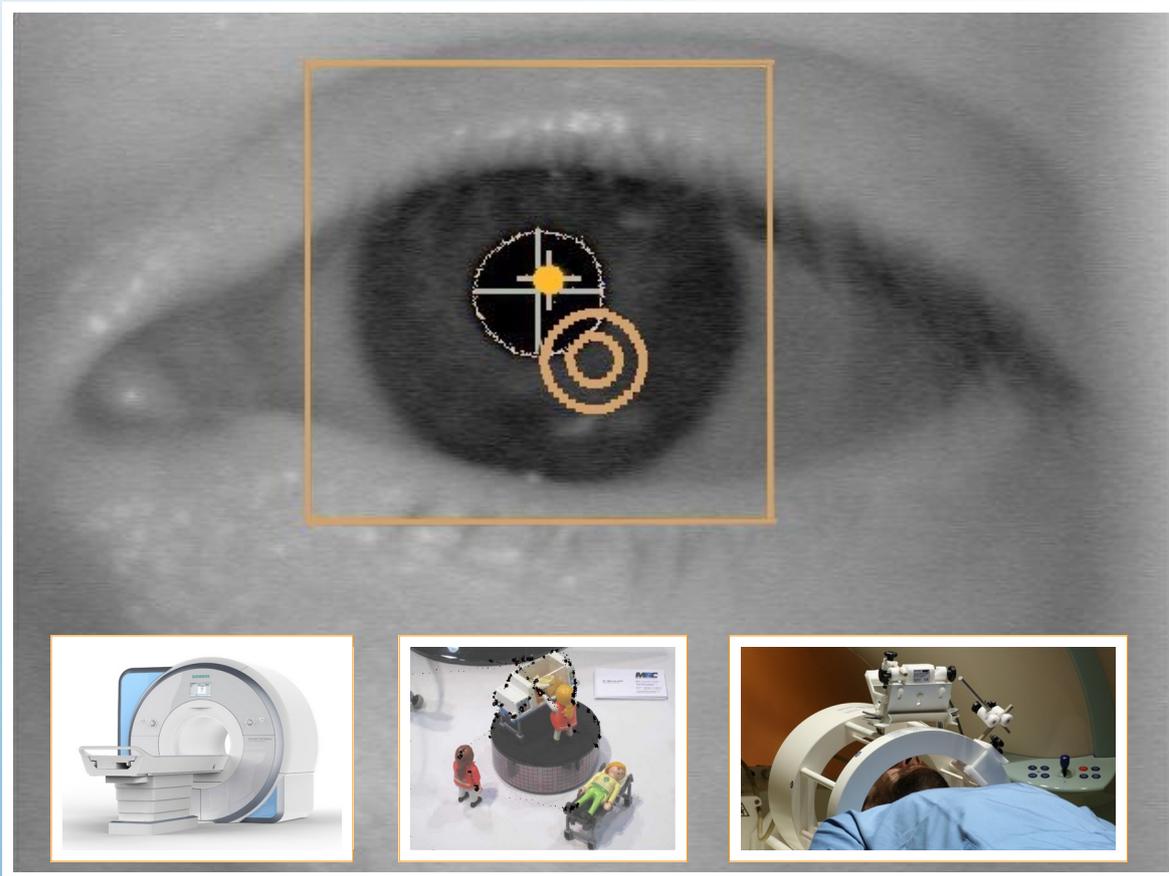# MRC Eye-Tracking

User Manual

Version: 1.7

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Contents

1. General description

The software "MRC Eye-Tracking" is intended to be used for gaze detection of human subjects. The main purpose is to use it in combination with the MRI compatible video cameras of MRC Systems GmbH. With these cameras an infrared LED creates a reflex from the cornea. The software detects this reflex and the boundary of the pupil ("dark pupil" method). From the relative positions of these markers the gaze can be determined. The accurate position of the line of sight on a projection or a display can be calculated after a calibration.

The software is available in two versions, one for monocular and one for binocular eye-tracking.

In both cases, there are two variants of the software:

- variant A for the analogue cameras 12M and 12M-i
- variant GigE for the digital MRC HiSpeed cameras

2. System requirements

2.1. Camera interface

The different versions of the software operate with different interfaces to the respective cameras:

- Variant A reads in the images of the analogue cameras via a frame grabber and is bound to this frame grabber. The software was tested with the frame grabbers DFG/USB2Pro, DFG/SV1/PCI and DFG/SV1/PCIe of the company TheImagingSource. For binocular eye-tracking you can either use two of these frame grabbers, but we have also tested the DFG/MC4/PCIe with 4 input channels. We recommend the use of the tested frame grabbers. You need a USB, PCI or a PCIe input at your computer or laptop.

- Variant GigE receives the images of the HiSpeed cameras via the GigE vision protocol. Here you need a GigabitEthernet network card, preferably with an Intel chip set and jumbo frame support (9 kByte), in you computer or laptop.

1) Since the eye-tracking algorithms benefit from a high calculation speed, we recommend to use the computer or laptop solely for the eye-tracking during an eye-tracking session. The network card should also be solely used for the communication with the camera and not for any other network communication.

2) Due to legal licensing reasons the software can only be used, if an activated frame grabber card (variant A) or an MRC camera (variant GigE) is connected to the computer or laptop, where the software is running.

2.2. I/O interfaces

The software "MRC Eye-Tracking" can be synchronised with other devices or software via a software interface (see section 10.1) or via hardware. For the hardware interface an I/O card of MRC is required.

2.3. Operation system

The software is available for Windows 7, 8 and 10 as well as for Linux.

3. Quick guide

This guide gives a brief overview on how to start to work with the eye-tracking system. You can find more details in section 5.

1) Install the software from the "MRC Eye-Tracking" CD. Please refer to section 5.1.

2) Connect the frame grabber to your USB port (2.0 or higher) of your laptop or computer or insert the frame grabber card into your PCI or PCIe slot. Install the driver for the frame grabber from the "MRC Eye-Tracking" CD. (In case of the GigE variant you have to connect the camera to your local network.)

3) Before each new experiment some parameters should be adjusted to the light conditions and the contrast of the subject's eye. To do this, start the MRC Eye-Tracking software and proceed as follows:

   a) Place the camera so that the eye is in the center of the live camera image. It should be displayed as large as possible, however, the complete eye must be visible during all eye movements. If necessary, exchange the lens. Note: There are three different lenses included in the delivery. In most cases the 16mm lens is suitable. But you can try another one. The focus adjustment is done by screwing the camera's lens in and out.

   b) Position the camera and the LED so that the cornea reflex is not inside the pupil.

   c) Open the **Detection** tab. Adjust the Detection of pupil's **Threshold (intensity)**. Choose this parameter so that the detection of the pupil is just possible. This is the case when the pupil is surrounded by an ellipse of small points with a cross in its center. Then set the value to approximately 5 points above this value.

   d) If you cannot find a value where the pupil can be detected, proceed as follows: Switch to the **Set up** tab. Adjust the **Min / Max pupil size** and the **Ratio** values so that they fit to the subject's pupil. To do this, click on the **Show** checkbox. Then you can see three circles in the camera window. These show the minimum pupil size, the real pupil size as determined by the eye-tracking algorithm, and the maximum pupil size. Take care that the maximum pupil size is always larger than the real pupil. Adjust the values accordingly. You can find further information in section 7.5.

   e) Adjust the value of the Detection of cornea reflex's **Threshold (Intensity)** approximately 5 points below the maximum value where the reflex is still found.

4) Switch to the **Calibration** tab and carry out a calibration. Refer to section 7.2 for details.

5) If you want to save the data and/or the video, switch to the **Recording** tab and enter a file name. Refer to section 7.3 for details.

6) If you do not get a reliable eye-tracking performance, read section 7.1 with the detection parameters and try to optimize them.

4. Specification and program functions

Eye-tracking	
Algorithm	Dark pupil eye-tracking with cornea reflex (monocular or binocular)
Accuracy *	0.4°
Precision *	0.5°
Frequency	Variant A: 60 Hz
	Variant GigE: 250 Hz
Calibration	Different patterns on separate screen, variable point diameters
	Selectable number of calibration points
	Real time calculation of calibrated gaze points with time stamp

Realtime display	
Camera image	Monocular: 640x480 pixels; binocular: 2x 320x240 pixels
	Overlay of detected pupil boundary and pupil center
	Overlay of detected cornea reflex
Gaze points	Display of determined gaze points in control screen
Presentation window	Display of various image formats
Calibration window	Real time comparison of gaze points with calibration points

Data analysis	
Gaze points	Overlay of calibrated gaze points over presentations
	Variable filter radii for clustering (heat maps)
	x and y data with time stamp for each camera frame
Pupil size	Lengths and angle of axes of elliptical fit
Time analysis	Definition of time intervals
Calibration	Display of accuracy (Gaze points relative to calibration points)
	Display of tolerance ranges 0.5° and 1°

Optimization	
Detection parameters	Levels, brightness, pupil contrast, elliptical shape
	Adjustable search region
	Blink recognition, Image smoothing
Calibration parameters	Display size, distance to display, calibration pattern
Recordings	Live video image, tracking data, calibration
Data analysis	Time intervals, filters

Interfaces	
Software interface	TCP/IP socket
Hardware interface	Digital I/O
Tracking data file	x/y gaze data and time stamp in Excel format

Supported cameras	
Composite video	60 Hz; MRC cameras: 12M, 12M-i
GigE vision	250 Hz (recommended); MRC cameras: MRC HiSpeed

System requirements	
Operation system	Windows 7, 8, and 10 / Linux
Frame grabber	for variant A: TheImagingSource DFG/USB2pro, DFG/SV1/PCI, DFG/SV1/PCIe, or DFG/MC4/PCIe
Network card	for variant GigE: card with Intel chipset, jumboframe support, 9kB

* **Accuracy** describes, to what extent the determined gaze point coincides with the real gaze point. It is defined as the average distance of the line of sight between the determined fixation point and the corresponding target (calibration point).

Precision is a measure of the possibility of the eye tracker to reliably determine the same gaze point again and again. In the ideal case the real gaze points and the determined gaze points are located in a small cluster close to each other. The precision is especially important to differentiate between fixations and saccades. To determine the precision the fixation points which are detected during the look onto a fixed target are analysed. The distance between the gaze points is measured and hence the precision is defined as the root mean square (RMS).

The values for the accuracy and precision have been determined in realistic sessions on different subjects. The accuracy of the gaze point detection depends on the quality of the calibration. Please take care for a good illumination of the eye and a stable fixation of the head. (Usually the stable fixation is automatically given in the MRI scanner due to the lying position and the support of the head on a cushion.)

For subjects with contact lenses it can be difficult to achieve a stable eye tracking.

5. Installation and getting started

5.1. Installing the software

The software is provided on a CD or as a downloadable file.

