User Manual

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1 INTRODUCTION

This document aims to give the reader necessary information about the project *Sensor Fusion for Hearing Aid Control*. The document assumes the reader has access to the *Git repository* [1].

2 HARDWARE

The hardware includes one pair of Tobii Pro Glasses 3 and a pair of hearing aid prototypes.

2.1 Tobii Pro Glasses 3

The Tobii Pro Glasses 3 comes along with batteries, hard drive with SD-card slot, equipment for Qualisys and calibration tools. There is a lot of information about the hardware and how to use the glasses on Tobii Pro:s homepage.

Figure 1: Tobii Pro 3 glasses components. Image rights: Tobii Pro AB

The components on the glasses seen in figure 1 are listed below:

1. **Infrared illuminators** - Illuminates the eyes to assist the eye tracking sensors.
2. **Head unit cable** - Connects tp the recorder unit to save and transmit data.
3. **High-definition scene camera** - Camera that captures the scene before the user.
4. **Microphone** - Picks up sound fro the user and the immediate surrounding.
5. **Eye tracking camera** - Records eye orientation and movement.
6. **Accessory attachment** - Used for optional accessories for example protective lenses.
7. **Nose pad** - Exchangeable and different sizes available in the case.

To start the glasses the following steps have to be followed:

1. Connect the glasses to the recorder unit through the HDMI cable.

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2. Press and hold the on-button until it stops flashing and stays static green.
3. Connect to the unit through WIFI. The password is **TobiiGlasses**.
4. Open the project application in order to start an experiment.

Further description on how to use the application is in the section below. Installation procedures are described in related GitLab repository.

2.1.1 *Glasses data*

The data accessible from the glasses are listed in Table 1. The data is structured as a dictionary.

Table 1: Data available from the Tobii Pro Glasses 3.

Field name	Description	Dimension
"ts"	Monotonic timestamp of the data	s
"acceleration"	Three-dimensional acceleration vector.	m/s^2
"gyroscope"	Three-dimensional orientation vector.	deg/s
"magnetometer"	Three-dimensional vector of the magnetic field.	μT
"gaze2d"	Horizontal and vertical position of the gaze on normalized video coordinates.	
"gaze3d"	Vergence point of the gaze from the right and the left eye with respect to the scene camera.	mm
"righteye.gazeorigin"	Location of the right eye relative the scene camera.	mm
"lefteye.gazeorigin"	Location of the left eye relative the scene camera.	mm
"righteye.gazedirection"	Estimated gaze direction in 3D for the right eye with the origin of the vector in the right gaze origin.	mm
"lefteye.gazedirection"	Estimated gaze direction in 3D for the left eye with the origin of the vector in the left gaze origin.	mm
"righteye.pupildiameter"	Diameter of the right eye pupil.	mm
"lefteye.pupildiameter"	Diameter of the left eye pupil.	mm

Note that all data does not arrive at the same time. Acceleration and gyroscope data is sampled at 100 Hz while magnetometer data is sampled at 10 Hz. For the gaze data, there is an option to either sample at 50 Hz and 100 Hz. All data is included with a time stamp.

2.2 Hearing Aids

The two hearing aid devices consists of two microphones each and one in-ear earbud. The microphones are connected to an amplifier with an RCA-connector (red and white). The earbud receives audio via the black connector. The input and output cables from the hearing aid are connected through a sound card of the model "MAYA44 USB+" which have 4-inputs and 4-outputs. The sound card has a USB connection to connect to a computer device. The amplifiers that are used are of model type "NANO-LP1". They consist av 2 input ports and 2 output ports. There are 2 amplifiers used where each one are for each earpiece. The hearing aid devices are powered by a 1.5 voltage battery through a circuit board.

3 G3 TERMINAL

The G3 terminal can be used to stream data from the Tobii Glasses 3 in real time using the asyncio API. The streamed data is

- Video stream
- IMU data
- Magnetometer
- Gaze data

The program can be run with different options that are given as arguments in the function call. The options are

- face
- video
- gaze
- orientation
- LSL
- save

The options can be written in any order and be combined in any desirable way. The options are implemented as modules and are described in more detail further down in this manual. An example of how to run the program with two options can be seen below.

```
$ python G3_run.py face LSL
```

3.1 Installation

Installation procedure for the program can be found in the corresponding README file in the git repository.

