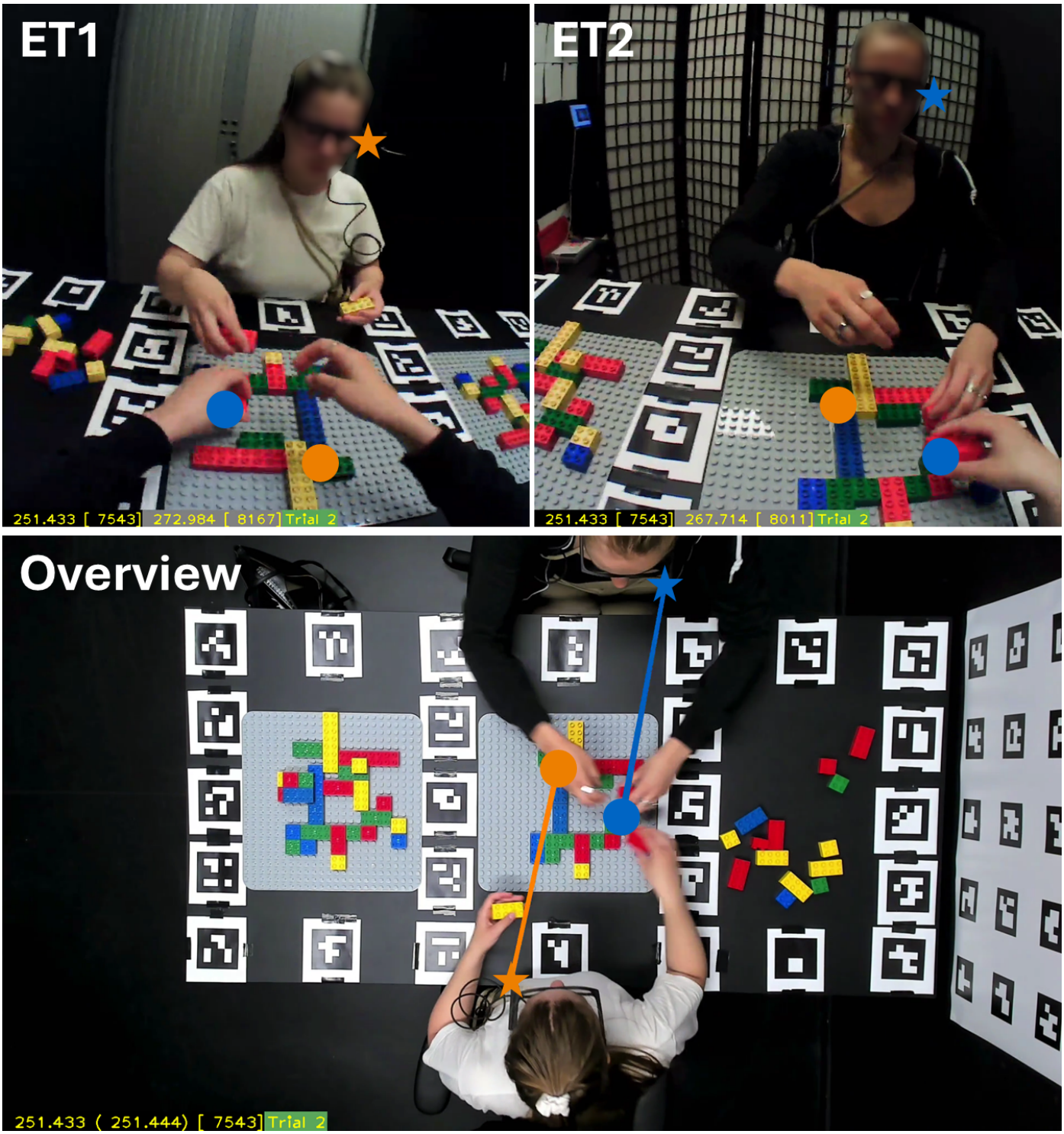
gazeMapper v1.4.1

Tool for automated world-based analysis of wearable eye tracker data. gazeMapper is an open-source tool for automated mapping and processing of eye-tracking data to enable automated world-based analysis. gazeMapper can:

1. Transform head-centered data to one or multiple planar surfaces in the world.
2. Synchronize recordings from multiple participants, and external cameras.
3. Determine data quality measures, e.g., accuracy and precision using glassesValidator (Niehorster et al., 2023).

If you use this tool or any of the code in this repository, please cite:
Niehorster, D.C., Hessels, R.S., Nyström, M., Benjamins, J.S. and Hooge, I.T.C. (submitted). gazeMapper: A tool for automated world-based analysis of gaze data from one or multiple wearable eye trackers. Manuscript submitted for publication, 2024 (BibTeX)
If you use the functionality for automatic determining the data quality (accuracy and precision) of wearable eye tracker recordings, please additionally cite:
Niehorster, D.C., Hessels, R.S., Benjamins, J.S., Nyström, M. and Hooge, I.T.C. (2023). GlassesValidator: A data quality tool for eye tracking glasses. Behavior Research Methods. doi: 10.3758/s13428-023-02105-5 (BibTeX)

Example



Example where gazeMapper has been used to map head-centered gaze from two head-worn eye tracker recordings to synchronized world-centered gaze data of the pair, drawn on an overview video recording with an additional external camera. From Hessels, R.S., Iwabuchi, T., Niehorster, D.C., Funawatari, R., Benjamins, J.S., Kawakami, S.; Nyström, M., Suda, M., Hooge, I.T.C., Sumiya, M., Heijnen, J., Teunisse, M. & Senju, A. (submitted). Gaze behavior in face-to-face interaction: A cross-cultural investigation between Japan and the Netherlands. Manuscript submitted for publication, 2024

How to acquire

GazeMapper is available from `https://github.com/dcnieho/gazeMapper`, and supports Python 3.11 on Windows, MacOS and Linux (newer versions of Python should work fine but are not tested).

For Windows users who wish to use the gazeMapper GUI, the easiest way to acquire gazeMapper is to download a standalone executable. The standalone executable is not available for MacOS or Linux. Complete installation instruction for MacOS and Linux users are available below.

For users on Windows, Mac or Linux who wish to use gazeMapper *in their Python code*, the easiest way to acquire gazeMapper is to install it directly into your Python distribution using the command `python -m pip install gazeMapper`. If you run into problems on MacOS to install the `imgui_bundle` package, you can try to install it first with the command `SYSTEM_VERSION_COMPAT=0 pip install --only-binary=:all: imgui_bundle==1.6.2`. Note that this repository itself is pip-installable as well: `python -m pip install git+https://github.com/dcnieho/gazeMapper.git#egg=gazeMapper`. NB: on some platforms you may have to replace `python` with `python3` in the above command lines.

Once pip-installed in your Python distribution, there are three ways to run the GUI on any of the supported operating systems:

1. Directly in the terminal of your operating system, type `gazeMapper` and run it (NB: this does not appear to work in Anaconda environments, use one of the below methods for those).
2. Open a Python console. From such a console, running the GUI requires only the following two lines of code:

```
import gazeMapper
gazeMapper.GUI.run()
```

3. If you run the gazeMapper's GUI from a script, make sure to wrap your script in `if __name__=="__main__"`. This is required for correct operation from a script because the GUI uses multiprocessing functionality. Do as follows:

```
if __name__=="__main__":
    import gazeMapper
    gazeMapper.GUI.run()
```

Complete instructions for MacOS

Installing and running gazeMapper on a Mac will involve some use of the terminal. In this section we will show you step by step how to install, and then what to do every time you want to run gazeMapper. Note that it is critical on MacOS that gazeMapper is installed natively, and not under Rosetta or Parallels. That will lead to an error when importing the `polars` package, and other unfixable errors. If you are not sure what kind of system you have, consult this page to learn how to find out.

Installing gazeMapper

1. To acquire and manage Python, install Anaconda by following these instructions. Additional notes:
    1. Choose the graphical installer.
    2. When clicking the installer link provided in these instructions, you may first be shown a user registration page. You can click "skip registration" there to directly go to the download files.
    3. Ensure that you choose the correct installer for your system (Intel or Apple Silicon). If you are not sure what kind of system you have, consult this page to learn how to find out.
2. Once anaconda is installed, open the Terminal application.
3. You now first need to make an environment with the correct Python version in which you can then install gazeMapper. To do so, type `conda create -n gazeMapper-env python=3.11 pip` and run the command. `gazeMapper-env` is the name of the environment you create with this comment.
4. Activate the environment you have just created: `conda activate gazeMapper-env`.
5. Now you need to install gazeMapper. Do the following in the below order:
    1. Type and run `SYSTEM_VERSION_COMPAT=0 pip install --only-binary=:all: imgui_bundle==1.6.2`
    2. Type and run `pip install gazeMapper`.

Updating gazeMapper

If you already have gazeMapper installed but want to update it to the latest version, do the following:

1. Open the Terminal application.
2. Activate the environment in which you have gazeMapper installed: type and run `conda activate gazeMapper-env`, where `gazeMapper-env` is the name of the environment you created using the above instructions. If you use an environment with a different name, replace the name in the command.
3. Type and run `SYSTEM_VERSION_COMPAT=0 pip install --only-binary=:all: imgui_bundle==1.6.2`
4. Type and run `pip install gazeMapper --upgrade`.

Running gazeMapper

If you have followed the above instructions to install gazeMapper, do the following each time you want to run gazeMapper:

1. Open the Terminal application.
2. Activate the environment in which you have gazeMapper installed: type and run `conda activate gazeMapper-env`, where `gazeMapper-env` is the name of the environment you created using the above instructions. If you use an environment with a different name, replace the name in the command.
3. Start the Python interpreter: type and run `python`.
4. Type and run `import gazeMapper`.
5. Type and run `gazeMapper.GUI.run()`.

Complete instructions for Linux

Installing and running gazeMapper on Linux will involve some use of the terminal. In this section we will show you step by step how to install, and then what to do every time you want to run gazeMapper.

Installing gazeMapper

1. You may well already have Python installed on your machine. To check, type and run `python3 --version` in a terminal. If this command completes successfully and shows you have Python 3.10 or later, you can skip to step 3.
2. To install Python, check what is the appropriate command for your Linux distribution. Examples would be `sudo apt-get update && sudo apt-get install python3.11` for Ubuntu and its derivatives, and `sudo dnf install python3.11` for Fedora. You can replace `python3.11` in this command with a different version (minimum 3.10).
3. Make a new folder from where you want to run gazeMapper, e.g. `mkdir gazeMapper`. Enter this folder: `cd gazeMapper`.
4. You now first need to make an environment in which you can then install gazeMapper. To do so, type `python3 -m venv .venv` and run the command.

5. Activate the environment you have just created: `source .venv/bin/activate`.
6. Now you need to install gazeMapper. To do so, type and run `pip install gazeMapper`.

Updating gazeMapper

If you already have gazeMapper installed but want to update it to the latest version, do the following:

1. Open the Terminal application.
2. Navigate to the gazeMapper install location and activate the environment in which you have gazeMapper installed: type and run `source .venv/bin/activate` in the location where you installed gazeMapper.
3. Type and run `pip install gazeMapper --upgrade`.

Running gazeMapper

If you have followed the above instructions to install gazeMapper, do the following each time you want to run gazeMapper:

1. Open the Terminal application.
2. Navigate to the gazeMapper install location and activate the environment in which you have gazeMapper installed: type and run `source .venv/bin/activate` in the location where you installed gazeMapper.
3. Type and run `gazeMapper`.

Usage

To use gazeMapper, first a recording session needs to be defined for the project. This entails telling gazeMapper which eye tracker and external camera recording(s) to expect, and what planes to map gaze to. The very simplest setup consists of a single eye tracker recording per session and a single plane to map gaze to, but multiple planes and any number of eye tracker and external camera recordings per session is supported. Sessions consisting of only a single external camera recording are not supported, at least one eye tracker recording should be included. Once this setup has been performed, new sessions can be created and recordings imported to the defined eye tracker and external camera recording slots of these new sessions. Once imported, further processing can commence.

The gazeMapper package includes a graphical user interface (GUI) that can be used to perform all configuration and processing. Below we describe three example workflows using the GUI. While most of gazeMapper's functionality will be used in these examples. For a full description of all configuration options, the reader is referred to the configuration section of this readme.

Besides using the GUI, advanced users can instead opt to call all of gazeMapper's functionality directly from their own Python scripts without making use of the GUI. The interested reader is referred to the API section below for further details regarding how to use the gazeMapper functionality directly from their own scripts.

Workflow and example data

Here we first present example workflows using the GUI. More detailed information about gazeMapper configuration is provided below. We strongly recommend new users to first work through these examples to see how gazeMapper works before starting on their own projects.

Examples:

1. Example 1 is a minimum example, using a single eye tracker recording per session and a single plane to map gaze to, along with a glassesValidator setup for determining data quality.
2. Example 2 is a more elaborate version of example 1, using two eye trackers recording per session that have to be synchronized and two planes to map gaze to (again along with a glassesValidator setup for determining data quality).
3. Example 3 is a recording where a participants looks at and interacts with multiple planes, including a moving plane, and is furthermore observed with an external overview camera. As with the other examples, a glassesValidator setup is used for determining data quality.

The data recordings required for running these examples is available here. Output gaze-on-plane, validation and videos resulting from running these examples is available here.

Example 1: Single participant and single plane

Example data, stimulus presentation code and the configuration and coding files needed for exactly recreating the below steps are provided.

Example 1 is a minimum example, showing a short recording where a participant looks at a single plane on which three images are shown in sequence. At the start of the recording, the participant is furthermore asked to look at a glassesValidator poster (Niehorster et al., 2023), to make it possible to determine data quality measures for the recording. Finally, the glassesValidator poster is also used for synchronizing the eye tracker's gaze data with its scene camera. We strongly recommend collecting data for both synchronization and data quality determination for all wearable eye tracker recordings. The preparation, data recording, and data analysis for this example were performed as follows:

1. The researcher prepares the recording space. This involves
    1. Preparing a glassesValidator poster (see steps 1 and 2 here), either printed so it can be hung in a convenient location (best such that it is not in view of the eye-tracker's scene camera during the rest of the experiment), or shown on a projector or another computer screen.
    2. A plane to which the gaze data will be projected needs to be delineated using ArUco markers. While in this example we achieve that by presenting ArUco markers on a computer monitor together with the stimulus images, it could also be achieved by attaching ArUco markers to the edge of the screen. More generally, any planar surface can be used by placing a sufficient number of ArUco markers on it. While there are no hard requirements on the number of ArUco markers that need to be visible in a scene camera video frame for the mapping of gaze to the plane to succeed, it is recommended to aims for at the very minimum a handful of markers that cover a reasonable space to achieve a high probability that the plane is detected correctly. We recommend that users pilot test extensively, under the lighting conditions of the experiment and using participant behavior expected during the experiment (given that both lower light and faster participant movements may decrease the likelihood that markers are detected successfully).

It is important that the exact positions, sizes and orientations of the individual ArUco markers are known. This is required for gazeMapper to be able to correctly determine the observer's position and orientation with respect to the plane, allowing for gaze to be projected to the plane. This information has to be provided to gazeMapper. For more information, see gazeMapper planes.

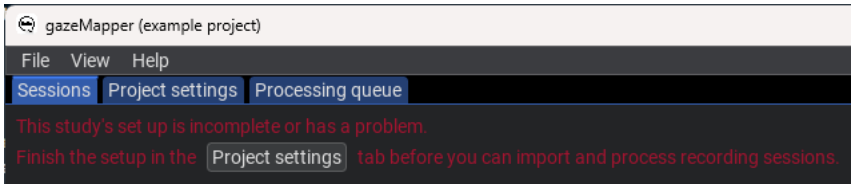
2. A recording then proceeds as follows.

    1. First the participant is positioned in front of the glassesValidator poster and completes a glassesValidator data collection (see step 3 here). Note that in the example, the validation is not performed at arm's length, but at the distance at which the rest of the task will be completed. If a single distance is predominant during an experiment, using a specific distance for the validation data collection is recommended.
    2. After this, while the participant remains at the same position, they are instructed to continuously fixate the fixation target at the center of the validation poster while slowly nodding no with their head five times, and then slowly nodding yes five times.
    3. Next, the main task commences. In the example, the participant simply views a picture presented on the screen, and presses the spacebar when they are done viewing the picture. Each picture presentation is preceded and succeeded by a sequence of single ArUco markers that allows to automatically delineate the trials in the recording.

3. To start processing a recording with gazeMapper, a gazeMapper project first needs to be created and configured. If you want to skip the configuration and just quickly test out gazeMapper, you can create a new gazeMapper project following the first step below, and then simply replace the content of this project's config folder with the configuration provided here. Reopen the project in gazeMapper after replacing the configuration and skip to step 4.

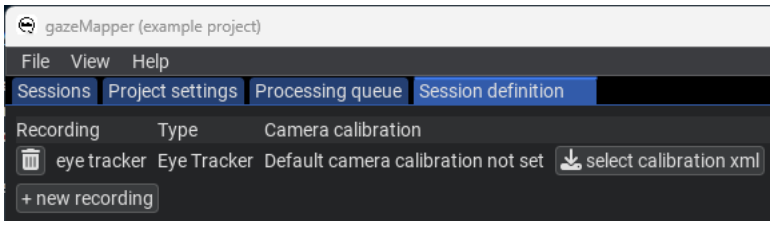
    1. Run gazeMapper and make a new gazeMapper project.

    2. You will be greeted by the following screen, go to the `Project settings` pane.

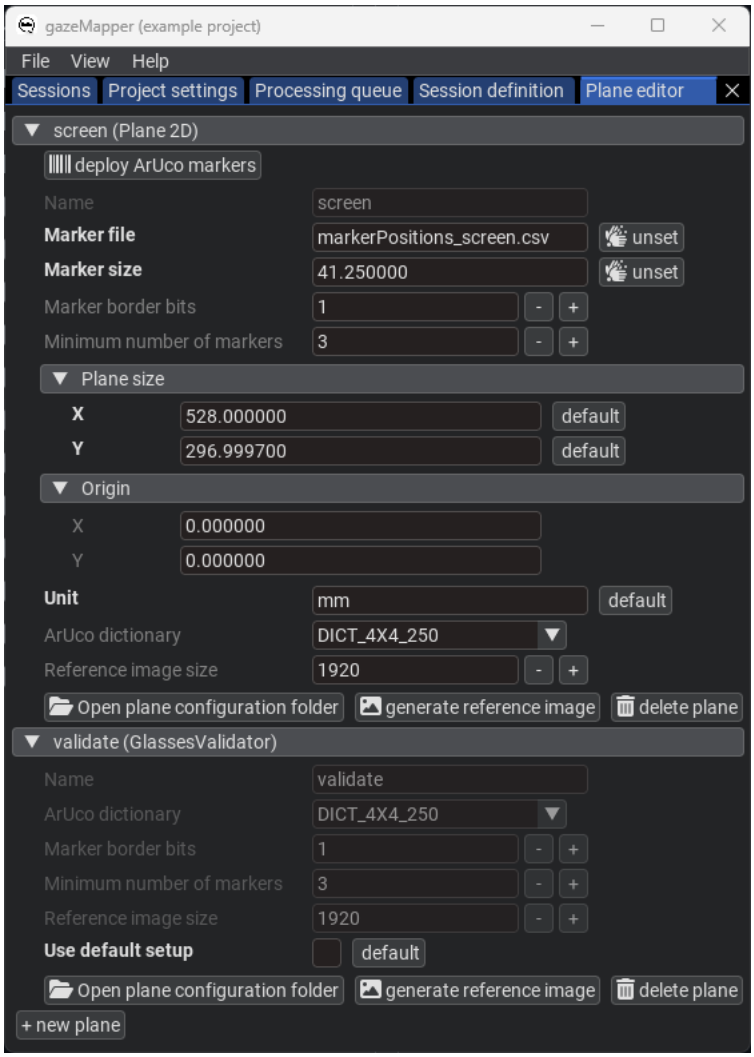
    3. First we have to tell gazeMapper what recordings to expect for a session, click on `Edit session definition` to do so.

    4. Click `+ new recording` to define a recording. Call it anything you wish, for instance `eye tracker`, and select `Eye Tracker` as recording type. The screen will now look as follows.

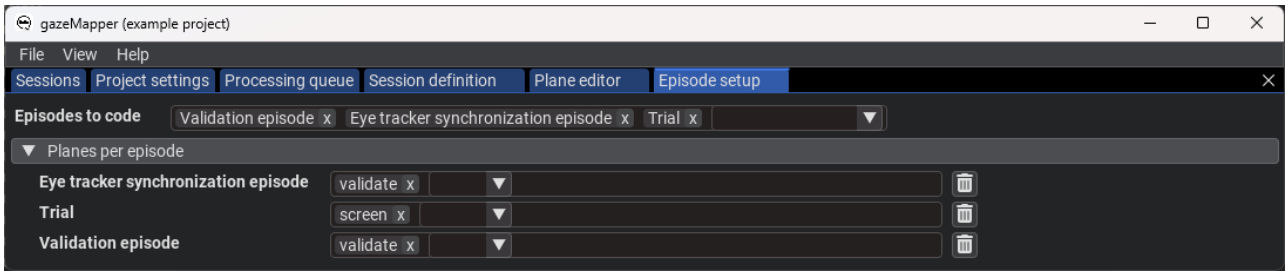
    5. Back on the `Project settings` pane, click on `Edit planes`. Here we need to add both the glassesValidator poster and the stimulus screen as planes.

        1. Click on `+ new plane` and call it `validate`. Select `GlassesValidator` as plane type.
        2. Since the example did not use the default glassesValidator poster printed on A2 format but instead presented the glassesValidator poster on screen, a custom glassesValidator setup is needed. To set this up, uncheck the `Use default setup` button for the validate plane. Press the `Open plane configuration folder` button to open the plane's configuration folder. The files there will have to be edited outside of gazeMapper to reflect the glassesValidator poster as presented on the computer screen. For this example, use the files available here, which were created based on calculations in the Excel sheet provided here. Besides custom `markerPositions.csv` and `targetPositions.csv` files to correctly specify the location of validation targets and ArUco markers on the screen, also the `validationSetup.txt` file was edited to set the correct size for the ArUco markers (`markerSide` variable), the validation targets' diameter (`targetDiameter`) and the size of the plane (`gridCols` and `gridRows`, which were set to the size of the monitor). Note that for glassesValidator, these sizes and positions are specified in cm, not mm.
        3. Click on `+ new plane` again and call it `screen`. Select `Plane 2D` as plane type.
        4. Place the `markerPositions_screen.csv` file in the screen plane's setup folder (again use the `Open plane configuration folder` button if needed). In the GUI, provide the name of this file for the `Marker file` parameter. This file was also created using the calculations in the Excel sheet provided here. For more information about such plane definition files, see below.
        5. Further configure the plane: set the `Marker size` to `41.25`, the `Unit` to `mm`, and the plane size to `X`: `528` and `Y`: `296.9997`. See the below image for the final plane configuration.



