Proceedings of Biomedical Engineering Projects

Bachelor - Biomedical Engineering
Master - Medical Engineering & eHealth
Academic year 2023/2024

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Contents

Foreword

Welcome to the Biomedical Engineering Projects proceedings!

The University of Applied Sciences Technikum Wien stands as a beacon of education in technology and digitization. Since its inception in 1994, it has nurtured over 13,000 graduates. Currently, more than 4,500 students across 30 bachelor's and master's degree programs are being honed into future leaders for the economy. These programs are offered in various formats, catering to daytime, evening, and distance learning. The courses provided are grounded in research yet attuned to practical applications. Alongside a robust technical education, equal emphasis is placed on fostering business acumen and personal growth. Strong affiliations and collaborations with businesses and industries create a pathway to remarkable career opportunities for both students and alumni. In both teaching and research, the dovetailing of theory and practice is a top priority.

Embedded within the curriculum of the *Biomedical Engineering (Bachelor)* and *Medical Engineering & eHealth (Master)* programs at the University of Applied Sciences Technikum Wien, lies a series of courses engineered to highlight collaborative efforts. Over the course of a year, students undertake an immersive journey through the intricacies of project management with a scientific lens, while collectively surmounting technical challenges. The inherent value of this framework is apparent, as knowledge finds its truest form of progression when wielded in practical scenarios.

The outcomes of numerous projects have consistently exceeded our expectations. We witness their tangible impact in industrial applications and their recognition on the global stage through presentations at international conferences, workshops, and academic publications.

In the past years, we invested a substantial effort in the process of finding a variety of suitable project topics, involving areas of medical software and hardware. Our aim is to link these projects with a cohort of students driven by genuine interest, as such individuals invariably yield superior outcomes.

We furthermore aspire to strengthen and expand upon existing collaborative efforts with industrial and scientific partners. The concept of co-supervision in these projects presents itself as a clear win-win scenario for all parties involved.

Contained within the subsequent pages, you will encounter projects tackled in the preceding academic year, alongside proposals for upcoming endeavours. We extend an invitation to you to connect with us if any of the topics resonate with your curiosity. Together, we possess the capability to refine, extend, or even conceive novel project topics that benefit everybody involved.

The students involved in the courses can use this proceeding as a source of inspiration and to get to know available topics. During the semester you will be asked to form a group and choose from the pool of available topics. Timely preparation will ensure that you end up with a project that fits your skills and interests

We eagerly anticipate the opportunity to engage with you!

Best regards,
Richard Pasteka
pasteka@technikum-wien.at
University of Applied Sciences Technikum Wine

Contributions
Biomedical Engineering
Bachelor Study Program
Group Posters

Further Development of the Respiratory Belt Transducer

Bettina Ernst, Olga Gebhard

Introduction

Respiratory monitoring, an important aspect of medical care, plays a crucial role in observing, analysing and evaluating patients' breathing patterns. As part of the Biomedical Signals and Medical Sensors course, this project focused on the design and development of a prototype respiratory belt transducer. This transducer works by detecting the movements of the chest wall through a sensor and converting these analogue movements into electrical signals that allow detailed monitoring and analysis. The development of this prototype involved not only creating a functional device and taking initial measurements, but also gaining practical experience in the design, application and development of medical devices.

Methods

- **Casing**
  - >> CAD- modelling: Fusion 360
  - >> 3D printing: PrusaSlicer, original Prusa MK4 3D printer
- **Circuit**
  - >> LT-Spice
  - >> Breadboard
  - >> Soldering
  - >> Troubleshootig
- **Integration of Digital Part**
  - >> Choosing Arduino Nano
  - >> Code in C
  - >> Arduino IDE

Results

Casing

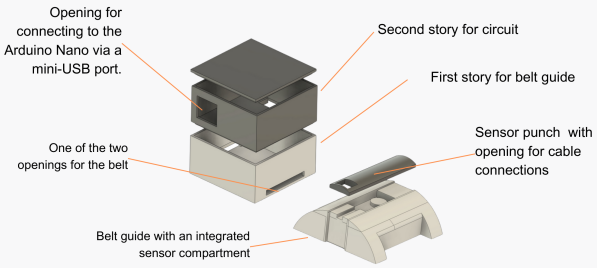


Figure 1: Fusion 360° 3D Design; Left: optimized two-story casing design. Right: Belt guide with an integrated sensor compartment and sensor stamp.

Circuit

- Negative converter (TC7660) and voltage divider: Vref for Sensor: -1V
- Dual OpAmp (MCP6002): Filter (Low Pass), Non-inverting Amplifier Gain: 10
- Arduino nano for Voltage supply and AD-conversion

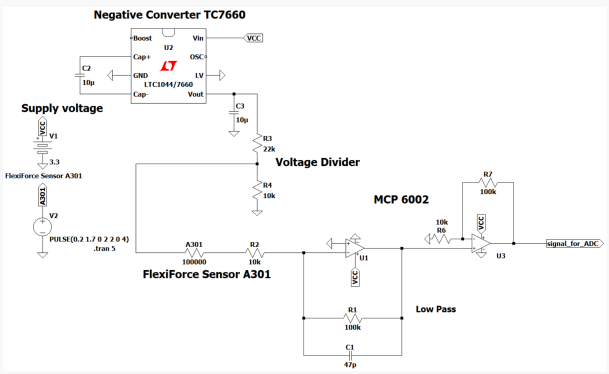


Figure 2: Circuit diagram created with LTspice with negative converter for the reference supply and dual opamp for filtering and amplifing the incoming signal

Prototype

- Belt guide with an integrated sensor compartment
- Rectangular, elongated sensor punch
- Soldering of circuit on a perfboard and integration of arduino nano

Figure 3: Assembled housing with integrated circuit and sensor. Left: First level with belt guide and integrated sensor in the sensor compartment as well as sensor stamp. Top right: Second level with inserted circuit.

Measurements

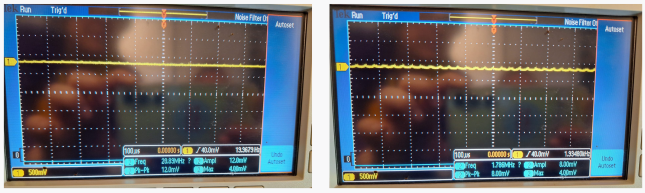


Figure 4: Oscilloscope measurement. Left: Complete exhalation. Right: complete inhalation

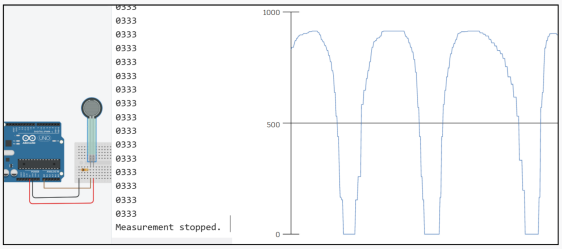


Figure 5: Tinkercad Simulation of AC-Conversion Code. Left: FlexiForce sensor setup. Right: Output attempting to roughly simulate and mimic the pressure of a breathing process

Discussion

- Casing: Integration of the band for better handling
- Circuit: Signal too weak for AD conversion

Implemented measures:

- Adaptation of the circuit
- Checking the signal strength in the circuit
- Arduino Pro Mini -> Arduino Nano for USB connection,more stable power supply (no batteries)

Results of implemented measures:

- Possible signal measurement up to the opamp

Further considerations and potential steps:

- Verification of opamp configuration and amplification
- Investigation of potential interference affecting the signal
- Evaluation of alternative components for the circuit

Patient Side ECG Phantom Signal Generator Circuit for ECG Equipment Testing

Herzberger Lukas, Krampl Sebastian | UAS Technikum Wien, BBE5

Introduction

As a medical ECG monitor has a very high responsibility and reliability, it has to be ensured that the measured ECG signal is accurate and not faulty in any way. Otherwise, symptoms of diseases might be detected wrongly, or already existing symptoms do not get revealed. Therefore, an ECG phantom is used. It is the counterpart to the ECG monitor and generates a simulated ECG signal with adjustable parameters of the pulse (in bpm), the amplitude (in mV) and the width of the QRS-complex (in ms). Furthermore, various pathological ECGs can be selected. Connecting an actual ECG monitor to the phantom, the medical device can get tested on showing correct values and measured data.

Methods

Software

- pointwise defined phys. ECG signal
- path. ECG: *PhysioNet* database
- output via ESP32 DAC channel (0-3V3)
- web application for parameter selection using HTML, CSS, JS (bpm, QRS width & amp, rhythm)
  → ESP32 as WiFi access point
  → transfer to `main.ino` via JSON

Hardware

- power supply: microUSB cable or battery
- signal adjustment via differential amplifier (offset correction, damping to mV range)
- charge pump for negative supply
- Resistor network for 12 lead generation
- LED for connection status
- All incorporated into one SMD-PCB

Case

- 3D PLA print
- includes PCB, battery, connectors & switch
- 4 mm banana plugs for connection to monitors

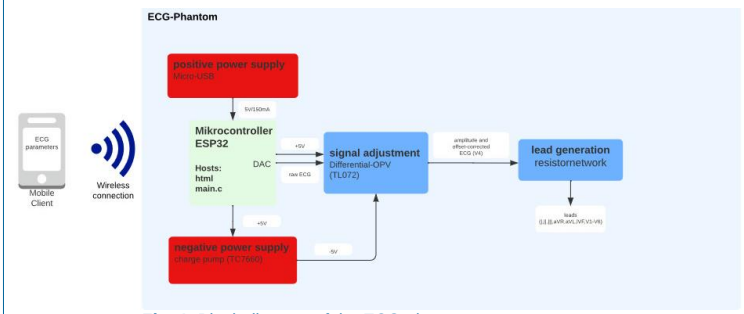


***Fig. 1**: Block diagram of the ECG phantom*

Results

Software

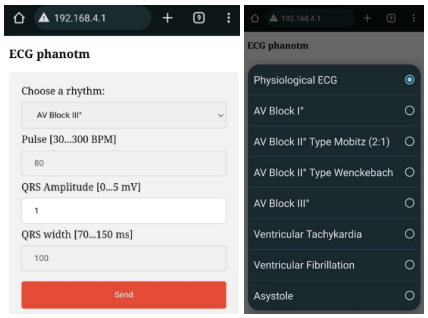


***Fig. 2**: Web app front page & rhythm selection*

Hardware

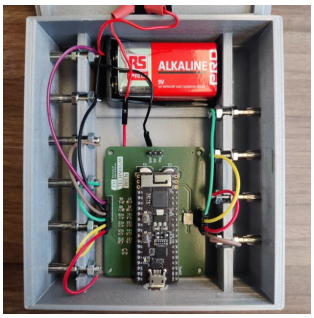


***Fig. 3**: Top view of final prototype*

Validation

- Measurement/evaluation: biopac & matlab
- Stepsize: 10 BPM, 500 uV, 10 ms
- Deviation of set parameters
  - Heart rate: 0.3% (30-300 BPM)
  - Amplitude: 2.5% (0.5-5 mV)
  - QRS-width: 2.3% (70-150 ms)

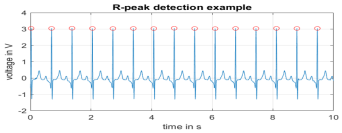


***Fig. 4**: R-peak detection in Matlab*

Discussion

All the set goals were achieved, and the validation of the variable parameters was also extremely satisfactory. It was also possible to implement the pathological ECGs that were not initially defined as project goal.

Problems & Adjustments

Interpolation factor change	Decreased the deviation
Change of damping factor	Achievement of more precise amplitudes
Issue when changing the rhythm	Pathological ECGs consist of 10 second time samples

Future prospects

- Adress the stated problems
- Automated ECG implementation
- Long rhythms for normed device testing

Resources

CPU fan model for student training in medical measurement technology

Marvin Abass, Anita Blazevic, Aleksandar Maksimovic

Introduction:

The acquisition of measured variables and the estimation of the achievable accuracies play a central role in medical measurement technology. The hardware currently used for the CPU fan model and the Excel used to evaluate the measured values are no longer state of the art. Therefore, our goal is to develop a CPU fan model, which is able to collect a variety of measurement data and to interpret this data intelligently.

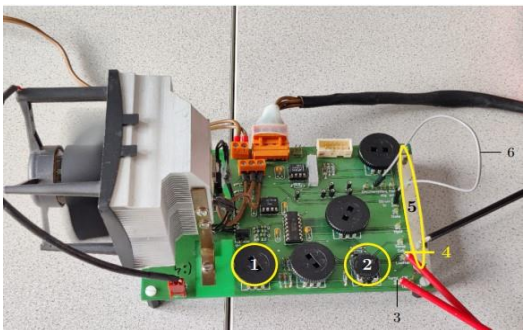


Figure 1: Current fan model used in the laboratory

1) Fan control
2) Current control for heating element
3) Tap point Temperature heat sink
4) Tap point fan voltage
5) GND-Bar
6) Wire jumper for manual current setting

Methods:

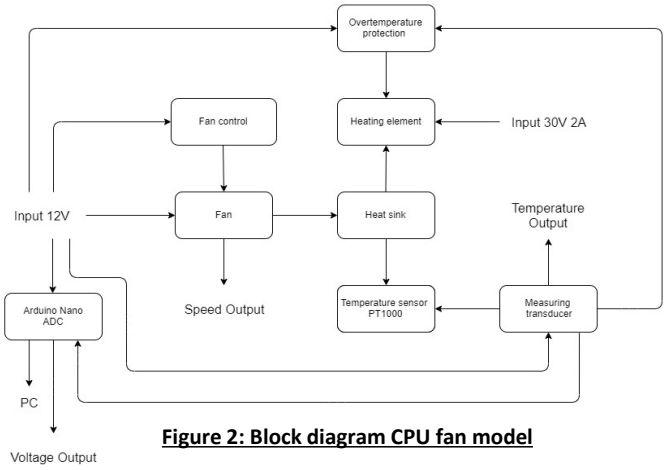


Figure 2: Block diagram CPU fan model

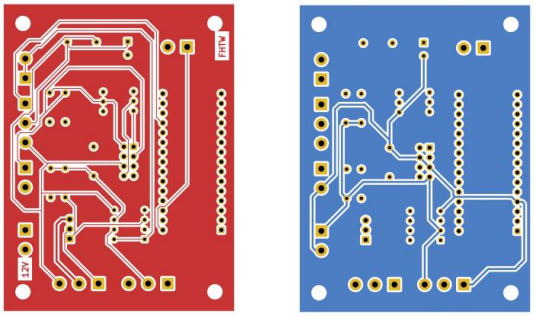


Figure 3: Front- and backside of the PCB

Results:

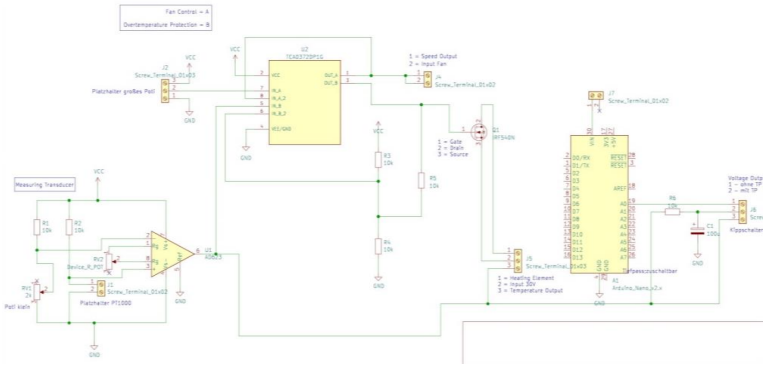
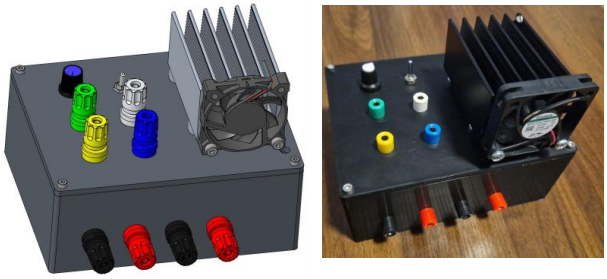


Figure 4: Circuit schematic CPU fan model



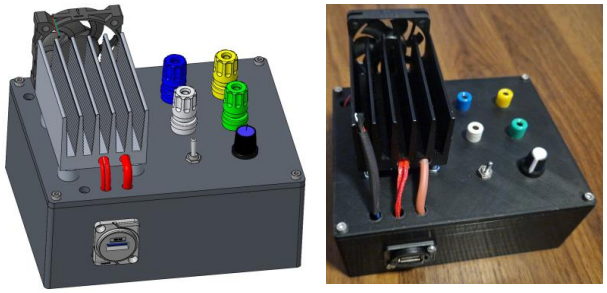


Figure 5: Casing CAD and realization

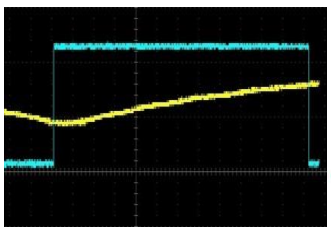


Figure 6: Heating Cycle

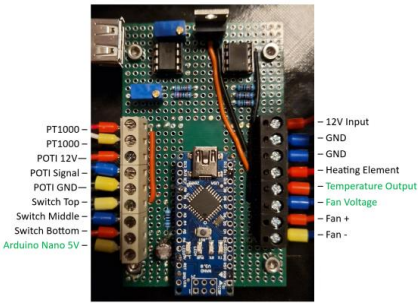


Figure 7: Circuit Board

Discussion:

- Rail-to-Rail InAmp
- Fan Control
- ABS case
- Small scale production

Driving system for a mookup loop

Kogler A., Nürnberger F., Zettel D.G.

