EyeGraph

Modularity-aware Spatio Temporal Graph Clustering for Continuous Event-based Eye Tracking

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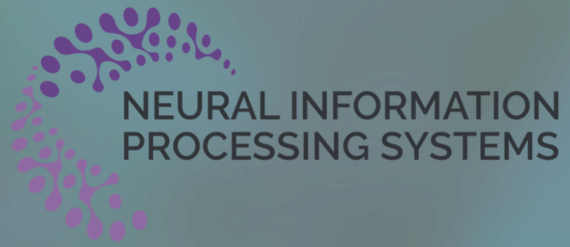
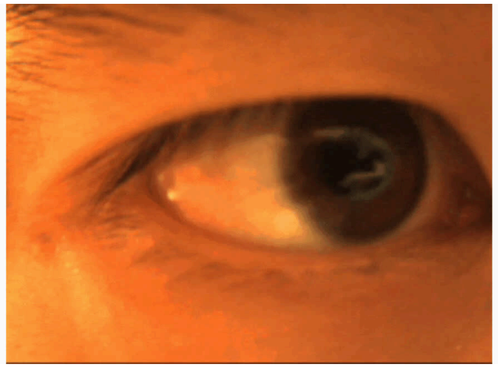


Continuous Eye Tracking

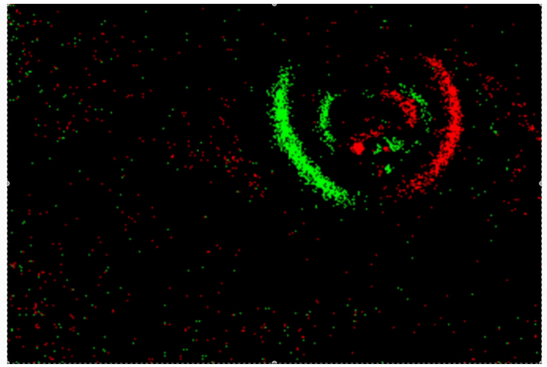
Why **Fine-grained, High-frequency** Eye Tracking?

RGB vs Event Vision

Eye, being the **fastest mechanical organ** in human body, exhibits **rapid** and **intricate** movements including **pupillary acceleration reaching values as high as 24, 000 deg/s²**



- Poor temporal resolution
- Higher susceptibility to motion blur and low lighting conditions
- Higher power consumption
- Synchronous and **Dense**



- **Higher temporal resolution**
- **Lower susceptibility to motion blur** and **low lighting** conditions
- **Lower power** consumption
- **Asynchronous** and Sparse

Event-based Eye Tracking

Approach Set 1: **RGB-guided** Pupil Localization in Events

Approach Set 2: **Exclusive Event-based** Pupil Localization

Suffers From

Mismatch with asynchronous event data

Dense 2D frames are **inadequate to capture full temporal** and geometric information

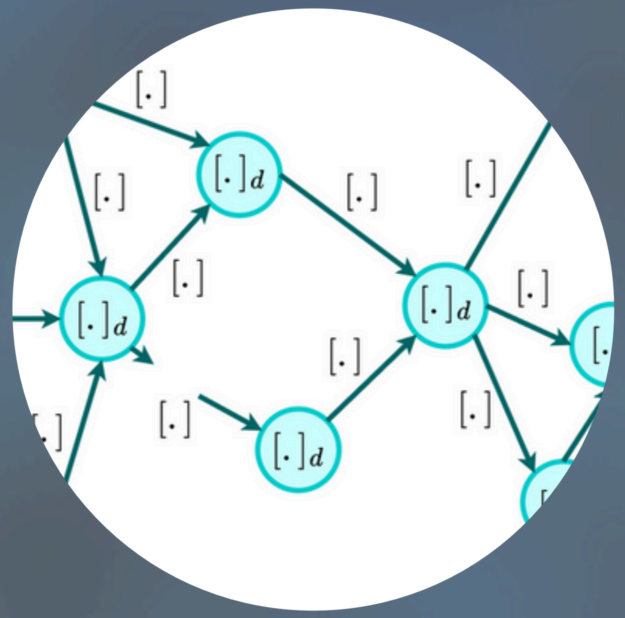
Further, both approaches have shortcomings of:

- Developed on datasets which lack **representativeness of real-world scenarios with varying illuminance and mobility**
- Guided by coarser labels present at fixed timesteps: **label sparsity**

