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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
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University of Applied Sciences Technikum Wien

**Contributions
Biomedical Engineering
Bachelor Study Program
Group Posters**

Wearable Heart Rate and ECG Monitoring

C. Fernandez Gonzalez, N. Kameoka, S.Mäkelä, B.Schlögl and J.Tesch

Abstract

We developed a low-power wearable ECG monitoring system capable of continuous real-time heart activity tracking. The device integrates a 3-lead electrode setup, an ESP32 microcontroller, local SD-card storage and BLE telemetry to a custom Flutter mobile app. Bench testing demonstrates stable signal acquisition, reliable R-peak detection and accurate HR/HRV computation suitable for long-term ambulatory monitoring.

Introduction

Long-term cardiac monitoring requires a solution that is comfortable, unobtrusive and capable of capturing reliable ECG signals during everyday activity.

Traditional ECG systems are designed for short clinical recordings and restrict natural movement, making them unsuitable for continuous use.

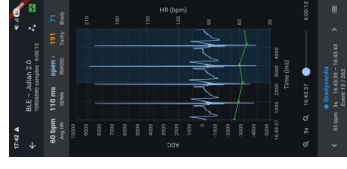
This project explores a wearable ECG concept that integrates textile-based electrodes with a compact embedded system to enable real-time signal acquisition and wireless transmission.

The aim is to provide a foundation for practical daily rhythm monitoring outside clinical environments.

Results

System Performance

- The prototype can successfully record and transmit ECG data continuously for at least six hours.
- The application works on Android and Apple devices.
- The application is able to display the ECG signal, heart rate, and a list of detected abnormalities.



Hardware Validation

- The assembled circuit integrates the ESP32 microcontroller, AD8232 ECG module, and microSD interface.
- Bench tests verified stable power delivery and synchronized data acquisition between analog and digital subsystems.



Discussion

The prototype demonstrated that a compact wearable system can capture stable ECG signals and support real-time heart-rate analysis during everyday activity.

The combination of local SD-card logging and BLE streaming proved reliable, ensuring continuous data availability even during connection interruptions.

Motion artifacts and electrode placement variability remain the main factors affecting signal quality, indicating the need for improved filtering and garment integration.

Despite these limitations, the system provides a solid foundation for practical long-term rhythm monitoring and shows clear potential for further development toward more advanced analytics and extended usability.

Next Steps

- Improve signal quality** by optimizing electrode placement and enhancing motion-artifact filtering.
- Refine wearable integration** through better textile design to increase comfort and long-term usability.
- Expand analytics** with additional rhythm-analysis features such as AV-block detection and advanced HRV metrics.
- Conduct extended testing** to validate performance against available reference data under real-world conditions.

Materials & Methods

The wearable ECG prototype consists of a three-electrode configuration connected to a AD8232 ECG module and controlled by an ESP32 microcontroller.

Analog signals are digitized at 500 samples per second and stored locally on a microSD card while simultaneously transmitted via Bluetooth Low Energy to a smartphone application.

The mobile app, developed in Flutter, visualizes real-time ECG waveforms and calculates heart-rate and HRV parameters.

Power is supplied by a portable battery pack enabling continuous operation for over six hours.

Signal processing includes band-pass and notch filtering to reduce motion and power-line noise, followed by R-peak detection, using the pan Tomkins algorithm, for HR and anomaly analysis.

WEARABLE ECG - SYSTEM

Biomedical Engineering

Cabak, Fischer, Bajlitz, Martincova, Hama - Reda

Introduction

Cardiovascular diseases are among the leading causes of death worldwide, making continuous heart monitoring increasingly important. This project focuses on developing a wearable ECG system that continuously monitors heart rate and ECG signals. The system utilises biosensors to capture cardiac signals and detect potential arrhythmias, while software algorithms process, analyse, and visualise the ECG data in real time.

Objective

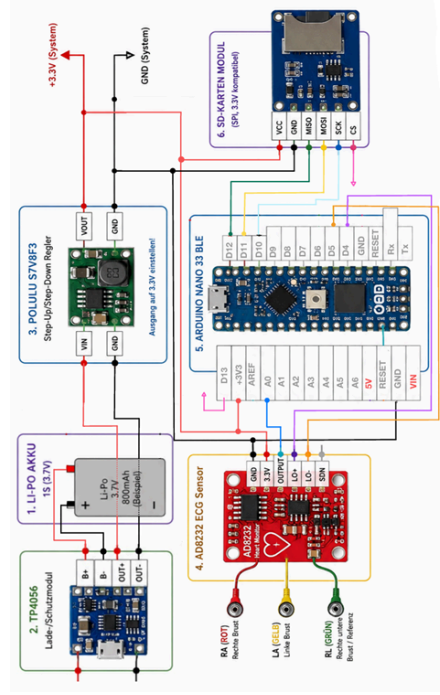
- Design and develop a wearable ECG acquisition system
- Wireless data transmission
- Low power consumption
- Lightweight
- Filtering and visualization
- Disease detection

References

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- <https://www.ncbi.nlm.nih.gov/books/NBK254/>
- <https://ecgwaves.com/topic/ecg-normal-p-wave-qrs-complex-st-segment-t-wave-j-point/>
- <https://www.ahajournals.org/doi/10.1161/circulationaha.106.180200>

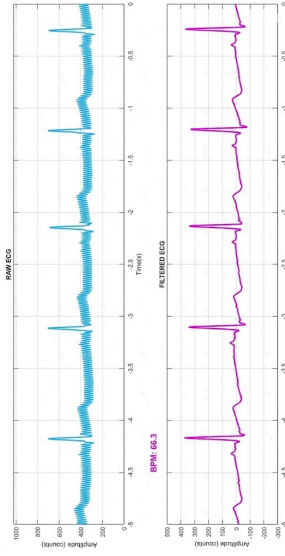
Materials & Methods

- ECG sampling at 250–500 Hz
- High-pass filter (0.5 Hz) to remove baseline drift
- 50 Hz notch filter for power-line interference suppression
- Low-pass filter (40 Hz) for high-frequency noise reduction
- Real-time R-peak detection and heart rate calculation
- Wireless transmission via Bluetooth
- Real-time visualization and processing in MATLAB
- Continuous monitoring of ECG waveform and heart rate



Results

- Successful acquisition of a 3-lead ECG signal
- Improved signal quality through analog and digital filtering
- Clear identification of ECG waveform features (QRS complexes)
- Real-time heart rate calculation implemented
- Wireless Bluetooth data transmission achieved
- Detection of bradycardia and tachycardia demonstrated



Discussion

- Functional proof-of-concept successfully developed
- ECG acquisition and BPM calculation worked reliably
- Bluetooth communication enabled wireless monitoring
- Future work: AF detection, AV-block detection, mobile app integration, SD-card logging and HRV analysis

Wearable Stress Monitoring

Authors: Ashmaan Saifee, Christian Kurz and Dilara Külec
Biomedical Engineering, UAS Technikum Wien, Vienna, Austria

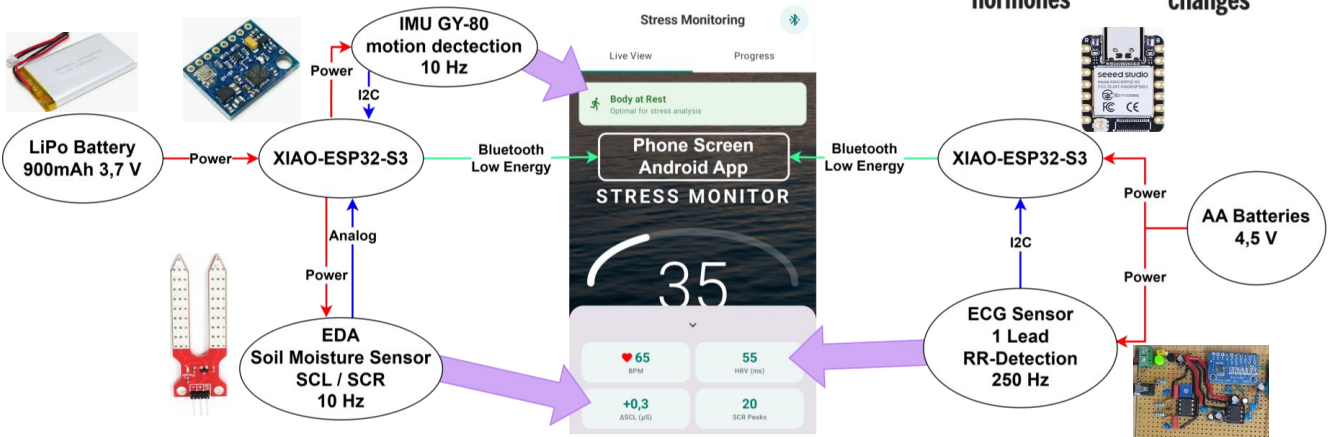
Abstract

This project presents the first-prototype for stress monitoring. Physiological and motion-related data are collected and sent to an Android-app via BLE. There data are processed and compared with a personal baseline to estimate the user's stress level.

Introduction

In this project, a multimodal approach is used to detect stress with ECG and EDA sensors. An IMU sensor is added to detect motion artefacts.

Materials & Methods



Results

The prototype shows the main workflow of the stress monitoring system. Sensor data can be sent to the Android app. Main screens: Live Session, History, and Summary. Four Stress feedback levels: Relaxed, Mild, Moderate and High. ECG, EDA, and IMU data are focused measurement sessions, handled as separate inputs and then improved signal quality and artefact detection.

Discussion

The prototype compares the current measurements with the user's own resting state. Movement information and artefact handling are important for a reliable interpretation of data. Future work should focus on more user sessions, improved signal quality and artefact detection.



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Non-Invasive Monitoring System for Respiratory Rate and Oxygen Saturation Measurement

Felix Dietl, Stefan Freyberger, Mohamed Amin Hamrouni, Vanessa Holzweber

ABSTRACT

This project presents a compact wearable system for monitoring SpO₂, heart rate, and respiratory rate. Using a microcontroller, PPG sensor, and OLED display, it combines PPG and thoracic impedance measurements with digital signal acquisition and analysis.[1,4]

INTRODUCTION

Monitoring of SpO₂, heart rate, and respiratory rate is essential in healthcare, even though existing systems are often expensive or limited to clinical settings. This project presents a compact, low-cost prototype for vital sign monitoring. [2]

MATERIALS & METHODS

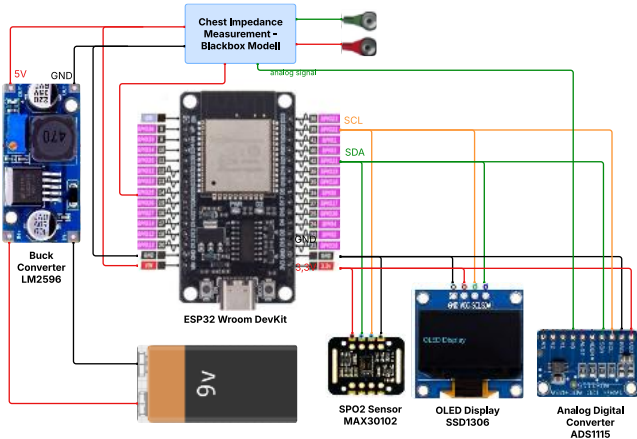


Figure 1: System overview of the wearable monitoring prototype.