Introduction

Goal of the project

- Development of pulsatile, pneumatic drive unit for a left and right ventricular assist device (SynCardia)

Mock-loop

- Simulation of cardiopulmonary circulation Ventricular Assist Devices (VADs): surgically implanted mechanical pumps

Use

- Support heart function in severe heart failure as temporary aid or permanent solution

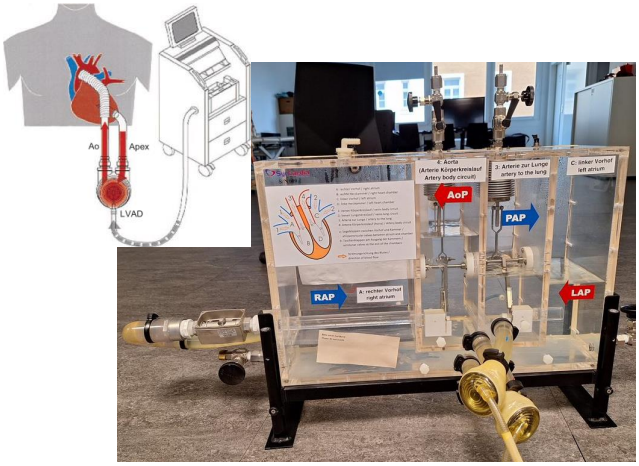


Figure 1: SynCardia TAH Mockup-Loop Model & Schematic of a ventricular assist device inclusive drive unit implanted in the body of a human being.[1] [2]

Methods

- CAD planning
- Metal working
- Laser cutting
- Programming C
- Electrical assembling
- Pneumatical assembling

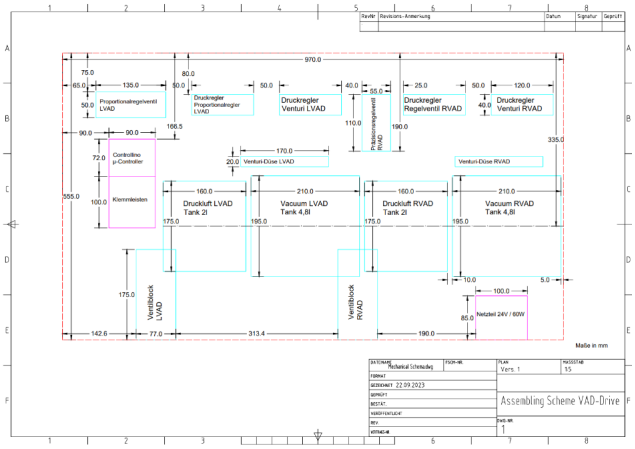


Figure 2: CAD drawing of the assembling diagram of the mounting plate in the housing

Results

Milestones

- Concept planning
- Cost estimate
- Material ordering
- Incoming goods
- Detailed planning
- Programming of the operating software
- Final assembly
- Test runs

Figure 3: Front panel with integrated display, control switches, pressure sensors and air outlets

Figure 4: Final setup with fully integrated electric, mechanic and pneumatic components

Discussion

Challenges

- Unexpected regulator reaction
- Order management
- Complex µ-controller programming
- Satisfaction with realization

Further outlook

- Regulator optimization
- Final pneumatic adjustment
- Better cable management
- Improving mobility - wheels on the housing
- Investigation of pathologies
- Study of all functions and settings of the SynCardia model

References:

[1] Crosby JR, DeCook KJ, Tran PL, Smith RG, Larson DF, Khalpey ZI, Burkhoff D, Slepian MJ., Physiological characterization of the SynCardia total artificial heart in a mock circulation system., 2015, https://doi.org/10.1097/mat.0000000000000192
[2] Kramer, Frank & Milting, Hendrik. (2011). Novel biomarkers in human terminal heart failure and under mechanical circulatory support. Biomarkers : biochemical indicators of exposure, response, and susceptibility to chemicals. 16 Suppl 1. S31-41. 10.3109/1354750X.2011.561498.

Development of a Measurement Setup for Filtering Face Pieces Efficiency Testing

Leon Ballabani, Maher Saadeddin, Madline Emrich

Introduction

The aim of this project was to create a setup to test the efficiency of filter face pieces (**FFP**). These are often used in occupational environments to protect against the inhalation of hazardous particles such as dust, mist, vapours or aerosols. [1,2]

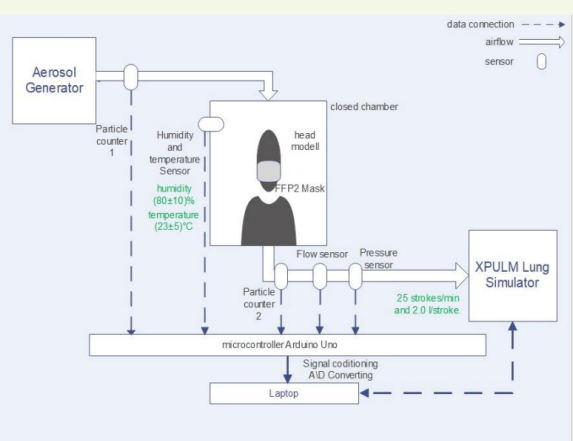


Figure 1: Block diagram of the setup

What do we want to measure?

- number of particles in the chamber and after inhalation
- temperature and humidity in the chamber
- air flow after inhalation through the mask
- pressure in the airways

Last semester: Developed experiment setup plan and purchased components
This semester: Assembly and testing

Results

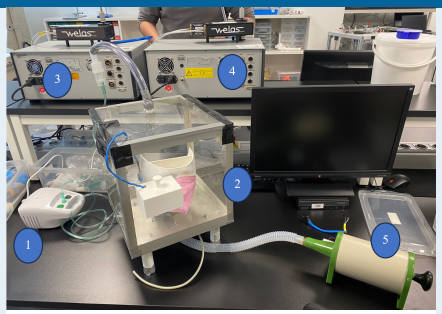


Figure 4: Final tests setup with aerosol generator (1), chamber with head model & mask (2), particle counter (3, 4) and pump as lung model (5)

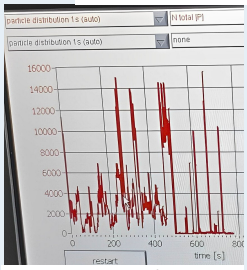


Figure 5: Results of particle distribution measurement with particle counter before filtering.

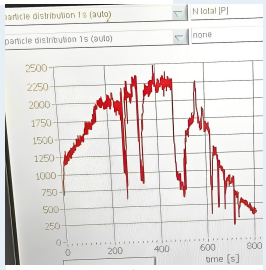


Figure 6: Results of particle distribution measurement with particle counter after filtering.

- maximum before inhaling: ~15500 Particles
- maximum after inhaling: ~2500 Particles

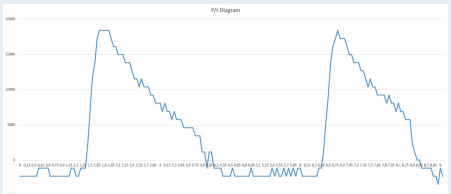


Figure 7: Pressure measurement to determine the tightness of the chamber. Graph shows that pressure drops, which indicates leaks.

Methods

The focus in this semester was on completing the following tasks:

- make the box leak-proof
- finish the head model and sealing it
- drill the holes in the top and bottom layer for two adapters
- create and 3D-print adapter number 1 and glue it into the top hole to connect the aerosol generator with the chamber
- create and 3D-print adapter number 2 and glue it into the bottom hole to connect the X-Pulm with the chamber
- include the sensors into the setup
- create and 3D-print a housing for the arduino and our circuit

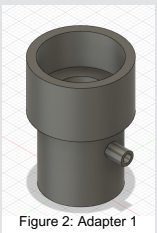


Figure 2: Adapter 1

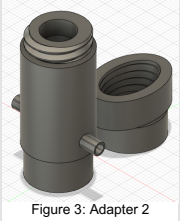


Figure 3: Adapter 2

Discussion

- ongoing box leakages, source unclear
- X-Pulm unavailable, alternative not compatible with our flow sensor
- pressure measurement and particle measurement were not possible at the same time
- tests only with water particles, meaning no real proof for filtering of viruses, dirt or bacteria

Learnings we made:

- with leaking problems: choose one proper method and invest more time in the beginning with it
- do more research on all components involved in the setup beforehand
- making sure that chosen components fit the quality criteria of the project

REFERENCES

[1]NORM EN 149. Available: https://cas-technik.de/normen/normen-atemschutz/norm-en-149
[2]'New Projects for Bachelor Biomedical Engineering,'. Available: https://moodle.technikum-wien.at/pluginfile.php/1743988/mod_resource/content/0/BSMS%20New%20Projects%20Proposals%202023

Environmental Monitoring Sensor Unit

by Blehova, Magyar and Müller

Introduction:

Environmental parameters have a significant impact on human health. We used sensors to determine and analyze the air quality indoors. We implemented measurements for temperature, humidity, carbon monoxide etc. This values are monitored live (to trigger an alarm, if a value reaches a problematic value) as well as saved, for flexible long-term analysis.

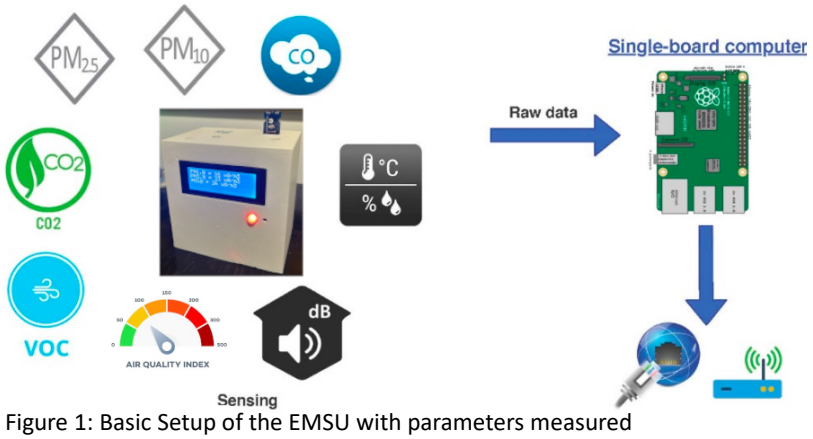


Figure 1: Basic Setup of the EMSU with parameters measured

Materials & Methods:

Sensors & Components: Temperature und Air Humidity [°C, %], Loudness [dB], CO2 [ppm], VOC [ppb], PM [ug/m3], CO [mV], Display, Voltage Level Converter, ADC, Buzzer, Red Led

Hardware: Raspberry Pi (main unit), 3D printed box/case
Software: Own Python Program, Mosquitto MQTT Broker, OpenHAB

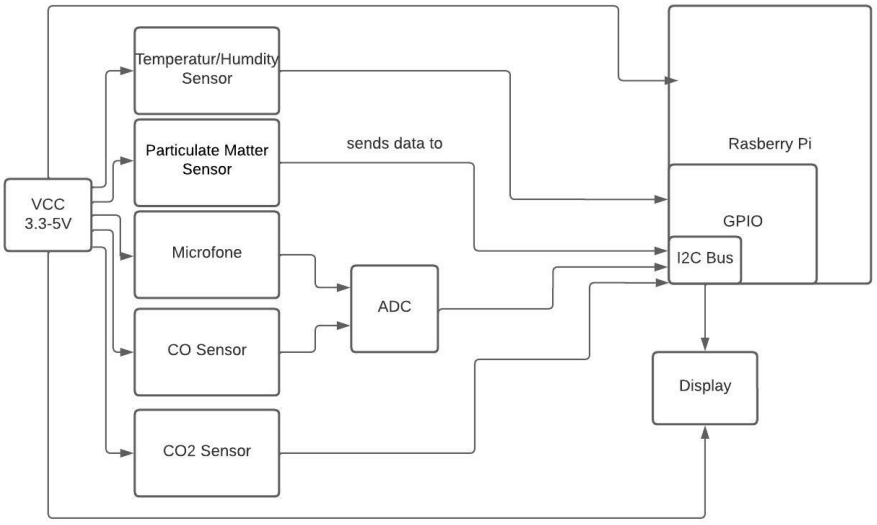


Figure 2: Hardware connection block diagram

Figure 3: Software flowchart

Results:

- Figure 4: Screenshot from our OpenHAB Installation, serves as GUI for the project
- Equipment tab: all sensors with corresponding measurement values listed
- Several graphs with unit and topic matching measurements

Discussion:

- Included 3,3V ↔ 5V Logic Converter for Display
- Own solution - commercial solution:
  - Available sensors
  - Execute different actions regularly
- Project Goals:
  - Well functioning protype
  - All wanted sensors/functions included and working
  - Easily Scalable

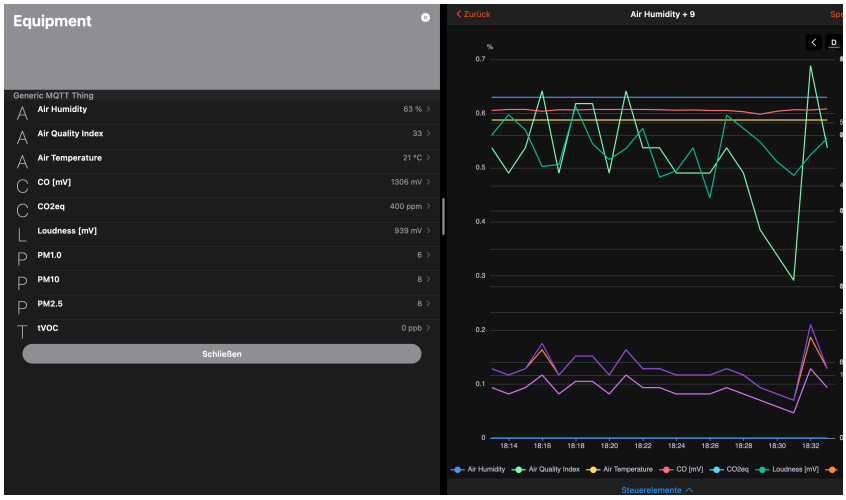


Figure 4: Measurement results with Graphs from OpenHAB

References:

- Text: own work
- Figure 1: Adapted from “BSMS New Projects Proposals 2023”
- Figure 2-4: own images

Online Lens Position Monitoring and Measurement Control for Automated Intraocular Lens Testing

Anna Hofbauer, Stefan Robien & Jonas Weber

1 INTRODUCTION

- The goal of the eye model is to measure and verify the optical characteristics of IOLs
- Since the lenses are always getting more precise the eye model must be updated to match the new standards
- Goals are:
  - Implementing new Sensors to verify the position of the lens and measure unwanted movements
  - Record Event Data of unwanted Movements
  - Implementing new Motor Drivers to improve positional accuracy
  - Improving the control circuitry (Arduino as internal Controller and Data Hub)

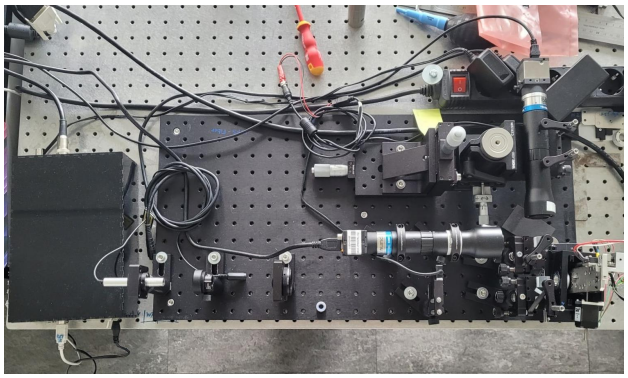


Figure 1: Current Eye Model

2 METHODS

The original plan was to use sensors for both tilt and shift but due to problems, we changed it to measure the shift via camera.

The tilt of the lens on the other hand is supposed to be measured via sensor. After not being able to find the right sensors for the specific requirements we chose an IR-Sensor for measurement.

For measuring the shift of the lens, we used the camera, that was already installed in the system. We created a MATLAB-Code to find the ellipse of the lens. The shift of the lens gets calculated through the distance of the inner and the outer circle of the lens.

Due to mayor changes in the project the final goal was adapted multiple times. Main point here was the availability of sensors and the available budget.

3 RESULTS

- We implemented an Arduino Uno as a controller for the whole hardware.
- The fundamental Matlab code remains unchanged. just the Communication-function was adapted to output the required json packet
- implementation that the Arduino sends out a status-packet if movement is finished or an error occurred.
- To join all components together an enclosure was 3D-printed to store all parts and enable sufficient cable Management
- The Tic-Motor-controllers were fixed to a PCB that has connectors for the connection pins as well as the required connections for 2 stepper-motors
- power supply to the Motor-Controllers is enabled via a barrel jack. The Arduino gets power from one of the Tics.

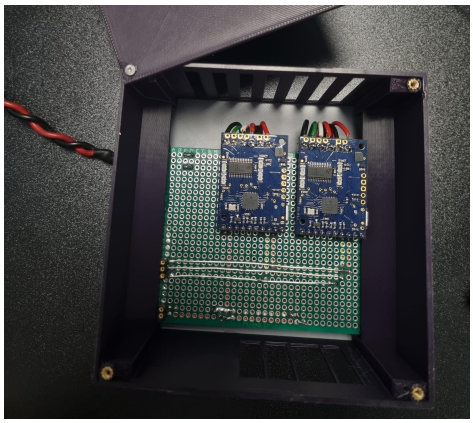


Figure 2: 3D-printed control box

4 DISCUSSION

Parts that didn't work that well:

- working on the imaging processing was good practice but unfortunately wasn`t needed for the project and the time spend could have been allocated differently

Parts that did work well:

- The design and revision of the case worked well and printing it with our 3D-printers worked flawlessly.

Future prospects:

- implementing the system into the given Matlab-Code
- fusing it into the eyemodel and connecting it with the project of the Master Study Group

→ a usable system to check if a IOL has shifted after the surgery

TRAXLER, L. *Testing the optical quality of intraocular lenses regarding postoperative tilt and decentration,* 2018.

MME contributes to the Patient Journey!

On their individual journey through healthcare ecosystems, patients experience many different encounters with people, institutions, devices, software, and other stakeholders (Figure 1). Our study program Medical Engineering & eHealth (MME) contributes technology that improves these encounters in the best possible way.

The core link between the health journey ecosystem and the MME study program is the course "Project Related Teamwork" (PRT) in the first and second semesters. This is where the pressing issues of the outside world meet students, lecturers, and our partner institutions to spark ideas.

Each year MME collects healthcare pain points from our partner institutions that they wish to address in the short term. These call for innovation and technological solutions of overarching clinical significance that MME can deliver. PRT then provides the platform to reach specific goals in structured one-year projects. Successfully problem-solving requires knowledge from many areas. The many MME courses add knowledge from their specific perspective.

In this way, the MME students experience a wide overview of the patient journey while diving deep into their specific field of interest. From PRT onward this continues in the third and fourth semester with the Master Thesis Project and culminates in the Master Thesis. For many students, this early engagement with real-world problems and healthcare institutions evolves into rewarding careers.

Figure 1: Schematic depiction of the complex healthcare ecosystem with many shareholders

Contributions
Medical Engineering & eHealth
Master Study Program
Group Papers

Mock Circulatory Loop Development for Hemodynamic Performance Evaluation of a Micro-Axial Pump for Acute Mechanical Circulatory Support

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***Abstract*— The Impella 5.5® (Abiomed, Inc., Denver, MA, USA) is currently considered the state of the art in the field of micro-axial blood pumps. Although it is being implanted in patients for short-term support, for example in cases such as cardiogenic shock, comprehensive studies on its hemodynamic characteristics are still lacking. To address this gap, a mock circulatory loop (MCL) was developed, with integrated biological valves and a glycerol-based blood-mimicking solution. The Impella 5.5® HQ curves showed increased flow rates at higher support levels. Signal comparisons indicated very similar results between Impella and aortic pressure measurements.**

I. Introduction

Cardiogenic shock, primarily caused by acute myocardial infarction, resulting in circulatory failure due to low cardiac output leading to tissue hypoxia.[1] The Impella 5.5® is used as a short-term bridging device, supporting the left ventricle (LV) and stabilizing the patient until recovery or further treatment such as durable left ventricular assist device (LVAD) implantation or heart transplantation, particularly in cases of cardiogenic shock.[2], [3] Although it is being implanted for short-term support, comprehensive studies on its hemodynamics are still lacking. While there are advances in computational modeling it still requires validation through MCL experiments to ensure accurate predictions of cardiovascular device behavior.[4] The goal of this project was to develop an MCL for evaluating the Impella 5.5® under various hemodynamic conditions by simulating the left human systemic circulation to address the previously stated research gap in fluid dynamics.

II. Materials & Methods

A. Mock circulatory loop assembly

The LV is simulated using a silicone model, while the mitral and aortic valves are initially replicated using porcine-derived valves, with one placed in the mitral position.[5] Due to rupture, the latter was later replaced with a mechanical valve. To conduct measurements, several sensors were placed in different sections of the MCL, as shown by the numbered sections in Figure 1. Pressure transducers are positioned in sections 1, 2, 3, and 4, while a flow sensor is located on the tube before section 5. The Impella 5.5 was inserted through the aortic chamber into the LV.

