

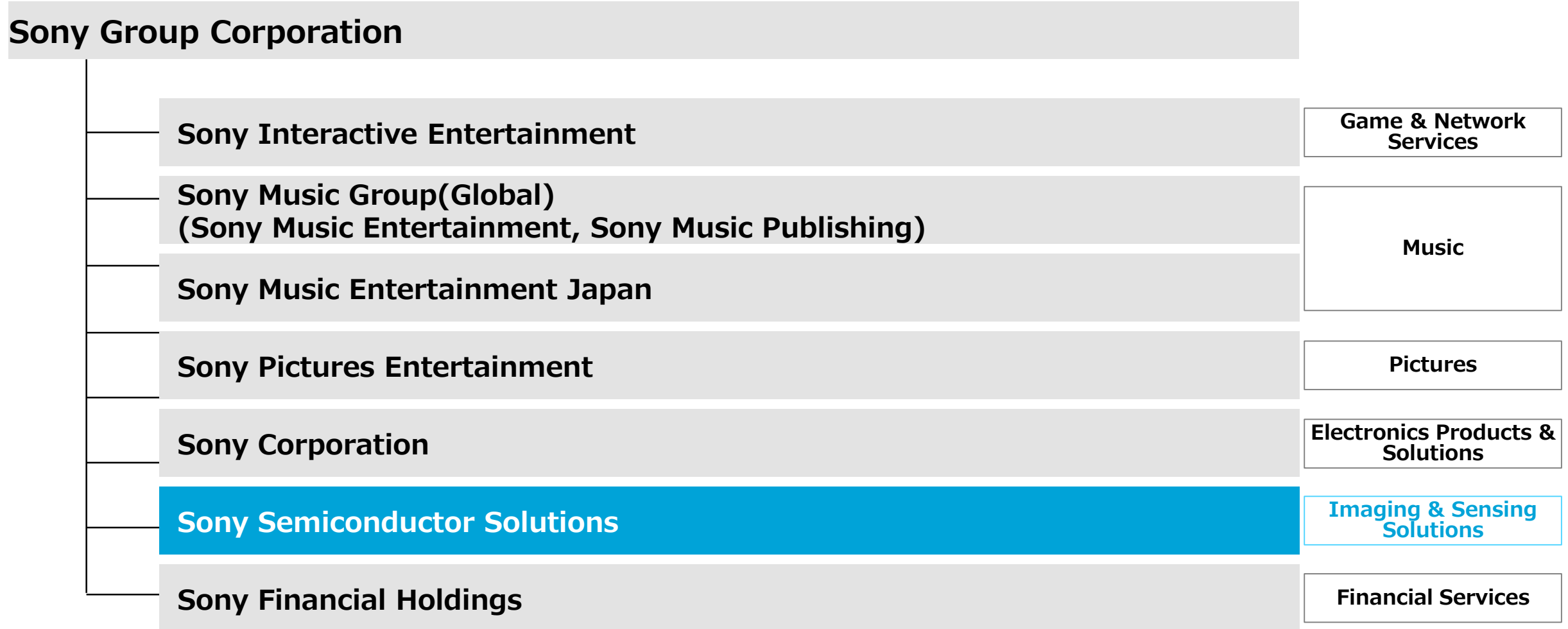
Event-Based Computer Vision at Sony AVS

CVPR 2021

Christian Brändli, CEO, Sony AVS

SONY

So Who Is Sony Semiconductor?



