FA-Harris:
A Fast and Asynchronous Corner Detector for Event Cameras

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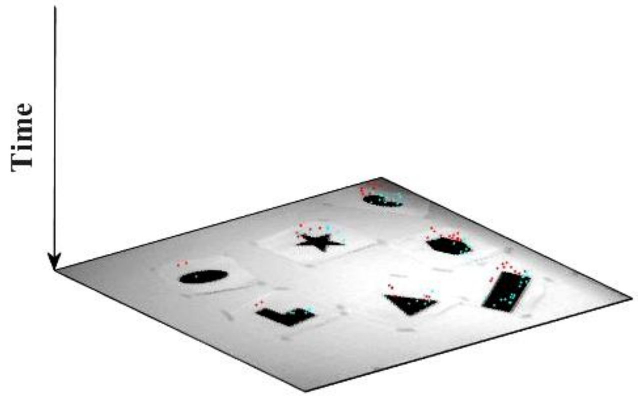
Research Motivation

- The existing visual SLAM systems suffer from several challenges, like high speed motion, high dynamic range, etc.
- The **event camera**, with the advantages of **low latency**, **low energy consumption**, **high temporal resolution** and **high dynamic range**, responds to local, pixel-level brightness changes instead of standard frames.



DAVIS 240C Dataset[1]

[1] Mueggler et al., The Event-Camera Dataset and Simulator: Event-based Data for Pose Estimation, Visual Odometry, and SLAM, IJRR 2017.

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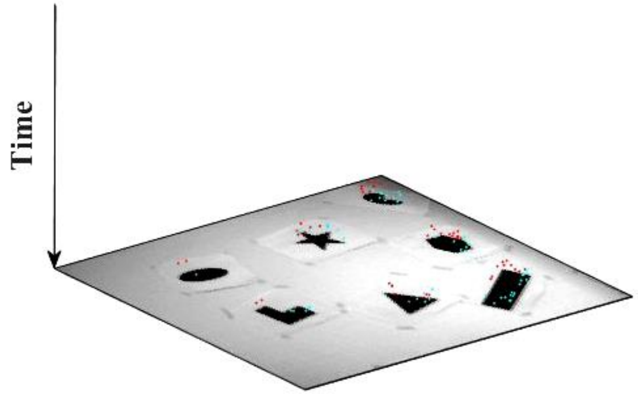
But standard vision algorithms can’t be applied directly.



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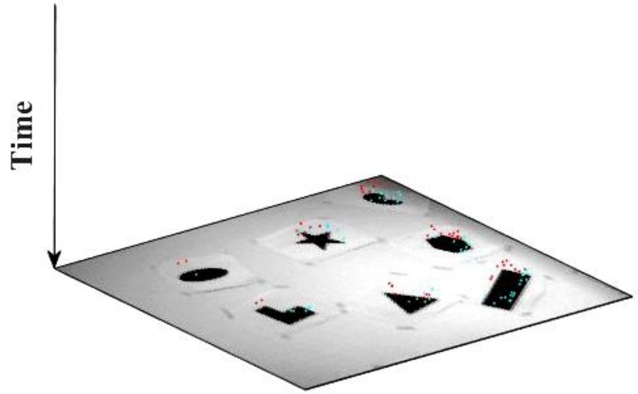

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Feature Detection

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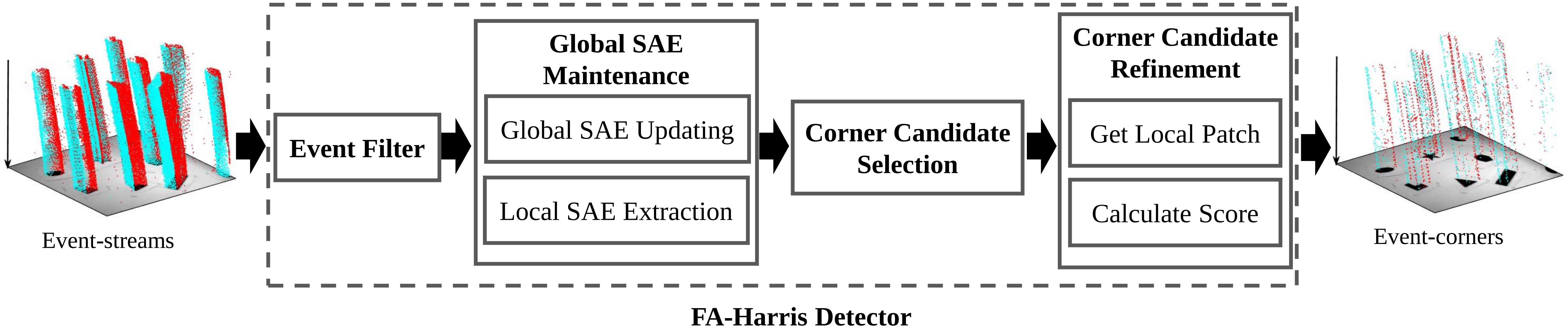
FA-Harris - Proposed Pipeline



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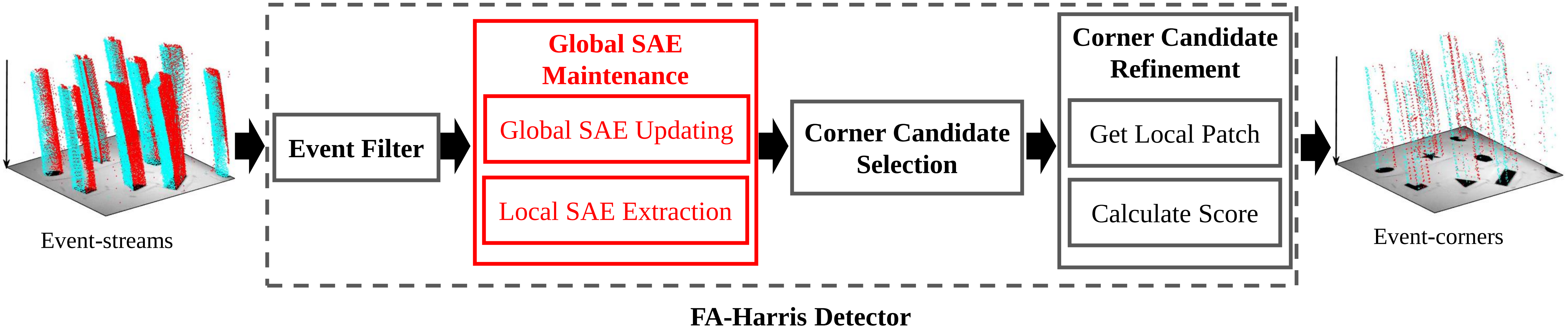