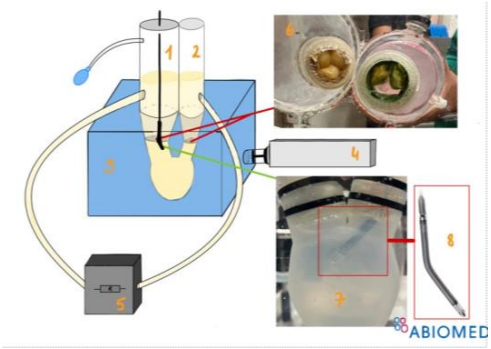

Figure 1: Illustration of the Mock circulatory loop (MCL). 1) Leakproof aortic chamber where the Impella 5.5 is inserted. 2) Open reservoir representing the left atrium. 3) Waterfilled box which houses the left ventricle (LV) where the Impella 5.5 is located. 4) ViVitro SuperPump (ViVitro Labs inc., British Columbia, Canada)[6] 5) Adjustable resistor representing peripheral resistance. 6) Biological aortic valves, right valve being in mitral position. 7) Impella pump inside the left ventricle (LV). 8) Illustration of the Impella 5.5.[2] The blue balloon pump is used to adjust the compliance inside the aortic chamber by pumping air in (decrease of compliance) or letting air out (increasing compliance).

The MCL was assembled to be airtight and leakproof using silicone gaskets and straps. Subsequently, the pressure sensors were calibrated against atmospheric pressure, and the flowmeter was calibrated using a known reference flow.

During the diastolic phase, the LV drew glycerol (used as a blood-mimicking solution) from the left atrium. The ViVitro piston pump generated pressure inside a water-filled box, causing the LV to collapse (simulating contraction) and pump the blood-mimicking glycerol solution into the aortic chamber and from there to the periphery.

B. HQ-Curves methods

The Impella 5.5® was tested at various P-Levels using the MCL to set head pressures, starting high and gradually decreasing. Pressure and flow rates were recorded across each support level to generate head pressure-Flow (HQ) curves. For each head pressure setting, aortic pressure (AoP) and left ventricular pressures (LVP) were recorded from both the Impella (placement signal (PS)) and the MCL, allowing for direct comparison of the signals.

C. Signal comparison methods

Bland-Altman plots were generated to compare the minimum, maximum, mean values of AoP and LVP between MCL and Impella measurements, highlighting their agreement, relationships, and potential discrepancies. Conversely, scatter plots depicted all AoP and LVP values from the MCL versus Impella measurements, offering a comprehensive view of their relationship. Pulse pressure analysis assessed the difference between the minimum (diastolic) and maximum (systolic) AoP in each cardiac cycle.

III. Results

A. Conducted Measeurments

Throughout P6 to P9, 40 measurements were conducted. Each measurement was recorded approximately one minute. The measurements are reflected as datapoints in the HQ-Curve, depicted in Figure 4. Data collection resulted in 9 data points each for P6 and P7, 11 data points for P8, and 12 data points for P9.

B. Mock circulatory loop assembly results

The MCL simulated a physiological condition, as shown in Figure 2 and a pathological condition, as depicted in Figure 3.

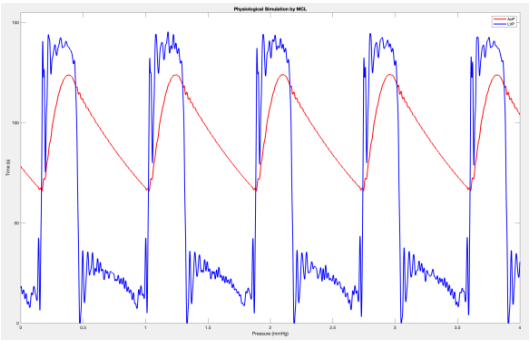

Figure 2: Simulation of a healthy heart. blue signal is left ventricular pressures (LVP) between 145 and 3mmHg, red signal is aortic pressure (AoP) being between 120 and 75 mmHg.

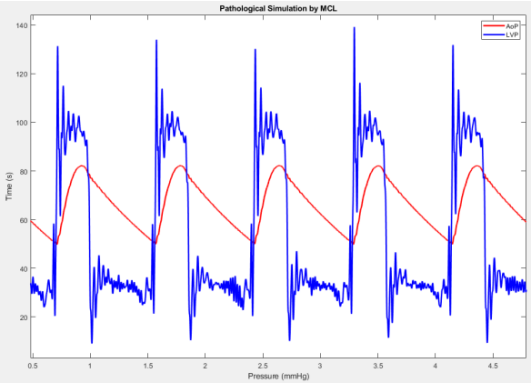

Figure 3: Pathological simulation by MCL, with pressure (mmHg) over time (s). The blue line represents Aortic Pressure (AoP) with high-frequency spikes, and the red line represents Left Ventricular Pressure (LVP) with smoother cycles.

C. HQ-Curves result

The HQ-Curves depicted in the Figure 4 illustrate the performance characteristics of the Impella 5.5® device across different pump support levels (P6, P7, P8, and P9). The x-axis represents the mean flow rate (L/min), while the y-axis shows the mean head pressure (mmHg). The curves demonstrate that higher pump support levels, such as P9, achieve greater flow rates and maintain higher head pressures compared to lower settings like P6.

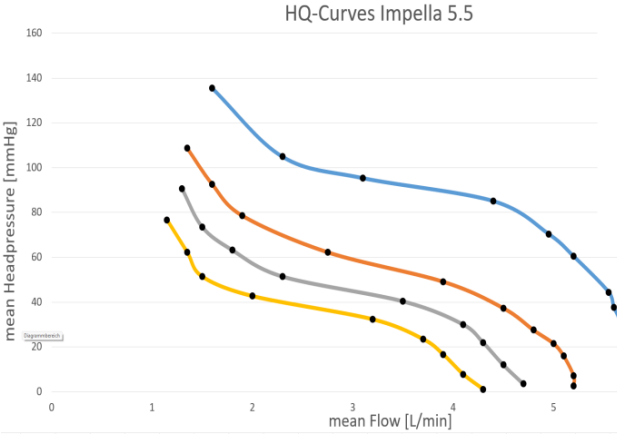

Figure 4: HQ-Curves across four P-Levels (P6 to P9). Black dots indicate recorded data points.

D. Signal comparison results

Data points were taken for P7, specifically the highest, the middle and the lowest point of the P7 HQ-curve. Bland-Altman plots illustrate the level of agreement and any biases between MCL and Impella measurements of AoP and LVP as depicted in Figure 5 and 6.

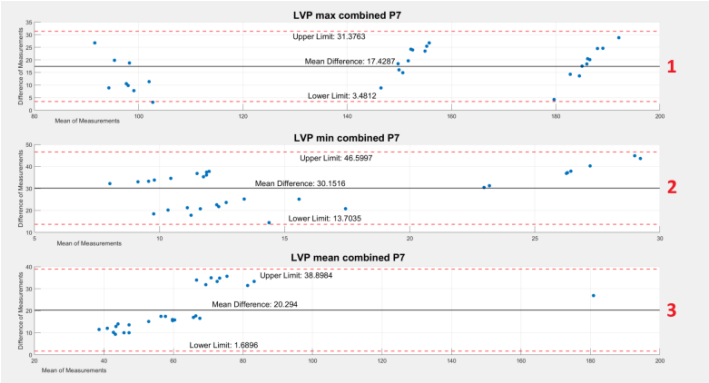

Figure 5: Bland Altman plot 1 and 2 show the difference between max and min pressure of the left ventricular pressures (LVP) for 10 cardiac cycles. Plot 3 illustrates the mean difference.

The Bland-Altman analysis for LVP mean corrected P7 measurements resulted in a mean bias of 2.7 with limits of agreement from -10.4 to 15.8 in the first plot. The second plot showed a mean bias of 10.7 with limits of agreement between -5.1 and 26.5. The third plot presented a mean bias of 8.5 with limits of agreement from -3.9 to 20.9.

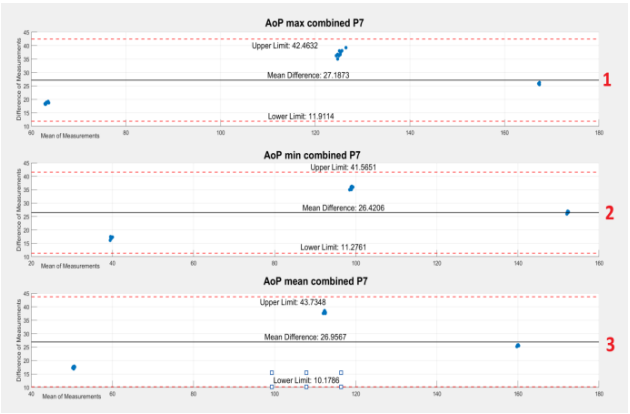

Figure 6: Bland Altman plot 1 and 2 show the difference between max and min pressure of the aortic pressure (AoP) for 10 cardiac cycles. Plot 3 illustrates the mean difference.

The Bland-Altman analysis for AoP combined P7 measurements resulted in a mean bias of 27.2 with limits of agreement from 11.9 to 42.5 in the first plot. The second plot showed a mean bias of 26.4 with limits of agreement between 11.2 and 41.6. The third plot presented a mean bias of 27.0 with limits of agreement from 10.2 to 43.7.

The scatter plot in Figure 7 and 8 illustrates the comparison of AoP measurements from the Impella and the MCL system, as well as the comparison of LVP measurements from the Impella and the MCL system. For AoP, the

correlation coefficient is 0.98 at the highest point, and 0.99 at both the middle and lowest points, indicating a very strong correlation. Similarly, for LVP, the correlation coefficients also demonstrate with 0.88 and 0.96 a strong positive correlation across all points.

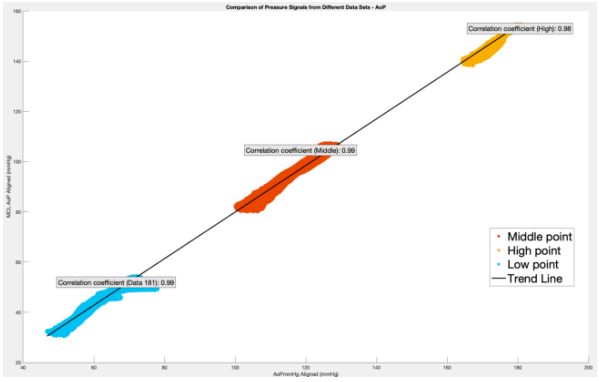

Figure 7: Scatter plot for the aortic pressure (AoP) of Impella and Mock circulatory loop (MCL)

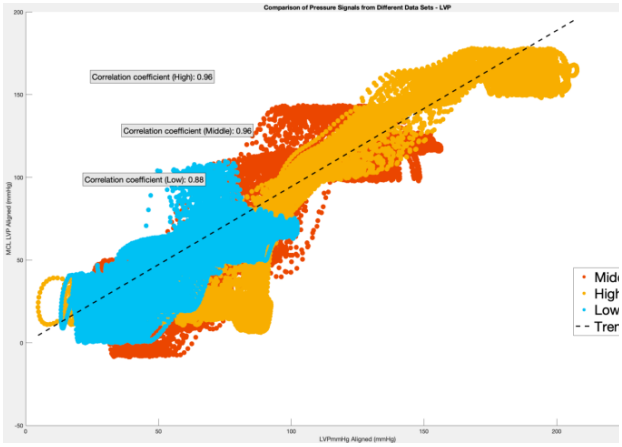

Figure 8: Scatter plot for the left ventricular pressures (LVP) of Impella and Mock circulatory loop (MCL)

Comparing the Impella PS and the measured AoP signals shows that their respective pulse pressures are closely aligned. This is illustrated by the Bland-Altman plot shown in Figure 9.

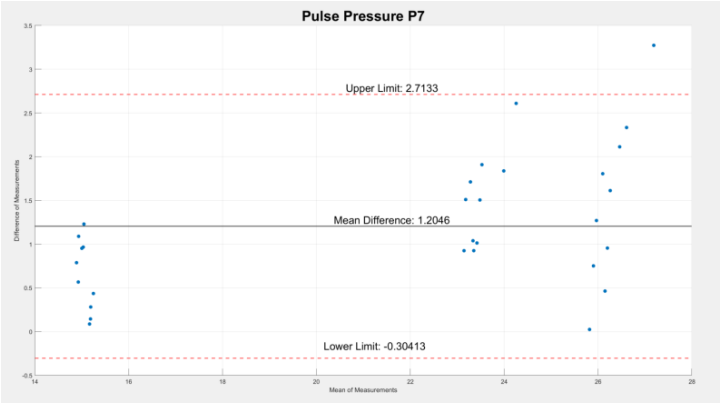

Figure 9: Pulse pressure difference between Impella and Mock circulatory loop (MCL) aortic pressure (AoP)

IV. Discussion

An MCL capable of simulating physiological and pathological conditions with the possibility for incorporating the Impella was successfully assmebled.

The HQ-Curve of the Impella was analyzed, and it was found to closely matcSh HQ-Curves from other sources, particularly featuring a flat plateau towards the middle section of the curves.[7] Differences in the amounts of data points record ewer due to the shorter range of the curves of lower P-Levels. The plateau indicates that a versatile flow range can be maintained by the system with minimal head pressure variations, ensuring stable hemodynamic support.
Inaccuracies were observed in the flow estimator of the Impella, with deviations between pump and MCL readings during full support. Further research is needed to objectively define and enhance flow estimator accuracy.

Differences within the Bland-Altman plots of AoP and LVP were within the limits of agreement. These differences primarily arise from the calibration disparity, as the MCL sensors were calibrated for the glycerol solution used, whereas the Impella 5.5® is calibrated for blood. Additionally, a rupture within the biological aortic valve in mitral position led to a switch to a mechanical valve during the project. This change introduced a water hammer effect in the LVP signal, indicated by strong spikes in the

signals, which also contributed to the observed differences.

Strong positive correlations were found between MCL and Impella measurements, with correlation coefficients as high as 0.99 for both AoP and LVP. This suggests reliable agreement between the two methods. However, at the lowest pressure level, the correlation drops to 0.88, indicating more variability in LVP readings at lower pressures, likely resulting due to calibration disparity and high noise caused by the water hammer effect.

Minor pulse pressure differences were observed between the AoP of the Impella and the MCL. While the pulse pressures appear similar, the Impella reads overall higher values, likely due to a different gain value used for calibration, which is more fitting for blood.

To conclude, the project successfully completed the development and commissioning of a leakproof and operational MCL. The system can simulate healthy physiological and heart failure conditions. Also, the airtight integration of the Impella 5.5, allowing for adjustable positioning within the targeted area was achieved.
The HQ-Curve analysis showed a close match to other sources, featuring a plateau for stable flow and minimal head pressure variation.
Differences in Bland-Altman plots for AoP and LVP were within the limits of agreement. Strong correlations (up to 0.99) were found between MCL and Impella measurements.

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Online Image Processing and Measurement Control for Automated Intraocular Lens Testing

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***Abstract*— Cataract, characterized by the clouding of the eye's lens, disrupts vision and can be effectively treated through surgery, in which the lens of the eye is replaced by an artificial intraocular lens (IOL). However, inherent optical aberrations in this lens can lead to suboptimal image quality caused by light dispersion, affecting image focus. To assess aberrations in IOLs, a dedicated device called Eye Model has been developed at UAS Technikum Wien, using conventional methods for data retrieval such as Thorlabs Hartmann-Shack Wavefront Sensor (WFS) software, Point Grey Camera Visualization software, and MATLAB for data analysis. This setup makes it difficult for users to work with these different platforms and is likely to cause synchronization errors. A new MATLAB GUI (Graphical User Interface) was developed to generate a single, simple, and easy-to-use platform that avoids dependency and synchronization with other software from different vendors. This allows all communication with the sensor and the camera to take place within a single platform that directly and automatically connects MATLAB with the WFS and the camera via code, acquiring information with minimal latencies and generating organized data analysis simultaneously. The developed GUI also automates the process of centering the IOL on the eye model, previously done manually and without software assistance. Finally, new artificial retinal models were manufactured, ensuring that the wavefront data processed by the sensor is of better quality. This innovation streamlines the evaluation process, enhancing the accuracy and convenience of aberration assessment in artificial lenses. Nevertheless, for full automation, further developments are required, such as a new Tilt&Shift unit, which allows for centering the lens based on the information obtained by the developed GUI.**

I. INTRODUCTION

The human eye comprises three layers. The outermost layer consists of the cornea and sclera, the middle layer contains the main blood supply to the eye and consists of the choroid, ciliary body, and iris from back to front. The innermost layer is the retina, which lies above the choroid and receives most of its nutrition from blood vessels within the choroid (Figure 01). The cavity formed by this three-layer covering contains the crystalline lens, positioned behind the iris. The crystalline lens is a nearly transparent biconvex structure whose sole function is to focus light rays onto the retina.

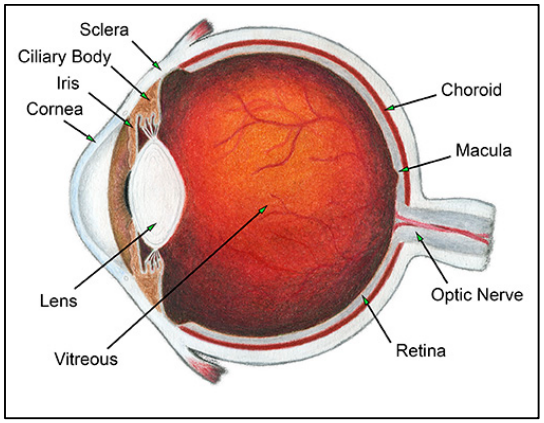

Figure 01.- Anatomy of the Human Eye.[1]

As individuals age, the crystalline lens may undergo cloudiness, leading to a condition known

as cataracts. This condition can be rectified through surgery, which involves the removal of the cloudy lens and its replacement with an artificial Intraocular Lens (IOL) to restore correct vision to the patient (Figure 02). Because the artificial IOL contains inherent aberrations in its construction (Spherical Aberration, Chromatic Aberration, Astigmatism, Coma, Higher-order Aberrations), the UAS Technikum Wien has developed an eye model, modelling the qualities of the human eye as accurately as possible, in order to analyse these aberrations under standardized methods, using as inputs the signal obtained with a Hartmann-Shack Wavefront Sensor (WFS), a device that measures the deformations of a light wavefront to identify and quantify these aberrations. Ideally, the aberrations analysed should be minimal, emulating the characteristics of the human eye.

Figure 02.- Different types of IOLs. [2]

When light enters the human eye, four reflections typically occur in the ocular structure, called Purkinje images: P1, also called corneal reflection or glint, is reflected from the outer surface of the cornea, P2 is reflected from the inner surface of the cornea and P3 is reflected from the outer surface of the lens, P4 is reflected from the inner surface of the lens and is also called the posterior lens reflection, and is the only one that is inverted. Currently, Purkinje images are widely used for the detection of Glaucoma, eye tracking in surgeries and centering of the IOL in lens replacement procedures (Figure 03).