We Build The World's Best Image Sensors

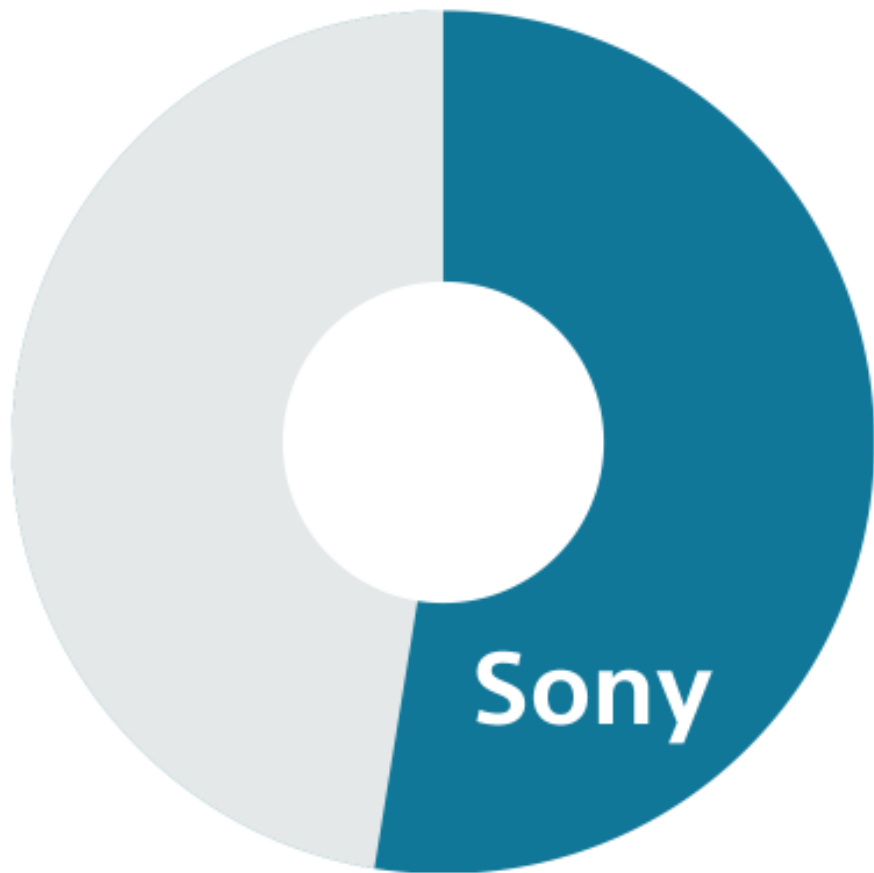
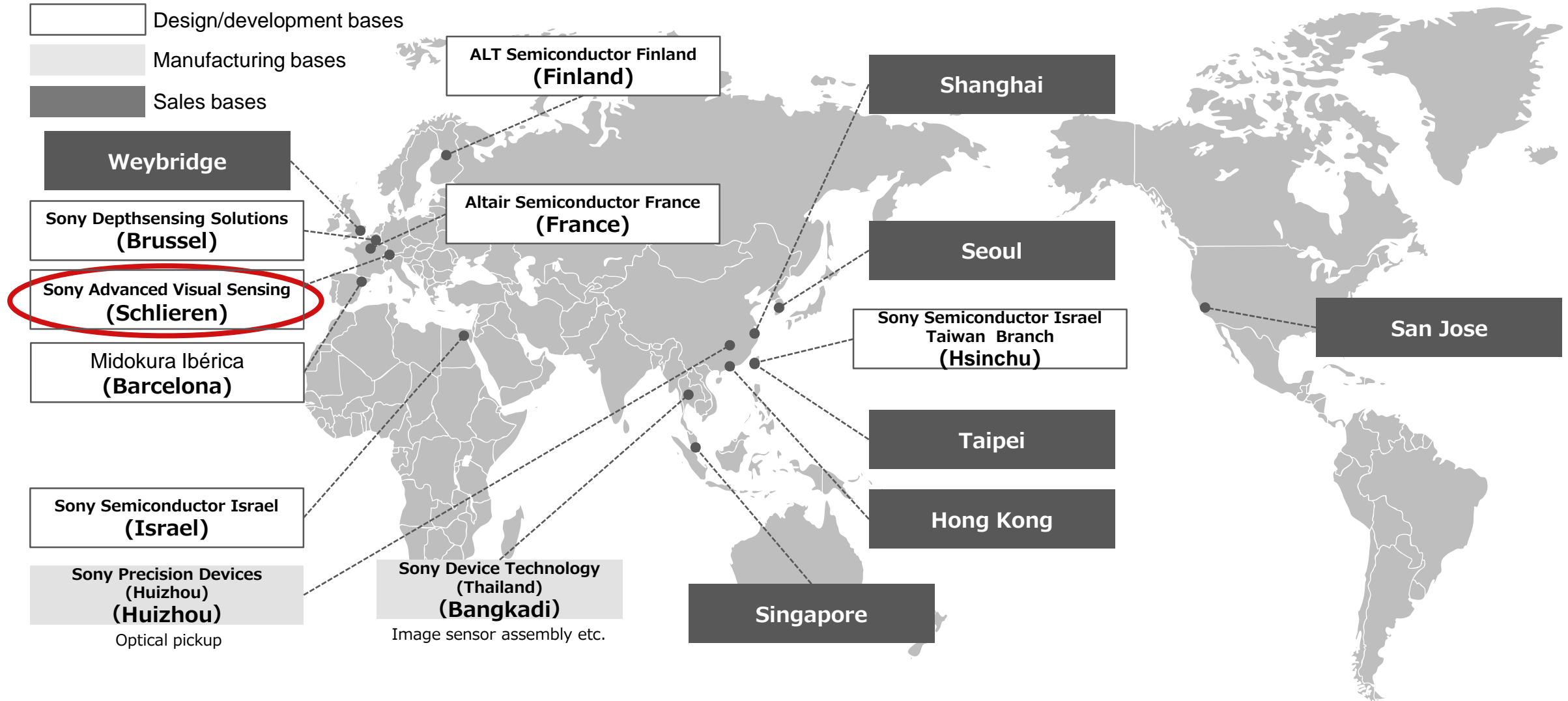


