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Enhancing Visual Place Recognition via Fast and Slow Adaptive Biasing in Event Cameras

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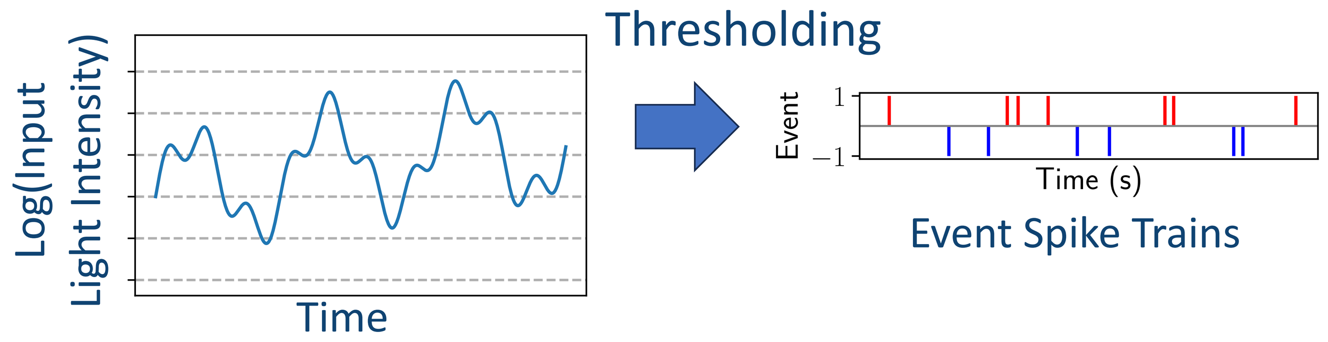
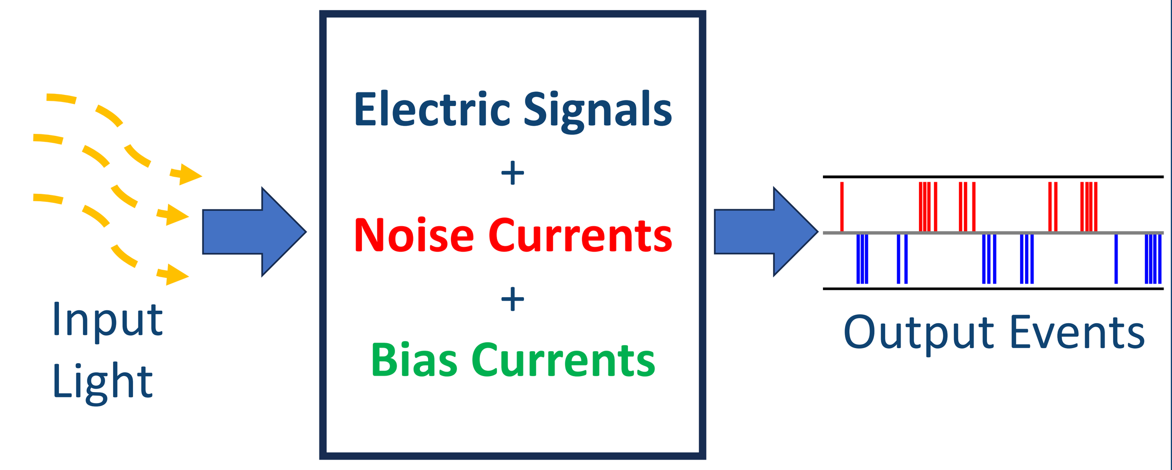
Motivation

Brief Introduction to Event Cameras



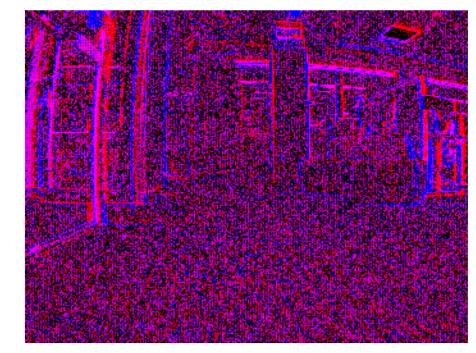
- Event cameras capture changes in input light intensity.
- Data is transmitted asynchronously from individual pixel circuits.
- They offer a higher dynamic range and lower latency than traditional frame-based cameras.

Event Camera : Simple Working Principle



- Pixel circuit convert light intensities into **electrical signals.**
- But **dark and leak currents** in the circuit cause noise events.
- Artificial **bias currents** help counter noise in the output.