- Surface of Active Events (SAE)

$$SAE : (x, y)_e \in \mathbb{R}^2 \mapsto t_e \in \mathbb{R}$$

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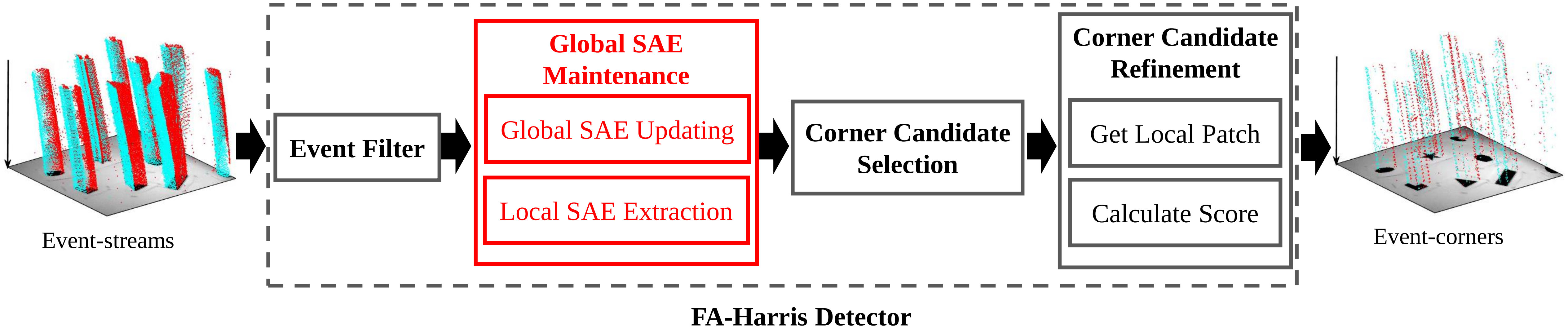

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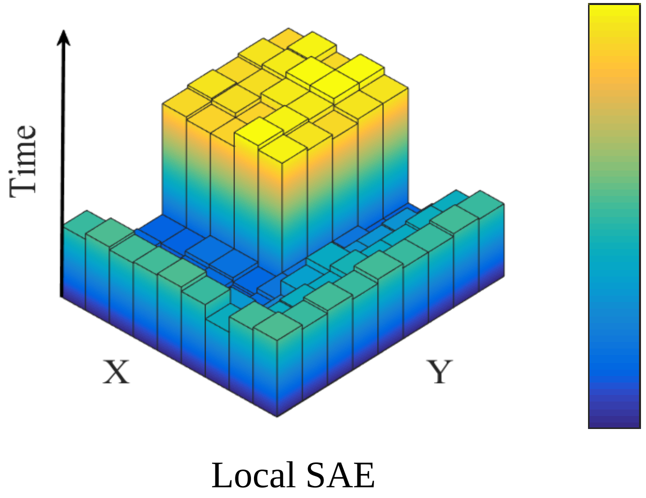

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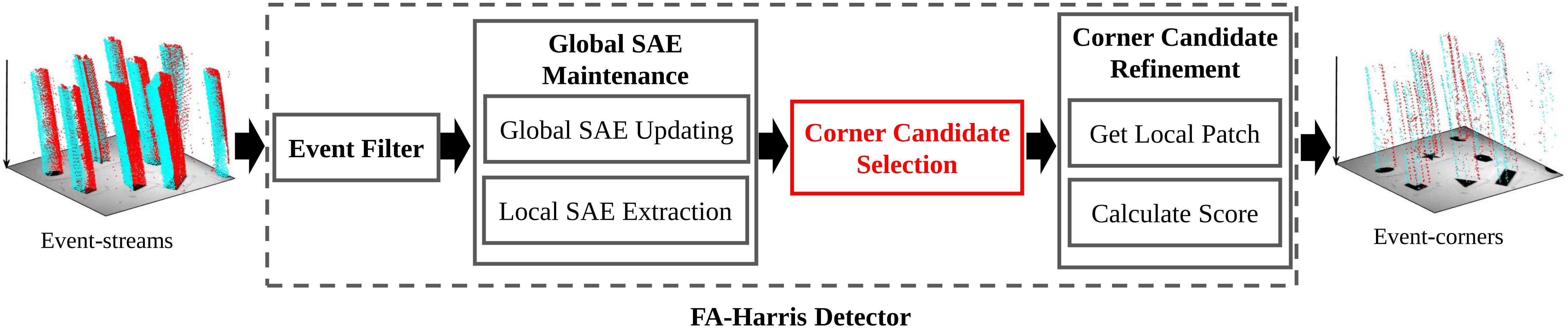
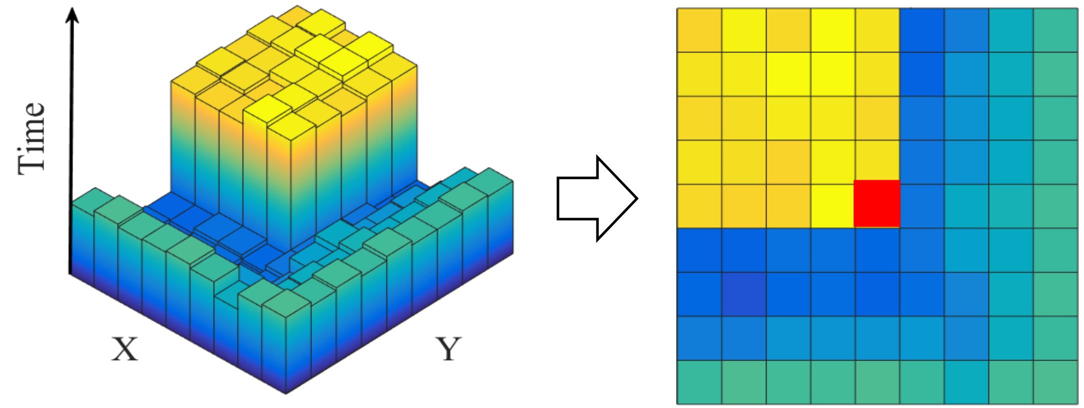
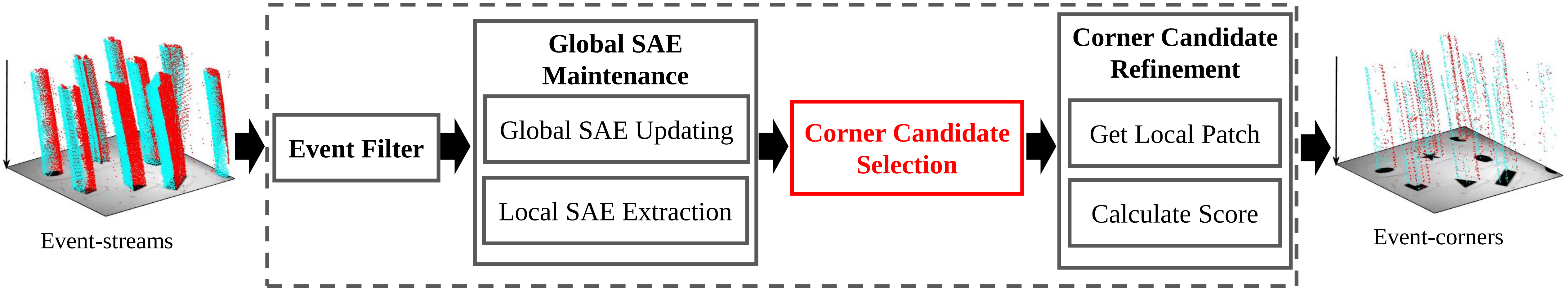




