E-Mamba: Using state-space-models for direct event processing in space situational awareness

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Idea

How can we grant **satellites** the ability **to see locally**?

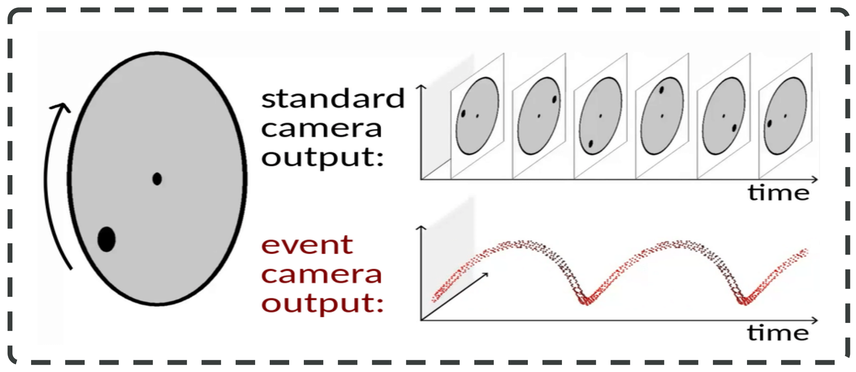
✖ Conventional **optical sensors** are **ill-suited** for the **space** environment.

- **High power** consumption and **data storage** usage

+ **slow** capture **rates**

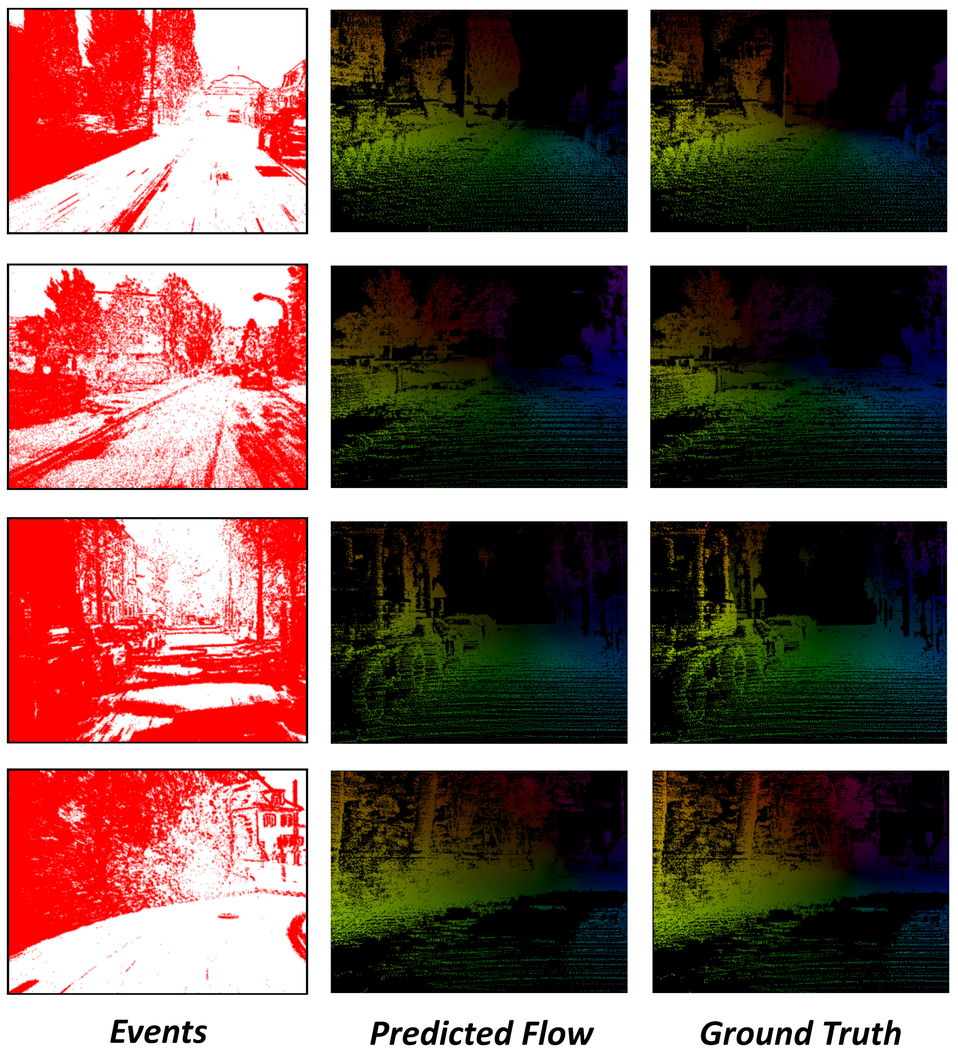
✔ **Event cameras overcome these limitations** with a **human vision-inspired** design.