Behavior of Noise in Accumulated Events

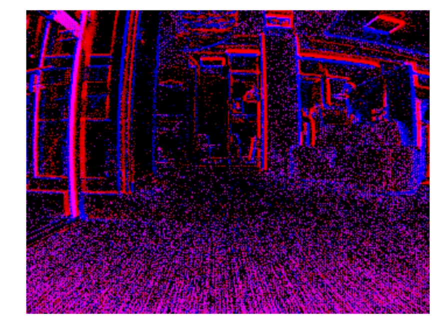


In low environment lighting:

- **Dark Currents** > **Input Signals**
- **Noise Events** > **Signal Events**
- High frequency noises dominate event output
- This leads to a high output event rate

In high environment lighting:

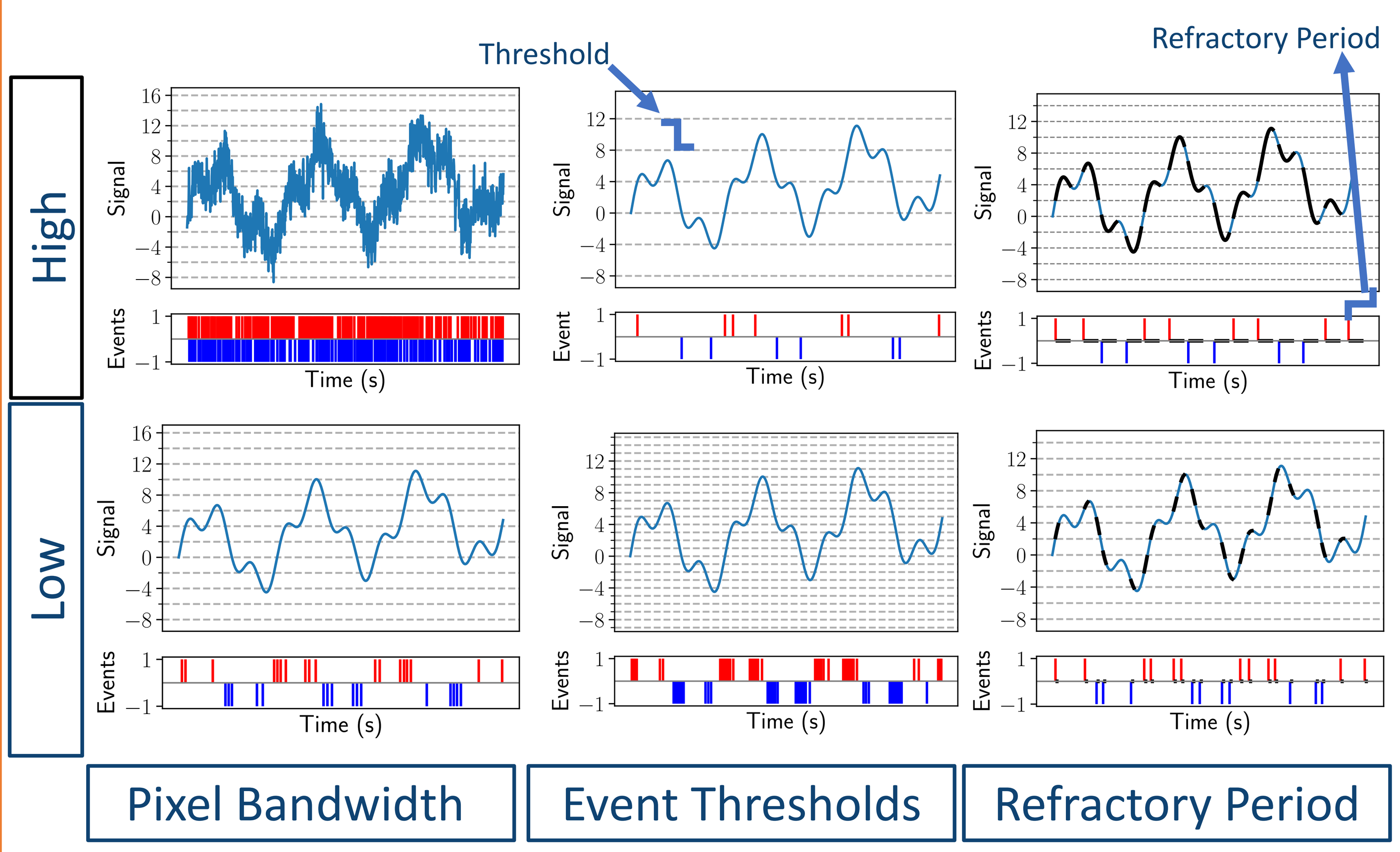
- **Input Signals > Noise Currents**
- More output events are generated from **input signals**
- This maintains a moderate output event rate