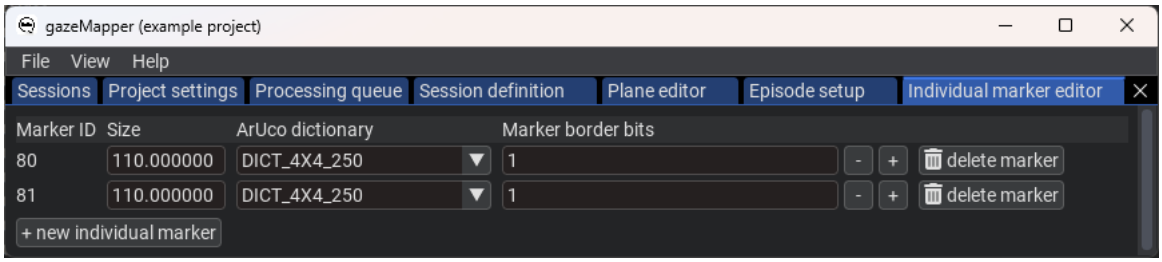
6. Back on the `Project settings` pane, click on `Episode setup`. Here we configure what episodes can be coded, and what plane(s) are associated with each episode.

    1. For the `Episodes to code`, add the `Validation episode`, `Eye tracker synchronization episode` and `Trial`.
    2. Under `Planes per episode`, add all three above items. Set the `validate` plane for the `Validation episode` and `Eye tracker synchronization episode`, and the `screen` plane for the `Trial` episode. This indicates that for episode in the recording coded as validation or synchronization episodes only the `validate` plane will be searched for and processed, while for trials the `screen` plane will be used.



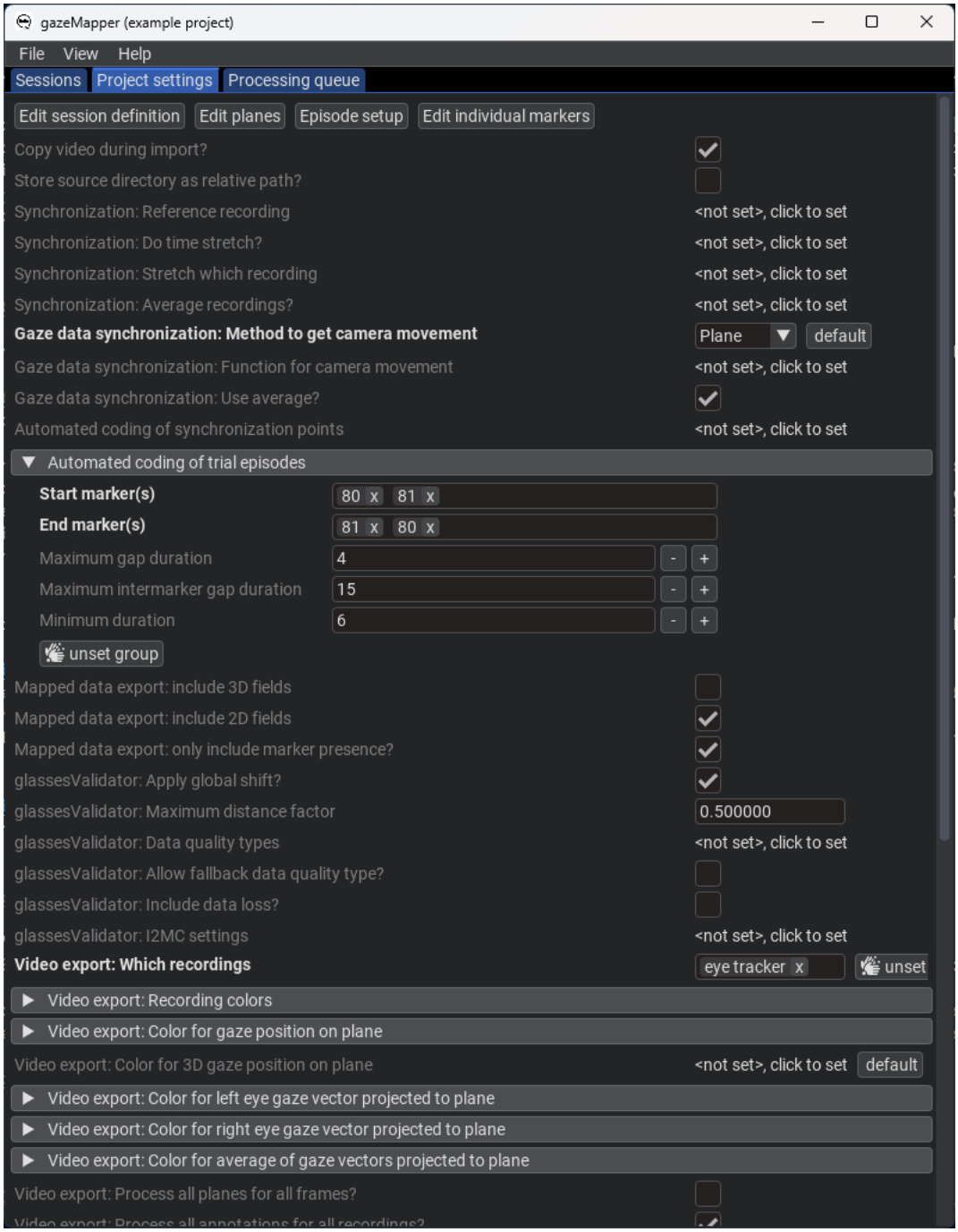
7. Next, detection of the markers to delineate trials needs to be configured. On the `Project settings` pane, click on `Edit individual markers` to configure these.

    1. Add two individual markers, using the `+ new individual marker` button. Add markers 80 and 81, both with a size of `110.0`. It should look like the image below.



8. Some settings also need to be configured on the `Project settings` page itself. Specifically, we need to set:

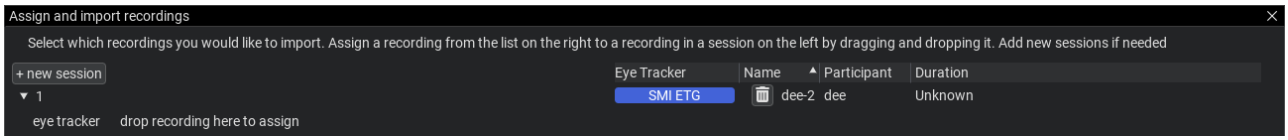
1. `Gaze data synchronization: Method to get camera movement` to `Plane` as we'll use the glassesValidator plane for synchronizing gaze data and the scene camera.
2. Set up `Automated coding of trial episodes` by clicking on `click to set`. Expand the created settings. Set `Start marker(s)` to `80 81` and `End marker(s)` to `81 80`, since these are the markers used in the example in that order to denote trial starts and ends. For the rest of the settings the defaults are ok. Note that also different markers or marker sequences can be used for starts and ends.
3. When processing the recording, we want to output a scene video with detected markers and gaze projected to the validation and screen planes. To set this up, set `Video export: which recordings` to `eye tracker`, the name of the recording we defined in the session definition.
4. Furthermore, set up a color with which to draw gaze in the `Video export: recording colors` field, using the color `Red`: `255`, `Green`: `127` and `Blue`: `0`.
5. Set `Video export: Videos on which to draw gaze projected to plane` to `eye tracker`.
6. Finally, open `Video export: Color for 3D gaze position on the plane` and click `Unset group` to unset that color, which means that that gaze type will not be drawn on the video.



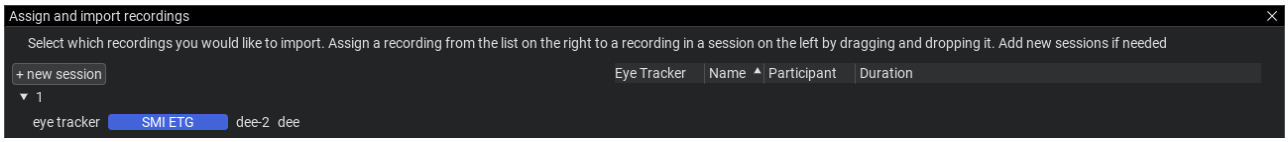
4. Now that the project is set up, we are ready to import and process recordings.

    1. On the `Session` pane, click `import eye tracker recordings`. There, select the folder containing the example data and indicate its an `SMI ETG` recording. Note that you could also trigger import by drag-dropping a data folder onto gazeMapper. Note also that an SMI ETG recording has to be prepared before it can be imported by gazeMapper. This preparation has already been performed for the included example data.

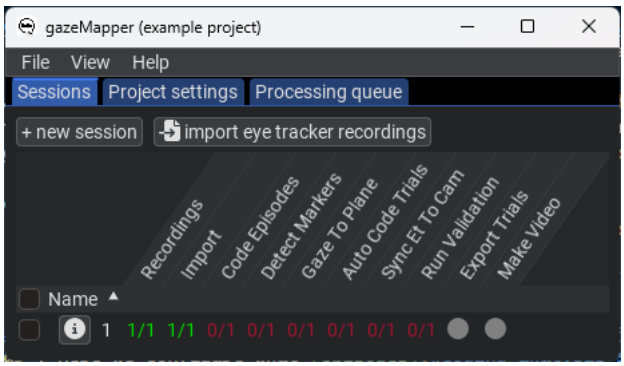
    2. On the window that pops up, click `+ new session`, and name the session `1` (or any name you like). Expand session `1`. You should now see the following:



3. Assign the recording to the session by dragging it from the right, and dropping it on the left where it says `drop recording here`.



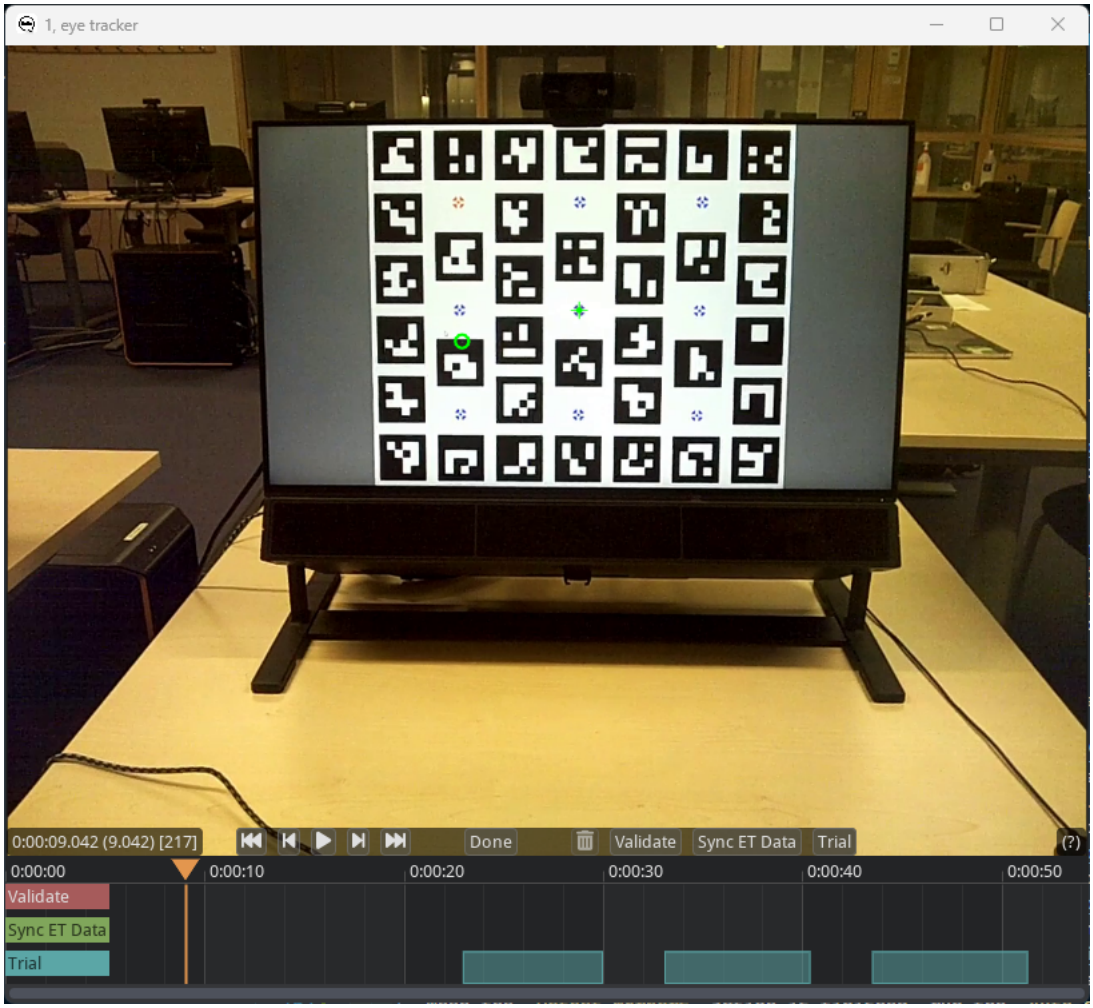
4. Click `Continue`. The recording will now be imported. When this is done, you should see the following:



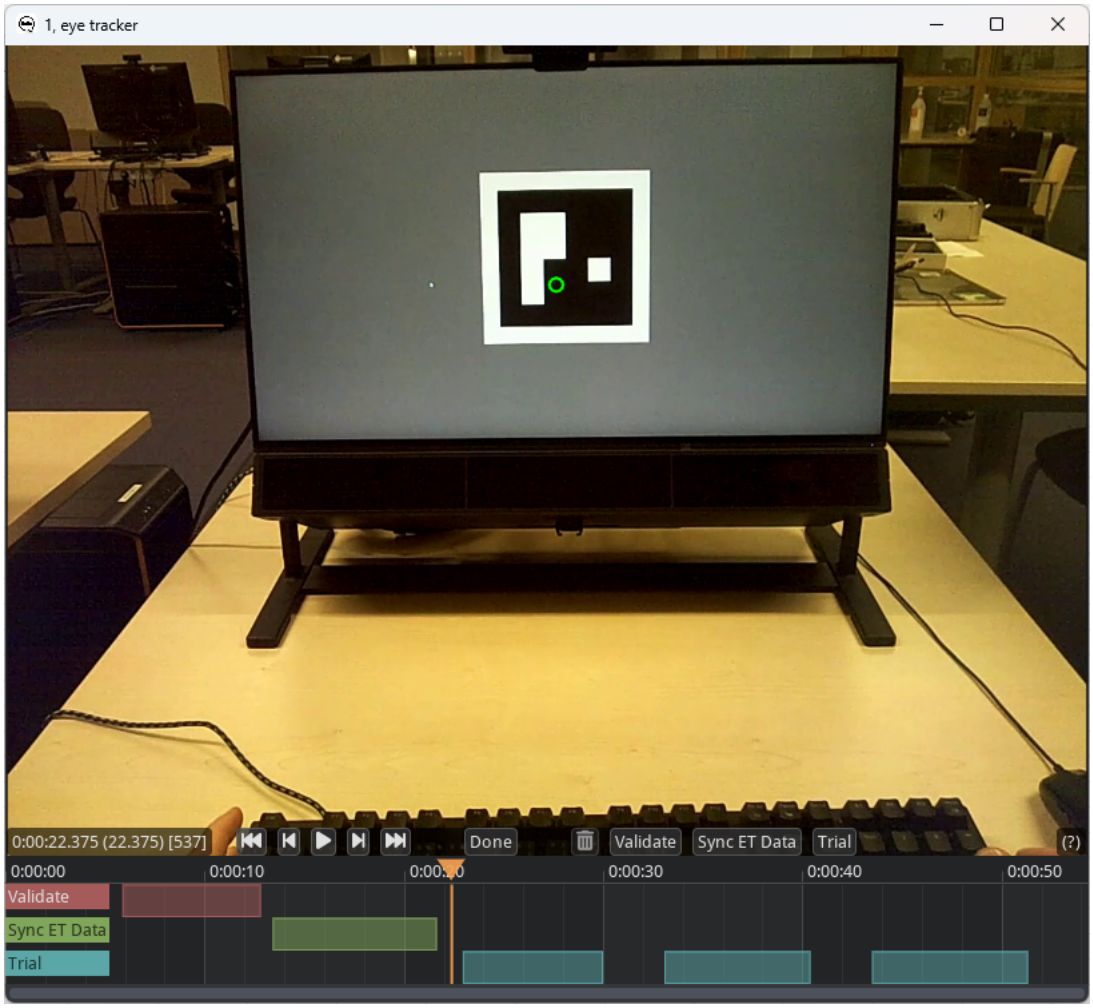
5. Next, run the `Detect markers` action by right-clicking on session `1` and selecting the action from the menu. This will detect all markers in the video, including those needed for automatic trial coding.

6. When the `Detect markers` action is finished, run the `Auto code trials` action.

7. Next, run the `Code episodes` action. This will bring up a coding GUI used for annotating where the episodes of interest are in the recording. `Trial` should already have been coded (see image below), use the GUI to check if trial starts and ends have been accurately determined.

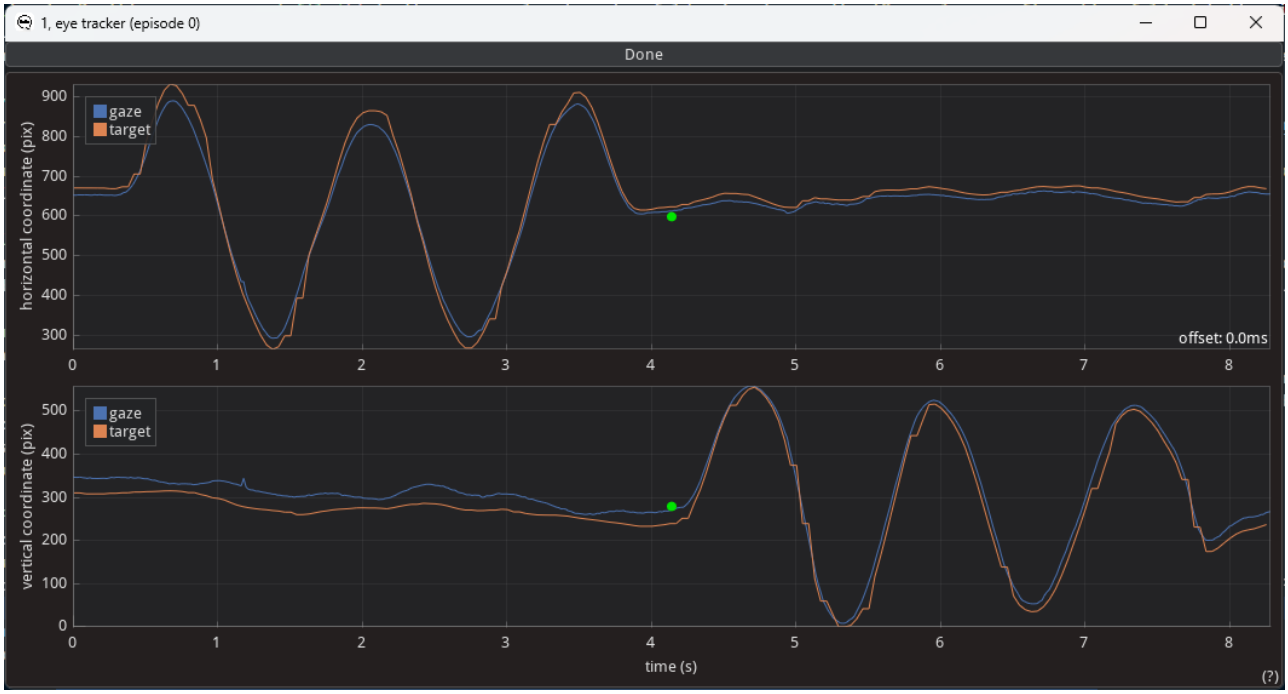


8. Use the seek functionality in the coder (you can press on the timeline underneath the video at the same height as the orange triangle, or use the video player controls) to find the start of the validation episode. Code the validation interval as described in step 5 in the glassesValidator manual. Furthermore, code the eye tracker synchronization episode as the beginning of the fixation on the center validation target before the participant starts nodding no and yes, and the end of the episode as the end of the fixation on the center validation target after the nodding:



Press `Done` to close the episode coding GUI. The coding file for this example can be found here.

9. Next, run the `Sync et to cam` action. This will open the following window:



To align the two signals in time with each other, drag the green dot in the middle of either plot. The horizontal offset is the applied time shift (indicated by the value in the lower-right corner of the upper plot). Any vertical shift is not stored, but can be useful when aligning the two signals. When done aligning the two signals, press done atop the window.

10. Next, run the `Gaze to plane` action.
11. Next, run the `Validation` action.
12. Finally, run the `Make mapped gaze video` action, which draws the detected markers, the participant's gaze and the projection of that gaze to the plane on the scene video, along with information about the episode annotations.
13. Now, you can export the gaze data projected to the plane, the created video and the glassesValidator data quality measures to a folder of your choosing using the `Export trials` action. An export for this example after following the above steps is available here.

Example 2: Two participants and two planes

Example 2 is an extension of example 1, scaling it up to recording two participants who are simultaneously recorded while viewing both their own and each others' screens on which three images are shown in sequence. At the start of the recording, like in example 1, both participants are furthermore asked to look at a glassesValidator poster (Niehorster et al., 2023), to make it possible to determine data quality measures for the recording. Finally, the glassesValidator poster is also used for synchronizing the eye tracker's gaze data with its scene camera. We strongly recommend collecting data for both synchronization and data quality determination for all wearable eye tracker recordings.

