CISS 2021 - 55th Annual Conference on Information Science and Systems

Foveal-pit inspired filtering of DVS spike response

Shriya T.P. Gupta [1] , Pablo Linares-Serrano [2] , Basabdatta S. Bhattacharya [3]
Teresa Serrano-Gotarredona [2]

[1] Microsoft R&D, India,
[2] IMSE-CNM (CISC and Universidad de Sevilla), Spain
[3] BITS Pilani Goa Campus, India

Outline

- Introduction
- Related Work
- Proposed Approach
- Results and Discussion
- Conclusion

Introduction

- Spiking Neural Networks (SNN) - energy-efficient alternative to Artificial Neural Networks

- Efficiency gain of SNNs through use of event-based sensors - neuromorphic Dynamic Vision Sensor (DVS)

- Foveal-pit informed Difference of Gaussian (DoG) filters - to capture the most perceptually important information

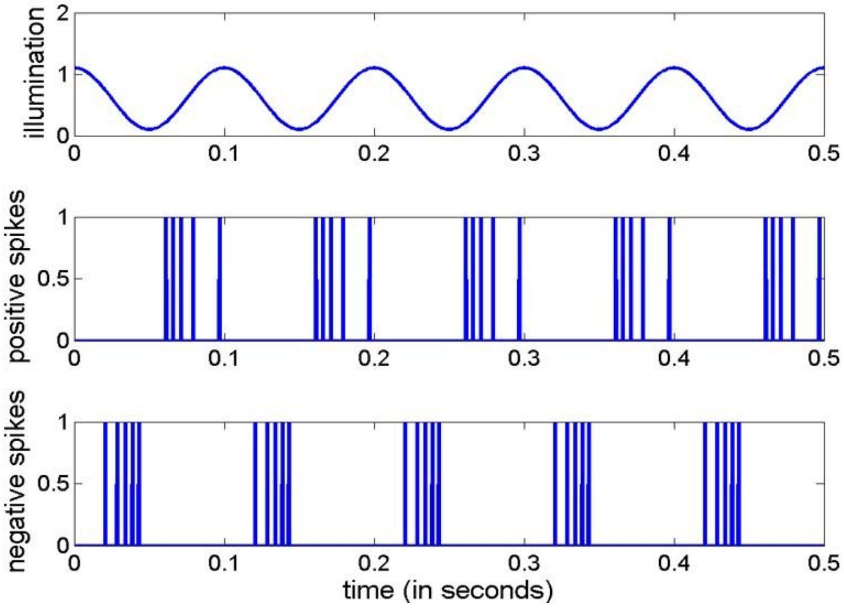


Fig: DVS spike response due to a sinusoidal illumination

Related Work

- Camunas-Mesa et al. [1] - shows efficiency gain in SNNs through the use of inputs from event-based sensors
- The use of DoG functions to model retinal filters - originally proposed by Rullen et al. [2] and receptive fields of the foveal-pit modelling presented in Bhattacharya et al. [3]
- Gupta et al. [4] - demonstrates the effect of foveal-pit inspired filtering for synthetically generated datasets like MNIST and Caltech.

[1] Camunas-Mesa et al. “An event-driven multi-kernel convolution processor module for event-driven vision sensors,” IEEE Journal of Solid-State Circuits.

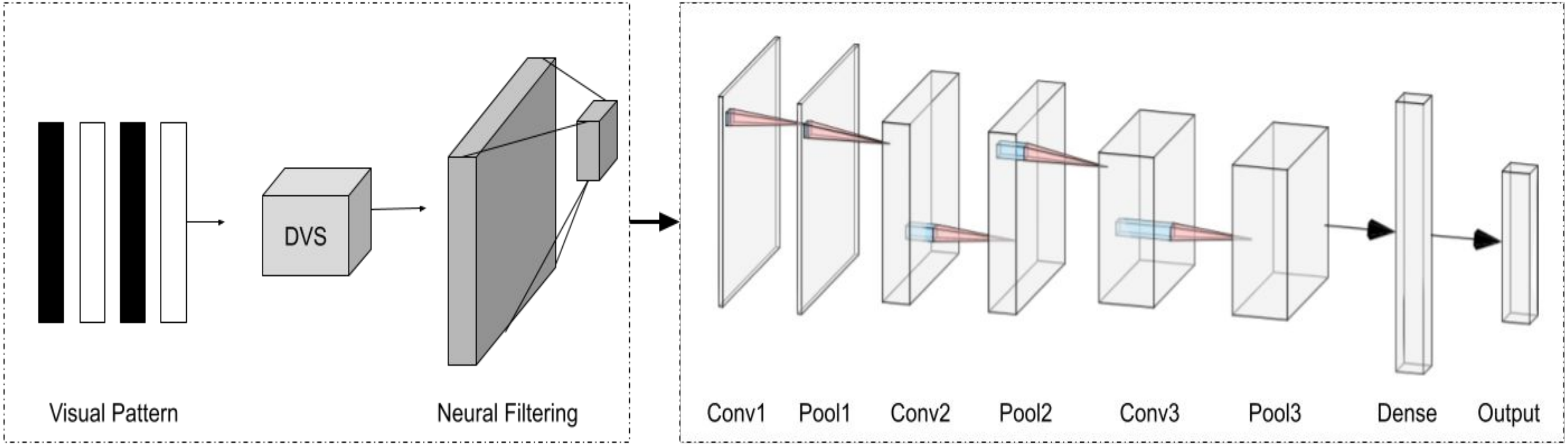
[2] R. V. Rullen and S. J. Thorpe, “Rate coding versus temporal order coding: what the retinal ganglion cells tell the visual cortex,” Neural computation.

