# Live Demonstration: Real-time Event-based Speed Detection using Spiking Neural Networks

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## Abstract

*Event cameras are emerging as an ideal vision sensor for high-speed applications due to their low latency and power consumption. DOTIE, a recent work in literature, has proposed a method to detect objects through spatial and temporal isolation of events with a spiking neural network. In this work, we implement DOTIE to detect a disk moving in a circular motion and identify the speed of rotation. We further validate the claim that spiking architectures can efficiently handle events by implementing DOTIE on Intel Loihi, a neuromorphic hardware suitable for spiking neural networks, and reveal a 14× reduction in energy consumption compared to the CPU implementation of DOTIE.*

## 1. Introduction and Motivation

**Speed Detection and Spiking Neurons** Detecting objects efficiently with low latency is a crucial task for high-speed applications such as autonomous navigation. To achieve efficiency in such systems, biologically inspired event cameras have been used in the place of traditional frame cameras as vision sensors. The events generated from such cameras are at a much higher speed and differ from traditional frame camera outputs. DOTIE [1] leverages the temporal information provided by events and detects objects by utilizing a single-layer light-weight spiking neural network (SNN) to separate objects based on their speed of movement.

**Utilizing Neuromorphic Hardware** Traditional GPUs and CPUs are not designed to handle the sparse and asynchronous nature of events and spiking neurons. Neuromorphic hardware, on the other hand, is specifically designed for deploying SNNs. Hence, in order to leverage and utilize the efficiency gains (both latency and energy) of DOTIE, we use Intel Loihi-2 [2], a recent neuromorphic chip suitable for spiking neural networks, as the hardware platform. This efficiency is quantified in terms of throughput and power consumption of the real-time deployment of the algorithm. In order to develop and run models on Loihi-2 we first port DOTIE's existing PyTorch model to Intel's open-source neuromorphic computing framework Lava. Once model porting is complete, we run experiments on both the Loihi-2 simulator that is packaged with Lava or connected to physical Loihi-2 chips by remotely accessing Intel's NRL (Neuromorphic Research Lab) cloud accounts. The Loihi-2 physical chips also come equipped with an energy profiling chipset that allows us to capture direct power measurements during runtime.

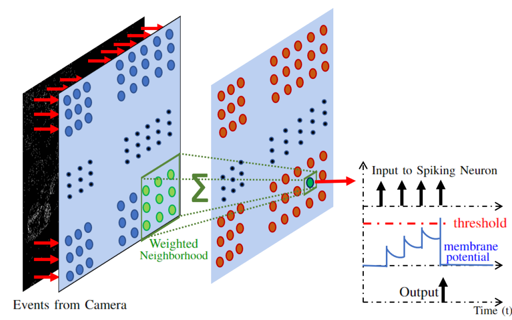



Figure 1. DOTIE's spiking architecture used to detect and isolate events belonging to objects moving at a particular speed bin.

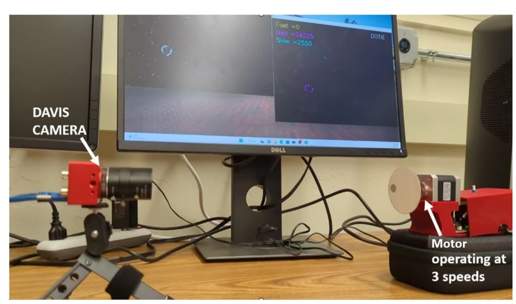
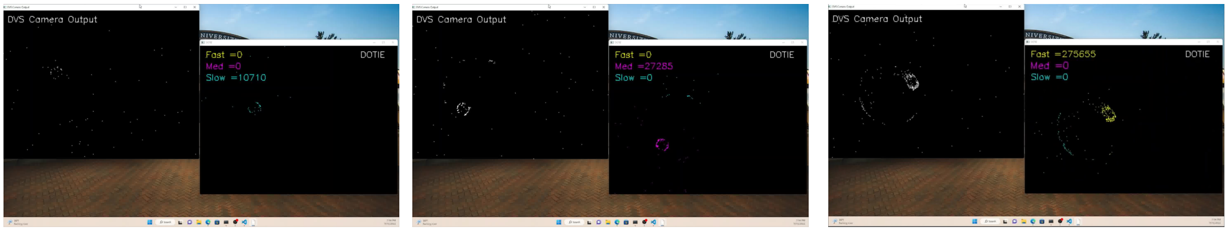



Figure 2. Experimental setup to demonstrate speed detection using DOTIE. The event camera is used to capture the events generated by a disk attached to a motor rotating at three different speeds.




