

Peiwen ZHANG, Jiangtao XU, Huafeng NIE, Zhiyuan GAO, Kaiming NIE, 2022. Motion detection for high-speed high-brightness objects based on a pulse array image sensor. *Frontiers of Information Technology & Electronic Engineering*, 23(1):113-122. <https://doi.org/10.1631/FITEE.2000407>

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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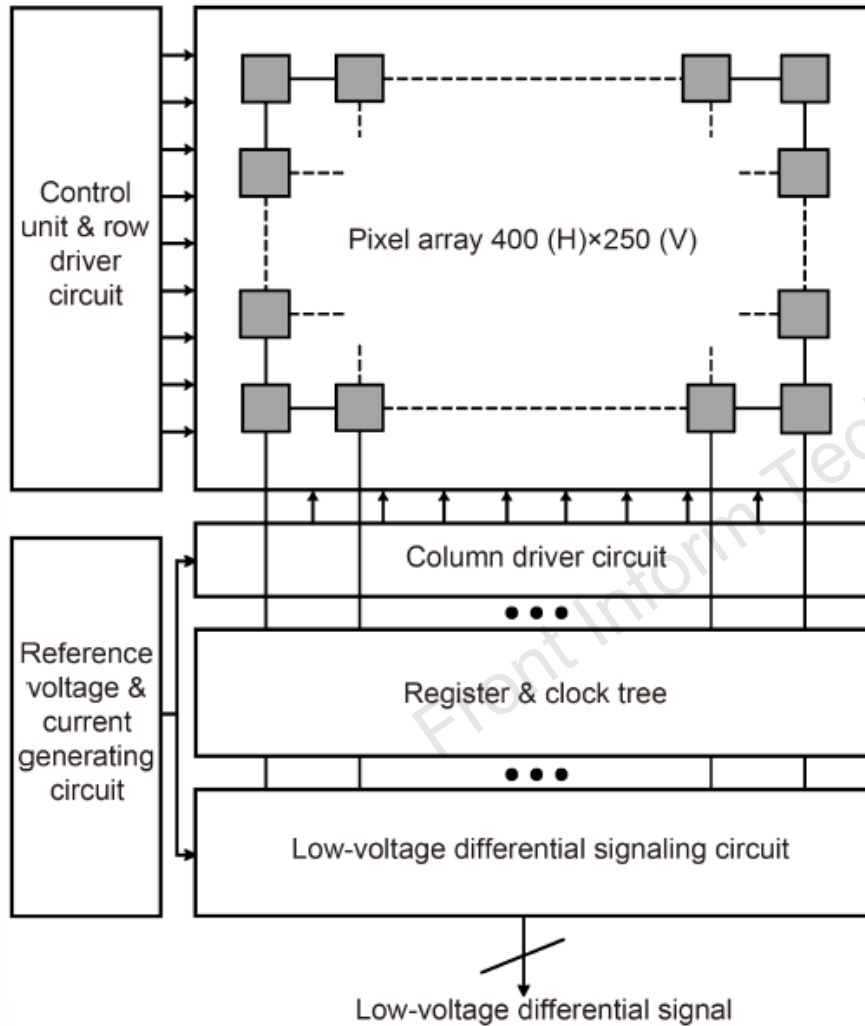
Motivation