5.1.1. Windows

The software consists of up to three components:

1. Eye-tracking application

   To install the eye-tracking application open the directory *Windows\MRC* in the installation medium and execute the installation file *MRC-Eye-Tracking_X.X-Bxxxx.msi* for the 64bit version. The installer will ask for administrator rights to install the application. After that there should be a start menu entry and a desktop icon *MRC Eye-Tracking* to start the program.

   The software is installed in the subdirectory *MRC\Eye-Tracking* in the Windows program directory (normally *c:\Program Files*). User data and setup files are stored in the user's documents directory (e.g. *c:\User\username\Documents*) in the directory *Eyetracking*.

2. Driver for analogue frame grabber (for variant A)
   To install the analogue frame grabber driver open the directory *usbconvcxn_x.x.x_tis* (USB2Pro) or *FrameGrabberDriver\bt878cap_xxx.tis* (PCI/PCIe), execute the file *drvInstaller.exe* and follow the instructions. The installer will ask for administrator rights to install the driver.
3. Driver for digital I/O card (optional)
   To install the driver for the digital I/O card open the directory *Windows\Digital_IO\ PCIS-DASK-vx.xx* and execute *setup.exe*. Select "Anyone who uses this computer (all users)" and follow the instructions. The installer will ask for administrator rights to install the driver.

5.1.2. Linux

We recommend to copy the software into a dedicated program directory on your computer or laptop. Please copy all files and subdirectories from the directory *<MRC_Eye-Tracking>*.

In case of variant A, you must further install the driver of the frame grabber card.

The software is then started by a call up of the file *eye*.

5.2. Data recording

An eye-tracking session starts with the selection of the camera. If you only have one camera, this camera will be automatically selected.

Before you start with data recording you must perform a calibration with the subject in the actual setup conditions. Only after a calibration you get real gaze and fixation points. You can find more information about the calibration in section 7.2.

Once the calibration is made the subject's gaze points are continuously shown in real time. In order to achieve a stable and accurate detection of the gaze points you can optimize the camera and additional detection parameters in the tab **Detection** (see section 7.1) to achieve a good illumination of the eye. The parameters can vary in each session. In the first adaptation of the software to your setup it can further be necessary to change some setup parameters (see section 7.5).

1) The calibration must be repeated for each subject. If you do not do this and if you also did not restart the software for this subject, the software applies old calibration data to the new subject.

2) After a calibration you must not change the recording conditions like distance of the display, shifts between eye-position and camera etc. Such changes would lead to wrong data.

3) After a calibration you might also see inserted gaze points even if there is no eye in the live camera image. This is only an artefact of the eye-tracking algorithm and you can ignore it.

You can record and save the live video image as well as the tracking data and the pupil size. The procedure is described in section 7.3. For an analysis of the tracking data you can follow the description in section 7.4.

6. Graphical user interface

In the following sections we will describe the graphical user interface of the software by means of screenshots of the software. The values in the screenshots are arbitrarily chosen.

6.1. Main window

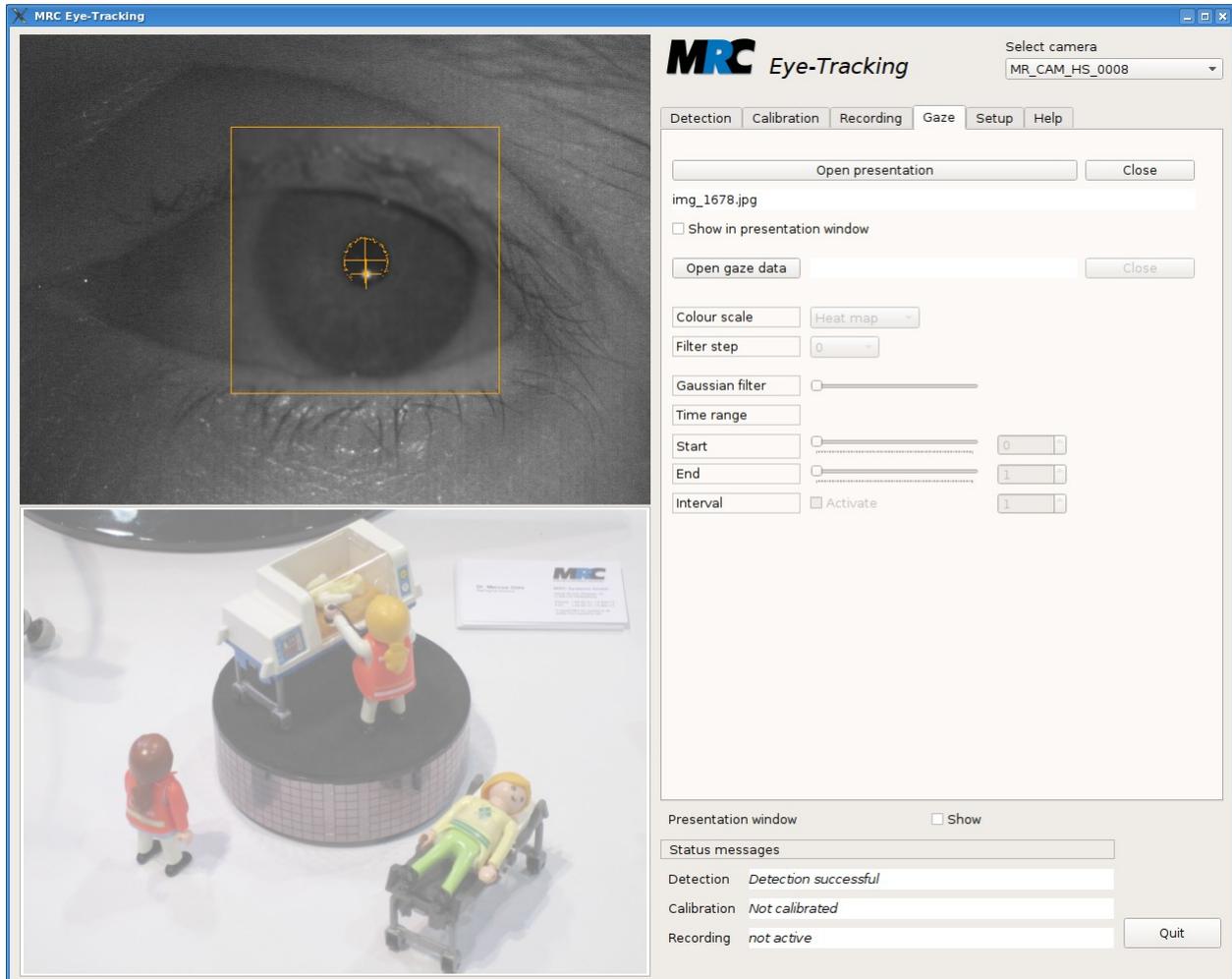Figure 1 shows the main window of the user interface.

Figure 1: Graphical user interface (main window)

The main window includes two display sections. In the upper left the live video image of the connected camera(s) is displayed. The display in the lower left is the control screen for the user. During the calibration the calibration points and during the tracking the subject's gaze points are shown in this display. It is also used to show tracking data from files.

On the upper right of the main window (or on the upper left in case of the binocular version) there is the menu item **Select camera** where you can select your camera. You can usually only select the cameras which are available at your site. The selection of the camera defines which variant of the software (A for an analogue camera or GigE for a digital camera) is started.

In case of binocular eye-tracking with analogue cameras you should always connect the cameras to the same frame grabbers, if you want to have the same matching of the cameras to the left and right displays in the live view.

Below the camera selection there is an area with different tabs for the setting of parameters and for the operation of the program.

On the lower right of the main window there are three lines for status messages and the button to quit the program.

In addition to the main window the software offers a presentation window which can be used for a larger display of calibration patterns or presentations. It is often displayed on a separate subject-oriented screen. The presentation window can be shown or hidden with the button **Show in presentation window** which is located below the tabs section.

6.2. Live camera(s) image and playing of videos

In the upper left of the display the live image of the connected camera(s) is shown. In case of monocular eye-tracking, the display size is 640x480 pixels. This corresponds to the resolution of the 12M and 12M-i cameras with an NTSC sensor and the resolution of the HiSpeed cameras with a set frame rate of 250 Hz. Images with a lower resolution are scaled and centred into the display. (In case of binocular eye-tracking, there are two live images with 320x240 pixels each.)

Depending on the setting in the tabs different objects can be overlaid over the live image display:

- the search region, where the program searches for the pupil
- the entered minimum and maximum radii for the pupil
- the pupil boundary determined by the program
- the centre of the pupil determined by the program
- the location of the cornea reflex determined by the program

You can find more information about the mentioned objects in sections 7.1 and 7.5.

Instead of the live image also video files taken with the MRC cameras can be played in the display in the upper left.

6.3. Control screen

At the lower left the main window includes the control screen. In this screen different information can be shown:

a) After a calibration the current gaze points of the subject can be shown in real time. These points are represented by two circles around the gaze point which mark a tolerance of 0.5° and 1°, respectively.

b) During a calibration the sequential calibration points are shown.

c) For the review of a calibration the full set of calibration points and the determined gaze points can be shown together.

d) When a video file is played in the live screen the determined gaze points with their tolerance circles are also shown in the control screen.

e) The control screen can further be used for data analysis. It allows to overlay the gaze points over a presentation which has presented to the subject (see section 7.4).

The current gaze points with their tolerances are continuously shown in real time in the control screen except when the tracking data of a saved file or the results of a performed calibration are shown. If no calibration has been performed, the gaze points can not be determined and shown.

6.4. Presentation window

The presentation window is intended to be presented to the subject on a display or via a projection. It can be placed on a second screen independently from the main window.

When the software is started the presentation window is initially hidden (or minimized). It can be shown (or maximized) with the Open Presentation button, which is below the tab section in the main window. If you remove the check at the button, it is hidden again. The showing and hiding can also be controlled via the window manager of your operation system. Just use the maximize/minimize icon or similar control elements of your window manager.

In the presentation window, different information is displayed:

    a) During the calibration, changing calibration points fade into the presentation window. The subject's task is to fixate one after the other of these points. In order to avoid a distraction of the subject, the gaze points, which are shown in the control screen, are not shown in the presentation window.

    b) During the eye-tracking you can show a presentation.

7. Tabs

For adjustments and the operation of the program the software has a set of tabs, which can be opened alternatively. In these tabs some related functions and settings are put together. In the following sections we describe the specific functions following the arrangement in the tabs. In case of the binocular version, some functions and settings occur twice so that you can control them for the left and the right eye independently.

7.1. Detection parameters

In the tab **Detection** you can adjust parameters which have influence on the detection of the pupil and the LED reflex from the cornea.

The tab includes some different parameters for connected analogue cameras (variant A) or connected digital cameras (variant GigE).