(a) Motor rotating at *slow* speed (b) Motor rotating at *medium* speed (c) Motor rotating at *fast* speed

Figure 3. Demonstration of speed detection using spiking neurons. The figure shows DOTIE's allocation of events into speed bins (shown in different colors) based on the speed of the object in the field of view.

## 2. Experimental Results

**Demonstrating Speed Detection** In order to demonstrate how DOTIE can effectively detect the speed of objects using only event data, we utilize a DAVIS346 Event Camera and an Electric DC Brushless Motor. A disk with a simple pattern drawn on it is attached to the motor to facilitate a more visible pattern to be captured by the event camera. Using an Arduino board, the motor was programmed to rotate at three different speeds (*slow*, *medium*, and *fast*). The setup is shown in Figure 2.

We then finetune the network weights of the spiking architecture from DOTIE to separate out events corresponding to the speed of the motor when they are being generated. We color the events based on the speed bin (*slow*, *medium*, and *fast*) they belong to. The sum total of events in each speed bin is shown in the top left corner of the visualization. Figure 3 shows examples of how DOTIE can detect the speed of the motor's rotation, by allocating events into speed bins.

**Demonstrating the Compute Efficiency of SNNs** For running power measurements of DOTIE on Intel Loihi we will use energy profiling that Loihi-2 is equipped with. We SSH into the Loihi-2 device via Intel's Neuromorphic Research Cloud account and run DOTIE on a subset of the MVSEC dataset [3].

| Platform | Dynamic Energy per Inference (mJ) | Frames per Second |
|---|---|---|
| CPU | 28.74 | 946 |
| **Loihi-2** | **2.32** | **266** |

Table 1. Energy and Throughput between Loihi and CPU

Due to the fact that Loihi-2 physical chips have certain constraints when visualizing outputs, we will show object detection of the Loihi demo via the Loihi-2 simulator in Lava. We achieve a bounding-box IoU score of roughly 80% between Loihi (Lava) and CPU (PyTorch) from a subset of 2000 images in MVSEC.

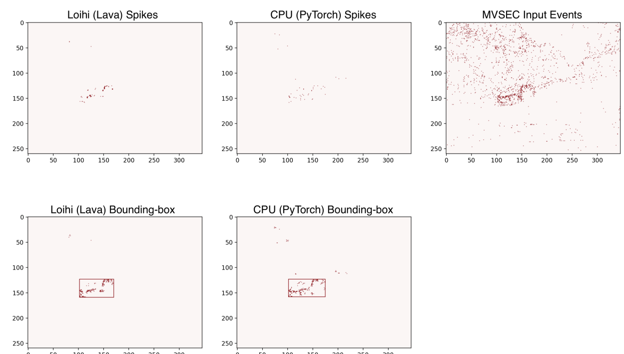



Figure 4. Loihi (Lava) and CPU (PyTorch) Spikes and Bounding-boxes from example frame in MVSEC dataset

## 3. Conclusion

We present a real-time working of DOTIE, a recent neuromorphic algorithm that utilizes data from event cameras in order to detect objects. We then show the working of DOTIE on neuromorphic hardware that is designed to provide energy efficiency and low latency. This serves as a useful demonstration to showcase the advantages of using event cameras, spiking neurons, and neuromorphic hardware.

## References

[1] Manish Nagaraj, Chamika Liyanagedera, and Kaushik Roy. DOTIE–detecting objects through temporal isolation of events using a spiking architecture. In *2023 International Conference on Robotics and Automation (ICRA)*. IEEE, 2023. 1

[2] Garrick Orchard, E Paxon Frady, Daniel Ben Dayan Rubin, Sophia Sanborn, Sumit Bam Shrestha, Friedrich T Sommer, and Mike Davies. Efficient neuromorphic signal processing with loihi 2. In *2021 IEEE Workshop on Signal Processing Systems (SiPS)*, pages 254–259. IEEE, 2021. 1

[3] Alex Zihao Zhu, Dinesh Thakur, Tolga Özaslan, et al. The multivehicle stereo event camera dataset: An event camera dataset for 3d perception. *IEEE Robotics and Automation Letters*, 3(3):2032–2039, 2018. 2