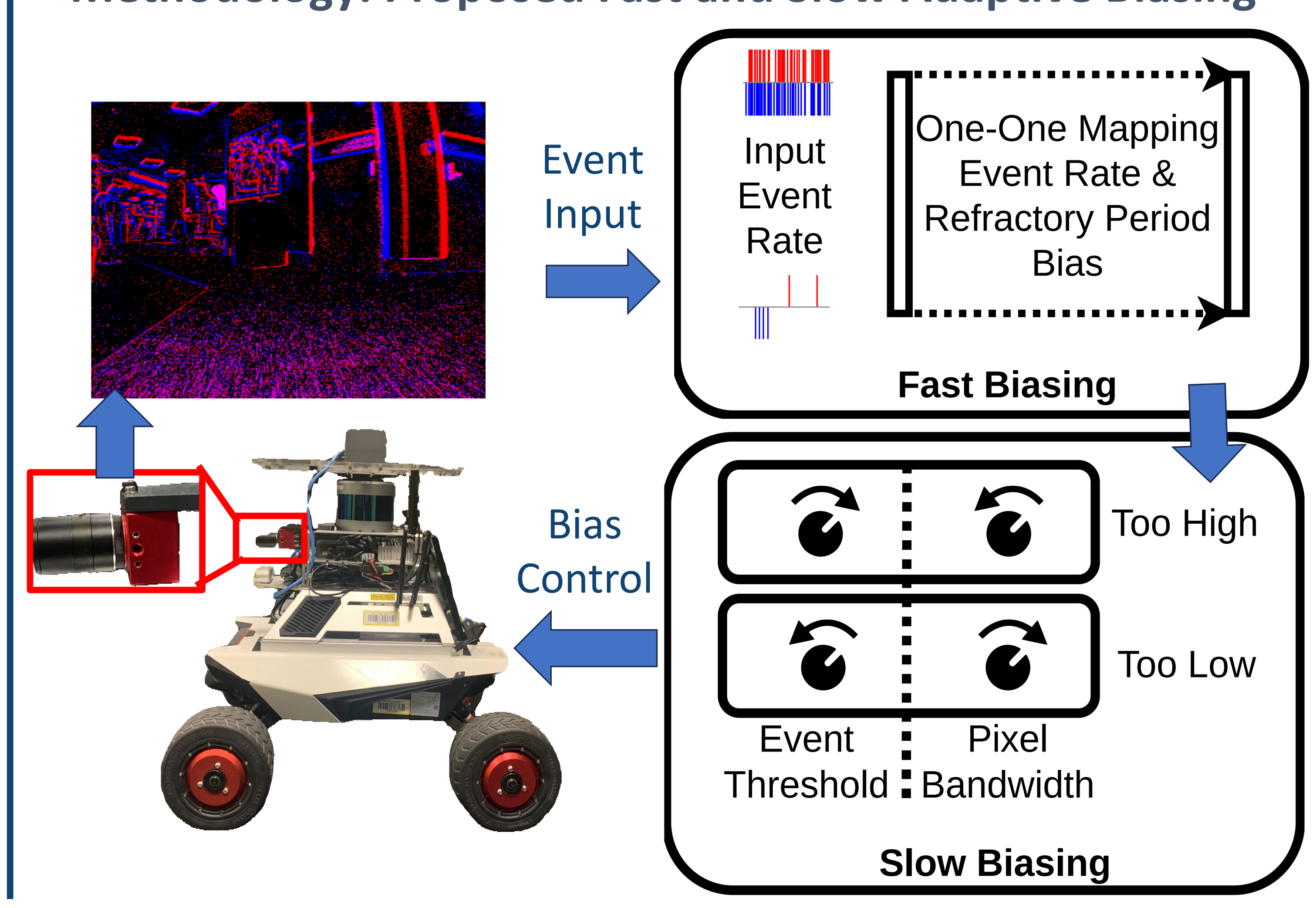
So, does maintaining a moderate event rate help **reduce** the effect of **noise** in the **output events**?!