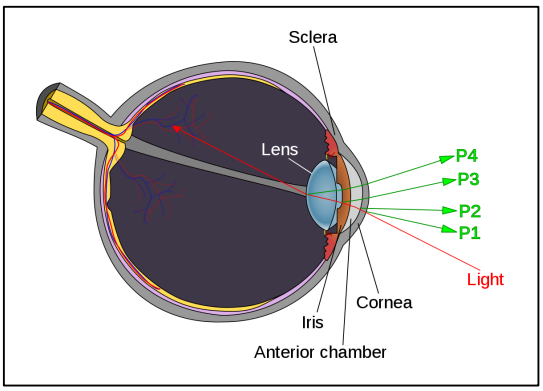

Figure 03.- Diagram depicting the four Purkinje images.

II. Materials & Methods

A. Hardware

The hardware for the project is a patented Eye Model (EM) by FH-Prof. Dr. Andreas Drauschke, which was used in previous research based on characterization techniques [3], the complete control of the hardware is based on MATLAB and utilizes each vendor's proprietary software to retrieve data from the WFS and Visualization Camera. The EM layout setup implemented in the Dvorak Master Thesis [4] currently works with the following components:

- Laser diode (532nm wavelength)
- Galilean Beam expander
- Iris diaphragm and Beam splitters
- Telecentric lens for imaging
- Imaging camera for imaging
- Telecentric lens (wavefront detection)
- Hartmann-Shack wavefront sensor
- Microlens array

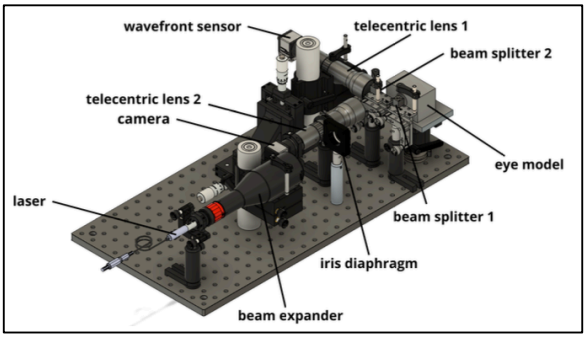

Figure 04: Isometric View of current layout.[3]

The essential element for data analysis is the Thorlabs WFS150-7AR wavefront sensor, which provides Real-Time Irradiance and Phase Measurements thanks to its array of microlenses and high-resolution CCD. To work with this CCD, an Edmund Optics Inc. #67-731 Telecentric Lense is used, with a magnification power of 0.75x.

As the source of illumination for wavefront analysis, a Thorlabs CPS532 532nm laser was used, with 4.5 mW of power this laser diode falls under the 3R laser safety class.

For lens centring in the EM, a Point Grey FL3-U3 monochromatic camera is used, in addition to an Edmund Optics Inc. telecentric lens #63-074, with magnification and focal aperture calculated specifically to work with the size of the beam splitter and camera used in the layout, this assembly setup will capture the images for Purkinje analysis. The main idea is that the camera only captures the red light (630nm) coming from the LED ring, so that the lens centring can be analysed separately with a different light source, leaving the green light from the laser for the WFS analysis and the red light from the LED ring for the analysis of the IOL centring in the eye model, for this purposes, filters are added to the corresponding telecentric lens.

In addition, after considerable research and testing of various materials and finishes, two new models of artificial retina were designed with the aim of reflecting light with scatter similar to the human retina and ensuring it could be homogeneous for the focal points of the WFS array of microlenses. For this purpose, several 3mm thick and 13mm diameter PMMA units were laser cut and tested with various combinations of paints, colors, and textures. Each unit was then tested individually on the eye model, and their scatter and reflection capacity were evaluated. The results were organized to choose the models that best met the objective of delivering homogeneous information without artifacts to the WFS.

B. Software

MATLAB's GUI (Graphical User Interface) provides a set of tools and features that allow the creation of interactive graphical interfaces for MATLAB programs. It is necessary to build applications or tools that have a visual component, enabling users to interact with our code in a more user-friendly and intuitive way. MATLAB's AppDesigner was used in the project specifically to generate the GUI interface that will host the connection code to the WFS. To obtain images of the IOL installed in the Model Eye and thus automate centration, the camera support package code available in MATLAB was also used, allowing communication with the camera directly from MATLAB.

Nevertheless, although the goal is to make the entire system independent of any proprietary software, the software must still be installed on the computer to be used because communication is done through the libraries of the installation packages of each one.

III. Results

A. Wavefront Analysis

The main result obtained is a new GUI that merges all the requirements of the Eye Model operation, integrating into a single software the MATLAB codes that were previously handled separately by manufacturer's proprietary software, thereby preventing some previous erratic behavior due to synchronization issues. In addition, the new GUI was programmed to improve usability, requiring as few clicks as possible to run a task while maintaining the same functionalities as the previous communication system and improving processing time by reducing the connection time to just 2 seconds (compared to up to 20 seconds in the previous system). It displays the Optical Transfer Function (OTF), the corresponding Modulation Transfer Function (MTF), and the Region of Interest (ROI) analysis for each interaction with the WFS. The wavefront analysis, with the information obtained in real time from the WFS, is shown in Figure 05.

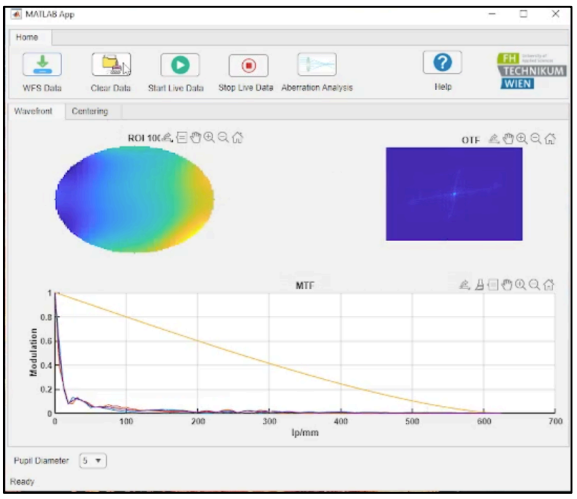

Figure 05: Screenshot of the new GUI programmed, Wavefront analysis Tab.

The direct connection to the wavefront sensor (WFS) was successfully established. The data processing uses the same code that was employed in the previous software interactions; the MTF and WF analysis functions remain unchanged. However, now the connection to the sensor is made directly through code with MATLAB, rather than using the manufacturer's software. Previously, due to the limitation of working with two different software packages, a script was used for MATLAB to open the Thorlabs software, save the WFS Zernike coefficients information in a .csv file, and then MATLAB would access this stored .csv file to perform the analysis. This limitation was fully addressed with the new GUI, which directly extracts the information from the WFS in MATLAB, avoiding errors in synchronization.

B. IOL Centering

To obtain a correct measurement of the Zernike coefficients in the WFS, the IOL must be correctly centered on the eye model. Previously, centering was done manually by looking at the image from the high-resolution camera and estimating how much the IOL should move. In the new GUI, it is possible to perform centering using Purkinje images through an image analysis, filtering, and structure recognition algorithm. This algorithm is based on previous research by Iribarren [5], which focuses on detecting the 4th Purkinje image, as it is best visualized with the existing setup. The connection takes just 2-3 seconds: first, an image is obtained without a lens; subsequently, another image is acquired with the IOL in position. After user verification, the centering analysis is carried out, obtaining the tilt and shift values in millimeters to advise on the movement of the stepper motors. A screenshot of the Centering tab is shown in Figure 06.

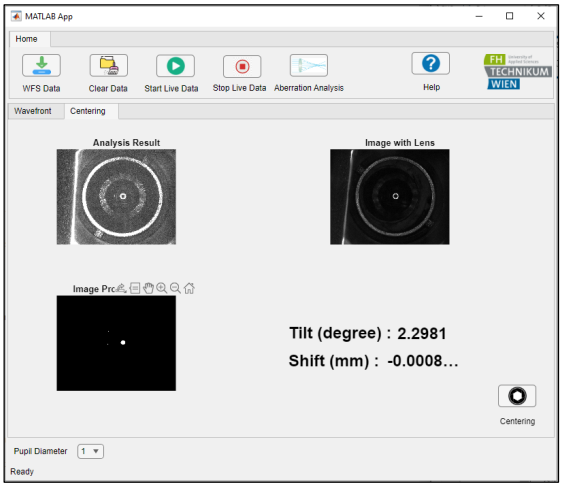

Figure 06. Screenshot of the IOL Centering feature.

C. Artificial Retina

The WFS has an array of microlenses that sense the incident light. For each of these microlenses to obtain information correctly, the light must be homogeneous throughout the array. Since we are working with double-pass measurements, the light source must pass through the lens, be diffused, and reflected off the retina to return to the beam splitter and be received by the WFS. After testing various materials that could imitate the characteristics of the human retina and possess the necessary properties for WFS sensing, two of them achieved maximum efficacy and homogeneity of incident light in the WFS. Some of the models tested are shown in Figure 07.

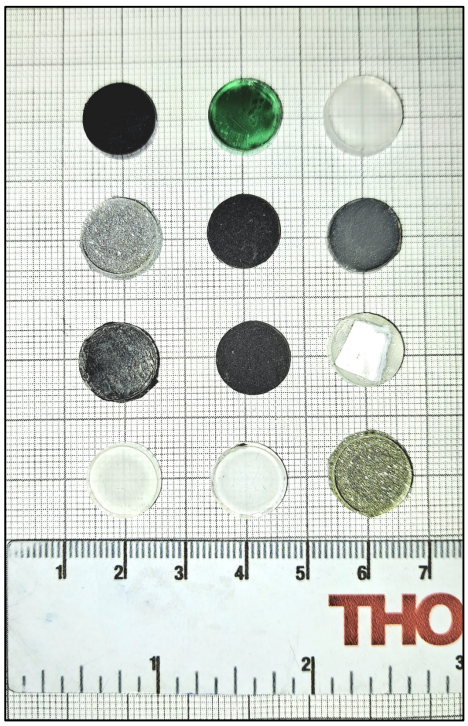

Figure 07. Artificial retina models tested on the eye model, tests were performed with different coatings such as: acrylic paint of different colors, reflective surfaces, frosted surface, transparent and laser engraved surfaces. all based on the same material, transparent PMMA, 3mm thick and 13mm in diameter.

The best results were obtained with black acrylic paint coating and frosted surface with black acrylic paint in the background. These two models achieved improved homogeneity compared to the previously used model. The resulting incoming light in the WFS and the comparison with the previous retina model are shown in Figure 08. They can be used interchangeably by researchers as they provide more focal points to the WFS microlenses

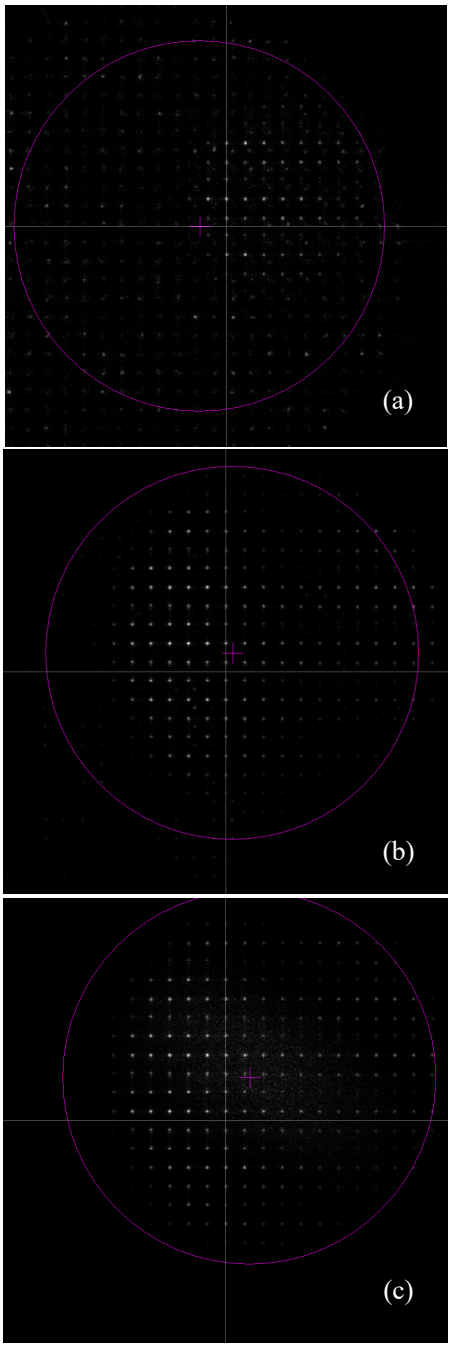

Figure 08. Incident Light in the WFS. (a) Original retina model. (b) New model with Acrylic Paint coating. (c) New model with frosted surface and black paint in the back side. The light is focused on a large amount of the microlenses of the array (white dots within the magenta circumference) and artifacts were highly reduced. Both new models present homogeneous light dispersion and reduced artifacts compared with the original model.

IV. Discussion

The project successfully achieved its goals by focusing on system stability and software usability for retrieving data from the WFS and high-resolution camera. A new GUI was developed using AppDesigner, enhancing result visualization and facilitating efficient lens centering.

Previously, the system relied on proprietary sensor software and manual user input, which was suboptimal. The updated version integrates sensor data retrieval within MATLAB, reducing user dependency and errors while consolidating all functionalities of the Eye Model into a single platform.

The new interface simplifies usage across different computers, eliminating the need to operate multiple programs. This automation enhances wavefront measurement and lens centering accuracy, reducing manual inputs. Additionally, the newly developed artificial retina models ensure an optimal distribution of light as an input signal to the WFS, thus avoiding unwanted artifacts.

Challenges remain, such as mitigating unwanted reflections of laser light affecting camera image quality. A proposed solution involves updating the current filter on the telecentric lens to better match the laser wavelength (using a 532 nm notch filter) or allowing only the wavelength corresponding to the red light used, essential for Purkinje centering analysis (using a 600-650 nm bandpass filter).

Future steps include fully automating motor movements based on numerical measurements obtained from the algorithm, which requires the development of a new Tilt & Shift unit that adjusts motors accordingly. This project is currently in development by Bachelor's students.

In summary, the project successfully achieved all initial objectives by automating data extraction and enhancing the user interface. While further improvements are necessary, communication with the devices has become more reliable, now featuring a direct connection via code. The system is user-friendly, requiring only a few clicks and 2 to 3 seconds to display the data and corresponding analysis on screen, and it no longer requires interaction with additional software.

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Interactive 3D WebGL cardiac application with focus on atrial fibrillation animation

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***Abstract*— Use of web-based visualizations with WebGL is increasingly trending in various scientific disciplines. A realistic 3D model with animations was produced, which can be used for understanding the anatomy, physiology and volumetric changes during a heart cycle. Making it user-interactive by allowing tools such as model rotation or adjusting heart rate, makes it a well-suited educational tool. The application targets medical students and individuals interested in cardiovascular health, focusing on the anatomy and physiology of the human heart in a visually appealing way.**

A 3D model of the human heart, downloaded from a public platform, was used. Adjustment and improvement of the model was performed in the 3D software Blender. Animations were coded in Three.js, powered by a backend server for calculations which communicates with the frontend using a RESTful API. Animations representing both physiological heart activity and atrial fibrillation activity are kept in a Redis database assessed by the backend server.
The model is displayed on a webpage using WebGL 3D rendering. The UI components required for input handling were developed in React.js.

The application displays a colored, animated model of the human heart in physiological sinus rhythm. Users can choose between changing animation to atrial fibrillation or selecting different cuts of the model to display animated inner structures or toggle labeling of the major structures. Heart rate can be interactively changed.

Our WebGL visualization of the human heart has proven to be a capable educational tool. Some challenges are still present, because the application currently displays a hollow interior when sliced by the user, which we are addressing by pre-coloring interstitial spaces in Blender. Additionally, the parallel processes of coloring and rigging have created challenges, necessitating the redo of texturing on the weight-painted model. While interactive features like orbiting and heart rate adjustments enhance user experience, further work is needed to display other pathologies and improve the accuracy of anatomical education, possibly with stereoscopic 3D models.
Keywords: cardiac simulation, web development, WebGL, 3D rendering
Academic Level: Master, MME,
Course: PRT

I. INTRODUCTION

Use of web-based visualizations using WebGL has continually increasing trend in various scientific disciplines (8). Simulation of complex models, such as an anatomically accurate 3D heart model, is a useful educational tool to display and study physiology, movement mechanisms and even anatomy. (9)

There have already been some major software developments in the area of numerical simulations. However, these can require a lot of technical skills from their users and might even require knowledge of programming or higher level mathematic for an effective use, making them unfit for the education of

people who are more knowledgeable in the medical field, but perhaps not in technical endeavors. (10)

We present an application displaying a 3D human heart model on a webpage, rendered using WebGL. The possibility of user interaction with anatomical visualizations and the accessibility via web and mobile clients makes the application well suited as an educational tool. [1]

The application presents a model with labelled and described anatomical structures, together with an animation of the cardiac cycle. Users can interact with the model in various ways, including orbital movement, modification of different animation parameters and cutting the model to view the inside.

The code itself was written in a way that makes it easily extensible, possibly even allowing an easy alternation to include more organs or other structures in the future. This is being done while maintaining a clean and simple to read codebase.

II. Materials & Methods

The 3D heart model was downloaded from a public platform, focused on distribution of open-source digital designs for 3D printing. [4] The manipulation of the model was performed in the 3D software Blender, such as texturing, rigging and weight painting.

During rigging, armature bones were placed inside both the major structures of the heart and the smaller internal structures, enabling dynamic movement later on in the application. Bones were named according to their location inside of the model.

To control the movement of the different structures of the heart, the model was manually weight painted in its entirety, in order to ensure each of the bones would only cause the correct parts of the mesh to move.

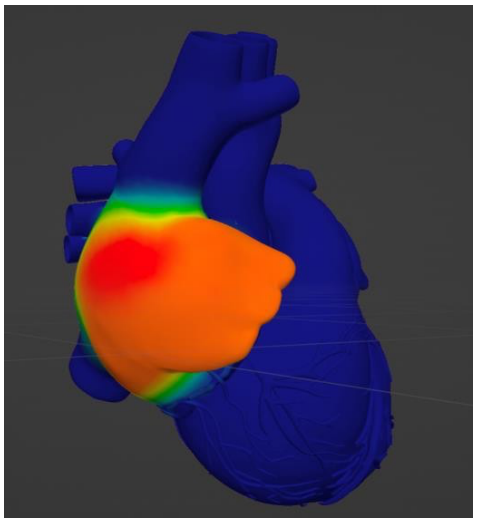

Figure 1 Weight painting process of the right atrium, shown in the Blender viewport.

Using the rigged and weight painted model, the animations were coded in Three.js. For this, the "useFrame()" hook of R3F was used to execute scale calculations on each frame update. At the beginning of every frame, a clock value is checked, which represents the different phases of the heart cycle. Depending on the clock result, the bones placed inside the model are scaled by a set amount. Once the animation runs through, the clock is reset so that the animation can start anew.

The keyframes of the animation and the amount of movement that needs to be performed on each of the bones are stored on a python backend server and served to the frontend application using a RESTful API.

The animation timing is based on percentage values. Each phase in the cycle has a duration in percent of the whole, allowing for dynamic changes of the heart rate displayed. By default, the program uses a heart rate of 80 bpm. [5]

In order to comply with the clock-based animation system the frontend requires, the percentages used in the cycle definitions are converted to second values on the backend server, given a particular input heart rate.

