Millimeter-Scale Neuromorphic Vision System

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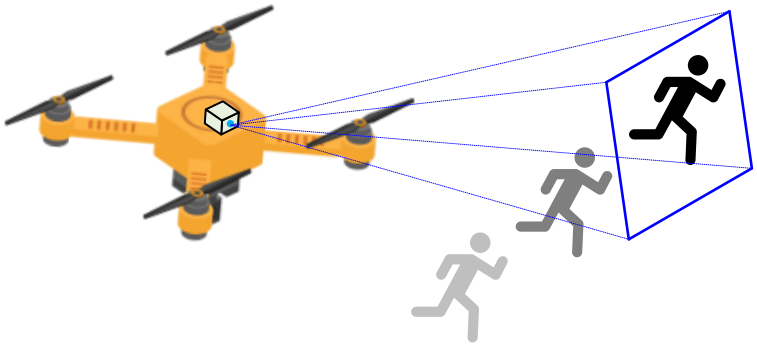
Motivation & Goal

Long-term Goal

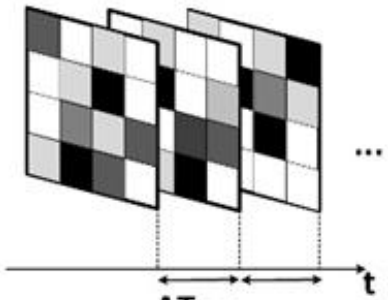
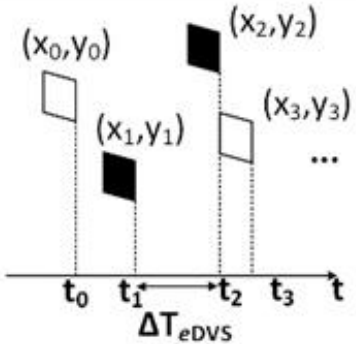
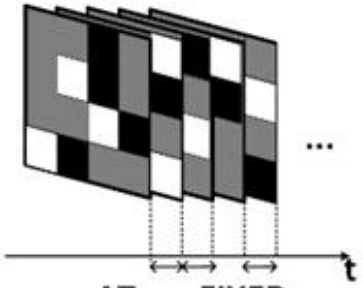
- Autonomous miniature drone (<10 cm or even < 2cm)



On-going Research

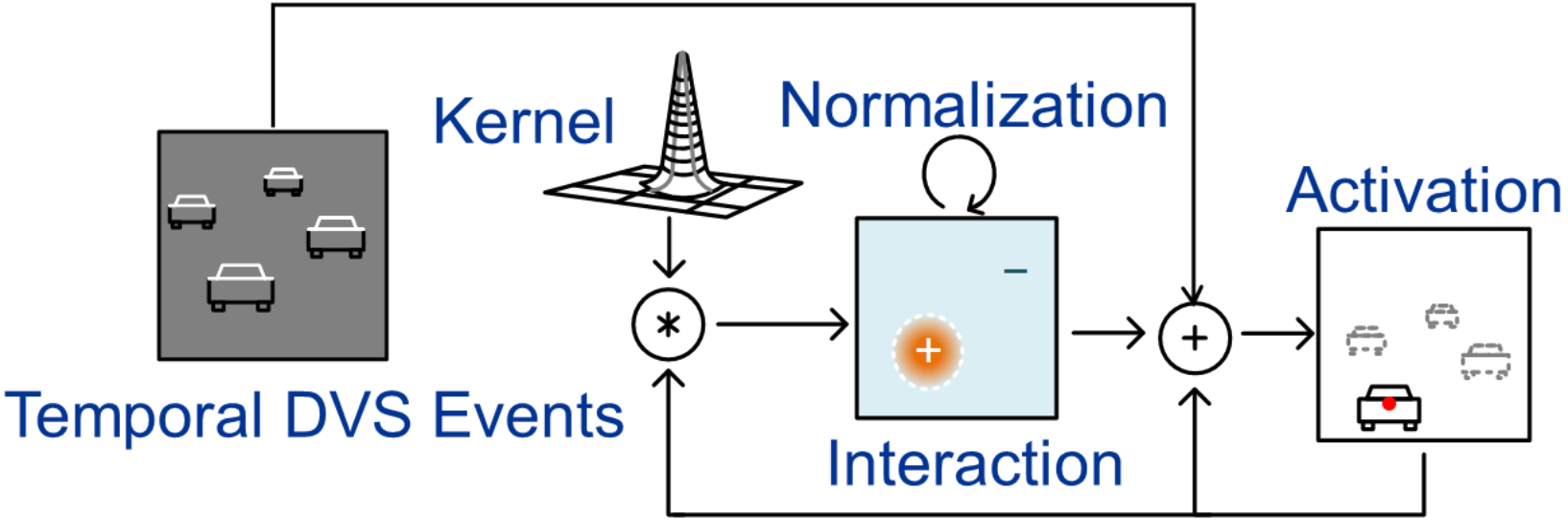
- Energy-efficient query driven dynamic vision sensor (qDVS)
- <1cm^3 by millimeter-scale sensing system platform
- Neuromorphic motion tracking
- No noticeable loading on drone (size, weight, and energy)

