Live Demo: E2P–Events to Polarization Reconstruction from PDAVIS Events

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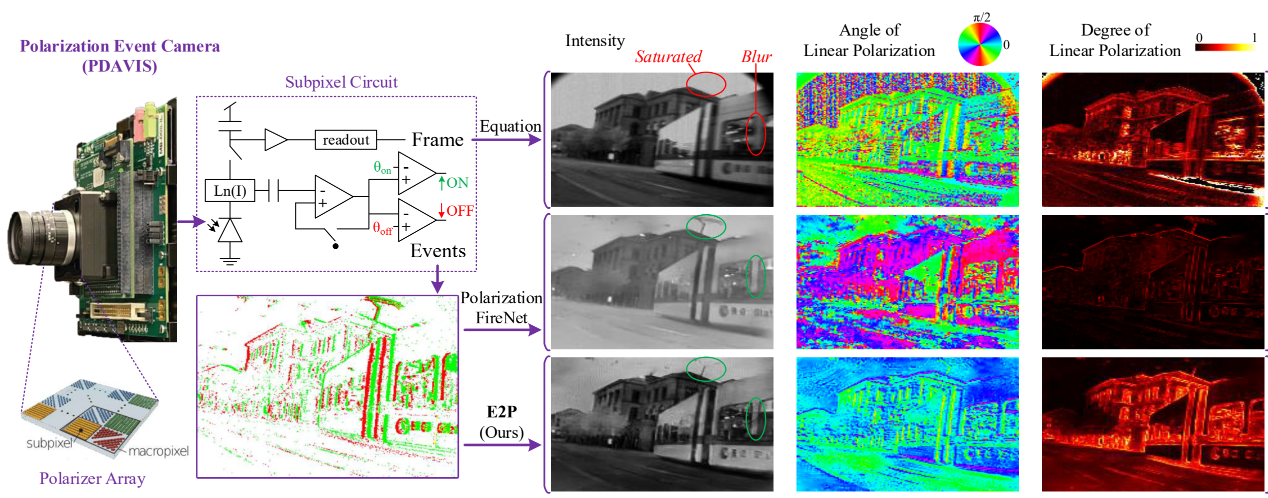

Figure 1. The polarization dynamic and active pixel vision sensor (PDAVIS) [3, 4] is integrated with a nanowire polarizer array. It concurrently outputs conventional polarization intensity frames and high dynamic range, quick asynchronous polarization brightness change events. Taking polarization events as input, our Events to Polarization (**E2P**) reconstructs sharp output with high dynamic range (**HDR**) and with a more accurate polarization reconstruction than from a naive reconstruction from separate intensity frames (Polarization FireNet). This figure is from [7].

Abstract

This demonstration shows live operation of of PDAVIS polarization event camera reconstruction by the E2P DNN reported in the main CVPR conference paper Deep Polarization Reconstruction with PDAVIS Events (paper 9149 [7]). Demo code: github.com/SensorsINI/e2p

Visual information is encoded in light by intensity, color, and polarization [1]. Polarization is a property of transverse light waves that specifies the geometric orientation of the oscillations (which can be described by the Angle of Linear Polarization (**AoLP**) and the Degree of Linear Polarization (**DoLP**)), providing strong vision cues and enabling solutions to challenging problems in medical [5], underwater [8], and remote sensing [9] applications.

Existing polarization digital cameras capture synchronous polarization frames with a linear photo response [2], while biological eyes tend to perceive asynchronous and sparse data with a compressed nonlinear response [1]. Inspired by the visual system of mantis shrimp [6], we developed the neuromorphic vision sensor called Polarization Dynamic and Active pixel VIsion Sensor (**PDAVIS**) illustrated in Figure 1 [3, 4]. It outputs a high-frequency stream of asynchronous polarization brightness change events from four nanowire polarization angles over a wide range of illumination[1]. PDAVIS also can output low-frequency synchronous frames like conventional polarization cameras, but E2P does not use them.

We reported [4] Deep Neural Network (**DNN**) reconstruction of polarization from PDAVIS using 4 indepen-

[1] see companion workshop paper 24.