Approach

Effect of Biases on Event Camera Output

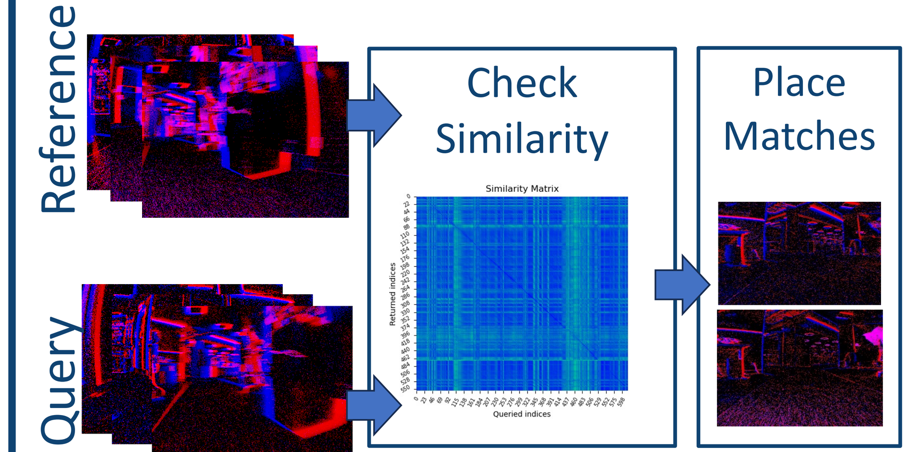


Methodology: Proposed Fast and Slow Adaptive Biasing



Downstream Task:

How do we know this way of biasing helps?



- We evaluate on the task of **Visual Place Recognition (VPR)**.
- In VPR, incoming query images are compared with a large number of reference images to find the best matching reference image.

Results

Baselines

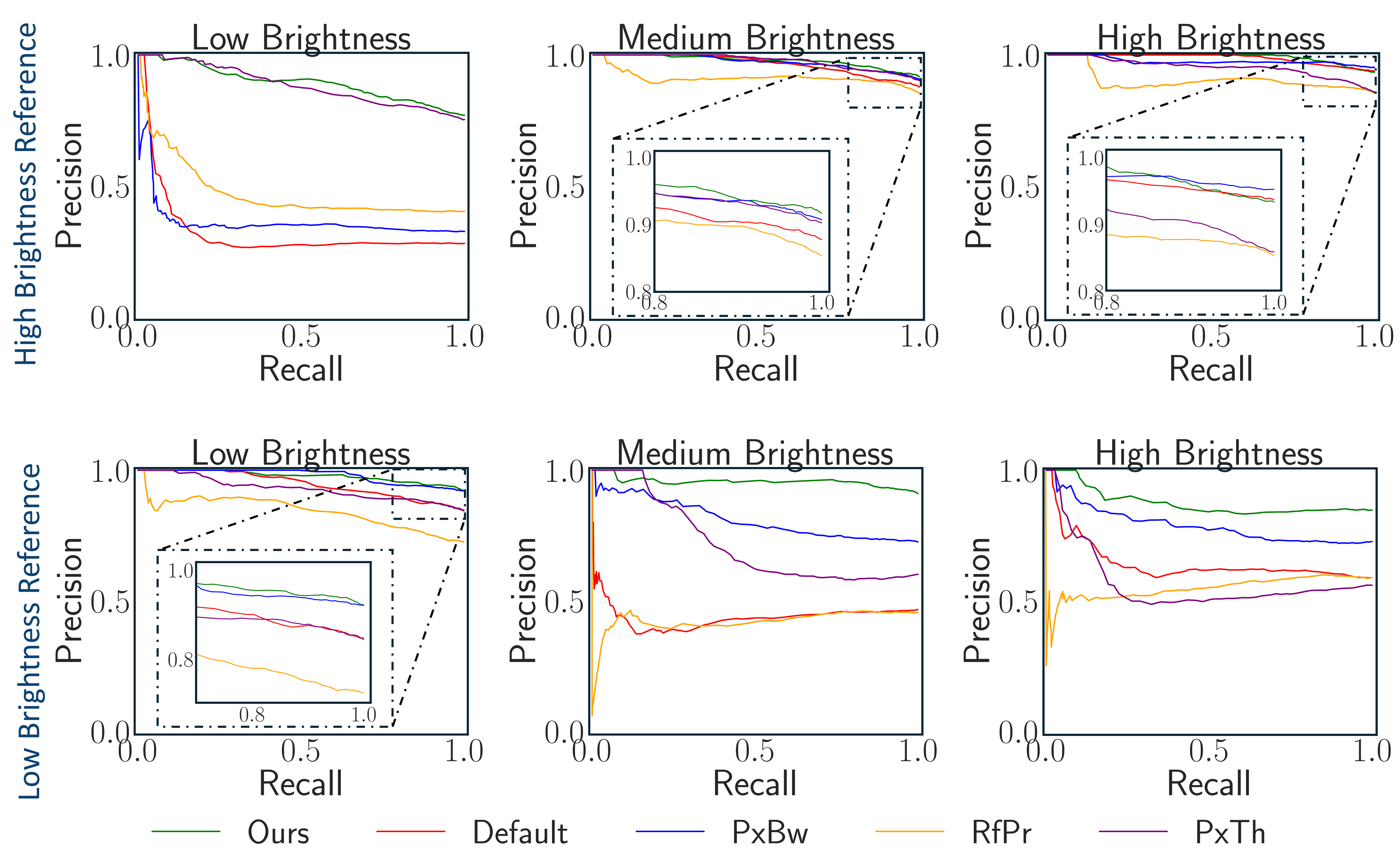
- **Default:** Naively use the biases on jAER when it is started [1]
- **PxBw:** Feedback control of pixel bandwidth to limit noise [2]
- **RfPr:** Feedback control of refractory period to limit event rate [2]
- **PxTh:** Feedback control of event threshold to bound noise [2]