7.1.1. Parameters for analogue cameras 12M or 12M-i

Figure 2 shows the tab **Detection** in the look of variant A for analogue cameras. Here, two camera parameters can be adjusted: **Brightness** and **Contrast**. With these parameters you can optimize the appearance of the regarded eye in the live view and hence the stability of the eye-tracking algorithm. Both parameters can be changed between 0 and 100 %.

    1) A change of the parameters is immediately visible in the live view. Hence you can vary the parameters until the contrast of the pupil and the LED reflex is perfect. If you activate the display of the determined pupil boundary points and the pupil's centre (see section 7.1.3) in the live view and/or the display of the detected cornea reflex (see section 7.1.4), you can also take the stability of these as a criterion to optimize the settings.

    2) If you later press **Save settings** in the tab **Setup** the settings in the tab **Detection** are also saved.

Figure 2: Tab for detection settings (variant A, monocular)

7.1.2. Parameters for digital HiSpeed cameras

Figure 3 shows the tab **Detection** in the variant GigE for cameras which communicate via the GigE vision protocol.

In case of these cameras the image contrast and hence the stability of the eye-tracking algorithm can be optimized by means of the settings for **Gain** and **Exposure time.**

The **Gain** can have values between 0 and 15, where 0 is the lowest and 15 is the highest gain. The effect of any changes can be immediately seen in the live view. The values for the **Exposure time** are given in microseconds (µs). You can also see any changes immediately.

Figure 3: Tab for detection parameters (variant GigE, monocular)

The HiSpeed camera has an additional adjustable parameter. With the **Divider for live image frequency** you can define, which number of camera frames is displayed in the live view. Usually the value 10 is entered here. This means that in the 250 Hz mode the camera frames are displayed with 25 Hz. In case of slow computers, where the display requires much processing time, you can further increase the value in order to decrease the number of frames. This setting does not affect the eye-tracking speed. The determination of the gaze points still uses all camera frames, if possible.

> The comments regarding the observation and savings of the parameters given for the variant A apply to variant GigE in the same way.

7.1.3. Parameters for pupil detection

For any connected camera there are various parameters to optimize the detection of the pupil.

- **Show:** With this checkbox you can define if the points of the pupil's boundary and the pupil's centre as they are determined by the eye-tracking algorithm are overlaid over the live view. If they are overlaid you can directly see whether or not the algorithm correctly detects the pupil.

- **Smooth image:** This checkbox activates a Gaussian smoothing (7x7) in the search region for the pupil. At frame rates of 50 or 60 Hz these smoothing is usually not necessary. If you have a bad image with an unstable eye-tracking you should first try to improve the camera parameters. Anyway, in case of noisy images the smoothing can further help to detect the pupil. For cameras with higher frame rates it can be necessary to activate the smoothing in order to get stable results.

- **Threshold (Intensity):** The pupil is recognized as a dark ellipse in the image. Here you can adjust the "dark" threshold as the lowest intensity which can be interpreted as a part of the dark pupil. The value corresponds to the difference between the grey value in the video and the darkest pixel in the search region. The effect of a threshold change can be immediately observed if you activate the display of the detected boundary of the pupil.

- **Ignore upper boundary:** With this percentage you can tell the algorithm to not take an entire ellipse but only a part of it to recognize the pupil geometry. This can be helpful if parts of the pupil are covered by the eye lid, a brow or anything else. The higher the percentage, the larger the part of the ellipse which is ignored. The algorithm does not expect an elliptical geometry at these positions.

- **Ignore lower boundary:** This percentage limits the algorithm to find the pupil at the lower boundary. It acts in a similar way as the percentage for the upper boundary.

- **Min. contrast at pupil margin:** In addition to the threshold the eye-tracking algorithm uses the contrast between the pupil and the iris, i.e. the contrast at the pupil margin, as a further criterion for the pupil characteristics. To prove this criterion the algorithm traces a ray from the centre of the pupil to the outside. The value of **Min. contrast at pupil margin** is added as a relative brightness difference (in gray values) to the intensity threshold of the pupil recognition. Only if the change of the brightness is larger than the value given here, a detected region is valued as the pupil.

- **Max. contrast at pupil margin:** The eye-tracking algorithm could by mistake take the transition from the iris to the sclera as the pupil margin. But this transition shall not be used. That is why the **Max. contrast at the pupil margin** is set as a second brightness value which is added to the pupil's threshold and which acts as the upper limit for the change of brightness at the pupil margin. If an adjacent pixel at the pupil margin is brighter, the point is rejected. If you fill in a high value here, the criterion is practically ignored.

7.1.4. Parameters for detection of the cornea reflex

For the detection of the cornea reflex there are only two parameters:

- **Show:** With this checkbox you can define whether or not the point of the cornea reflex as it is determined by the algorithm is overlaid over the live view.

- **Threshold (Intensity):** The reflex of the LED on the cornea appears as a bright point in the live view. Especially in case of subjects wearing glasses there can often be other reflexes (e.g. from the glasses frame) in the image. With this parameter you can set a "bright" threshold from where on the intensity is taken as the cornea reflex. The higher the value, the lower the probability that other regions in the image have a similar brightness. On the other hand, the value must of course not be higher than the brightness of the cornea reflex. Otherwise the reflex would not be detected.

7.1.5. Adjustment of the search region

The search region limits the region in the live view, within which the eye-tracking algorithm searches for the pupil and the cornea reflex. The region is a square, and there are two settings:

- **Show:** This checkbox defines whether or not a frame around the region is shown in the live view.

- **Size:** This value defines the size of the square's sides in pixels.

1) If the subject's head is moving only a little bit, you can choose a small region around the pupil as the search region. The algorithm will then find the pupil and the cornea reflex with better stability. It can especially help to ignore reflexes closer to the borders of the live view.

2) The size of the search region strongly affects the required processing time of the search algorithm. If you can choose a smaller region due to a stable position of the eye in the live view, the algorithm is faster, since it has to consider only this smaller region. Especially in case of slow computers it can be of advantage to increase the tracking frequency by decreasing the search region.

7.2. Parameters for calibration

7.2.1. Calibration procedure

During a calibration a sequence of calibration points which are distributed over the entire window are shown in the presentation window. The subject is asked to fixate one after the other of the points which fade in.

Each calibration point first appears as a big black point. As soon as the entered number of tracking data is reached, the point is scaled down. The actual calibration starts with the small points. Calibration points which are not successfully calibrated, are calibrated once again after the first cycle.

To give you the chance to observe the calibration progress, the calibration points are also displayed in the control screen during the calibration. Here, the calibration points are only shown as simple points without the mentioned change of size. If a calibration point is not sufficiently fixated within the entered time, the point is temporarily marked with a cross in the control screen and the calibration is continued with the next point. At the end the calibration points which had not been fixated sufficiently are shown again.

After a calibration you can observe all determined gaze points in relation to the displayed calibration points in the control screen. In addition to the calibration points per se also the range of tolerances of gaze points which differ by 0.5° and 1°, respectively, are displayed. This facilitates

the evaluation of the calibration quality. (For the correct determination of the tolerances, the correct distance to the display must be entered in the tab **Setup**.)

1) The calibration must be repeated before each new experiment. Also if you work with different subjects during a session, you must carry out a calibration for each subject. If you do not do this and if you also did not restart the software for this subject, the software applies old calibration data to the new subject.

2) After a calibration you must not change the recording conditions like distance of the display, shifts between eye-position and camera etc.. Such changes would lead to wrong results.

3) In case of binocular eye-tracking, the calibration process is performed for both eyes at the same time. Therefore, the settings must be adjusted for both eyes before the calibration can be started.

7.2.2. Calibration parameters

Figure 4 shows the tab for adjusting the calibration parameters and for displaying the calibration results.

Figure 4: Tab for calibration parameters
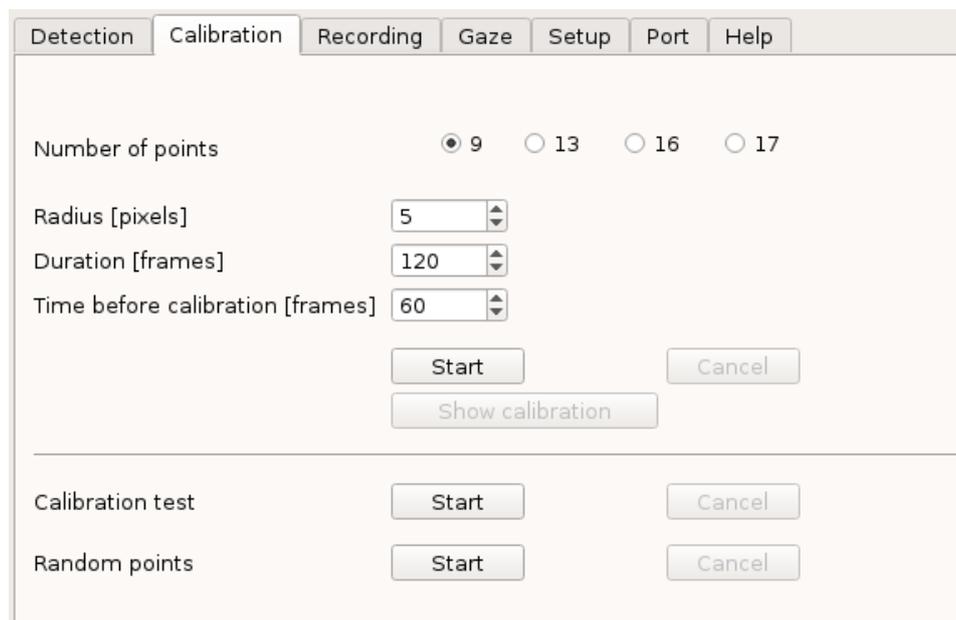
The parameters can be used as follows:

- **Number of points:** Via the number of calibration points you can choose between different calibration patterns. Figure 5 shows the different options with 9, 13, 16 or 17 calibration points.

