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Motion detection for high-speed high-brightness objects based on a pulse array image sensor

Key words: Optical flow; Retina-like image sensor; Pulse triggered; High-speed targets; Vision processing

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Motivation

1. The extraction of optical flow (OF) is challenging when dealing with high-speed targets. Also, the performance of image sensors has a great influence on the accuracy of OF extraction.

2. Traditional image sensors capture images using a shutter, which causes problems such as an excessive amount of data and heavy calculation burden.

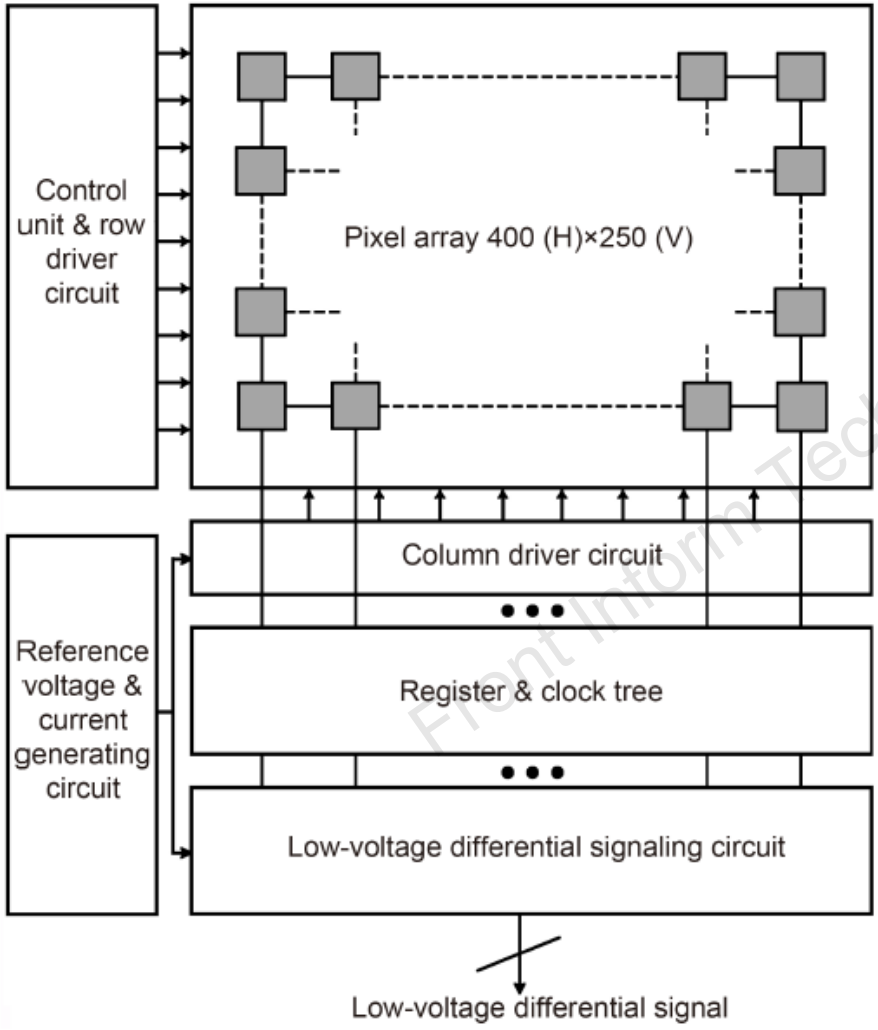
3. Bionic cameras such as the dynamic vision sensor with address-event representation can reduce data volume but may cause data loss.

Main idea

1. We proposed a pulse array image sensor (PAIS) using pulse interval representation. Compared with traditional image sensors, PAIS has a lower data volume and higher time resolution. Compared with address-event representation (AER) image sensors, it has higher data completeness and overcomes the limitations of AER sensors in motion detection in high-speed environments.