Example data, the configuration and the coding files needed for exactly recreating the below steps are provided. The stimulus presentation code is the same example 1, except that for one of the stimulus presentation computers `sync_marker_qshow` should be set to `true`, and for the other computer `plane_which` should be set to `2`. Note that to keep the example simple, image presentation on the two systems was not synchronized other than by the two participants attempting to synchronize their key presses. Any real experiment would likely synchronize stimulus presentation on the two computers, e.g. using Lab Streaming Layer.

Steps 1 and 2 are mostly the same as for Example 1, with the following additional points to note:

1. The two participants perform validation with glassesValidator poster, and nodding no and yes for eye tracker synchronization one after the other. This ensures that only one glassesValidator is shown at a time across the stimulus computers. Should both posters be presented at the same time, troubles may arise where part of one poster may be visible for the other eye tracker. This would severely interfere with the ability to determine where the glassesValidator plane is, cause the output of the validation routine to be wildly off. Should simultaneous validation be required, a second glassesValidator poster should be made using a set of markers that does not overlap with the markers used on the first poster. See the glassesValidator manual for instructions about customizing the poster. More generally, care should be taken to only use unique markers during a recording and not have any marker appear in more than one plane or as one of the trial delineation or synchronization markers.
2. The stimulus presentation program now also shows synchronization markers at the start and end of the recording. These are used to provide visual transients in both scene camera streams that can be used to synchronize the two recordings together. Using ArUco markers, these transients can be automatically detected, but any transient visible to all cameras can be used and the moment at which it occurs manually coded.

Nonetheless, below we provide a full description of how recording preparation, data recording, and data analysis for this example were performed:

1. The researcher prepares the recording space. This involves
    1. Preparing a glassesValidator poster (see steps 1 and 2 here), either printed so it can be hung in a convenient location (best such that it is not in view of the eye-tracker's scene camera during the rest of the experiment), or shown on a projector or another computer screen. It is important that the exact size of the ArUco markers and their location is known.
    2. A plane to which the gaze data will be projected needs to be delineated using ArUco markers. While in this example we achieve that by presenting ArUco markers on a computer monitor together with the stimulus images, it could also be achieved by attaching ArUco markers to the edge of the screen. More generally, any planar surface can be used by placing a sufficient number of ArUco markers on it. While there are no hard requirements on the number of ArUco markers that need to be visible in a scene camera video frame for the mapping of gaze to the plane to succeed, it is recommended to aims for at the very minimum a handful of markers that cover a reasonable space to achieve a high probability that the plane is detected correctly. We recommend that users pilot test extensively, under the lighting conditions of the experiment and using participant behavior expected during the experiment (given that both lower light and faster participant movements may decrease the likelihood that markers are detected successfully).

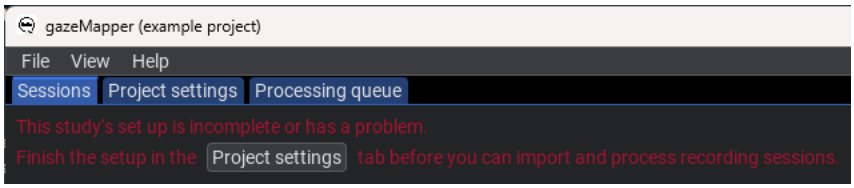
    It is important that the exact positions, sizes and orientations of the individual ArUco markers are known. This is required for gazeMapper to be able to correctly determine the observer's position and orientation with respect to the plane, allowing for gaze to be projected to the plane. This information has to be provided to gazeMapper. For more information, see gazeMapper planes.

2. A recording then proceeds as follows.
    1. Both participants are positioned in front of the stimulus screens. One participant is designated the `lead`, the other the `follower` (they could for instance be teacher and student, and also the names used could of course be anything).
    2. Both participants look at the screen of the lead participant, where an ArUco marker is shown for automatic synchronization.
    3. One participant is first presented with the glassesValidator poster and completes a glassesValidator data collection (see step 3 here). Note that in the example, the validation is not performed at arm's length, but at the distance at which the rest of the task will be completed. If a single distance is predominant during an experiment, using a specific distance for the validation data collection is recommended.
    4. After this, while the participant remains at the same position, they are instructed to continuously fixate the fixation target at the center of the validation poster while slowly nodding no with their head five times, and then slowly nodding yes five times.
    5. When the first participant is done, the other participant performs the same validation and synchronization procedure from the last two steps.
    6. The main task commences. In the example, the participants simply view pictures presented on their screen and also look at each other's screens. They press the spacebar when they are done viewing the picture, after which a new picture is shown. Rough synchronization between the presentations is maintained by the participants attempting to press the spacebar in synchrony. On both screens, each picture presentation is preceded and succeeded by a sequence of single ArUco markers that allows to automatically delineate the trials in the recording. Note however that the trial delineation of the lead recording will be used by both recordings in gazeMapper.
    7. Finally, both participants look at the screen of the lead participant again, where another ArUco marker is shown for synchronization.

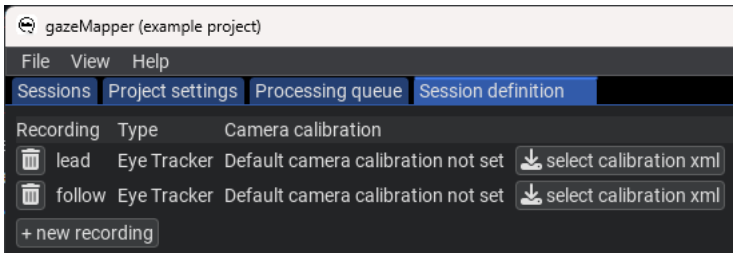
3. To start processing a recording with gazeMapper, a gazeMapper project first needs to be created and configured. If you want to skip the configuration and just quickly test out gazeMapper, you can create a new gazeMapper project following the first step below, and then simply replace the content of this project's config

folder with the configuration provided here. Reopen the project in gazeMapper after replacing the configuration and skip to step 4.

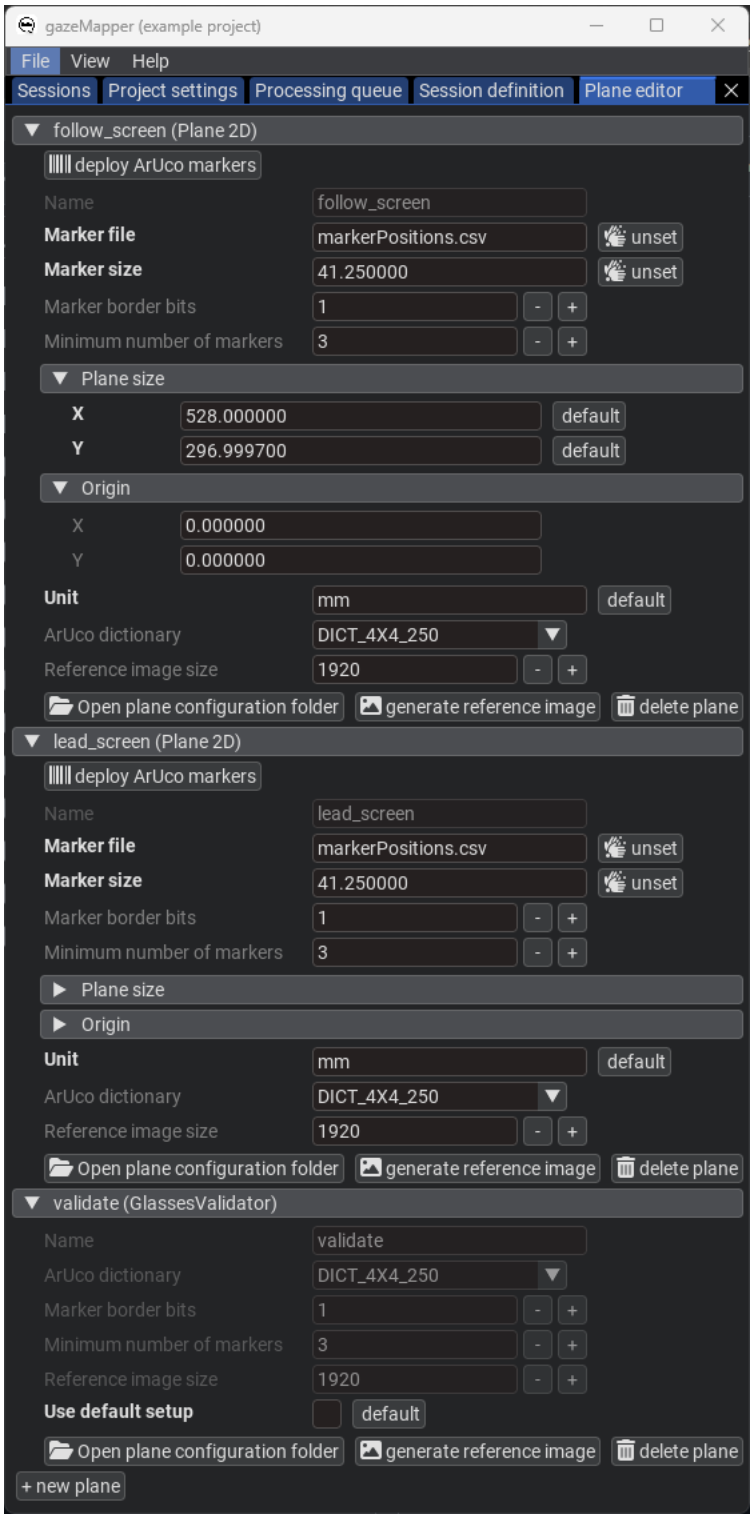
1. Run gazeMapper and make a new gazeMapper project.
2. You will be greeted by the following screen, go to the `Project settings` pane.



3. First we have to tell gazeMapper what recordings to expect for a session, click on `Edit session definition` to do so.
4. Click `+ new recording` to define two recordings. We'll call one `lead` and the other `follow`. Select `Eye Tracker` as recording type for both. The screen will now look as follows.

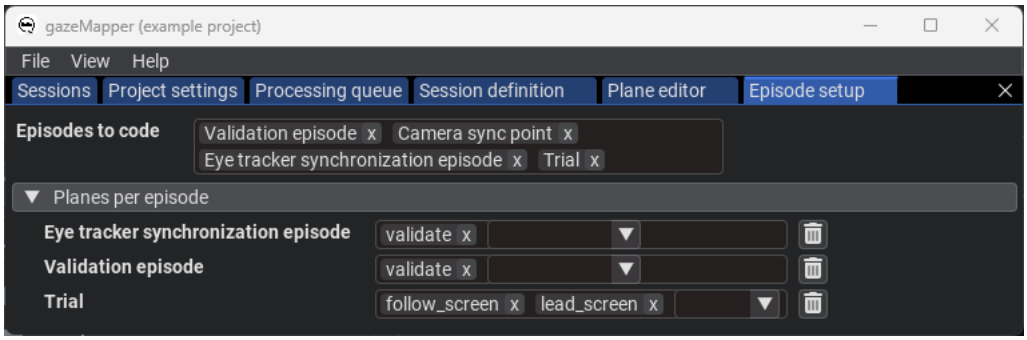


5. Back on the `Project settings` pane, click on `Edit planes`. Here we need to add both the glassesValidator poster and the stimulus screen as planes.
    1. Click on `+ new plane` and call it `validate`. Select `GlassesValidator` as plane type.
    2. Since the example did not use the default glassesValidator poster printed on A2 format but instead presented the glassesValidator poster on screen, a custom glassesValidator setup is needed. To set this up, uncheck the `Use default setup` button for the validate plane. Press the `Open plane configuration folder` button to open the plane's configuration folder. The files there will have to be edited outside of gazeMapper to reflect the glassesValidator poster as presented on the computer screen. For this example, use the files available here, which were created based on calculations in the Excel sheet provided here. Besides custom `markerPositions.csv` and `targetPositions.csv` files to correctly specify the location of validation targets and ArUco markers on the screen, also the `validationSetup.txt` file was edited to set the correct size for the ArUco markers (`markerSide` variable), the validation targets' diameter (`targetDiameter`) and the size of the plane (`gridCols` and `gridRows`, which were set to the size of the monitor). Note that for glassesValidator, these sizes and positions are specified in cm, not mm.
    3. Add two more planes using the `+ new plane` button. Call them `lead_screen` and `follow_screen`. Select `Plane 2D` as plane type for both.
    4. Place the `markerPositions_screen.csv` files found here for the screens in the respective screen plane's setup folder (again use the `Open plane configuration folder` button if needed). In the GUI, provide the names of these files for the `Marker file` parameter. These files were also created using the calculations in the Excel sheet provided here. For more information about such plane definition files, see below.
    5. Further configure both planes: set the `Marker size` to `41.25`, the `Unit` to `mm`, and the plane size to `X`: `528` and `Y`: `296.9997`. See the below image for the final plane configuration.



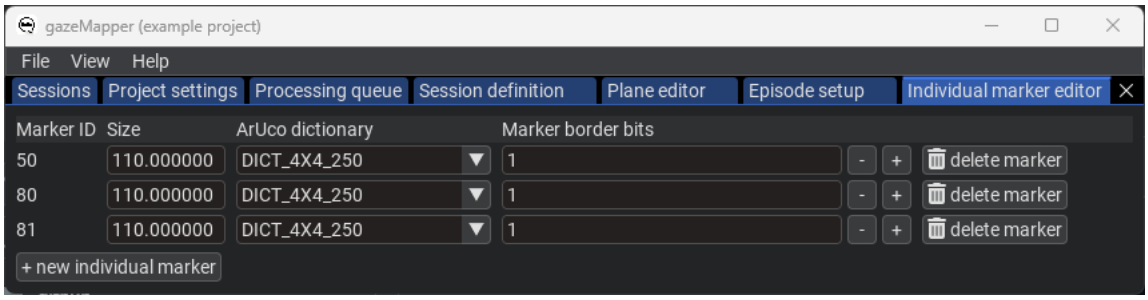
6. Back on the `Project settings` pane, click on `Episode setup`. Here we configure what episodes can be coded, and what plane(s) are associated with each episode.

    1. For the `Episodes to code`, add the `Validation episode`, `Camera sync point`, `Eye tracker synchronization episode` and `Trial`.
    2. Under `Planes per episode`, add the `Validation episode`, `Eye tracker synchronization episode` and `Trial` items. Set the `validate` plane for the `Validation episode` and `Eye tracker synchronization episode`, and the two `screen` planes for the `Trial` episode. This indicates that for episode in the recording coded as validation or synchronization episodes only the `validate` plane will be searched for and processed, while for trials the `screen` planes will be used.



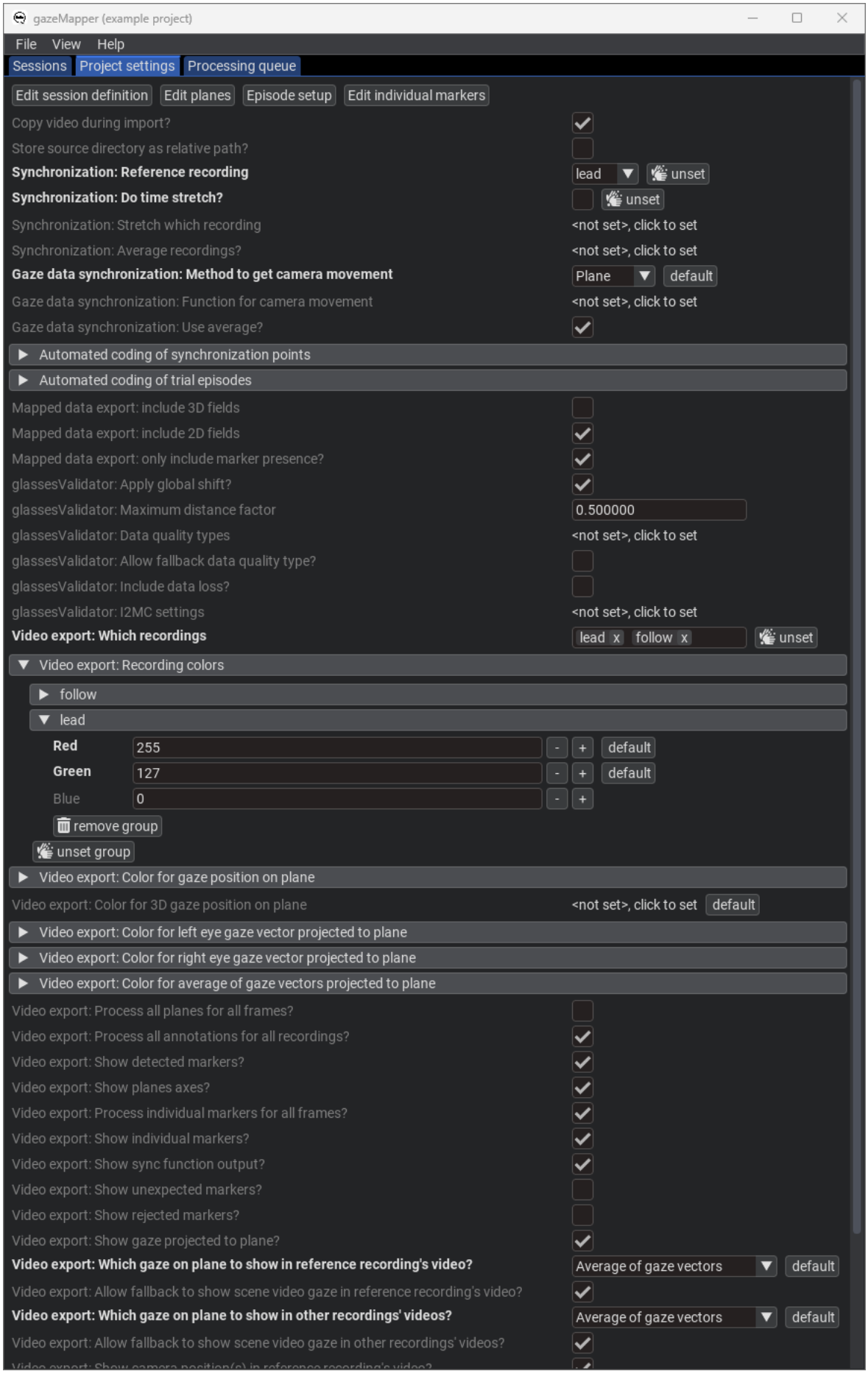
7. Next, detection of the markers to delineate trials needs to be configured. On the `Project settings` pane, click on `Edit individual markers` to configure these.

    1. Add three individual markers, using the `+ new individual marker` button. Add markers 50, 80 and 81, all with a size of `110.0`. It should look like the image below.



8. Some settings also need to be configured on the `Project settings` page itself. Specifically, we need to set:

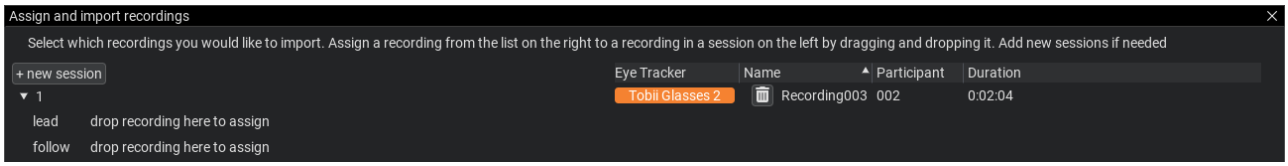
    1. `Synchronization: Reference recording` to `lead`.
    2. `Synchronization: Do time stretch?` to False (unchecked/disabled).
    3. `Gaze data synchronization: Method to get camera movement` to `Plane` as we'll use the glassesValidator plane for synchronizing gaze data and the scene camera.
    4. Set up `Automated coding of synchronization episodes` by clicking on `click to set`. Expand the created settings. Set `Marker(s)` to `50`. For the rest of the settings the defaults are ok. Note also that multiple markers could be used as synchronization points.
    5. Set up `Automated coding of trial episodes` by clicking on `click to set`. Expand the created settings. Set `Start marker(s)` to `80 81` and `End marker(s)` to `81 80`, since these are the markers used in the example in that order to denote trial starts and ends. For the rest of the settings the defaults are ok. Note that also different markers or marker sequences can be used for starts and ends.
    6. When processing the recording, we want to output scene videos for both with detected markers and gaze of both participants projected to the validation and screen planes. To set this up, set both `lead` and `follow` (the names of the recordings we defined in the session definition) for `Video export: which recordings`.
    7. Furthermore, set up the colors with which to draw gaze in the `Video export: recording colors` field. Press `Add item` and add both the `lead` and `follow` recordings. For `lead`, use the color `Red`: `255`, `Green`: `127` and `Blue`: `0`. For `follow`, use the color `Red`: `0`, `Green`: `95` and `Blue`: `191`.
    8. Open `Video export: Color for 3D gaze position on the plane` and click `Unset group` to unset that color, which means that that gaze type will not be drawn on the video.
    9. Set `Video export: Videos on which to draw gaze projected to plane`, `Video export: Videos on which to draw gaze vectors(s)` and `Video export: Videos on which to draw camera position(s)` all to both `follow` and `lead`.
    10. For `Video export: Which gaze on plane to show?` select `Average of gaze vectors`. This will use, if the eye tracker provides it, the intersection of the gaze vectors with the plane instead of the gaze position on the scene video. This may be more accurate, depending on the assumptions in the eye tracker for determining the scene position on the gaze video. Users are recommended to pilot what setting is most suitable for their project and equipment.



4. Now that the project is set up, we are ready to import and process recordings.

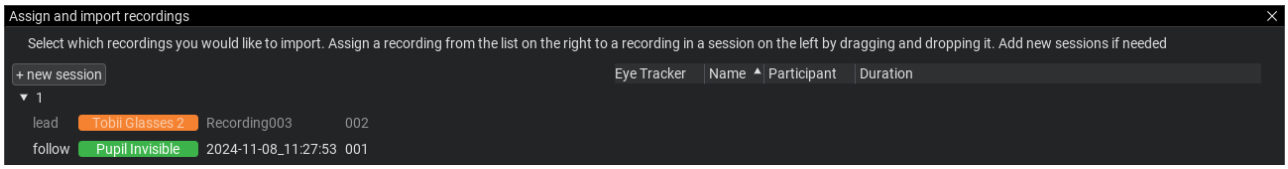
    1. On the `Session` pane, click `import eye tracker recordings`. There, select the folder containing the example data and indicate you're looking for `Tobii Glasses 2` recordings. Note that you could also trigger import by drag-dropping a data folder onto gazeMapper.