- **Radius:** This value defines the size of the small calibration points. It is given in pixels. The biggest calibration point is the 4 times as big.
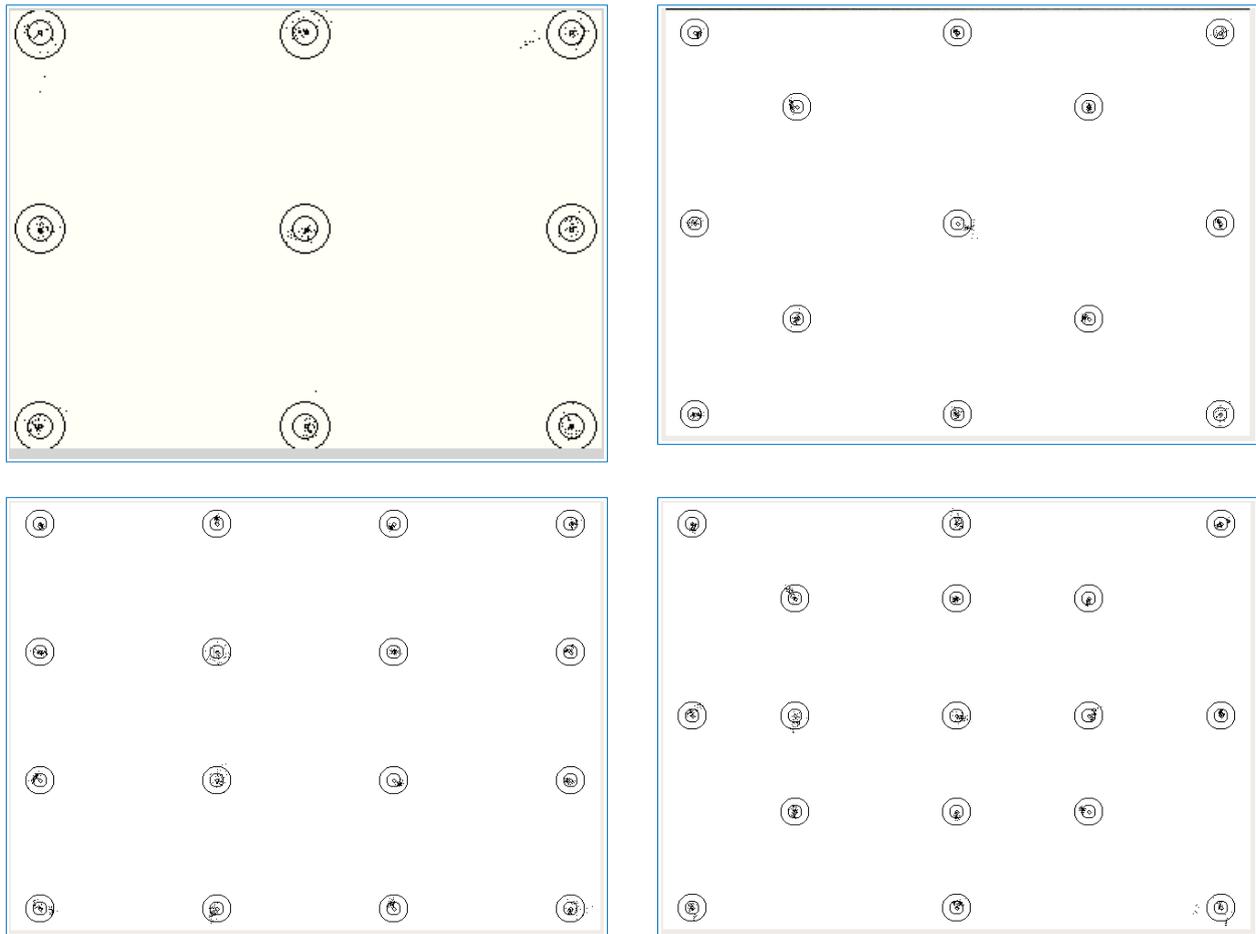
Figure 5: Distribution of 9, 13, 16 and 17 calibration points over the area of the presentation window. The tolerance regions and the determined gaze points are also displayed (see text).

- **Duration:** Here you can define how long a single calibration point shall be displayed. The value gives the number of frames with a successful processing of the gaze point, in which each calibration point is shown. In case of a camera with 60 Hz a value of e.g. 60 means that the point is shown for at least 1 s before the calibration jumps to the next point. If some gaze points are not determined within this time, the calibration takes respectively longer. In case of HiSpeed cameras you have to enter higher values in order to realize the same duration.

- **Time before calibration:** With this parameter you can define how long the calibration algorithm will wait at each calibration point until the calibration starts for this point. The time is defined as the number of frames in which the eye-tracking algorithm has detected tracking data. This delay makes sure that the calibration does not start before the eye has surely arrived at a defined region of interest. With longer times you can allow the subject a more relaxed session since she or he will have more time to jump to the next calibration point.

- **Start:** This button starts the calibration. If it was not opened yet, the presentation window where the calibration pattern is displayed will now be opened. If at the start of the calib-

ration any other information is displayed in the presentation window, e.g. a presentation with a data analysis, this information will be deleted.

- **Cancel:** With this button you can cancel a running calibration.

> If you later press **Save settings** in the tab **Setup** the settings in the tab **Calibration** are also saved.

7.2.3. Calibration review

In order to enable an accurate analysis of gaze data it is important to perform an accurate calibration. That is why the software offers the possibility to review the calibration results:

- **Show calibration:** With this button you can open the currently effective calibration. The calibration points will then be shown together with gaze points of the subject which occurred during the last calibration. In that way you can evaluate how well the subject fixated the calibration points. As long as no calibration is available (status "no calibration"), the button is disabled.

> The gaze points are not shown in the presentation window. Thus, you can present this window to the subject on a separate screen without confusing her or him.

- **Calibration test:** The calibration test enables a review of the eye tracking quality during a running calibration. It allows to determine the accuracy of the subject's fixation. The test can only be performed if a calibration has already taken place. It repeats the fading in of calibration points and simultaneously shows the calibrated "live" gaze points of the subject. The gaze points are only shown in the control screen.
- **Random points:** This test also allows the evaluation of the eye-tracking quality. Here, 20 points are placed in a random pattern in the presentation window.

7.3. Settings for recordings

The software "MRC Eye-Tracking" enables to save and to display tracking data as well as to save and play videos. The saving of the respective files is managed in the tab **Recording**. The tab also includes the options to play videos which have been recorded with MRC cameras. The display of tracking data for a data analyses is managed with the tab **Gaze**.

Figure 6 shows the tab for the management of recordings.

With **Save as ...** you can open the file manager for the tracking data and the live view, where you can define the location and the file name of the respective recording. The recording is started with **Start** and terminated with **Stop**.
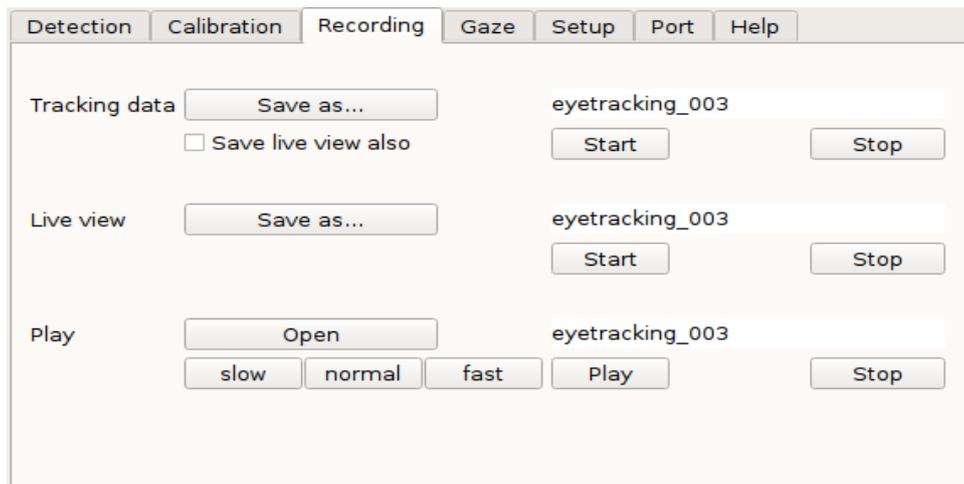
Figure 6: Tab for the management of recordings

Tracking data are saved in files with the extension .trk.

If you activate the checkbox **Save live view also**, the current live view will be saved together with the tracking data in the same path with the same file name and the extension .vid.

Live view video recordings are saved as raw video data with the extension .vid. Whenever you record a live video, additional files with the same file names but other extensions will be saved, too: .set for specific settings, .cal for calibration data, .fit for fit parameters, and .pts for calibration or test points.

If you enter a file name for the tracking data or the video file which already exists, a consecutive number starting with 001 and a code for the camera model will be added to the file name. If the file name already ends with a number, the number will be increased until a number is assigned which does not exist yet.

In case of binocular eye-tracking you can decide if the data for only eye 1, only eye 2, or both eyes are saved.

With a click on the button **Play … Open** the file manager is opened, too. Here you can call up the file of a saved video. With **Play** and **Stop** you can start and stop the playback of a saved raw video file with the extension .vid.

You can play the video with normal, slow, and fast speed. The different speeds are achieved by breaks between single frames. In case of recordings with the 12M / HiSpeed cameras these breaks are 100ms/20ms for the **slow**, 10ms/2ms for the **normal** and 0ms/0ms for the **fast** speed.

7.4. Settings for presentations and gaze visualisation

Figure 7 shows the tab **Gaze**, where you can open a presentation. Further, the tab includes some functions for the analysis of gaze data.
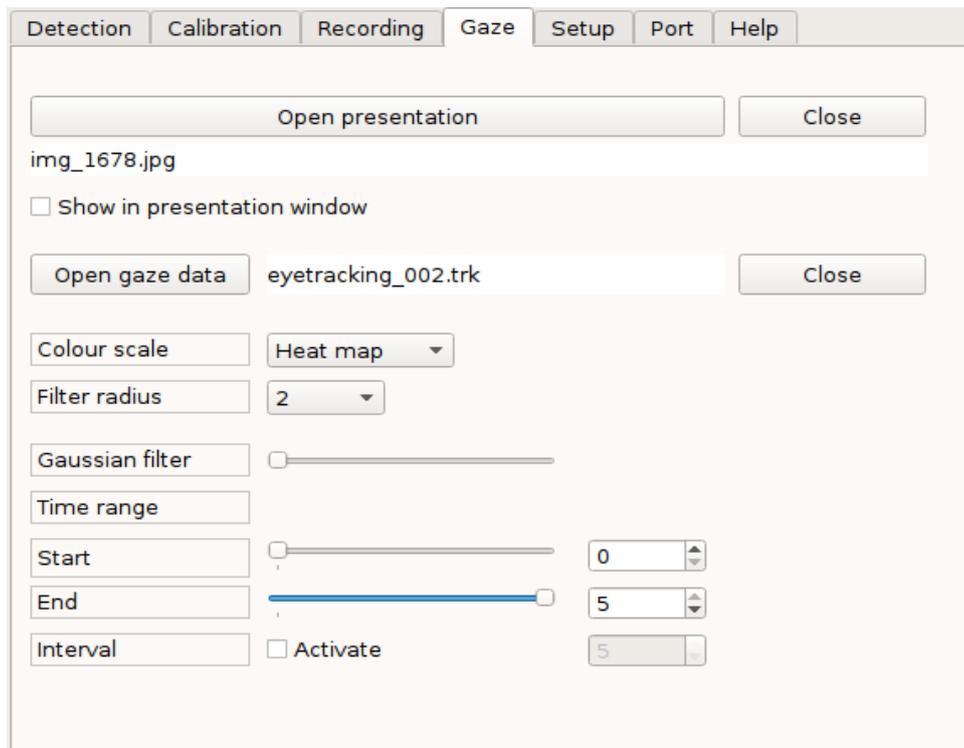
Figure 7: Tab for the opening of presentations and the analysis of gaze data (monocular)

7.4.1. Presentations

Via the button **Open presentation** you can open the file manager and call up a presentation. The presentation will then be displayed in the control screen and – if the checkbox **Show in presentation window** is checked – in the presentation window, too.