- **Asynchronous, µs** temporal **resolution** + minimal **power** and **storage** requirements

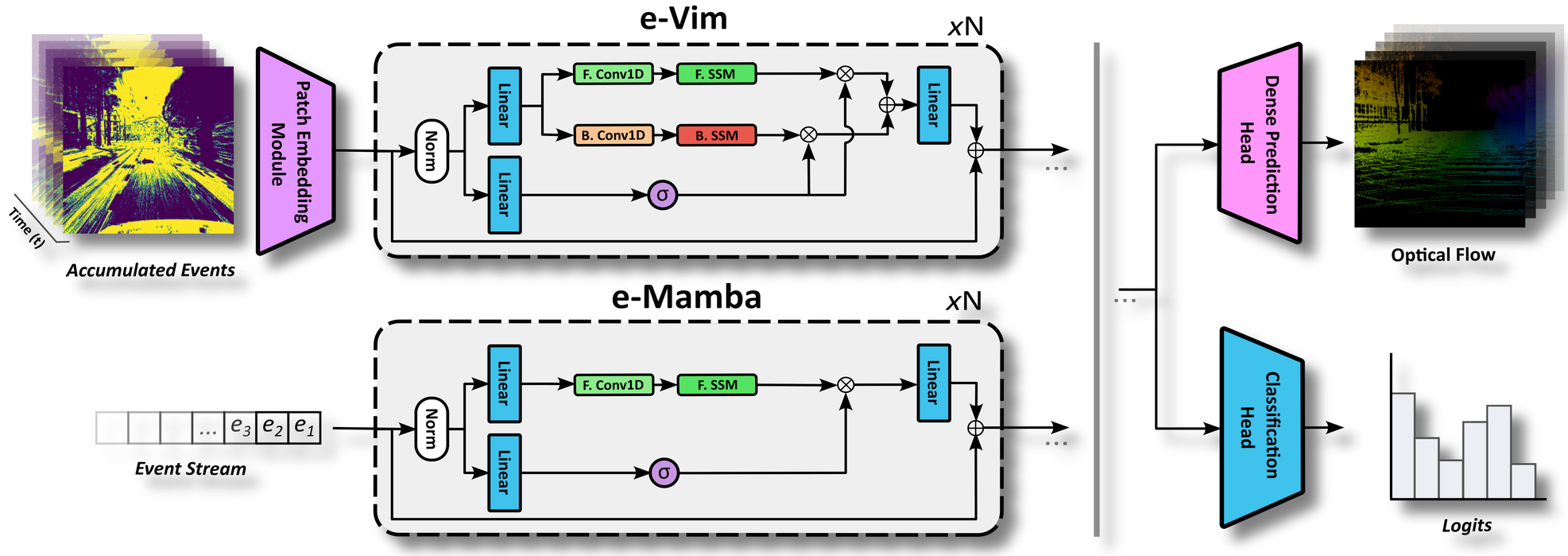


⭐ We propose a novel **event-processing approach** based on **State-Space Models**, capable of processing event-data **in real-time** during **in-orbit operations.** Our technique can exhibit **competitive performance** with **< 76K parameters.**

Qualitative Results



Methodology



Quantitative Results

Dataset	Model	Base	N_{bins}		lr		Repre.		Aug.		# params	Time*
			15	2	$1e^{-3}$	$3e^{-4}$	Voxel	Hist.	NDA	Rand.		
DVS128	EvT+	97.57	-	-	-	-	-	-	-	-	$0.66M$	-
	TORE	96.2	-	-	-	-	-	-	-	-	$5.94M$	-
	S-former	98.96	-	-	-	-	-	-	-	-	$9.28M$	-
	E-Mamba	60.02	-	-	-	-	-	-	90.97	-	$75.5K$	$1.45ms$
	$E\text{-}Vim_S$	84.03	84.03	79.51	84.03	80.9	84.03	91.01	86.46	83.4	$383K$	$1.66ms$
CIFAR10-DVS	EvS	68.0	-	-	-	-	-	-	-	-	N/A	-
	NDA	81.7	-	-	-	-	-	-	-	-	$132.8M$	-
	S-former	81.4	-	-	-	-	-	-	-	-	$9.28M$	-
	E-Mamba	32.4	-	-	-	-	-	-	35.97	-	$75.5K$	$1.45ms$
	$E\text{-}Vim_S$	59.7	59.7	53.8	59.1	58.9	59.7	60.01	62.5	54.3	$1.2M$	$4.01ms$

* Avg. inference time over 1000 runs.

Dataset	Model	N_{bins}		lr		Repre.		# params
		30	40	$1e^{-3}$	$5e^{-5}$	Hist.	Voxel	
DSEC-flow	$E\text{-}Vim_S$	0.5636	0.572	0.5384	0.59	0.502	0.523	$1.2M$

Highlights!

⭐ **Competitive** task performance.

⭐ **>99% reduction** in model size w.r.t. state of the art.

⭐ Event-by-event **streaming inference.**

⭐ **<1.5ms** prediction-rate on desktop **CPUs**.

Conclusion

We introduced an efficient **perception framework** based on **event cameras** and **State-Space Models** to enhance the **high-speed collision avoidance** and **situational awareness** capabilities of **satellites** in **space.**