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

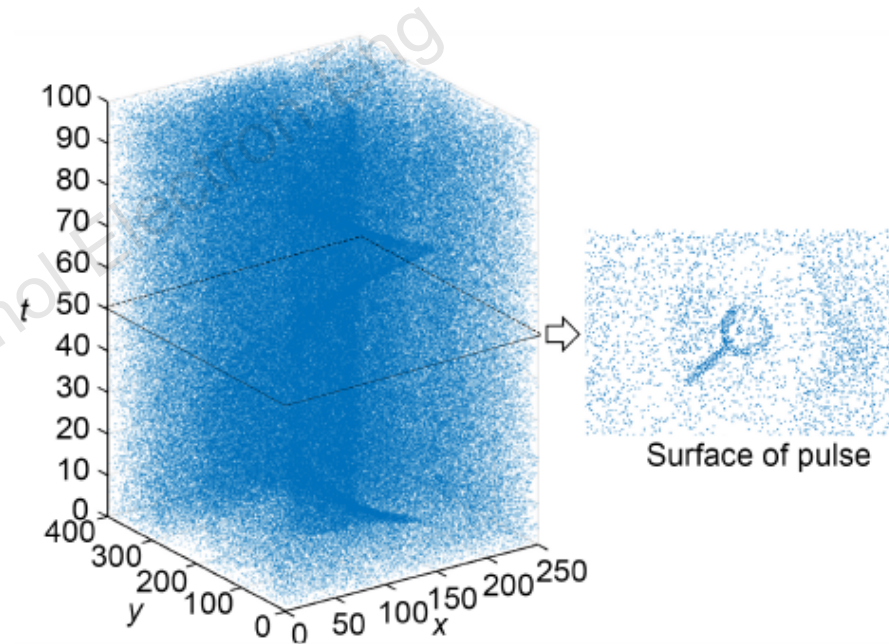
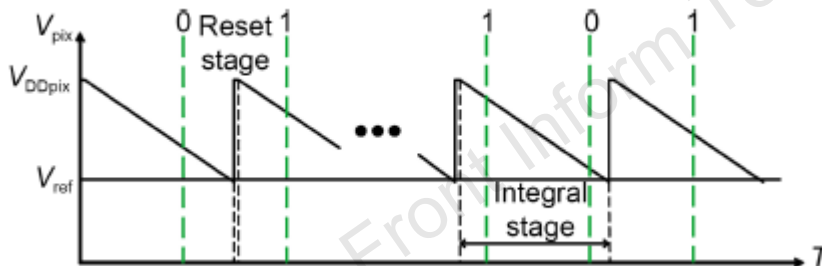
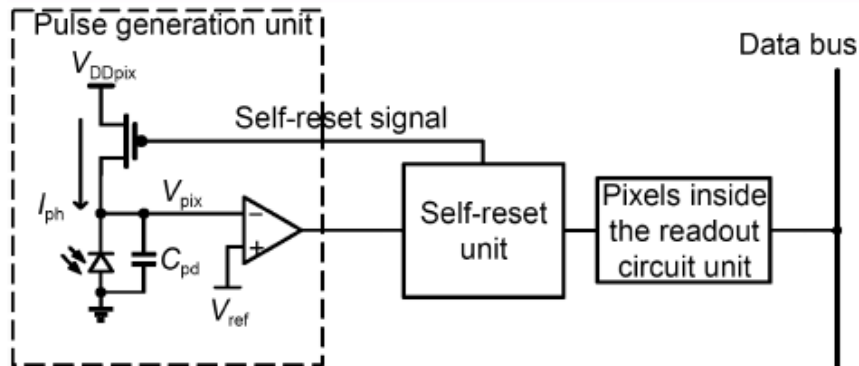
1. We proposed a pulse array image sensor (PAIS) using pulse interval representation. Compared with traditional image sensors, PAIS has a lower data volume and higher time resolution. Compared with address-event representation (AER) image sensors, it has higher data completeness and overcomes the limitations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



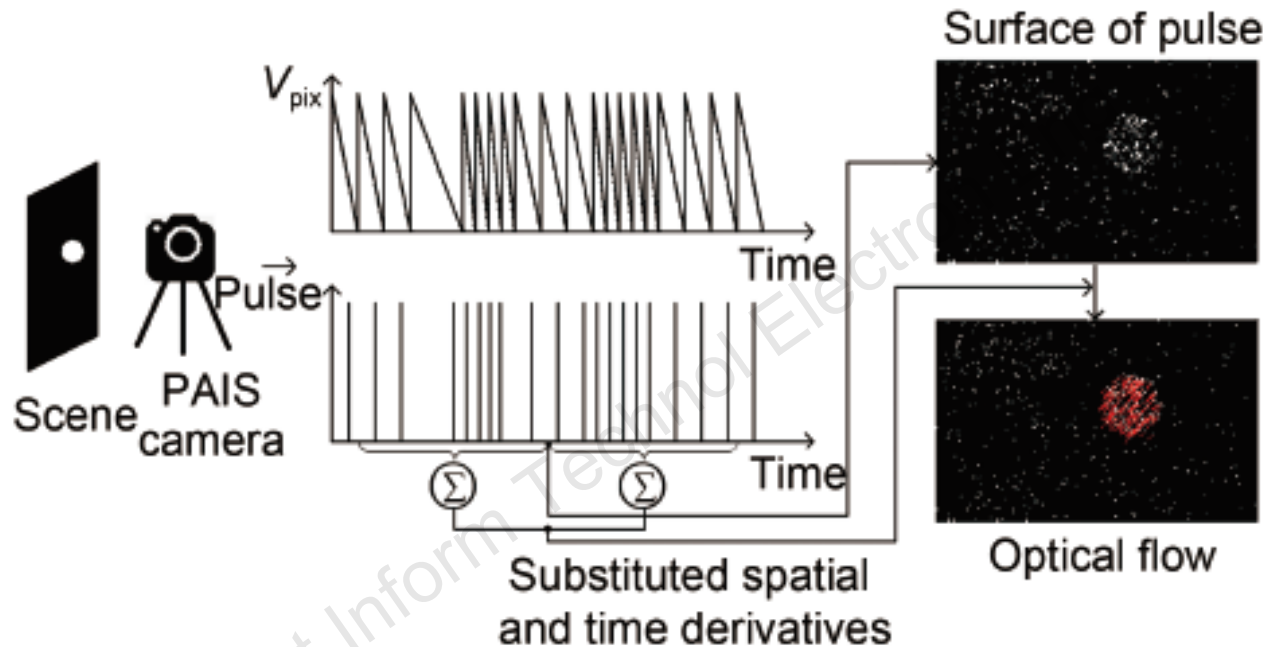
PAIS consists of a pulse pixel array, row and column driving circuit, timing control and latching circuit, reference voltage and current generation circuit, low-voltage differential signaling (LVDS) interface circuit, and serial peripheral interface (SPI) circuit.