Dynamic Vision Sensor (DVS)

ACTIVE PIXEL SENSOR (APS)	EVENT DRIVEN DYNAMIC VISION SENSOR (*e*DVS)	QUERY DRIVEN DYNAMIC VISION SENSOR (*q*DVS)
		

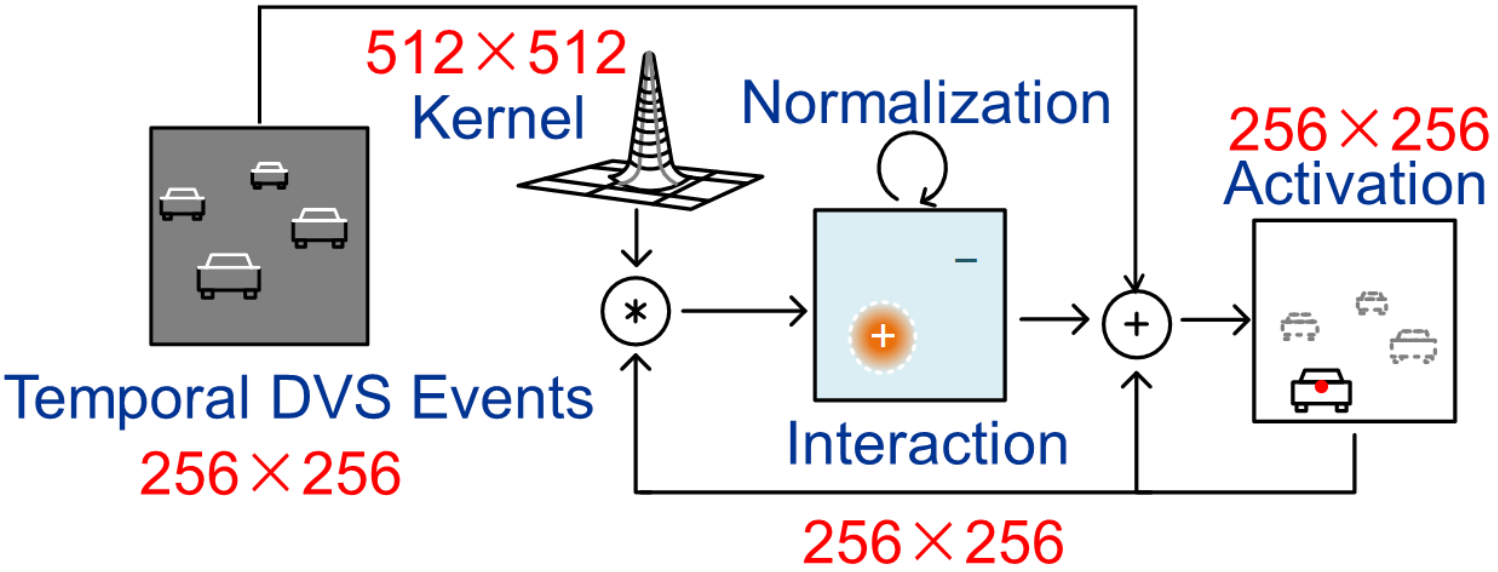
[Kubendran, CICC, 2021]