Used Methodes:

1. PPG for SpO₂ and heart rate
2. Thoracic impedance for respiration measurement
3. Embedded signal processing with ESP32

System Part	Description
ESP32	Data processing & control
MAX30102	SPO2 and heart rate sensing using red/IR LEDs
Chest electrodes	Respiration measurement via thoracic impedance
Signal processing	Filtering, amplification & ADC conversion
Software	Arduino IDE, LTspice, I ² C communication

Table 1: Components and functions of the monitoring system.

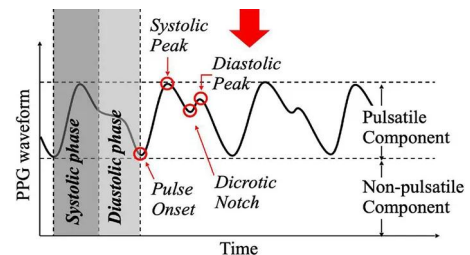


Figure 2: Characteristic PPG waveform with annotated signal features.[3]

RESULTS

Prototype Performance

- Stable PPG signal acquisition achieved
- Real-time SpO₂ and heart rate display
- Detection algorithm reduced invalid readings
- Respiratory waveform extracted in simulation

✓ HR ✓ SpO₂ ✓ IR

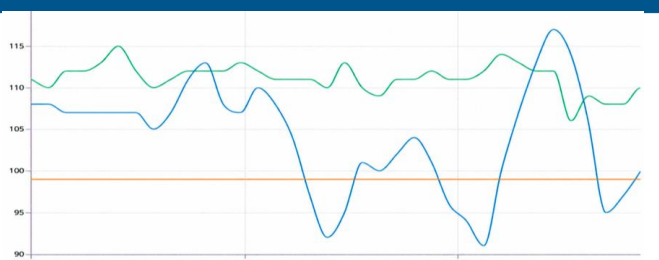


Figure 3: Simulated respiratory waveform from thoracic impedance measurement.

DISCUSSION

The prototype demonstrate real-time measurement of SpO₂, heart rate, and respiratory rate using compact, low-cost hardware (total cost below ~50 €). Its modular design supports future wearable integration, though signal quality remains sensitive to motion artefacts and ambient light. Future work will focus on the impedance measurement and improved filtering. [4, 5]

References: [1] J. Allen, Photoplethysmography and its application in clinical physiological measurement, *Physiol. Meas.*, vol. 28, no. 3, pp. R1–R39, 2007. doi: 10.1088/0967-3334/28/3/R01 [2] A. Jubran, Pulse oximetry, *Crit. Care*, vol. 19, no. 1, p. 272, 2015. doi: 10.1186/s13054-015-0984-8 [3] J. Park et al., Photoplethysmogram Analysis and Applications: An Integrative Review, *Front. Physiol.*, vol. 12, p. 808451, 2022. doi: 10.3389/fphys.2021.808451 [4] A. K. Gupta, Respiration Rate Measurement Based on Impedance Pneumography, Texas Instruments, 2011. [Online]: [ti.com/lit/an/sbaa181](https://www.ti.com/lit/an/sbaa181) [5] C. Redmond, Transthoracic Impedance Measurements in Patient Monitoring, Analog Devices, 2013. [Online]: Available: <https://www.ti.com/lit/an/sbaa181/sbaa181.pdf>

Obstacle Avoidance on a Wheelchair using Time-of-Flight Sensors

Authors: Demian Höferl (be24b045), Sebastian Luberdä (be24b007), Clemens Mandl (be24b072), Florian von Gäßler (be24b046)

Abstract

This project investigates the feasibility of a sensor-based assistance system using time-of-flight (ToF) sensors to detect nearby obstacles and improve navigation safety. A proof-of-concept prototype and a second multi-sensor prototype were developed using VL53L8CX sensors, an ESP32S3 microcontroller, and a web-based user interface for wireless real-time visualization.

Introduction

Wheelchair users often encounter obstacles in everyday environments, especially in narrow indoor spaces. This project investigates a low-cost obstacle detection system using time-of-flight (ToF) sensors to improve navigation safety. The aim is to detect nearby obstacles and provide intuitive feedback through a web-interface on a smartphone.

Materials and Methods

• **Batterypowered:** USB Powerbank



4x VL53L8CX [5]

- 4000mm Range
- 60° FOV + 8x8 Resolution

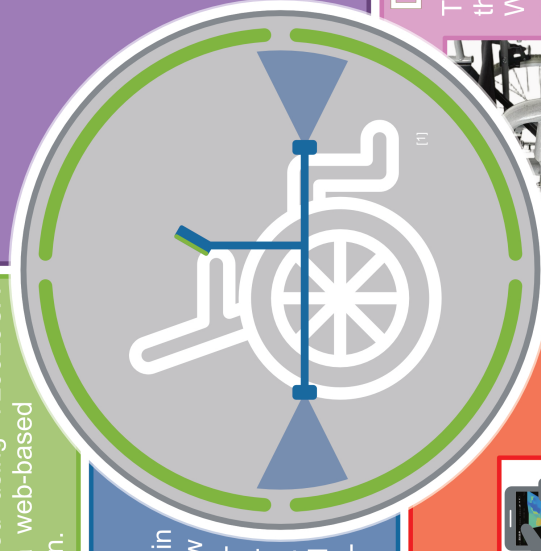
ESP32 S3 [3]

- Interpolation
- Interpretation



Webserver [4]

- Visualization
- Data-Logging



Results

Hardware:

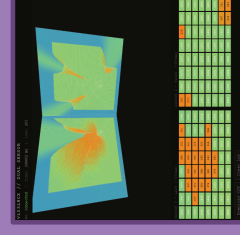
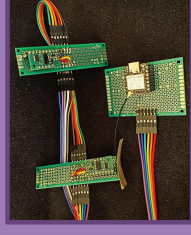
- I²C Protocol: re-addressing using LP-pins
- 8 Lane Bus: VCC, GND, SDA, SCL, 4x LP

Limitations:

- direct sunlight
- reflective surfaces

Interface:

- 2 Sensors / Frame
- Data Matrices
- Download CSV
- Gyroscopic measurements



Discussion

The prototype confirms the **technical viability** of the chosen components and system architecture. While steps towards mounting the system to a wheelchair have been taken, a full implementation has not been achieved. Future plans include the use of cat8 cables to achieve stable and secure communication between each peripheral unit.



Impressum

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 - Dipl.-Ing. Dr. techn. Harald Sina (harald.sina@technikum-wien.at)

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- Images:**
 [1] SVG Wheelchair: SVG Repo, <https://asing.svgrepo.com/svg/69672/wheelchair>
 [2] VL53L8CX Image: Pololu Robotics & Electronics, <https://www.pololu.com/product/3419>
 [3] Xiao ESP32S3 Image: seed studio Wkt: https://wiki.seedstudio.com/xiao_esp32s3_pin_multiplexing/

- [4] SVG Smartphone: SVG Repo, <https://www.svgrepo.com/svg/5145/hand-graving-smartphone>
Sources:
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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.

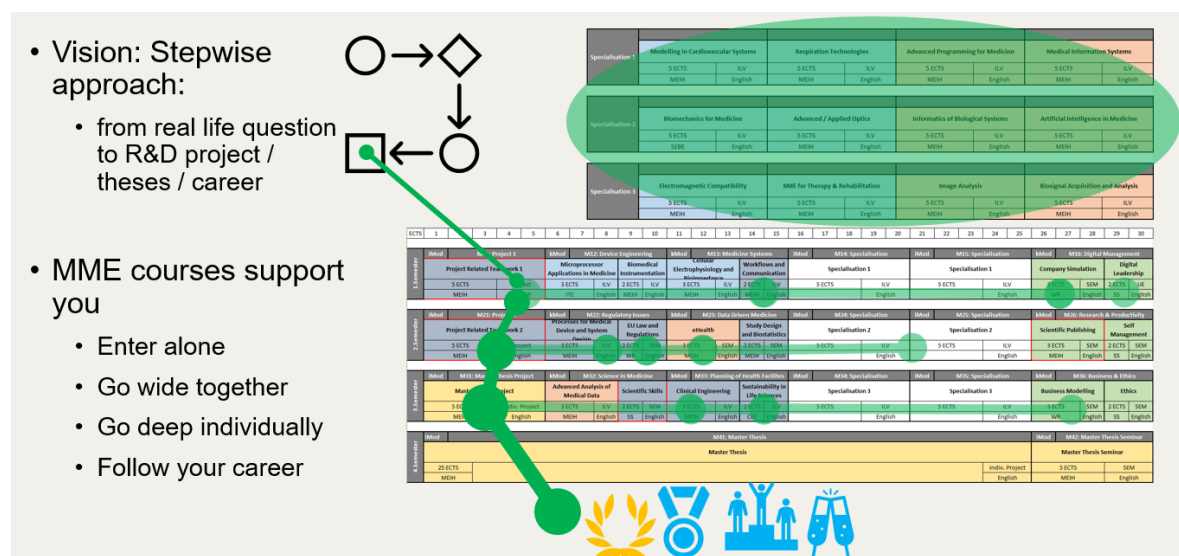


Figure 1: Schematic depiction of a student’s pathway: choosing and engaging in projects that contribute to solving healthcare pain points along the way.

**Contributions
Medical Engineering & eHealth
Master Study Program
Group Papers**

Heart Hackathon

Bedran Aksu, Patricia Glavas, Thomas Schwab, Mohammad Teimori
University of Applied Sciences Technikum Wien
Supervisor: Marcus Granegger

Abstract - Total artificial hearts (TAHs) are mechanical circulatory support systems for patients with end-stage biventricular heart failure. This project investigates a TAH concept based on a progressive cavity pump (PCP). The work extends the previous semester status with an updated prototype strategy, a passive magnetic bearing layout, a TwinMesh to Simcenter STAR-CCM+ workflow, and a revised drive concept. The cardan shaft compensates the angular and eccentric offset between the motor axis and the PCP rotor motion and transfers torque to the rotor. This solution lowers prototype complexity and supports experimental validation before an implantable drive architecture is developed. Results include a 3D- manufactured rotor-stator prototype with integrated magnets, structured mesh generation, and first transient STAR-CCM+ runs. Additionally, the current prototype drive system includes a cardan shaft system which could be operated with a conventional DC motor.