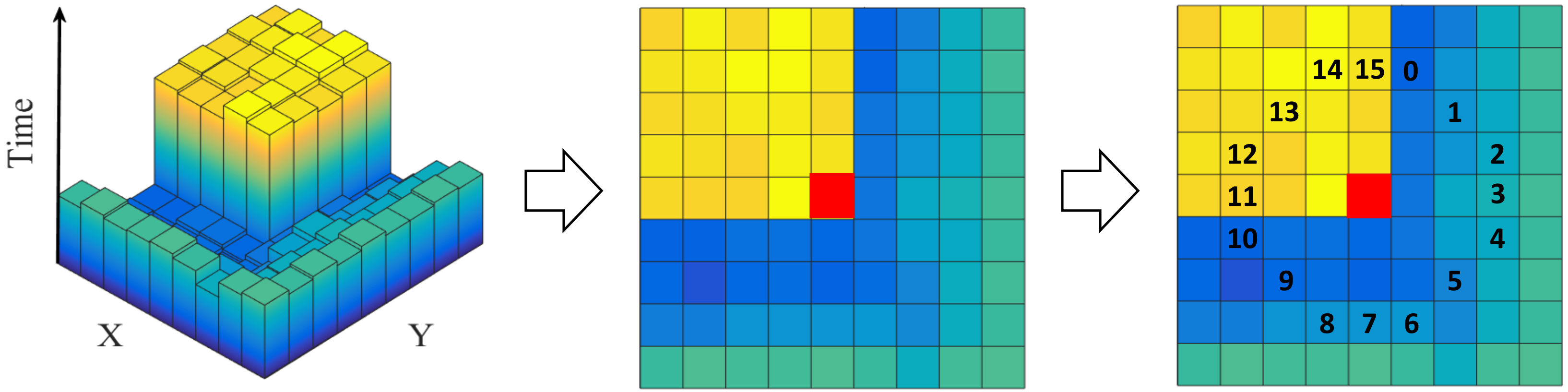
(a) Local SAE

(b) Top view

FA-Harris - Proposed Pipeline

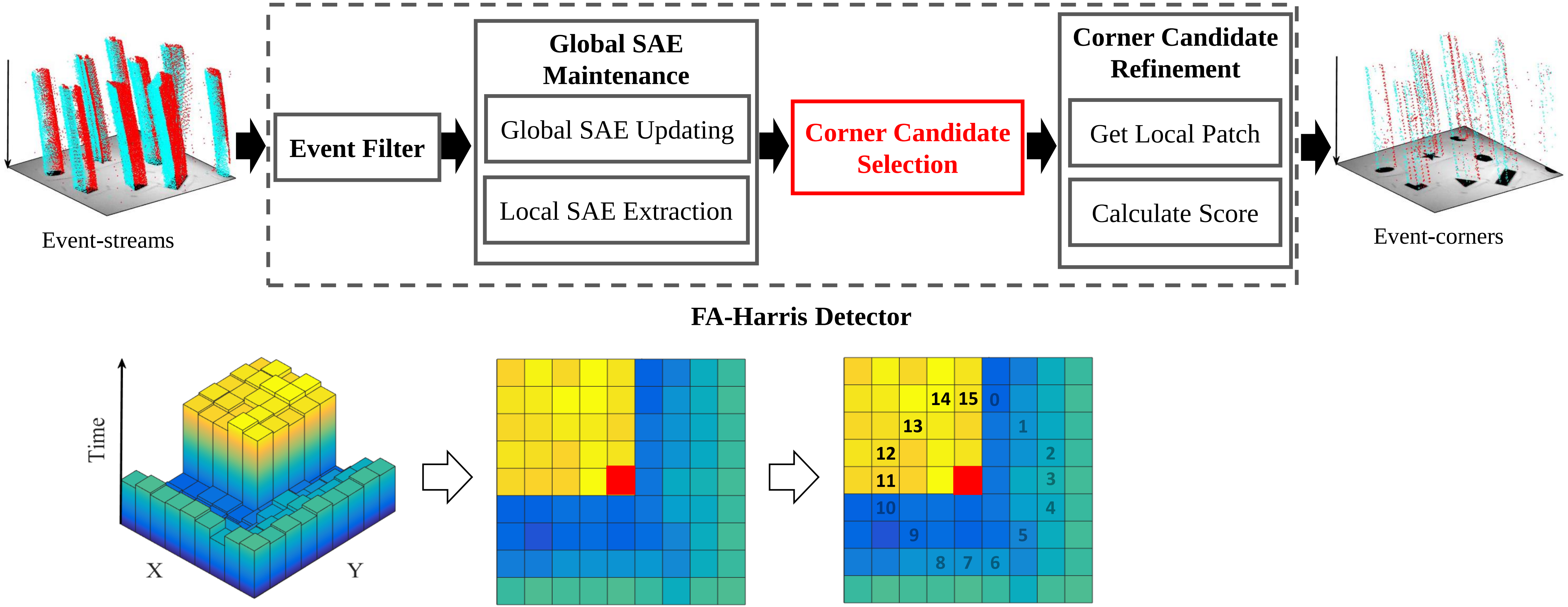


FA-Harris Detector



(a) Local SAE (b) Top view (c) Inner Circle

FA-Harris - Proposed Pipeline