Dynamic Neural Fields (DNF)



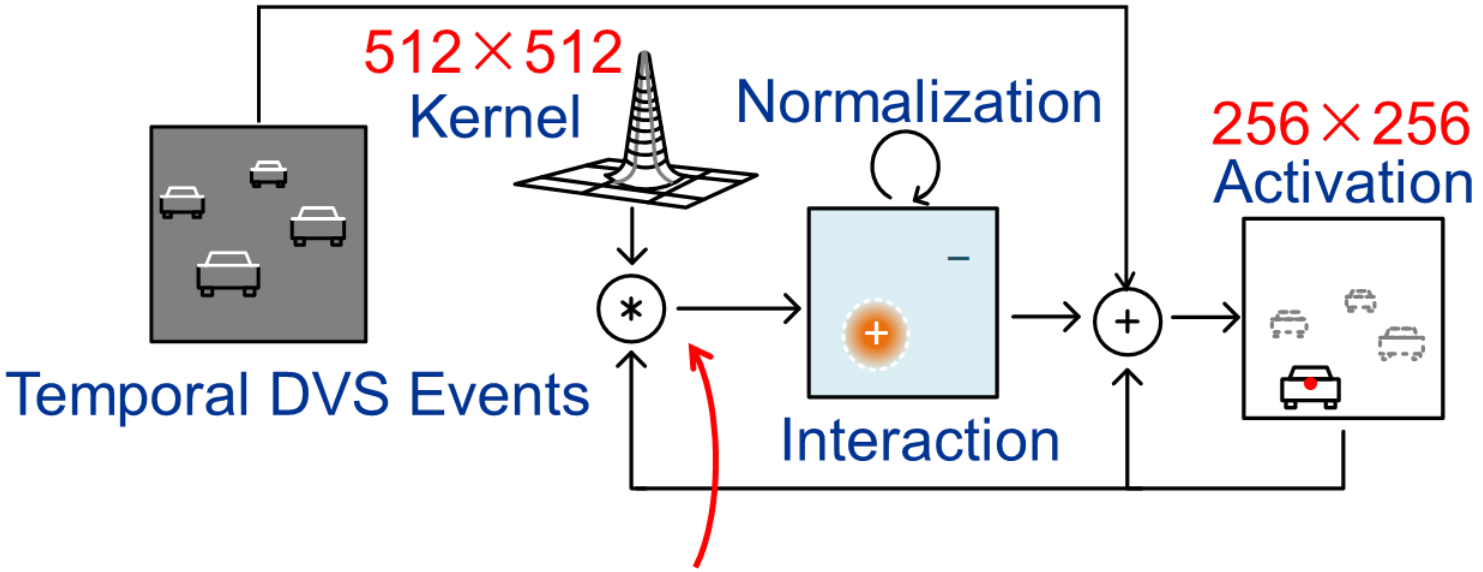
[Li, TVLSI, 2024]

Challenges (1/3)