The current version only supports various image file formats, but no videos or other kinds of presentations.

For the display in the control screen and in the presentation window the presentation will be scaled to the size of the respective screen. If the width to height ratio of a presentation does not fit to the target screen, the larger dimension will be scaled to fit. In the other dimension the presentation will be filled with a margin.

If the presentation window is hidden, it will be shown automatically. With a click on **Close** you can close the presentation in both screens. It there are some data displayed at this time, they are closed, too.

If you want to change the dimensions of a presentation in the presentation window, you can change it in the tab **Setup** (see section 7.5).

7.4.2. Data analysis and filtering

The calibrated tracking data are saved as x and y values together with a time stamp in the tracking data file (see section 10.3.1). You can open the file with a spreadsheet program like Excel and visualize the data as time courses with the functions of that program.

In addition, the software "MRC Eye-Tracking" also allows a simple analysis of the tracking data. You can e.g. overlay the calibrated tracking data from a saved file over the corresponding presentation. Figure 8 shows an example.
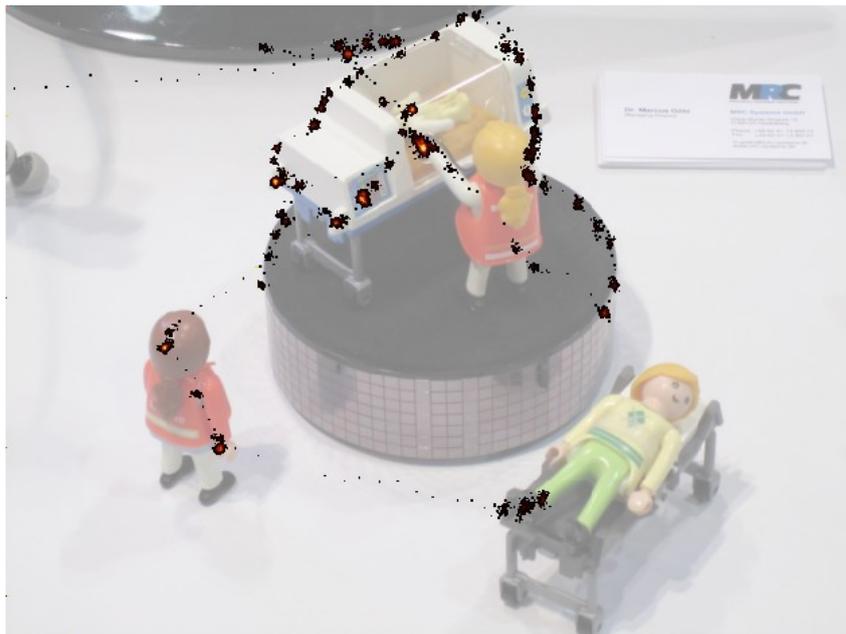

Figure 8: Example of a data analysis: The tracking data are overlaid as black points over a presentation presented during a session. In that way it gets visible, where the subject has looked at. By setting a time interval (see text) you can further analyse the sequence of the gaze points. The data are displayed in the control screen.

Gaze points can only be loaded for analysis, if the corresponding presentation is already loaded (see section 7.4.1). With **Open gaze data** you can open the file manager and open a tracking data file with the extension .trk. The tracking data in the file are overlaid over the presentation. With **Close** you can remove the data. The presentation itself will remain open.

For further analysis the gaze points of the subject are added up at each pixel of the presentation and displayed with different colour modes in order to identify and visualize the regions, where the subject has looked at for a variable time. The following colour scales are available:

- a glow scale
- as false colours
- black & white
- in case of the binocular version, you can display the gaze points of both eyes with different colours (orange for first data set, green for second data set)

There are also two different filters in the tab, a 3-stage Gaussian filter, whose extension can be chosen with the Filter radius, and a **Gaussian filter** which is taken from the Qt library. In case of the 3-stage filter the radius 0 means that the raw data are displayed. With radius 1 each considered pixel is extended to its 8 adjacent pixels. With radius 2 the extension is increased to the next ring of 16 adjacent pixels. The result is normalized in each case. With the Gaussian filter of Qt you can also adjust a blur of the gaze points, here in 10 stages.

The filters are applied one after the other. After each manipulation (of the filter radius, of the Qt Gaussian filter, or of the time interval) first the 3-stage filter is calculated and then the Qt filter is applied on the result of this calculation.

7.4.3. Time intervals

With the adjustments of the Time range you can set a time interval for the data of a tracking file. In order to do this you can set the **Start** and the **End** of the time interval. Only the gaze points within this time interval are displayed or used for any filter operations. Alternatively, by checking the function **Interval**, you can define the desired length of the interval in the keypad. If you then shift the starting point, the end point will be shifted accordingly. It applies in the similar way, if you shift the end point.

7.5. Setup parameters

In this tab you can set some parameters in addition to the parameters in the tab **Detection** for optimizing the eye-tracking. Since these parameters are usually set only once and do not have to be adjusted for individual subjects, we have put them together in this separate tab.

Figure 9 shows the tab for the setup parameters.

The following parameters are organized in this tab:

- **Show:** With this checkbox you can define if the set values for the minimally and the maximally allowed pupil size are illustrated as circles in the live view.

- **Min. pupil size:** Here you can define which minimum pupil sizes the eye-tracking algorithm shall accept. The input is made in the number of pixels. The smaller the value, the more likely the algorithm can wrongly take other structures than the pupil as the pupil. The factory setting is 10.

- **Max. pupil size:** Here you can define which maximum pupil sizes the eye-tracking algorithm shall accept. The input is made in the number of pixels. The factory setting in the software is 120.

- **Ratio:** This parameter describes the maximally allowed asymmetry between the height and the width of the ellipse for finding the pupil.

- **Presentation window (width x height):** Here you can enter the width and the height of the presentation window.

- **Position X, Y:** These values define the position of the presentation window. They allow to move the window without any mouse interactions. The window can only be moved by change of these values.

Figure 9: Tab for setup parameters (variant A, monocular)

Any changes of the window's size or the position will reset the calibration.

- **Foreground and Background** (Colours)**:** Here you can enter values for the colours used for calibration. The values are inserted as the hexadecimal representation for the RGB colour values. The format is 0xRRGGBB, where the range for each colour is from 0x00 to 0xff.

- **Max. blinking duration**: The eye-tracking-algorithm automatically moves the search region for the pupil and the cornea reflex in such a way, that the centre of the region lies in the centre of the pupil as it was detected in the previous frame. Here you can define how long the eye-tracking algorithm does not move the search region if it does not detect the pupil and/or the cornea reflex e.g. due to blinks or other impacts. If it is not able to take data within the allowed number of frames, the program will centre the region in the centre of the live view.

- **Use half-frames:** This parameter is only available in variant A. The 12M and 12M-i cameras provide half-frames with a line offset with a rate of 60 Hz, i.e. a full frame with a rate of 30 Hz. If you check this option, each half-frame will be analysed for the eye-tracking so that the eye-tracking operates with a frequency of 60 Hz.

- **Distance to display:** Here you should enter the distance between the eye-tracking camera and the display or projection. If you are working with a mirror, you should add the distance to the mirror.

- **Pixel width:** Knowing the pixel width on a display enables the calculation of the accuracy of a gaze point.

  > You can calculate the respective width from the display width and the number of columns on the display. E.g. on a 19 inch display (width = 378 mm) with 1,280 columns the pixel width is 0.295mm.

- **Smoothing gaze display**: This value represents the number of single gaze points over which the software averages before it displays the average gaze point. The saved values are not averaged.

- **Averaging of accuracy:** For the calculation of the gaze accuracy the software calculates an average over single frames. Here you can define how many frames are considered in the average.

- **Adjustment of gain in live view:** Here you can change the threshold for the pupil detection in different segments of the live view compared to the setting of the **Threshold (Intensity)** in the tab **Detection**. This is e.g. helpful if the eyes are not homogeneously illuminated due to a sidewise mounting of the light source. The entered values can be positive or negative. Positive values are added to the threshold, negative values are subtracted. In case of binocular eye-tracking, there are two tables, one for each eye.

- **Advanced button**: Open dialog for fine tuning of advanced tracking parameters and parameters for digital camera models.

7.5.1. Advanced Setup

In the advanced setup dialog shown in figure 10 you can control the following parameters:
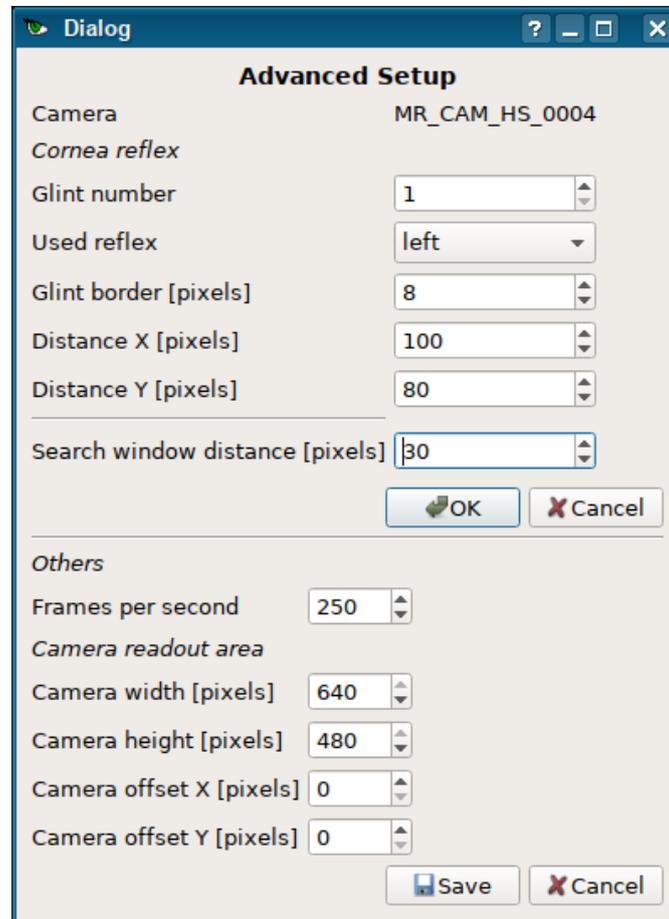
Figure 10: Advanced setup dialog (HiSpeed camera)

- **Glint number:** Number of glints which are detected and separately tracked by the algorithm. If your system generates more the one glint on the eye, you can set the appropriate value here.