3.2 Face Tracking

When the G3 terminal is run with the option "face" the face tracking module is run. The module detects faces in the visual field of the glasses. When a face is detected, it is tracked. A limitation of the face tracker module is that it only tracks one face, that means that if there is more than one face visible in the frame of the glasses' camera it will act as if there is only one face present. The tracked face is marked with a box.

The module also estimates the 3D-position of the tracked face in a coordinate system relative to the glasses. The position is given in polar coordinates. If the G3 terminal is run with the "video" command the estimated position of the face is displayed in the video.

3.3 Video

When the G3 terminal is run with the option "video" a separate window will pop up and display the video feed from the scene camera of the glasses. If the face tracking is also active the video will contain a box of the tracked face and display the estimated position of the tracked face in polar coordinates, see section 3.2.

3.4 Gaze Tracking

When the G3 terminal is run with the option "gaze" the 3D-position of the gaze intersect is estimated. The position is given in polar coordinates relative to the glasses. A plot of the estimated 3D gaze point is displayed, see figure xx. If the program is run together with the video command the corresponding 2D gaze point to the scene camera will be displayed on the video on the form of a red dot.

3.5 Orientation

When the G3 terminal is run the angles for yaw, pitch and roll of the glasses will be estimated. A plot of the angles can be displayed by using the option "orientation" when running G3 terminal.

3.6 LSL

When the G3 terminal is run with the option "LSL" a stream of the gaze information is done with 'Lab Streaming Layer' [2]. This program enables data transfer from one program to another on the same computer. This stream enables the hearing aids to receive gaze information and choose the beamforming direction from it. To be able to benefit from this option, both the Tobii Pro G3 and the hearing aids must be run simultaneously. This is described in section 5.

3.7 Save

When the G3 terminal is run with the option "save" the data from the run is saved. The data that is saved depends on which options the G3 terminal is run with.

If the face tracking is active the following is saved after finished run:

- **"face_tracking.txt"** - A text file containing a list of all estimated face positions with their corresponding timestamp.
- **"video_face_tracking.avi"** - A video of the scene camera stream with the face tracking displayed.

If the gaze tracking is active the following is saved after finished run:

- **"gaze_tracking.txt"** - A text file containing a list of all estimated 3D gaze positions with their corresponding timestamp.
- **"video_gaze_tracking.avi"** - A video of the scene camera stream with 2D gaze tracking displayed.

3.8 Run-time options

During run-time there are a ways of interacting with the program. This is done by typing commands followed by 'enter' in the terminal during the execution of the program. A list of the options are given below.

- q: exit program
- calibrate: calibrate gaze of user (NON FUNCTIONING)
- rec: start recording
- stop: stop recording

The command 'q' is used to quit the program and stop all data streams and live processing. This can also be done with 'ctrl-c'.

'calibrate' should be used to calibrate the gaze estimation for a user with the included calibration markers before experiments. This is currently non-functioning and we refer to subsection 3.9 on how to do this.

'start' and 'stop' run-time options starts and stops a recording of the raw measurement data from the Tobii G3 glasses. The recording will then be found on the SD-card inside the glasses. Note that this type of recording is not any different than recording from the 'Tobii Pro Glasses 3 Controller' and will not record the processed data, for example orientation estimate. The main purpose of recording the data is to be able to run the processing offline with our other processing script, see subsection 3.11.

3.9 Gaze calibration

The calibration functionality is not currently working for the streamer. Therefor, before an experiment, download the controller from:

`https://www.tobii.com/products/eye-trackers/wearables/tobii-pro-glasses-3#download`

Then make the calibration there. This program is also nice to have for recording data and updating the firmware of the glasses.

3.10 Orientation calibration

The gyroscope needs to be calibrated to get reasonable orientation results. For 10 seconds, place the G3 glasses on a flat surface in an environment free from materials that can disturb the magnetic field. Data will be obtained and the bias of the gyroscope will be calculated and compensated for. Regarding the magnetometer, the calibration is done automatically when G3 terminal is run. Important to mention is that the magnetometer calibration is done when the glasses is located in Linköping. If the glasses is used in another location, a new calibration should be done to obtain the correct magnetic field, magnetic strength and bias of the magnetometer.

3.11 Running on recorded data

One can also run the modules on recorded data from the glasses. The files of the recording should be located in the "\recording" directory. Not all files from a recording are necessary to run the program, table 2 lists the files needed.

