OpenSFEDS dataset

Introduction

The OpenSFEDS dataset (Open Sensor Fusion Eyes Data Set) is a novel dataset of 2.25M synthetic, time-synchronized eye-image pairs captured using a simulated RGB camera (640 x 480 px) and a set of 16 simulated photosensors placed on an on-axis sensor grid. The dataset has been created using a simulation framework based on UnityEyes [1, 2, 3], allowing for the synthesis of wide subjects' appearance, illumination, and camera position variability. The dataset includes two subsets:

- *OpenSFEDS-Static*: 450K independent image pairs, with uniform gaze distribution covering ±25◦ of visual angle.
- *OpenSFEDS-Temporal*: 1.8K, 2s sequences of image pairs at 500 Hz with gaze extracted from real eye movement traces of the GazeBase dataset [4], featuring smooth pursuits, fixations, and saccades.

The paper introducing and describing the dataset is available here.

Each camera-photosensor image pair belongs to a dataset *sample*. Each sample is defined by the fixed or variable appearance of the left periocular region of a synthetic identity, with given gaze direction, sensor grid locations, and scene configuration (e.g., illumination). These attributes are referred to as metadata, and are provided alongside each image pair for each dataset sample. In practice, photosensor intensity values are provided within the metadata files instead of providing them as images. The dataset is provided with subject-independent train-test splits following a 4:1 ratio.

Gaze direction (`g_x` and `g_y`) is given in degrees in the eye-in-head coordinate system (x – eye rotation about the X axis/vertical movement, positive downward; y – eye rotation about the Y axis/horizontal movement, positive towards nose). It can be converted to the camera coordinate system following the provided sensor grid translation and rotation information (see the paper supplementary material for more details on the coordinate system).

Both data subsets follow the same folder structure:

```
- <dataset name>/
    - <split>/
        - metadata.csv
        - HDCam/
            - <identity>/
                - <unique_id>.jpg
                - ...
            - ...
    - ...
```

We also provide the following additional data, which will be described below:

```
- fixed_identity_features.csv
- OpenSFEDS-Temporal_additional/
```

- gazebase_mapping.csv
- eyemov_classification_test.csv

Subject identities and generated fixed variability

The dataset features 60 synthetic identities. Each identity is characterized by a set of attributes illustrated in Table 1, referred to as *fixed variability* in the paper, and provided in the f*ixed_identity_features.csv* file. Translation and rotation of the sensor grid is defined by per-person face and head anatomy differences, sampled from an empirical distribution. Subject identities are shared between Static and Temporal data subsets.

Variable	Description
identity	Subject identifier
iris_size	Size of iris (factor)
iris_texture	Iris texture identifier (following UnityEyes nomenclature)
skin_texture	Skin texture identifier (following UnityEyes nomenclature)
pca_coeffs	PCA coefficients of the periocular region for the given subject identity
bottom_lashes	Length of bottom lashes (factor)
top_lashes	Length of top lashes (factor)
eyeball_rot_z	Rotation of the eyeball about the Z axis (degrees)
x_trans	Horizontal translation of the sensor grid wrt. the origin of coordinates (center of the eye) in cm
y_trans	Vertical translation of the sensor grid wrt. the origin of coordinates (center of the eye) in cm
z_trans	Translation in Z axis of the sensor grid wrt. the origin of coordinates (center of the eye) in cm
x_rot	Rotation of the sensor grid about the X axis wrt. the origin of coordinates (center of the eye) in degrees (pitch)
y_rot	Rotation of the sensor grid about the Y axis wrt. the origin of coordinates (center of the eye) in degrees (yaw)
z_rot	Rotation of the sensor grid about the Z axis wrt. the origin of coordinates (center of the eye) in degrees (roll)
pupil_size	Size of the pupil (factor)

Table 1. Attributes provided for each synthetic identity of OpenSFEDS

OpenSFEDS-Static

The metadata provided for each sample of the OpenSFEDS-Static data subset is described in Table 2. Each row of the metadata file is associated with one sample of the dataset. Translation and rotation of the sensor grid is performed on top of the fixed per-subject variability to simulate sensor shifts, sampled from an empirical distribution. These translation and rotation shifts, in addition to pupil size and scene illumination changes, are referred to as *variable variability* in the paper. However, the provided metadata files already provide the combined fixed+variable variability values.

Variable	Description

unique_id	Unique identifier of each image, in the form of <run_id>_<sample_id>. it associates each metadata row with an image (it's the image file name)
g_x	Rotation of the eyeball about the X axis (vertical movement) in degrees
g_y	Rotation of the eyeball about the Y axis (horizontal movement) in degrees
identity	Subject identifier
run_id	ID of the run of a full-sized gaze grid
sample_id	ID of the sample within a full-sized gaze grid
x_trans	Horizontal translation of the sensor grid wrt. the origin of coordinates (center of the eye) in cm
y_trans	Vertical translation of the sensor grid wrt. the origin of coordinates (center of the eye) in cm
z_trans	Translation in Z axis of the sensor grid wrt. the origin of coordinates (center of the eye) in cm
x_rot	Rotation of the sensor grid about the X axis wrt. the origin of coordinates (center of the eye) in degrees (pitch)
y_rot	Rotation of the sensor grid about the Y axis wrt. the origin of coordinates (center of the eye) in degrees (yaw)
z_rot	Rotation of the sensor grid about the Z axis wrt. the origin of coordinates (center of the eye) in degrees (roll)
pupil_size	Size of the pupil (factor)
intensity	Illumination intensity (factor)
amp_0-amp_15	Intensity values of the 16 photodiodes (row-major order)