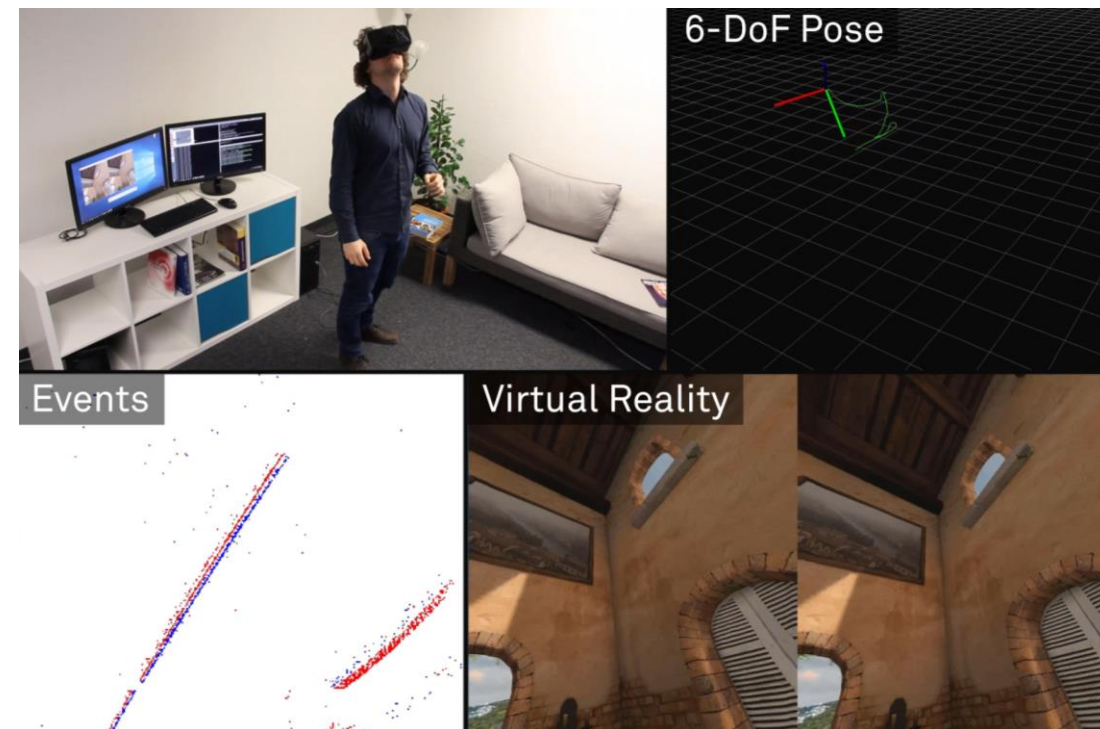
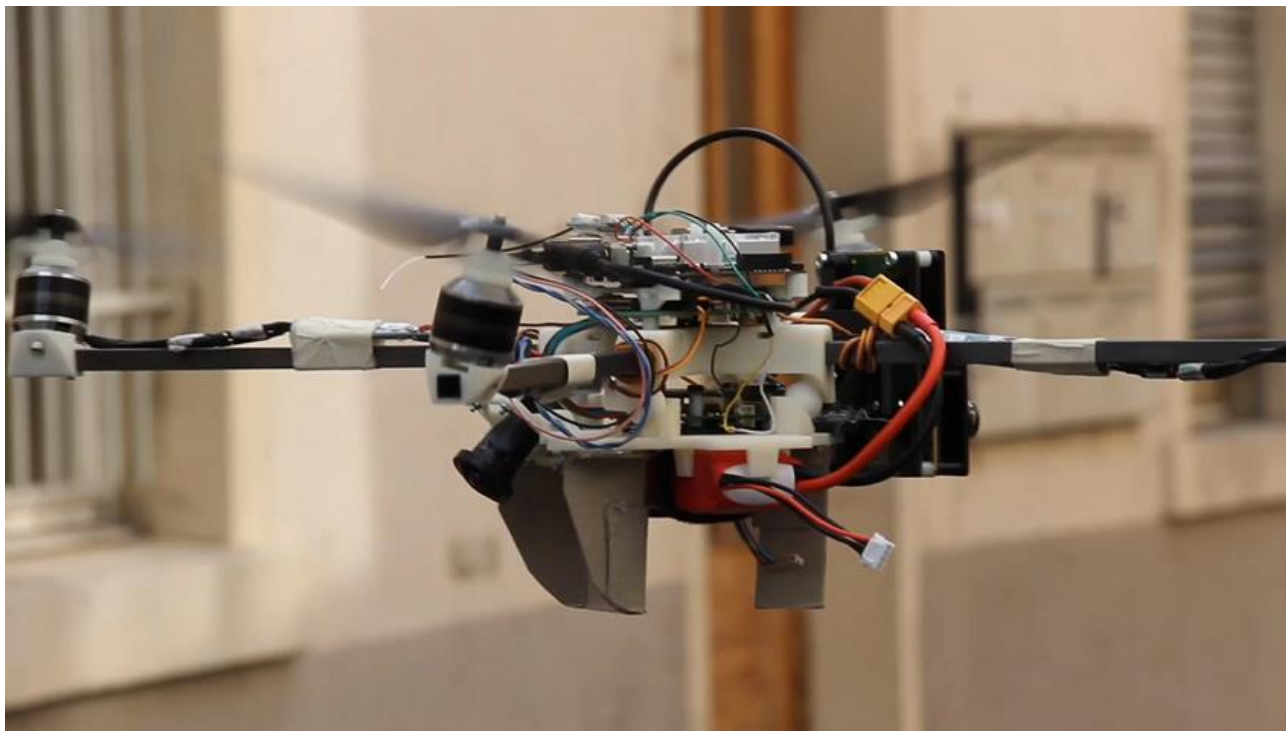
Image Sensor Sales