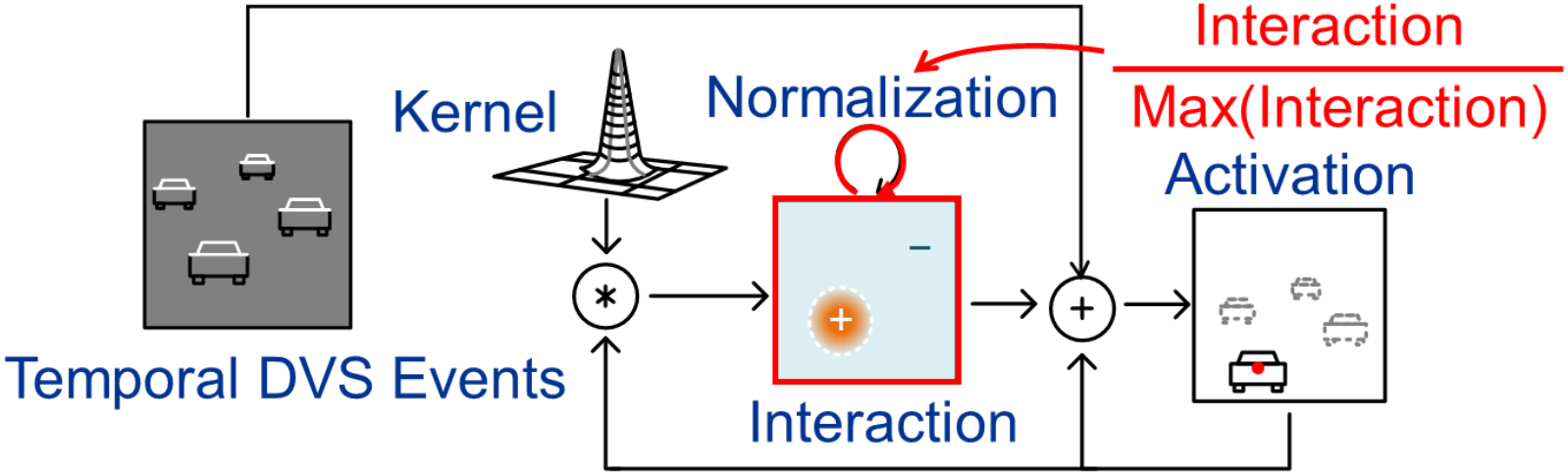


- Total data size: 349 kB
- Memory block area: 0.55mm^2 (28nm)

Challenges (2/3)

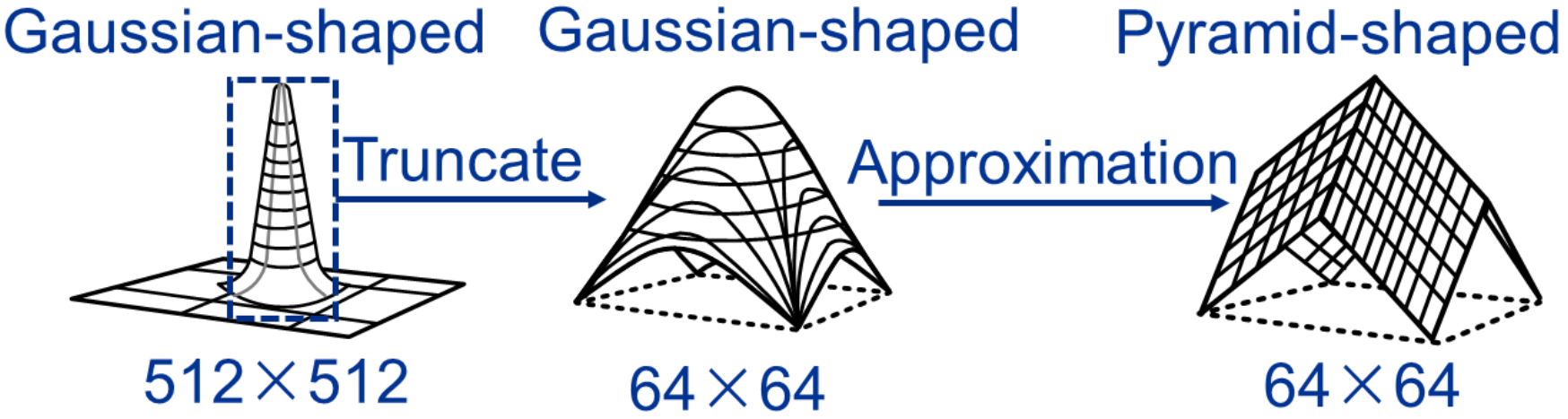


Challenges (3/3)