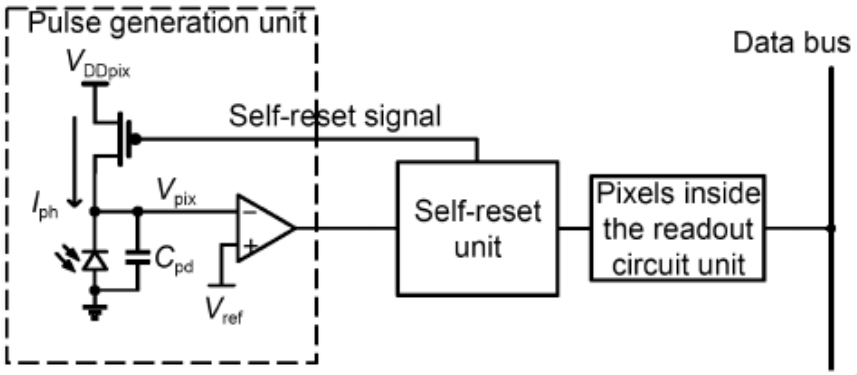
2. We also proposed a relative method to obtain the OF for PAIS, using an event selection filter formed naturally by the sensor to reduce the computational cost of OF extraction.

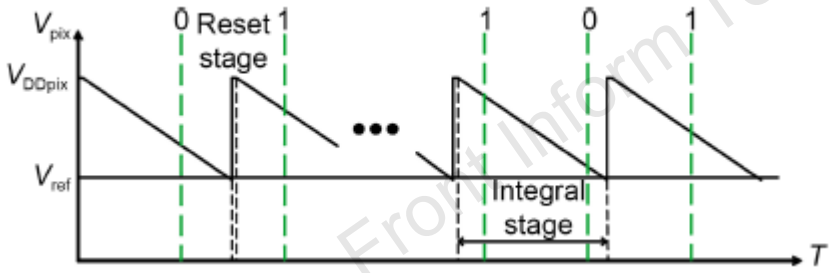
Pulse array image sensor (PAIS)

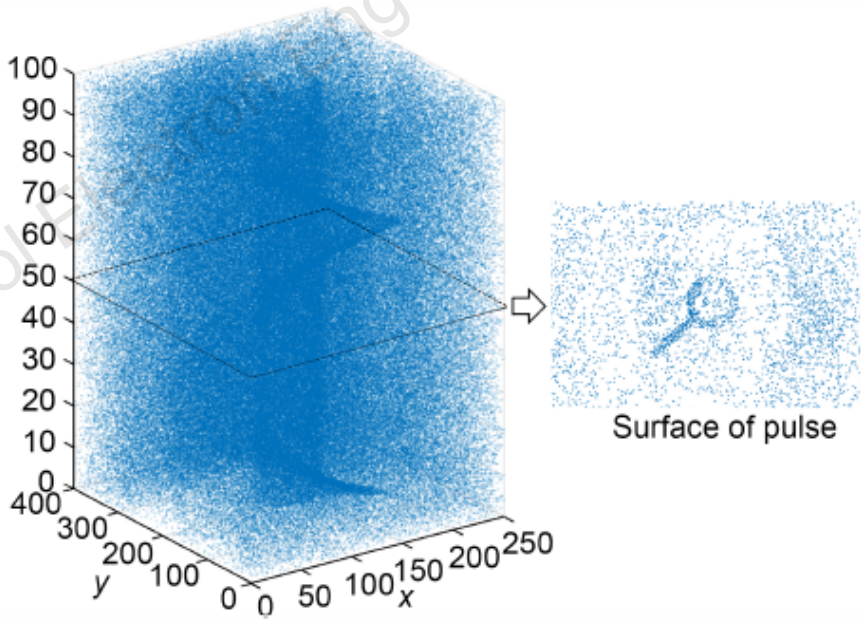


PAIS consists of a pulse pixel array, row and column driving circuit, timing control and latching circuit, reference voltage and current generation circuit, low-voltage differential signaling (LVDS) interface circuit, and serial peripheral interface (SPI) circuit.