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

Enough PR ...
... Let's Talk Technology

What Is A Temporal Contrast Event?

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

$$e = \{x, y, \check{p}, \check{t}\} : \exists e_{x,y}[j] \left(\check{p} = \begin{cases} 1 \text{ for } \int_{T[j-1]}^{\check{t}} C_{x,y}^t(t) + \dot{N}_{x,y}(t) dt \geq \Theta^{ON} \\ 0 \text{ for } \int_{T[j-1]}^{\check{t}} C_{x,y}^t(t) + \dot{N}_{x,y}(t) dt \leq \Theta^{OFF} \end{cases} \right)$$

... the integral since the last timestamp...

... of the temporal contrast...

... and the noise ...

... is below ...

...or above a threshold

What is Temporal Contrast?

Temporal contrast is the rate of illumination change...

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

... 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 ...

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

... a **"temporal contrast step"**, ...

... or a fixed step factor.

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

Then What Makes Up a Temporal Contrast Step?

The “event magnitude” is ...

$$EM_{x,y}[j] = \Delta C_{x,y}^t(t_0, t_1) = \int_{T[j-1]}^{T[j]} \underbrace{\frac{d \log(I(k, t))}{dt}}_{\text{illumination change}} + \underbrace{\frac{dR}{dt}}_{\text{reflectance change}} - \underbrace{\frac{dR}{dx} \frac{dx}{dt}}_{\text{spatial contrast}} - \underbrace{\frac{dR}{dy} \frac{dy}{dt}}_{\text{optical flow}} dt$$

... the temporal contrast step encoded by one event, ...

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

So What To Do With Events

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

event magnitude (points to $EM_{x,y}[j]$)
illumination change (points to $\frac{d \log(I(k, t))}{dt}$)
reflectance change (points to $\frac{dR}{dt}$)
spatial contrast (points to $\frac{dR}{dx}$)
optical flow (points to $\frac{dx}{dt}$ and $\frac{dy}{dt}$)