The model was textured manually in blender, using the UV mapping tool for mapping the texture representation directly to the mesh face.

The controls the application provides were implemented using OrbitControls, a native Three.js approach to giving the user control over the scene they are viewing.

When the heart rate is changed by the user, an event is raised which causes the application to reload animation data from the backend with the new and updated heart rate. The server returns the updated animation cycle definitions and the pumping speed changes.

The different animations for physiological and atrial fibrillation are kept in a small Redis in-memory database, which is periodically written to the disk and accessed by our backend server. This allows for on-the-fly modifications of important parameters and removes computing load from the frontend.

Predefined and dynamically applied slicing planes allow users to view the heart from different angles from the inside.

Labelling of major structures of the heart was accomplished by creating a spherical component with a click handler. When one of these markers is clicked, it shows a label with the name and function of the structure. The marker also changes its color to indicate that this structure label is currently open.

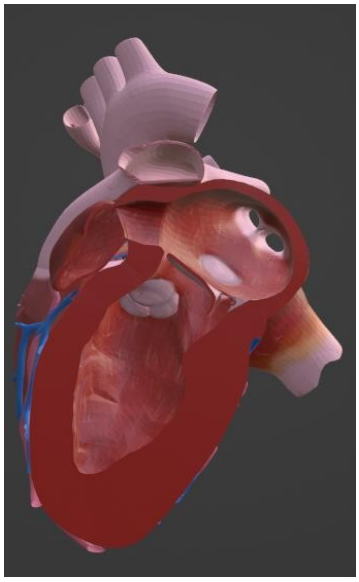

Figure 3 Heart model with slice through right and left atrium

III. RESULTS

The current state of the application presents the user with a colored, animated model of the human heart in a pumping motion. By default, the pumping shows the motions of a physiological sinus rhythm. The user can adjust the heart rate according to their liking; however, the accuracy and smoothness of the animation was only tested in a range of 30 – 200 bpm.

Apart from modifying the heart rate, the application also allows for its users to change the behavior of the animations. Currently, it can be switched from a physiological pumping motion to visualizing atrial fibrillation and back.

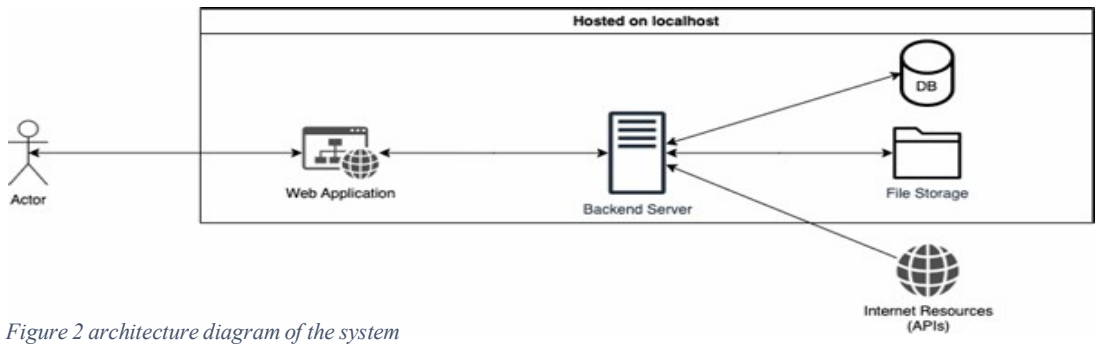

Figure 2 architecture diagram of the system

The selection causes a reload of the animation data fetched from the backend, causing an immediate update once the data has arrived.

Furthermore, users can also open a “slicing menu” where they can select one of three different planes, along the model can be cut in half. That way the internal structures of the model can be viewed, without losing animations.

The coloring of the model shows a realistic texture for the atria, ventricles and major blood vessels. Smaller blood vessels were colored in a way that makes them more easily distinguishable, sacrificing some realism.

The code was written in an extensible way, using the JSON format for the definition of the animations and their cycles. The same format was also used for defining label text and content. This enables the application to load and animate any combination of models and corresponding JSON documents, allowing for simple adaptation in the future.

By adding orbital controls, the model can be navigated using a mouse pointer, making it possible to freely explore different angles of the model.

The applications further present its users with a button that toggles labelling on and off. When toggled on, white spheres appear above all of the major structures of the heart. When they are clicked, they present the user with the name of the structure, and some information about it.

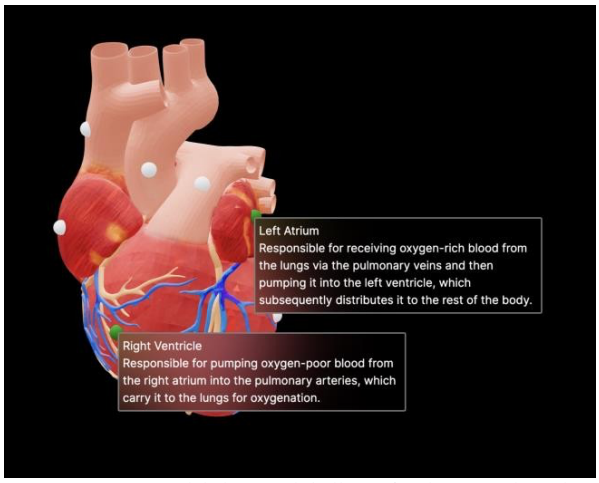

Figure 4: Heart model showing labelling of right ventricle and left atrium opened in application.

IV. DISCUSSION

We have shown the capabilities of our WebGL visualization using a human heart model.

A remaining limitation of the application is the fact that when the user selects a plane for slicing, the model is hollow where it should show myocardium. Because we failed in attempting to dynamically fill this gap, we decided on preparing models, where the interstitial space was pre-colored in blender. This allowed us to still show the insides of the heart, but it is limiting the flexibility, and the freedom users have when interacting with our application.

Another problem we are facing is the fact that coloring and rigging were done in parallel, now causing trouble when trying to merge the progress of the two. Because we are unable to simply combine the work that has been done, this challenges us to redo the texturing work on the now correctly weight-painted model.

Adding interactive capabilities, such as orbiting around the model, the ability to change heart rate or click on and see major heart structures, created a more user-friendly learning tool. However, the project still requires some work to allow users to show other pathologies than atrial fibrillation.

The use of monoscopic 3D displayed models for anatomy education is considered error prone by some

literature. [2], [3] A possibly more effective strategy would involve incorporating stereoscopic 3D models. However, this would result in needing specific technology to view the application. [3], [5]

The previously mentioned modularity of the code makes this project easily extensible, even past its run time, possibly even allowing the animation of different organs or other structures of the human body, by merely adapting the model and the JSON data controlling animations.

Another point where the project needs more input is the 1D animation of an action potential during the heart pumping.

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Further development of a perfusion-driven, ex-vivo animal lung preservation system

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***Abstract*— Ex-vivo lung perfusion (EVLP) systems have become a crucial part of research, ensuring adherence to the 3R principle. They play a vital role in the context of lung transplantation by enhancing the viability and function of the donor lung for the recipient. The following paper deals with the further enhancement of an ex-vivo porcine lung preservation system that combines static cold storage (SCS) with machine perfusion. The prototype comprises a lung container, liquid reservoir, pump as well as pressure, temperature and flow sensors, where the sensor values can be displayed in a graphical user interface (GUI) in Python. The goals for this year include implementing new pressure sensors, pump for increased flow rate, considering tubing and connector modifications and the software migration from Python to LabVIEW. Results show the existing system's hardware, newly substituted components, and components with medical equivalents that have been integrated and are still undergoing testing during this phase of the project. Flowmeter calibration measurements have been conducted to ensure accuracy and reliability of the sensors as well as to validate the pump's functionality. Regarding the software migration, a software prototype in LabVIEW 2019 incorporating the compatible myRIO device has been built, including functionalities of the previous system. Testing and validating of the overall system still need to be conducted to guarantee effective hardware and software integration.**

I. INTRODUCTION

Ex-vivo Lung Perfusion (EVLP) protocols are a significant advancement in lung organ transplantation and preservation. EVLP protocols typically include processes such as normothermia, ventilation, and perfusion to ensure lungs remain in a medically viable and functional state during the evaluation period. These protocols involve the evaluation and maintenance of donor lungs to enhance their viability and function before transplantation. They have the potential to extend the pool of viable donor organs by allowing the assessment and restoration of lungs from deceased donors, including those from post-cardiac arrest or non-conventional sources deemed too risky for transplantation. A previous setup by our colleagues focused on reducing dependency on animal lungs in ex-vivo porcine lung preservation by improving a hybrid system that combines static cold storage (SCS) with machine perfusions is our starting ground. [1] The objective is to redesign and deconstruct the present system based on the limitations and achievements of the previous prototype, combining a measuring system and a prototype device for an overall improved system. The proposed changes include sensor upgrades, pump and tubing modifications, changing flow rates, improving pressure sensors, switching from Python to LabVIEW, and possibly integrating sensitivity and pH sensors.

II. Materials & Methods

To start with enhancing the setup, it was initially important to get a thorough understanding of the topic and the current EVLP system. Special focus was laid on identifying the perfusion protocol and application, hardware components and the software for display of measurement values. An examination of limitations within the system served as a crucial foundation to define clear goals of the project. Included in our setup is an ESP32 microcontroller to regulate the whole setup, a diaphragm pump to control the flowrate of the perfusate, a temperature sensor in the perfusate reservoir, two pressure transducers one to measure the Pulmonary Artery Pressure (PAP) and the other measures the Left Atrial Pressure (LAP) a container for the lungs and two flow sensors the first detects the incoming flow rate and the latter the outflowing flowrate. To ensure a leak proof connection between multiple components a few connectors have been designed and 3D printed, and some parts mounted to ensure a more secure connection.

A. Hardware

The upgraded perfusion system has a more powerful diaphragm pump with an optimal flow rate of 1.5-4.3 L/min. Because the existing arrangement has a large resistance, the disconnected pump should be able to produce more than 3 L per minute. Integrating two pumps in parallel has been investigated, but it may result in synchronization challenges, increased complexity, and maintenance. A medical equivalent pump was attempted but failed owing to financial constraints. The replacement pump, a 12V diaphragm pump from SEAFLO, satisfies the previous requirements and may be adjusted with a potentiometer. Diaphragm pumps are commonly employed in medical pump applications and a suitable medical device equivalent was not discovered due to the necessity to purchase through a medical facility or a lack of price information.

MAX31865 is an easy-to-use resistance to digital converter and temperature sensor PT100 will continue to be used in their current form, however as this sensor does not have a datasheet, testing and calibration are required. In medical applications, it is a common temperature sensor which measures temperature by detecting a change in resistance.

The system's current flow sensor, YF-B5 114991175, is judged appropriate and can stay in place as there was no medical device equivalent found. It receives 5V from the ESP32, can operate between 1 and 30 L/min, and provides an analog output signal. Due to its ample pin count, connections, and functionality, the existing ESP32 pico-kit microcontroller will not be replaced. There are two I2C ports, four SPI ports, and 34 general input/output (GPIO) pins on it. The device has a 32-bit processor, a USB connection to a PC, and the ability to supply voltages between 3.3 and 5 volts. It should be adequate for the objectives of this project. Therefore, the following key parameters were considered [2,3,4]:

Table 1: expected value ranges for pressure and flow within the EVLP system. PAP = Pulmonary Artery Pressure, LAP = Left Atrial Pressure

Parameter	*Value range*
PAP	10-20mmHg
LAP	3-5mmHg
Flow	1.5-4L/min

Besides, as the system might expand, establishing a uniform data transmission protocol within the system would be a great advantage. Therefore, preferably I^2C-compatible components were examined. Overall, the hardware components should be sufficient to measure the expected values accurately and provide an adequate flow rate as described in EVLP systems. Figure 1 depicts the current setup of the prototype containing a lung container, liquid reservoir, roller pump, sensors for flow, temperature and pressure which are read by a microcontroller and displayed in a GUI.

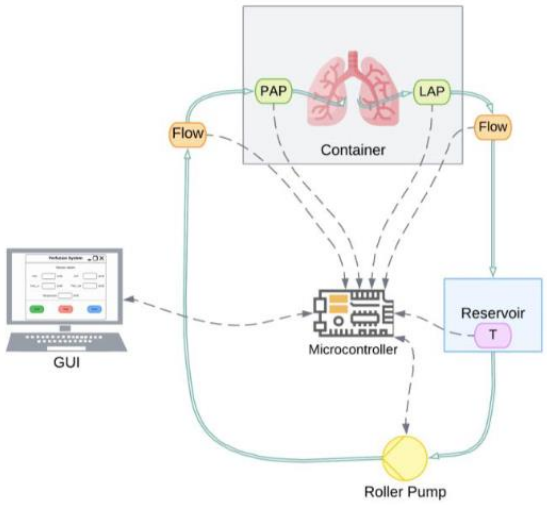

Figure 1: current EVLP setup

B. Software

For the measurements, the sensors in the system are currently read-out by an ESP32 microcontroller. Flow, pressure and temperature values are displayed by a Python GUI developed by the previous team with an option to save the values in a .csv-file for further analysis. The software is fully operational, however due to the rather inconvenient text-based coding environment for such application, there has been a great interest to migrate the software from Python to the graphical-programming environment LabVIEW from National Instruments (NI), allowing easier modifications and control for future expansion, also with the possibility to replace the ESP32 microcontroller with a LabVIEW compatible NI myRIO device provided by the UAS Technikum Wien.

III. Results

In-depth research has been carried out on the required specifications for the essential hardware components such as pressure sensors, and the pump. A 12V diaphragm pump by SEAFLO, which has a 4.3 L/min pumping capability, was found to be an effective replacement for the previous roller pump which delivered about 1.59L/min without resistance which was then lowered to 0.9L/min with all the system's added resistance. The maximum flow of the new pump was tested without resistance by pumping 1.5 L of water and measuring the time it took for the body of water to completely transfer from one container to the other end of the pump into a second container. This was performed three times, and the average time it took for the pump to move 1.5L of water was 21.24 seconds, which was then recorded in the final calculations, proving that the pump has a flow rate of approximately 4.24L/min without a connection to the remaining setup and, therefore, without resistance. The next stage would be to add the entire system's resistance and measure the overall flow rate to confirm it still equals the needed amount of 2L per minute. Finally, incorporating flowmeter measurements into the system can help validate the pump's functionality. The calibration of our flow sensors included measuring reference volumes ranging from 1000 to 2000 mL. For sensor 1 and sensor 2, we determined the offset value to be -96.019 mL and -108.052 mL, respectively. Multiple connectors have also been designed for connection between pressure transducers and containers, a fraction retaining previous connectors. As for the pressure sensors, the previous sensors were small SMD components powered by 3.3 V and read via SPI. However, since they were connected via copper wires, and one sensor got damaged, they needed to be substituted. Finding a suitable pressure sensor was challenging because the available non-SMD sensors did not meet the required measuring range and accuracy to read the left arterial pressure (LAP), which is anticipated to be 3-5 mmHg. A potential non-medical substitute was the "ABP2DRNT006KG2A3XX" by Honeywell, which has a 0-30 mmHg read range, 0.25% accuracy, an I2C or SPI communication interface, and a 3.3V supply voltage with a through-hole mounting. This would have simplified the wiring compared to the previous SMD sensors. Ultimately, it was decided to use the medical transducers "Combitrans EC HLM Wien" by B. Braun, which closely reflect the medical EVLP system. These medical blood pressure transducers share the same working principle as the previously incorporated sensors and the ones by Honeywell. In each case, the pressure is

measured through a membrane that changes the electrical resistance within the transducer based on the applied pressure. The transducer features a continuous flush rate of 3 mL/h at 300 mmHg and a quick flush rate of >2 mL/s. This custom-designed blood pressure transducer kit, used in the AKH hospital, is not available for purchase by non-medical facilities. Therefore, it could not be included in any cost analysis. The transducers are compact, assumed to be pre-calibrated with constant electrical characteristics, incorporate a clear casing for simple visual monitoring, and a three-way stopcock. The communication output is an analogue signal. Nevertheless, testing and calibration of the transducer will be conducted to ensure accuracy. A connector case for the transducers has been designed and 3-D printed. It encloses pogo pins which are soldered to wires from the microcontroller. The case consists of a rectangular prism that has 4 openings in the center for the pins which are aligned with the connections on the transducer. This design also has a fixed feature at the top that allows for the transducer to be slid into the exact position of the pins where the signal, ground, and supply voltage will be established. The current "YF-B5 114991175" flow sensors which are hall effect sensors were deemed suitable and remained unchanged since a medical device substitute could not be found.

A GUI prototype has been created with LabVIEW to switch from Python. The new GUI utilizes the LabVIEW 2019 myRIO Toolkit, designed to integrate seamlessly with the NI myRIO hardware. The software connects via USB to the myRIO hardware, enabling real-time signal readout and display. The new LabVIEW GUI retains all functionalities of the previous Python-based system, including real-time display of flow, pressure, and temperature data, as well as data saving in .txt files. Additionally, waveform charts have been incorporated to provide a visual representation of the data. Initial testing involved connecting sensors directly to the myRIO hardware, bypassing the ESP32 microcontroller. It demonstrated correct detection of pulses from the Hall effect flow sensors when water was passed through. However, further adjustments in the LabVIEW code are necessary to ensure continuous data collection for accuracy.

Algorithms for converting raw data obtained by the myRIO have been implemented for both flow sensors as well as the temperature sensor by applying modified calculations of the previous team's code in LabVIEW. The wheatstone bridge initially used to calculate the resistance change has also been migrated to LabVIEW, eliminating the need to connect the temperature sensor to the circuit board. Furthermore, the storage of the data in individual .txt files on a USB stick connected to the myRIO hardware was successful.

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Figure 2: Front panel of the LabVIEW software prototype

IV. Discussion

The EVLP system was thoroughly researched and improved through initial research. Despite initial uncertainties, the project was successfully established by identifying flaws, confirming expected parameters, and setting key parameter values. Clear project goals were established, and team members were assigned responsibilities. The second phase focused on selecting hardware components replacements, such as pressure sensors and a diaphragm pump, but faced challenges such as finding budget-friendly components and finding non-SMD pressure sensors with a small pressure range. Additionally, calibrating the flow sensor has presented multiple challenges, from reading faulty results, to delays

due to difficulty establishing a secure communication between the hardware to Arduino via ESP32-Pico4 board. The current pump's flow rate proved to be sufficient when tested without extra resistance. The next stage would be to add the entire system's resistance and measure the overall flow rate to confirm it still equals the needed amount of 2L per minute. Finally, incorporating flowmeter measurements into the system can help validate the pump's functionality. On the software front, implementing LabVIEW has been challenging, given the team's low to non-existent familiarity with the platform and the complexity of the migration process. Nonetheless, an attempt was made to create a software in LabVIEW with the corresponding myRIO device. Some promising results could be noted in this area. Nonetheless, there are still several challenges that must be addressed to fully replace the previous developed software. Ultimately, LabVIEW aims to replace both the ESP32 microcontroller and the Python GUI, leveraging National Instruments' established measurement tools widely used in biomedical applications. However, comprehensive validation is still required to confirm the new software's functionality and reliability within the system. In the final project stage, it is crucial to ensure the hardware and software are connected properly and validate the system by measuring flow, pressure, and temperature accurately.