    2. On the window that pops up, click `+ new session`, and name the session `1` (or any name you like). Expand session `1`. You should now see the following:



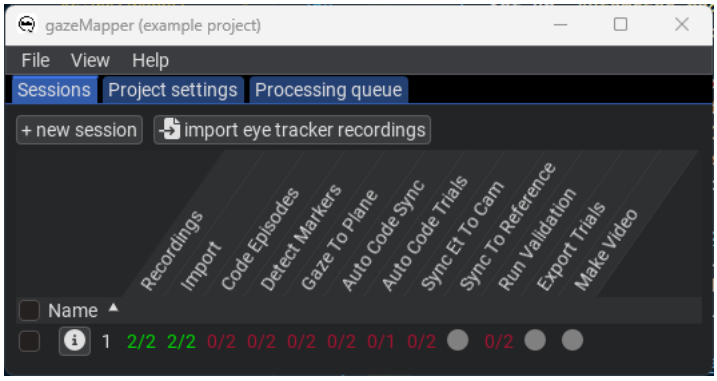
3. Assign the recording to the session by dragging it from the right, and dropping it on the left for the `lead` recording where it says `drop recording here`. Click `Continue`. The recording will now be imported.

4. Again click `import eye tracker recordings`, select the folder containing the example data and this time indicate you're looking for `Pupil Invisible` recordings. Assign the found Pupil Invisible recording to the `follow` recording.



Note that in real use cases with more recordings that you can assign multiple recordings to one or multiple sessions in one go using this dialogue.

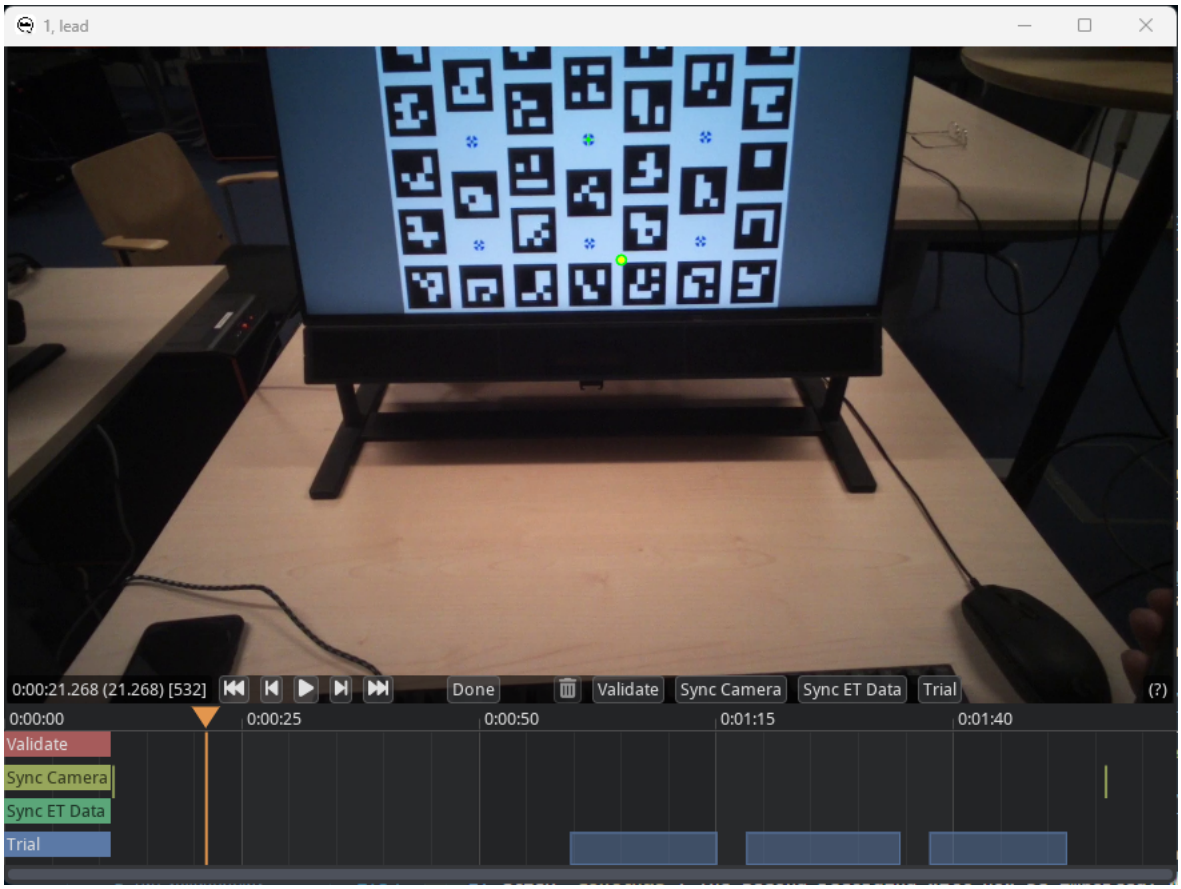
5. Click `Continue`. The second recording will now be imported. When this is done, you should see the following:



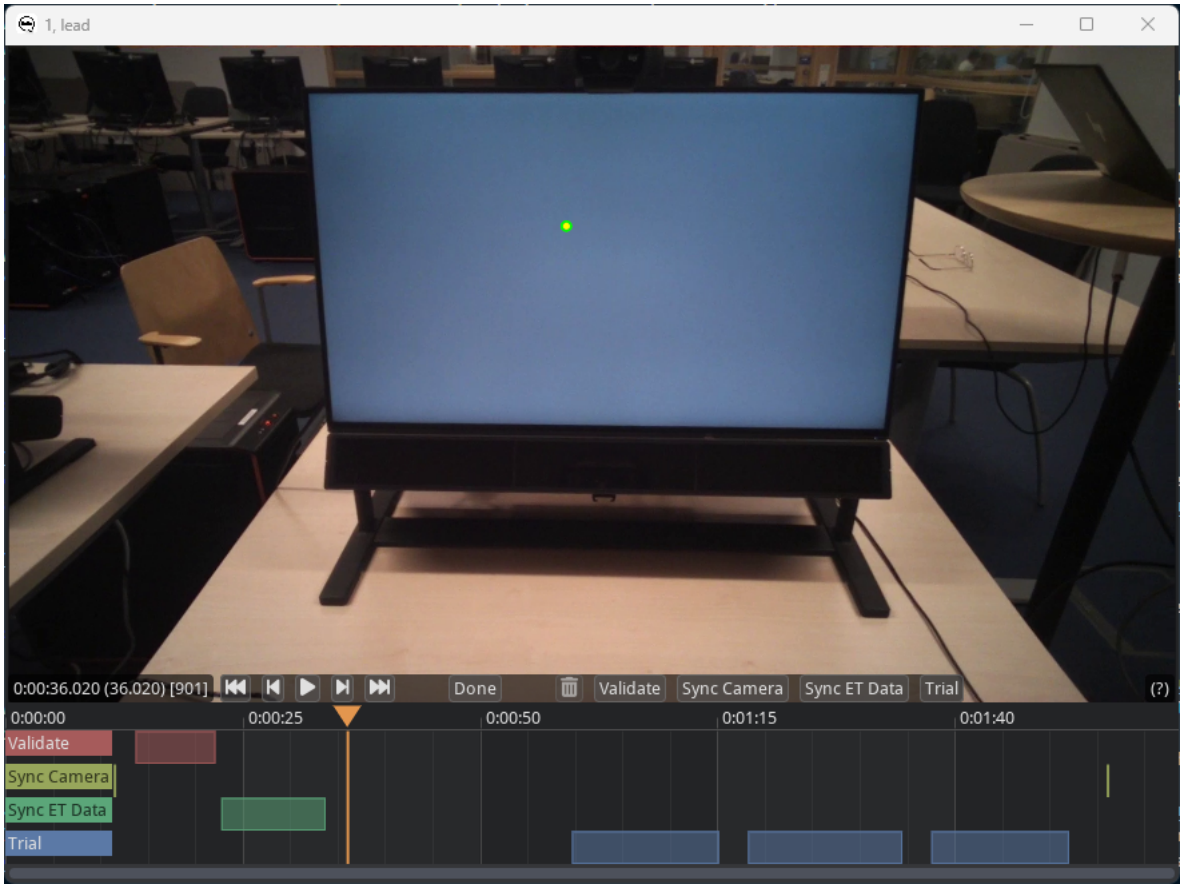
6. Next, run the `Detect markers` action by right-clicking on session `1` and selecting the action from the menu. This will detect all markers in the video, including those needed for automatic trial coding.

7. When the `Detect markers` action is finished, run the `Auto code sync` and `Auto code trials` actions.

8. Next, run the `Code episodes` action. This will bring up a coding GUI used for annotating where the episodes of interest are in the recording. `Trial` and `Sync camera` should already have been coded (see image below), use the GUI to check if trial starts and ends and the synchronization timepoints have been accurately determined.

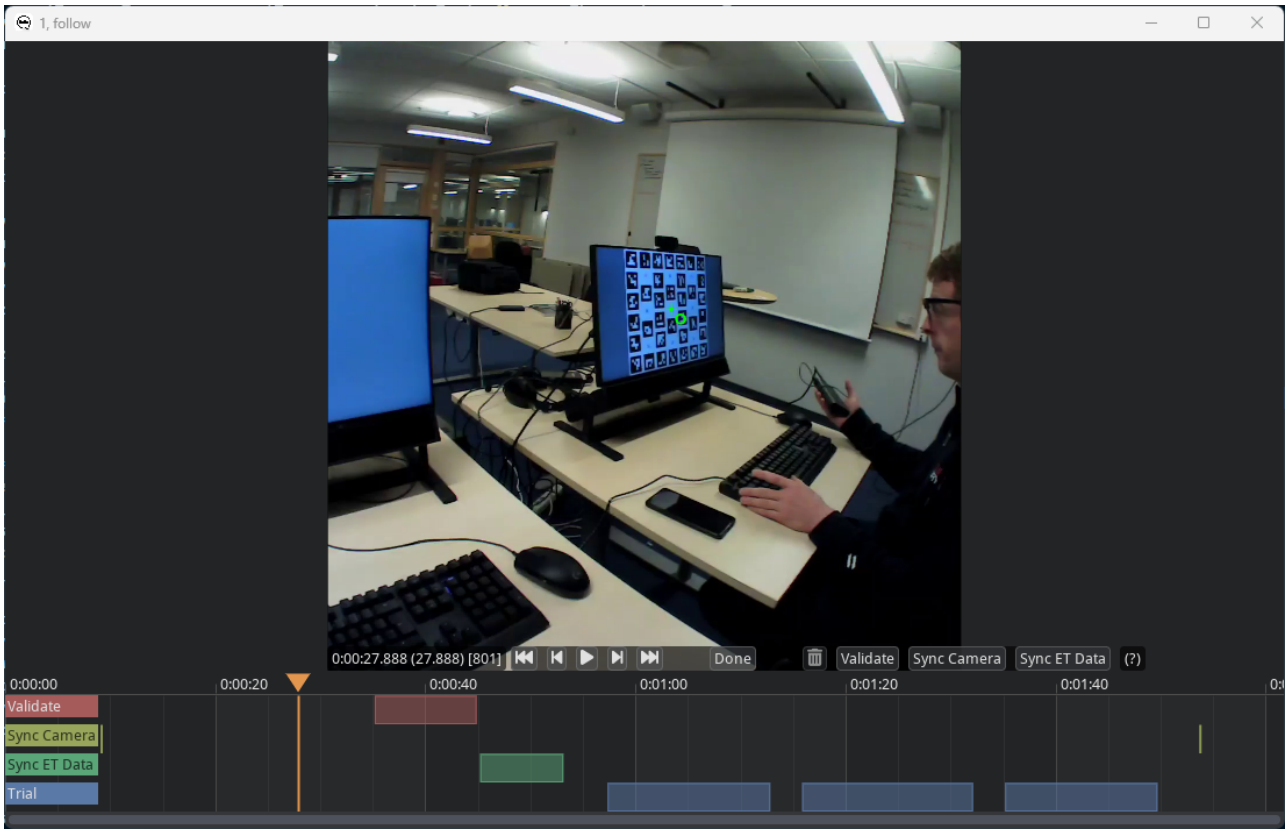


9. Use the seek functionality in the coder (you can press on the timeline underneath the video at the same height as the orange triangle, or use the video player controls) to find the start of the validation episode. Code the validation interval as described in step 5 in the glassesValidator manual. Furthermore, code the eye tracker synchronization episode as the beginning of the fixation on the center validation target before the participant starts nodding no and yes, and the end of the episode as the end of the fixation on the center validation target after the nodding:



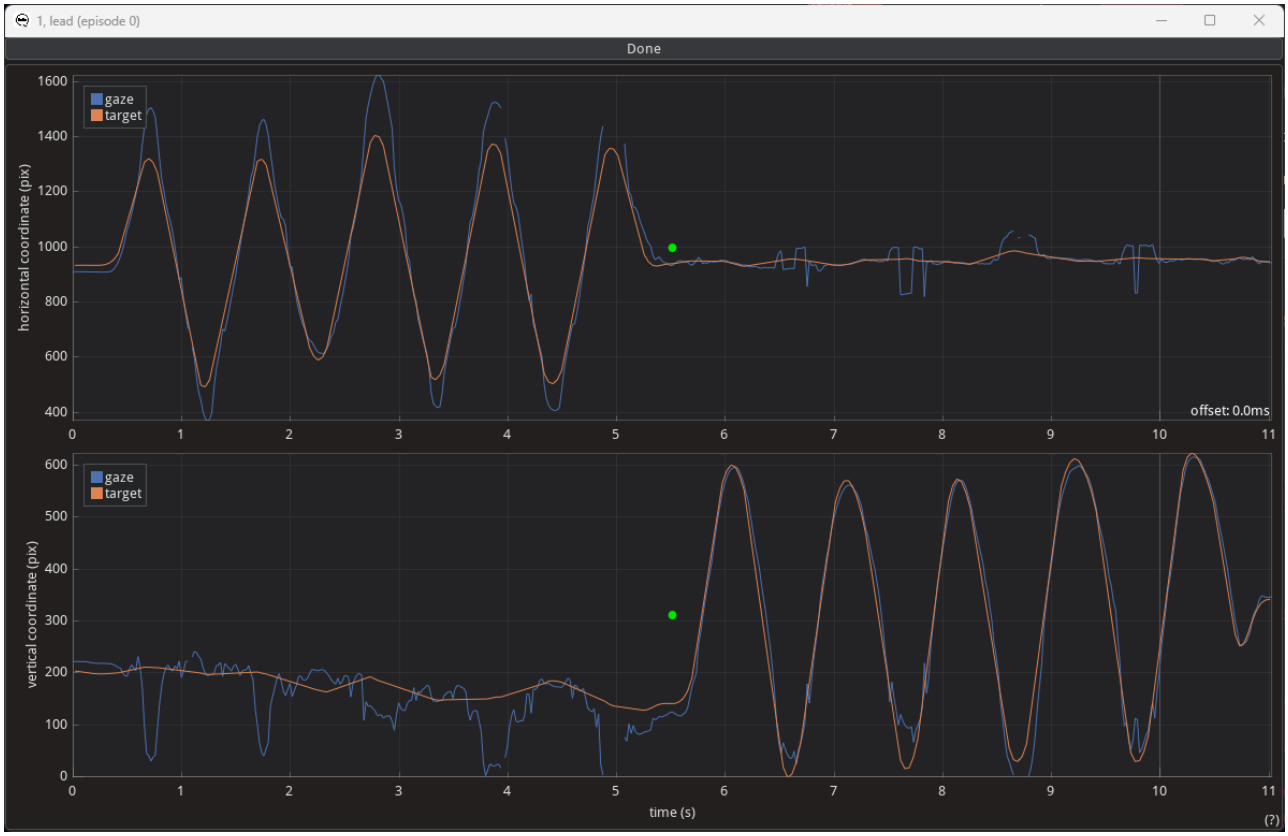
Press Done to close the episode coding GUI.

10. The coding GUI for the other recording of the session will now appear. Also code the validation and eye tracker synchronization episode for this recording. Once done it should look as follows:



Press `Done` to close the episode coding GUI. The coding files for this example can be found here.

11. Next, run the `Sync et to cam` action. This will open the following window:



To align the two signals in time with each other, drag the green dot in the middle of either plot. The horizontal offset is the applied time shift (indicated by the value in the lower-right corner of the upper plot). Any vertical shift is not stored, but can be useful when aligning the two signals. When done aligning the two signals, press done atop the window.

12. Next, run the `Sync to reference` action to synchronize the two recordings together.
13. Next, run the `Gaze to plane` action.
14. Next, run the `Validation` action.

15. Finally, run the `Make mapped gaze video` action, which draws the detected markers, the participant's gaze and the projection of that gaze to the plane on the scene video, along with information about the episode annotations.

16. Now, you can export the gaze data projected to the plane, the created video and the glassesValidator data quality measures to a folder of your choosing using the `Export trials` action. An export for this example after following the above steps is available here.

Example 3: One participant, multiple planes and an overview camera

Example data, the configuration and the coding files needed for exactly recreating the below steps are provided. The stimulus material and used planes are also available.

Example 3 is a more advanced example, showing a recording of a participant looking at and interacting with multiple planes while also being filmed with an external overview camera. The participant is performing a super simplified stock counting task, where they count how many apples, pear and mangos are on images on an iPad and then report their counts on papers spread across the scene. At the start of the recording, the participant is furthermore asked to look at a glassesValidator poster (Niehorster et al., 2023), to make it possible to determine data quality measures for the recording. Finally, the glassesValidator poster is also used at both the start and the end of the recording for synchronizing the eye tracker's gaze data with its scene camera. The preparation, data recording, and data analysis for this example were performed as follows:

1. The researcher prepares the recording space. This involves

    1. Printing a glassesValidator poster (see steps 1 and 2 here) and hanging it on the wall.
    2. Preparing the stimulus material on the iPad, including ArUco markers to define the stimulus plane, and ArUco markers for automatic delineation of trials and automatic synchronization of the eye tracker and the overview camera.
    3. Multiple further planes for the fruit counts have to be printed and distributed around the recording space.
    4. Set up an external camera. Set it up such that both the observer and the various planes are in view during the whole recording, such that a sufficient number of markers is visible in each recording, and use that reflections of the environment on the tablet do not cause issues with later processing of the recording. Note here that during pilot recordings of this example, we ran into issues with ArUco markers being reflected in the tablet and being detected by gazeMapper, and with the lighting in the room making part of the tablet screen illegible. To solve this, we have adjusted camera positions and selectively switched off lights to alleviate these issues.

    As in the previous examples, it is important that the exact positions, sizes and orientations of the individual ArUco markers are known. This is required for gazeMapper to be able to correctly determine the observer's position and orientation with respect to each plane, allowing for gaze to be projected to these planes. This information has to be provided to gazeMapper. For more information, see gazeMapper planes.

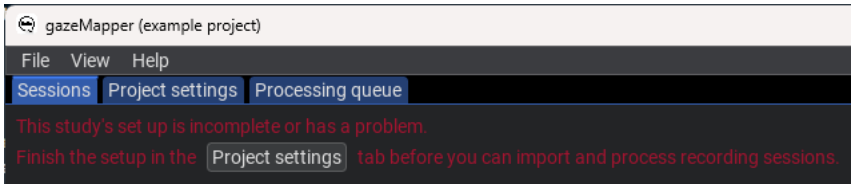
2. A recording then proceeds as follows.

    1. First the participant holds up the iPad so that the overview camera can see the contents of its screen, and also looks at the iPad. They then activate the PowerPoint presentation on the iPad, which flashes a synchronization marker on the screen, which will be used in analysis to synchronize the overview camera to the eye tracker recording.
    2. Then, the participant is positioned in front of the glassesValidator poster and completes a glassesValidator data collection (see step 3 here).
    3. After this, while the participant remains at the same position, they are instructed to continuously fixate the fixation target at the center of the validation poster while slowly nodding no with their head five times, and then slowly nodding yes five times.
    4. Next, the main task commences. The participant again picks up the iPad and continues the PowerPoint presentation. Next in the presentation two ArUco markers are shown in sequence that allows to automatically delineate the trials in the recording. Then, a stimulus image is shown. The participant counts the number of apples, pear and mangos in the image, and writes their count on the paper for the respective fruit. Once done, they continue the presentation. A sequence of ArUco markers is shown signalling the end of the trial, and thereafter another sequence signalling the start of the next trial. The participant again writes down their fruit count and advances the presentation, upon which the trial end ArUco marker sequence is again shown.
    5. They then stand in front of the glassesValidator poster and again slowly nod no with their head five times, and then slowly nod yes five times while maintaining fixation of the fixation target at the center of the validation poster.
    6. Finally, the participant holds up the iPad to the overview camera and advances the presentation, upon which another ArUco marker for synchronization is shown.

3. To start processing a recording with gazeMapper, a gazeMapper project first needs to be created and configured. If you want to skip the configuration and just quickly test out gazeMapper, you can create a new gazeMapper project following the first step below, and then simply replace the content of this project's config folder with the configuration provided here. Reopen the project in gazeMapper after replacing the configuration and skip to step 4.

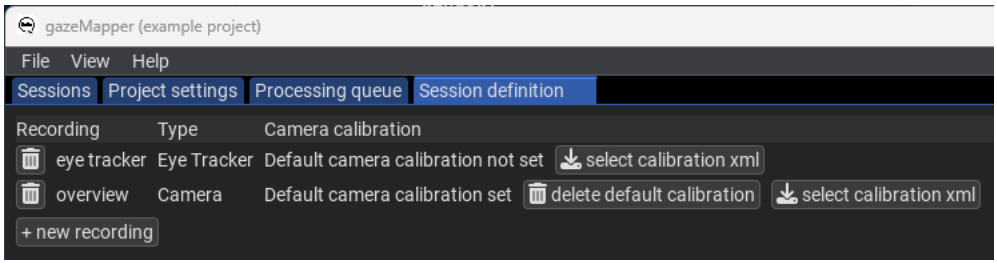
    1. Run gazeMapper and make a new gazeMapper project.