I. INTRODUCTION

Heart failure and the shortage of donor organs drive the need for long-term mechanical circulatory support. A Total Artificial Heart (TAH) replaces both ventricles and all four heart valves, enabling their use in complex cardiac conditions. Early TAHs were based on positive-displacement pumping principles, but they were limited by size and durability [1], [2], [3]. In contrast, modern systems, such as BiVACOR's TAH, commonly use rotary blood-pump architectures, which offer compactness and fewer moving parts, but may also introduce disadvantages such as non-physiological flow characteristics, limited pulsatility, high-shear regions, hemolysis and thrombosis risks. Progressive Cavity Pumps (PCPs) are a compact rotary positive-displacement devices, that generate a continuous, low-pulsation, valve-free flow through sealed rotor-stator cavities, making them suitable for steady flow applications [4]. Based on these characteristics the previous team chose to investigate a PCP-based TAH concept. The PCP contains two separate channels that simultaneously transport blood to the systemic and pulmonary circulatory systems (see Figure1).

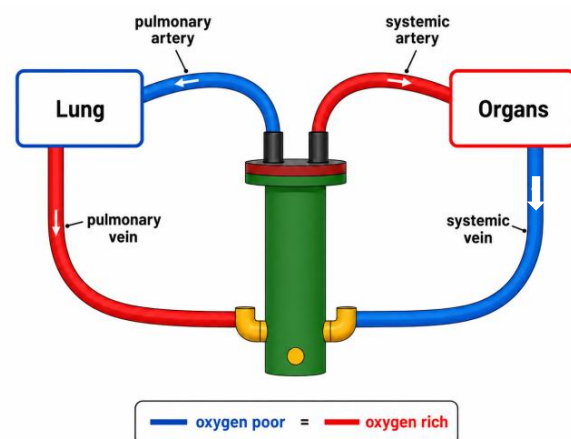


Figure 1: Prototype of the TAH illustrating how the two separate circuits are connected to the cardiovascular system.

II. MATERIALS & METHODS

A. Hardware

Pump Prototype:

The current hardware status comprises a resin-based 3D-printed rotor and stator fabricated from a rigid, transparent photopolymer resin. The prototype was designed and developed in CAD (Fusion 360) and manufactured to analyse movement-related challenges and to support the configuration of the magnetic bearing system, which consists of repelling

permanent magnets along the rotor and stator for stabilization (position of magnets shown in Results Figure 5).

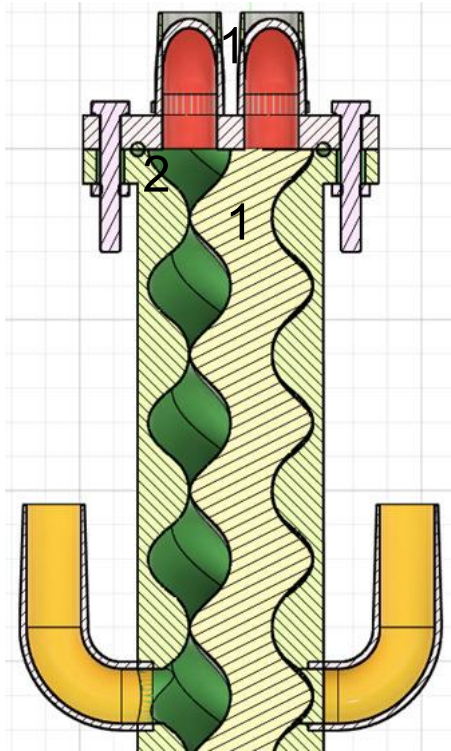


Figure 2: Hardware architecture - Progressive-cavity TAH concept. The helical rotor (1) turns inside the stator (2) and moves the volume in the cavities from inlet to outlet. With this movement, pulsatile flow is created without valves.

Drive System Concept

Due to its geometry, the PCP requires both rotational and eccentric movement of the rotor. Therefore, a cardan shaft (universal joint shaft), is selected as the coupling element between the DC motor and the rotor. This component enables torque transmission between non-aligned axes and compensates for the angular and eccentric displacement between the motor axis and the rotor axis. Therefore, the rotor can follow the progressive cavity motion inside the stator, while continuous rotation and simple speed could be provided using a DC motor.

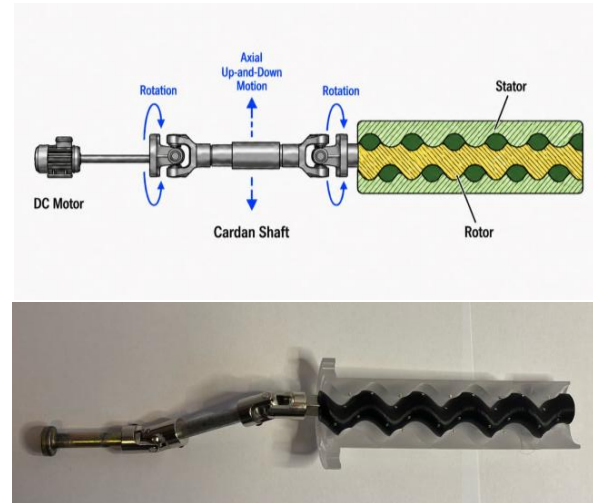


Figure 3: Figure: Main mechanical configuration of the PCP system. DC motor transmits rotational motion to the pump through a cardan shaft. The blue arrows indicate the rotational movement at the shaft couplings and the axial up-and-down motion of the intermediate shaft during operation.

B. Software

TwinMesh is used for structured hexahedral mesh generation for positive-displacement machines, including gap resolution. The mesh is imported into Simcenter STAR-CCM+ for transient CFD. Blood is modeled with a non-Newtonian law, for example Carreau-Yasuda or Quemada. Post-processing includes:

- Pressure rise across the pump and flow rate to derive a pressure-flow relation
- Volumetric efficiency and leakage indicators
- Wall shear stress and time-averaged shear metrics as hemolysis screening indicators
- Residence time and recirculation zones as thrombosis risk screening indicators

III. RESULTS

CFD Simulations:

TwinMesh meshing steps including the STAR-CCM+ import and post-processing pipeline are set up. Initial CDF results show that the pressure is not uniform along the pump length. Lower pressure values (blue green range in Figure 3) are observed near the inlet side, while the pressure progressively increases toward the outlet side resulting in a peak pressure of 45 mmHg and outflow of 9.62 L/min.

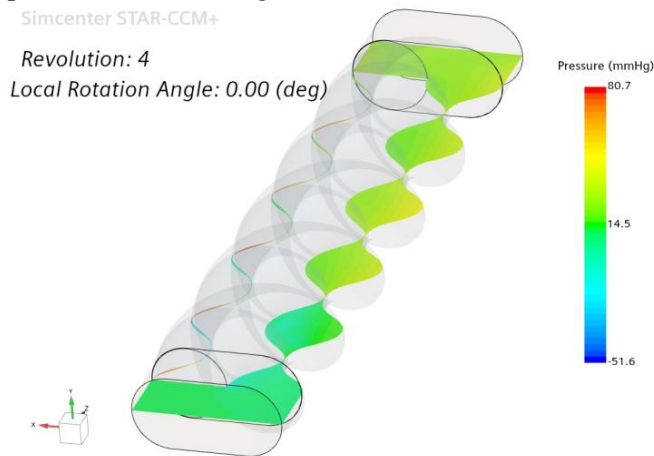


Figure 4: Pressure distribution in the chambers of the PCP. Constant flow and density (1050kg/m^3); viscosity: 3.5 cPa .

Bearing developments resulted in implementing a passive bearing system. Permanent passive magnets with dimensions of $1\times 1\times 1\text{ mm}$ and a holding force of 0.69N (on iron) are positioned along the axial direction, following the helical structure of both parts. Contact-free stabilization of the rotor is achieved by arranging the rotor and stator magnets such that opposite poles face each other. (see Figure 5).

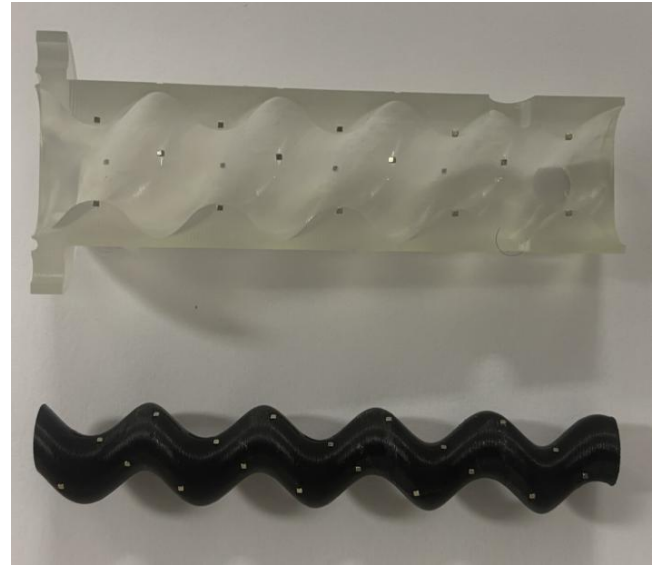


Figure 5: Photo of passive-magnetic bearing system showing the position of the magnets in the 3d manufactured prototype of the PCP.

IV. DISCUSSION

Static Test Loop- Step planned for July 2026

To validate whether the simulated flow and pressure generated from the pump are sufficient, a static test loop will be implemented to experimentally evaluate the generated flow rate and pressure characteristics of the TAH prototype. Two reservoirs will represent the left and right ventricular volumes. The pump inlets will be connected to the respective reservoirs, while the outlets will return the fluid back into the system. Pressure sensors (TruWave™ Disposable Pressure Transducers) and flow probes (Sonoflow CO.55/100 V2.0) will be installed on the outflow grafts to measure pressure and volumetric flow rate. This setup will allow direct comparison between experimental results and CFD predictions.