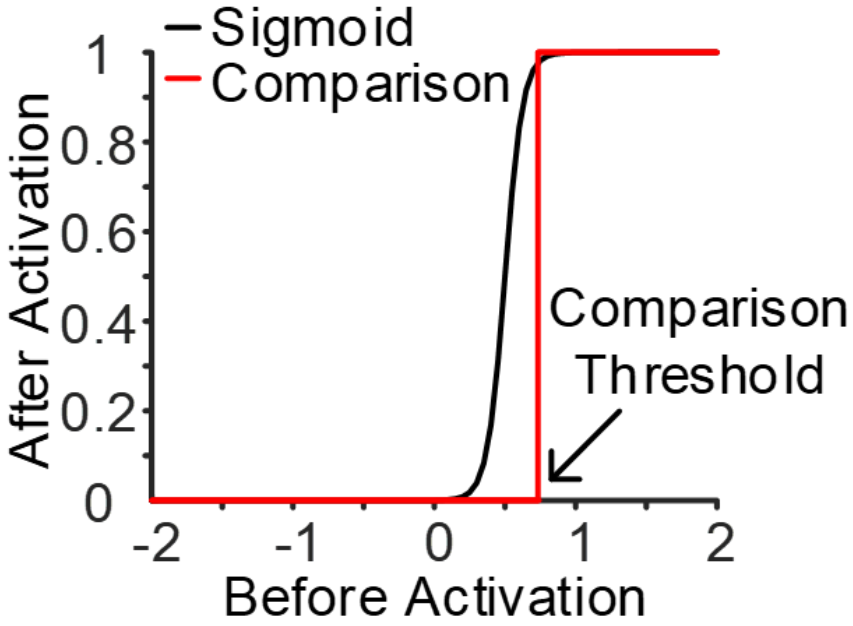


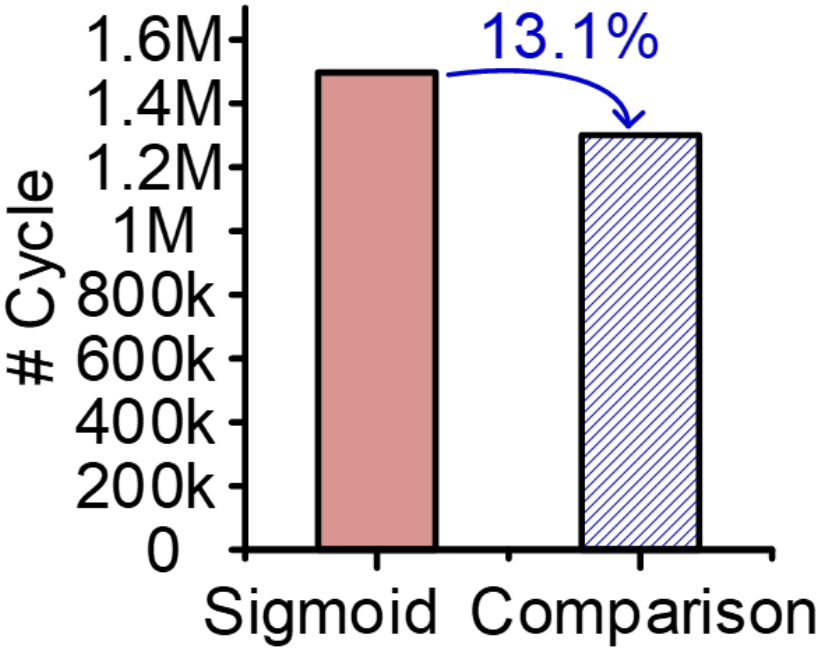
- Interaction: convolution result normalized to [-1, 1]
- Find maximum of the convolution result as divisor
- Wait until convolution completes

Proposed Techniques (1/3)