- **Used reflex:** If you have more than on glint, you can select the leftmost or rightmost one. This reflex is than used by the tracking algorithm.

- **Glint border:** This defines a margin around the glints, wherein the pupil detection is disabled.

- **Distance X/Y:** This defines the maximum allowed distance between the detected glint and the pupil position. If the distance is larger, the measurement is dropped.

- **Search window distance:** This defines the distance from the camera image border, which is not used/useful for tracking. The search window will be placed in this distance from the image boarder.

The following parameters are only visible, if a digital MRC camera is selected. To activate the new values, you have to press the lower save button and restart the application. The values are set to the next possible value during the restart:

- **Frames per second:** (only for HiSpeed camera) Set the FPS value of the camera. This can be used to reduce the maximal frame rate, which is defined by the read out area.

- **Camera width and height:** Defines the size of the readout area. For the HiSpeed camera, this values can be used to reach higher frame rates.

- **Camera offset X/Y:** With this values you can move the readout area on the camera e.g. to centre the readout area on the optical axis of the lens.

7.5.2. Saving of settings

The basic setting and the initial values for the setup parameters are saved in a .xml file. They are read out when the program is started. Any changes in this tab get effective immediately without the need to save them. With a click on **Save** or **Save as** you can save them as the new initial values (default values). They are used when the program is started again. With **Save as** you can give them you own file name. With **Load** you can load a specific file.

With a click on **Reset** you can read in the values which are saved in the .xml file. With the button **Factory settings** you can go back to the default values of the delivery condition of the software.

1) With **Settings** you do not only save the setting in the tab **Setup**, but also those in the tabs **Detection** and **Calibration**.

2) When you exit the program the last settings are not saved automatically. Thus, if you want to save the last settings, you should click on **Settings** before you exit the program.

3) When you restart the program the values of the .xml file are loaded. Anyway, if you play a saved video file the values which had been set during the video recording are used instead of the default values.

7.5.3. Determination of pupil size

The eye-tracking algorithm automatically determines the pupil size. In more detail, it calculates the two axes (= twice the semi-axes) of the pupil which result from the fit to the pupil boundary. It further determines the angle between these axes to the horizontal. These data are written into the tracking file, too (see section 10.3.1).

1) The lengths of the pupil's axes are given in camera coordinates, i.e. as the number of pixels in the live view. If you need absolute values, you have to calibrate the size for your optical conditions since they depend on the distance between the eye and the camera.

2) The exact value of the pupil size slightly depends on the adjusted threshold for the pupil detection (parameter **Threshold (Intensity)** in the **Detection** tab). You can observe the effect of the threshold, if you activate the checkbox **Show** for **Detection of pupil**.

7.6. Port settings

In this tab you can configure the port for the TCP/IP communication with other programs. Figure 11 shows the tab with typical values.
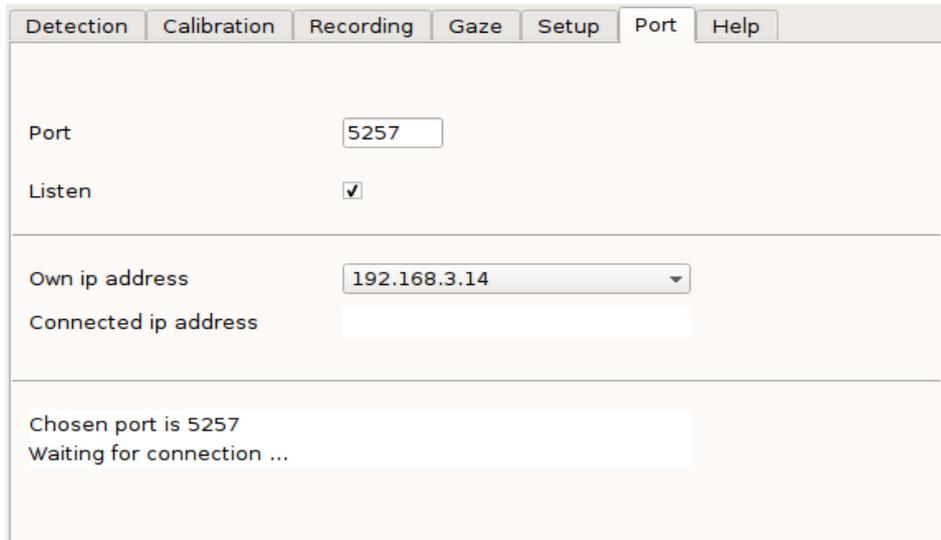
Figure 11: Tab with settings and displays of TCP/IP socket

The following parameters are organized in this tab:

- **Port:** Here you can enter the port number. This number is similar to a mailbox. It is used to assign and forward network requests to the corresponding applications. Port numbers are regularly between 1024 and 65535. The number must not be used by any other network components.

- **Listen:** By clicking this checkbox you can listen on the entered port for any network communication. If the checkbox is not activated, there will be no communication.

- **Own ip address:** Here you have to enter the IP address of your computer.

- **Connected ip address:** Here, the IP address of the connected computer is displayed.

Below these parameters there is an area were messages of the network communication are displayed.

7.7. Help

In the tab **Help** (see figure 12) you can find information about the software version and the producer. In addition, you can open the user manual in pdf format.
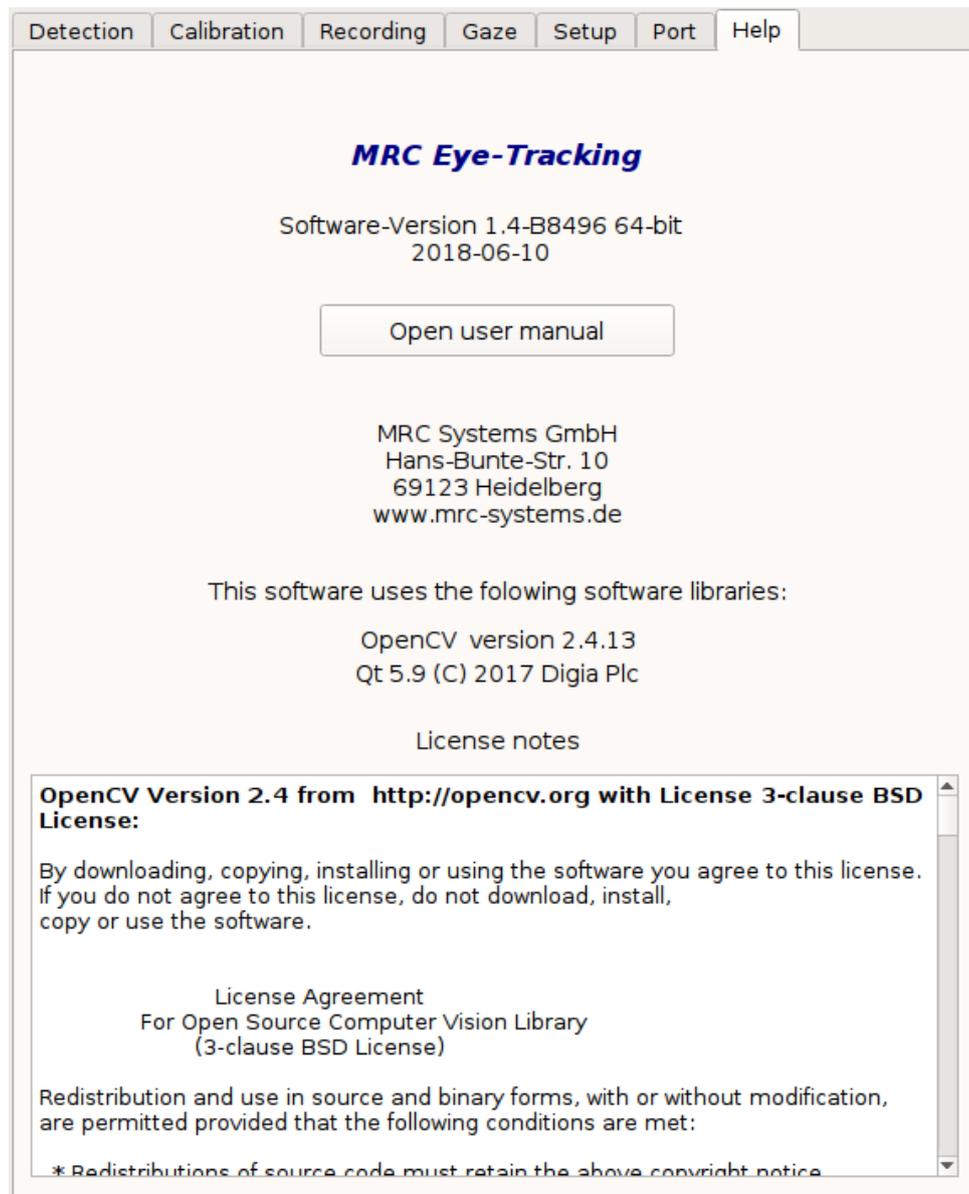
Figure 12: Tab showing the software version, the producer, and a link to the user manual

8. Status messages

Below the tabs there is a window section with three lines for status messages. In the upper line the detection status is shown, in the middle line the calibration status, and in the bottom line the status of recordings. In the recording states you can amongst others see if a video or the tracking data are currently saved or not.
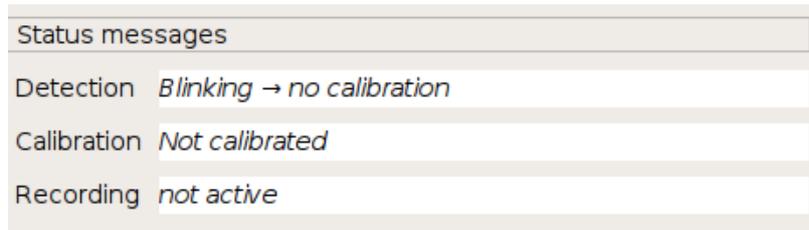
Figure 13: Window section for status messages

There are the following states:

Sector	State
Detection	• no detection of pupil → calibration not possible • no detection of pupil → no calibration • no detection of pupil • Eye tracking • Calibration • no cornea reflex → calibration not possible • no cornea reflex → no calibration • no cornea reflex • Detection successful • Blink • Blink → calibration not possible • Blink → no calibration
Calibration	• not calibrated • Calibration is running • calibrated
Recording	• Saving of data • Saving of data and live view • Saving stopped • Recording of live view • Recording of live view stopped • Video playing • Video playing stopped • not active

9. Indication and error screens

The software has various indication and warning screens which automatically pop up if specific functions can not be executed. The different screens are shown in the following figure. The text is self-descriptive in most cases.
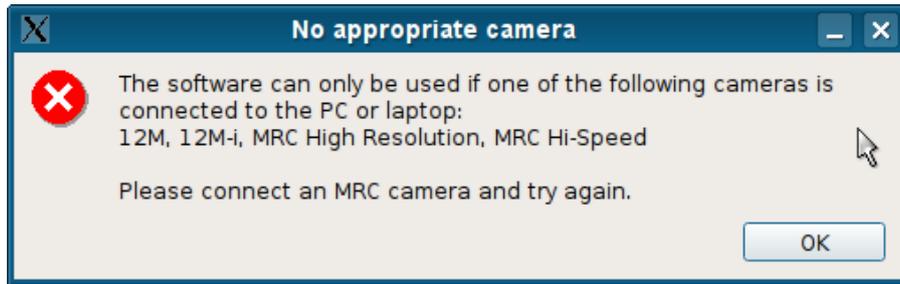
Figure 14: Indication if no camera is connected when you start the program

In case of binocular eye-tracking you can get more specific warnings if one of the required two frame grabbers is missing.