    2. You will be greeted by the following screen, go to the `Project settings` pane.

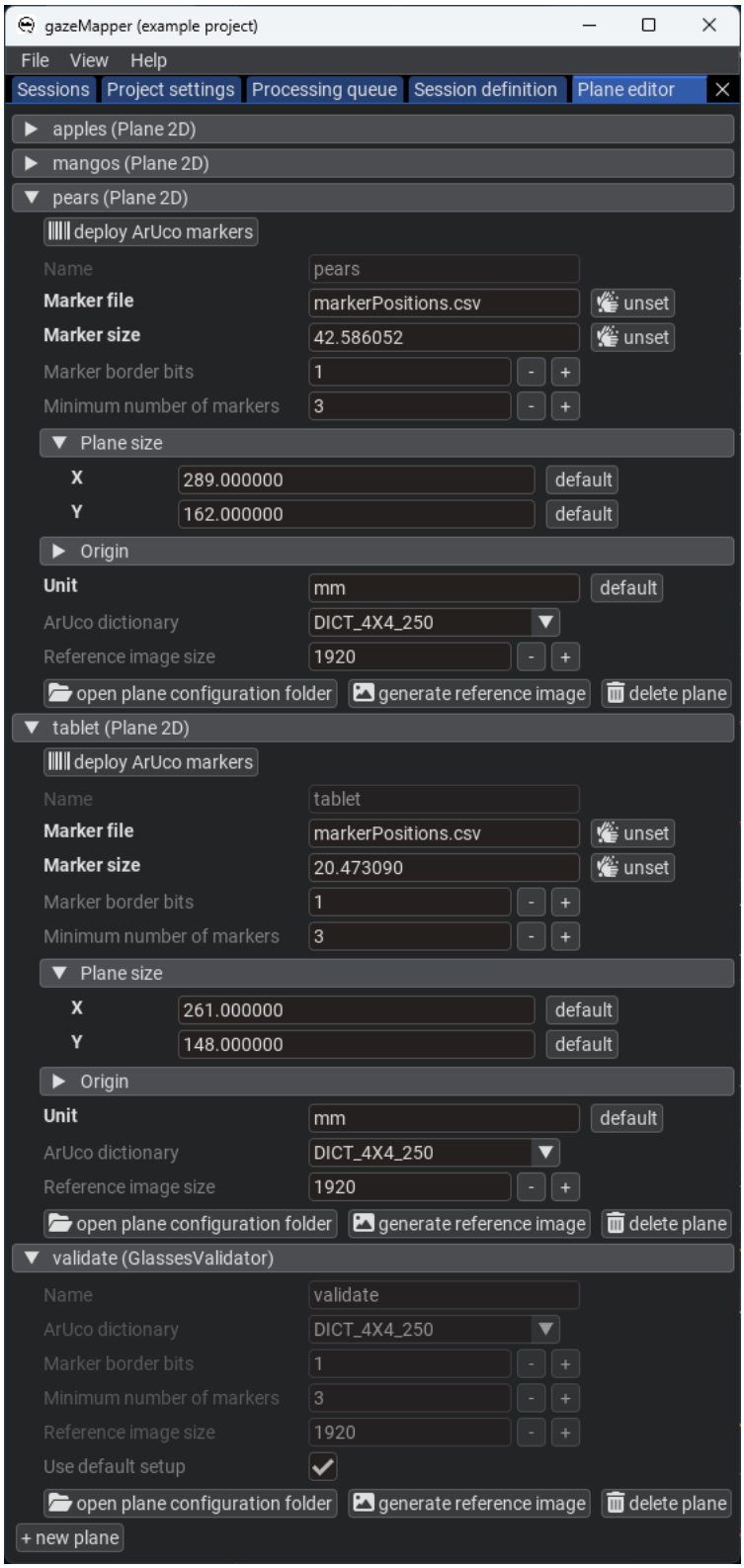
    3. First we have to tell gazeMapper what recordings to expect for a session, click on `Edit session definition` to do so.

    4. Click `+ new recording` to define two recordings. We'll call one `eye tracker` and the other `overview`. Select `Eye Tracker` as recording type for the eye tracker recording, and Camera as the type for the overview recording. Next, add a camera calibration file for the camera recording (this is not needed for the eye tracker recordings, as the used eye tracker provides a calibration for the scene camera). To do so, click the `select calibration xml` button, and load this file. The screen will now look as follows.



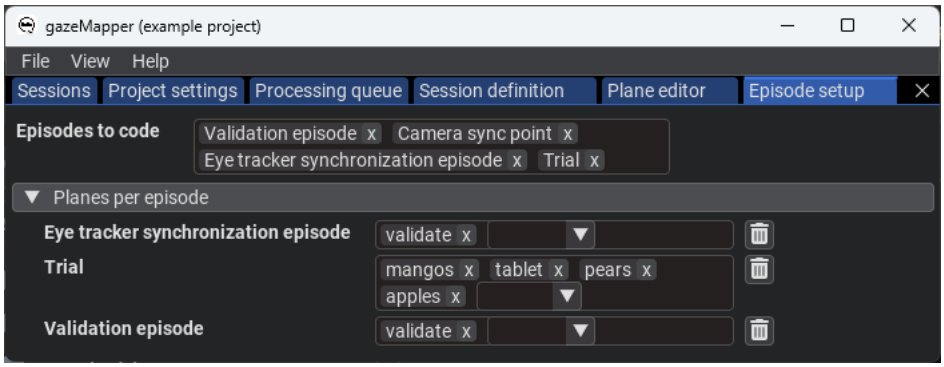
5. Back on the `Project settings` pane, click on `Edit planes`. Here we need to add the glassesValidator poster, the iPad screen and the three answer sheets as planes.

    1. Click on `+ new plane` and call it `validate`. Select `GlassesValidator` as plane type. Since the default A2 glassesValidator poster was used, this plane requires no further configuration.
    2. Add four more planes using the `+ new plane` button. Call them `tablet` and `apples`, `pears` and `mangos`. Select `Plane 2D` as plane type for all four.
    3. Place the `markerPositions.csv` files found here for the four planes in the respective plane's setup folders (use the `Open plane configuration folder` button in gazeMapper to find the plane's folder, if needed). In the GUI, provide the names of these files for the `Marker file` parameter. These files were created using the calculations in the Excel sheet provided here. For more information about such plane definition files, see below.
    4. Further configure the planes: for the tablet plane, set the `Marker size` to `20.47309`, set it to `42.586052` for the other three planes. For the tablet plane, set the plane size to `X`: `261` and `Y`: `148`, for the other three planes set it to `X`: `189` and `Y`: `162`. For all four planes, set the `Unit` to `mm`. See the below image for part of the final plane configuration.



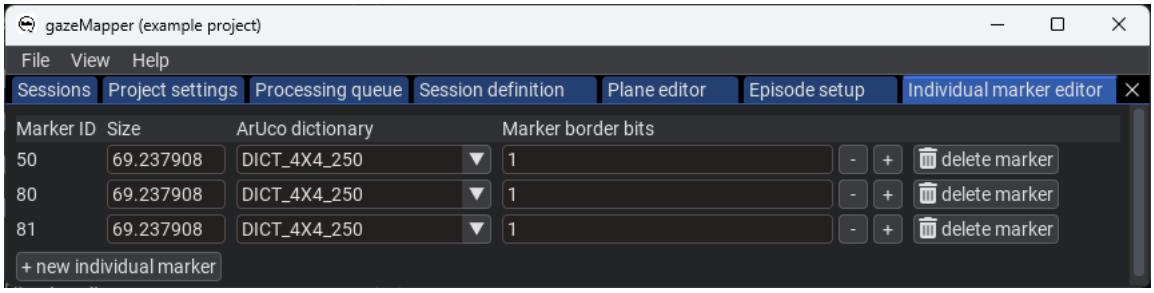
6. Back on the `Project settings` pane, click on `Episode setup`. Here we configure what episodes can be coded, and what plane(s) are associated with each episode.

    1. For the `Episodes to code`, add the `Validation episode`, `Camera sync point`, `Eye tracker synchronization episode` and `Trial`.
    2. Under `Planes per episode`, add the `Validation episode`, `Eye tracker synchronization episode` and `Trial` items. Set the `validate` plane for the `Validation episode` and `Eye tracker synchronization episode`, and the four other planes for the `Trial` episode. This indicates that for episodes in the recording coded as validation or synchronization episodes only the `validate` plane will be searched for and processed, while for trials the other four planes will be used.



7. Next, detection of the markers to delineate trials needs to be configured. On the `Project settings` pane, click on `Edit individual markers` to configure these.

    1. Add three individual markers, using the `+ new individual marker` button. Add markers 50, 80 and 81, all with a size of `69.237908`. It should look like the image below.



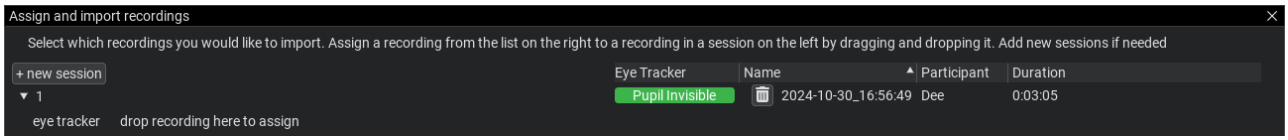
8. Some settings also need to be configured on the `Project settings` page itself. Specifically, we need to set:

    1. `Synchronization: Reference recording` to `eye tracker`.
    2. `Synchronization: Do time stretch?` to True (checked/enabled).
    3. `Synchronization: Stretch which recording?` to `Other recording(s)`.
    4. Click `Synchronization: Average recordings?` to create the setting, but do not assign any recording, since we do not want to use this functionality.
    5. `Gaze data synchronization: Method to get camera movement` to `Plane` as we'll use the glassesValidator plane for synchronizing gaze data and the scene camera.
    6. Set up `Automated coding of synchronization episodes` by clicking on `click to set`. Expand the created settings. Set `Marker(s)` to `50`. For the rest of the settings the defaults are ok. Note also that multiple markers could be used as synchronization points.
    7. Set up `Automated coding of trial episodes` by clicking on `click to set`. Expand the created settings. Set `Start marker(s)` to `80 81` and `End marker(s)` to `81 80`, since these are the markers used in the example in that order to denote trial starts and ends. For the rest of the settings the defaults are ok. Note that also different markers or marker sequences can be used for starts and ends.
    8. When processing the recording, we want to output scene videos for both with detected markers and gaze of both participants projected to the validation and screen planes. To set this up, set both `eye tracker` and `overview` (the names of the recordings we defined in the session definition) for `Video export: which recordings`.
    9. Furthermore, set up the colors with which to draw gaze in the `Video export: recording colors` field. Press `Add item` and add the `eye tracker` recording (the overview recording cannot be added as it has no gaze data). For the `eye tracker` recording, use the color `Red`: `255`, `Green`: `127` and `Blue`: `0`.
    10. Finally set `Video export: Videos on which to draw gaze projected to plane`, `Video export: Videos on which to draw gaze vectors(s)` and `Video export: Videos on which to draw camera position(s)` all to `overview`. For `Video export: Videos on which to draw gaze projected to plane`, also specify `eye tracker`. Set `Video export: Gaze position margin` to `0.1`.

4. Now that the project is set up, we are ready to import and process recordings.

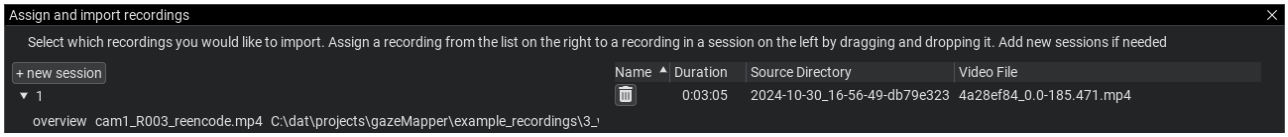
    1. On the `Session` pane, click `import eye tracker recordings`. There, select the folder containing the example data and indicate you're looking for `Pupil Invisible` recordings. Note that you could also trigger import by drag-dropping a data folder onto gazeMapper.

    2. On the window that pops up, click `+ new session`, and name the session `1` (or any name you like). Expand session `1`. You should now see the following:



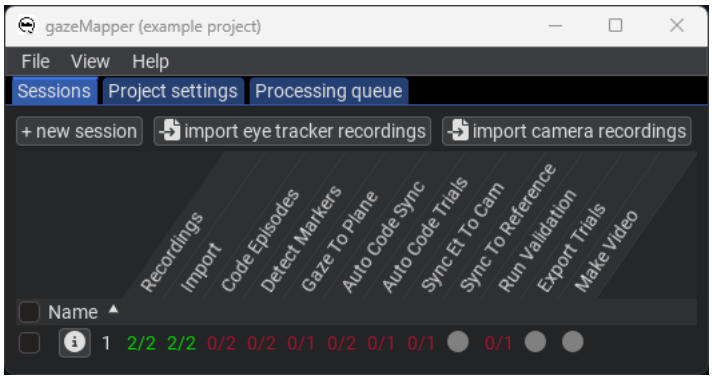
3. Assign the recording to the session by dragging it from the right, and dropping it on the left for the `eye tracker` recording where it says `drop recording here`. Click `Continue`. The recording will now be imported.

4. Click `import camera recordings`, select the folder containing the example data and click continue. Assign the found camera recording (`cam1_R003_reencode.mp4`) to the `overview` recording.



Note that in real use cases with more recordings that you can assign multiple recordings to one or multiple sessions in one go using these dialogues.

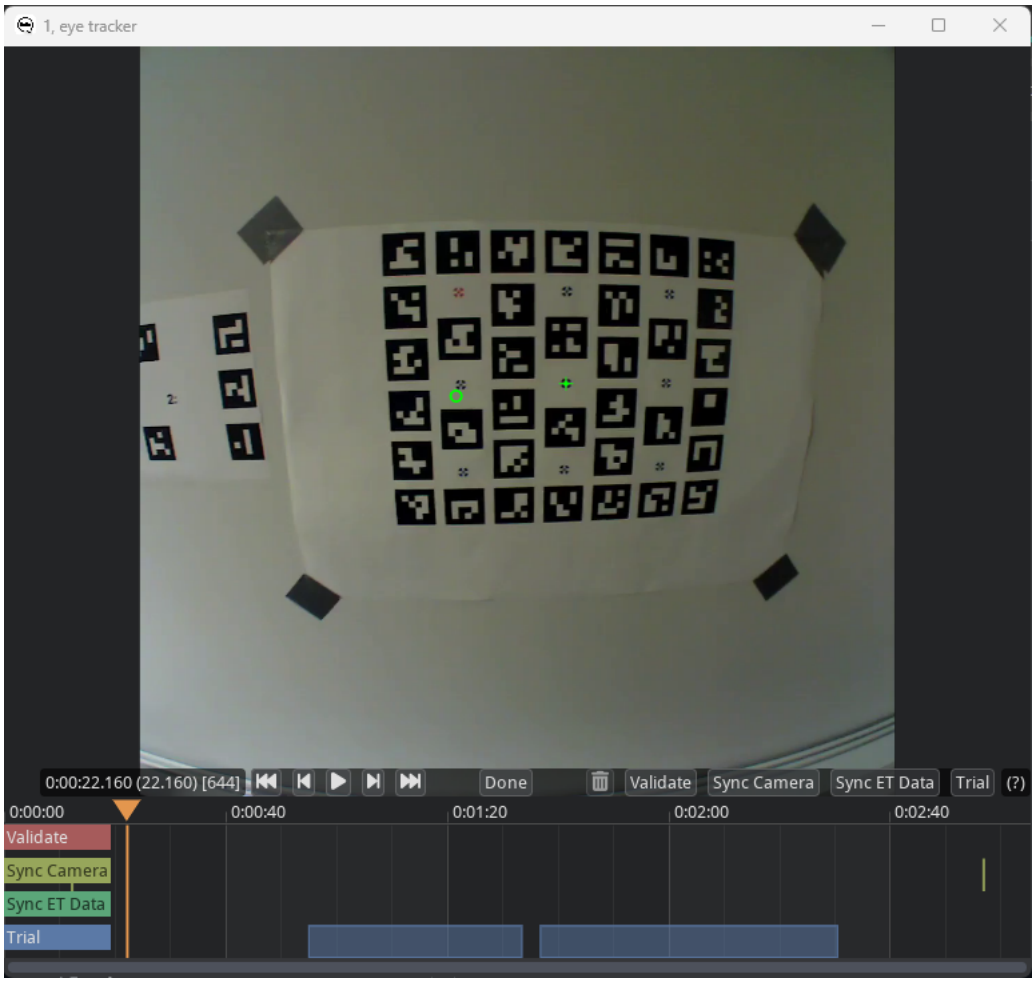
5. Click `Continue`. The camera recording will now be imported. When this is done, you should see the following:



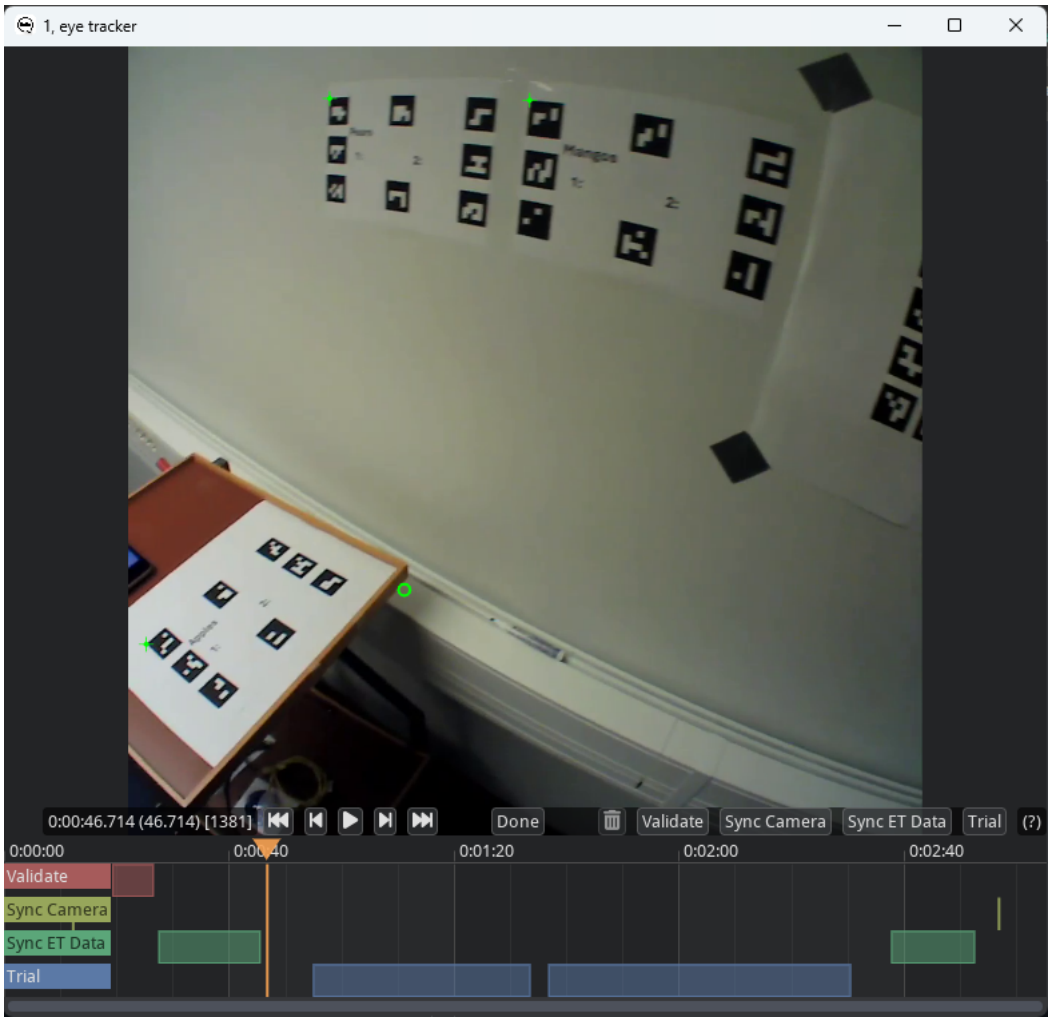
6. Next, run the `Detect markers` action by right-clicking on session `1` and selecting the action from the menu. This will detect all markers in the video, including those needed for automatic trial coding.

7. When the `Detect markers` action is finished, run the `Auto code sync` and `Auto code trials` actions.

8. Next, run the `Code episodes` action. This will bring up a coding GUI used for annotating where the episodes of interest are in the recording. `Trial` and `Sync camera` should already have been coded (see image below), use the GUI to check if trial starts and ends and the synchronization timepoints have been accurately determined.



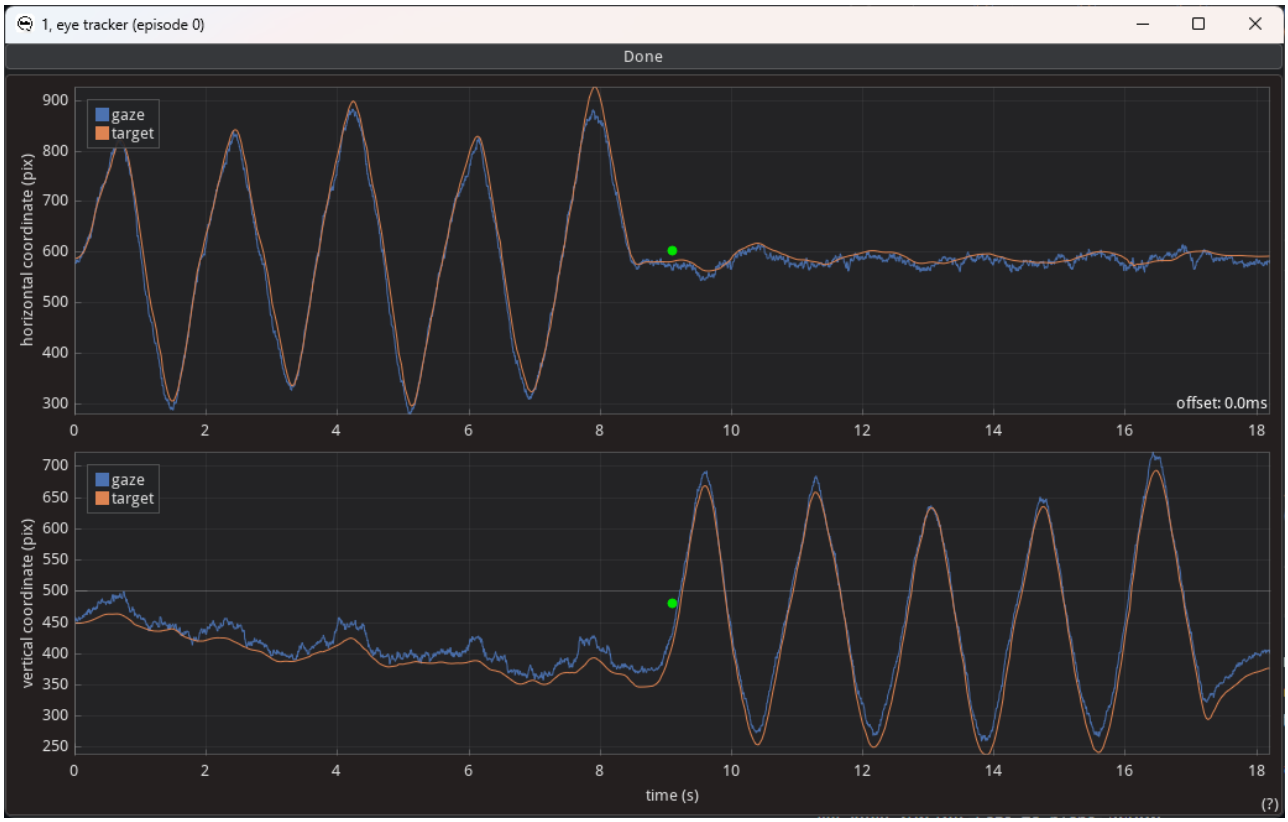
9. Use the seek functionality in the coder (you can press on the timeline underneath the video at the same height as the orange triangle, or use the video player controls) to find the start of the validation episode. Code the validation interval as described in step 5 in the glassesValidator manual. Furthermore, code the eye tracker synchronization episode as the beginning of the fixation on the center validation target before the participant starts nodding no and yes, and the end of the episode as the end of the fixation on the center validation target after the nodding. Code both the episode at the beginning of the recording and the episode near the end of the recording:



Press `Done` to close the episode coding GUI.

