Neuromorphic Cameras

- **Record asynchronous events** based on pixel-level changes in brightness
- Pixels are sensitive to log of brightness, resulting in high dynamic range (~120 dB)
- **Eliminates redundant data**, producing 100 – 1,000 times less data than a traditional camera
- **Sparse output** reduces computational cost

Brandli, C., et al. (2014). IEEE J. Solid-State Circ. (2014)
Lichtsteiner, P., et al. (2008). IEEE J. Solid-State Circ. (2008)
M. Mahowald, Springer Science & Business Media. (1994)
E. Culurciello and A. G. Andreou, Analog Integrated Circuits and Signal Processing (2006)
K. A. Zaghloul and K. Boahen, IEEE Transactions on Biomedical Engineering (2004)

Neuromorphic Cameras: Event Generation

- Neuromorphic cameras generate asynchronous events instead of frames

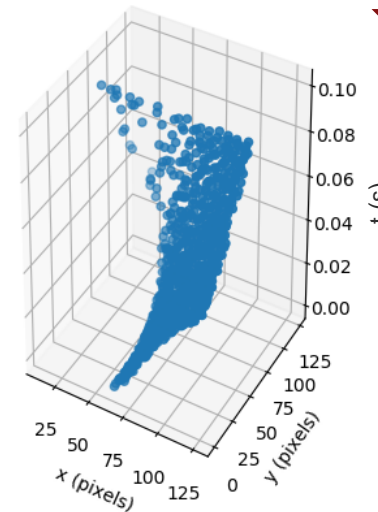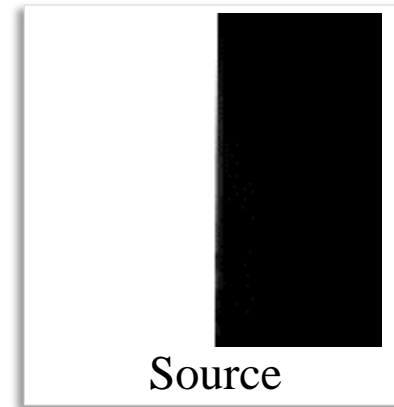- An event at (x, y) is generated at time t_i, with polarity

$$p_i = \begin{cases} 1, & \text{if } \ln[I(x,y,t_{i-1})] - \ln[I(x,y,t_i)] \leq -\theta \\ -1, & \text{if } \ln[I(x,y,t_{i-1})] - \ln[I(x,y,t_i)] \geq \theta \end{cases}$$

- The ith event $\mathbf{e}_i$ is described by the tuple $\mathbf{e}_i = (x, y, t, p)_i$
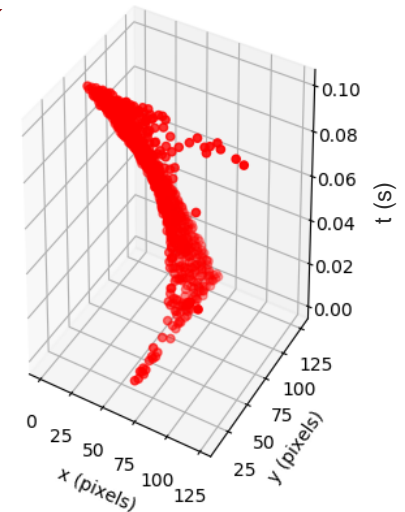
$$x, y \in \mathbb{N}^+ \qquad t \in \mathbb{R}^+ \qquad p \in \{-1, 1\}$$

- The set of all events is

$$\mathcal{E} = \{\mathbf{e}_i \mid i = 1, \ldots, N\}$$

Source

"On" Events
$(p_i = 1)$

"Off" Events
$(p_i = -1)$

3

Live Demo

Demonstrate functionality of neuromorphic cameras by simulation with a live webcam feed

Simulated Office Environment

Traditional Cameras

Camera 1

Camera 2

Simulated Office Environment

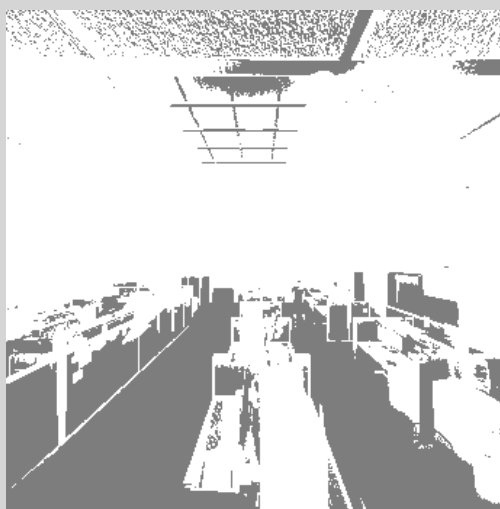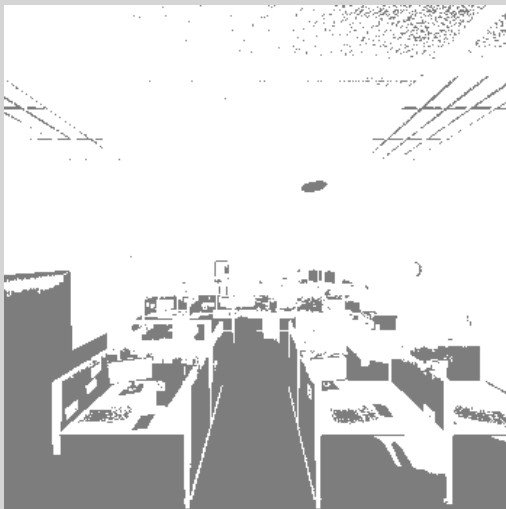|	Camera 1	Camera 2
Traditional Cameras		
Neuromorphic Camera		

Transmitting only changes reduces data by multiple orders of magnitude

Motion Detection and Clustering