Pulse array image sensor (PAIS)

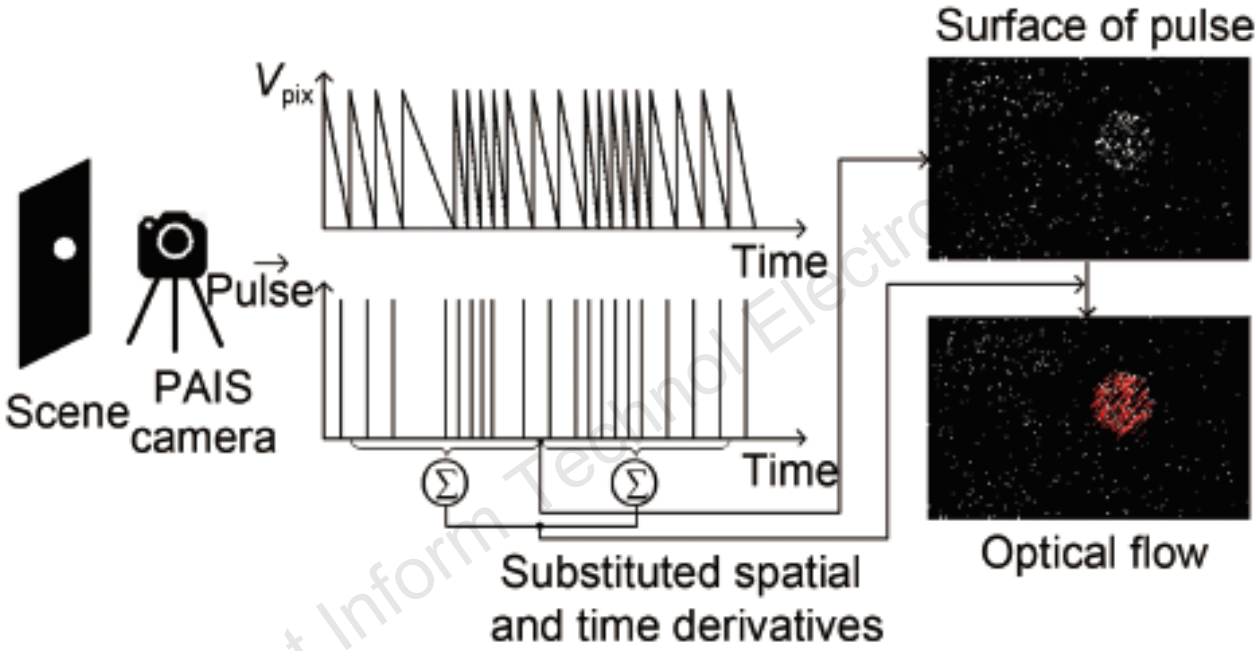






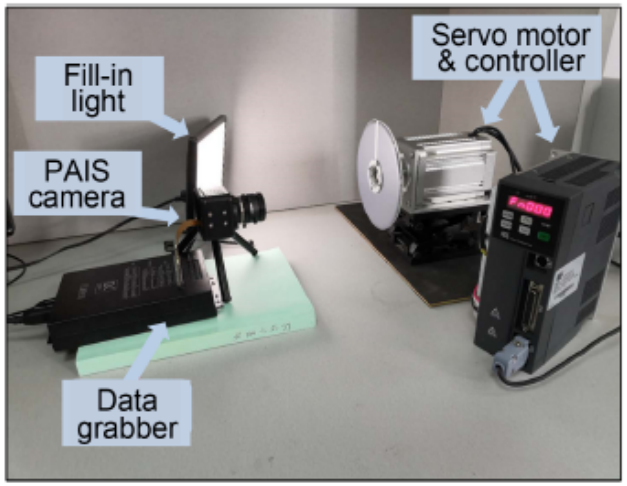
PAIS can convert light into a series of pulse intervals.