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

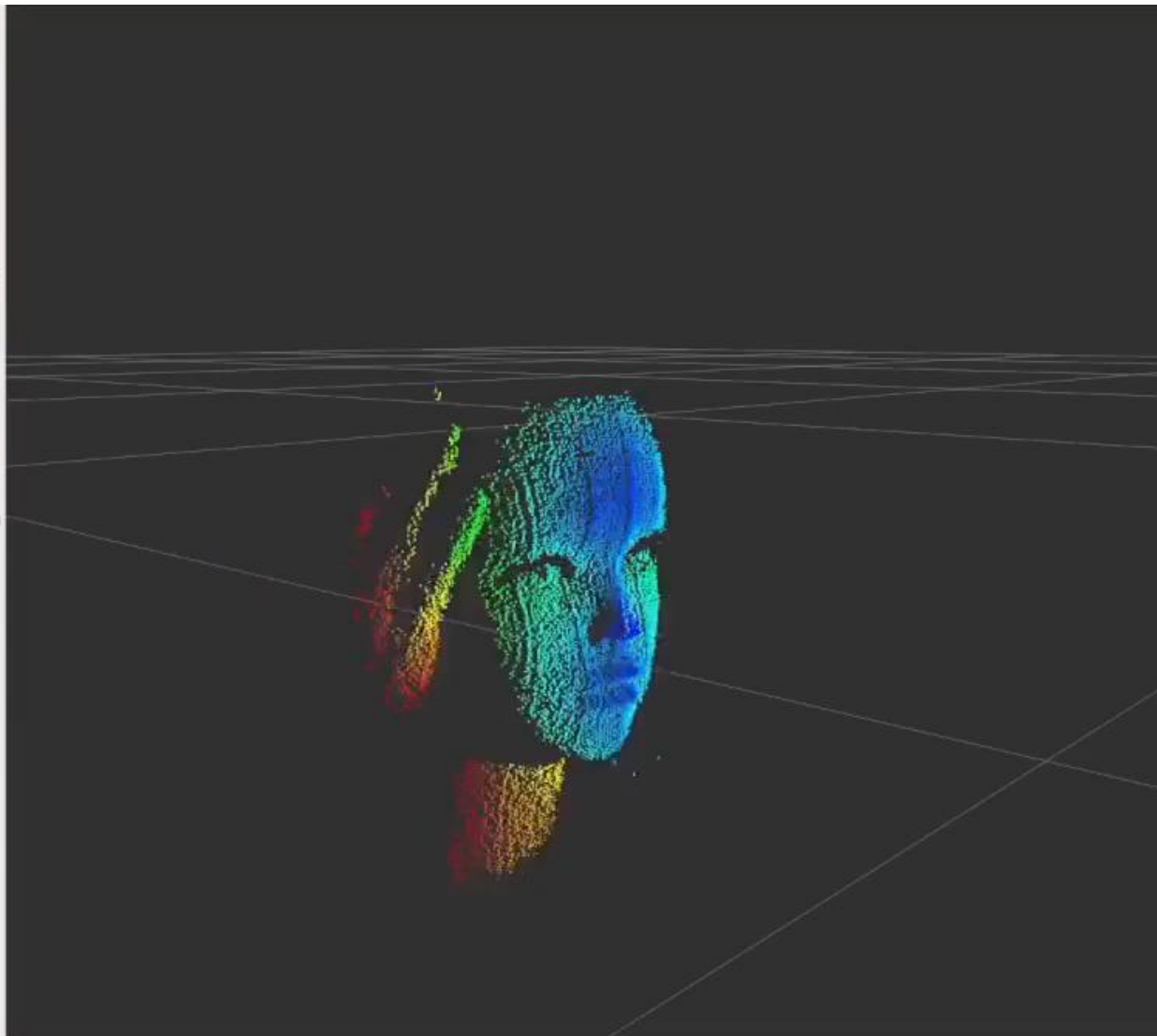
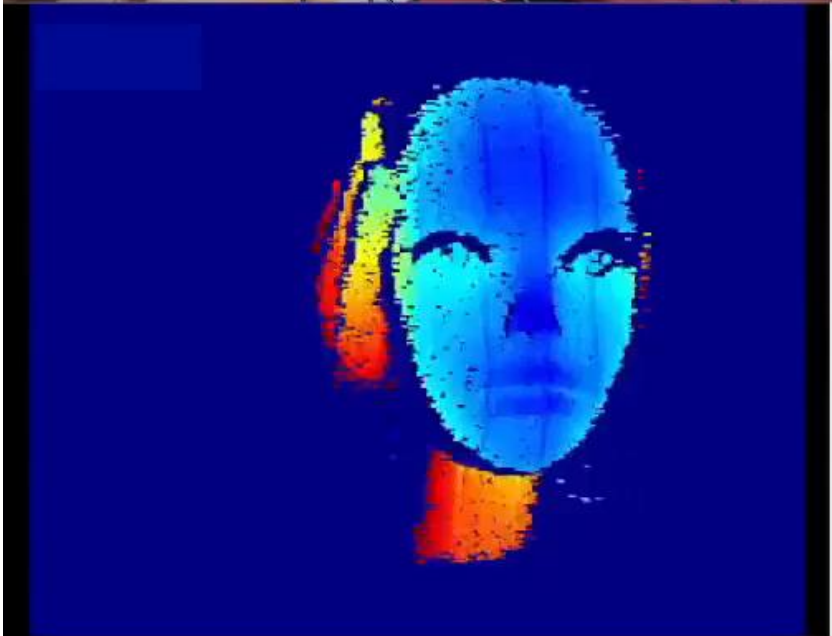
$$EM_{x,y}[j] = \int_{T[j-1]}^{T[j]} \boxed{\frac{d \log(I(k, t))}{dt}} + \frac{dR}{dt} - \frac{dR}{dx} \frac{dx}{dt} - \frac{dR}{dy} \frac{dy}{dt} dt$$