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Mental Health on FHIR

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The "Mental Health on FHIR" project tackles the integration of CDA and FHIR into mental health care to address training gaps, privacy concerns, and interoperability issues. It features a patient mobile app for recording health metrics and a doctor-facing Windows Forms application for managing patient data. By using FHIR for secure data sharing and CDA for standardized records, the project aims to enhance patient-centric, secure mental health care. Achievements include developing these applications, establishing a FHIR server, and implementing a Patient Summary Generator. The project has improved data exchange, performance, and security, with ongoing refinements needed.

I. INTRODUCTION

Integrating advanced technologies like Clinical Document Architecture (CDA) and Fast Healthcare Interoperability Resources (FHIR) into mental health care presents unique challenges. These include a lack of training in these technologies, privacy concerns, interoperability issues due to the narrative nature of mental health documentation, and regulatory barriers. Existing electronic health record (EHR) systems are often not well-suited to mental health needs.

The "Mental Health on FHIR" project aims to enhance mental health care delivery through an innovative software system that utilizes the FHIR standard for secure and efficient data sharing between patients and healthcare providers. This system includes a mobile application for patients to record health metrics and medication details, and a Windows Forms application for doctors to access and manage patient information. By adhering to FHIR standards, the project aims to make mental health care more patient-centric, adaptable, and secure.

An analysis of existing mental health software solutions highlighted the need for features such as telemedicine, psychological summary reports, data exchange, and customizable applications. No current solution meets all these needs (McGinnis et al., 2021; Sharma et al., 2020). The proposed IT architecture uses principles from the Integrating the Healthcare Enterprise (IHE) initiative and HL7 standards, including CDA and FHIR.

CDA ensures uniformity and security in the exchange of electronic clinical documents, facilitating interoperability and enhancing patient care. The Audit Trail and Node Authentication (ATNA) standard ensures the security and traceability of healthcare IT systems. FHIR advances data exchange and interoperability, supporting diverse data formats and communication protocols (Bender & Sartipi, 2013).

In this project, patients use a mobile app to complete questionnaires, record vital statistics, and log medication details, which are securely transmitted using FHIR and stored as CDA documents. Doctors access this data through a Windows Forms application to manage treatment plans, ensuring personalized care.

User requirements include an intuitive patient interface for data entry, secure data transmission via FHIR, standardized record-keeping in CDA

format, and a detailed overview of patient data for healthcare providers. Both interfaces should be user-friendly to enhance engagement and effectiveness.

II. Materials & Methods

The "Mental Health on FHIR" project integrates several critical components to enhance mental health care through advanced technology. Central to the project are two mobile applications, both developed in C# .NET MAUI, tailored respectively for patients and healthcare providers. The patient-centric application allows users to access their mental health records, schedule appointments, and interact with healthcare providers. Conversely, the healthcare provider application facilitates the management of patient records, scheduling, and communication.

The backbone of the project is a FHIR server, which handles all data transactions and ensures compliance with the FHIR standard. Complementing this is the Patient Summary Generator, software that converts patient data into Clinical Document Architecture (CDA) documents, promoting seamless integration with existing health records.

The project is methodically structured into phases, each culminating in specific milestones: the initial versions of both mobile applications, the full operational capability of the FHIR server, the implementation of the Patient Summary Generator, and the comprehensive system integration and testing. Each milestone is subject to rigorous evaluation to ensure alignment with project objectives, adherence to medical documentation standards, robust data security, and user-friendliness. These evaluations guide necessary adjustments, ensuring the project's continuous alignment with its goals.

Technical documentation is pivotal, with UML diagrams providing a visual representation of the system's architecture and components. These include class diagrams illustrating system structure, sequence diagrams detailing interactions between objects, and component diagrams demonstrating the organization and dependencies among software components and the hardware they interact with.

Information models define the data structure and types used within the system, including FHIR Resource Models that represent medical data per FHIR standards, and CDA Document Structures detailing the composition of patient summaries and other clinical documents.

The system architecture is comprised of various hardware and software elements: two mobile applications, a central FHIR server, and software for CDA document generation. Secure network architecture ensures compliant data exchange protocols between mobile applications and the server.

Timing diagrams illustrate the chronological sequence of operations within the system, such as patient data retrieval and synchronization processes. Transaction diagrams display interactions between different system actors, including data exchanges between the mobile applications and communication with the FHIR server.

Each system component is detailed with its functionalities, interactions, and dependencies, encompassing user interfaces, data input/output, local storage, and communication protocols for mobile apps; data storage, processing, and API endpoints for the FHIR server; and conversion algorithms and data formatting procedures for the CDA document generator.

Unit testing ensures individual components function as expected, covering mobile app functionalities and FHIR server API endpoints. System integration testing validates data consistency and interaction between different system components. End-to-end testing simulates real-world scenarios to verify the complete system's workflow from patient data entry to CDA document generation, including security and compliance checks to meet GDPR and ISO27001 standards.

A comprehensive approach to risk management underpins the project, emphasizing secure

software development practices, separation of software components, robust error handling, and stringent data security and privacy measures. This ensures the robustness and security of the software system, safeguarding sensitive mental health data in compliance with privacy regulations.

III. Results

The "Mental Health on FHIR" initiative has yielded significant and multifaceted results, demonstrating considerable promise in the realm of mental health data exchange and interoperability. Central to this project's success is the utilization of FHIR (Fast Healthcare Interoperability Resources), which has proven effective in enabling seamless communication across diverse mental health systems. This capability is crucial in an era where data fragmentation can severely hinder comprehensive patient care and the efficacy of mental health interventions (Wang et al., 2018).

The project faced a series of interoperability challenges, including data consistency issues and integration difficulties with existing health records, which, though initially problematic, were ultimately resolved through diligent troubleshooting and optimization. Addressing these challenges was instrumental in enhancing data accuracy and completeness, thereby ensuring that patient information was not only accessible but also reliable and comprehensive. The resolution of these interoperability issues underscores the robustness of the FHIR framework in managing and integrating disparate data sources, which is a critical aspect of modern healthcare informatics.

System performance metrics further underscored the success of the project. The infrastructure enabled by FHIR demonstrated robust response times and maintained high system uptime. These performance indicators are essential for the continuous and reliable operation of mental health services, which depend on the timely and consistent availability of data. The stability and efficiency of the FHIR-enabled system contribute to its overall reliability, making it a dependable backbone for mental health data management.

Security measures within the project were also notably effective. Given the sensitive nature of mental health data, ensuring its protection against unauthorized access and breaches is paramount. The implemented security protocols were rigorously tested and validated, confirming their efficacy in safeguarding patient information. This aspect of the project not only complies with legal and ethical standards but also fosters trust among users, who can be confident that their personal health information is secure.

Adherence to the project timeline was another significant achievement. Key milestones were reached within the planned schedule, demonstrating effective project management and coordination. This punctuality in meeting deadlines is indicative of the project's well-structured approach and the efficiency of its execution strategy. Additionally, resource allocation was handled judiciously, balancing human and technological resources to maximize productivity and minimize waste.

User experience tests were conducted, garnering positive feedback from both patients and healthcare providers. Patients appreciated the intuitive interface and the ability to track their health metrics conveniently, while healthcare providers valued the comprehensive overview of patient data and the seamless integration with existing health records. However, suggestions for further improvements were noted, such as enhanced customization options for data entry forms and additional features for telemedicine consultations. These suggestions are being evaluated for future implementation.

IV. Discussion

The "Mental Health on FHIR" project has achieved results that align closely with the initial requirements and analytical frameworks, highlighting both successes and areas for potential enhancement. The project effectively demonstrated the capability of FHIR to facilitate efficient data exchange and interoperability

across diverse mental health systems, thereby meeting the fundamental requirement of seamless communication. Furthermore, the analysis of data accuracy and completeness indicated significant improvements, addressing a critical need for reliable mental health data. The robust performance metrics of the system affirmed the project's success in delivering a stable and responsive infrastructure.

Nonetheless, it is imperative to acknowledge the challenges encountered throughout the project. Despite the resolution of interoperability issues, these challenges underscore the necessity for ongoing refinement in this area. The user experience was predominantly positive; however, there are opportunities to further enhance the interface based on user feedback.

The need for the project arises from the inadequacies of current solutions to meet the specific requirements of mental health care, including the need for detailed psychological summary reports, seamless telemedicine integration, and secure, standardized data exchange. Existing software solutions, such as Cerner Millennium and Epic Systems, while comprehensive, often lack the flexibility and specificity required for effective mental health care (Kern et al., 2018).

Looking ahead, future steps should include a sustained commitment to refining interoperability and addressing any residual challenges. Leveraging user feedback for continuous system improvement is essential. Additionally, exploring further security measures to enhance data protection warrants consideration. Extending the project to accommodate evolving mental health standards and technologies will ensure its continued relevance within the dynamic healthcare landscape. Continuous monitoring and evaluation are crucial for the project's sustainability, ensuring it remains adaptable to emerging needs and technologies within the mental health domain.

The goal of this project is to establish mental health software as a medical device, ensuring that it meets the stringent requirements for clinical use and providing reliable, secure, and comprehensive support for mental health care.

V. Conclusion

The "Mental Health on FHIR" project has successfully developed and implemented a system that leverages the FHIR standard for secure and efficient data sharing in mental health care. Key achievements include the development of patient and doctor-facing applications, the establishment of a FHIR server, and the implementation of a Patient Summary Generator. The project has improved data exchange, system performance, and data security.

Future steps involve refining the system based on user feedback, enhancing interoperability features, and continuously improving security measures. By addressing these areas, the project aims to provide a robust, secure, and user-friendly solution for mental health care, ultimately establishing the software as a certified medical device.

Improvement of the fitting quality and acceptance of upper limb prosthetic devices using VR

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***Abstract*— The abandonment of upper limb prosthesis is higher compared to lower limb prosthesis. The reasons behind the prosthesis rejection are emotional impact, limited functionality, low fitting quality and discomfort. Virtual reality (VR) is a powerful tool which offers immersive and interactive experiences. The aim of the project is to create a VRtraining environment for individuals with transradial upper limb amputations to improve their proficiency with prosthetics, acceptance, fitting, and phantom pain reduction. Utilizing the HTC Vive setup, the VR environment features activities of increasing difficulty, including fitting exercises, a memory game, and a sortbox activity. Muscle activity tracking is achieved through the MyoWare 2.0 setup and Arduino Uno. Future testing on amputees and their feedback can refine the VR training environment, enhancing its suitability for users, and serving as an effective practice tool and muscle training aid for prosthesis use. The potential of VR testing environments in prosthetic training is highlighted.**

I. INTRODUCTION

The upper limb amputations come with a higher emotional impact than other types of amputations. The abandonment rate of the upper limb prosthesis is higher compared to lower limb prosthesis cumulating up to 44%. The most important reasons for the prosthesis abandonment are lack of comfort, lack of sensorial feedback, functionality, and predictability. The fitting process of the active prosthesis is related to the electrodes positioning which is very important in prosthesis actuation. The fitting of the active prosthesis can illustrate the problematic communication of electrodes in case direct communication with the skin is hindered because of different covers the patient must wear [1]. Miscommunication of the electrodes can happen if the patient moves to perform daily tasks and the EMG sensors are moved. Miscommunication of the electrodes is an important issue that must be addressed, as the EMG signals actuate the prosthesis [2]. Another often occurring problem for patients with upper limb amputations is phantom limb pain. Phantom limb pain is characterized by feeling pain in the amputated body part. Reports point out that 80-85% of amputees suffer from severe pain episodes with symptoms such as throbbing, burning, stabbing, tingling, squeezing, shocking, and cramping throughout the missing limb. Phantom pain can range from mild to severe, it can last from second to days even longer [3]. Virtual reality can be a useful tool for creating training environments, especially in the field of medicine. This technology offers a positive

outcome for individuals with upper limb amputations providing them a virtual space for training purposes. Specifically, it can serve as a valuable resource for fitting prosthetics and facilitating general use. By developing a risk-free virtual training space, amputees can enhance their familiarity and comfort with prosthetic devices [3]. A training environment focused on improving the fitting and acceptance quality of upper limb amputees is developed in Unity. This approach, using the HTC Vive setup, aims to decrease the phantom limb pain among individuals with upper limb amputations.

For individuals with upper limb amputations, providing them a virtual space for training purposes. Specifically, it can serve as a valuable resource for fitting prosthetics and facilitating general use. By developing a risk-free virtual training space, amputees can enhance their familiarity and comfort with prosthetic devices [4]. A training environment focused on improving the fitting and acceptance quality of upper limb amputees is developed in Unity. This approach, using the HTC Vive setup, aims to decrease the phantom limb pain among individuals with upper limb amputations.

II. Materials & Methods

The VR training environment within this current project consists of four tasks, each increasing in difficulty, for the user to achieve. Before beginning the stations, amputees must first select which side their prosthesis will be on. At each station the user can click on a question mark panel that explains the current station.

Fitting station

Since fitting can be a major issue for amputees, a station just for fitting has been chosen to implement. There, the user can get familiar with the VR setup at the “Fitting Station”. A maze-like shape, as shown in figure 1, appears in front of the participant.

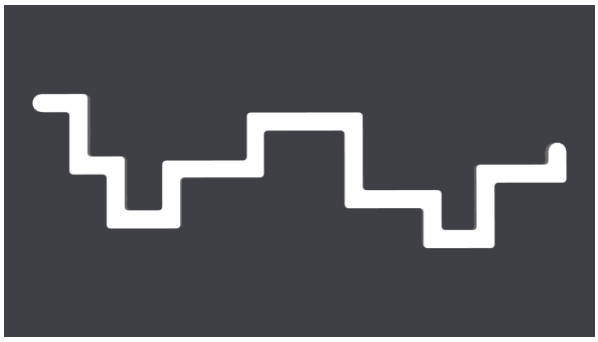

Figure 1: Fitting station: Follow the spline.

At the current state of the project, a ray is emitted out of the prosthesis, checking for collisions along its way. When the ray hits the object, it turns green, indicating that the user is on the right path. If the ray does not collide with the object, it turns red. At the second level of the "Fitting Station," the users must perform two contractions with their stump. To detect the contraction, muscle activity is measured by attached electrodes. The last level of the first station shows a longer and more complicated line to follow. Both maze models are designed in Inventor.

Memory station

At the second station, the user can play the well-known "Memory" game. At the first level, eight cards appear in front of the user. The theme of the images is sightseeing buildings in Europe. The cards can be seen in Figure 2. The backside of the cards faces the users, so they do not see the pictures on the other side. When the participant touches a card, it gets flipped. After that, they can touch another card that gets flipped as well. If both cards have the same picture on them, it is a match, and they stay turned. If they do not match, both get flipped again after three seconds. The user has to memorize the position of the pictures and can flip another pair. Once the user manages to flip each pair, they can continue to the next level by clicking the button.

Figure 2: First level of the Memory station; The images on the cards show buildings from all over Europe.

In the next level the number of cards increases. This time, the participant not only has to touch the card, but also perform a contraction with the prosthesis to turn around the cards. The cards have a dimension of 150mm x 70mm thought to reflect the real card dimension and be easy to hold.

Sortbox station

The rules of the third and final station are based on a children's game called "sortbox". On the table in front of the user, a box and some shapes of animals appear. As seen in figure 3, there is an empty shape of the corresponding animal on each side of the box.

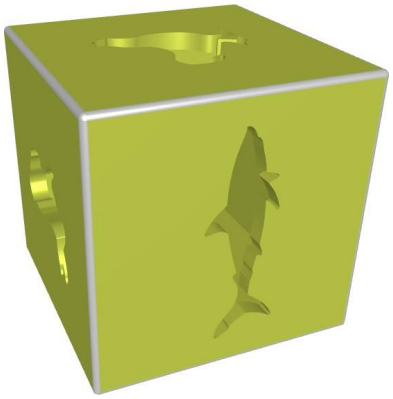

Figure 3: Third station: *Sortbox*

In the first level, the user must pick up the correct piece that is currently missing from the top of the box. When the amputee holds the piece with the virtual prosthetic, a script continuously checks if it collides with the correct side of the box. If there is a collision on the correct side, the piece snaps into the empty space, and the box rotates, revealing the next missing animal on the top of the box. For the second level, the user has to interact with both hands. This time, the box does not rotate automatically but has to be turned with the spare hand. At the third level of the Sortbox station, the animals are divided into two pieces, as seen in Figure 4. The amputee has to assemble each animal before it can be inserted in the box. Each corresponding pair gets assigned with a tag, such as "dog_piece." A script is created that checks for collision between the separated pieces, similar to the one used to check the collisions between the box and a whole piece.

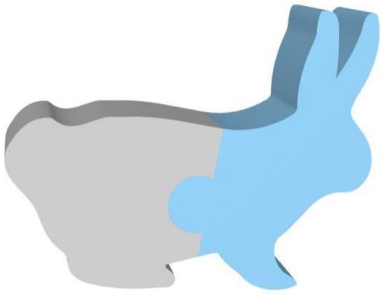

Figure 4: Third level of Sortbox: *Rabbit puzzle*

If two parts with the same tag collide, they get automatically assembled into one piece. Next, the assembled piece can be inserted into the right side of the box again. The modelling and splitting are done in Inventor, with textures and colours applied in Blender.

The table and the chair for the virtual environment are modelled using Inventor and blender. Further, the 3D model of the bebionic hand prosthesis, received from Ottobock, is adapted for Unity needs.

Bebionic hand

To ensure the best similarity to the real world, the bebionic hand is attached to a human model by first identifying a suitable 3D model and performing a transradial amputation in Blender.

A custom socket, designed in Inventor and exported to Blender, connects the hand and the model, filling gaps to ensure a proper fit. The model is rigged in Blender, exported as an .fbx file, and imported into Unity, but initial attempts to continue in Unity failed due to rigging errors. These errors were addressed by manually adjusting the rig in Blender, clearing the parent relationship, and setting automatic weights before re-importing the model into Unity. Inverse Kinematics (IK) is applied to animate the model naturally, but custom animations must be recorded manually in Blender first, due to incompatibilities with Unity's animation library. Finally, the model is rigged and animated in Blender and imported into Unity, where it is integrated into the training environment.

III. RESULTS

VR Room

The VR room is developed in Unity. The chair and the table are placed in the center of the room, as seen in Figure 5.

Figure 5: Initial VR Setup in Unity

Activities

The VR training environment for amputees was implemented, incorporating the specified four tasks that progressively increase in difficulty. Each station was designed to address different aspects of prosthesis use and user interaction.

At the developed Fitting Station, the initial maze-like shape and subsequent levels were set up to familiarize users with the VR environment and measure their muscle activity via electrodes. After completing this station, users should be familiar with performing muscle contractions and accurately moving their hands within the VR environment.

The Memory Station requires users to touch the cards and perform a muscle contraction to flip them over, thus integrating the simultaneous use of prosthesis control and hand movement. This station, with its dual-action requirements, was implemented to provide a challenging cognitive and physical exercise for the users.

The Sortbox Station is the most complex, requiring the highest level of coordination and control. As the levels progressed, the tasks demanded the use of both hands, significantly increasing the difficulty. Users had to rotate the box with one hand while positioning the shapes with the other, enhancing their bimanual coordination. Additionally, in that station, users must hold the muscle contraction for a longer duration to insert the shapes into the box. This extended contraction requirement provided a more challenging and realistic simulation of prosthesis use in daily tasks.