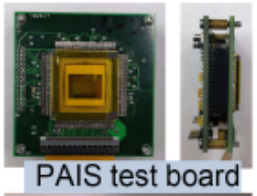
Optical flow extraction method



We accumulate the continuous pulse data over a period of time to substitute for the gray value information and to obtain spatial and temporal derivatives.

Major results

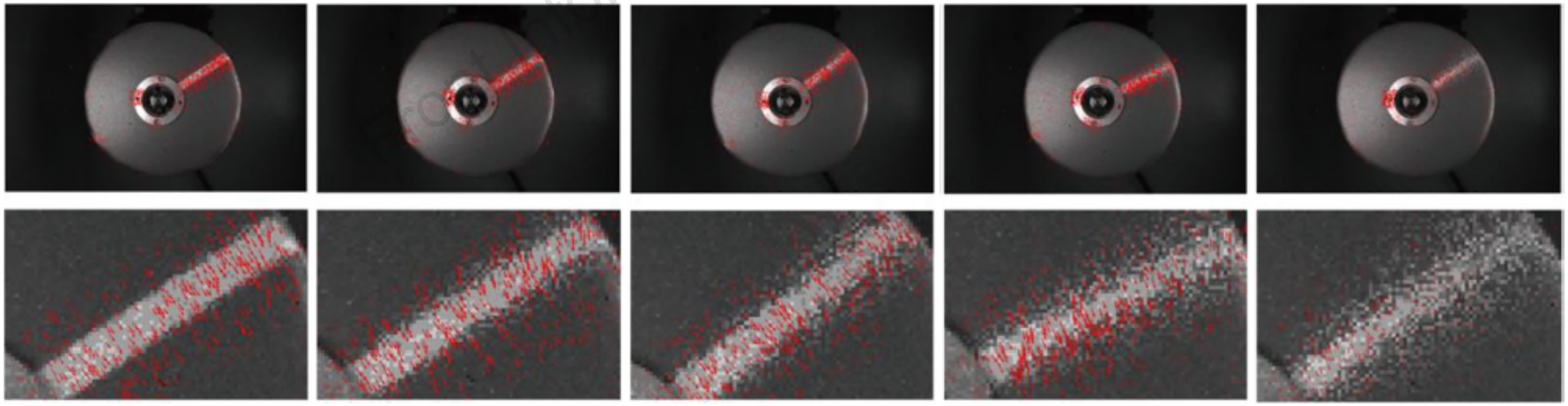




PAIS test board

PAIS camera

The imaging system and the optical flow extraction results



Major results

Results of optical extraction from a real PAIS camera at different speeds

Rotating speed (r/min)	Point number		Ratio (%)		AEE (%)	AAE (°)
	Total triggered	In the target area	Total filtration ratio	In the target area		
500	5371	163	94.63	3.03	44.16±2.68	10.51±3.11
1000	5385	138	94.61	2.56	51.09±3.40	15.01±1.96
1500	5352	108	94.65	2.02	51.76±3.60	15.20±1.73
2000	5316	97	94.68	1.82	48.50±4.09	12.46±1.54
2500	5390	105	94.61	1.95	50.26±2.06	12.30±0.95
3000	5499	90	94.50	1.64	41.07±2.19	10.31±2.63
3500	5480	88	94.52	1.61	58.81±3.23	18.72±2.50
4000	5478	57	94.52	1.04	71.01±9.59	30.34±3.89
4500	5327	71	94.67	1.33	72.81±7.43	39.36±4.05

Conclusions

We proposed an alternative framework to calculate optical flow (OF) based on PAIS. This sensor represents light intensity information with pulse intervals. The OF extraction method makes full use of the advantages of PAIS. Experiments showed that the OF extraction method can filter the redundant information efficiently for high-speed high-brightness targets. The results presented should be valuable in applications requiring rapid and even real-time analysis of high-speed events, such as vision-based guidance for imaging moving projectiles or high-speed autonomous aircraft.

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