Pulse array image sensor (PAIS)



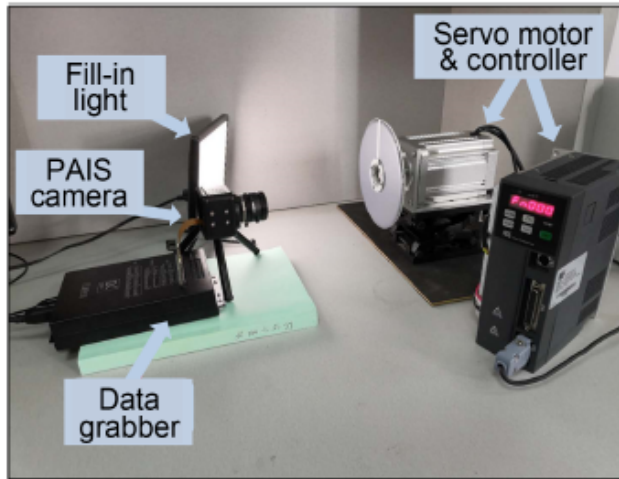
PAIS can convert light into a series of pulse intervals.

Optical flow extraction method

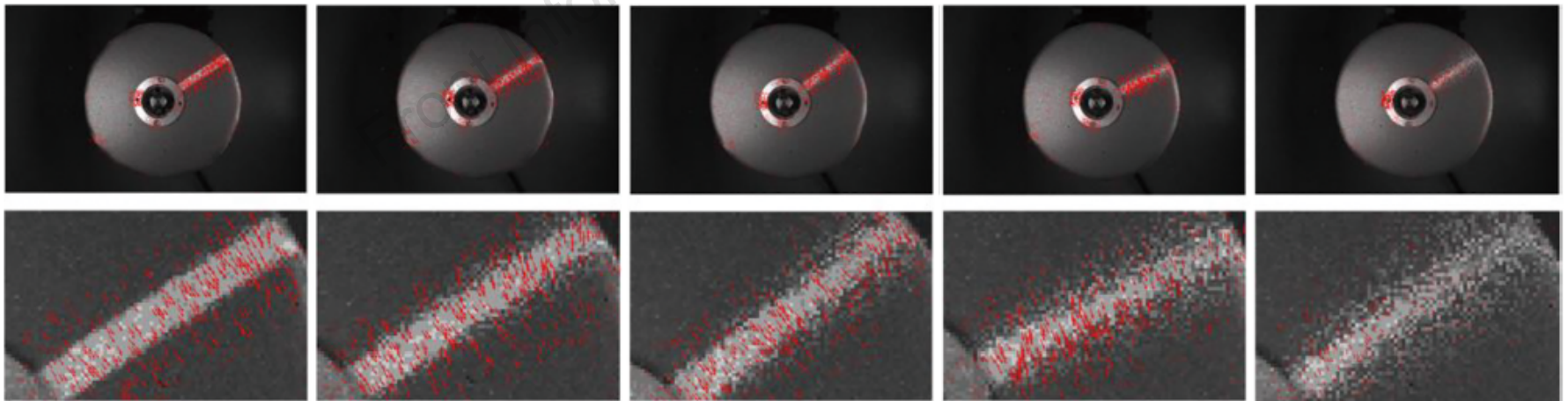


We accumulate the continuous pulse data over a period of time to substitute for the gray value information and to obtain spatial and temporal derivatives.

Major results



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.



徐江涛，博士生导师，天津市智能科技产业专家咨询委员会专家，天津市集成电路与计算系统技术工程中心主任。主要从事CMOS图像传感器研究工作，具体包括基于仿生机理的智能图像传感芯片、亿级像素成像芯片，基于飞行时间的3D成像芯片、微光成像芯片等。承担国家科技重大专项、国家重点研发计划、国家自然科学基金、天津市人工智能重大专项等20余项。作为第一或通讯作者发表学术论文100余篇，其中SCI检索70余篇，作为第一发明人授权发明专利50余项，多项研究成果实现产业化。牵头获得第22届中国专利优秀奖，获2018年天津市科技进步一等奖、2019年天津市专利金奖、第十五届天津青年科技奖。