To address the lack of representativeness of event eye tracking datasets

A large-scale multi-modal near-eye tracking monocular dataset collected while mimicking in-the-wild settings

To address the label sparsity, RGB-guidance and inadequate 2D representations

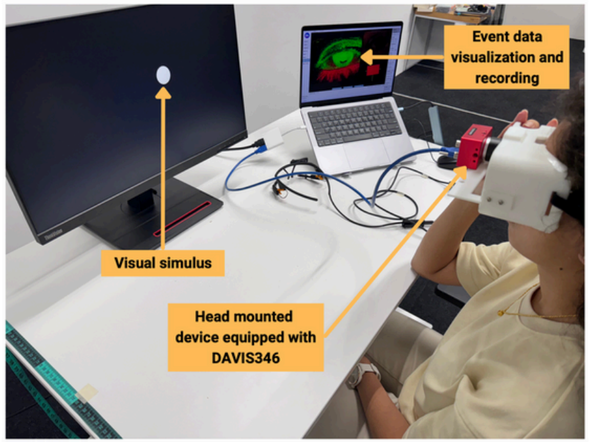


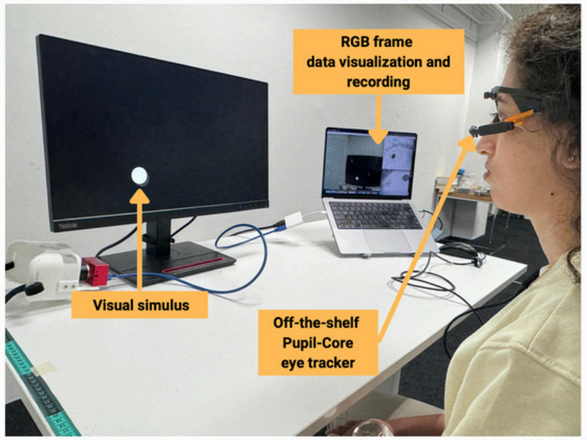
An unsupervised topology-aware graph-based approach for event-only eye tracking

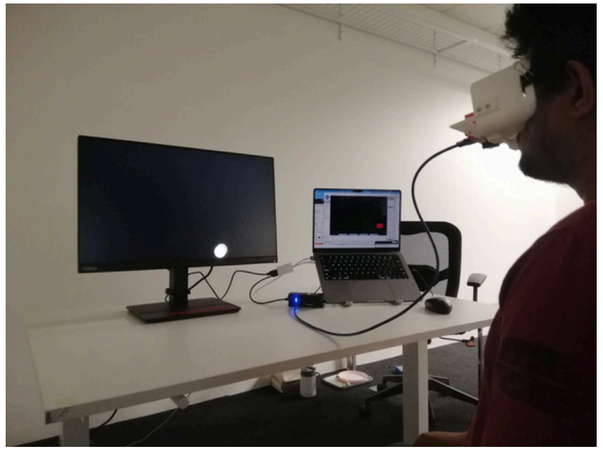
EyeGraph

EyeGraph In-the-wild Dataset

Monocularly collected from **40 participants**, who are **visual stimuli-guided**, using a **wearable event camera attached to a head-mounted device** under (1) **conventional lab** settings, (2) **changing** ambient **illuminance** and (3) **user mobility**