This paper presents an initial framework for the development of a PCP-based TAH, with emphasis on simulation-driven design evaluation. The primary contribution lies in establishing structured CFD results, capable of assessing hydraulic performance at an early design stage. The chosen methods, combining structured hexahedral meshing using TwinMesh with transient CFD simulation in Simcenter. CFD results show different pressures at certain cavities of the pump, which indicates that the

rotating cavity mechanism transports the fluid from one chamber to the next and produces a gradual pressure build-up along the axial direction. The proposed magnetically stabilized drive concept, using passive magnets, shows that the implementation of magnets along both the rotor and the stator can improve the stabilization of the desired rotor motion. This arrangement supports the rotor during operation and helps to reduce unwanted lateral displacement and mechanical instability. Therefore, the magnetic interaction between the rotor and stator is considered as a passive stabilization method, which can contribute to a more controlled and reliable movement of the pump drive system. The proposed drive unit concept represents a practical prototype solution, since it allows rapid assembly, variation of the rotational speed, visual inspection of the mechanical motion, and direct comparison with the CFD results. While these advantages make the system suitable for preliminary experimental validation, for a later implantable version, further design modifications are required. In particular, the electronics and the blood-contacting components must be separated and the overall size of the drive unit must be reduced.

Conclusion and next Steps

This project paper updates the previous semester's abstract for a PCP-based total artificial heart concept. The current work includes a printed rotor- stator prototype, a passive magnetic bearing arrangement, a TwinMesh to STAR-CCM+ workflow including preliminary results. Additionally, an updated prototype drive concept using a DC motor and cardan shaft is included.

Next steps include advanced CFD results, as well as the integration of the DC motor and cardan shaft combination in the existing prototype. Additionally, the prototype will be tested using a testbench, including sensors to validate pressure difference and flow rate.

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Electrical Impedance Tomography Model

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Abstract— The neonatal period is linked to a high risk of respiratory failure, therefore it requires continuous and reliable assessment of lung function. Electrical impedance tomography (EIT) is a non-invasive, radiation-free technique that allows for real-time monitoring of ventilation and lung recruitment, but its clinical application is limited by a lack of standardized calibration tools. This work presents the design of a size-scalable neonatal EIT phantom consisting of a transparent saline-filled tank, an inflatable lung model, surface electrodes, and an interface for a ventilator. A functional phantom prototype was manufactured, and lung characteristics were assessed. Additionally, the physiological lung model was compared to a pathological model, mimicking acute respiratory distress syndrome (ARDS).

I. INTRODUCTION

The neonatal period is one of the most vulnerable phases of human life, with respiratory complications being one of the most common causes of death. [1] Thus, real-time assessment of pulmonary functions is of high clinical relevance. EIT is a non-invasive, radiation-free imaging technique that monitors regional lung ventilation by measuring the changes in electrical impedance in the thorax using surface electrodes. Air-filled lung tissue exhibits a higher electrical impedance than surrounding tissues, therefore the cyclic changes in lung volume during breathing can be reconstructed into cross-sectional images. [2] This way EIT can assess pressure, allow for continuous monitoring of the pulmonary function, and test lung recruitment. Still, EIT is not routinely used in neonatal care due to limited awareness, definition of concrete EIT metrics, and artefactual data management. [3] Thus, the goal of this project is to develop a neonatal EIT phantom that mimics key physiological and anatomical properties of

neonates between 27 and 40 weeks of gestational age, such as total lung capacity (43 to 52 mL/kg [4]), tidal volume (6 mL/kg [5]) and chest circumference (19.8 to 27.4 cm [6], [7]).

Ultimately, the phantom is intended to be used as a potential platform for the calibration of EIT devices, validation of measurement protocols, and training applications. To achieve this, the phantom design must reproduce clinically relevant neonatal dimensions and lung volumes while being compatible with the Sentec LuMon™ EIT monitoring system. The phantom also requires a ventilator interface that is compliant with ISO 5356 standards to allow a connection to ventilators, in this case the fabian® HFO ventilator

To investigate both physiological and pathological ventilation patterns, two lung configurations were developed: a normal neonatal lung model and a lung model with reduced volume, representing the decreased compliance associated with ARDS. [8]

II. MATERIALS & METHODS

A. Software

To ensure scalability of the design across typical size configurations of preterm and term infants, an interactive Autodesk Fusion script [9] was implemented. Upon launch, the script prompts the user for relevant input dimensions, such as chest circumference, height of the torso, and total volume of the lungs (Fig. 7).

Literature-based suggestions for these parameters are provided for different growth stages. After confirmation, the compartments of the tank, a stand for the tank, and the molds for the tank walls and lungs are generated based on the provided input (Fig. 8). In a final step, the user can export the individual components for the subsequent manufacturing steps.

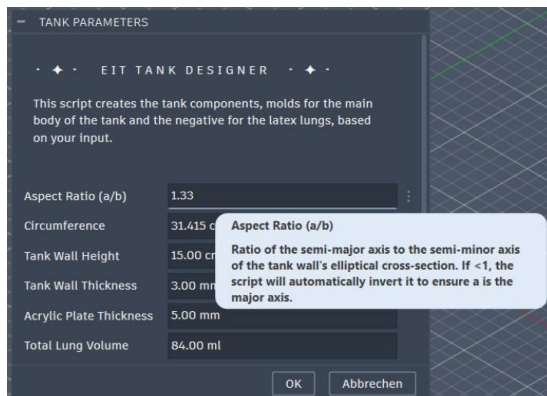


Fig. 7: Fusion script prompt for user input; pre-filled parameters for a term neonate

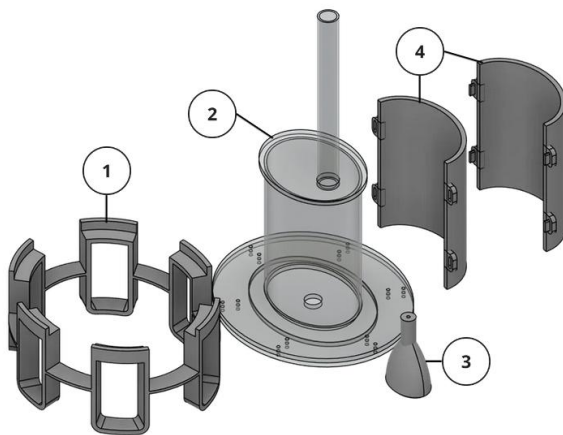


Fig. 8: Fusion script result; tank stand (1), tank compartment (2), and molds for tank wall (3) and lungs (4) generated from user input parameters

B. Hardware

For the assessment of compatibility with the ventilation and EIT system (Fig. 1), the Fusion script was used to design a term-equivalent prototype with a chest circumference of 31.4 cm and a total lung volume of 84 ml. These input parameters were derived from real 3D imaging data provided by Professor Fujibuchi from Kyushu University (CN)[10].

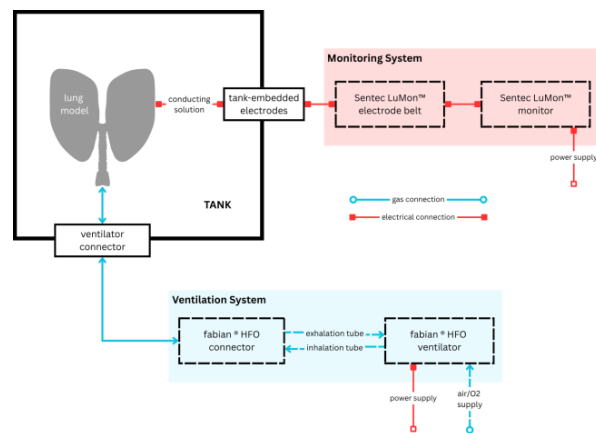


Fig. 1: System design and interfaces; red = electrical connections; blue = gas connections

The designed and manufactured prototype is composed of a transparent acrylic tank with a two-lobed flexible lung model mounted on a custom Y-connector. The latter is docked to a 15 mm off-the-shelf medical connector to guarantee interoperability with standard medical ventilation systems. Partially laminated, self-adhesive electrode bands that are routed through the bottom lid towards the outside of the tank serve as the interface for the EIT electrode belt. The system features a removable lid and a tube on the top for minimizing measurement artefacts caused by water ripples (Fig. 2).

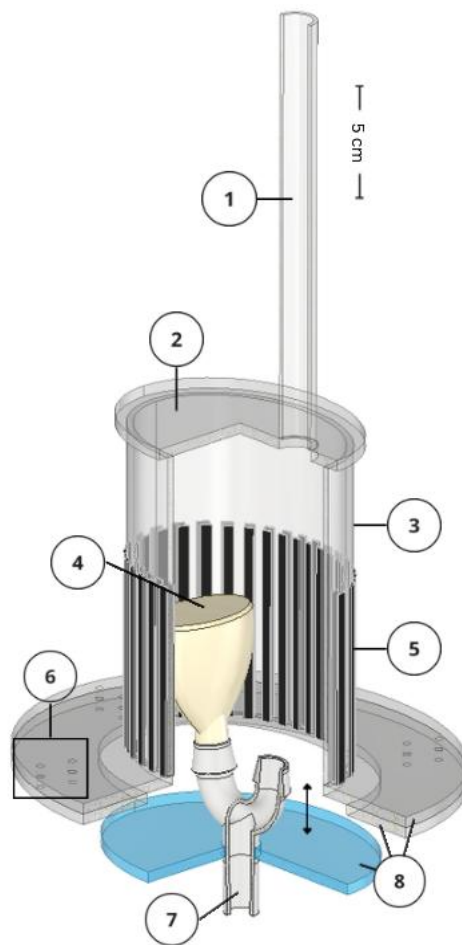


Fig. 2: cut view of prototype concept; 1 – tube for minimization of water ripple artefact, 2 – top lid, 3 – tank wall, 4 – flexible lung lobe, 5 – self-adhesive electrode tapes, 6 – mounting point for lid fixation clamp, 7 – custom Y-connector (simplified visualization), 8 – bottom lid composed of three plates, removable part in blue

The tank was manufactured from a circular acrylic tube into an elliptical shape, which approximates the anatomical chest circumference of a neonate, using heat. To aid this process, a mold for the tube was designed and 3D-printed. The tube was first heated to 70°C. After 5 minutes, the temperature was increased to 135°C. Every two minutes the temperature is increased by 5°C. After two minutes at a temperature of 150°C, the tube became malleable. Using heat-resistant gloves and the mold, the tube was first shaped and then left to cool.

Top and bottom panels and the small acrylic tube were attached using acrylic glue. Six toggle clamps were then screwed onto the bottom panel for exchangeability of the lung models. The connector for the lungs was glued into the removable lid. A rubber gasket was cut to fit the lid opening to prevent leakage.

A laminated electrode array was developed to interface the phantom with the LuMon™ EIT belt system. Nickel-coated copper conductive tape strips were laminated onto PET sheets, forming a flexible and waterproof electrode structure (Fig. 3).