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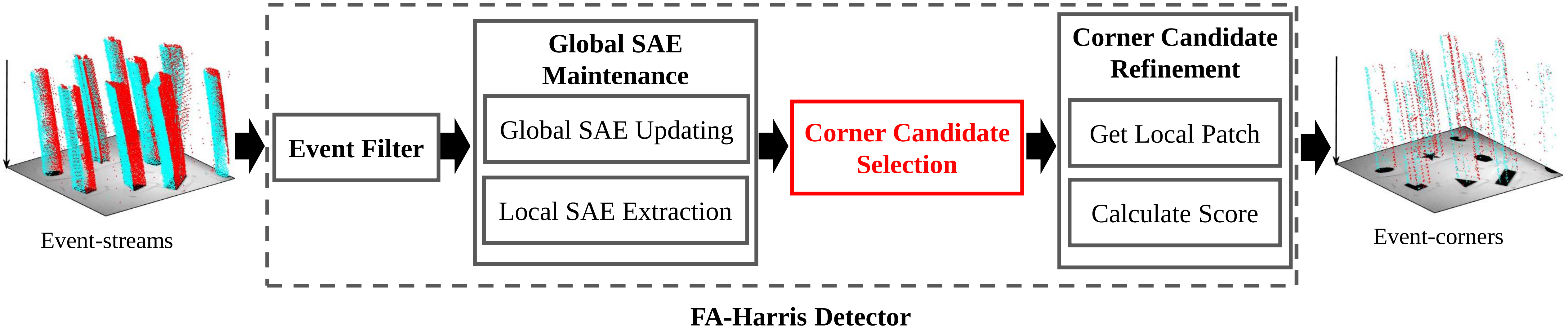

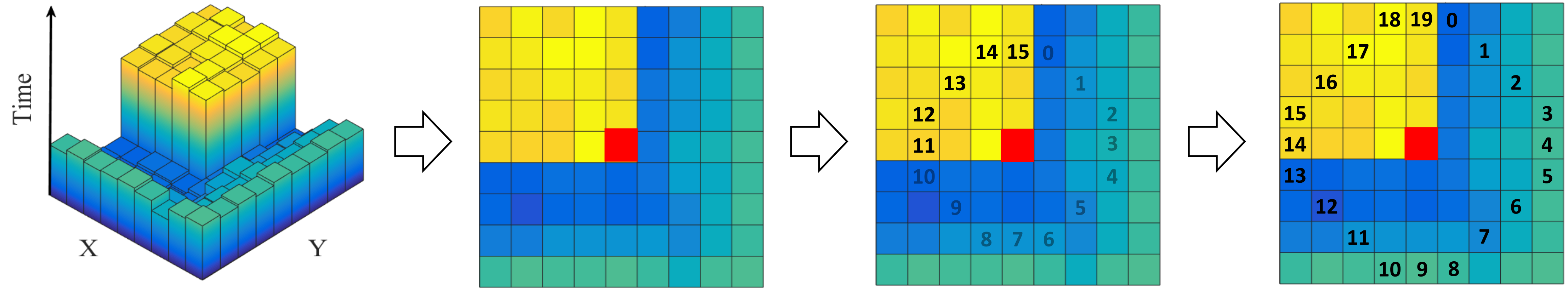

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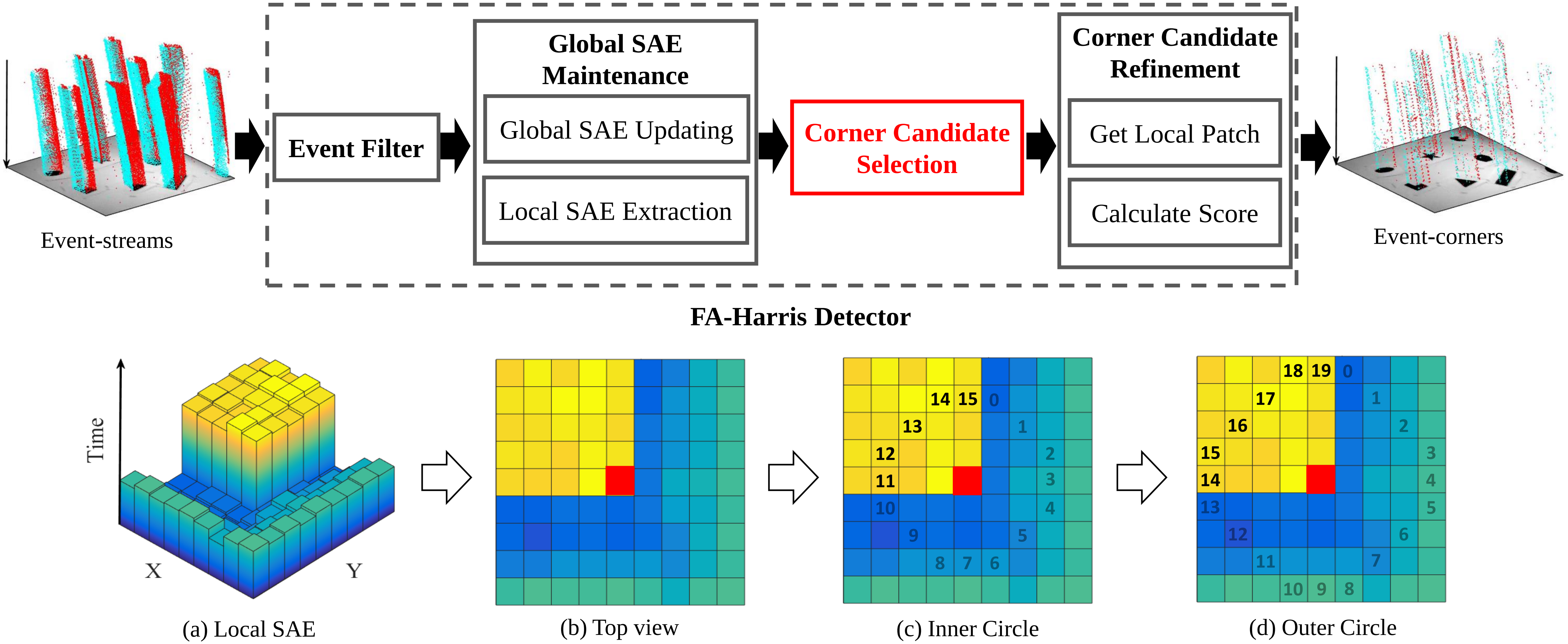