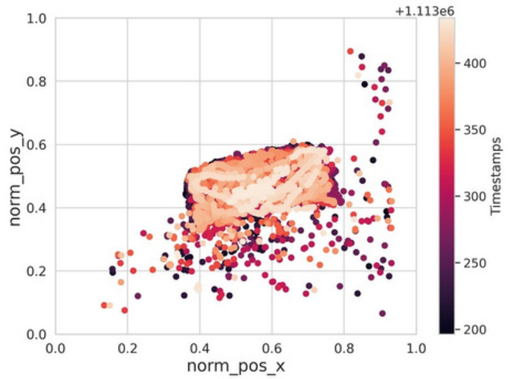


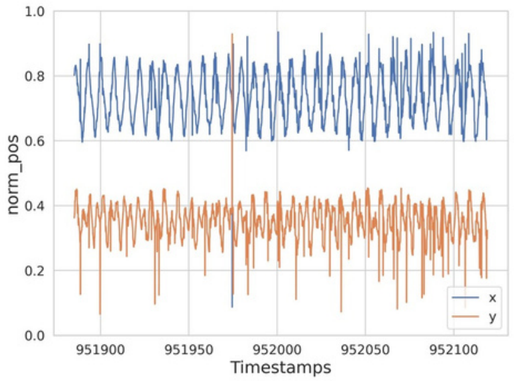
EyeGraph In-the-wild Dataset

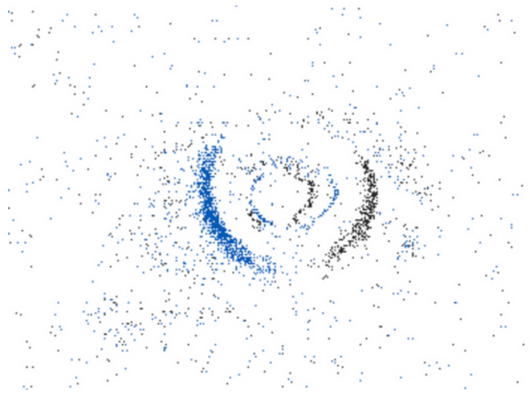
- **Pupil Tracking** as End Goal
- **Spatio-Temporal Graph** Representation
- **Unsupervised Learning**
- Accompanies **RGB Frame Data**
- **Monocular** and **Multi-modal**
- From **40 participants**

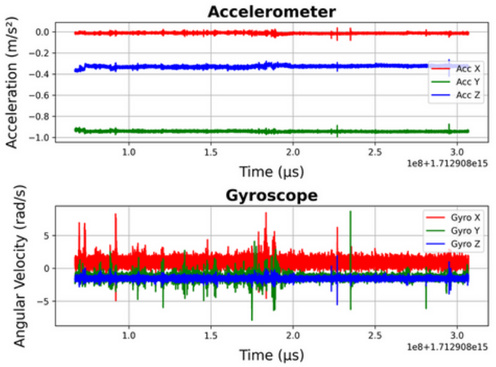
- Has **Off-the-shelf eye tracker data for cross modal investigations**
- Allowed and measured **head-movements**
- Allowed and measured **lighting changes**
- Accounts **participant mobility**

In overall, has nearly **3.3 billion events**, **2 million grayscale images** from event camera and **5 million video frames** from eye tracker (~115GB)

