Bringing a Blurry Frame Alive at High Frame-Rate with an Event Camera

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Problem Formulation

\[ \text{DAVIS} = \text{Intensity Image} + \text{events} \]

<table>
<thead>
<tr>
<th>Image</th>
<th>&gt;10ms latency</th>
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<tbody>
<tr>
<td>Events</td>
<td>&gt;0.02ms latency</td>
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Motivation

• High temporal resolution for events;
• Inherent blurry effects for images;

Event cameras are more likely to capture a blur image as it is designed for high dynamic motion scenery.

Possible Solution: reduce the exposure time – dark and noisy image.

• Existing computer vision algorithms designed for standard cameras cannot be applied to event cameras directly.
Our Goal

To reconstruct a **high frame-rate, sharp** video from a single blurry frame and its event data.
What is an Event?

$L$ is the intensity image, $f$ is the reference timestamp. The event is triggered when a change in the log intensity exceeds a given threshold $c$. 
What is an Event?

\[ \log(L(f)) + \text{Events} = \log(L(t)) \]

\[ E(t) = \int_f^t e(s) ds \]

\( E(t) \) denotes the integral of events between time \([f, t]\).
What is blur?

\[ B = \frac{1}{T} \int_{f-T/2}^{f+T/2} L(t) \, dt \]

\( B \) is the blur image, equals to the integral of the latent images during the exposure time \([f-T/2, f+T/2]\).
Pipeline – Event-based Double Integral (EDI)

Blur Image

Latent Images
Pipeline – Event-based Double Integral (EDI)
Model – First Integral

\[ L(t) = L(f) \exp(-cE(t)) \]

\[ E(t) = \int_{f}^{t} e(s) \, ds \]

Initial condition \( L(f) \) and threshold \( c \) are unknown.
Model – Second Integral

Blur Image

\[ B = \frac{1}{T} \int_{f-T/2}^{f+T/2} L(t) \, dt \]

Latent Images – L(t) sequence

\[ L(t) = L(f) \exp\left( c \int_{f}^{t} e(s) \, ds \right) \]

EDI

\[ B = \frac{L(f)}{T} \int_{f-T/2}^{f+T/2} \exp\left( c \int_{f}^{t} e(s) \, ds \right) \, dt \]
Model – Event-based Double Integral (EDI)

\[ B = \frac{L(f)}{T} \int_{f-T/2}^{f+T/2} \exp \left( c \int_{f}^{t} e(s) \, ds \right) \, dt \]

\[ \log(L(f)) = \log(B) - \log \left( \frac{1}{T} \int_{f-T/2}^{f+T/2} \exp \left( c \int_{f}^{t} e(s) \, ds \right) \, dt \right) \]
Finding \( c \)

Events

small \( c \)

large \( c \)

proper \( c \)

Reconstructed

Edge
Finding $c$

cross-correlation

Fibonacci search
Results

Blur Image

[1] Only use event
[3] Only use image

Events

[2] Event & Image
Ours Event & Image

Results

Input blur image

Output sharp video
Results

Input blur image

Output sharp video
Results

Input blur image

Output sharp video
High frame rate video generation

$t = 1$

$t = 2$

$t = 3$
Results

Average result of the reconstructed videos on dataset[4]

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<tbody>
<tr>
<td>PSNR(dB)</td>
<td>25.52</td>
<td>26.34</td>
<td>25.84</td>
<td>25.62</td>
<td>28.49</td>
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<tr>
<td>SSIM</td>
<td>0.7685</td>
<td>0.8090</td>
<td>0.7904</td>
<td>0.8556</td>
<td>0.9199</td>
</tr>
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When the input image is blur, a trivial solution would be:

- **Baseline 1**: Deblurring + Reconstruction
- **Baseline 2**: Reconstruction + Deblurring

Results

Baseline 1  Baseline 2  [2]  [3]

\(t = f - 1\)  \(t = f\)  \(t = f + 1\)  \(t = f + 2\)

Our
Thank you
Poster number - 136

Code, Data, Demo, and Extension Work