The conductive paths are routed from the inner tank wall to the outside through the bottom lid, enabling direct contact with the LuMon™ belt without electrical feedthroughs or soldered connections.

The electrode layout was designed for the LuMon™ belt, resulting in 50 electrode positions with 3 mm electrode width and 3 mm spacing.

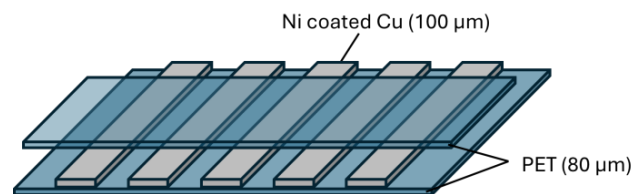


Fig. 3: Schematic of the laminated electrode structure (PET layers and nickel-coated copper tape showing exposed active electrode regions)

The lung model consists of two flexible, hollow lobes which are able to deform during ventilation. Each lobe was designed to hold the typical air volume for a neonate of this size. These flexible lung models were created by coating a 3D-printed mould with Glorex Plastylate liquid latex. Four layers of latex were added once the previous layer had dried. This provided a sufficiently thick and elastic membrane.

The assessment of the prototype was carried out in accordance with an adopted measurement protocol from previous experimental studies [11]. Measurements were performed in IPPV ($f = 20$ bpm) and HFO ventilation ($f = 300$ bpm) modes, which are state of the art in the treatment of neonates [12]. A stepwise incremental and decremental pressure protocol over PEEP levels of 0-7 mbar and mean airway pressure levels of 5-13 mbar was performed, while recording total impedance over time with the EIT monitor. The ventilation data was exported to assess pressure and volume as well as resistance and compliance of the stand-in lungs.

III. RESULTS

The previously established heating strategy was used to successfully shape the tank body. All required acrylic panels were laser-cut, and the phantom was assembled (Fig. 4). The final phantom setup was leakproof.

The electrode configuration was evaluated under LuMon™ Belt Neo operation. It demonstrated stable coupling with the belt system, and the majority of channels showed reliable contact performance. 1–2 electrodes exhibited reduced signal quality, which, depending on operating conditions, corresponds to ~93–96% functional electrode performance.

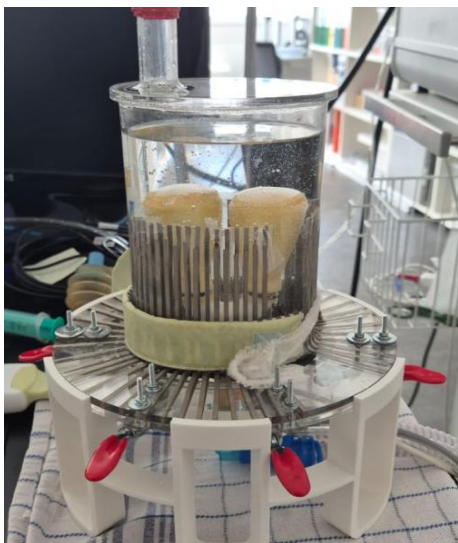


Fig 4: Assembled setup with full electrode configuration

The development of the lung model resulted in flexible lung lobes (Fig. 5) with a total volume of 42 mL each, capable of sustaining repeated inflation and deflation of the ventilator due to the elastic nature of the latex.



Fig. 5: Flexible lung lobe, attached to the U-connector

Using the Fusion script, a second set of lung models was manufactured with a 20% lower volume of 33.5 mL, aimed to simulate the decreased compliance connected to ARDS.

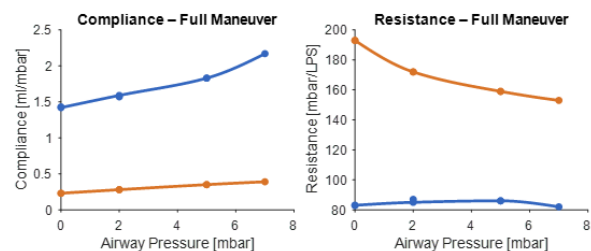


Fig. 6: Measured compliance and resistance of physiological and ARDS lungs, orange = ARDS lungs, blue = physiological lungs

The ARDS lungs showed a lower compliance and a higher resistance than the physiological lung model.

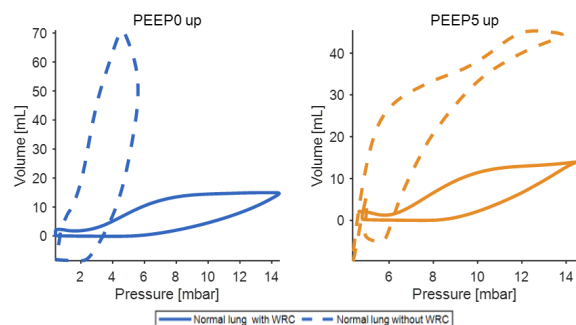


Fig. 7: P-V loops at 0 and 5 PEEP with and without WRC

P-V loops with and without the water ripple column (WRC) were recorded and compared. The results show that a higher maximum volume was achieved without the WRC, but with the WRC, more stable P-V loops were recorded.

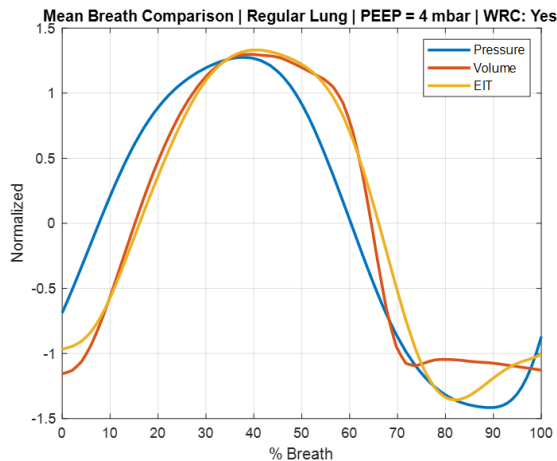


Fig. 8: Normalized pressure, volume, and EIT signal over one breathing cycle

Figure 8 shows the normalized mean breath profiles of pressure, volume, and EIT signal over one full breathing cycle. The EIT signal closely follows the volume curve throughout both inspiration and expiration. They exhibit a temporal delay relative to the pressure signal.

IV. DISCUSSION

The designed phantom prototype serves as a functional model for a neonatal EIT and is scalable across size configurations via Fusion Script.

Regarding the manufactured prototype, the size and shape of thorax and lungs are inspired by an anatomically correct 3D scan of a neonate. During the development of the shaping strategy for the tank wall, heating the acrylic gradually proved to be the most effective method, while overheating had to be avoided to prevent deformation. A 3D-printed mold was essential for maintaining a symmetrical tank shape during cooling, as hand shaping without a mold caused distortions. Although the mold showed slight heat deformation, this had little effect on the final shape.

Previous versions of the phantom showed that a larger number of toggle clamps improved the leak-proofness of the tank tremendously. Additional layers of glue and a gasket with greater thickness and a reduced sealing width provided the most reliable seal.

The reduced signal quality of some electrodes was linked to local variations in mechanical contact pressure between the belt and the tank surface. Despite these minor inconsistencies, the system provided a stable baseline for EIT measurements.

While the lung models largely performed as intended, for the ARDS lungs, a more sensible approach to limit compliance would have been to either construct a cage around the lungs or increase the layers of latex to limit expansion.

As suggested in the literature, the ARDS lungs exhibited a reduced compliance. The increased resistance could be attributed to the reduced lung volume, which limits expansion and would therefore require higher pressure changes to achieve a given volume change compared to the physiological lung model.

The comparison of the pressure–volume loops recorded with and without the filled WRC represents a trade-off between pressure–volume stability and achievable lung volume. The reduced maximum achieved lung volume was likely the result of additional hydrostatic pressure exerted by the water column, and the consistent pressure–volume behavior indicates that the WRC minimized surface ripple formation and the associated pressure fluctuations.

The observed lag between the pressure signal and the volume/EIT signals during the breathing cycle reflects the time required for airflow to inflate and deflate the lungs after changes in airway pressure. The strong similarity between the volume and EIT curves indicates that the changes in lung volume were consistently reflected in the EIT measurements throughout the entire breathing cycle. This suggests that the

phantom demonstrates realistic and reproducible behavior under mechanical ventilation.

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3D printed tOCT mount

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Optical Coherence Tomography in Transmission Mode (tOCT) is a non-invasive imaging modality that enables high-resolution, real-time characterisation of biological specimens by measuring light transmitted through the sample [1]. This project documents two successive phases of development toward a functional tOCT setup. PRT1 established the mechanical and electronic foundation: a 3D-printed linear stage, a NEMA 11 stepper motor with lead screw, an A4988 driver circuit, and a basic motor-control firmware running on an Arduino UNO R4 WiFi. PRT2 extended this foundation with a stabilising base to eliminate platform drift, bidirectional motor control at two selectable speeds, and a Python-based graphical user interface (GUI) integrating live camera feed from a Blackfly BFLY-U3-50H5M camera, image and video capture, and real-time stage-position tracking displayed as an overlay on every captured frame. The system achieved a theoretical linear resolution of 10 μm per full step and a commanded increment of 0.01 mm, consistent with the spatial sampling requirements of the tOCT application. With the full optical path assembled, an initial recording confirmed correct position tracking during continuous motion but revealed multiple concentric ring patterns rather than the single fringe pattern expected of the interference signal, motivating further optical diagnosis as the next step.

I. INTRODUCTION

Medical imaging is a cornerstone of modern diagnostics, and early detection of tissue abnormalities significantly improves patient outcomes [1]. OCT provides a non-invasive method for rapidly characterising biological tissue in three dimensions, and extending it to Transmission OCT (tOCT) combines structural visualisation with molecular specificity, increasing diagnostic value in biological studies [2]. However, many existing systems rely on costly, laboratory-grade translation stages that limit deployment outside specialist settings. This project addresses that gap through a multidisciplinary approach – mechanical design, additive manufacturing, electronics, and software development – to implement a low-cost, custom-built tOCT stage from the ground up.

PRT1 established the hardware foundation—stage geometry, actuation, driver circuit, and basic firmware. PRT2 built on this by improving

mechanical stability, extending the firmware to support two motor speeds, and developing a complete software layer consisting of a Python GUI with integrated camera control and position tracking. The GUI provides an intuitive interface for real-time stage control, allowing an operator to acquire spatially registered image sequences without manual intervention. Together, the two phases deliver a compact, controllable platform that has now been used with the full optical setup assembled, with optical signal quality the current focus.

