Requirement specification

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DOCUMENT HISTORY

Version	Date	Changes made	Sign	Reviewer
0.1	2022-09-16	First draft.	All	GH
0.2	2022-09-21	Second draft	All	GH
0.3	2022-09-27	Third draft	All	GH
1.0	2022-09-29	First version	All	GH
1.1	2022-12-06	First revision	TT, GA	GH

1 INTRODUCTION

As a collaboration between Linköping University and Oticon, a company developing hearing aid technology, this project has been an ongoing development process for the recent years. By further development of existing features the final goal is to have a hearing aid product better suited for noisy environments. New for this year is access to new hardware (G3) with improved capabilities. This project is part of the course TSRT10 at Linköping University and will follow the project model LIPS. The requirement specification document is a part of LIPS and lists the requirements for the final product.

1.1 Partners

The people involved in this project are the customer, orderer, supervisor, and the project group.
Customer: Sergi Rotger Griful (SEGR), Eriksholm Research Centre.
Orderer: Martin Skoglund (MNSK), Division of Automatic Control at LiTH.
Supervisor: Johanna Wilroth, PhD student, Division of Automatic Control at LiTH.
Project group, 6 students at LiTH.

1.2 Aims and goals

The aim of this project is to improve and further develop the already existing features as well as implement them on the new hardware. There is also a wide extension of new features to be developed and implemented on the hardware. The system will be able to orient the user, detect and track potential speakers relative to the user as well as determine the activity of speaking. The system will be able to detect and analyze eye movements. Improvements of the simulation environment will be conducted to be able to provide realistic data and to integrate the new hardware.

- Make the software work for G3
- Improve modules and calibration using eye-tracking
- Improve the simulation environment to generate realistic data for the new hardware
- Make the program easy to use both for people developing new features but also for the user of the Tobii Glasses

1.3 Use

The system will combine information about the environment and the user to track and localize potential speakers as well as determine if someone is speaking. This will provide a proper foundation for filtering out noise.

1.4 Background information

Hearing aid devices are designed to improve the hearing of hearing impaired persons by filtering out noise and amplifying the ”sound of interest”. This ability is partly lost in noisy environments due to the difficulties to filter the signal with good results. The cocktail party effect refers to the ability of people to suppress noise by focusing on one person speaking. By utilizing and combining different sensors and cameras a view of the environment can be constructed. This information can then be used to artificially create the cocktail party effect for a hearing-impaired person.

1.5 Definition of terms

Table 1 shows the definitions of acronyms and terms used in the requirement specification.

Table 1: Definition of terms

Terms	Meaning
sim-env	The simulation environment is a combination of Gazebo with ROS, where instructions from ROS controls the Gazebo environment.
GUI	Graphical user interface, in which the user can interact with the program.
SLAM	Simultaneous localization and mapping.
IMU	Inertial measurement unit.
ISY	The department of electrical engineering at Linköping University.
DP	Decision point.
LIPS	Project model, containing rules, instructions and templates to conduct a project.
User	Refers to the person using the Tobii Pro Glasses.
Speakers	Refers to people talking in the environment of the user.
EKF	Extended Kalman Filter

2 SYSTEM OVERVIEW

The hardware used in the system is Tobii Pro Glasses 2 (G2), for this project new hardware, Tobii Pro Glasses 3 (G3), must be implemented such that it can work for the current modules. The G2 glasses consist of a pair of spectacle frames with a forward-oriented camera, and two eye-tracking cameras per eye, a microphone, and an IMU. The G3 consists of the same hardware as the G2 but also has a magnetometer and overall better sensors.

The wide angle scene forward-oriented camera is used to identify whether surrounding people are speaking or not in order for the hearing aid to focus on such person. The camera and IMU is also used with statistical localization methods such as EKF and SLAM to estimate the the users position, head orientation and position of surrounding people. New localization methods such as JPDA, IMM and MHT will be implemented in hope of improved results.

The simulation environment from previous year will be extended with new modules.

The system as a whole can currently approximate other people's orientation relative to the user and identify whether people are speaking. Using all this information about the system it is seen that there is potential to further develop the system such that all the information mentioned above can be used to detect who the user is speaking to or focusing on one or more people at each time instant. If it would be made possible for the system to detect if the user is focusing on one or more people at each time instant, that information could be used to amplify the sounds only from the people the user is interested in hearing.