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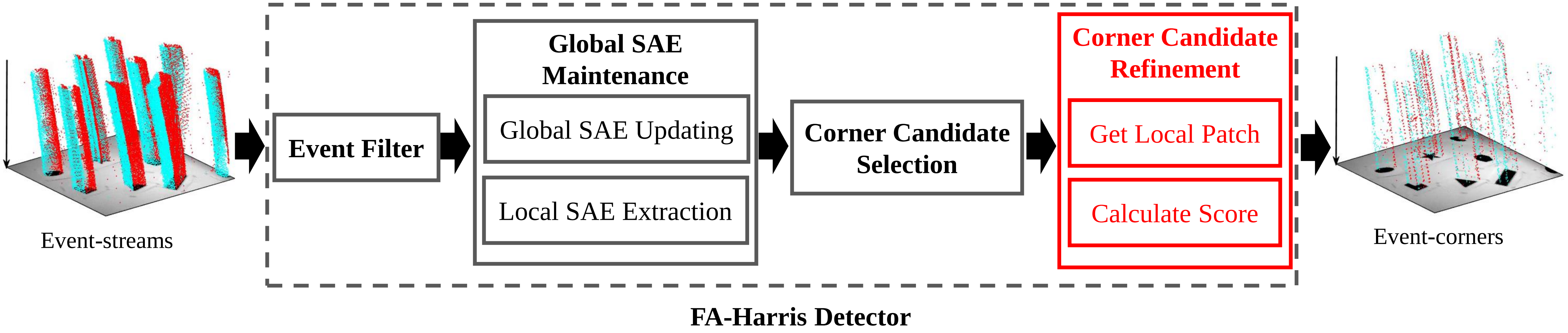

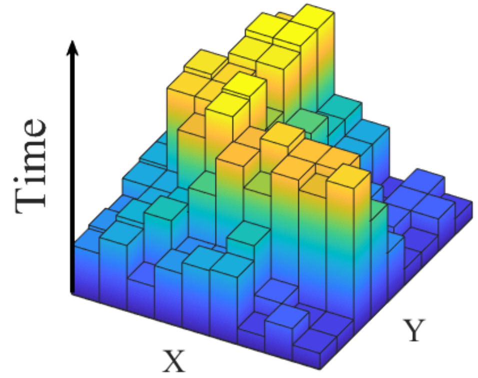

Local SAE

0	1	1	1	0	0	0	0	0
0	0	1	1	0	0	0	0	0
0	1	1	1	0	0	0	0	0
0	0	1	1	0	0	0	0	0
0	1	1	1	0	0	0	0	0
0	1	1	1	1	1	1	1	0
0	0	1	1	0	1	1	0	1
0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0

Local Patch

Global SAE Construction and Updating

- Our method maintains a global SAE with the size width×height instead of maintaining a local SAE for each pixel in the imaging plane[2].
- It greatly contributes to the speed-up of our algorithm.

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  - Real-time performance of the methods with our proposed strategy or not.

Scenes	Algorithm	Updating time [s]	Total time [s]
shapes	eHarris*[2]	50.64	71.85
	G-eHarris*	**0.26**	**47.27**
dynamic	eHarris*[2]	219.63	288.15
	G-eHarris*	**0.79**	**147.89**
poster	eHarris*[2]	556.39	746.73
	G-eHarris*	**1.94**	**375.02**
boxes	eHarris*[2]	640.33	812.13
	G-eHarris*	**2.23**	**418.82**

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2× faster

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Corner Candidate Selection and Refinement

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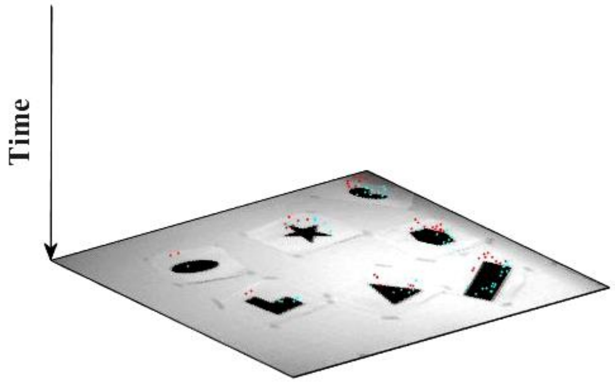
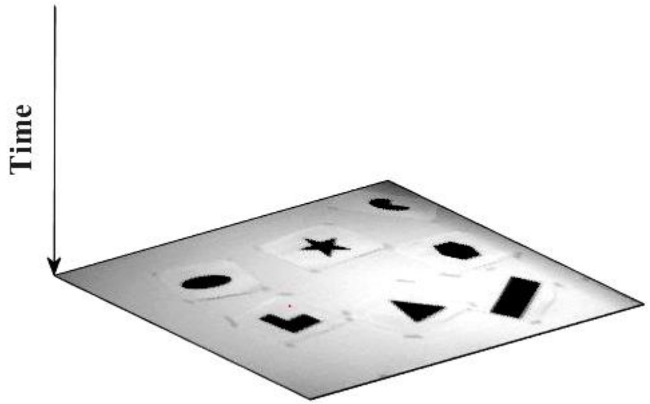
- **Corner candidate selection method** subsamples the original event-streams to enhance the real-time performance of our algorithm.



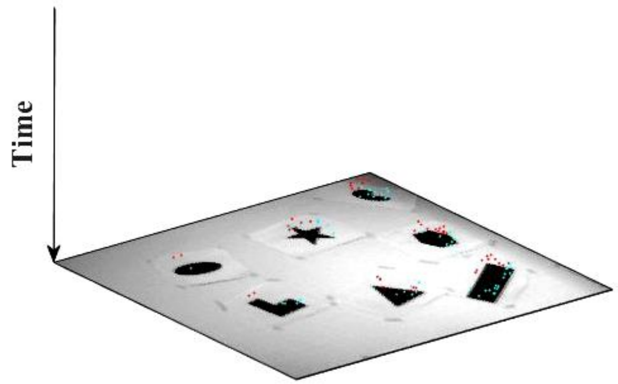
Events



Corner Candidates

Corner Candidate Selection and Refinement

- Our method employs a corner candidate selection and refinement strategy.
- **Corner candidate selection method** subsamples the original event-streams to enhance the real-time performance of our algorithm.
- **Corner candidate refinement method** helps to achieve better accuracy performance.