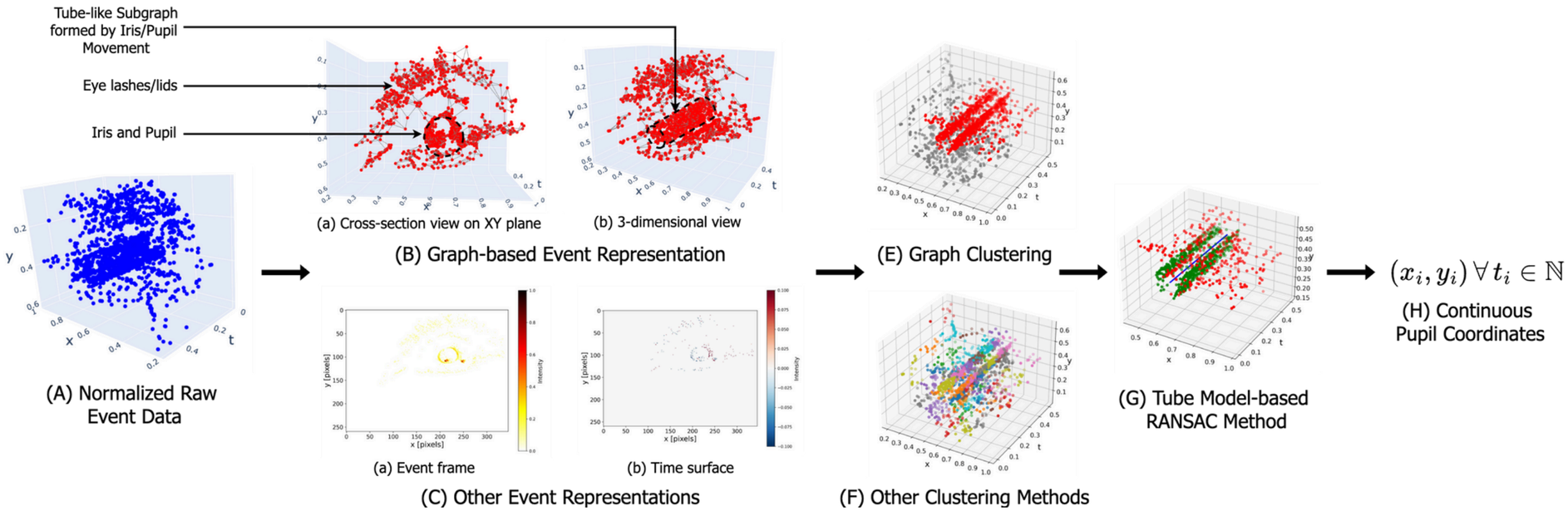








EyeGraph Method for Eye Tracking

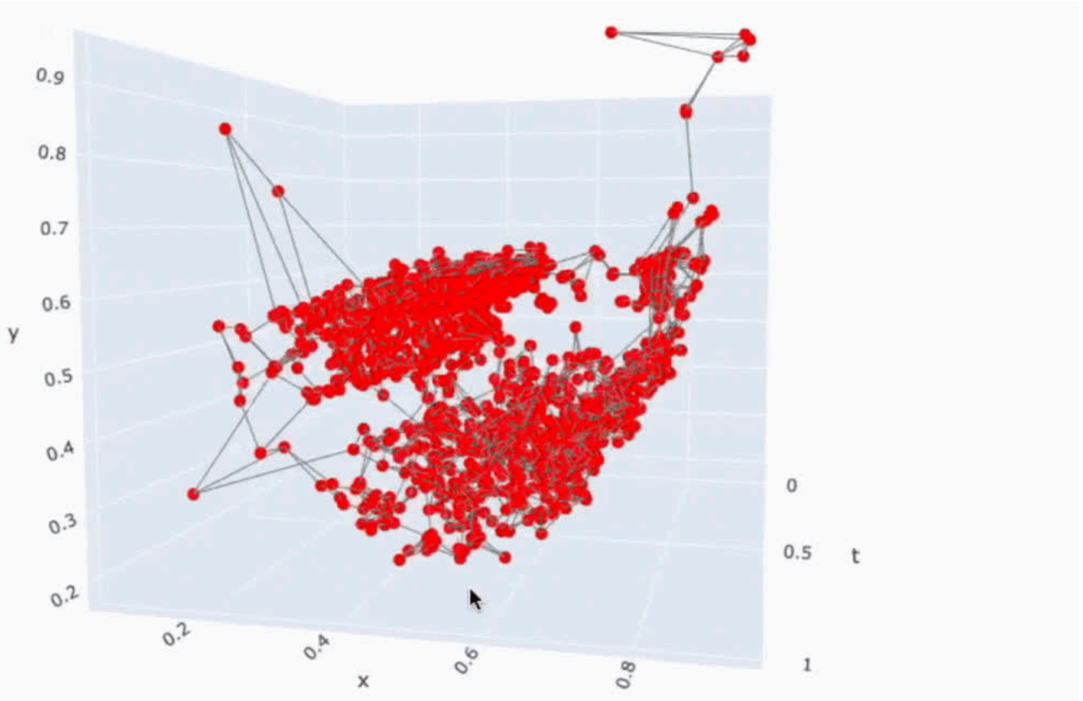


To **accurately** and **continuously** record eye movements **with high temporal resolution**, we (a) process sparse events as **asynchronously and temporally evolving graphs**, and (b) adopt an **unsupervised modularity-aware graph** learning to effectively **cluster distinct ocular regions** as a means for pupil tracking

EyeGraph Method for Eye Tracking

To generate **dynamic** and **temporally evolving spatio-temporal graphs**, we propose an **adaptive edge construction method** which focuses on a **Gaussian Mixture Model-based soft clustering** approach **to spatially group and temporally connect** distinct macroscopic parts of the human eye

Our novel **topologically guided modularity-aware graph clustering** approach **balances spatial proximity and temporal continuity** of events, while **accounting the modular structure** of the underlying graph representation, to **reflect the natural progression of gaze** behavior over time



EyeGraph Results, Impact and Future

- **Achieves tracking performance comparable to supervised approaches** while **consistently outperforming** other **unsupervised approaches,** even under **varying illuminance and mobility**

- **Future versions with more naturalistic in-the-wild studies** in both indoor and outdoor environments so as to capture finer-grained **continuous variation in illuminance**, and during **diverse set of physical activities**

- EyeGraph dataset will be instrumental in **studying fine-grained pupillary movements for diverse applications** while EyeGraph methods will also be useful in other domains such as **automotive vision** and **robotics**

THANK YOU

Check out more details and upcoming releases of EyeGraph at

https://eye-tracking-for-physiological-sensing.github.io/eyegraph/

If needed clarifications, please contact us at

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