10. The coding GUI for the other recording of the session will now appear. Here too, check that the synchronization timespoints are correctly coded. Press `Done` to close the episode coding GUI. The coding files for this example can be found here.

11. Next, run the `Sync et to cam` action. This will open the following window:



To align the two signals in time with each other, drag the green dot in the middle of either plot. The horizontal offset is the applied time shift (indicated by the value in the lower-right corner of the upper plot). Any vertical shift is not stored, but can be useful when aligning the two signals. When done aligning the two signals, press done atop the window.

12. Next, run the `Sync to reference` action to synchronize the two recordings together.
13. Next, run the `Gaze to plane` action.
14. Next, run the `Validation` action.
15. Finally, run the `Make mapped gaze video` action, which draws the detected markers, the participant's gaze and the projection of that gaze to the plane on the scene video, along with information about the episode annotations.
16. Now, you can export the gaze data projected to the plane, the created video and the glassesValidator data quality measures to a folder of your choosing using the `Export trials` action. An export for this example after following the above steps is available here.

gazeMapper projects

The gazeMapper GUI organizes recordings into a project folder. Each session to be processed is represented by a folder in this project folder, and one or multiple recordings are stored in subfolders of a session folder. After importing recordings, all further processing is done inside these session and recording folders. The source directories containing the original recordings remain untouched when running gazeMapper. A gazeMapper project folder furthermore contains a folder `config` specifying the configuration of the project. So an example directory structure may look like:

```
my project/
├── config/
│   ├── plane 1/
│   ├── plane 2/
│   └── validation plane/
├── session 01/
│   ├── teacher/
│   ├── student/
│   └── overview camera/
├── session 02/
│   ├── teacher/
│   ├── student/
│   └── overview camera/
...
```

where `session 01` and `session 02` are individual recording session, each made up of a teacher, a student and an overview camera recording. `plane 1` and `plane 2` contain definitions of planes that gazeMapper will map gaze to and `validation plane` is an additional plane used for validation of the eye tracker's calibration using glassesValidator, see below for documentation.

When not using the GUI and running gazeMapper using your own scripts, such a project folder organization is not required. Working folders for a session can be placed anywhere (though recording folders should be placed inside a session folder), and a folder for a custom configuration can also be placed anywhere (but its location needs to be provided using the `config_dir` argument of all the functions in `gazeMapper.process`). The `gazeMapper.process` functions simply take the path to a session or recording folder.

Output

During the importing and processing of a session, or an eye tracker or camera recording, a series of files are created in the working folder of the session and the recording(s). These are the following (not all of the files are created for a camera recording, for instance, there is no gaze data associated with such a recording):

file	location	produced by	description
`calibration.xml`	recording	`Session.import_recording`	Camera calibration parameters for the (scene) camera.
`frameTimestamps.tsv`	recording	`Session.import_recording`	Timestamps for each frame in the (scene) camera video.
`gazeData.tsv`	recording	`Session.import_recording`	Gaze data cast into the glassesTools common format used by gazeMapper. Only for eye tracker recordings.
`recording_info.json`	recording	`Session.import_recording`	Information about the recording.
`recording.gazeMapper`	recording	`Session.import_recording`	JSON file encoding the state of each recording-level gazeMapper action.
`worldCamera.mp4`	recording	`Session.import_recording`	Copy of the (scene) camera video (optional, depends on the `import_do_copy_video` option).
`gazeOverlay.mp4`	recording	`Session.make_gaze_overlay_video`	Video of the eye tracker scene camera with overlaid gaze point.
`coding.tsv`	recording	`process.code_episodes`	File denoting the analysis, synchronization and validation episodes to be processed. This is produced with the coding interface included with gazeMapper. Can be manually created or edited to override the coded episodes.

file	location	produced by	description
`planePose_<plane name>.tsv`	recording	`process.detect_markers`	File with information about plane pose w.r.t. the (scene) camera for each frame where the plane was detected.
`markerPose_<marker ID>.tsv`	recording	`process.detect_markers`	File with information about marker pose w.r.t. the (scene) camera for each frame where the marker was detected.
`planeGaze_<plane name>.tsv`	recording	`process.gaze_to_plane`	File with gaze data projected to the plane/surface. Only for eye tracker recordings.
`validate_<plane name>_*`	recording	`process.run_validation`	Series of files with output of the glassesValidator validation procedure. See the glassesValidator readme for descriptions. Only for eye tracker recordings.
`VOR_sync.tsv`	recording	`process.sync_et_to_cam`	File containing the synchronization offset (s) between eye tracker data and the scene camera. Only for eye tracker recordings.
`detectOutput.mp4`	recording	`process.make_video`	Video of the eye tracker scene camera or external camera (synchronized to one of the recordings if there are multiple) showing detected plane origins, detected individual markers and gaze from any other recordings eye tracker recordings. Also shown for eye tracker recordings are gaze on the scene video from the eye tracker, gaze projected to the detected planes. Each only if available, and enabled in the video generation settings.
`session.gazeMapper`	session	`Session.import_recording`	JSON file encoding the state of each session-level gazeMapper action.
`ref_sync.tsv`	session	`process.sync_to_ref`	File containing the synchronization offset (s) and other information about sync between multiple recordings.
`planeGaze_<recording name>.tsv`	session	`process.export_trials`	File containing the gaze position on one or multiple planes. One file is created per eye tracker recording.

Coordinate system of data

gazeMapper produces data in the reference frame of a plane/surface. This 2D data is stored in the `planeGaze_*` files produced when exporting the gazeMapper results, and also in the `planeGaze_*` files stored inside individual recordings' working folders. The gaze data in these files has its origin (0,0) at a position that is specified in the plane setup (or in the case of a glassesValidator poster at the center of the fixation target that was indicated to be the center target with the `centerTarget` setting in the validation poster's `validationSetup.txt` configuration file). The positive x-axis points to the right and the positive y-axis downward, which means that (-,-) coordinates are to the left and above of the plane origin, and (+,+) to the right and below.

Eye trackers

gazeMapper supports the following eye trackers:

- AdHawk MindLink
- Generic*
- Pupil Core
- Pupil Invisible
- Pupil Neon
- SeeTrue STONE
- SMI ETG 1 and ETG 2
- Tobii Pro Glasses 2
- Tobii Pro Glasses 3
- Viewpointsystem VPS 19

- The generic eye tracker allows users to import recordings made with unsupported eye trackers into tools built upon glassesTools, if the user has already converted the recording to the glassesTools format themselves. The name of the eye tracker can be set in the recording info file through the `eye_tracker_name` property, so that recordings from different devices imported as generic eye tracker recordings can be distinguished.

Pull requests or partial help implementing support for further wearable eye trackers are gladly received. To support a new eye tracker, implement it in glassesTools.

Required preprocessing outside gazeMapper

For some eye trackers, the recording delivered by the eye tracker's recording unit or software can be directly imported into gazeMapper. Recordings from some other eye trackers however require some steps to be performed in the manufacturer's software before they can be imported into gazeMapper. These are:

- *Pupil Labs eye trackers*: Recordings should either be preprocessed using Pupil Player (*Pupil Core* and *Pupil Invisible*), Neon Player (*Pupil Neon*) or exported from Pupil Cloud (*Pupil Invisible* and *Pupil Neon*).
    - Using Pupil Player (*Pupil Core* and *Pupil Invisible*) or Neon player (*Pupil Neon*): Each recording should 1) be opened in Pupil/Neon Player, and 2) an export of the recording (`e` hotkey) should be run from Pupil/Neon Player. Make sure to disable the `World Video Exporter` in the `Plugin Manager` before exporting, as the exported video is not used by glassesTools and takes a long time to create. If you want pupil diameters, make sure to enable `Export Pupil Positions` in the `Raw Data Exporter`, if available. Note that importing a Pupil/Neon Player export of a Pupil Invisible/Neon recording may require an internet connection. This is used to retrieve the scene camera calibration from Pupil Lab's servers in case the recording does not have a `calibration.bin` file.
    - Using Pupil Cloud (*Pupil Invisible* and *Pupil Neon*): Export the recordings using the `Timeseries data + Scene video` action.

    - For the *Pupil Core*, for best results you may wish to do a scene camera calibration yourself, see https://docs.pupil-labs.com/core/software/pupil-capture/#camera-intrinsics-estimation. If you do not do so, a generic calibration will be used by Pupil Capture during data recording, by Pupil Player during data analysis and by the glassesTools processing functions, which may result in incorrect accuracy values.
- *SMI ETG*: For SMI ETG recordings, access to BeGaze is required and the following steps should be performed:
    - **NB**: Note that it is critical that a `SYNC_ET_TO_CAM` action is performed for SMI ETG recordings. This is required because the gaze timestamps in the export file created below have an unknown zero that is not related to the scene video clock, and no info about offset between these clocks is available. The gaze signal and video feed have to be manually aligned (synchronized).
    - Export gaze data: `Export` -> `Legacy: Export Raw Data to File`.
        - In the `General` tab, make sure you select the following:
            - `Channel`: enable both eyes
            - `Points of Regard (POR)`: enable `Gaze position`, `Eye position`, `Gaze vector`
            - `Binocular`: enable `Gaze position`
            - `Misc Data`: enable `Frame counter`
            - disable everything else
        - In the Details tab, set:
            - `Decimal places` to 4
            - `Decimal separator` to `point`
            - `Separator` to `Tab`
            - enable `Single file output`
        - This will create a text file with a name like `<experiment name>_<participant name>_<number> Samples.txt` (e.g. `005-[5b82a133-6901-4e46-90bc-2a5e6f6c6ea9]_005_001 Samples.txt`). Move this file/these files to the recordings folder and rename them. If, for instance, the folder contains the files `005-2-recording.avi`, `005-2-recording.idf` and `005-2-recording.wav`, amongst others, for the recording you want to process, rename the exported samples text file to `005-2-recording.txt`.
    - Export the scene video:
        - On the Dashboard, double click the scene video of the recording you want to export to open it in the scanpath tool.
        - Right click on the video and select settings. Make the following settings in the `Cursor` tab:
            - set `Gaze cursor` to `translucent dot`
            - set `Line width` to 1
            - set `Size` to 1
        - Then export the video, `Export` -> `Export Scan Path Video`. In the options dialogue, make the following settings:
            - set `Video Size` to the maximum (e.g. `(1280,960)` in my case)
            - set `Frames per second` to the framerate of the scene camera (24 in my case)
            - set `Encoder` to `Performance [FFmpeg]`
            - set `Quality` to `High`
            - set `Playback speed` to `100%`
            - disable `Apply watermark`
            - enable `Export stimulus audio`
            - finally, click `Save as`, navigate to the folder containing the recording, and name it in the same format as the gaze data export file we created above but replacing `recording` with `export`, e.g. `005-2-export.avi`.

gazeMapper sessions

Defining gazeMapper sessions

A gazeMapper session represents a single recording session. It may consist of only a single eye tracker recording, but could also contain multiple (simultaneous) eye tracker and external camera recordings. When setting up a gazeMapper project, one first defines what recordings to expect for a recording session. This is done in the `Session definition` pane in the GUI or by means of a `gazeMapper.session.SessionDefinition` object. A session definition contains a list of expected recordings, which are defined using the `+ new recording` button on the `Session definition` pane in the GUI, or by means of `gazeMapper.session.RecordingDefinition` objects passed to `gazeMapper.session.SessionDefinition.add_recording_def()`. Each recording definition has a name and an eye tracker type (`gazeMapper.session.RecordingType`), where the type can be an eye tracker recording (`gazeMapper.session.RecordingType.Eye_Tracker`) or a (external) camera recording (`gazeMapper.session.RecordingType.Camera`). This session definition is typically stored in a JSON file `session_def.json` in the configuration directory of a gazeMapper project.

Storage for gazeMapper sessions

As outlined above, each gazeMapper session is its own folder inside a gazeMapper project. The name of the session is simply the name of the folder (which we will term the session working folder). You can thus rename a session by renaming its working folder. Similarly, each recording's working folder is stored inside the session working folder, with as folder name the name defined for the corresponding recording in the session definition. You are advised not to manually rename these folders, as folders with a name different than that defined in the session definition are not recognized by gazeMapper.

Loading gazeMapper sessions

When opening a gazeMapper project folder, each subfolder of the project folder containing a `session.gazeMapper` status file is taken to be a session, regardless of whether it has recording working folders or not. Similarly, recording working folders in a session working folder with names that match the recordings defined in the project's session definition will be loaded automatically.

gazeMapper planes

The main goal of gazeMapper is to map head-referenced gaze data recording with a wearable eye tracker to one or multiple planes in the world. That means that gazeMapper determines where on the plane a participant looks, regardless of where in their visual field the plane appears, and that gazeMapper's output expresses gaze in the plane's reference frame. To be able to perform this mapping, gazeMapper needs to be able to determine where the participant is located in space and how they

are oriented with respect to the plane (that is, their pose). This is done by placing an array of fiducial markers of known size and known spatial layout on the plane that can be detected through computer vision and used to determine the participant's pose. See the example above for what such an array of fiducial markers looks like.

For gazeMapper to be able to do its job, it needs to have precise information about the array of fiducial markers that defines the plane(s). When designing these arrays, it is important to use unique markers (in other words, each marker may only be used once across all planes and other markers that appear in the recording, e.g. for synchronization or automatic trial coding). Any dictionary of fiducial markers understood by OpenCV's ArUco module (cv2.aruco, see `cv::aruco::PREDEFINED_DICTIONARY_NAME`) is supported (i.e. various ArUco marker dictionaries, as well as April tags), the default is `DICT_4X4_250`.

Planes are configured in the `Plane editor` pane in the GUI or by means of `gazeMapper.plane.Definition` objects. There are two types of planes, either a generic 2D plane (`gazeMapper.plane.Type.Plane_2D`), or a glassesValidator plane (`gazeMapper.plane.Type.GlassesValidator`). The configuration of a plane is stored in a subfolder of the project's configuration folder. The name of the plane is given by the name of this folder. For generic 2D planes, two configuration files are needed: a file providing information about which marker is positioned where and how each marker is oriented; and a settings file containing further information about both the markers and the plane. glassesValidator planes have their own settings and are discussed below. Here we describe the setup for generic 2D planes. It should be noted that a png render of the defined plane is stored in the plane's configuration folder when running any gazeMapper processing action, or by pressing the `generate reference image` button in the GUI. This can be used to check whether your plane definition is correct.

A generic 2D fiducial marker plane is defined by a file with four columns that describes the marker layout on the plane:

Column	Description
`ID`	The marker ID. Must match a valid marker ID for the marker dictionary employed, and must be unique throughout the project.
`x`	The horizontal location of the marker's center on the plane (mm).
`y`	The vertical location of the marker's center on the plane (mm).
`rotation_angle`	The rotation of the marker, if any (degree).

A file with this information should be stored under any name (e.g., `markerPositions.csv`) in the plane's configuration folder inside the project's configuration folder. See the example data for an example of such a file (TODO).

To be able turn the information of the above file into a plane, further settings are needed:

Setting	Description
`marker_file`	Name of the file specifying the marker layout on the plane (e.g., `markerPositions.csv`).
`marker_size`	Length of the edge of a marker (mm, excluding the white edge, only the black part).
`marker_border_bits`	Width of the black border around each marker.
`plane_size`	Total size of the plane (mm). Can be larger than the area spanned by the fiducial markers.
`origin`	The position of the origin of the plane (mm).
`unit`	Unit in which sizes and coordinates are expressed. Purely for informational purposes, not used in the software. Should be mm.
`aruco_dict`	The ArUco dictionary (see `cv::aruco::PREDEFINED_DICTIONARY_NAME`) of the markers.
`ref_image_size`	The size in pixels of the image that is generated of the plane with fiducial markers.

These settings are typically stored in a file `plane_def.json` in the plane's configuration folder inside the project's configuration folder.

Validation (glassesValidator planes)

gazeMapper has built-in support for computing data quality from the gaze data of a participant looking at a validation poster using glassesValidator. To use this functionality, a plane of type GlassesValidator (`gazeMapper.plane.Type.GlassesValidator`) needs to be defined in the project's setup. By default, the default glassesValidator plane is used for a GlassesValidator plane. When the default checkbox is unchecked in the GUI (the `is_default` setting in `plane_def.json` is False), a custom configuration can be used. When unchecking this checkbox in the GUI, files containing the plane setup are deployed to the plane configuration folder, so that the user can edit or replace them. API users are requested to call `glassesValidator.config.deploy_validation_config()` to deploy the glassesValidator configuration files to the plane's configuration folder. The customization options for a glassesValidator plane are documented here.

Individual Markers

Besides planes, gazeMapper can also be configured to detect and report on the appearance of individual markers. This is configured in the `Individual markers editor` pane in the GUI or by means of `gazeMapper.marker.Marker` objects.

Actions

gazeMapper can perform the following processing actions on a wearable eye tracking data. Some, like detecting the fiducial markers and projecting gaze data to the plane(s), are always available, some other actions are only available when certain settings are enabled. Unavailable actions are not shown in the GUI. Some actions depend on the output of other actions. Such actions whose preconditions have not been met cannot be started from the GUI. Some actions are performed on a gazeMapper session (e.g., `SYNC_TO_REFERENCE` and `MAKE_MAPPED_GAZE_VIDEO`) whereas others are run on one recording at a time (e.g., `CODE_EPISODES` and `DETECT_MARKERS`). The former will be referred to as session-level actions, the latter as recording-level actions. API use is not gated by such checks, but errors may be raised due to, for instance, missing input files. All available actions (`gazeMapper.process.Action`) are listed in the table below, more details about some of these processing actions are provided in the section below.

Action	Availability	Level	Description

Action	Availability	Level	Description
IMPORT	always	recording	Import a recording from a source directory to a recording working directory, which includes casting the eye tracker-specific data format into the glassesTools common format used by gazeMapper.
MAKE_GAZE_OVERLAY_VIDEO	always	recording	Make videos of the eye tracker scene camera with overlaid gaze point on the scene video. Can be made directly after import and is not affected by any of the video settings, these are for the MAKE_MAPPED_GAZE_VIDEO action.
CODE_EPISODES	always	recording	Code analysis, synchronization and validation episodes in a recording. Shows a coding GUI.
DETECT_MARKERS	always	recording	Detect fiducial markers and determine participants pose for one or multiple planes and individual markers.
GAZE_TO_PLANE	always	recording	Mapping head-referenced gaze to one or multiple planes.
AUTO_CODE_SYNC	auto_code_sync_points option	recording	Automatically find sync points in the scene/external camera videos. Only makes sense to perform if there are multiple recordings in a session, since otherwise there is nothing to synchronize.
AUTO_CODE_TRIALS	auto_code_trial_episodes option	recording	Automatically find trial start and ends using fiducial markers in the scene camera.
SYNC_ET_TO_CAM	get_cam_movement_for_et_sync_method option	recording	Synchronize gaze data to the scene camera. Shows a GUI for manually performing this synchronization.
SYNC_TO_REFERENCE	sync_ref_recording option	session	Synchronize the gaze data and cameras of multiple recordings. Only makes sense to perform if there are multiple recordings in a session, since otherwise there is nothing to synchronize.
RUN_VALIDATION	plane setup and episode coding setup	recording	Run glassesValidator to compute data quality from the gaze data of a participant looking at a validation poster.
EXPORT_TRIALS	always	session	Create file for each recording containing the gaze position on one or multiple planes.
MAKE_MAPPED_GAZE_VIDEO	video_make_which option	session	Make videos of the eye tracker scene camera or external camera (synchronized if there are multiple) showing gaze on the scene video from the eye tracker, gaze projected to the detected planes, detected plane origins, detected individual markers, and gaze from other eye tracker recordings (if available).

In the GUI, an overview of what processing actions are enqueued or running for a session or recording are shown in the Sessions pane, in the detail view for a specific session, and in the Processing queue pane.

Coding analysis, synchronization and validation episodes

To process a recording, gazeMapper needs to be told where in the recording several events are, such as the trial(s) for which you want to have gaze data mapped to the plane. There are four types of episodes (glassesTools.annotation.Event) that can be coded, which are available depends on the set of events that are set to be coded for the project with the episodes_to_code setting. Some may not be of use, depending on the configuration of the gazeMapper project:

Episode	Availability	Description
Trial	always	Denotes an episode for which to map gaze to plane(s). This determines for which segments there will be gaze data when running the gazeMapper.process.Action.EXPORT_TRIALS action.
Validate	plane setup	Denotes an episode during which a participant looked at a validation poster, to be used to run glassesValidator to compute data quality of the gaze data.
Sync_Camera	sync_ref_recording option	Time point (frame from video) when a synchronization event happened, used for synchronizing different recordings.
Sync_ET_Data	get_cam_movement_for_et_sync_method option	Episode to be used for synchronization of eye tracker data to scene camera (e.g. using VOR).