Real-Time Data Transfer from MyoWare 2.0 to Unity

Building on the MyoWare 2.0 Arduino integration, the project now enables real-time data transfer from MyoWare 2.0 surface electromyography sensors to Unity. This allows the translation of muscle activity into virtual movements within a Unity-based virtual reality environment, providing smooth and immediate visual feedback. As users contract their muscles, the electrodes measure the activity and send the data to an Arduino, which then transmits it to Unity. Unity reads this data in real-time and maps it to a range between 0 and 1. Based on the received value on Unity, an animation of the prosthesis is executed.

Contraction Bar

The MyoWare 2.0 board communicates with Unity via a serial port connection, allowing continuous transmission and real-time

monitoring of electromyographic signals. Unity captures and interprets these signals, enabling visualization and analysis of muscle activity. The contraction bar provides immediate feedback, allowing users to adjust their muscle contractions based on the visual feedback.

Figure 6: Contraction bar in Unity

This threshold is adjustable based on the user's ability and is visible in every activity station, situated in the upper section of the start menu. This integration enhances user interaction by offering real-time, visual feedback of muscle activity, making the virtual experience more immersive and responsive. The contraction bar is demonstrated in Figure 6. The implemented VR training starts with the patient's fitting of the setup which is used in detection of the muscle activity and data transfer. The hardware setup of the project consists of the Myoware muscle sensor, Arduino Mega 2560 board, connecting cables, jump wires, HTC Vive glasses, trackers, lighthouse, and the laptop with the VR training environment. For upcoming applications and patients testing a socket is created where the Arduino board and the wires are inserted for better accuracy of the muscle and overall stump position.

IV. Discussion

The current VR environment can be further used by upper limb transradial amputees to analyze its impact on prosthesis acceptance, fitting, and phantom limb pain management. After the initial testing round with patients, the VR environment can be refined and further developed as a training tool for amputees. For example, to provide a more enjoyable experience, haptic and audio feedback can be implemented. To keep track of user's progress, a scoring system for each level can be developed. Also, the accuracy as well as the efficacy of the EMG signals can be further improved. In rehabilitation training, VR can offer immersive, interactive exercises tailored to individual needs, simulating real-life scenarios to help patients practice daily activities in a controlled, safe setting. It provides instant feedback and tracks progress, facilitating adjustments to optimize therapy. Additionally, the engaging nature of VR enhances motivation and adherence to rehabilitation programs, potentially leading to improved outcomes.

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New Projects for Master Medical Engineering & eHealth

Development of a Mobile Mock Circulatory Loop of a Micro-Axial Pump for Training Purposes of Medical Professionals

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***Summary* — This project focuses on the design, production, and construction of a mobile mock circulatory loop (MCL) for training purposes. The portable MCL will simulate cardiovascular system dynamics, providing a hands-on platform for training and evaluating the Impella 5.5 micro-axial pump under various hemodynamic conditions. Key objectives include creating the CAD design, building the mobile setup, and developing training modules for analyzing pump performance and identifying adverse conditions. The project aims to enhance practical skills in cardiovascular engineering, CAD design, bio-signal analysis, and data science, preparing users for real-world clinical applications.**

Keywords: ***Mechanical circulatory support, micro-axial pump, cardiogenic shock, in-vitro, hemodynamics, pump performance, Mobile Circulatory Loop, Cardiovascular Simulation, CAD Design***

Academic Level: ***Master, MME***

Course: ***PRT***

I. BACKGROUND

Heart failure is a prevalent and life-threatening condition that poses significant challenges to contemporary healthcare systems. Despite advancements in medical therapies, a subset of patients with severe heart failure remains refractory to conventional treatment options. In such cases, mechanical circulatory support (MCS) devices have emerged as vital therapeutic tools to augment cardiac output and restore systemic perfusion. The Impella 5.5 pump (Abiomed Inc., Aachen, Germany), a miniaturized short term ventricular assist device (VAD), has gained attention due to its potential to provide hemodynamic support with a minimally invasive approach (surgical placement via the right axillary artery).

The Impella 5.5 is an intravascular, micro-axial flow pump designed to provide left ventricular support in patients with severe, end-stage heart failure (e.g. cardiogenic shock) as a bridge to recovery, bridge to decision or bridge to heart transplantation. This device offers advantages over larger, long-term MCS devices such as the HeartMate 3 VAD (Abbott Inc., USA), including reduced invasiveness, improved patient mobility, and decreased risk of complications such as bleeding and infection. However, despite its enormous potential, comprehensive evaluation and quantification of its hemodynamic effects are essential for optimizing patient outcomes and refining clinical protocols and patient management strategies.

This project is dedicated to the design, production, and construction of a mobile in-vitro mock circulatory loop (MCL) for training purposes of medical professionals. The mobile MCL will simulate the dynamics of the cardiovascular system, providing a hands-on platform for training and evaluating the performance of the Impella 5.5 micro-axial pump under various controlled hemodynamic conditions. This setup will allow users to simulate and analyze different clinical scenarios, such as

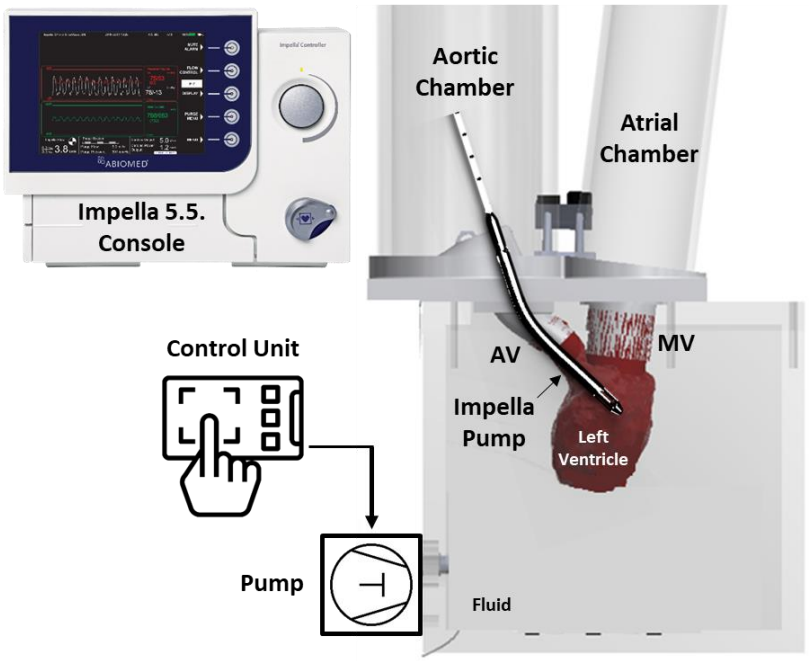

Figure 1: Overview of the available stationary test stand

varying degrees of heart failure or changes in pre- and afterload, enhancing their understanding of the pump's behavior in real-world conditions. Users will also be able to download and analyze pump performance data (logfiles) in real-time, enabling a data-driven approach to training that supports evidence-based decision-making and improves the clinical application of the Impella 5.5 pump.

While computational modeling and simulation are valuable tools for predicting device behavior and its effects on cardiovascular dynamics, hands-on experimental validation with a mobile mock circulatory loop remains essential. This approach will provide an interactive platform for understanding complex cardiovascular interactions that models alone might not fully capture. Additionally, analyzing pump data from the MCL can help identify adverse hemodynamic conditions, further enhancing training outcomes and improving patient management.

II. PROJECT OBJECTIVES

The objectives of this project are to:

- Design the CAD model for the mobile MCL, focusing on portability and ease of use in various training environments.
- Produce and construct the mobile MCL, integrating the Impella 5.5 pump with flow and pressure sensors to simulate various hemodynamic conditions.
- Produce and develop a µC driven control unit for the pump (including software)
- Test the platform under different scenarios, download and analyze pump data (logfiles), and develop training modules that include the identification of undesired hemodynamic conditions (e.g., suction or pump malposition).

III. LEARNING OUTCOMES

By the end of this project, you will get familiar with:

- Fundamentals of cardiovascular engineering and short-term mechanical circulatory support for end-stage heart failure.
- Operational principles of intravascular, micro-axial flow pumps designed for left ventricular unloading.
- CAD design and production processes for biomedical devices, particularly those intended for training applications.
- Bio-signal acquisition and analysis, including both non-invasive and invasive vital parameters.
- Time-domain signal processing of pump data and application of data science methods such as data mining and clustering.
- Biostatistics and effective collaboration within a multidisciplinary team of biomedical engineers and physicians.

This project aims to provide you with practical experience and comprehensive knowledge, directly applicable to the development, design, and use of mobile training tools in cardiovascular engineering and patient care.

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Heart Hackathon – Vienna Initiative

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***Summary* — For patients with severe heart failure, the implantation of a total artificial heart (TAH) is the only chance to survive. The Heart Hackathon is a global student team competition to develop new TAHs. The aim of this project is to participate in this international challenge and design and test a new concept for a TAH in cooperation with the Medical University of Vienna.**

Keywords: ***Total Artificial Heart, Heart Hackathon, Heart Failure, Medical Device Development***

Academic Level: ***Master , MME,***

Course: ***PRT***

I. BACKGROUND

Cardiovascular diseases (CVD) are the leading cause of death globally. A significant proportion of CVD patients will suffer heart failure, ultimately requiring a heart transplant. In certain circumstances, a total artificial heart (TAH) is the best option for the patient while waiting for a donor heart to be found [1].

Figure 1 The SynCardia Total Artificial Heart. Two implanted volume displacement pumps are pneumatically driven by an external power and control unit. [2]

Total artificial hearts are implantable devices that replace the diseased natural heart to restore perfusion in advanced heart failure patients. As the human heart has two pumping chambers, the left and right ventricle for the systemic and pulmonary part of the circulation, a TAH incorporates two pumps. Figure 1 shows one of the few currently clinically used TAH, the SynCardia TAH, which has been in clinical use for more than 35 years [2].

Since the first implantation of a TAH 50 years ago, technological advances have been made but only a few devices have been introduced with many challenges remaining [3]. **A versatile and reliable TAH providing good quality of life for these patients is still an unmet medical need**.

The **Heart Hackathon** is a global initiative where student teams (undergraduate and graduate) participate in a year-long competition working on innovative solutions to develop TAHs.

II. PROJECT OBJECTIVES

In the course of this project, you build a team and will register for the Heart Hackathon (https://www.hearthackathon.com/). The project will be supported by the CARE group led by ap. Prof. Marcus Granegger at the department of Cardiac Surgery of the Medical University of Vienna. The steps of this project are to:

- research of TAHs and their development using literature. Webinars are also provided by the organizers.
- design, simulate, build and test TAH concepts.
- document and report the project progress and get feedback from industry partners and professionals.

The objective of the project is to:

- develop a TAH pump designs that can deliver 5L/minute at appropriate systemic and pulmonary pressures (i.e. the flow rate and pressures to support a human) and
- build one or more bench-top prototypes, that can be unrefined and bulky at this stage [1].

The project results will be submitted and presented to the Heart Hackathon Organizers. The best teams will be invited to present at an international conference (International Society of Mechanical Circulatory Support) and awarded a prize.

III. LEARNING OUTCOMES

By the end of this project, you will get familiar with many tools involved in the development of a medical device [4], for instance:

- Computer Aided Design
- Additive manufacturing
- In-vitro mock loops
- Numerical Modelling
- Computational Fluid Dynamics
- Presentation to scientific community at international conference

"Through this event, students will be given the opportunity to connect with industry professionals and researchers in the field of artificial hearts, revealing new networks, pathways, and job opportunities." [1]

IV. LITERATURE

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Further Development of A Pneumatic Mock Circulatory Heart Loop

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***Summary* — The mock circulatory loop is a simulated system that mimics the human cardiovascular system and is used to study the dynamics of blood flow, pressure, and other parameters. The loop typically includes a pump, tubing system, sensors and measuring instruments to monitor and record data. The basis of this project is work from previous years which dealt with developing a preliminary version of a pneumatically driven circulatory loop. The system was successfully capable of simulating a heart with adjustable heart rate and systolic pressure. The goal of this project is to improve and further develop the mock-up loop by adding further pressure driving capabilities and sensing elements.**

Keywords: ***Cardiac simulation, Pneumatic, Control Theory***
Academic Level: ***Master, MME***
Course: ***PRT-1 & PRT-2***

I. BACKGROUND

The cardiovascular system plays a vital role in the human body by facilitating the transportation of essential elements, such as nutrients, oxygen, and waste products. It operates through a continuous loop that consists of the heart, which pumps blood, and blood vessels, which carry the blood throughout the body. The study of this system and its functions is critical for diagnosing and treating various cardiovascular diseases. To enable these endeavors, researchers have created a mock circulatory loop. This technique simulates the functions of the cardiovascular system by creating a circuit that closely resembles the heart and blood vessels. The mock circulatory loop helps researchers understand the dynamics of blood flow, pressure, and other parameters in a controlled setting, thereby improving their understanding of the human cardio-vascular system.

One of the main benefits of the mock circulatory loop is that it enables researchers to study the cardiovascular system under controlled conditions. For instance, they can alter the flows, pressures and timings of the pumps and valves within the loop to examine their impact on the system. They can also introduce different substances into the loop to investigate their effects.

A preliminary version of such a system was developed by a student group in the previous year. The task would be to further expand on the capabilities of the said system by introducing more and finer control on the individual components, such as: valves and pumps, as well as implementation of measurement capabilities.

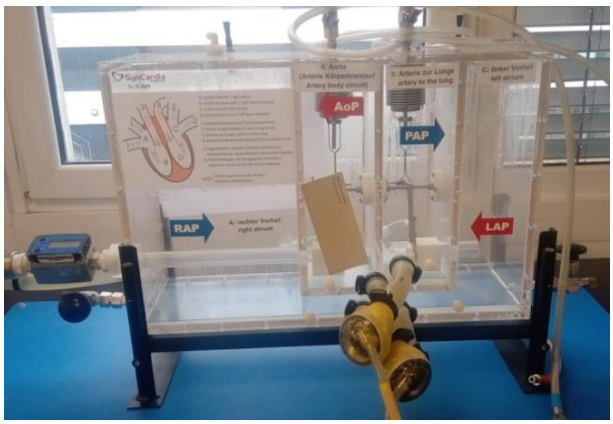

Figure 1: Heart circulatory loop by SynCardia

II. PROJECT OBJECTIVES

The objectives of this project are to:

- Implement a diastolic control circuit into the current setup. (pneumatic regulation)
- Develop a measurement system for all available parameters. (sensors)
- Develop a single point of control and measurement. (GUI, HMI)
- Evaluate and document the system and its output. (exhaustive documentation)
- Design teaching and simulation exercises involving the full capabilities of the system for future use.

At the current stage, the system is only capable of adjusting the heart rate and the systolic pressure. The goal of this project would entail the expansion of the simulation capabilities of the system by including, but not limited to, implementation of a diastolic pressure control and timing, implementation of heart-valve movement and synchronization functionality, implementation of sensors to measure cardiac output and pressures throughout the system, and expansion on the current software to single point of control and measurement suite.

Documentation on the current system will be available and serve as a basis for further development.

Figure 2: Current setup. Left: Pneumatic tanks and control. Right: Pneumatic pumps and heart mock-up

III. LEARNING OUTCOMES

By the end of this project, you will get familiar with:

- Anatomy and physiology of the human circulatory system
- Analyses and evaluation of existing mock circulatory loops and design plans for hardware and software modifications
- Pneumatically driven systems and industrial pneumatic components (valves, sensors, etc.)
- Programming of microcontrollers and interfacing with industry-norm communication protocols
- Design and implementation of Graphical User Interfaces and Human Machine Interfaces
- Control theory and -engineering

Literature

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CENTER FOR MEDICAL PHYSICS AND BIOMEDICAL ENGINEERING
MEDICAL UNIVERSITY OF VIENNA

FH University of Applied Sciences TECHNIKUM WIEN

3D printed optical coherence tomography

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***Summary* — Optical coherence tomography (OCT) is a cutting-edge imaging technology primarily used in ophthalmology and increasingly applied in other medical fields. This project focuses on the design and construction of a new generation of a 3D-printed OCT demonstrator. The goal is to reduce production costs and promote the use of open-source OCT components, thereby making the technology more accessible for educational and public demonstrations.**

Keywords: ***OCT, 3D printing***
Academic Level: ***Master , MME,***
Course: ***PRT***

I. BACKGROUND

Optical coherence tomography (OCT) is a non-invasive imaging technique that has revolutionized ophthalmic healthcare over the past 30+ years. [1] The foundation for OCT was laid by Fercher et al. in Vienna when they used interferometry to measure axial eye length in the early 1990s [2]. Today, OCT is the standard of care and, impacting millions of people annually.

More recently, OCT has been appl ied to other human organs, including the skin, bladder, and cardiovascular system. As a non-contact imaging technique, OCT has the potential to reduce the need for invasive and often painful biopsy procedures, enabling real-time diagnosis during medical appointments.

Figure 1 depicts the basic schematic of an OCT system. A laser with short coherence length emits light towards a beam splitter, which directs part of the light to the sample arm and the remainder to the reference arm. The back-reflected light from both arms is recombined at the beam splitter, where it interferes and is then directed to a detector. By calculating the Fast Fourier Transform (FFT) of the acquired signal, a depth profile of the imaged sample is generated. Scanning in one or two dimensions produces a 2D or 3D image of the sample.

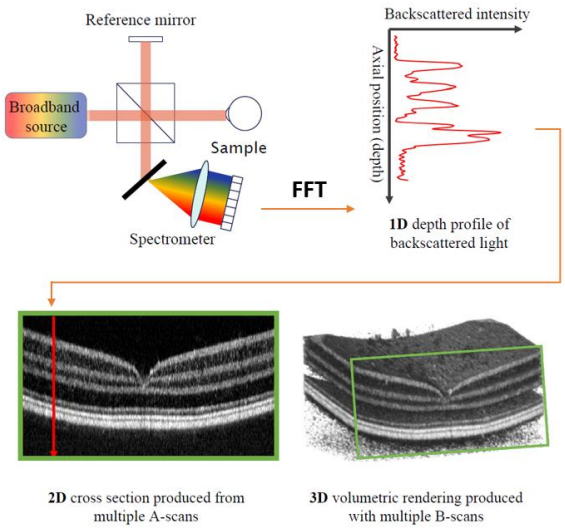

Figure 1. Principle schematic of optical coherence tomography (in the spectral domain) and basic postprocessing steps from raw data to a 2D and 3D representation of a human retina.

Despite Austria's significant contributions to the development of OCT, the general public remains largely unaware of its history and impact. To address this, the SPIE & OSA student chapter of the Medical University of Vienna developed a 3D-printed OCT system demonstrator (see Figure 2), which primarily serves as an inexpensive housing for standard OCT components. This device showcased at the Lange Nacht der Museen (Long Night of the Museums), where

approximately 1500 visitors learned about OCT and experienced live demonstrations.

To further promote OCT in educational and public settings, this project aims to design and build a second-generation demonstrator. The new version will replace standard opto-mechanical components, such as lens holders and translation stages, with 3D-printed parts, thereby reducing costs and simultaneously increasing accessibility.