The data files should be named according to table 2 which are the default names of a recording done on the glasses. The program can be run with all the same options as the live version, see above description of the options. An example of how to run the program with two options can be seen below.

```
$ python G3_offline.py face save
```

Note that when running on recording data the program will run until it is finished and then exit automatically.

Table 2: Naming of data files for running the program on recordings.

Data	Name of file
2D and 3D gaze data	gazedata.gz
Accelerometer, gyroscope and magnetometer data	imudata.gz
Video from scene camera	scenevideo.mp4

4 HEARING AIDS

This section will focus on the user manual for the hearing aid devices. The hearing aids are used for two separate modules. The two modules are Sound Source Tracking module and Beamforming module. The two modules are separated in two folders called "Sound Source Tracking" and "Beamforming".

4.1 Hardware setup

All hardware components needed for the two modules are described in section 2.2. To setup the hardware, the battery first need to be connected in parallel to the two hearing aid devices through e.g. a circuit board. Which connector that belongs to the positive and which connector that belongs to the negative for the hearing aids are unknown. To find which one that belongs to which need to be decided by testing.

Connect the red audio cables to the right input channel (denoted "R") on the amplifiers and the white cable to the left input channel (denoted "L") on the amplifiers. Turn the amplifiers on and connect them to a power outlet. Connect thereafter four RCA connector cables from the output of the amplifiers to the input channels on the sound card. Connect thereafter the black output cables from the hearing aid to two of the output channels one and two on the sound card. Lastly, connect a USB cable from the computer to the sound card. For the Sound Source Tracking and beamforming modules, the microphones belonging to the left ear are connected to input channel one and two, and for the right ear the input channels are three and four. Assuming that the hardware is not faulty form e.g. loosely fit cables, the distinction between the two microphones on each microphone is not necessary for these modules.

It is important to note that the hardware used for the hearing aid devices are very sensitive. The connectors from the hearing aids can be a bit loose which can result in extremely high and noisy measurements. This makes it important to be aware of the volume if the input is directly connected to the output of the hearing aids since it can result in a very sharp and loud sound which can be quite painful for the user if they are not ready for it. Over time, the cables connecting the battery to the hearing aids may deteriorate, resulting in insufficient voltage reaching the hearing aids and causing performance issues. Changing the cables after some time can therefore be necessary. Same goes for the battery. Therefor it is important to check the voltage that goes into the hearing aid devices once in a while. The voltage should be around 0.7-1.5 volt.

After everything is connected and the hardware setup is finished the led lamps for the input on the sound card should light up when you speak into the microphones on the hearing aids. The four led lamps corresponds to the four input channel signal strength and therefor represent the signal strength of the hearing aids microphones. The input led lamps is a good way to check if all the hearing aids microphones are connected properly and successfully measures sounds.

4.1.1 *Soundcard setup*

In order to use the MAYA44 USB+ soundcard, the MAYA44 driver need to be downloaded. The most recent driver can be downloaded at the ESI website. The driver for MAYA444 USB+ comes with a control panel. The control panel can be seen in figure 2. The most important parameters that can be controlled in the control panels are the volume, "Sample rate", "USB Buffer" and "Latency". The "Sample rate", "USB Buffer" and "Latency" parameters can be changed in the Config section of the control panel. However, these parameters should not be changed while the souncard is in use and ruining. It is also important to note that these parameters can also be changed with SoundMexPro and Audio Toolbox. This control panel is therefore not necessary to star and use for the code to work with the exception for the Sound Source Tracking, where the latency needs to be chosen to 32.

