Neuromorphic Fringe Projection Profilometry

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I. Supplementary Material

In this document, we present the algorithmic details of two important steps in the neuromorphic technique reported in the main manuscript: (i) Conversion of event streams to wrapped phase; and (ii) compensation of shadows by inpainting.

A. From Event Streams to Wrapped Phase

The procedure to compute the phase map from the event streams is described in Algorithm 1. The wrapped phase matrix is denoted by W. The matrix E contains the event stream $s(x, y, t)$ at each of the pixel locations (x, y). The time-offset that encodes the depth at the pixel is the difference between the time of maximum temporal cross-correlation T_{max} and the start time t_0. We measure the start time t_0 for a reference pixel $(x_{\text{ref}}, y_{\text{ref}})$ that corresponds to the background. T_{max} is calculated using the formula described in Equation 2. Using the time-offset, we further calculate the wrapped phase at each pixel (x, y) using Equation 3. The time period P_{time} corresponds to the temporal frequency ω_0.

Algorithm 1: Calculation of the wrapped phase from the event stream.

Input : Event matrix E of dimensions $w_{\text{cam}} \times h_{\text{cam}}$ containing events corresponding to each of the pixel locations

Output: Wrapped phase matrix W of dimensions $w_{\text{cam}} \times h_{\text{cam}}$

Ref $\leftarrow (x_{\text{ref}}, y_{\text{ref}})$
$t_0 \leftarrow$ Start time of $s(x_{\text{ref}}, y_{\text{ref}}, t)$
for *Indices* (x, y) *in* E **do**
  $T_{\text{max}}(x, y) = \arg\max_t \langle s(x, y, t), s(x_{\text{ref}}, y_{\text{ref}}, t) \rangle$
  $W(x, y) \leftarrow \mod (T_{\text{max}}(x, y) - t_0, P_{\text{time}}) \cdot \frac{2\pi}{P_{\text{time}}}$
end

B. Compensation of Shadows by Inpainting

Algorithm 2 describes the inpainting process that compensates for the missing phase in the shadow regions. The pixels in the event matrix E that do not record any events are the shadow pixels. We inpaint these pixels using the precomputed wrapped phase matrix R of the fringe pattern without the object. The matrix W_{comp} contains the shadow-compensated or inpainted wrapped phase.

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Algorithm 2: Shadow compensation by inpainting.

Input : Event-stream matrix E
Reference image wrapped phase R
Wrapped phase image W

Output: Compensated wrapped phase image W_{comp}

for *Indices* (x, y) *in* E **do**
  if *E(x, y) is Empty* **then**
    $W_{\text{comp}} \leftarrow R(x, y)$
  else
    $W_{\text{comp}} \leftarrow W(x, y)$
  end
end

The code for the Neuromorphic Fringe Projection Profilometry (NFPP) technique reported in this paper is available here.