[3] B. S. Bhattacharya and S. B. Furber, “Biologically inspired means for rank-order encoding images: A quantitative analysis,” IEEE transactions on neural networks , vol. 21, no. 7, pp. 1087–1099, 2010.

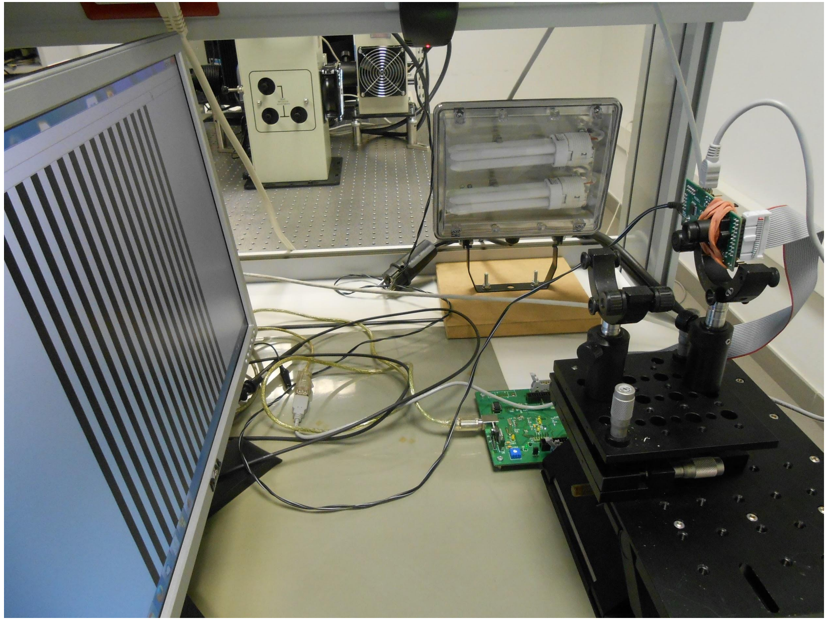
[4] S. T. Gupta et al. “Implementing a foveal-pit inspired filter in a spiking convolutional neural network: a preliminary study,” in IJCNN.

Proposed Approach

Architecture of the proposed DVS based spiking CNN



DVS setup to record spike responses



Foveal-pit inspired neural filters

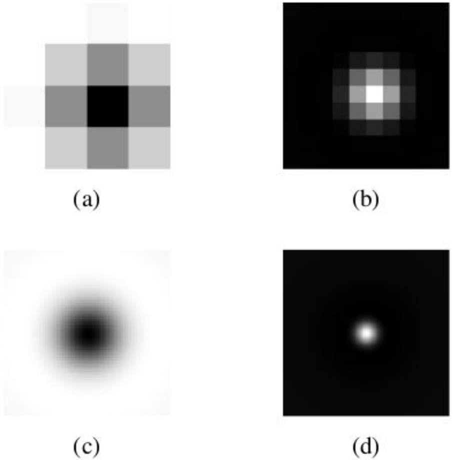


Fig. 2. The ganglion cells modelled using DoG functions representing the (a) off-center midget cell (b) on-center midget cell (c) off-center parasol cell and (d) on-center parasol cell.

Ganglion Cell Types		Receptive Field Simulation Parameters: Matrix Size (n)	Std. Dev. Center (σ_c)	Center Width in Pixels (w_c)	Std. Dev. Surround (σ_s)	Sampling Resolution
Midget	OFF-center	5×5	0.8	3	$6.7 \times \sigma_c$	$\frac{1}{\sqrt{2}}$
	On-center	11×11	1.04 $\simeq (1.3 \times 0.8)$	5		
Parasol	Off-center	61×61	8 $\simeq (10 \times 0.8)$	33	$4.8 \times \sigma_c$	$\frac{5}{\sqrt{2}}$
	On-center	243×243	10.4 $\simeq (10 \times 1.04)$	53		

Source: Bhattacharya et al.. “Biologically inspired means for rank-order encoding images: A quantitative analysis.” IEEE transactions on neural networks.