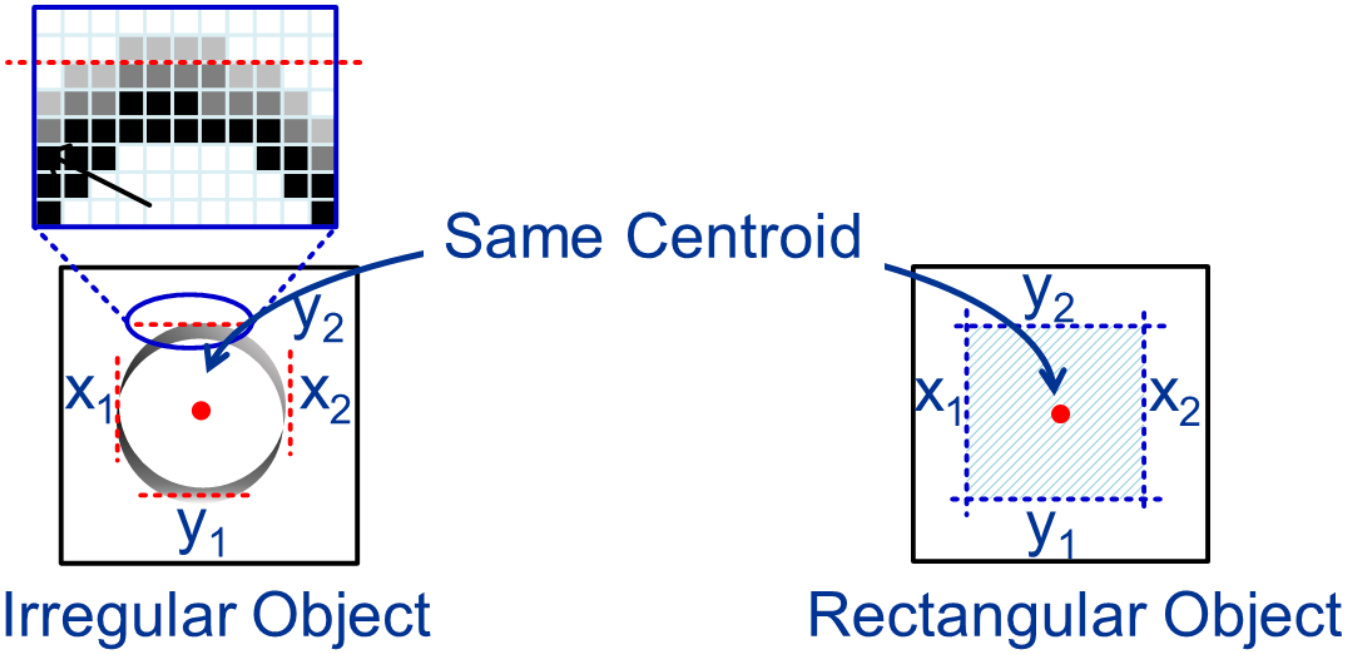


Proposed Techniques (2/3)