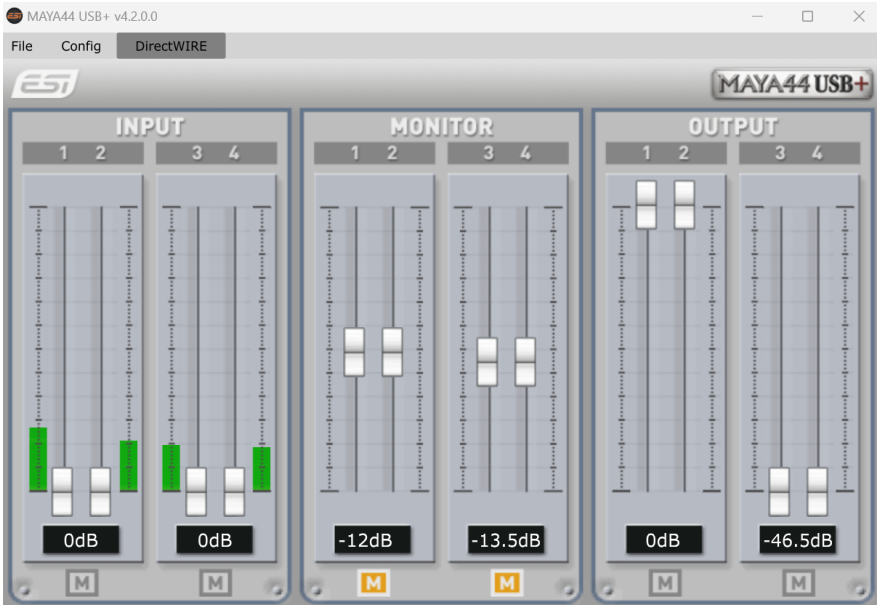

Figure 2: MAYA44 USB+ Control Panel.

4.2 Sound Source Tracking

This section will cover the sound source tracking module. The two main MATLAB files for running the Sound Source Tracking are called "LiveSoundSourceTracking.m" and "OfflineSoundSourceTracking.m". LiveSoundSourceTracking are used to track a sound source live. The code can also be told to store the measurements received from the live session in a .wav files for each microphone. The OfflineSoundSourceTracking is used to track a sound source offline, given four sound measurements in .wav format. The location to the four recorded files from each microphone need to be selected in the beginning of the code. The toolboxes used for this module are SoundMexPro, Audio Toolbox and Deep Learning Toolbox. SoundMexPro is a source tool for sound applications and is further explained in section 4.2.1.

4.2.1 *SoundMexPro*

SoundMexPro is a toolbox made for multi-channel I/O and real-time processing of audio signals. The folder for the SoundMexPro toolbox are located in the Hearing_Aid_Control folder. After running code that are using SoundMexPro it is important to run the command "clear soundmexpro". Not doing this will result in SoundMexPro still running in the background and the hearing aids will output noise. Clearing SoundMexPro is also crucial before recording or playing any sound using any other audio toolbox. A manual for SoundMexPro can be found on their website. Another way of getting familiar with SoundMexPro is to run and read the code of their tutorial functions. Their tutorial functions are located in a folder called tutorial in the SoundMexPro folder.

4.3 Beamforming

This section will cover the beamforming module. The main MATLAB file for running the beamformer are called beamformer_live. The toolbox used this module are Audio Toolbox. After recording and playing any sound with this

toolbox it is important to use the commands "release(speakerDevice)" and "release(microphoneDevice)". It is crucial that this is done before using SoundMexPro and as mentioned before in section 4.2.1 it is also really important that SoundMexPro is cleared before recording and playing any sound using Audio Toolbox.

5 ENTIRE SYSTEM

5.1 Introduction

It is possible to run the Tobii G3 glasses and the Hearing Aids live and control the beamforming direction with your eye-gaze. It is fairly simple to do this, basically you run the separate scripts simultaneously with a few changes. To do this, both the Tobii Pro G3 glasses and the hearing aids must be set up on the same computer according to section 3 and section 4.

5.2 Beamforming with Gaze-data

In this section it is described how to control the beamformer of the hearing aids with the gaze information of the Tobii Pro G3.

5.2.1 *Run Tobii G3 glasses*

Start the glasses and connect with the glasses via wifi or cable. Run the data streamer found in the folder *G3_terminal* for the glasses with the run option 'LSL'. Other options can also be used simultaneously.

```
$ python G3_run.py LSL
```

5.2.2 *Run Hearing aids*

Connect the sound-card to the computer and the battery to the hearing aids. After starting the glasses, the hearing aids can be run as below.

1. Check line 13 in **beamformer_live.m** the code and make sure that $gaze\_control = true$
2. Run the script **beamformer_live.m** in Matlab

You should now be running both the Tobii G3 Glasses and the Hearing aid beamformer, also controlling the beamforming direction with your gaze.

REFERENCES

[1] "Oticon gitlab," https://gitlab.liu.se/tsrt10/2023/oticon, [Online; 2023].

[2] "Lab streaming layer," https://labstreaminglayer.org/#/, [Online; accessed November 28, 2023].