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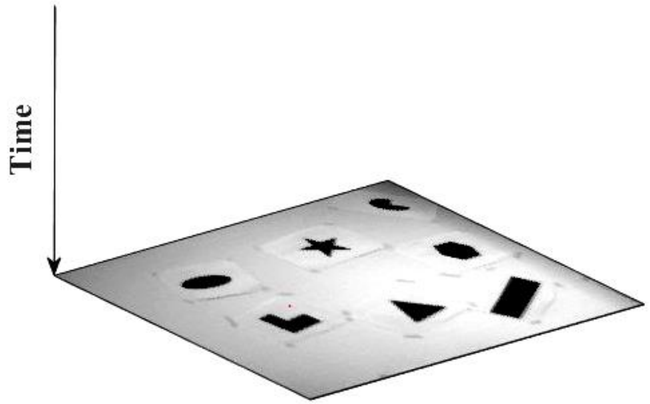
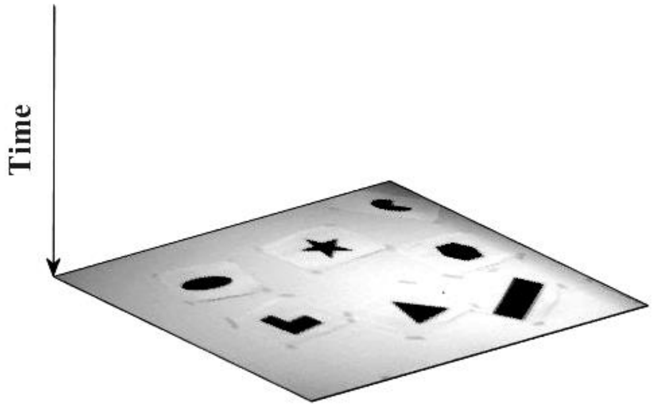
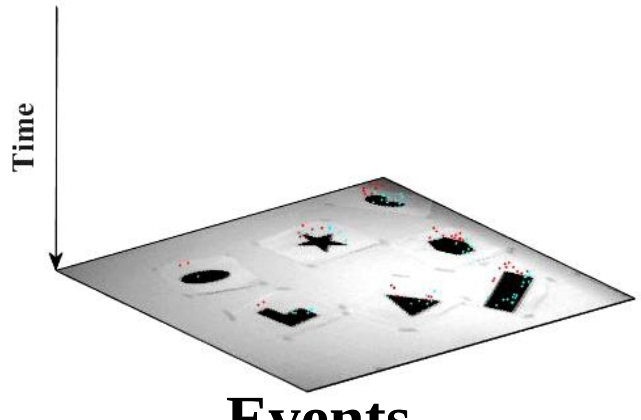


