Project Proposal - Cornea Sense

1. Introduction

The cornea, essential for vision, heavily relies on its water content. Imbalances, like corneal edema, impair vision and demand timely treatment. Current assessment methods, in general related to pachymetry, are often invasive, not necessarily accurate, and costly, leading to suboptimal outcomes and rising healthcare costs.

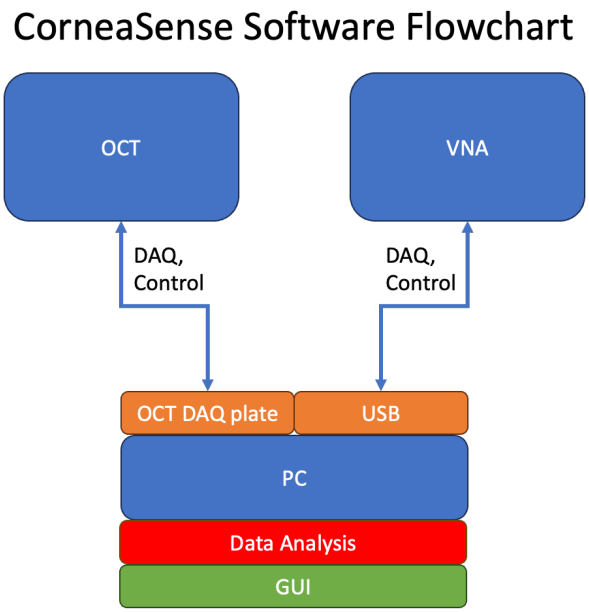
We at Cornea Sense are building a diagnostic medical device to cornea screening, seamlessly integrated with OCT devices. Utilising patented terahertz technology, our device enables non-invasive and non-ionising measurement of tissue hydration, aiding in the early detection of complications and diseases in cornea. This is a R2B (research to business) project funded by Business Finland and Aalto University.

2. Project goals

The goal of this particular project is to develop a software application for Cornea Sense diagnostic system which integrates two scientific devices: an Optical Coherence Tomography device (OCT) and a Vector Network Analyzer (VNA). The software should provide functionalities for controlling the devices, synchronizing their operations, Data Acquisition (DAQ), and performing analysis on the collected data. Additionally, the application should include a graphical user interface (GUI) for user interaction.

Tasks:

1. Device Control
2. DAQ
3. Data Analysis
4. Synchronization
5. GUI (an add-on, can be de-prioritized)



1. Device Control

Develop software modules to control the OCT and VNA, allowing for configuration, initialization, and operation of both devices.

OCT

- Establish connection and initialization of the device.
- Implement functions to start, stop and configure the device. Examples of configurations needed to control: 1) reference level, 2) scan area, 3) scan rate, 4) illumination level and contrast, 5) modes (2D, 3D).

VNA

- Establish connection and initialization of the device.
- Implement functions to start, stop and configure the device. Examples of configurations needed to control: 1) frequency range, 2) number of data points, 3) measurement type.

2. DAQ

Capture and store data from both devices during their operation. Allow real-time monitoring of devices status (e.g., operational state, error messages, etc).

OCT

- Capture images from the OCT light source with a specific scan rate (e.g., one image per 100 ms).

VNA

- Collect digitized data of signal amplitude and phase.

3. Data analysis

Provide analysis tools for processing and visualizing the collected data.

OCT

- Based on the captured image, calculate thickness and radius of curvature of the object (cornea).
- Show coordinate grid on the captured image.

VNA

- Implement signal processing toolkit such as Fourier transform and Time-Gating.
- Using physical and mathematical models, calculate permittivity of the object and extract water content.

4. Synchronization

Implement synchronization mechanisms to coordinate the operations of the OCT scanner and VNA. The main point of synchronization is to achieve fast and bugless simultaneous control, DAQ and data analysis for both devices.

5. GUI

Design and implement a user-friendly graphical interface to facilitate control, monitoring, and data analysis.

OCT panel

- Area for showing captured images (refreshing in real time)
- Control panels to change parameters such as 1) image contrast, 2) properties of the object (e.g., refractive index), 3) settings of the device.
- Monitor panels to show parameters, such as 1) extracted properties of the sample (thickness, radius of curvature), 2) coordinates, 3) other information of the device status and settings.

VNA panel

- Graphs of collected and analyzed signals.
- Analysis panel which includes various signal processing settings for Fourier transform, Time-Gating as well as modelling.
- Panel with the information about calculated water content of the object.

3. Technologies

Programming language

Thorlabs (the OCT device manufacturer) provides sdk and libraries for following coding languages:

1. C++
2. LabView
3. Matlab (limited set of libraries)
4. Python (nor released yet, scheduled for the end of 2024/ beginning of 2025)

The Matlab and Python scripts will call the C.dll library. Thus, the speed of operation with important parameters such as image refresh rate is independent from the used

coding language. Thorlabs does not provide a specific Matlab SDK, but you would have to create your own interface via calllib().

At this point, we use Thorlabs software to control the device and to analyse the data coming from OCT (with GUI) and VNA device control and data analysis is based on our own Matlab code (no GUI).

Task 3 OCT analysis will be based on already made code provided by Thorlabs. VNA part can be provided by us (already made in Matlab) as it requires competencies in physics and math.

4. Requirements for the students

It is important to have a good command knowledge of the coding languages (at least C++, good to have Matlab too, but not compulsory, as we have plenty of expertise in Matlab)

The topic is not difficult but requires some creativity and attention to details. We are building a medical device, so no shortcuts here, only reliably code and documenting everything.

5. Legal Issues

Intellectual Property Rights (IPR): All IPRs to all Results will be transferred to the Client.

Confidentiality: The client will share some confidential information with the students.

6. Client

Cornea Sense is a R2B project from Aalto University, ELEC. The key contact for this project are

- Anton Chernenko anton.chernenko@aalto.fi +358504707406 (business expert)
- Roman Grigorev roman.grigorev@aalto.fi (technical expert)

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Roman and Anton will provide as much time as needed for successful project implementation.

We can provide a desk/s for the project if needed, as well as access to the software.

Client representative(s)

- See above

Preselected Student Team Members

- NA

7. Additional information

We will be looking for 1-2 SW developers at the time of project incorporation, planned for June-August 2025. Hence this will be a great opportunity to learn about the project beforehand and increase your chances of landing an interesting and rewarding role later on with Cornea Sense.