Quantitative Comparisons (Metric: Recall@1)

Reference	Query	Default [1]	PxBw [2]	RfPr [2]	PxTh [2]	Ours
High Brightness	Low	0.43	0.5	0.48	0.83	**0.85**
	Medium	0.96	0.96	0.91	0.91	0.96
	High	0.96	0.96	0.87	0.92	0.96
Low Brightness	Low	0.90	0.96	0.81	0.91	0.96
	Medium	0.70	0.88	0.62	0.76	0.93
	High	0.67	0.87	0.67	0.75	**0.91**

- Superior performance in VPR using our approach
- Notable performance improvements in conditions of maximum difference between reference and query sets; i.e. reference set comes from the high brightness and query comes from low brightness sets (0.85 Recall@1) and vice versa (0.91 Recall@1).

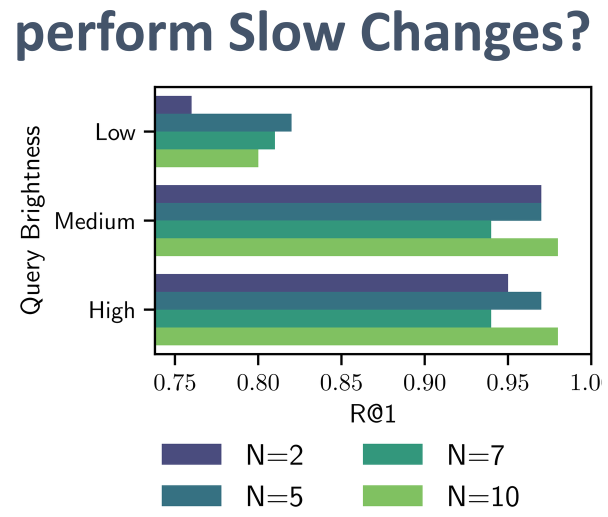
Precision-Recall Curves



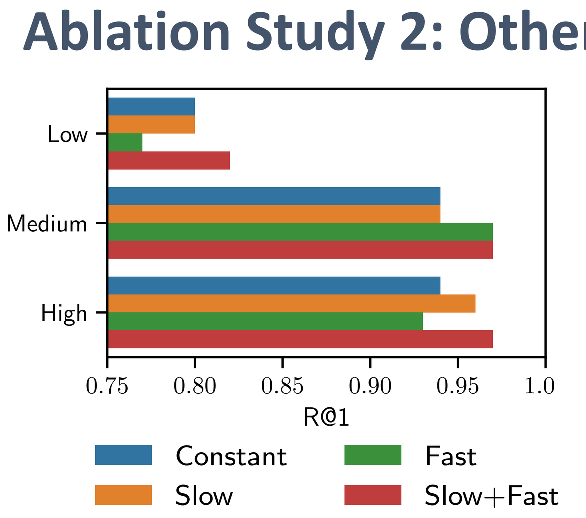
- The worst performing run from each method is chosen for plotting the PR curves.
- Our performance remains better or on-par with the baselines in high-brightness reference conditions (top).
- Our approach performs better than all baseline techniques in low-brightness reference conditions (bottom).

Ablation Study 1: How often do we perform Slow Changes?

- N is the number of fast changes during which the event rate consistently remains outside the desired bounds to trigger a slow change.
- N = 5 was chosen for the main experiments above.



Ablation Study 2: Other Internal Baselines?



The fast + slow controller performs much better when compared to the individual fast controller, slow controller, and a constant biased setting.

References

[1] T. Delbruck et al., "Frame-free dynamic digital vision," in International Symposium on Secure-Life Electronics, Advanced Electronics for Quality Life and Society, 2008, pp. 21–26.

[2] T. Delbruck, R. Graca, and M. Paluch, "Feedback control of event cameras," in IEEE/CVF Conference on Computer Vision and Pattern Recognition, 2021, pp. 1324–1332.