Figure 15: Error, if the communication (GigE) with the digital camera can not be established

Figure 16: Error when reading/writing the path to presentations or tracking data in config.txt

If no configuration file exists, it is automatically created.
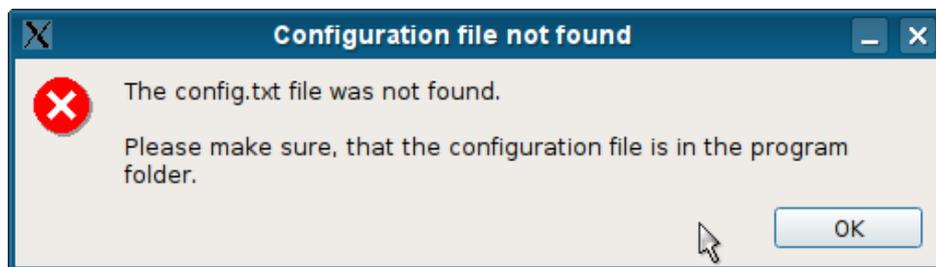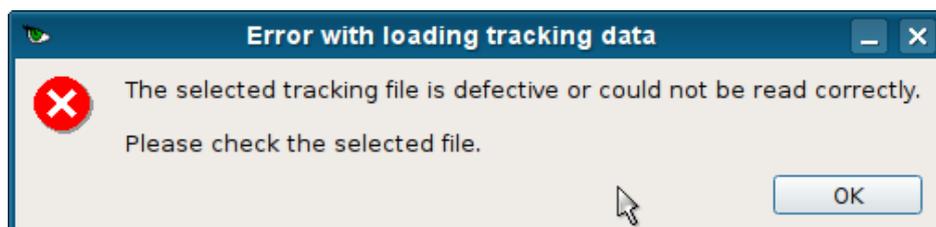
Figure 17: Error with loading an invalid tracking file

These error messages can have several root causes. In most cases they are due to a .trk file which is not in accordance with the file specification or which does not include any gaze points.
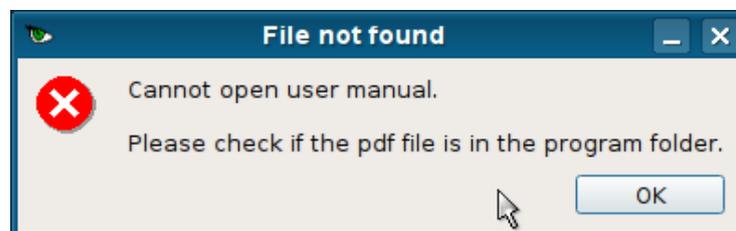
Figure 18: Error if the user manual is not available

10. Interfaces, synchronisation with other devices

10.1. TCP/IP socket

If you intend to communicate via a software interface from another program with the eye-tracking you can use the TCP/IP socket. We can provide you with a dynamic link library (DLL) which you can link to the other program. It allows you to use various functions which are described in sections 10.1.2 to 10.1.4. The following section 10.1.1 describes how to establish the connection.

10.1.1. Connection

First you have to configure the connection. In the "MRC Eye-Tracking" software this is done in the tab **Port** (see section 7.6), where you have to enter a valid port and your IP address. By checking **Listen** you can confirm that the port will be opened and listen to the network communication.

At the other end, in the DLL, the port is connected with the function *"eye_connect"*. This function needs the IP address of the eye-tracking computer as a parameter as well as the port which is appointed in the eye-tracking software. This information is displayed in the tab **Port**.

The function *"eye_disconnect"* closes the connection and deletes the connection data.

You can save the port settings in the tab **Setup** with **Save Settings**. It is also possible to edit the settings in the Setup_Global.xml file (see section 10.3.3). The initial factory settings are given in the following table.

Parameter	Factory setting	Description
port	5257	Port which is displayed on the user interface at startup
buffer_size	1000	Size of the socket read buffer (in bytes)
timeout_socket	300000	Time (in ms) that the connection remains open without any communication taking place
timeout_command	100	Time (in ms) how long to wait for missing data of a command
auto_start	false	Opens the communication directly after the start of the program

10.1.2. Transfer of eye-tracking data

The DLL provides functions for reading the tracking data and the additionally calculated data of the eye-tracking software. The current gaze point and the pupil size can be transferred separately. In addition, it is possible to request an entire data set as a combined structure. This data set includes the following data:

Name	Description
timestamp	Time stamp of camera at time of generation of data set
pupil	x and y position of centre of pupil
found_pupil	Status of pupil detection
glint	x and y position of cornea reflex
found_glint	Status of detection of cornea reflex
calibrated	Status of calibration
pupil_size	Pupil size (lengths of axes of elliptical fit, given in camera pixels)
pupil_angle	Pupil angle (angle of axes of elliptical fit)
vek	Vector between cornea reflex and centre of pupil
pos	x and y coordinates of gaze (in pixels of display)
eventtype	Event which occurred during recording of data set 0 = tracking 1 = gaze 2 = event 3 = presentation
event_text	Description of occurred event

The software makes use of a FIFO buffer to save a limited number of such data sets (FIFO: first-in – first-out). The maximum number of data sets in the FIFO is 1000.

There are two different methods for a client to communicate with the eye-tracking software. The data can either be transferred as a list of data sets already saved in the FIFO or as a continuous data stream of new data. The second method allows a faster transfer of the latest values and therefore a real-time operation.

As long as no data are requested by the client, they are continuously saved in the FIFO. If then a request occurs, the oldest data in the FIFO are transferred. It is possible to transfer a selected number of data sets. The function *"eye_get_events(counts)"* returns the given number (counts) of data sets. If the data stream functionality is not activated, the receiver gets a list of data sets as they are currently saved in the FIFO. Thus, the user should first request for the number of available data sets by means of *"eye_get_events_count()"* and then request for the respetive number. Afterwards, the client can analyse these data sets. The functions *"eye_get_gaze()"* and

"eye_get_pupil_size()" return the latest (not the oldest!) gaze point and the pupil size saved in the FIFO, respectively. In summary, in case of this method the client sends a request to the eye-tracking software and has to wait for the return of the values.

In contrast, if the data streaming is activated with *"eye_start_stream(data type)"* the eye-tracking software continuously streams the values of the given parameter so that the client can read them directly from a buffer in the client software. This reduces the latency via the network.

Data streaming is possible for the following data:

Data type	Value
entire data set	0
gaze	1
pupil size	2

Examples for the latencies with and without streaming are:

1) without stream: eye_get_pupil_size();   typical latency: 0.125 s

2) with data stream: eye_start_stream(2);

                                     eye_get_pupil_size();   typical latency: 0.09 s

10.1.3. Remote control of calibration

It is possible to remotely start a calibration with the different calibration patterns described in section 7.2.2. The function *"eye_start_calibrate"* has a parameter for the number of calibration points. The function *"eye_get_status"* requests for the state of the calibration. There are four different states. Please consider that the calibration can not start before the tracking algorithm detects the eye.

Description	Value
Error	-1
not calibrated	0
calibration is running	1
calibrated	2

If the calibration shall use a window of the external software, the functions *"eye_get_calibstate"* or *"eye_get_calibration_point"* can be used. Please take care that the size of the window corresponds to the size of the calibration window in the eye-tracking software.

10.1.4. Summary of functions

The following functions are available via the TCP/IP communication protocol. They are included in the TCP/IP DLL. Where applicable, the parameters of the functions are listed.

Function	Parameters	Description
Connection / Disconnection		
eye_connect()	'IP address', port	Connection to "MRC Eye-Tracking" software
eye_disconnect()		Disconnection

Function	Parameters	Description
Data requests		
eye_get_events_count()		Request for the number (count) of available data sets in buffer
eye_get_events()	Counts	Request for the list of a given number (counts) of data sets
eye_get_gaze()		Request for last gaze point
eye_get_pupil_size()		Request for current pupil size
Synchronisation		
eye_get_timestamp()		Request for current time stamp
eye_set_software_event()	String max 255 chars	Write string into the tracking file with timestamp
Data streams		
eye_start_stream()	entire data set: 0 gaze: 1 pupil size: 2	Activation of data streaming
eye_stop_stream()		Deactivation of data streaming
Calibration		
eye_start_calibrate()	Number of points (9, 13, 16, 17)	Start of calibration with the respective number of points
eye_stop_calibration()		End of calibration
eye_get_status()		Request for current status of calibration
eye_get_calibstate()		Request for coordinates of calibration point
eye_get_calibration_point()		Request for number and coordinates of calibration point
Parameter settings		
eye_set_parameter(,)	Parameter_name, value	General function: Setting of a parameter with a value.
	'eye_tracking_path', value	Path and file name of tracking file
	'eye_video_path', value	Path and file name of video file
	'eye_save_tracking', value	Data sets are (not) saved in tracking file. The value can only be 'true' or 'false'.
	'eye_save_tracking_and_video', value	Tracking file and video file are (not) saved. The value can only be 'true' or 'false'.
	'eye_timeout_command', value (in ms)	Time waited for a reply of the eye-tracking software
	'eye_timeout_calibrate', value (in ms)	Time waited for the detection of the eye during calibration
eye_set_display_parameter()	Display resolution x, y, distance between display and camera, pixelsize; (in mm)	Setting of display parameters of calibration window
eye_set_displaymode()	Width, height	Setting of display size of calibration window

Function	Parameters	Description
Parameter requests		
eye_get_parameter()	'eye_timeout_command'	Time waited for a reply of the eye-tracking software
	'eye_timeout_calibrate'	Time waited for the detection of the eye during the calibration
	'eye_status_detection'	Request for a parameter. Values: 1 = no detection of pupil → calibration not possible 2 = no detection of pupil → no calibration 3 = no detection of pupil 4 = eye-Tracking 5 = calibration 6 = no cornea reflex → calibration not possible 7 = no cornea reflex → no calibration 8 = no cornea reflex 9 = detection successful 10 = blink 11 = blink → calibration not possible 12 = blink → no calibration
eye_get_version()		Request for current version of eye-tracking software
eye_start_video_recording()		Start of video recording
eye_stop_video_recording()		Stop of video recording
eye_get_last_error()		Request for the latest occurred error

10.1.5. Matlab examples

If you are interested to use the TCP/IP communication, we can provide you with software examples for Matlab.