Furthermore, the Trial, Validate and Sync_Camera episodes need to be associated with one or multiple planes to be detected during these episodes. Which planes to detect per episode is set up with the planes_per_episode setting.

Note that when you have multiple recordings, glassesTools.annotation.Event.Trial events can only be coded for the reference recording (set by the sync_ref_recording setting). The trial coding in the reference recording is automatically propagated to the other recordings once they are synchronized.

The coding is stored in the coding.tsv file in a recording directory.

Automatic coding of analysis and synchronization episodes

gazeMapper supports automatically coding synchronization points (glassesTools.annotation.Event.Sync_Camera) and trial intervals (glassesTools.annotation.Event.Trial) using fiducial markers in the scene video. Specifically, individual markers can be configured to denote such sync points and

individual markers or sequences of individual markers can denote the start of a trial or the end of a trial. To do so, first the individual markers to be used for this purpose need to be configured to be detected by the `gazeMapper.process.Action.DETECT_MARKERS` action. Then, on the `Project settings` pane, automatic coding of synchronization points can be configured using the `auto_code_sync_points` option, and automatic coding of trial starts and ends using the `auto_code_trial_episodes` option.

Note that when the `gazeMapper.process.Action.AUTO_CODE_SYNC` or `gazeMapper.process.Action.AUTO_CODE_TRIALS` actions are run from the GUI, these reset the `gazeMapper.process.Action.CODE_EPISODES` to not run status. This is done to require that the output of the automatic coding processes is manually checked in the coding interface before further processing is done. Make sure to zoom in on the timeline (using the mouse scroll wheel when hovering the cursor over the timeline) to check that there are not multiple (spurious) events close together.

Automatic coding of synchronization timepoints

For automatic coding of synchronization points, the configuration of the `auto_code_sync_points` option works as follows. First, any marker whose appearance should be taken as a sync point should be listed by its ID in `auto_code_sync_points.markers`. Sequences of frames where the marker(s) are detected are taken from the output of the `gazeMapper.process.Action.DETECT_MARKERS` action and processed according to two further settings. Firstly, any gaps between sequences of frames where the marker is detected that are shorter than or equal to `auto_code_sync_points.max_gap_duration` frames will be filled (i.e., the two separate sequences will be merged in to one). This reduces the chance that a single marker presentation is detected as multiple events. Then, any sequences of frames where the marker is detected that are shorter than `auto_code_sync_points.min_duration` frames will be removed. This reduces the chance that a spurious marker detection is picked up as a sync point. For the purposes of this processing, if more than one marker is specified, detections of each of these markers are processed separately.

Automatic coding of analysis episodes

For automatic coding of trial starts and ends, the configuration of the `auto_code_trial_episodes` option works as follows. First, the marker whose appearance should be taken as the start of a trial should be listed by its ID in `auto_code_trial_episodes.start_markers` and the marker whose disappearance should be taken as the end of a trial in `auto_code_trial_episodes.end_markers`. Different from the synchronization point coding above, trial starts and ends can be denoted by a sequence of markers, do decrease the change for spurious detections. To make use of this, specify more than one marker in `auto_code_trial_episodes.start_markers` and/or `auto_code_trial_episodes.end_markers` in the order in which they are shown. If this is used, trail starts are coded as the last frame where the last marker in the sequence is detected, and trial ends as the first frame where the first marker of the sequence is detected. Sequences of frames where the marker(s) are detected as delivered by the `gazeMapper.process.Action.DETECT_MARKERS` action are processed as follows. First, detections for individual markers are processed with the same logic for removing spurious detections as for `auto_code_sync_points` above, using the `auto_code_trial_episodes.max_gap_duration` and `auto_code_trial_episodes.min_duration` parameters. If a trial start or end consists of a single marker, that is all that is done. If a trial start/end consists of a sequence of markers, then these sequences are found from the sequence of individual marker detections by looking for detections of the indicated markers in the right order with a gap between them that is no longer than `auto_code_trial_episodes.max_intermarker_gap_duration` frames.

Synchronization

For eye tracker recordings, the gaze data is not always synchronized correctly to the scene camera. Furthermore, when a gazeMapper session consists of multiple recordings from eye trackers and/or external cameras, these have to be synchronized together. GazeMapper includes methods for solving both these sync problems.

Synchronizing eye tracker data and scene camera

Synchronization of the eye tracker data to the scene camera is controlled by the `get_cam_movement_for_et_sync_method` setting. If `get_cam_movement_for_et_sync_method` is set to an empty string (default) means that the eye tracker data will not be synchronized to the scene camera. If it is set to another value, the following occurs. Synchronization of the eye tracker data to the scene camera can be checked and corrected using what we will call the VOR method. In the VOR method, an observer is asked to maintain fixation on a point in the world while slowly shaking their head horizontally (like saying no) and vertically (like saying yes). When performing this task, the eyes are known to counterroll in the head with 0 latency and perfect gain, meaning that gaze is maintained on the point in the world during the head movement. That means that the executed eye and head movement are synchronized perfectly with each other, and this can be exploited to synchronize the eye tracking data and scene camera feeds in a recording. Specifically, the eye movement during the VOR episode is recorded directly by the eye tracker, while the head movement can be extracted from the scene camera video. Aligning these two signals with each other allows checking and removing any temporal offset, thus synchronizing the signals. With gazeMapper, the head movement can be extracted from the scene video using one of two methods, configured with the `get_cam_movement_for_et_sync_method` setting. If `get_cam_movement_for_et_sync_method` is set to `'plane'`, then head movement is represented by the position of the origin of an indicated plane in the scene camera video, as extracted through pose estimation or homography using gazeMapper planes. If `get_cam_movement_for_et_sync_method` is set to `'function'`, a user-specified function (configured using the `get_cam_movement_for_et_sync_function` setting) will be called for each frame of the scene video in a `glassesTools.annotation.Event.Sync_ET_Data` episode and is expected to return the location of the target the participant was looking at. For instance, the example function at `gazeMapper.utils.color_blob_localizer` tracks objects of a certain solid color (we have used a solid green disk for this purpose in one experiment).

Once both eye movement and head movement signals have been derived for a `glassesTools.annotation.Event.Sync_ET_Data` episode, these are shown in a GUI where they can checked for any synchronization problem, and be manually aligned to correct for such problems if needed.

Synchronizing multiple eye tracker or external camera recordings

Recordings in a gazeMapper session can be synchronized by precisely coding when a visual event occurs in the camera feed of each of the recordings. Such an event could for instance be made by flashing a light, using a digital clapperboard, or showing an ArUco marker on a screen that is visible in all cameras. The latter can be used for automatically finding the synchronization timepoints. Synchronizing multiple recordings using such synchronization timepoints is done by setting the `sync_ref_recording` setting to the name of the recording to which the other recordings should be synchronized. We will call the recording indicated by the `sync_ref_recording` setting as the reference recording. For instance, if you have two recordings in a session, `et_teacher` and `et_student`, then setting `sync_ref_recording` to `et_teacher` will cause the timestamps of the `et_student` recording to be altered so that they're expressed in the time of the `et_teacher` recording. Using a single synchronization timepoint, offsets in recording start points can be corrected for. By default, when multiple synchronization timepoints have been coded, the average of the offsets between the recordings for all these timepoints is used to synchronize the recordings.

By setting `sync_ref_do_time_stretch` to `True`, multiple time points can however also be used to correct for clock drift. Different video recordings may however undergo clock drift, meaning that time elapses faster or slower in one recording than another. In a particularly bad case, we have seen this amount to several hundred

milliseconds for a recording of around half an hour. If clock drift occurs, correcting time for one recording by only a fixed offset is insufficient as that will synchronize the recordings at that specific timepoint in the recording, but significant desynchronization may occur at other timepoints in the recording. When `sync_ref_do_time_stretch` is `True`, clock drift is additionally corrected for by the synchronization procedure by calculating the difference in elapsed time for the two recordings, and stretching the time of either the reference recording (`sync_ref_stretch_which` is set to `'ref'`) or the other recording(s) (`sync_ref_stretch_which` is set to `'other'`). Note that currently only the `'ref'` setting of `sync_ref_stretch_which` is implemented. Finally, there is the setting `sync_ref_average_recordings`. If it is set to a non-empty list, the time stretch factor w.r.t. multiple other recordings (e.g. two identical eye trackers) is used, instead of for individual recordings. This can be useful with `sync_ref_stretch_which='ref'` if the time of the reference recording is deemed unreliable and the other recordings are deemed to be similar. Then the average time stretch factor of these recordings may provide a better estimate of the stretch factor to use than that of individual recordings.

Configuration

In this section, a full overview of gazeMapper's settings is given. These settings are stored in a `gazeMapper.config.Study` file, and stored in the `study_def.json` JSON file in a gazeMapper project's configuration directory.

Setting name in GUI	**Setting name in settings file**	**Default value**	**Description**
`Session definition` pane	`session_def`		gazeMapper session `gazeMapper.sessio`
`Plane editor` pane	`planes`		gazeMapper plane s `gazeMapper.plane`
Episodes to code on the `Episode setup` pane	`episodes_to_code`		gazeMapper coding `glassesTools.anno`
Planes per episode on the `Episode setup` pane	`planes_per_episode`		gazeMapper coding detect for each episc `glassesTools.anno` of plane names as va
`Individual marker editor`	`individual_markers`		gazeMapper individu `gazeMapper.marker`
Copy video during import?	`import_do_copy_video`	`True`	If `False`, the scene v the video of an exter gazeMapper recordi the video will be loa directory (so do not must be transcoded
Store source directory as relative path?	`import_source_dir_as_relative_path`	`False`	Specifies whether th in the recording info relative path (`True`). imported recording moved to another lo still be found as long up and in the directc `../original reco`
Registered custom eye trackers	`import_known_custom_eye_trackers`	`None`	gazeMapper allows i which no specific su recording data is pre glassesTools' generic specific known gene import.
Synchronization: Reference recording	`sync_ref_recording`	`None`	If set to the name of of other recordings i recording.
Synchronization: Do time stretch?	`sync_ref_do_time_stretch`	`None`	If `True`, multiple syn stretch factor to com synchronizing multip `sync_ref_recordi`

Setting name in GUI	Setting name in settings file	Default value	Description
Synchronization: Stretch which recording	`sync_ref_stretch_which`	`None`	Which recording(s) s `sync_ref_do_time_` `'ref'` and `'other'`. `sync_ref_recordi`
Synchronization: Average recordings?	`sync_ref_average_recordings`	`None`	Whether to average recordings if `sync_r` Should be set if `sync`
Gaze data synchronization: Method to get camera movement	`get_cam_movement_for_et_sync_method`	`''`	Method used to deri synchronizing eye tra Possible values are `' 'function'`
Gaze data synchronization: Function for camera movement	`get_cam_movement_for_et_sync_function`	`None`	Function to use for c synchronizing eye tra `get_cam_movement_` `'function'`. Should `gazeMapper.confi` object.
Gaze data synchronization: Use average?	`sync_et_to_cam_use_average`	`True`	Whether to use the a episodes. If `False`, tl used, the rest are igr
Automated coding of synchronization points	`auto_code_sync_points`	`None`	Setup for automatic timepoints. Should b `gazeMapper.confi`
Automated coding of trial episodes	`auto_code_trial_episodes`	`None`	Setup for automatic be a `gazeMapper.co` object.
Mapped data export: include 3D fields?	`export_output3D`	`False`	Determines whether scene camera refere invoking the `gazeMapper.proces` See the glassesTools
Mapped data export: include 2D fields?	`export_output2D`	`True`	Determines whether plane's reference fra `gazeMapper.proces` See the glassesTools
Mapped data export: only include marker presence?	`export_only_code_marker_presence`	`True`	If `True`, for each mar the export created b `gazeMapper.proces` indicating whether tl on a given frame. If included in the expo
glassesValidator: Apply global shift?	`validate_do_global_shift`	`True`	glassesValidator sett interval the median p gaze data and the m overall shift of the da fixations to targets w offset in the data. It samples far outside t if there is no data fo
glassesValidator: Maximum distance factor	`validate_max_dist_fac`	`.5`	glassesValidator sett limit when assigning If for a given target t away than *[minimu fixation point will be be matched to any fi essentially disable.

Setting name in GUI	Setting name in settings file	Default value	Description
glassesValidator: Data quality types	`validate_dq_types`	`None`	glassesValidator sett you would like to cal When none are selec recording. When nor depending on the va setting, either an err used instead. Wheth depends on what typ for a recording, as w calibrated. See the g more information.
glassesValidator: Allow fallback data quality type?	`validate_allow_dq_fallback`	`False`	glassesValidator sett `validate_dq_types` raised when the indi available, if `True`, a s be used instead.
glassesValidator: Include data loss?	`validate_include_data_loss`	`False`	glassesValidator sett will include data loss each target on the va loss of the whole rec to report in your pap
glassesValidator: I2MC settings	`validate_I2MC_settings`	`I2MCSettings()`	glassesValidator sett classifier used as par assigned to validatio `gazeMapper.confi`
Video export: Which recordings	`video_make_which`	`None`	Indicates one or mul videos of the eye tra camera (synchronize are multiple) showin individual markers ar eye tracker recordin recordings are gaze tracker, gaze project if available, and enab settings. Value shoul
Video export: Recording colors	`video_recording_colors`	`None`	Color used for drawi scene camera and ga Each key should be a be a `gazeMapper.co`
Video export: Color for gaze position on plane	`video_projected_vidPos_color`	`RgbColor(255,255, 0)`	Color used for drawi the scene video tran value is not set. The `gazeMapper.confi`
Video export: Color for 3D gaze position on plane	`video_projected_world_pos_color`	`RgbColor(255, 0,255)`	Color used for drawi recorded 3D gaze po value is not set. The `gazeMapper.confi`
Video export: Color for left eye gaze vector projected to plane	`video_projected_left_ray_color`	`RgbColor( 0, 0,255)`	Color used for drawi recorded left eye's g set. The value should `gazeMapper.confi`
Video export: Color for right eye gaze vector projected to plane	`video_projected_right_ray_color`	`RgbColor(255, 0, 0)`	Color used for drawi recorded right eye's not set. The value sh `gazeMapper.confi`

Setting name in GUI	Setting name in settings file	Default value	Description
Video export: Color for average of gaze vectors projected to plane	`video_projected_average_ray_color`	`RgbColor(255, 0,255)`	Color used for drawi of the recorded left a drawn if value is not `gazeMapper.confi`
Video export: Process all planes for all frames?	`video_process_planes_for_all_frames`	`False`	If `True`, shows detec frames. If `False`, det during the episode(s
Video export: Process all annotations for all recordings?	`video_process_annotations_for_all_recordings`	`True`	Episode annotations the screen. If this set the recording for wh the other recordings
Video export: Show detected markers?	`video_show_detected_markers`	`True`	If `True`, known detec output video.
Video export: Show planes axes?	`video_show_plane_axes`	`True`	If `True`, axes indicati plane are drawn at tl
Video export: Process individual markers for all frames?	`video_process_individual_markers_for_all_frames`	`True`	If `True`, detection re video. If `False`, dete coded episodes of th
Video export: Show individual markers?	`video_show_individual_marker_axes`	`True`	If `True`, the pose axi individual markers is
Video export: Show sync function output?	`video_show_sync_func_output`	`True`	Applies if the `get_c` setting is set to `'fur` the function on the c
Video export: Show unexpected markers?	`video_show_unexpected_markers`	`False`	If `False`, only marke configured individua If `True`, also other, u
Video export: Show rejected markers?	`video_show_rejected_markers`	`False`	If `True`, all shapes th rejected by OpenCV' debug purposes.
Video export: Videos on which to draw gaze projected to plane	`video_show_gaze_on_plane_in_which`	`None`	For the listed record (both the gaze point right eyes' gaze vect for eye tracker recor recordings in a sessi recordings (if availab indicated video(s).
Video export: Videos on which to draw gaze vectors(s)	`video_show_gaze_vec_in_which`	`None`	For the listed record positions of the cam gaze position of thes in the generated vid
Video export: Videos on which to draw camera position(s)	`video_show_camera_in_which`	`None`	For the listed record other recordings is n
Video export: Which gaze on plane to show in reference recording's video?	`video_which_gaze_type_on_plane`	`glassesTools.gaze_worldref.Type.Scene_Video_Position`	Sets which gaze-on- scene video or from is used for the gaze videos.

Setting name in GUI	Setting name in settings file	Default value	Description
Video export: Allow fallback to showing gaze on plane based on scene video gaze?	`video_which_gaze_type_on_plane_allow_fallback`	`True`	Sets if it is allowed to the gaze position on position on the video in the "Video export: setting is not availab
Video export: Gaze position margin	`video_gaze_to_plane_margin`	`0.25`	Gaze position more t plane will not be dra
Number of workers	`gui_num_workers`	`2`	Each action is proces can handle one actio means more actions having too many wil freeze the program a much of the process thread, set this value of threads available have running or enq will only be changed cancelled.

`gazeMapper.config.AutoCodeSyncPoints`

These settings are discussed here.

Setting name in GUI	Setting name in settings file	Default value	Description
Markers	`markers`		Set of marker IDs whose appearance indicates a sync point.
Maximum gap duration	`max_gap_duration`	`4`	Maximum gap (number of frames) to be filled in sequences of marker detections.
Minimum duration	`min_duration`	`6`	Minimum length (number of frames) of a sequence of marker detections. Shorter runs are removed.

`gazeMapper.config.AutoCodeTrialEpisodes`

These settings are discussed here.

Setting name in GUI	Setting name in settings file	Default value	Description
Start marker(s)	`start_markers`		A single marker ID or a sequence (`list`) of marker IDs that indicate the start of a trial.
End marker(s)	`end_markers`		A single marker ID or a sequence (`list`) of marker IDs that indicate the end of a trial.
Maximum gap duration	`max_gap_duration`	`4`	Maximum gap (number of frames) to be filled in sequences of marker detections.
Maximum intermarker gap duration	`max_intermarker_gap_duration`	`15`	Maximum gap (number of frames) between the detection of two markers in a sequence.
Minimum duration	`min_duration`	`6`	Minimum length (number of frames) of a sequence of marker detections. Shorter runs are removed.

`gazeMapper.config.CamMovementForEtSyncFunction`

These settings are used for when the `get_cam_movement_for_et_sync_method` setting is set to `'function'`, see here.

Setting name in GUI	Setting name in settings file	Default value	Description
Module or file	`module_or_file`		Importable module or file (can be a full path) that contains the function to run.
Function	`function`		Name of the function to run.
Parameters	`parameters`		`dict` of `kwargs` to pass to the function. The frame to process (`np.ndarray`) is the first (positional) input passed to the function, and should not be specified in this dict.

`gazeMapper.config.I2MCSettings`

Settings used when running I2MC fixation classifier used as part of determining the fixation that are assigned to validation targets. Used for the `gazeMapper.process.Action.RUN_VALIDATION`, see here. N.B.: The below fields with `None` as the default value are set by glassesValidator based on the input gaze data. When a value is set for one of these settings, it overrides glassesValidator's dynamic parameter setting.

Setting name in GUI	Setting name in settings file	Default value	Description
Sampling frequency	`freq`	`None`	Sampling frequency of the eye tracking data.
Maximum gap duration for interpolation	`windowtimeInterp`	`.25`	Maximum duration (s) of gap in the data that is interpolated.
# Edge samples	`edgeSampInterp`	`2`	Amount of data (number of samples) at edges needed for interpolation.
Maximum dispersion	`maxdisp`	`50`	Maximum distance (mm) between the two edges of a gap below which the missing data is interpolated.
Moving window duration	`windowtime`	`.2`	Length of the moving window (s) used by I2MC to calculate 2-means clustering when processing the data.
Moving window step	`steptime`	`.02`	Step size (s) by which the moving window is moved.
Downsample factors	`downsamples`	`None`	Set of integer decimation factors used to downsample the gaze data as part of I2MC processing.
Apply Chebyshev filter?	`downsampFilter`	`None`	If `True`, a Chebyshev low-pass filter is applied when downsampling.
Chebyshev filter order	`chebyOrder`	`None`	Order of the Chebyshev low-pass filter.
Maximum # errors	`maxerrors`	`100`	Maximum number of errors before processing of a trial is aborted.
Fixation cutoff factor	`cutoffstd`	`None`	Number of standard deviations above mean k-means weights that will be used as fixation cutoff.
Onset/offset Threshold	`onoffsetThresh`	`3.`	Number of MAD away from median fixation duration. Will be used to walk forward at fixation starts and backward at fixation ends to refine their placement and stop algorithm from eating into saccades.
Maximum merging distance	`maxMergeDist`	`20`	Maximum Euclidean distance (mm) between fixations for merging to be possible.
Maximum gap duration for merging	`maxMergeTime`	`81`	Maximum time (ms) between fixations for merging to be possible.
Minimum fixation duration	`minFixDur`	`50`	Minimum fixation duration (ms) after merging, fixations with shorter duration are removed from output.

`gazeMapper.config.RgbColor`

Setting name in GUI	Setting name in settings file	Default value	Description
R	`r`	`0`	Value of the red channel (0-255).
G	`g`	`0`	Value of the green channel (0-255).
B	`b`	`0`	Value of the blue channel (0-255).

Overriding a project's settings for a specific session or recording

gazeMapper support overriding a subset of the above settings for a specific session or recording. These settings overrides can be set in the GUI on the pane for a specific session, and are stored in JSON files (`study_def_override.json`) in the respective session's or recording's working directory. Programmatically, these settings overrides are handled using `gazeMapper.config.StudyOverride` objects. When using the API, settings can furthermore be overridden by means of keyword arguments to any of the `gazeMapper.process` functions. When overriding subobjects of a `gazeMapper.config.Study` (such as fields in a `dict`), set only the fields you want to override. The other fields will keep their original value.

API

All of gazeMapper's functionality is exposed through its API. Below are all functions that are part of the public API. gazeMapper makes extensive use of the functionality of glassesTools and its functionality for validating the calibration of a recording is a thin wrapper around glassesValidator. See the glassesTools and glassesValidator documentation for more information about these functions.