Corner Candidates

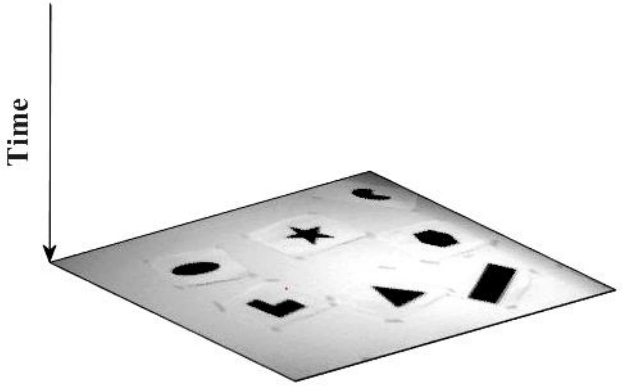


Event-corners

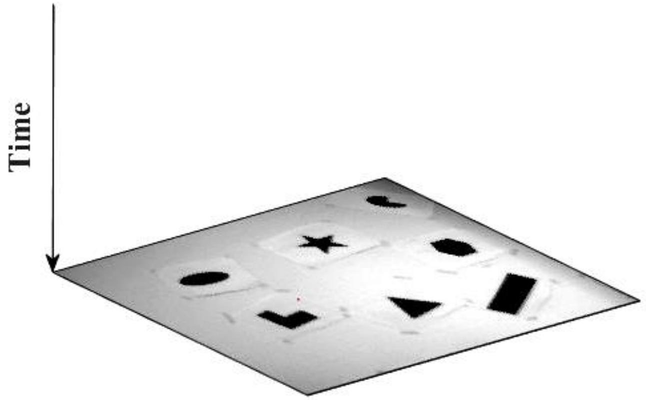
Event-corners in Spatio-temporal System



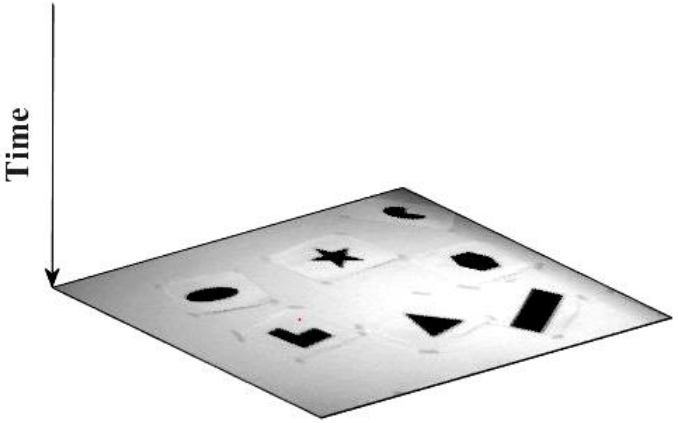
Events



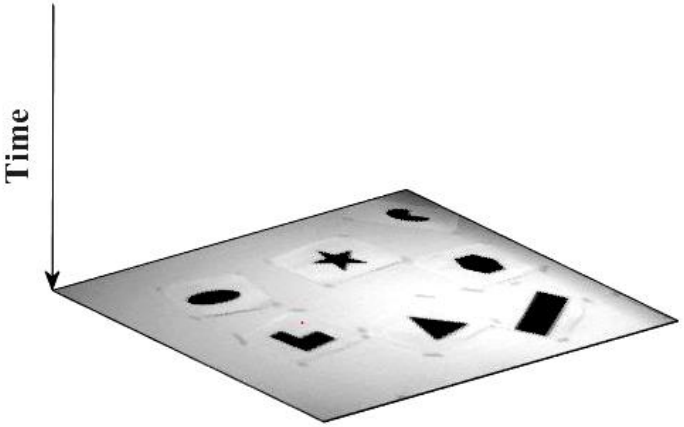
eHarris*



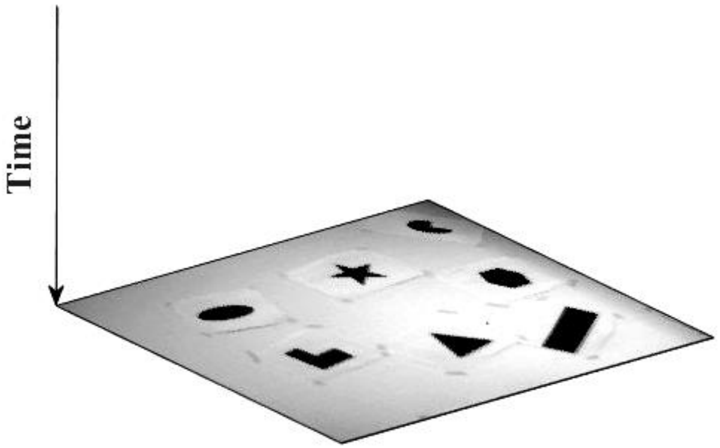
G-eHarris*



eFAST*[3]



Arc*[4]



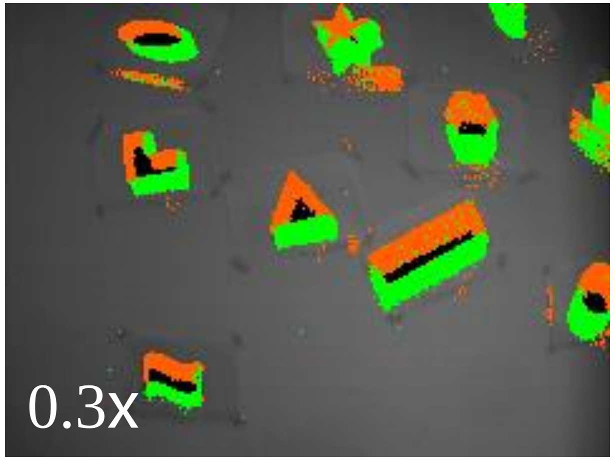
Ours

[3] Mueggler et al., Fast Event-based Corner Detection, BMVC 2017.
[4] Alzugaray et al., Asynchronous Corner Detection and Tracking for Event Cameras in Real Time, RAL 2018.

Comparison

Our proposed method:

- can detect the corners with large angles



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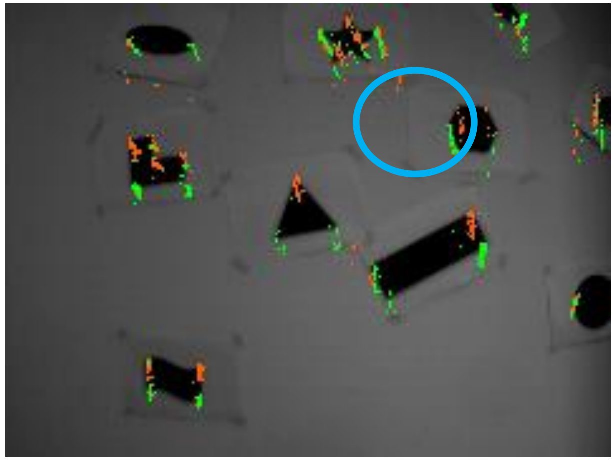
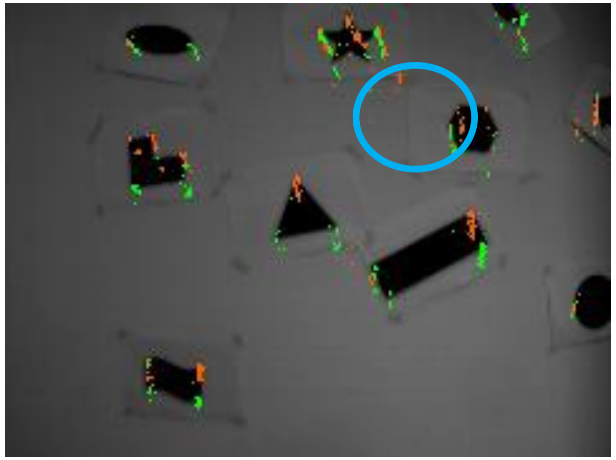


eHarris*

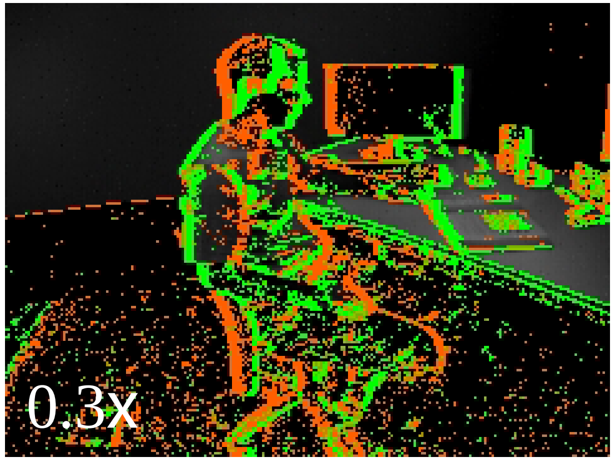


Ours

Comparison

Our proposed method:

- can detect the corners with large angles
- can reduce noise and wrong detections



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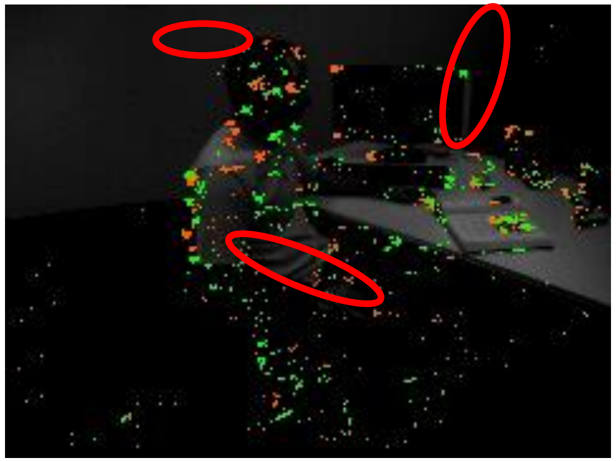
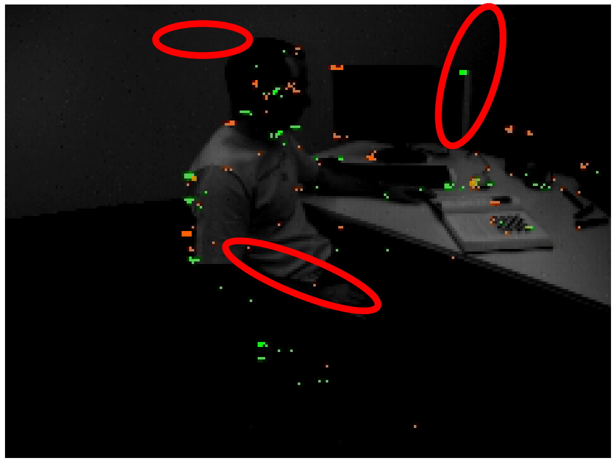