II. MATERIALS & METHODS

A. System Architecture

The system consists of three integrated subsystems: the mechanical stage, the motor-driver electronics, and the software control layer. Table 1 gives an overview of the main components. A PC runs the Python GUI, which communicates with the Arduino over USB serial

at 9600 baud. The Arduino drives the A4988 stepper driver, which in turn actuates the NEMA 11 motor connected to the stage lead screw.

Table 1. System components overview.

Subsystem	Component
Mechanical	3D-printed stage (MT1/M-based)
Mechanical	Stabilizing base
Motor	NEMA 11 stepper motor
Driver	A4988 stepper driver
Electronics	Arduino UNO R4 WiFi
Software	Python / Tkinter GUI
Camera	Blackfly BFLY-U3-50H5M

B. 3D Printing and Mechanics

The stage geometry was designed in Fusion 360, initially derived from a Thorlabs MT1/M translation stage model [3] and then fully redrawn to incorporate the required modifications, as the original CAD sketch was not editable. The stage was printed on a Bambu Lab P1S using PLA filament with a 0.4 mm nozzle, 0.2 mm layer height, and 15% infill. The design consists of two parts: a fixed base with an integrated motor holder, and a movable top component that guides the pinhole along the x-axis. During early testing, vibration-induced drift of the moving platform was identified as a problem. To address this, an additional stabilising base was designed and 3D-printed. This base surrounds and supports the stage, eliminating the drift and providing a stable foundation for optical measurements.

The pinhole is mounted on the moving top component of the stage.

C. Electronics

The NEMA 11-based linear actuator was selected over three alternative stepper options after comparing step size, torque, and price; its integrated lead screw additionally removed the

need for a separately mounted spindle. An A4988 stepper motor driver controls the motor (1.8° step angle, 200 steps per revolution [5, 6]), powered by an external 24 V supply. The DIR pin is connected to Arduino pin D4 and the STEP pin to D5. A 100 μ F ECMO capacitor across the motor supply terminals suppresses voltage spikes and ensures stable operation. Motor, driver, and Arduino were assembled on a compact breadboard, with a separate board managing the external power connectors.

D. Arduino Firmware

The firmware was written in C++ using PlatformIO in Visual Studio Code, building on the step-count-based serial control developed in PRT1. It implements a simple single-character serial command protocol:

- F — move forward (clockwise); sets DIR HIGH, resets step counter
- B — move backward (counter-clockwise); sets DIR LOW, resets step counter
- S — stop; reports accumulated step count as STOPPED
- H — fast mode; step delay 2000 μ s (default)
- L — slow mode; step delay 8000 μ s

On startup the Arduino sends READY to confirm the serial link is active. In the main loop, when the state is FORWARD or BACKWARD, the doStep() function pulses the STEP pin high then low with the configured delay between transitions, producing continuous motion until a stop command is received.

E. Python GUI and Camera Integration.

The GUI was developed in Python using Tkinter and runs on a standard PC. It is structured around two parallel threads: a serial communication thread handling Arduino commands and responses, and a camera thread streaming frames from the Blackfly camera via the PySpin SDK and OpenCV. This separation keeps the interface

responsive regardless of motor state or camera load.

The interface is divided into two panels (Figure 1). The left panel shows the live camera feed with the current stage position overlaid in the upper-left corner. The right panel contains the motor controls and status displays:

- CONNECT ARDUINO button with a COM port input field to establish the serial link
- CURRENT POSITION display (in mm), updated after every stop event, with a CLEAR POSITION button to reset the reference
- SLOW MODE / FAST MODE toggle, selecting between the 8000 μ s and 2000 μ s step delays
- FORWARD (CW), STOP MOTOR, and BACKWARD (CCW) buttons for direct motor control
- POSITION HISTORY log showing each stop position in sequence
- CAPTURE PHOTO and RECORD VIDEO buttons below the camera feed; files are saved automatically to a dedicated folder on the PC

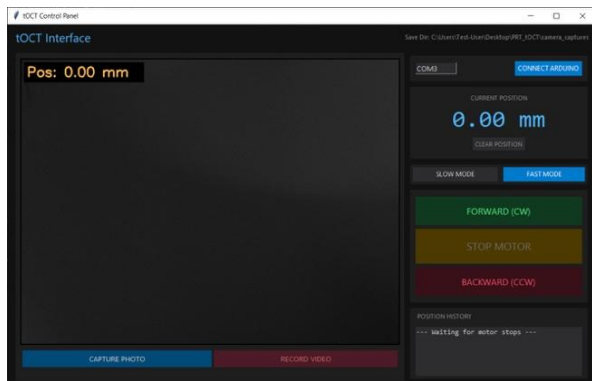


Figure 1: tOCT Control Panel GUI. Left: live camera feed with position overlay. Right: motor controls, position display, speed selector, and position history log.

Position is calculated from the step count reported by the Arduino on each stop event. Each

step corresponds to 0.01 mm of linear travel (100 steps/mm, derived from the 2 mm lead screw pitch and 200 steps/revolution). The cumulative position is updated incrementally with the sign determined by the last direction of motion, and is embedded as a text overlay on every captured image and video frame using OpenCV.

F. Optical Equipment

The following optical components are part of the assembled tOCT setup, used to acquire the recording described in Section III.D. Integration into a fully automated scan workflow is ongoing. Camera: Blackfly BFLY-U3-50H5M (USB3 Vision, monochrome, 5 MP, FLIR Systems)

Laser: The Red Helium-Neon (HeNe) Laser (05(N)-LLR-811]

III. RESULTS

A. Mechanical Performance

The 3D-printed stage demonstrated smooth and repeatable linear motion along the x-axis. The addition of the stabilising base resolved the platform drift observed during initial testing, making it a prerequisite for valid optical measurements. The two-part stage design—fixed base plus movable top—remained structurally rigid throughout all test sessions (Figure 4).

B. Motor Control and Positioning

The theoretical linear resolution of the system is 10 μ m per full step and 0.01 mm per commanded increment, corresponding to a conversion factor of 100 steps/mm derived from the 2 mm lead screw pitch and 200 steps/revolution. This resolution is consistent with the spatial sampling requirements of the tOCT application, where the pinhole must be scanned across the optical field with sufficient granularity to capture the interference pattern.

Both speed modes functioned as expected. Fast mode (2000 μ s delay) allowed rapid traversal of the available travel range. Slow mode (8000 μ s

delay) produced noticeably smoother motion, which is preferable when fine-positioning the pinhole relative to the optical axis. The motor responded promptly and reliably to all serial commands across all test sessions.

C. GUI and Camera

The GUI established stable serial communication with the Arduino and streamed live video from the Blackfly camera without interruption during testing. The position overlay was correctly rendered on the camera feed and on all saved captures. The position history log updated correctly after each stop event, providing a clear record of stage movements within a session.

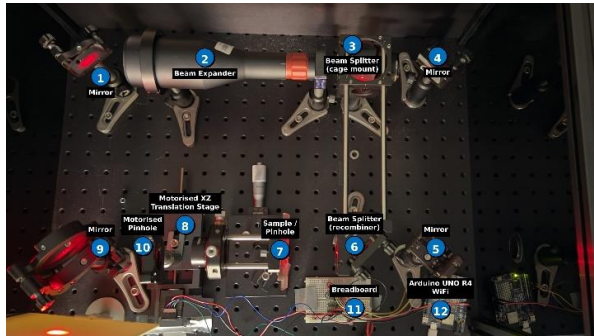


Figure 3: Complete hardware setup.

D. Recorded Acquisition

A short video was recorded with the full optical setup assembled and the camera positioned to capture the interference signal while the stage was driven continuously over a 5.4 s interval. The capture confirms that the GUI's position overlay remains correctly synchronised with the stage throughout continuous motion, rather than only at discrete stop events: Figure 3 shows two frames extracted from this recording, with the visible pattern displaced between a position of 0.12 mm and -8.44 mm, consistent with the commanded travel direction and the 100 steps/mm conversion factor. However, the recorded image does not show the single, well-defined fringe pattern expected from the tOCT interference signal. Instead, multiple concentric ring sets are visible

simultaneously, indicating that more than one optical path is currently reaching the sensor.

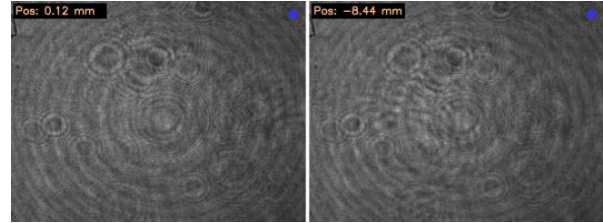


Figure 4: Recorded sensor image during continuous stage motion, with live position overlay. Multiple concentric ring sets are visible rather than a single fringe pattern.

Left: 0.12 mm. Right: -8.44 mm, 5.4 s later.

IV. DISCUSSION

The project has achieved its core objectives for both phases. The mechanical stage performs reliably, and the stabilising base proved essential — the drift problem it solved would otherwise have made optical alignment impossible. The firmware extension to two speeds added meaningful practical value: slow mode is well-suited for fine positioning, while fast mode reduces the time needed to traverse the full range. The Python GUI unifies all subsystems into a single interface. Having motor control, live imaging, and position tracking in one window is a significant improvement over the serial-monitor-only workflow of PRT1 and makes the system practical to operate. Embedding position data directly into saved captures is particularly useful for correlating image content with stage position in future experiments. The recorded acquisition described in Section III.D corroborates this in practice: the overlay tracked the commanded motion continuously, not only at the discrete stop events used for the position log. One current limitation is that position tracking is open-loop: without an encoder or limit switch, any missed steps will accumulate as positional error over time. The travel range of approximately 10 mm is sufficient for the current development phase but will need to be reassessed as the optical alignment is refined. A second, more pressing limitation concerns the optical

signal itself: with the full optical path assembled, the recorded image (Figure 4) shows multiple concentric ring sets rather than the single, clean fringe pattern expected of the tOCT interference signal. This is most likely caused by a combination of spurious reflections within the optical path and incomplete spatial filtering at the pinhole, allowing scattered or stray light to reach the sensor alongside the intended coherent path. Distinguishing between these contributions, and reducing them until a single dominant pattern is obtained, is necessary before A-scan measurements can be attempted.

Future work includes diagnosing and eliminating the source of the multiple ring patterns observed in the recorded data—through systematic isolation of optical components and review of surface coatings and pinhole alignment—to obtain a single, clean interference pattern suitable for an A-scan. Further steps include implementing software-defined travel limits to protect the stage, and extending the design to a second axis.