2.1 Description of the product

The system will consist of one pair of Tobii Pro Glasses 2 and one pair of Tobii Pro Glasses 3. It is possible to estimate the position of the user's head, and where the user is looking. It is also possible to generate a face mesh for each person in the user's field of view, to determine if a person is speaking or not. There is also a simulation environment which

shall be further developed to be able to use for easy testing, scenarios, and to test situations that cannot be performed in reality due to for example safety reasons.

2.2 Product components

The product includes Tobii Pro 2 and Tobii Pro 3 glasses. These can be seen in Figures 1 and 2. It also consists of software written mainly in Python, which contains face analysis-, eye-tracking and SLAM-modules. There is also a simulation environment used for testing and further development.

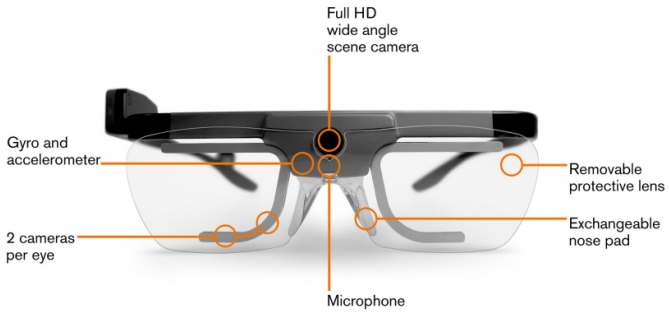

Figure 1: Tobii Pro Glasses 2. Image rights: Tobii Pro AB

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Figure 2: Tobii Pro Glasses 3. Image rights: Tobii Pro AB

2.3 Dependency of other systems

The project will continue the work of the previous projects:

- A thesis [1] within the area
- The work done by previous project groups, as well as previously developed code [2] and documentation [3]

The software dependencies include but are not limited to the following:

- Python packages such as: opencv-python, opencv-contrib-python, numba, pyquaternion, scipy, matplolib
- Face detection: onnx, onnx-tf, onnx-runtime, tensorflow, Media Pipe Face Mesh
- qualisys: qtm
- ROS2
- Gazebo

2.4 Included sub-systems

The software developed within the project will contain modules for face analysis, SLAM, and eye-tracking. The simulation environment will be used to simulate objects, both still and moving, as well as receivers and transmitters of sound. This will all be configured using a GUI.

2.5 Limitations

There are only 240 hours per person to spend on the project, which enumerates a total of 1440 working hours. The software that has been and will be developed will have a high time complexity which will demand powerful computers that can run the software.

3 COMPLETE SYSTEM

The requirements listed in this section applies on the integrated systems consisting of the each subsystem. The specifics of each subsystems will be included within its own section.

3.1 Design requirements

Listed below are the requirements for the design of the complete system.

Requirement	Version	Description	Priority
1	1.0	The applicable new modules should be compatible with G2.	1
2(Removed)	1.1	The new module for orientation estimation with the magnetometer and IMU should be compatible with G3.	1
3(Removed)	1.1	The new module for localization estimation with the magnetometer and IMU should be compatible with G3.	1
4(Removed)	1.1	The existing module of orientation estimation with camera and IMU should be compatible with G3.	1
5(Removed)	1.1	The existing module of localization estimation with camera and IMU should be compatible with G3.	1
6(Removed)	1.1	The existing face mesh-module should be compatible with G3.	1
7	1.0	The new modules should not interfere with existing functionality.	1
8(Removed)	1.1	The system should be able to provide real-time localization estimation of up to three speakers based on new functionalities from G3.	1
9	1.0	The systems real-time localization estimation should have a maximum error of 10 %	1
10	1.0	Calibration data for the forward-facing camera should be saved.	1
11	1.0	It should be possible to specify which saved forward-facing camera calibration data should be used in the software.	1

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Requirement	Version	Description	Priority
12(Removed)	1.1	The bias of the hearing aid accelerometer shall be calculated and compensated for.	1
13(Removed)	1.1	The bias of the G3 accelerometer shall be calculated and compensated for.	1
14(Removed)	1.1	The bias of the G3 magnetometer shall be calculated and compensated for.	1
15(Removed)	1.1	The bias of the G3 gyroscope shall be calculated and compensated for.	1

4 SIMULATION ENVIRONMENT

The current simulation environment created by last year's group is to be further developed in order to test the algorithm and development. It can be used as a tool to test and verify cases not fit for physical testing. Listed below are the requirements for the simulation environment.

4.1 Verification of algorithm

The simulation environment should further be used as a tool to verify the existing modules and new modules under development. Listed below are the requirements for the algorithm verification in the simulation environment.