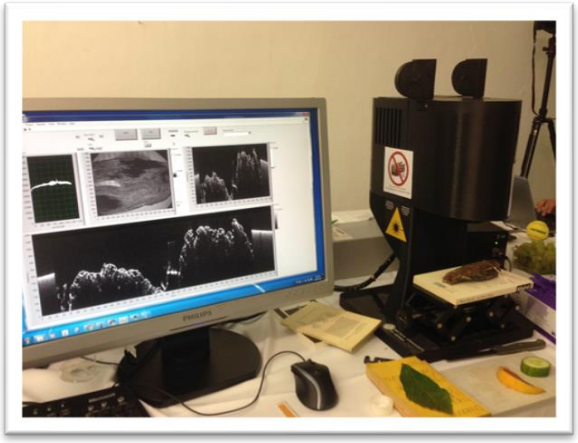

Figure 2 First-generation OCT demonstrator in use, imaging a dried muscle.

II. PROJECT OBJECTIVES

The primary objective of this project is to design and build a next-generation OCT demonstrator, focusing on reducing the cost and increasing the availability of open-source OCT components.

Specific objectives include:

- Defining the requirements for opto-mechanical parts for OCT application.
- Reviewing the expenses associated with standard opto-mechanical components for OCT (e.g. www.thorlabs.com).
- Designing and constructing opto-mechanical components using CAD software to create fixed and adjustable mirror/lens mounts, beam splitter holders, translation stages, polarization paddles, optical path alignment tools, and more.
- Printing, assembling, and testing individual components and the complete OCT system.
- Comparing the costs of commercial components with those of 3D-printed components.

The final product will be a functional OCT demonstrator that is more affordable and accessible, making it suitable for educational purposes and public exhibitions.

III. LEARNING OUTCOMES

By the end of this project, you will get familiar with:

- Proficiency in constructing and designing using CAD software for 3D printing.
- A solid understanding of the principles of OCT.
- Experience in integrating 3D-printed components into opto-mechanical systems.
- Practical, hands-on experience in assembling and testing complete OCT systems.

Literature

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Creating a Flexibility and Mobility Report with Motion Analysis in OpenCap Software for Injury Prevention

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***Summary* — This project focuses on improving the assessment of flexibility and mobility to prevent injuries and enhance health outcomes. Utilizing OpenCap's advanced markerless motion capture technology, students will identify and test effective exercises, develop a standardized movement routine, and create code to automatically analyze motion data. The project aims to provide accurate feedback into joint mechanics and muscle flexibility, leading to better rehabilitation strategies. Key learning outcomes include motion analysis, data processing, and the application of programming in healthcare.**

Keywords: ***Flexibility Assessment, Motion Analysis, Injury Prevention, Biomechanics***
Academic Level: ***Master, MME, 1st Semester***
Course: ***PRT 1***

I. BACKGROUND

Poor mobility and flexibility are significant contributors to a range of health issues. Insufficient flexibility can lead to an increased risk of injuries, particularly in the elderly, where it is associated with falls and subsequent loss of independence. Furthermore, limited joint range of motion has been linked to chronic pain conditions, such as low back pain, and can exacerbate musculoskeletal disorders. The lack of mobility not only hinders daily activities but also diminishes overall quality of life. Even in younger populations, muscle tightness can lead to specific injuries. For instance, increased iliopsoas muscle tightness has been identified as a predictive factor for developing lumbar pain in adolescent athletes.

This clear relationship between mobility, flexibility, and overall health emphasizes the need for effective assessment tools and interventions.

In recent years, the integration of advanced motion analysis technologies has become increasingly vital for enhancing injury prevention strategies and improving health outcomes. The proposed project aims to leverage the capabilities of OpenCap, a markerless motion capture software, to assess flexibility and mobility effectively. OpenCap has demonstrated comparable statistical power to traditional motion capture systems and force plate analysis, while significantly reducing the time required for data collection and analysis. By implementing a deep learning marker enhancer, OpenCap converts sparse data points into comprehensive biomechanical data, providing clinicians and researchers with detailed insights into joint mechanics and flexibility measurements. This capability is particularly valuable for

understanding the complex motions required in various therapeutic and athletic environments.

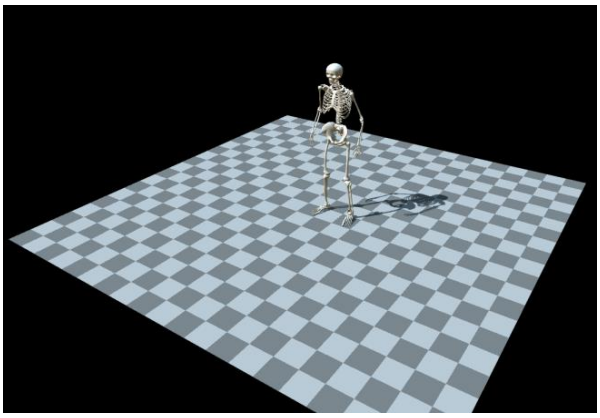

Figure 1: Screenshot of the skellet avatar representing the test person from the movement analysis in OpenCap software.

II. PROJECT OBJECTIVES

The objectives of this project are to:

- Identify the most effective exercises/tests for assessing overall flexibility and mobility
- Develop a movement routine for OpenCap
- Create code to automatically analyze motion analysis files
- Generate a report to highlight muscle shortening and joint movement limitations
- Create a GUI for report settings

The students need to start by researching and selecting exercises or tests that are most indicative of overall flexibility and mobility. This involves reviewing scientific literature and expert recommendations to identify exercises that not only measure flexibility and mobility accurately but also contribute to injury prevention and health promotion. These exercises will form the basis for further analysis.

Once the key exercises have been identified, the students should perform these exercises using the OpenCap motion analysis software. The goal is to collect data on specific metrics such as knee angles, hip flexor angles, and other relevant measurements that provide insight into the individual's flexibility and mobility.

After conducting the exercises, the students should critically evaluate the accuracy of the measurements obtained from OpenCap. They need to determine if the data collected is precise enough to provide meaningful insights into the person's flexibility and mobility. If the measurements are not sufficiently accurate, the students should identify and replace the exercise with one that yields better results.

Based on the exercises that have proven to yield accurate and meaningful data, the students should design a standardized movement routine. This routine will serve as the baseline for future assessments of patients' flexibility and mobility, ensuring consistency and reliability in measurements.

The final and main task involves writing code that can automatically analyze the motion analysis files generated from OpenCap. The code should process the data to identify patterns, such as muscle shortening and joint movement restrictions, and then generate graphs that visually represent these findings. This visualization will help in quickly assessing a patient's condition and identifying areas that need improvement. The report's content shall be controlled via a GUI to display only the relevant information.

Three IPads can be borrowed from UAS Technikum Wien whenever needed for conducting motion analysis.

Requirements for the specific tasks are programming skills, hands-on mindset and the willingness to deal with medical journals.

Depending on the project's progress, the solutions might be tested with peer users.

III. LEARNING OUTCOMES

By the end of this project, you will learn to:

- Conduct low cost motion analysis while ensuring accuracy
- Critically examine the significance of measured values
- Process and analyse motion data
- Create a GUI

Literature

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Lung Simulation in Augmented Reality (AR) for Upper Airways

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***Summary* — Recent developments in augmented reality (AR) have shown the increasing potentials of this technology in healthcare applications. It has been shown that AR can improve the human understanding of complex anatomical structures, which can be effectively utilized to support medical training and education by creating immersive and interactive environments. The scope of this project is to take advantage of this technology to integrate anatomical geometry medical image data generated from medical simulations into AR environments to provide real-time visualization of lung function, including cross-sectional views and detailed analysis of airflow dynamics. The results will cover various breathing conditions, offering an innovative approach to understanding complex respiratory processes.**

Keywords: Lung Simulation, Augmented Reality, 3D Modeling, Upper Airways, Flow simulation
Academic Level: ***Master , MME***
Course: ***PRT***

I. BACKGROUND

Understanding how air moves through the upper airways is essential for diagnosing and treating respiratory conditions. Due to the complex nature of the air flow in the air ways, traditional methods often struggle to convey the complexity to the medical staff. Augmented reality (AR) offers an advanced way to visualize lung function interactively and in real-time, which can significantly improve both educational and clinical outcomes [1], [2].

To achieve that, 3D simulated animations that take into account the geometry, density, shape, and types of vital organs, pathways and air particles are usually used to offer the scientific understanding of the processes of particle deposition and air flow. These animations are then integrated in the AR environment to provide user-friendly visualization.

A recent study showed the potential of deploying these techniques to quantify COVID-19 Infections in the Lung [1]. A. Farnoud *et al.* similarly demonstrated the possibility to analyze nasal drug delivery by integrating large eddy simulations [3]. Another paper described deploying these techniques in thoracic surgery settings for preoperative planning and intraoperative assistance, where it enhances procedural accuracy and surgical confidence by providing detailed 3D-renderings of the thoracic cavity and lung anatomy [4].

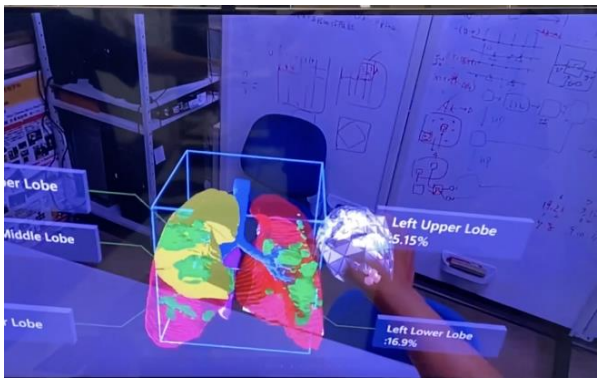

Figure 1: A user observes a patient's lung using an AR immersive experience. [1]

II. PROJECT OBJECTIVES

The aim of this project is to develop an AR tool that offers an interactive 3D visualization of a lung model which can simulate airflow and particle deposition through the airways using augmented reality techniques for integration and visualizations. The students will mainly focus on literature research about the techniques used in data acquisition, computational fluid dynamics (CFD) simulation, 3D modeling techniques and game engines. This educational tool will help illustrate how various respiratory conditions impact airflow, contributing to a deeper understanding of breathing conditions.

The objectives of this project are to:

- comprehensive literature review on state-of-the-art procedures related to upper airway airflow and particle distribution, as well as lung modeling for effective respiratory simulation.
- Utilize an upper airway geometry from published studies, integrate a pre-existing asset, or design a 3D model from different medical 3D imaging data to simulate respiratory airflow patterns and particle deposition in the human airways [1]
- Develop the AR tool: incorporate the previously conducted simulations into the AR environment to visualize lung function and airflow dynamics within the upper airways to:
    - Provide real-time visualizations of airflow within the upper airways under various conditions. [3]
    - Allow users to interact with the AR visualization, such as zooming in/out, rotating the model, and viewing cross-sections of the airways. [4]

By achieving these project objectives, the 3D respiratory model will provide an engaging and informative platform for users to explore the anatomical aspects of the upper airways in an interactive and visually appealing manner, while also simulating different breathing conditions for real-time exploration of airflow within the upper airways. The AR tool can be compared against existing visualization methods to ensure its effectiveness and accuracy.

In this project, the student can choose from various 3D modeling techniques, flow simulation methods, and AR platforms (such as Unity, ARToolKit, or Google ARCore) that best match their skills. Programming skills and a high level of creativity in problem-solving are key requirements. Depending on the project's progress, the solutions may be tested with peer users

III. LEARNING OUTCOMES

By the end of this project, you will get familiar with:

- Apply animation and modeling techniques to demonstrate the lung functionality.
- Analyze various respiratory airflow patterns and particle distribution in the human airways.
- Develop an interactive AR tool capable of real-time visualization of airflow dynamics under different breathing conditions and perform cross-sectional analyses of airflow within different sections of the airways.

Literature

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Patient Journeys – Starting with a First Step

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Summary — This project explores the integration of IT solutions in healthcare, focusing on the "Patient Journey"—the pathway patients follow through various stages of care, from ambulatory services to hospitalization, aftercare, and therapy. The goal is to design and develop a flexible IT system that enables seamless information flow and bi-directional communication among healthcare providers, patients, and their families. The project begins with a gap analysis of existing IT solutions to identify areas where current systems fail to support efficient medical information exchange and coordinated care. Based on this analysis, students will develop software prototypes using standardized protocols like HL7 FHIR. While specific implementation details may evolve, the foundational work will establish a versatile architecture adaptable to future needs. By the project's conclusion, participants will gain both theoretical knowledge and practical experience in creating integrated, patient-centered healthcare systems.

Keywords: ***Patient journey, standardized communication, HL7 FHIR***
Academic Level: ***Master , MME,***
Course: ***PRT***

I. BACKGROUND

The healthcare sector is increasingly reliant on IT-based services to support healthcare providers in their daily routines. One of the critical areas of focus today is the sharing of information among and between physicians. Standardization organizations specify data models and communication interfaces to harmonize data formats and communication pathways. These efforts often result in encapsulated systems designed to fulfill specific purposes.

However, considering the complex needs of real-world healthcare, a more comprehensive IT system would be preferable. The concept of the "Patient Journey" [1] focuses on the complex pathways a patient navigates within the healthcare setting, such as transitioning from an ambulatory setting to hospitalization, followed by aftercare, therapy, and the necessary social services during recovery. In an ideal scenario, IT solutions and architectures should facilitate a seamless flow of information among healthcare providers, doctors, nurses, caregivers, and—importantly—patients and their relatives.

In addition to integrating available information, these systems should support workflow management to track and update patient care plans. This also necessitates bi-directional communication among the involved participants, addressing not only questions concerning documented decisions but also other critical aspects of patient care. Ultimately, such a system would require levels of automation (potentially supported by AI) to assist in managing patient journeys effectively.

II. PROJECT OBJECTIVES

The objectives of this project are to:

- Explore patient journeys across multiple healthcare providers.
- Investigate existing IT solutions for interconnecting healthcare providers and conduct a gap analysis.
- Develop software prototypes to address identified gaps.

Specifically, the project will identify missing or needed components, such as infrastructure for the exchange of medical documents and information, bi-directional communication between (1) healthcare providers, (2) healthcare providers and patients/relatives, and (3) different patients, as well as automation processes that support the overall patient journey. Based on the gap analysis, software solutions will be developed to bridge selected gaps, utilizing standardized communication standards.

While the specific objectives may evolve as the project progresses, depending on the focus areas identified by students or experts, the general concepts can be designed and developed from the outset. This initial groundwork will serve as a backbone for the final solution, ensuring that the core infrastructure and fundamental components are robust and adaptable.

Throughout the project, students may choose to concentrate on specific aspects of the implementation, such as enhancing bi-directional communication between healthcare providers and patients or automating key processes within the patient journey. This flexibility allows the project to accommodate varying interests and expertise while still aligning with the overall goal of creating a comprehensive, patient-centric IT system.

III. LEARNING OUTCOMES

By the end of this project, participants will:

- Gain familiarity with patient journeys and current approaches in healthcare (theoretical).
- Understand IT architectures, communication standards, frameworks, and terminologies either currently in use or applicable to new scenarios (theoretical).
- Acquire practical experience in implementing FHIR-based [2] software applications (practical).

Participants will explore the theoretical aspects of patient journeys, including the current challenges and existing solutions within the healthcare system. This project presents a novel approach to designing a healthcare system that equally addresses the needs of both patients and healthcare professionals, with the potential to revolutionize the sector. IT architectures based on harmonized and standardized use cases and requirements will provide the necessary building blocks. Furthermore, implementing HL7 FHIR applications will offer valuable insights into this widely adopted communication model, which is becoming a standard in healthcare software systems. Other standards, such as HL7 CDA, might also be considered as alternatives to FHIR, as they are still in use today. In combination with standardized vocabularies, this could achieve both semantic and syntactical interoperability. Finally, the integration of workflow digitalization and automation technologies will contribute to a more patient-centric healthcare system.

Literature

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Mapping of Standardized Data Formats

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Summary —This project aims to explore and develop methods for mapping medical data between different formats used in healthcare, specifically focusing on the transition from primary use formats (HL7 CDA and HL7 FHIR) to secondary use formats (OHDSI OMOP CDM). The project will involve studying existing communication standards, investigating technologies like the MaLaC-HD mapping tool, and defining mapping rules using the HL7 FHIR Mapping Language. Participants will gain in-depth knowledge of these data models, relational databases, and harmonized terminologies. While the project does not require application development, it will focus on creating robust IT communication strategies that facilitate seamless data transformation. The outcomes will support the efficient exchange of medical information, bridging the gap between data documentation and scientific research, ultimately benefiting healthcare professionals, researchers, and patients.

Keywords: ***Mapping, Medical Data Format, HL7 FHIR, OHDSI, OMOP***
Academic Level: ***Master , MME,***
Course: ***PRT***

I. BACKGROUND

Over the past decade, significant efforts have been made to facilitate the sharing of medical data and information between healthcare institutions and professionals. Communication standards have been developed and implemented to standardize data sharing practices and establish common terminologies, aiming to achieve semantic interoperability. However, there is no single communication standard or terminology universally adopted across the healthcare sector. Instead, multiple approaches exist, each serving specific purposes. Furthermore, newer standards are gradually replacing older ones, but the ability to interpret information in legacy formats remains crucial, necessitating the development of mapping strategies.

Another challenge lies in transforming data used for documenting patient health status into formats suitable for large-scale scientific research (i.e., the primary versus secondary use of medical data). Key data formats relevant in Austria and globally include HL7 CDA and HL7 FHIR [1] for primary use, and OHDSI (OMOP) CDM [2] for secondary use. Establishing mappings between these formats would enable the translation of information from the older CDA standard (ref Austrian Implementation Guides [3]) to the newer HL7 FHIR standard, or from HL7 FHIR to OMOP.

In summary, healthcare depends on the accurate transformation of data into the required formats based on the context and purpose of data sharing.

II. PROJECT OBJECTIVES

The objectives of this project are to:

- Explore communication standards used for primary use (CDA and FHIR) and secondary use (OMOP).
- Investigate available technologies for mapping between different formats (e.g., the mapping tool MaLaC-HD).
- Define and implement mapping rules to convert data between formats and terminologies (using tools like the FHIR

Mapping Language) and demonstrate the representation of mapped data.

The project will begin by acquiring in-depth knowledge of the chosen data formats, with a focus on specific application areas. Currently, HL7 FHIR and OMOP are of particular interest, as they bridge the gap between the emerging European Health Data Spaces for primary and secondary data use. Participants will also need to understand and investigate applicable terminologies. Finally, mapping approaches, such as those using MaLaC-HD, will be explored and iteratively tested using specifications from HL7 Europe (e.g., HL7 Europe Laboratory Report) and the OMOP data model provided by OHDSI. This process will involve defining mapping rules that can be applied to transform data from one format to another.

III. LEARNING OUTCOMES

By the end of this project, participants will:

- Understand the HL7 FHIR and OMOP data models.
- Enhance their knowledge of relational databases.
- Gain familiarity with harmonized terminologies used in the selected field of application.
- Apply HL7 FHIR Mapping Language to develop mapping routines for the data models and terminologies.
- Potentially implement configuration tools to assist in specifying mapping rules or develop visualization tools to simplify the interpretation of these rules.

Although this project does not mandate the development of applications, it is highly focused on IT communication standards. The project aims to explore and demonstrate how mapping between different medical data formats can be achieved. This work will pave the way for seamless transformation between primary and secondary data use, ultimately benefiting patients, healthcare professionals, researchers, and policymakers.

Literature

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