illumination change



Active Lighting

High-Speed 3D

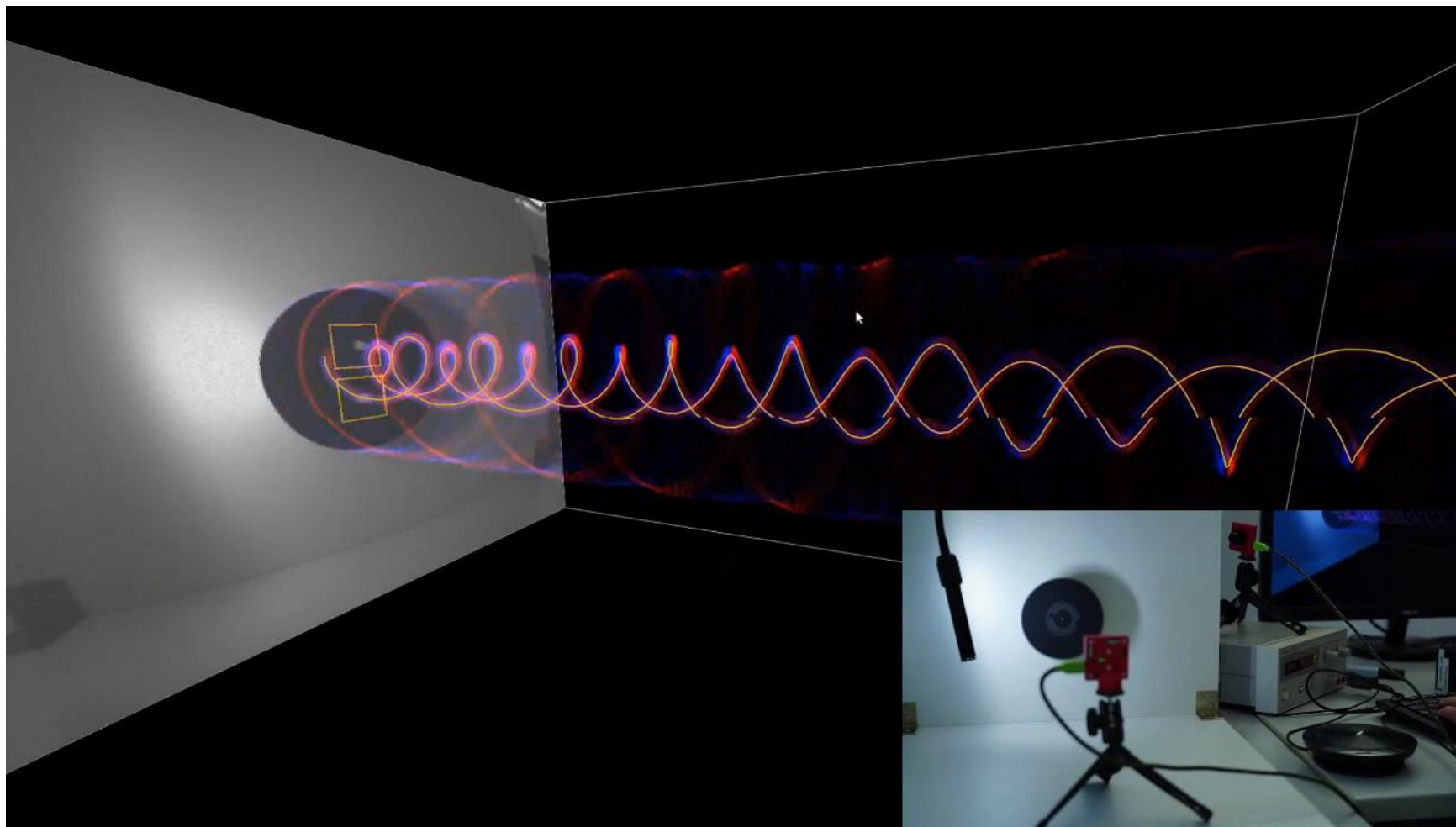


So What To Do With Events

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

optical flow
↓
Tracking

Very Fast Real-Time Tracking Of Dots



Better For Fast Motion than Open CV

Event-based



Replay speed: 0.5