Requirement	Version	Description	Priority
16	1.0	It should be possible to evaluate the target tracking modules against ground truth data from the sim-env with a maximum error of 10%	1
17	1.0	It should be possible to evaluate the new modules against ground truth data from the sim-env with a maximum error of 10%.	1
18	1.0	It should be possible to manually set the trajectory of the gaze vector in the sim-env.	2
19(Removed)	1.1	The sim-env should be able to simulate a scenario with 5 or more sources of background noise.	2
20	1.0	The sim-env should be able to simulate sensor noise with zero mean Gaussian-distributed noise.	2
21	1.0	The sim-env should be able to simulate sensor noise with non zero-mean Gaussian-distributed noise.	2
22	1.0	The sim-env should be able to simulate sensor noise which is Exponential-distributed.	2
23	1.0	The sim-env should be able to simulate sensor noise which is Laplace-distributed.	2

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Requirement	Version	Description	Priority
24	1.0	The sim-env should be able to simulate sensor noise which is bimodal-distributed.	2
25	1.0	The sim-env should be able to simulate sensor noise which is multimodal-distributed with at least 3 peaks.	3

4.2 Implementation of new hardware

The long-term goal is to have software applicable for different hardware the current simulation environment must be adapted to work for G3 as well.

Requirement	Version	Description	Priority
26	1.0	It should be possible to simulate IMU-data from the G3 in the simulation environment.	1
27	1.0	It should be possible to simulate magnetometer data from the G3 in the simulation environment.	1

4.3 Usability

Listed below are the requirements for making the applications more user-friendly and accessible.

Requirement	Version	Description	Priority
28(Removed)	1.1	The functionality of the GUI should be intact when resizing the window.	2
29(Removed)	1.1	The GUI should have a button to terminate/cancel the simulation.	3
30(Removed)	1.1	Every free text box should have an explanation available to read in the GUI.	3
31	1.0	It should be possible to launch the sim-env in the terminal with fewer commands than 4.	1
32	1.0	It should be possible to launch the GUI in the terminal with fewer commands than 4.	1
33	1.0	It should be possible to open the sim-env with one command.	3
34	1.0	It should be possible to launch the GUI with one command.	3
35	1.0	It should be possible to modify the behavior of the sim-env using program flags when launching the program.	1
36	1.0	It should be possible to launch a pre-defined test with a program flag while launching the program.	2

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Requirement	Version	Description	Priority
37	1.0	It should be possible to install all dependencies for the programs with only one command.	2

5 LOCALISATION

5.1 Eye Tracking

Eye tracking is the technology of tracking eye position and eye movement which has gained significant importance in the recent years. Previous project groups has not included the eye tracking system in the requirements, therefore its reasonable to try to improve the eye tracking system. Listed below are the requirements for the eye tracking.

Requirement	Version	Description	Priority
38	1.0	The intensity of light directed toward the user's eyes should be estimated.	2
39	1.0	The size of the eye's pupil should be measured with different levels of light intensity.	2
40	1.0	The impact the level of light intensity has on the pupil size should be compensated for.	3
41	1.0	Measured data should be stored locally on the computer running the software.	1
42	1.0	Estimated data should be stored locally on the computer running the software.	1
43	1.0	A module for estimating the average eye saccade frequency should be implemented.	3
44	1.0	The average eye saccade frequency when the user is listening to one person should be estimated.	3
45	1.0	The average eye saccade frequency when the user is listening to two or more people should be estimated.	3
46	1.0	The system should be able to identify locations with a high eye fixation.	3
47	1.0	The system should be able to detect smooth pursuit within 1 second when an object moves with a velocity between 1 km/h to 5km/h.	1
48	1.0	The system should be able to detect at least 80% of saccades with an amplitude of at least 0.5°.	1

5.2 Target tracking

Requirement	Version	Description	Priority
49	1.0	The eye tracking data should be able to be used in the EKF- and SLAM-modules in real time.	1
50	1.0	The magnetometer in the G3 should be accessible and used in the EKF- and SLAM-modules.	2
51	1.0	The target and object tracking in the SLAM-module should be combined.	2
52	1.0	At least one new statistical target tracking method (ex. JPDA, IMM or MHT) should be implemented.	1

6 G3 GUI

Requirements for the new G3 GUI.