Spiking Convolutional Neural Network

TABLE I
DIMENSIONS OF THE SCNN LAYERS.

Layer	No. of filters	Input size	Kernel size
Conv1	8	(128, 128)	3
Pool1	-	(128, 128)	2
Conv2	16	(64, 64)	3
Pool2	-	(64, 64)	2
Conv3	32	(32, 32)	3
Pool3	-	(32, 32)	2
Flatten	-	(16, 16)	-
Dense	-	(1, 8192)	-
Outputs	-	(1, 7)	-

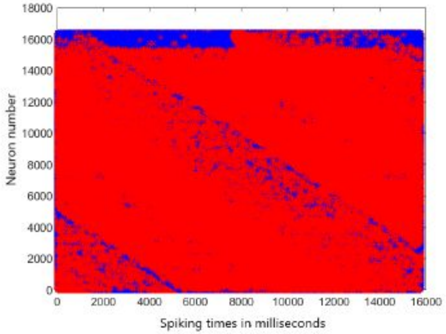
Results and Discussion

Quantitative Results

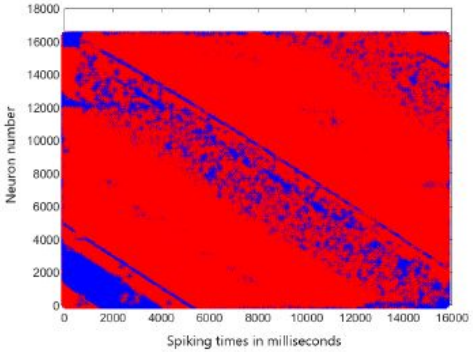
TABLE II
ACCURACIES (%) FOR THE FRAME-BASED DVS INPUT

Scenario	Cell - Type	CircShift	Accuracy
Unfiltered	-	-	65.0 %
Filtered	off-center midget	0	77.5 %
	on-center midget		85.0 %
	off-center parasol		92.5 %
	on-center parasol		87.5 %
Filtered	off-center midget	1	77.5 %
	on-center midget		85.0 %
	off-center parasol		100.0 %
	on-center parasol		85.0 %

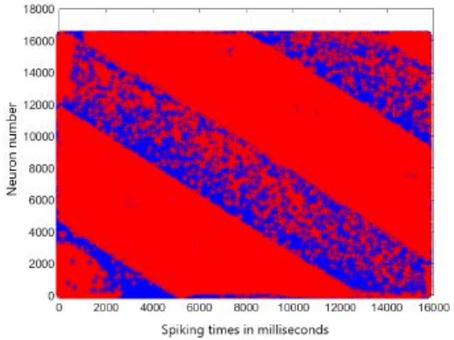
Qualitative Results



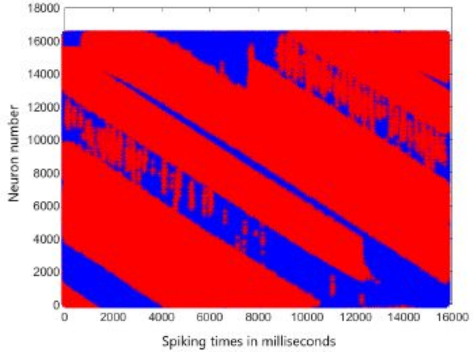
(a) Unfiltered scenario



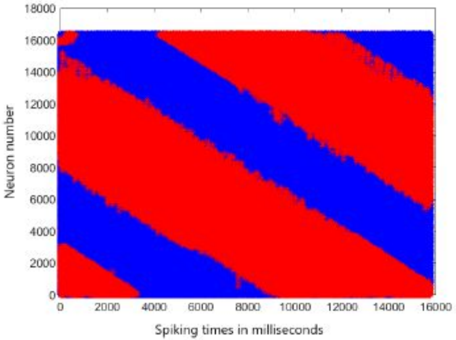
(b) Filtered: Unshifted midget



(d) Filtered: Circular-shifted midget



(c) Filtered: Unshifted parasol



(e) Filtered: Circular-shifted parasol

Conclusion

Conclusions

- Proposed model demonstrates the effect of applying neural filtering to data generated from a neuromorphic vision sensor.
- Achieves an improvement of around 35% over the classification using unfiltered DVS responses.
- Depicts importance of foveal-pit inspired neural filtering in redundancy reduction of the DVS inputs + discarding irrelevant background information.

Future Directions

- Adapting the proposed SCNN to process event-based data and evaluate the effects of the bio-inspired neural filtering on continuous outputs of a neuromorphic DVS.
- Verify effect of DoG filters on DVS spike responses of larger and more complex datasets.

Thank you