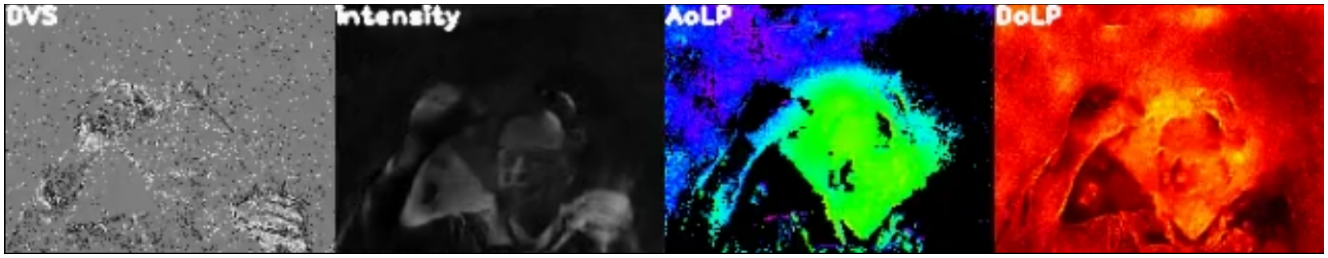

Figure 2. **E2P demo computer display.** The output display shows the Dynamic Vision Sensor (**DVS**) input to the E2P network and the reconstructed intensity, angle, and degree of linear polarization reconstructed by the E2P network. Pixels with DoLP less than 0.35 are masked out in the AoLP display. The rectangular filter is highly polarized at this moment is oriented at a particular angle coded by the AoLP HSV color. The DoLP is colored using a HOT color mapping.

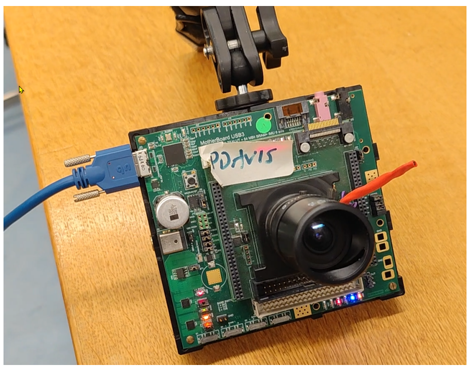

Figure 3. PDAVIS USB camera

dent intensity reconstructions from the 4 polarization angle channels. We computed DoLP and AoLP from these separate channels using standard formulas. Reconstruction was acceptable, but we significantly improved reconstruction accuracy in [7] by directly reconstructing all 3 output channels in a single integrated DNN. This demo paper reports details of our live demonstration implementation of the E2P reconstruction.

1. Demonstration Setup and User Experience

Figs. 2 and 3 show our camera and computer output. A prototype PDAVIS camera is connected to a computer by USB cable. The DNN E2P inference is computed and rendered by the laptop GPU. The demonstration allows users to see the output of a PDAVIS camera in response to various polarization targets such as polarizing filters and shiny surfaces. The computer display shows the raw event input to E2P and the reconstructed intensity, angle, and degree of linear polarization. Users can record short sequences and play them back in slow motion.

2. Implementation

The PDAVIS E2P demo is implemented in Python (see the code link after the abstract). It runs in two separate processes launched from Python's multiprocessing framework.

The *producer* process receives event data from the PDAVIS[2] and constructs the input voxel volume. It sends it to the consumer thread using a Python `Pipe()`.

The *consumer* process receives the voxel volume and then runs E2P on the computer GPU using PyTorch. Then it renders this output as intensity, AoLP, and DoLP. Since AoLP is not meaningful unless there is significant DoLP, we draw AoLP pixels that have low DoLP as black.

Using two processes enables true multiprocessing, which is otherwise not easily implemented in Python. The consumer process collects events concurrently with the inference computed by the consumer thread.

To improve reconstruction accuracy for the expected demonstration environment, we collected several thousand additional PDAVIS frames (to generate the target ground truth intensity, AoLP, and DoLP outputs) with about 150M PDAVIS events. We collected these additional data from the PDAVIS camera by moving the polarization filter targets by hand and while moving the PDAVIS camera around our laboratory. The data preparation and training procedure is described in our code repository. The total dataset is about 250GB on disk. Training the model on all the data takes several days on an NVIDIA GeForce RTX 3090 with 24GB of memory.

3. Summary

Readers are invited to view video of the demonstration on our project github page.

Acknowledgments

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[2] With github.com/duguyue100/pyaer

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