`gazeMapper.config`

function	inputs	output	description

function	inputs	output	description
`guess_config_dir`	1. `working_dir`: location from which to start the search 2. `config_dir_name`: name of the configuration directory, `'config'` by default. 3. `json_file_name`: name of a study configuration file that is expected to be found in the configuration directory, `'study_def.json'` by default.	1. `pathlib.Path`	Find the path of the project's configuration directory when invoked from a directory 0, 1, or 2 levels deep in a project directory.
`load_override_and_apply`	1. `study`: `gazeMapper.config.Study` object to which to apply override. 2. `level`: `gazeMapper.config.OverrideLevel` (`Session` or `Recording`) for override to be loaded. 3. `override_path`: path to load the study setting override JSON file from. Can be a path to a file, or a path to a folder containing such a file (in the latter case, the filename `'study_def_override.json'` will be used). 4. `recording_type`: `gazeMapper.session.RecordingType` (used when applying a recording-level override, else `None`). 5. `strict_check`: If `True`, raise when error is found in the resulting study configuration.	1. `gazeMapper.config.Study`: Study configuration object with the setting overrides applied.	Load and apply a setting override file to the provided study configuration.
`load_or_create_override`	1. `level`: `gazeMapper.config.OverrideLevel` (`Session` or `Recording`) for override to be loaded. 2. `override_path`: path to load the study setting override JSON file from. Can be a path to a file, or a path to a folder containing such a file (in the latter case, the default filename `'study_def_override.json'` will be used). 3. `recording_type`: `gazeMapper.session.RecordingType` (used when applying a recording-level override, else `None`).	1. `gazeMapper.config.StudyOverride`: study override object	Loads the override object from the indicated file if it exists, else returns an empty object.
`apply_kwarg_overrides`	1. `study`: `gazeMapper.config.Study` object to which to apply override. 2. `strict_check`: If `True`, raise when error is found in the resulting study configuration. 3. `**kwargs`: overrides to apply, specified by means of keyword-arguments.	1. `gazeMapper.config.Study`: Study configuration object with the setting overrides applied.	Apply overrides specified as keyword arguments.
`read_study_config_with_overrides`	1. `config_path`: path to study configuration folder or file. 2. `overrides`: `dict` of `gazeMapper.config.OverrideLevel`s (`Session` or `Recording`) to be loaded and corresponding path to load them from. 3. `recording_type`: `gazeMapper.session.RecordingType` (used when applying a recording-level override, else `None`). 4. `strict_check`: If `True`, raise when error is found in the resulting study configuration. 5. `**kwargs`: additional overrides to apply, specified by means of keyword-arguments.	1. `gazeMapper.config.Study`: Study configuration object with the setting overrides applied.	Load study configuration and apply specified setting overrides.

gazeMapper.config.Study

member function	inputs	output	description
__init__	Takes all the parameters listed under configuration.		
check_valid	1. strict_checkIf True, raise when error is found in the resulting study configuration. If False, errors are ignored, only defaults are applied.		Check for errors and apply defaults.
field_problems		1. gazeMapper.type_utils.ProblemDict: Nested dict containing fields (if any) with configuration problems, and associated error messages.	Check configuration for errors and returns found problems.
store_as_json	1. path: path to store study setting JSON file to. Can be a path to a file, or a path to a folder containing such a file (in the latter case, the default filename 'study_def.json' will be used).		Store project configuration to JSON file.
get_empty (static)		1. gazeMapper.config.Study: Empty (every default) study configuration object.	Get default study configuration object.
load_from_json (static)	1. path: path to load study setting JSON file from. Can be a path to a file, or a path to a folder containing such a file (in the latter case, the default filename 'study_def.json' will be used). 2. strict_check: If True, raise when error is found in the resulting study configuration.	1. gazeMapper.config.Study: Study configuration object.	Load settings from JSON file.

gazeMapper.config.OverrideLevel

Enum:

Value	Description
Session	Session-level override (setting overrides for a specific session).
Recording	Recording-level override (setting overrides for a specific recording).
FunctionArgs	Specifies overrides provided by means of keyword-arguments.

gazeMapper.config.StudyOverride

member function	inputs	output	description
__init__	1. level: OverrideLevel. 2. recording_type: gazeMapper.session.RecordingType (used when applying a recording-level override, else None).		
get_allowed_parameters (static)	1. level: OverrideLevel. 2. recording_type: gazeMapper.session.RecordingType (used when applying a recording-level override, else None).	1. Whitelist of parameters that can be set.	Get parameter whitelist for this override level (and recording type, if applicable).
apply	1. study: gazeMapper.config.Study object to which to apply override. 2. strict_check: If True, raise when error is found in the resulting study configuration.	1. gazeMapper.config.Study: Study configuration object with the setting overrides applied.	Apply overrides to a Study object.

member function	inputs	output	description
`store_as_json`	1. `path`: path to store study settings override JSON file to. Can be a path to a file, or a path to a folder containing such a file (in the latter case, the default filename `'study_def_override.json'` will be used).		Store project configuration overrides to JSON file.
`load_from_json` (static)	1. `level`: OverrideLevel. 2. `path`: path to load study settings override JSON file from. Can be a path to a file, or a path to a folder containing such a file (in the latter case, the default filename `'study_def_override.json'` will be used). 3. `recording_type`: `gazeMapper.session.RecordingType` (used when applying a recording-level override, else `None`).	1. `gazeMapper.config.StudyOverride`: Study configuration override object.	Load settings from JSON file.
`from_study_diff` (static)	1. `study`: `gazeMapper.config.Study` object for a specific session or recording. 2. `parent_config`: `gazeMapper.config.Study` to compare to. 3. `level`: OverrideLevel. 4. `recording_type`: `gazeMapper.session.RecordingType` (used when applying a recording-level override, else `None`).	1. `gazeMapper.config.StudyOverride`: Study configuration override object.	Get the difference in configuration between two `Study` objects (only check whitelisted attributes), and return as `StudyOverride` object.

gazeMapper.episode

function	inputs	output	description
`Episode.__init__`	1. `event`: `glassesTools.annotation.Event`. 2. `start_frame`: start frame of episode. 3. `end_frame`: end frame of episode (not set if `event` is a timepoint instead of an episode).		Episode constructor: makes object that encodes a time point or episode in the recording.
`read_list_from_file`	1. `fileName`: path of `csv` file to read episodes from (by default a `coding.csv` file).	1. list of `Episode`s.	Read a list of episodes from a `csv` file.
`write_list_to_file`	1. `episodes`: list of `Episode`s to store to file. 2. `fileName`: path of `csv` file to store episodes to (by default a `coding.csv` file).		Store a list of episodes to a `csv` file.
`get_empty_marker_dict`	1. `episodes`: list or dict of `glassesTools.annotation.Event`s that should appears as keys in the output dict. Optional, if not specified, all `glassesTools.annotation.Event`s are used.	1. Empty dict with specified event types as keys.	Get empty dict that can be used for storing episodes grouped by event type.
`list_to_marker_dict`	1. `episodes`: list of `Episode`s. 2. `expected_types`: list or dict of `glassesTools.annotation.Event`s that may appear in the list of input `episodes`. Optional, if not specified, all `glassesTools.annotation.Event`s are allowed.	1. Dict with episodes grouped by event type.	Take an intermixed list of episodes and organize into a dict by event type.
`marker_dict_to_list`	1. `episodes`: dict with episodes grouped by event type.	1. Intermixed list of episodes.	Take a dict with `Episode`s grouped by event type and turn into intermixed list of episodes (sorted by `start_frame` of the `Episode`s).
`is_in_interval`	1. `episodes`: dict or list of `Episode`s. 2. `idx`: frame index to check.	1. Boolean indicating whether `idx` is within one of the episodes.	Check whether provided frame index falls within one of the episodes.

gazeMapper.marker

function	inputs	output	description
Marker.__init__	1. id: The marker ID. Must be a valid marker ID for the specified marker dictionary. 2. size: Length of the edge of a marker (mm, excluding the white edge, only the black part). 3. aruco_dict: The ArUco dictionary (see cv::aruco::PREDEFINED_DICTIONARY_NAME) of the marker. 4. marker_border_bits: Width of the black border around the marker.		Marker constructor: makes object that encap that can be detected with the functionality ir
get_marker_dict_from_list	1. markers: list of Marker objects.	1. Dict with properties of each marker.	Turn list of Marker objects into a dict organi properties of each marker. Used by glassesTools.aruco.PoseEstimator.ad
load_file	1. marker_id: ID of marker to load marker detection/pose results for. 2. folder: Folder from which to load the marker detect output file.	1. pandas.DataFrame containing marker detection/pose results for a specific marker.	Load marker detection/pose results for a spe
code_marker_for_presence	1. markers: pandas.DataFrame or dict of pandas.DataFrames organized by marker ID containing marker detection/pose results for a specific marker.	1. Input dataframe with a boolean column added (*_presence) denoting whether marker was detected or not for the video frame on that row in the dataframe.	Code markers for whether they were detecte
fill_gaps_in_marker_detection	1. markers: pandas.DataFrame containing marker detection/pose results for a specific marker 2. fill_value: Value to put for missing rows.	1. Input data frame with missing rows added so that the frame_idx column is a contiguous series.	Rows may be missing in a marker detection/ function fills those missing rows with the ind frame_idx column is a contiguous series.

gazeMapper.plane

function	inputs	output	description
make	1. p_type: plane type. 2. name: Name of the plane. 3. path: Path from which to load information about the plane. Needed for a GlassesValidator plane if using a non-default setup. 4. **kwargs: additional arguments that are passed along to the plane defition object's constructor.	GlassesValidator or Plane_2D definition object.	Make plane definition object of given type and name.
get_plane_from_path	1. path: plane definition folder in the project's configuration folder.	1. a glassesTools.plane.Plane object.	Load plane definition from file and use it to construct a glassesTools.plane.Plane object.

function	inputs	output	description
`get_plane_from_definition`	1. `plane_def`: plane definition object. 2. `path`: plane definition folder in the project's configuration folder.	1. a `glassesTools.plane.Plane` object.	Construct a `glassesTools.plane.Plane` object from a plane definition object.
`get_plane_setup`	1. `plane_def`: plane definition object.	1. Dict with information about the plane's setup.	Turns a plane definition object into a dict with information about that plane that is needed for `glassesTools.aruco.PoseEstimator.add_plane()`.

`gazeMapper.plane.Type`

Enum:

Value	Description
`GlassesValidator`	Plane is a glassesValidator poster.
`Plane_2D`	Plane is a general 2D plane.

`gazeMapper.plane.Definition` and subclasses

`gazeMapper.plane.Definition_GlassesValidator` and `gazeMapper.plane.Definition_Plane_2D`

member function	inputs	output	description
`__init__`	1. `type`: plane type. 2. `name`: Name of the plane.		
`field_problems`		1. `gazeMapper.type_utils.ProblemDict`: Nested dict containing fields (if any) with configuration problems, and associated error messages.	Check configuration for errors and returns found problems.
`fixed_fields`		1. `gazeMapper.type_utils.NestedDict`: Nested dict containing fields (if any) that cannot be edited.	Get list of fields that cannot be edited (should be displayed as such in the GUI).
`has_complete_setup`		1. Boolean indicating whether plane setup is ok or not.	Check whether plane setup is ok or has problems.
`store_as_json`	1. `path`: Path to store plane definition JSON file to. Can be a path to a file, or a path to a folder containing such a file (in the latter case, the default filename `'plane_def.json'` will be used).		Store plane definition to JSON file.
`load_from_json` (static)	1. `path`: path to load plane definition JSON file from. Can be a path to a file, or a path to a folder containing such a file (in the latter case, the default filename `'plane_def.json'` will be used).	1. `GlassesValidator` or `Plane_2D` definition object.	Load plane definition from JSON file.

`gazeMapper.process`

`gazeMapper.process.Action` is described above.

`gazeMapper.process.State` enum:

Value	Description
`Not_Run`	Action not run.
`Pending`	Action enqueued to be run.
`Running`	Action running.
`Completed`	Action ran successfully.

Value	Description
`Canceled`	Action run cancelled.
`Failed`	Action failed.

NB: the `Pending`, `Canceled` and `Completed` states are only used in the GUI.

function	inputs	output	description
`action_to_func`	1. `action`: a `gazeMapper.process.Action`.	1. Callable for performing the indicated action.	Get the callable (function) corresponding to an Action.
`is_session_level_action`	1. `action`: a `gazeMapper.process.Action`.	1. Boolean indicating whether action is session level or recording level.	Get whether action is a session level action.
`is_action_possible_given_config`	1. `action`: a `gazeMapper.process.Action`. 2. `study_config`: a `gazeMapper.config.Study` object.	1. Boolean indicating whether action is possible.	Get whether a given action is possible given the study's configuration.
`is_action_possible_for_recording_type`	1. `action`: a `gazeMapper.process.Action`. 2. `rec_type`: a `gazeMapper.session.RecordingType`.	1. Boolean indicating whether action is possible.	Get whether a given (recording-level) action is possible for a recording of the indicated type.
`get_actions_for_config`	1. `study_config`: a `gazeMapper.config.Study` object. 2. `exclude_session_level`: Boolean (default `False`) indicating whether session-level actions should be included in the return value.	1. A set of possible actions.	Get the possible actions given a study's configuration.
`action_update_and_invalidate`	1. `action`: a `gazeMapper.process.Action`. 2. `state`: the new `gazeMapper.process.State`. 3. `study_config`: a `gazeMapper.config.Study` object.	1. Dict with a `State` per `Action`.	Update the state of the specified action, and get the state of all actions possible for the study (updating one state may lead to other actions needing to be rerun).
`get_possible_actions`	1. `session_action_states`: Dict with a `State` per session-level `Action`. 2. `recording_action_states`: Dict per recording with as value a dict with a `State` per recording-level `Action`. 3. `actions_to_check`: a set of `Action` to check. 4. `study_config`: a `gazeMapper.config.Study` object.	1. A dict with per action either a Boolean indicating whether the action can be run (for session-level actions), or the names of recordings for which the action can be run (for recording-level actions).	Get which actions can be run given the currect session- and recording-level action states.

`gazeMapper.session`

`gazeMapper.session.RecordingType`

Enumeration

Value	Description
`Eye_Tracker`	Recording is an eye tracker recording.
`Camera`	Recording is an external camera recording.

`gazeMapper.session.RecordingDefinition`

member function	inputs	output	description

member function	inputs	output	description
`__init__`	1. `name`: Name of the recording. 2. `type`: a `gazeMapper.session.RecordingType`.		
`set_default_cal_file`	1. `cal_path`: Path to calibration file (OpenCV XML). 2. `rec_def_path`: Path to the recording's configuration folder.		Set the default calibration for the (scene) camera for this recording. Copies the calibration XML file to the recording's configuration folder.
`get_default_cal_file`	1. `rec_def_path`: Path to the recording's configuration folder.	1. Path to the default calibration file. `None` if it does not exist.	Get's the default calibration file, if any.
`remove_default_cal_file`	1. `rec_def_path`: Path to the recording's configuration folder.		Removes the default calibration file.

`gazeMapper.session.Recording`

member function	inputs	output	description
`__init__`	1. `definition`: a `gazeMapper.session.RecordingDefinition` object. 2. `info`: a `glassesTools.recording.Recording` or `glassesTools.camera_recording.Recording` object.		
`load_action_states`	1. `create_if_missing`: Boolean indicating whether the action states file should be created for the recording if its missing.		Load the action states from file into the object's `state` property.

`gazeMapper.session.SessionDefinition`

member function	inputs	output	description
`__init__`	1. `recordings`: (Optional) list of `gazeMapper.session.RecordingDefinition` objects.		
`add_recording_def`	1. `recording`: a `gazeMapper.session.RecordingDefinition` object.		Adds a new recording to the session definition.
`get_recording_def`	1. `which`: Name of recording for which to get the definition.	1. A `gazeMapper.session.RecordingDefinition` object. Throws if not found by name.	Get the recording definition by name.
`is_known_recording`	1. `which`: Name of recording.	1. Boolean indicating whether a recording by that name is present in the session definition.	Check whether a recording by that name is present in the session definition
`store_as_json`	1. `path`: Path to store session definition JSON file to. Can be a path to a file, or a path to a folder containing such a file (in the latter case, the default filename `'session_def.json'` will be used).		Store session definition to JSON file.

member function	inputs	output	description
`load_from_json` (static)	1. `path`: path to load session definition JSON file from. Can be a path to a file, or a path to a folder containing such a file (in the latter case, the default filename `'session_def.json'` will be used).	1. A `gazeMapper.session.SessionDefinition` object.	Load session definition from JSON file.

`gazeMapper.session.Session`

NB: For the below functions, a recording name should be a known recording set in the session's `gazeMapper.session.SessionDefinition` object, it cannot be just any name.

member function	inputs	output
`__init__`	1. `definition`: a `gazeMapper.session.SessionDefinition` object. 2. `name`: Name of the session. 3. `working_directory`: Optional, path in which the session is stored. 4. `recordings`: Optional, list of `gazeMapper.session.Recording` objects to attach to the session.	
`create_working_directory`	1. `parent_directory`: Directory in which to create the session's working directory. Typically a gazeMapper project folder.	
`import_recording`	1. `which`: Name of recording to import. 2. `cam_cal_file`: Optional, camera calibration XML file to use for this recording. 3. `**kwargs`: additional setting overrides passed to `gazeMapper.config.read_study_config_with_overrides` when loading settings for the session.	
`add_recording_and_import`	1. `which`: Name of recording to import. 2. `rec_info`: a `glassesTools.recording.Recording` or `glassesTools.camera_recording.Recording` object describing the recording to import. 3. `cam_cal_file`: Optional, camera calibration XML file to use for this recording.	1. A `gazeMapper.session.Recording` object.
`load_existing_recordings`		
`load_recording_info`	1. `which`: Name of recording.	1. A `glassesTools.recording.Recording` or `glassesTools.camera_recording.Recording` object describing the recording.
`add_existing_recording`	1. `which`: Name of recording.	1. A `gazeMapper.session.Recording` object.
`check_recording_info`	1. `which`: Name of recording. 2. `rec_info`: a `glassesTools.recording.Recording` or `glassesTools.camera_recording.Recording` object describing the recording.	
`update_recording_info`	1. `which`: Name of recording. 2. `rec_info`: a `glassesTools.recording.Recording` or `glassesTools.camera_recording.Recording` object describing the recording.	

member function	inputs	output
`add_recording_from_info`	1. `which`: Name of recording. 2. `rec_info:` a `glassesTools.recording.Recording` or `glassesTools.camera_recording.Recording` object describing the recording.	1. A `gazeMapper.session.Recording` object.
`num_present_recordings`		1. The number of known recordings that are present.
`has_all_recordings`		1. Boolean indicating if all known recordings are present.
`missing_recordings`	1. `rec_type`: a `gazeMapper.session.RecordingType` (optional). If specified, only report missing recordings of the specified type.	1. List of missing recording names.
`load_action_states`	1. `create_if_missing`: Boolean indicating whether the action states file should be created for the session if its missing.	
`is_action_completed`	1. `action`: a `gazeMapper.process.Action`.	1. Boolean indicating whether the action is completed.
`action_completed_num_recordings`	1. `action`: a `gazeMapper.process.Action`. Should be a recording-level action.	1. The number of recordings for which the action has completed.
`from_definition` (static)	1. `definition`: a `gazeMapper.session.SessionDefinition` object. Can be `None`, in which case the session definition is loaded from the gazeMapper project's configuration. 2. `path`: Path pointing to the working directory of a session. If the `definition` argument is not provided, this working directory should be part of a gazeMapper project so that the project's configuration direction can be found.	1. A `gazeMapper.session.Session` object.

Free functions

function	inputs	output	descri
`read_recording_info`	1. `working_dir`: path to a direction containing a gazeMapper recording. 2. `rec_type`: a `gazeMapper.session.RecordingType`.	1. A `glassesTools.recording.Recording` or `glassesTools.camera_recording.Recording` object. 2. The path to the recording's (scene) video.	Load r the sp
`get_video_path`	1. `rec_info`: A `glassesTools.recording.Recording` or `glassesTools.camera_recording.Recording` object.	1. The path to the recording's (scene) video.	Get th record video
`get_session_from_directory`	1. `path`: path to a direction containing a gazeMapper session. 2. `session_def`: A `gazeMapper.session.SessionDefinition` object.	1. A `gazeMapper.session.Session` object.	Load t from t gazeM directc

function	inputs	output	descri
`get_sessions_from_project_directory`	1. `path`: path to a gazeMapper project directory, containing gazeMapper sessions. 2. `session_def`: Optional `gazeMapper.session.SessionDefinition` object. If not provided, the session definition is loaded from file from the project's configuration directory.	1. A list of `gazeMapper.session.Session` objects.	Load t the inc gazeM directc
`get_action_states`	1. `working_dir`: path to a direction containing a gazeMapper session or recording. 2. `for_recording`: Boolean indicating whether the path contains a gazeMapper session (`False`) or recording (`True`). 3. `create_if_missing`: Boolean indicating whether the status file should be created if it doesn't exist in the working directory (default `False`). 4. `skip_if_missing`: Boolean indicating whether the function should throw (`False`) or silently ignore when the status file doesn't exist in the working directory.	1. Dict with a `State` per `Action`.	Read t sessio status
`update_action_states`	1. `working_dir`: path to a direction containing a gazeMapper session or recording. 2. a `gazeMapper.process.Action`. 3. `state`: the new `gazeMapper.process.State`. 4. `study_config`: a `gazeMapper.config.Study` object. 5. `skip_if_missing`: Boolean indicating whether the function should throw (`False`) or silently ignore when the status file doesn't exist in the working directory.	1. Dict with a `State` per `Action`.	Updat the sp and st status

Citation

If you use this tool or any of the code in this repository, please cite:
Niehorster, D.C., Hessels, R.S., Nyström, M., Benjamins, J.S. and Hooge, I.T.C. (in prep). gazeMapper: A tool for automated world-based analysis of wearable eye tracker data
If you use the functionality for automatic determining the data quality (accuracy and precision) of wearable eye tracker recordings, please additionally cite:
Niehorster, D.C., Hessels, R.S., Benjamins, J.S., Nyström, M. and Hooge, I.T.C. (2023). GlassesValidator: A data quality tool for eye tracking glasses. Behavior Research Methods. doi: 10.3758/s13428-023-02105-5

BibTeX

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