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FHIR Based Visualizer

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Abstract—This extended abstract presents a web-based prototype for visualizing the European Patient Summary (EPS) in the context of the European Health Data Space (EHDS) regulation (2025) and its cross-border care objectives. The system parses administrative and clinical data from HL7 FHIR R4 resources (with planned HL7 CDA support), maps them to a unified internal model aligned with the minimum exhaustive patient summary dataset, and exposes the result through a Spring Boot REST API. A React + Vite frontend retrieves DTO-based payloads and renders a structured practitioner-oriented view. Requirements were derived from standards and guideline analysis, and practitioner-focused use cases and development followed an agile sprint process. A formative usability evaluation was conducted with ten healthcare professionals in Austria. The collected qualitative feedback was analyzed and used to implement targeted UX improvements to the frontend, including a redesigned landing page, an improved visual hierarchy for information that is critical to patient safety and closing gaps in the translation. Limitations include incomplete multilingual handling, missing CDA import, and potential mapping divergence from external implementations.

I. INTRODUCTION

With the enactment of the European Health Data Space (EHDS) regulation in 2025 [1], European citizens gained the right to access their existing health records in digital form, while the regulation simultaneously promotes secure cross-border health-data exchange. At present, operational cross-border services remain limited. The European Patient Summary (EPS) [2] is intended to address this gap by enabling healthcare professionals abroad to rapidly identify critical patient information. However, although the EHDS regulation and the Patient Summary guideline define general constraints for EPS implementation, substantial design choices, such as the selection and cardinality of summary components, remain at the responsibility of implementers. In practice, EPS content is still

commonly exchanged using HL7 CDA [3] documents, while HL7 FHIR [4] is increasingly adopted as the preferred standard for modern interoperable systems. Against this background, the present project develops a web-based prototype that parses medical and administrative patient data from FHIR resources. It maps the extracted information to a unified internal data model compliant with the dataset defined in the “minimum/nonexhaustive patient summary dataset”[5], and visualizes the resulting summary in a structured interface.

To achieve this, relevant FHIR resources are identified, component cardinalities are defined, parsers and mappers are implemented, representative datasets are collected or generated (including HL7 examples and synthetic data), and a REST API with a corresponding web frontend is provided for visualization. Moreover,

healthcare professionals operating in cross-border scenarios often face significant time constraints and language barriers, meaning that a purely technical exchange of patient data is insufficient. Instead, an optimized, visually structured interface is required to reduce cognitive load and prevent medical errors when reading foreign patient records. In line with this need, the paper also reports on a formative evaluation conducted with healthcare professionals and the resulting refinements made to the prototype.

II. MATERIALS & METHODS

Development and testing were performed on consumer laptops with local execution. No dedicated server or hardware was required. The backend is implemented in Java using Spring Boot [6] and exposes a REST API for request handling and server-side logic. HL7 FHIR R4 resources are processed using the HAPI FHIR [7] library for Java. The frontend is a React web application built with Vite, providing a component-based interface for displaying patient summary sections. Development tooling includes Git and GitHub for version control [8], [9], Maven [10] for backend builds and dependency management, and npm [11] for frontend dependencies and builds. Regarding the internal data model, specific HL7 FHIR R4 resources were prioritized to reflect the most critical medical information. These included the Patient, Condition, AllergyIntolerance, and MedicationStatement resources. To ensure compliance with GDPR and EHDS privacy requirements during the Azure deployment, no real patient data was processed. Instead mock HL7 examples were utilized to simulate realistic clinical payloads. CDA support is only partially implemented. The W3C XPath library [12] is used for XML parsing, however mapping requires a different approach and some information from the CDA document is lost to conform to the FHIR oriented DTOs.

During development, an agile process was applied. Work packages were organized into iterative sprints of approximately 2–4 weeks, depending on team workload and availability. Sprint tasks were planned and, when required, reprioritized or rescheduled in the preceding sprint to maintain progress.

Requirements were derived through document and standards analysis and by defining practitioner-focused use cases. Use cases were defined exclusively for medical practitioners in cross-border treatment scenarios. To prepare the prototype for external usability testing, additional frontend refinements were performed with a focus on readability, visual consistency, and practitioner-oriented presentation of patient information. Furthermore, a deployment strategy was established to provide centralized access to the application without requiring local installation. For this purpose, the web application frontend was deployed on Microsoft Azure. However, since the Azure deployment did not run reliably during the planned evaluation period, the usability sessions were ultimately conducted in person together with the participants rather than remotely.

In parallel, a structured questionnaire was designed to support formative evaluation of the interface and identify potential improvements for future iterations. The questionnaire targets healthcare-related stakeholders and focuses on usability, information prioritization, and interaction design in cross-border treatment scenarios. Questions address topics such as first impressions of the interface, intuitiveness of navigation, visibility and ordering of information, the usefulness of potential filtering or search functions, and suggestions for adding or removing interface components. Open-ended feedback was intentionally included to collect qualitative observations and practitioner-specific requirements. The questionnaire was distributed using Google Forms and preceded by three preparatory tasks covering current medication,

implants and devices as well as allergies or critical alerts. Ten healthcare professionals based in Austria, recruited through the personal and academic networks of the project team, completed the evaluation. Responses were pseudonymized as P1 to P10.

III. RESULTS

The implemented prototype demonstrates an end-to-end Patient Summary Visualizer for EPS data, compliant with the “Guidelines on minimum/nonexhaustive patient summary dataset for electronic exchange in accordance with the cross-border directive”[5]. A Spring Boot backend exposes RESTful endpoints and processes relevant HL7 FHIR R4 resources. Patient-related resources are loaded from a local repository, parsed into objects, and transformed via a dedicated layer into Data Transfer Objects (DTOs). This establishes a unified internal representation that decouples the frontend from raw exchange formats and supports consistent visualization.

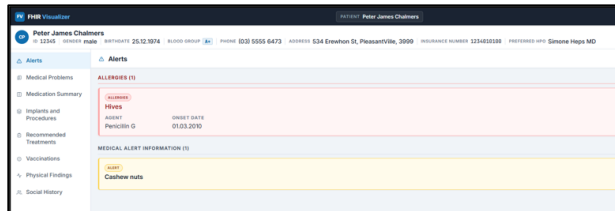


Figure 1: Final frontend version after incorporating evaluation feedback

The backend is organized into separate services for administrative/demographic and clinical content, which results in a modular structure that can be extended with additional sections and resource types. Administrative and clinical content are served by two corresponding services, a PatientAdministrativeDataService and a PatientClinicalDataService, both built on a shared ResourceReader component that loads patient

related FHIR resources from a local repository. Resource specific mappers, implemented with MapStruct for FHIR resources and a Document Object Model based approach for the CDA path, convert these resources into the same set of DTOs regardless of the original source format. The React + Vite frontend retrieves DTOs via HTTP requests and renders them in a practitioner-oriented, clearly structured layout (e.g., alerts, medical history, medical problems, medication summary). Multi-language support is implemented with dictionary-based translations, including English and German in the prototype, and accessibility is supported through keyboard operability and a restrained color scheme. The frontend was visually revised and deployed on Microsoft Azure, enabling remote access to the prototype for evaluation and demonstration purposes. The updated interface provides a more polished and structured presentation of Patient Summary information and supports testing under realistic usage conditions.

In addition, a practitioner-oriented evaluation questionnaire was completed and distributed to collect structured feedback regarding usability and interface design. The questionnaire includes both closed and open-ended questions covering navigation, information hierarchy, visual presentation, and desired functionality. The completed evaluation identified ten recurring themes across participant feedback, addressing both general usability and patient safety concerns. Five of these were prioritized and implemented in a subsequent revision of the frontend, including a redesigned landing page, an improved visual hierarchy with color coded alerts, a corrected language dropdown position, closing gaps in the German interface labels and persistence of the selected language across sessions. Five further themes, such as missing timestamp and source information, the placement of implanted devices under medical problems and requests for filtering, search and medication interaction features, were

identified as relevant but deferred due to scope constraints.

IV. DISCUSSION

The prototype demonstrates the technical feasibility of a web-based Patient Summary Visualizer, but several limitations affect completeness and interoperability. Multilingual support is only partially functional, as coded clinical content cannot be reliably translated in the backend without terminology servers and due to missing local SNOMED CT editions. CDA import has not yet been fully implemented, which restricts compatibility with institutions exchanging EPS data as CDA.

The partial implementation of CDA documents introduced new challenges. EHDS documentation and specifications regarding the patient summary are fragmented and hard to source. Publicly available patient summary data is scarce and only one example was found for the international patient summary. Additionally, the initial library intended for CDA parsing was incompatible with the use case and an alternative had to be used.

In addition, FHIR mapping decisions were required due to flexibility in the minimum exhaustive dataset, introducing a risk of divergence from other implementations. Finally, recent EHDS information models and stronger usability requirements were not fully considered. While the current prototype only processes synthetic data to avoid privacy risks, transitioning to a real-world clinical environment would require the integration of strict security measures. Future iterations of the system would need to implement robust user authentication, role-based access control, end-to-end encryption and audit logging to fully comply with GDPR and the stringent data protection rules introduced by the EHDS.

The formative evaluation completed with ten healthcare professionals provided concrete insights into perceived usability and relevance of

the presented Patient Summary information, and the resulting frontend adjustments are described above. Since the Azure deployment did not operate reliably, the evaluation sessions were conducted in person, which introduces a risk of bias as participants may have moderated critical remarks in the presence of the development team. The sample was further limited to ten participants recruited through personal and academic networks and based in Austria, which restricts the generalizability of the findings, particularly regarding the cross border and multilingual context the application is intended to serve. The evaluation also remained purely qualitative. Future work should therefore combine a larger and more diverse participant group across member states with quantitative task based metrics, such as time on task, success rate and error rate, to obtain a more objective and comparable assessment of usability. Further technical future work includes the full implementation and validation of CDA support, integration with terminology services such as SNOMED CT to improve multilingual translation of clinical concepts, testing with larger and more diverse datasets to evaluate scalability and robustness, as well as a clearer comparison with existing Patient Summary visualization solutions. Addressing these aspects would further strengthen the practical applicability and interoperability of the proposed solution.

A more customizable interface for practitioners was explored during development but ultimately abandoned due to quality assurance problems that would arise and concerns about its suitability in cross-border healthcare contexts. Personalized or configurable layouts may appear beneficial at first glance, as practitioners naturally differ in their workflows, clinical specializations, and information priorities. However, in cross-border treatment scenarios this inverts. The challenge is not familiarity but unfamiliarity, clinicians encountering a foreign patient summary must orient themselves rapidly within data they have

never seen before, often under time pressure and across language barriers. A standardized, predictable interface directly addresses this challenge. Strong variations in layout, prioritization, or navigation between implementations could increase cognitive load and reduce interoperability at the workflow level, even if technical interoperability is maintained. Therefore, future refinements should focus on improving clarity and efficiency within a consistent interface structure according to the healthcare personnel that will utilize it, instead of enabling customizable interfaces for everyone.