10.2. Digital I/O

The software "MRC Eye-Tracking" can receive triggers (events) from external sources via a digital I/O card. Two inputs for TTL signals are provided (INT1_IN and INT2_IN). The transition from HIGH to LOW initiates an interrupt.

If a trigger is received by one of the inputs, the event is recorded in the tracking file (see section 10.3.1) as an additional line with the respective time stamp:

time stamp Trigger INT1_IN detected

time stamp Trigger INT2_IN detected

In addition, the software can send the clock pulse of the video frames via a digital I/O line. Two outputs are used (OUT1 and OUT2) with the following signals:

OUT1 is set from HIGH to LOW before any video frame is processed by the software. Then the output is set to HIGH again.

In case of the HiSpeed camera, OUT2 is set to LOW whenever a video frame is displayed. Then the output is set to HIGH again. The clock of this output is hence defined by the parameter **Divider for the live view frequency**, which can be adjusted in the tab for the parameters for digital HiSpeed cameras.

In case of the binicular version, OUT2 performs as OUT1 but for the second camera.

10.3. File formats

10.3.1. Tracking file (.trk)

The tracking data are saved in a file with the extension .trk. This file consists of a header, a data section and an end line.

The header starts with the key word "start". Here, the time stamp and the absolute start time of the session, the size of the presentation window, and the distance to the display are recorded. In addition it includes a fourth line with the column headings for the data.

The data section consists of the following 12 columns:

Column	Value
1	Time in milliseconds
2 and 3	Coordinates of the pupil's centre (in camera coordinates)
4 and 5	Coordinates of the cornea reflex (in camera coordinates)
6 and 7	x and y value of the difference vector between pupil centre and cornea reflex (pixels)
8 and 9	Coordinates of the calculated gaze points on the display according to the calibration
10 to 12	Lengths of pupil's axes (in pixels), angle to horizontal (in rad)

Events are inserted as extra lines with an own time stamp.

The end line consists of the keyword "stop" followed by the time stamp and the absolute clock time of the end of the measurement.

If the pupil could not be detected, the wording "no pupil" is entered in the second column. These lines are ignored in the data analysis.

If the columns 8 and 9 do not include a value in any of the rows, an error message pops up.

If you strive for a high temporal accuracy, you can calibrate the timing of the single frames by means of the indications for the start and the stop time of the session. The start and stop lines include the timestamps and the absolute clock time. From the difference you can calculate your calibration.

Example:

```
start timecounter: 879462.0 time: 2017-04-04T12:56:09.274+0200
presentation_size: 1200 900
distance 900
time(ms) sp_pup:x y sp_glint:x y vector:x y gaze:x y pupilsize: 2a 2b angle

879481.0  216.5 184.8  207.5 206.6  8.92568 -21.8513  455.653 328.294  70.1
74.2 1.783513
879514.3  216.4 185.1  207.8 207.4  8.61145 -22.2588  453.133 324.755  68.7
73.9 1.431403
879547.7  216.4 185.1  207.3 207.5  9.07348 -22.4279  456.432 323.876  68.0
73.8 1.688932
879581.0  216.5 185.1  207.7 207.2  8.847    -22.0387  454.976 326.733  69.6
74.5 1.989388
879614.4  216.5 184.1  207.8 206.6  8.67271 -22.4823  453.467 323.045  69.4
74.7 2.235635
...
880581.9  189.0 170.4  192.5 200.7  -3.49796 -30.3127  360.175 247.753  66.8
72.8 1.681531
880615.3  189.6 171.6  192.5 201.3  -2.96342 -29.6987  364.311 253.335  66.2
73.3 1.662327
880648.7  no pupil  195.2 201.6  no vector  no gaze  no pupil geometry
880682.1  no pupil  214.3 202.1  no vector  no gaze  no pupil geometry
880715.4  250.0 172.5  221.8 201.1  28.2328 -28.5326  588.983 294.304  68.9
74.5 1.537552
880748.8  250.5 170.9  222.0 200.2  28.4955 -29.2931  590.48 288.297  69.8 74.3
2.136281
...
895929.3  no pupil  170.8 192.0  no vector  no gaze  no pupil geometry
895962.7  no pupil  170.8 191.7  no vector  no gaze  no pupil geometry
895996.1  no pupil  170.7 192.3  no vector  no gaze  no pupil geometry
stop timecounter: 896029.4 time: 2017-04-04T12:56:25.845+0200
```

If you create a tracking file from a calibration test, additional columns will be added to each row. These additional columns include information about the accuracy:

Colunm	Value
13 and 14	"Test" followed by the displayed test points (x and y). The coordinates are given as the number of pixels in the presentation.
15 and 16	"D" followed by the distance of the measured / fixated points (x and y) from the displayed test points, given in mm, calculated by means of the pixel size.
17	"T" Angular deviation in radians

The values are only correct if you have inserted correct data for the **Pixel width** and the **Distance to display** in the **Set-up** tab.

In case of the function **Random points** the following averages are recorded every 10 measured points:

Column	Value
18	"accuracy" and average of the angular deviation
19	"precision" and the RMS value of the angular deviation of each two sequential gaze points within 10 measurements

The number of averaged points can be defined in the settings file via the parameter *number_of_frames_for_averaging_accuracy_and_precision*.

In case of the function **Calibration test** the determination of "accuracy" and "precision" only takes place at the end of the measurement and is calculated from all points of the test.

10.3.2. Live image file (.vid)

Videos recorded with the MRC cameras are saved in the file format Y800 (640x480).

10.3.3. Setup files (.xml)

Main parameters of the eye-tracking software are saved in the file *User\Documents\Eyetracking\Settings\Setup_Global.xml*.

In this file you can modify Matlab extension variables and define if the software shall run in monocular or binocular mode, if available.
Camera specific parameters are saved in the file

User\Documents\Eyetracking\Settings\Setup_camera_code.xml.

Example for variant A: Setup_MRC_CAM_12M_000x.xml

<SetupML>

<setup number_of_frames_per_calibration_point="120" number_of_frames_per_blinc="10" minimum_number_of_pixels_to_the_image_border="30" minimum_accuray_of_calibration_pupil_center_based="10" minimum_number_of_pixels_for_the_pupil_size="10" height_of_calibration_window="900" minimum_accuray_of_calibration_vector_based="2" width_of_calibration_window="1200" number_of_frames_for_averaging_accuracy_and_precision="10" maximum_number_of_pixels_for_the_pupil_size="120" ratio_of_pupil_width_and_height="1.2" number_of_bytes_per_pixel="4" size_of_a_pixel_in_mm="0.277" size_of_calibration_point="5" distance_to_the_monitor_in_mm="800" number_of_frames_to_find_a_calibration_point="60" show_frames="2"/><rueckgabe accuracy="0" accuracy_of_calibration="0" precision_of_calibration="0" precision="0" status_of_information="0" status_of_test="0" status_of_calibration="0"/><eingabe smooth="1" draw_pupil_center="1" contrast_between_pupil_iris="1" draw_quality="1" percentage_of_edgepoints_to_ignore_under="0" number_of_calibration_points="9" detection_method="2" status_of_video_play="0" number_of_frames_to_smooth_over="1" halfframe="1" draw_window="1" draw_pupil_width="0" draw_edgepoints="1" tracking_method="1" status_of_video_storage="0" window_width="250" dark_threshold_of_the_pupil="26" status_of_storage="0" contrast_between_iris_rest="109" video_speed="10000" percentage_of_edgepoints_to_ignore_above="0" STOP="0" draw_glint_center="1" draw_eyetracking="1" draw_gaze="0" bright_threshold_of_the_glint="250"/><PupilOffsetMatrix val_0_2="0" val_1_1="0" val_2_0="0" val_1_2="0" val_2_1="0" val_2_2="0" val_0_0="0" val_0_1="0" val_1_0="0"/>
</SetupML>

Example for variant GigE: Setup_MR_CAM_HS_xxxx.xml

<SetupML>

<setup maximum_number_of_pixels_for_the_pupil_size="120" distance_to_the_monitor_in_mm="500" width_of_calibration_window="1200" number_of_frames_per_calibration_point="199" show_frames="10" minimum_accuray_of_calibration_pupil_center_based="10" size_of_calibration_point="5" minimum_number_of_pixels_to_the_image_border="20" size_of_a_pixel_in_mm="0.295" minimum_number_of_pixels_for_the_pupil_size="10" minimum_accuray_of_calibration_vector_based="2" ratio_of_pupil_width_and_height="1.2" number_of_frames_to_find_a_calibration_point="100" height_of_calibration_window="900" number_of_frames_for_averaging_accuracy_and_precision="250" number_of_frames_per_blinc="60"/><rueckgabe accuracy_of_calibration="0" accuracy="0" status_of_information="0" status_of_test="0" status_of_calibration="0" precision="0" precision_of_calibration="0"/><eingabe draw_edgepoints="1" detection_method="2" tracking_method="1" video_speed="10000" status_of_video_storage="0" window_width="273" status_of_storage="0" bright_threshold_of_the_glint="250" draw_glint_center="1" draw_quality="0" draw_pupil_center="1" halfframe="0" contrast_between_iris_rest="56" draw_pupil_width="0" number_of_calibration_points="9" draw_window="1" draw_eyetracking="1" status_of_video_play="0" dark_threshold_of_the_pupil="25" STOP="0" percentage_of_edgepoints_to_ignore_above="0" percentage_of_edgepoints_to_ignore_under="0" smooth="1" number_of_frames_to_smooth_over="1" contrast_between_pupil_iris="1" draw_gaze="1"/><PupilOffsetMatrix val_0_1="-5" val_2_2="-2" val_0_0="-2" val_2_0="0" val_1_2="-2" val_1_1="0" val_2_1="0" val_0_2="-5" val_1_0="-2"/>
</SetupML>

11. Libraries and licences

The MRC Eye-Tracking software uses the following libraries with specific licences:

a) OpenCV version 4.1.1 from http://opencv.org with 3-clause BSD license

b) QT 5.9 with LGPLv3 licence

The information on the licences is included as data files on the installation medium and displayed in the tab **Help**.

12. Contact

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The software "MRC Eye-Tracking" is continuously developed further. Changes compared to this user manual can occur.