Table 2. Attributes provided for each sample of OpenSFEDS-Static

OpenSFEDS-Temporal

The metadata provided for each sample of the OpenSFEDS-Temporal data subset is described in Table 3. Each row of the metadata file is associated with one sample of the dataset. Variable variability is applied as for OpenSFEDS-Static.

For completeness, in the `gazebase_mapping.csv` file (`OpenSFEDS-Temporal_additional` folder) we provide the filenames of the sequences used from GazeBase, associated to each of the subsequences of the OpenSFEDS-Temporal data subset, in the format illustrated in Table 4. GazeBase filenames implicitly include the anonymized participant identifier, round, session, and task performed.

Variable	**Description**
unique_id	Unique identifier of each image, in the form of <subsequence_id>_<n>. It associates each metadata row with an image (the image file name)
n	Number of frame within sequence after downsampling
real_n	Number of frame within sequence before downsampling (real_n = n*2 + 1)
g_x	Rotation of the eyeball about the X axis (vertical movement)
g_y	Rotation of the eyeball about the Y axis (horizontal movement)
identity	Subject identifier

subsequence_id	Subsequence identifier
x_trans	Horizontal translation of the sensor grid wrt. the origin of coordinates (center of the eye) in cm
y_trans	Vertical translation of the sensor grid wrt. the origin of coordinates (center of the eye) in cm
z_trans	Translation in Z axis of the sensor grid wrt. the origin of coordinates (center of the eye) in cm
x_rot	Rotation of the sensor grid about the X axis wrt. the origin of coordinates (center of the eye) in degrees (pitch)
y_rot	Rotation of the sensor grid about the Y axis wrt. the origin of coordinates (center of the eye) in degrees (yaw)
z_rot	Rotation of the sensor grid about the Z axis wrt. the origin of coordinates (center of the eye) in degrees (roll)
pupil_size	Size of the pupil (factor)
intensity	Illumination intensity (factor)
amp_0-amp_15	Intensity values of the 16 photodiodes (row-major order)

Table 3. Attributes provided for each sample of OpenSFEDS-Temporal

Variable	**Description**
real_n	Number of frame within sequence (same as `real_n' from OpensFEDS-Temporal metadata)
subsequence_id	Subsequence identifier to which the given frame belongs (same as `subsequence_id' from OpensFEDS-Temporal metadata)
file	Name of file from GazeBase to which the given frame belongs

Table 4. Additional information provided for OpenSFEDS-Temporal, to map the provided sequences with the original data from the GazeBase dataset

Reproducing the paper

In the paper, the train split is further divided into subject-independent training and validation splits to select the best architecture and hyperparameters of each evaluated approach. The identities used for validation are:

```
['identity_000044', 'identity_000129', 'identity_000328', 'identity_000
443', 'identity_000502', 'identity_000556', 'identity_000638', 'identit
y_000699', 'identity_000707', 'identity_000828', 'identity_000874', 'id
entity_000927']
```

The eye movements featured in the OpenSFEDS-Temporal test split are classified into *saccades*, *fixation/smooth pursuit*, and *other* to evaluate the performance as a function of eye movement type. Classification was carried out with the I-VT method of [5] using a saccade threshold of 70 deg/s. We provide the computed events in the `eyemov_classification_test.csv` file (`OpenSFEDS-Temporal_additional` folder).

References

[1] Erroll Wood, Tadas Baltrušaitis, Louis-Philippe Morency, Peter Robinson, and Andreas Bulling. 2016a. A 3D Morphable Eye Region Model for Gaze Estimation. In Proc. European Conference on Computer Vision. 297–313.

[2] Erroll Wood, Tadas Baltrušaitis, Louis-Philippe Morency, Peter Robinson, and Andreas Bulling. 2016b. Learning an appearance-based gaze estimator from one million synthesised images. In ACM Symp. Eye Tracking Research and Applications. 131–138.

[3] Erroll Wood, Tadas Baltrušaitis, Xucong Zhang, Yusuke Sugano, Peter Robinson, and Andreas Bulling. 2015. Rendering of Eyes for Eye-Shape Registration and Gaze Estimation. In Proc. IEEE International Conference on Computer Vision. 3756–3764.

[4] Henry Griffith, Dillon Lohr, Evgeny Abdulin, and Oleg Komogortsev. Gazebase, a large-scale, multi-stimulus, longitudinal eye movement dataset. Scientific Data, 8(1):1–9, 2021.

[5] Oleg V. Komogortsev, and Alexey Karpov. 2013. Automated classification and scoring of smooth pursuit eye movements in the presence of fixations and saccades. Behavior research methods, 45, 203-215.