#### SONY

### Event-Based Computer Vision at Sony AVS

CVPR 2021

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### So Who Is Sony Semiconductor?

#### **Sony Group Corporation**

	Sony Interactive Entertainment	Game & Network Services
	Sony Music Group(Global) (Sony Music Entertainment, Sony Music Publishing)	Music
	Sony Music Entertainment Japan	
	Sony Pictures Entertainment	Pictures
	Sony Corporation	Electronics Products & Solutions
	Sony Semiconductor Solutions	Imaging & Sensing Solutions
	Sony Financial Holdings	Financial Services

### We Build The World's Best Image Sensors



#### **Image Sensor Sales**

Worldwide No.1 share of more than 50% (Revenue basis)

### Who is Sony AVS?



### And What Does Sony AVS Do?



#### We built and build Event-Based Computer Vision Algorithms

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# Enough PR ...

# ... Let's Talk Technology

### What Is A Temporal Contrast Event?

A temporal contrast event is a tuple of an address with polarity  $\tilde{p}$  and timestamp  $\check{t}$ . Such an event is created when ...

$$e = \{x, y, \breve{p}, \breve{t}\}: \exists e_{x,y}[j] \left( \breve{p} = \begin{cases} 1 \text{ for } \int_{T[j-1]}^{\breve{t}} C_{x,y}^{t}(t) + \dot{N}_{x,y}(t) \, dt \ge \Theta^{ON} \\ 0 \text{ for } \int_{T[j-1]}^{\breve{t}} C_{x,y}^{t}(t) + \dot{N}_{x,y}(t) \, dt \le \Theta^{OFF} \end{cases} \right)$$
  
... of the temporal contrast... ... is below ...  
... the integral since the last timestamp... ... and the noise ... ... or above a threshold

### What is Temporal Contrast?

Temporal contrast is the rate of illumination change...

$$C_{x,y}^{t}(t) = \frac{1}{I_{x,y}(t)} \frac{d I_{x,y}(t)}{dt} = \frac{d \left( ln \left( I_{x,y}(t) \right) \right)}{dt}$$

... normalized by the absolute intensity...

... which is equivalent to the log intensity change rate.

### So What is Encoded By an Event?

Integrating temporal contrast results in ...

 $\int_{t_0}^{t_1} C_{x,y}^t(t) dt = \Delta C_{x,y}^t(t_0, t_1) = ln\left(I_{x,y}(t_1)\right) - ln\left(I_{x,y}(t_0)\right) = ln\left(\frac{I_{x,y}(t_1)}{I_{x,y}(t_0)}\right)$ ... a "temporal contrast step", ...

... which is a fixed step in log intensity ...

### Then What Makes Up a Temporal Contrast Step?

The "event magnitude" is ...



... which in turn is made up of different components.

### So What To Do With Events



#### **Entropy**:

- Smart Triggering \_
- Smart Processing \_

#### **Active Lighting:**

- Structured Light
- Active Marker Tracking
- Visible Light -Communication

#### **Reconstruction:**

- Imaging -
- Mapping -
- **Classification:**
- Object

#### **Tracking:**

- Camera:
  - VIO
- World:
  - User
  - Objects -

# Some Examples

### So What To Do With Events

$$EM_{x,y}[j] = \int_{T[j-1]}^{T[j]} \frac{dlog(I(k,t))}{dt} + \frac{dR}{dt} - \frac{dR}{dx}\frac{dx}{dt} - \frac{dR}{dy}\frac{dy}{dt}dt$$
  
illumination change  
Active Lighting

### **High-Speed 3D**



### So What To Do With Events

$$EM_{x,y}[j] = \int_{T[j-1]}^{T[j]} \frac{dlog(I(k,t))}{dt} + \frac{dR}{dt} - \frac{dR}{dx}\frac{dx}{dt} - \frac{dR}{dy}\frac{dy}{dt}dt$$
optical flow
Tracking

### Very Fast Real-Time Tracking Of Dots



### **Better For Fast Motion than Open CV**



### **And More Robust On Repetitive Structures**



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### So What To Do With Events

$$EM_{x,y}[j] = \int_{T[j-1]}^{T[j]} \frac{dlog(I(k,t))}{dt} + \frac{dR}{dt} - \frac{dR}{dx}\frac{dx}{dt} - \frac{dR}{dy}\frac{dy}{dt}dt$$
spatial contrast
Reconstruction

### Sensor Fusion of iToF and EVS for Efficient Depth Sensing



### To Capture What Our Engineers Are Doing In the Office



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