Arc*

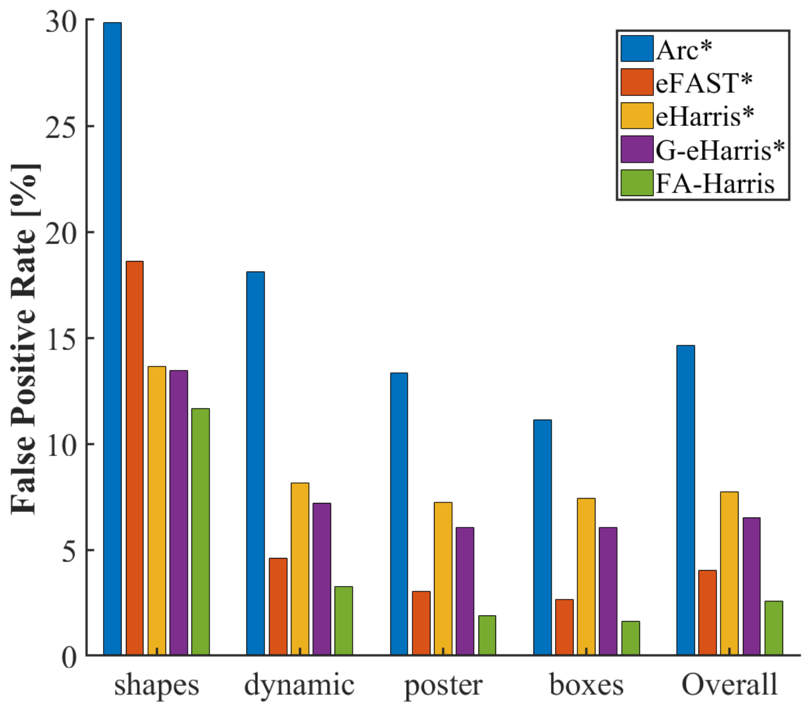


Ours

Evaluation

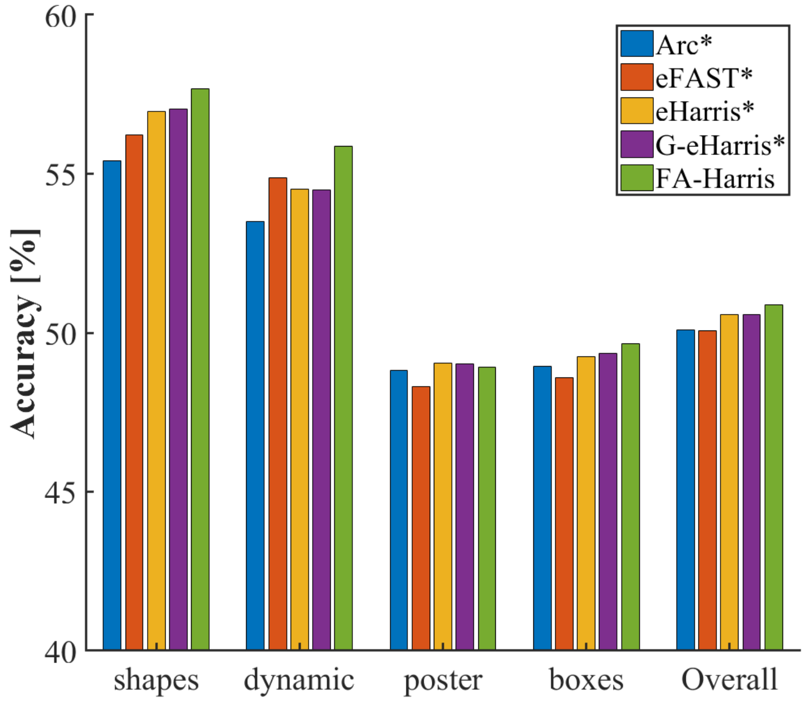
- The **False Positive Rate (%)** of different event-based corner detectors on different scenes.

Alg. \ Scene	shapes	dynamic	poster	boxes	Overall
Arc*	29.88	18.10	13.34	11.13	14.64
eFAST*	18.62	4.59	3.04	2.67	4.01
eHarris*	13.63	8.15	7.22	7.42	7.75
G-eHarris*	13.46	7.21	6.04	6.04	6.52
Ours	**11.68**	**3.28**	**1.90**	**1.61**	**2.58**



FPR

Evaluation



Accuracy

- The **accuracy (%)** of different event-based corner detectors on different scenes.

Alg. \ Scene	shapes	dynamic	poster	boxes	Overall
Arc*	55.42	53.50	48.81	48.94	50.10
eFAST*	56.22	54.86	48.30	48.60	50.06
eHarris*	56.97	54.50	**49.04**	49.26	50.56
G-eHarris*	57.04	54.50	49.02	49.35	50.57
Ours	**57.66**	**55.86**	48.91	**49.66**	**50.88**

Evaluation

- **Computational performance** of different event-based corner detectors.

Algorithm	**Time per event [μs/event]**	**Max.event rate [Meps]**
Arc*	0.14	7.23
eFAST*	0.40	2.51
eHarris*	5.02	0.21
G-eHarris*	2.69	0.37
Ours	**0.66**	**1.54**

Evaluation

- **Computational performance** of different event-based corner detectors.

	Algorithm	Time per event [μs/event]	Max.event rate [Meps]
	Arc*	0.14	7.23
	eFAST*	0.40	2.51
8×	eHarris*	5.02	0.21
4×	G-eHarris*	2.69	0.37
	Ours	**0.66**	**1.54**

Conclusions

- **Real-time:** 8× faster than eHarris*
- **Accuracy:** Better performance compared to the previous methods
- **Asynchronous:** Detects event-corners on event-streams directly

Thanks for your attention!