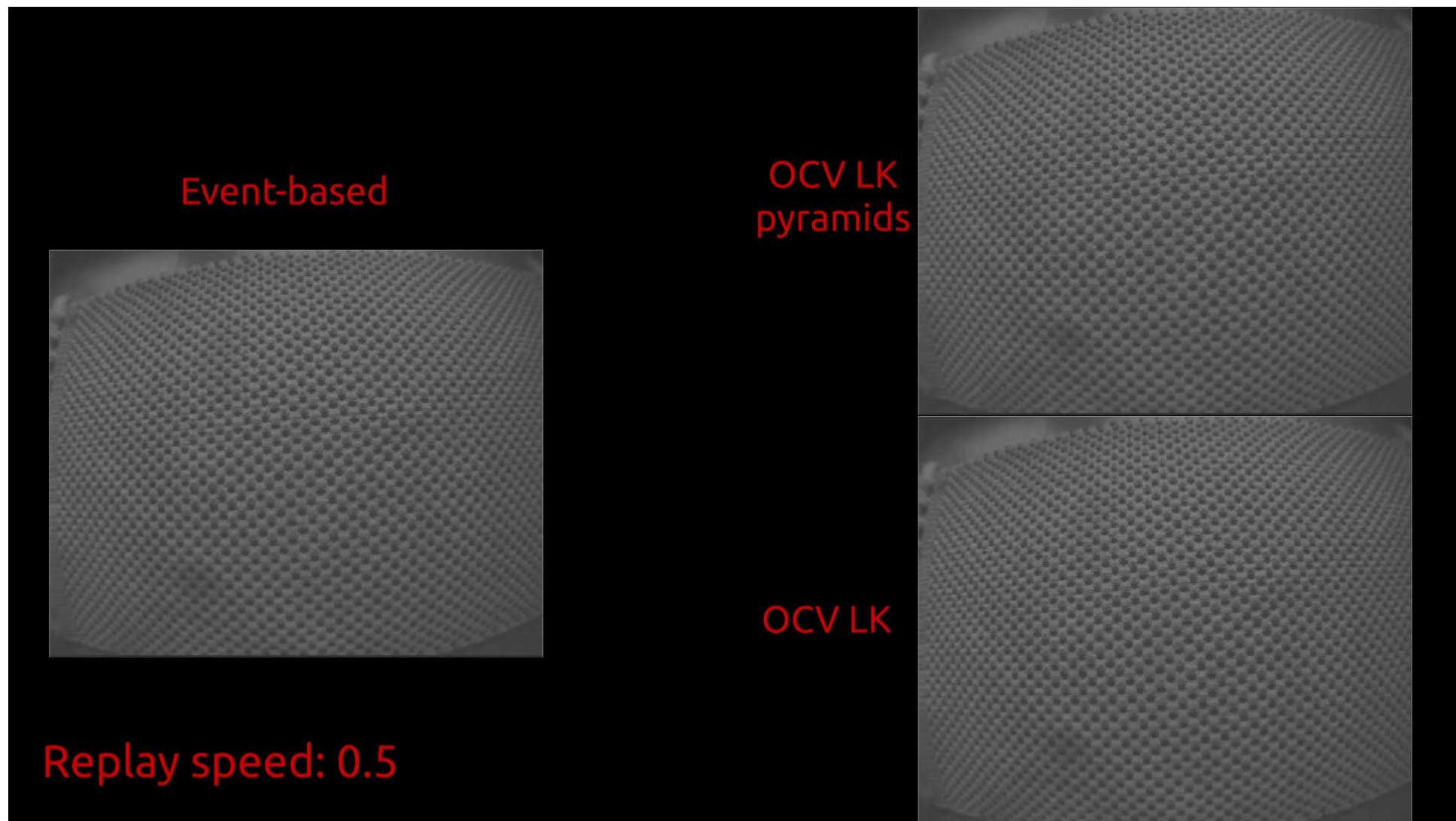
OCV LK
pyramids



OCV LK



And More Robust On Repetitive Structures



So What To Do With Events

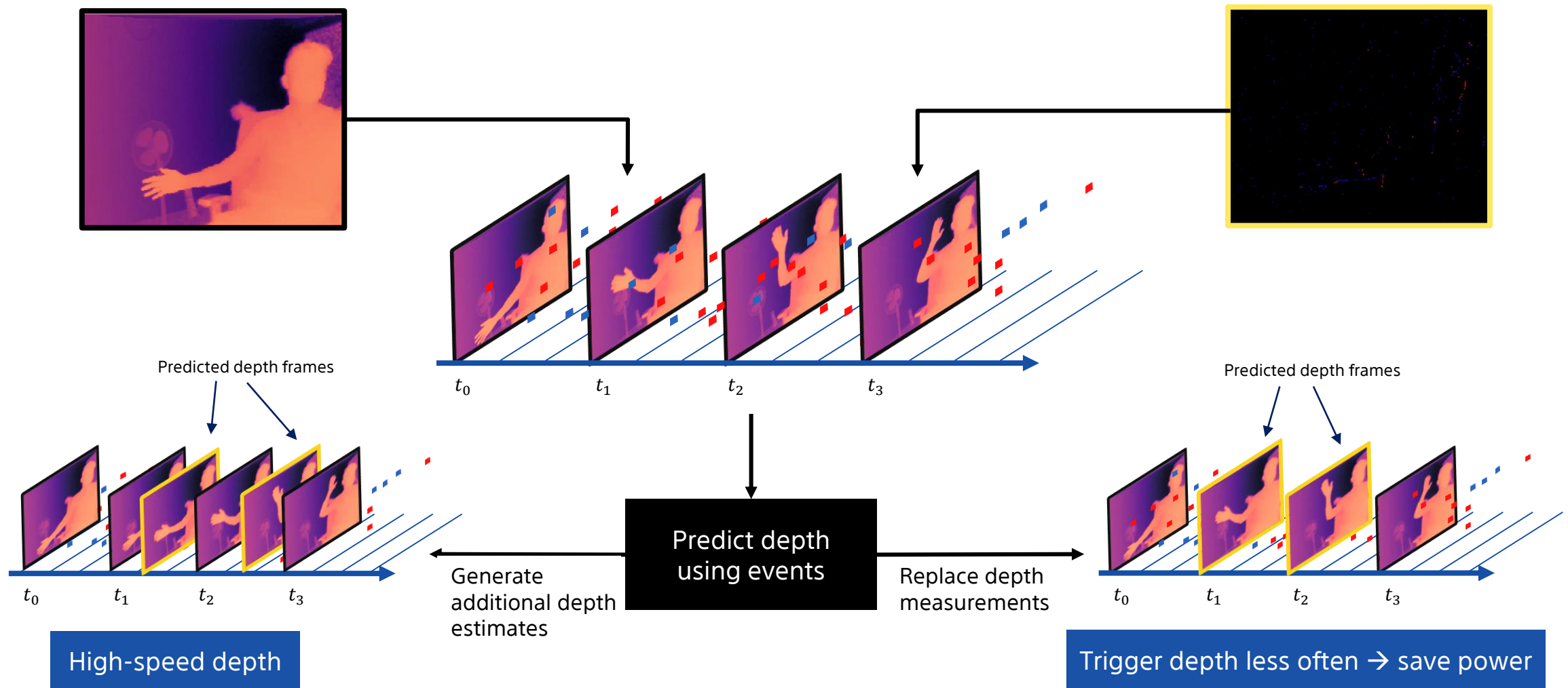
$$EM_{x,y}[j] = \int_{T[j-1]}^{T[j]} \frac{d \log(I(k, t))}{dt} + \frac{dR}{dt} - \boxed{\frac{dR}{dx}} \frac{dx}{dt} - \boxed{\frac{dR}{dy}} \frac{dy}{dt} dt$$