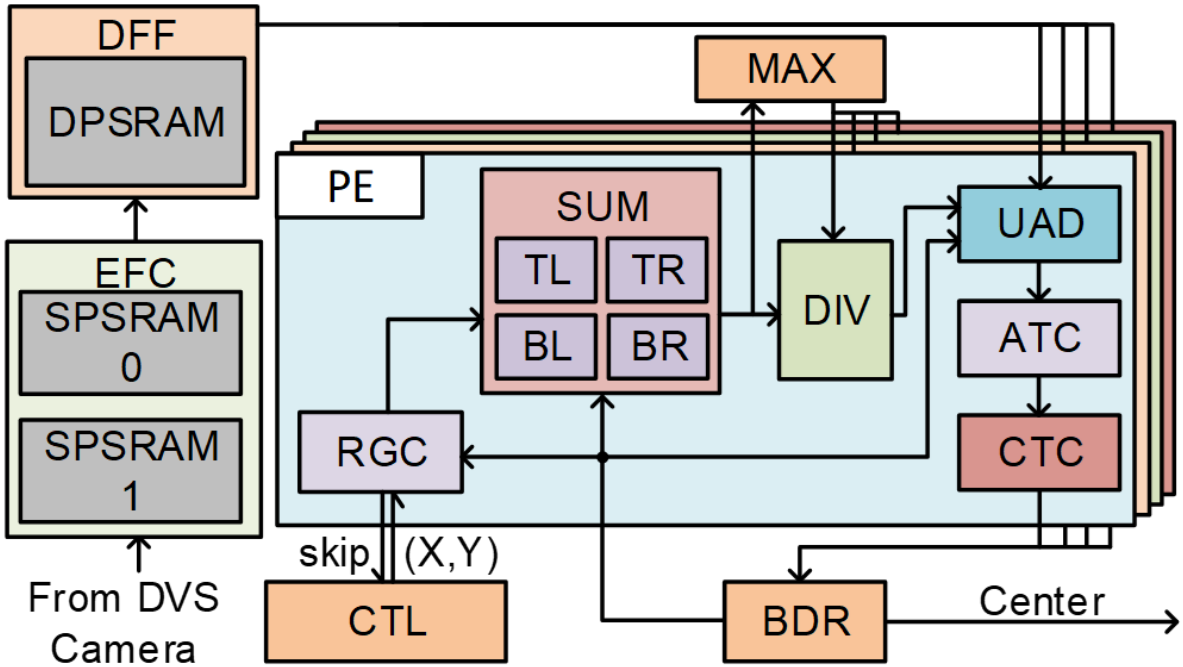




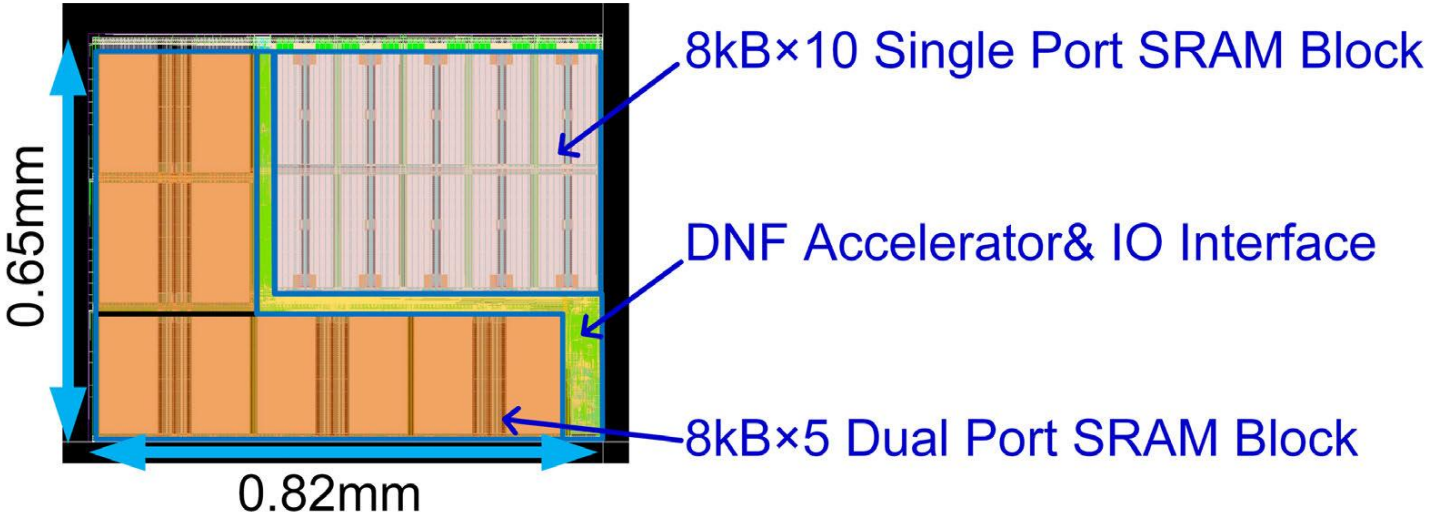
Proposed Techniques (3/3)



Implementation (1/3)



Implementation (2/3)