Requirement	Version	Description	Priority
53(NEW)	1.1	The GUI should be construced such that acceleration data is displayed to the user.	1
54(NEW)	1.1	The new GUI should be constructed such that gyroscope data is displayed to the user.	1
55(NEW)	1.1	The new GUI should be constructed such that magnetometer data is displayed to the user.	1
56(NEW)	1.1	The new GUI should be constructed such that scene camera is displayed to the user.	1
57(NEW)	1.1	The new GUI should be constructed such that gaze point is displayed to the user.	1
58(NEW)	1.1	The new GUI should be able to provide calibration of the eye tracking.	1
59(NEW)	1.1	The code is safely written (eg. closing connections, waiting for threads to join etc).	1
60(NEW)	1.1	The code is written to be maintainable (eg. using code conventions, modularity etc). such that it enables future development.	1
61(NEW)	1.1	G3 data should be easily accessable to enable further processing in real time without impact on performance (eg. using non-blocking functions for streaming).	1

7 POSSIBILITIES TO UPGRADE

The requirements to enable further development are listed below.

Requirement	Version	Description	Priority
62	1.0	The project should have documentation containing explanations of all modules and functions.	1
63	1.0	A User Manual describing the system and how to utilize it should be written.	1
64	1.0	The User Manual should be independent and detailed.	2
65	1.0	All code should be stored in a GitLab repository and made available for future development.	1
66	1.0	All files that are not suitable to be revision controlled, for example, data files, should be stored in a large file storage.	1

8 ECONOMY

The economy requirements are listed below.

Requirement	Version	Description	Priority
67	1.0	Each group member should spend at least 240 hours on the project.	1
68	1.0	ISY and Eriksholm Research Centre should provide up to 40 hours of guidance.	1
69	1.0	One project room provided by ISY should be available for the project.	1

9 SAFETY AND SECURITY REQUIREMENTS

In order to ensure the safety of each group member and to minimize the risk of property damage, the following safety requirements have been implemented.

Requirement	Version	Description	Priority
70	1.0	All tests must be authorized by the responsible for testing before being performed.	1
71	1.0	All group members must familiarize themselves with the security protocol of the testing area (Visionen).	1

10 DELIVERY

The delivery requirements are listed below.

Requirement	Version	Description	Priority
72	1.0	A status report including a time report should be delivered to the orderer at the end of each week.	1
73	1.0	DP2: Delivery of the requirement specification, project plan, time plan and a first draft of the design specification.	1
74	1.0	DP3: Delivery of the design specification and test plan.	1
75	1.0	DP4: All functionality in subsystems, modules and the simulation environment should be complete.	1
76	1.0	DP5: The entire system should be functional. Delivery of test protocols and user guide including a presentation showing that the requirements from the requirement specification have been fulfilled.	1
77	1.0	DP6: Delivery of the technical report, an after study, a poster presentation, the project web page and project movie.	1

11 DOCUMENTATION

Table 13 lists all documents that shall be produced in the project

Table 13: Documents to be produced.

Document	Language	Aim	Target	Format
Project plan	English	Describes how the project should be conducted and group responsibilities	Project members, Orderer, course responsible	PDF
Time plan	English	Describes how the time should be spent in the project. Includes a time report.	Project members, Orderer	Excel spreadsheet
Requirement specification	English	Determination of the projects and products requirements	Project members, Orderer	PDF
Design specification	English	Describes how the system should be designed to meet the requirements	Project members, Orderer	PDF
Test plan	English	Describes how the requirements are to be tested.	Project members, Orderer	PDF
Technical documentation	English	A collection of all the conducted tests	Project members	PDF
Project report	English	A report summarizing the project and its outcome.	Project members, Orderer, course administrators	PDF
After study	English	A reflection of the project as a whole.	Course administrators	PDF

12 QUALITY

The following requirements are to be met in order to ensure the quality of the finished product.

Requirement	Version	Description	Priority
78	1.0	Discrepancies between ground truth and calculated values shall be measured and documented.	1
79	1.0	Technical documentation following academic standards must be maintained throughout the project.	1
80	1.0	Code must be commented and follow Google code standards [4].	1

REFERENCES

[1] A. Fredriksson and J. Wallin, "Mapping an auditory scene using eye tracking glasses," Master's thesis, Linköpings University, Department of Electrical Engineering, 2020.

[2] (2022) Oticon gitlab repository.

[3] M. H. Mediaa, A. Lidström, G. Hilding, M. Öhgren, A. Åsbrink, and M. Lundström. (2021) Sensor fusion for hearing aid control webpage.

[4] (2022) Google Style Guides.