spatial contrast

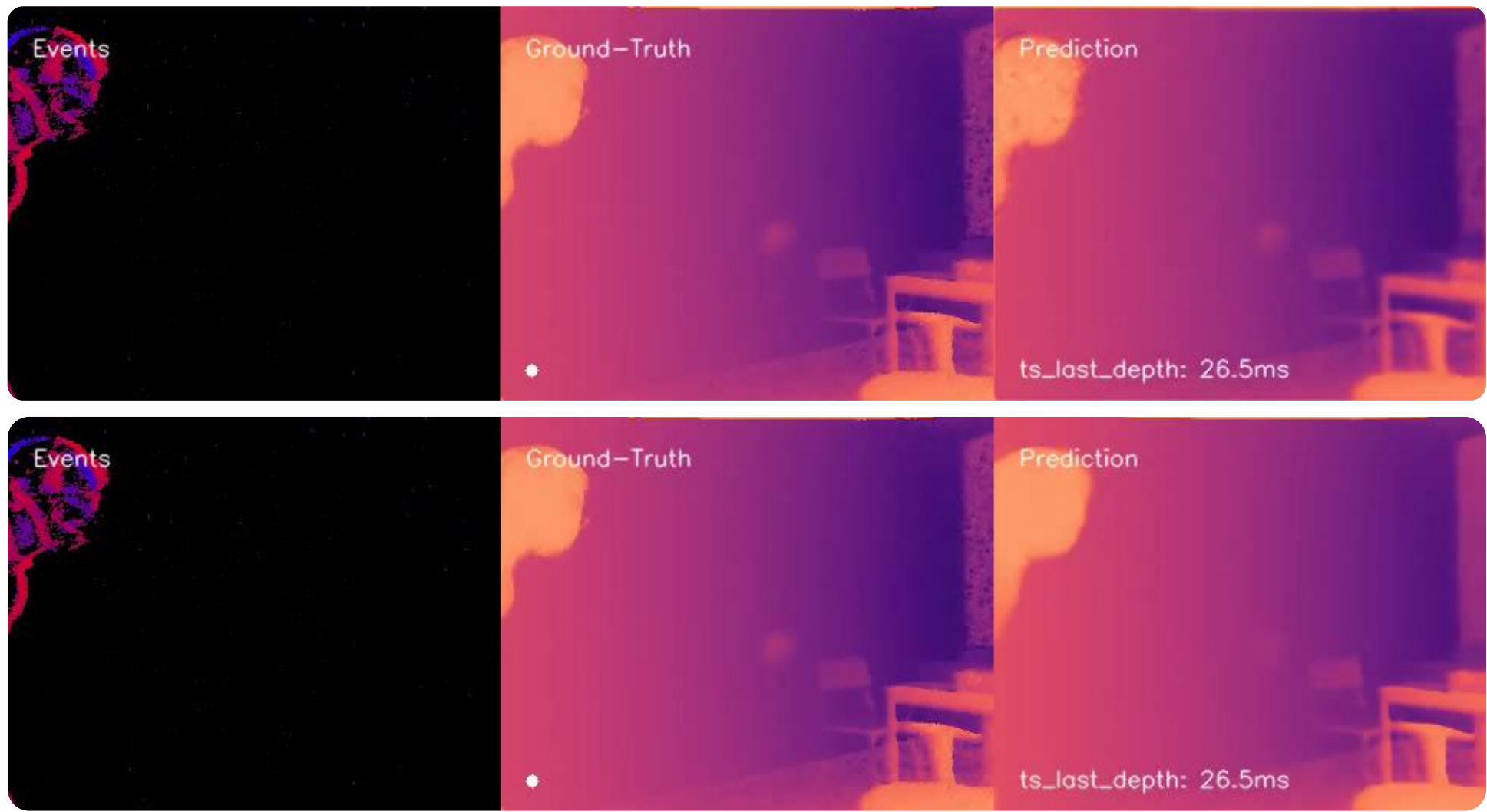


Reconstruction

Sensor Fusion of iToF and EVS for Efficient Depth Sensing



To Capture What Our Engineers Are Doing In the Office



If You Like To Work With The Latest And Greatest Sensors

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