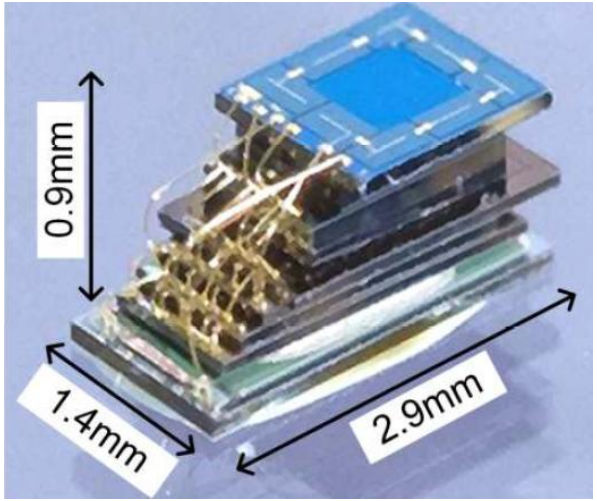


Implementation (3/3)

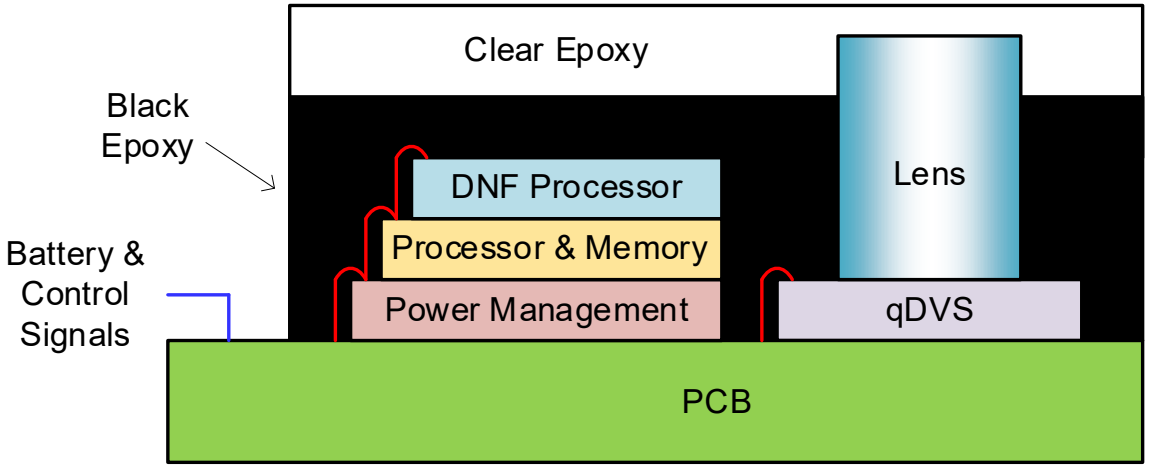
[Li, TVLSI, 2024]

	TCAS-II 2023 [18]	TCAS-II 2023 [19]	AICAS 2020 [11]	This Work
Supply Voltage (V)	1.1	0.89 - 1.2	0.5 - 1.25	1
Approach	DNN	DVS+SNN	DVS+DNF	DVS+DNF
Area (mm^2)	23	107.2	60	0.53
Throughput (fps)	69.8	100	2000	211.1
Power (mW)	71.2	208.1	N/A	1.68

Future Works



[Li, ESSCIRC ’21]



References

1. R. Kubendran, A. Paul, and G. Cauwenberghs, “A 256×256 6.3pJ/pixel-event Query-Driven DVS with Energy-Conserving Row-Parallel Scanning,” IEEE CICC, Austin, TX, 2021, pp. 1–2. doi: 10.1109/CICC51472.2021.9431446.
2. Y. Li, V. S. Vivekanand, R. Kubendran, and I. Lee, “Dynamic Neural Fields Accelerator for a Millimeter-Scale Tracking System,” IEEE Trans. VLSI Syst., vol. 32, no. 10, pp. 1940–1944, Oct. 2024. doi: 10.1109/TVLSI.2024.3416725.
3. I. Lee*, R. Hsiao*, G. Carichner, C.-W. Hsu, et al., “mSAIL: Milligram-Scale Multi-Modal Sensor Platform for Monarch Butterfly Migration Tracking,” ACM MobiCom, Oct. 2021. (*equal contribution). Best Paper Award