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LIST OF FIGURES

Figure 1: Current frontend state with an example patient loaded 3

Vaccination Tracking Made Easy: A FHIR-Based Registry for Patients and Providers

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Abstract—Interoperable access to pediatric immunization records is necessary since vaccination data management is still dispersed within healthcare systems. This project offers a web platform for recording kid vaccinations that is based on FHIR and is intended for use by parents or legal guardians as well as healthcare professionals. The system makes use of a dedicated HAPI FHIR R5 server, a Spring Boot REST API backend, and a Vue 3 TypeScript Progressive Web Application frontend.

Vaccination-related data is organized using HL7 FHIR R5 resources, and Practitioner and RelatedPerson access is separated using SMART-on-FHIR-inspired authentication and role-based access management. DTOs, mapper classes, service layers, and a central FhirGateway facilitate manageable backend development by separating application logic from FHIR resource processing. The prototype demonstrates how modern web technologies and FHIR-based interoperability may support vaccination record continuity, safe access, and future integration with healthcare systems.

Index Terms—HL7 FHIR R5, vaccination tracking, paediatric immunization, SMART on FHIR, interoperability, role-based access control, Progressive Web Application

I. INTRODUCTION

Vaccination records are frequently scattered over several paper records and various clinical systems. This does not offer adequate continuity of treatment and raises the possibility of missed, delayed, or duplicate vaccines.

Although they have limited interoperability, recently created information systems have demonstrated gains in tracking and covering vaccination data. These restrictions nevertheless make it difficult for healthcare providers to communicate with one another [1]. In this instance, HL7 FHIR enhances real-time surveillance, facilitates scalable public health interventions, and aids in the adoption of standardized digital infrastructures for immunization registries [2], [3]. The primary means of facilitating data transmission across various systems is through application programming interfaces (APIs); in essence, an API establishes a set of guidelines that permit communication between two software programs. However, HL7 is still actively developing immunization-related functionality in FHIR, with resources defined and verified for wider actual usage [4], [5].

The Austrian recommended vaccination schedule was used as the national reference for the tracking workflow. It provides age-based recommendations for childhood immunisations, including vaccines such as rotavirus, diphtheria, tetanus, pertussis, MMR, varicella, HPV, influenza, and tick-borne encephali-

Austria: Recommended vaccinations

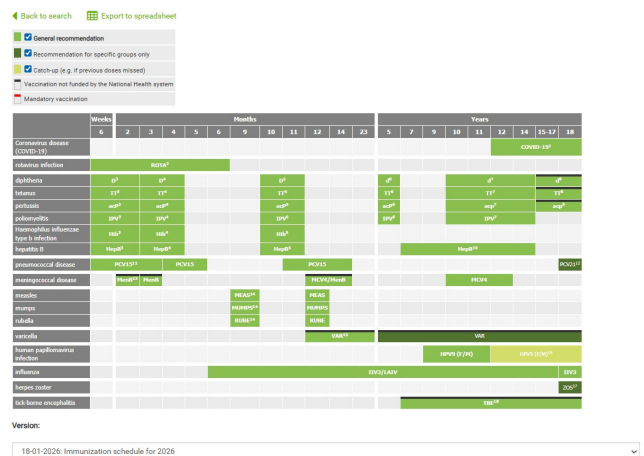


Fig. 1. Architecture of the vaccination tracking system

tis. In this project, the schedule supports the identification of upcoming or missing vaccinations based on the child's age [6].

II. MATERIALS & METHODS

The project was developed as an online platform for tracking children vaccinations based on FHIR. For standardised healthcare data storage and exchange, it uses a client-server architecture with a local HAPI FHIR R5 server, a Java SpringBoot backend, and a Vue 3 TypeScript Progressive Web Application frontend. Figure 1 presents the overall architecture of the vaccination tracking system. The Vue PWA frontend communicates with the Spring Boot backend through REST API requests and receives JSON responses. The backend is structured into controller, service, DTO, mapper, FHIR gateway, security, and SMART-on-FHIR layers. FHIR-based healthcare data is exchanged with the local HAPI FHIR R5 server, where resources such as *Patient*, *Practitioner*, *Related-Person*, and *Immunization* are handled.

A. Backend

The backend was implemented using a layered structure consisting of controllers, services, DTOs, mapper classes, and a central FhirGateway. Controllers expose REST endpoints, services handle application logic, DTOs transfer simplified

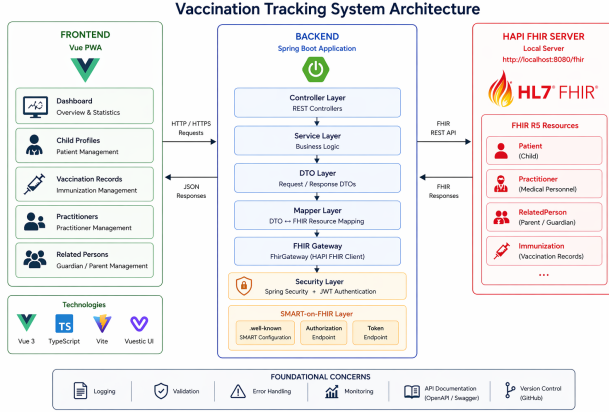


Fig. 2. Architecture of the vaccination tracking system

data between frontend and backend, and mapper classes convert DTOs into FHIR R5 resources. The FhirGateway manages communication with the HAPI FHIR server.

The main FHIR resources used in the system include Patient, Practitioner, RelatedPerson, and Immunization. Additional resources such as Appointment, Encounter, Observation, Condition, Consent, Communication, AdverseEvent, CarePlan, and Goal were included to support a broader vaccination workflow.

Authentication was implemented using a SMART-on-FHIR-inspired login flow with JWT-based access control. The system separates practitioner and parent or guardian access, allowing role-based interaction with sensitive child vaccination data [8].

B. Frontend

Vue 3 and TypeScript are used to construct the frontend as a responsive Progressive Web Application. The interface remains modular, reusable, and maintainable due to its component-based structure. To create, get, and update vaccination-related data, the frontend uses REST APIs to interface with the Spring Boot backend.

A role-specific, SMART-on-FHIR-based process is used for authentication. After logging in, parents or legal guardians get access to a different dashboard with limited features. The frontend supports key views in English and German and does not permanently store clinical records in the browser. Instead, vaccination data is accessed during authenticated sessions through backend-mediated FHIR interactions, while the authoritative records remain stored in the FHIR server environment.

III. RESULTS

The developed application successfully implements a complete FHIR R5-based paediatric vaccination tracking system. The backend enables healthcare professionals and parents/legal guardians to manage vaccination data using standardized HL7 FHIR R5 resources stored in a local HAPI FHIR server.

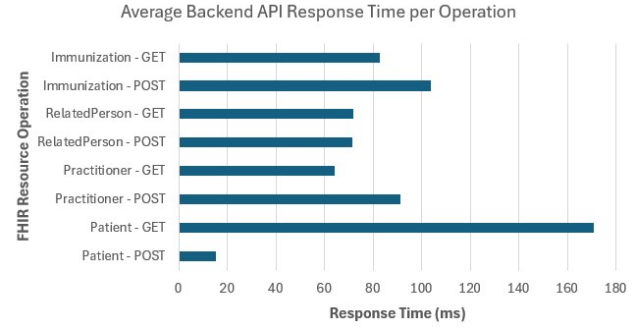


Fig. 3. Architecture of the vaccination tracking system

Two role-specific portals were fully implemented. The Practitioner Portal allows healthcare professionals to authenticate via SMART on FHIR, manage child profiles, create and update immunization records, and access comprehensive clinical overviews. The RelatedPerson Portal (for parents and legal guardians) provides full read access to linked children's vaccination history while restricting updates to general demographic and contact information only (name, phone, email, address). Clinical data such as immunizations, care plans, and goals remains read-only for this role.

Age-based immunization recommendations aligned with the Austrian paediatric vaccination schedule are dynamically generated by the backend, taking into account the patient's date of birth and previously administered vaccines. This improves clinical decision support and helps reduce missed or delayed vaccinations [7].

FHIR mapper classes were implemented to convert DTOs into FHIR R5 resources and to convert FHIR resources back into response DTOs. The FhirGateway centralizes communication with the HAPI FHIR server and supports reusable create, read, update, and search operations. SMART-on-FHIR-inspired authentication with JWT-based access control was implemented to protect backend endpoints. Role-based access separates practitioner and parent or guardian workflows. Backend performance was evaluated locally with 100 HTTP requests per endpoint. All operations achieved a **100% success rate** with average response times ranging from 15 ms to approximately 170 ms (Figure 2).

Overall, the system provides a unified, secure, and interoperable digital vaccination registry that significantly reduces the fragmentation of records and supports continuity of care.

IV. DISCUSSION

This project demonstrates that a modular backend architecture based on HL7 FHIR R5, combined with a Progressive Web Application (PWA) frontend and RESTful principles, can effectively support vaccination management in paediatric care. The system provides two fully functional role-specific portals: a comprehensive Practitioner Portal for healthcare professionals and a RelatedPerson Portal for parents and legal guardians.

A dedicated service layer, together with DTOs, mapper classes, and a central FhirGateway, encapsulates all business logic and HL7 FHIR interactions. This clear separation of concerns ensures consistent data retrieval and validation across endpoints while maintaining full interoperability with the HAPI FHIR R5 server. Services leverage the HAPI FHIR client to query, create, and update standardized resources, while custom Profiles and external Value Sets enforce data quality and semantic consistency. SMART on FHIR authentication with JWT-based token validation and strict role-based access control guarantees secure access: practitioners have full read/write permissions, whereas RelatedPerson users have complete read access to linked children's records but are restricted to updating only general contact information.

Backend performance evaluation showed excellent results, with all tested endpoints achieving a 100% success rate and low response times in the local environment. The Vue 3 + TypeScript PWA frontend offers a responsive, bilingual, and user-friendly interface with smooth navigation, loading states, and clear feedback, significantly improving accessibility for both user groups.

Despite these achievements, the current implementation also reveals limitations of FHIR-based immunization workflows. The prototype was tested only in a local, controlled environment with synthetic data. Real-world usability testing with actual patients, parents, and practitioners has not yet been conducted. Furthermore, event-driven notifications (e.g., email or push reminders) and integration with national systems such as ELGA remain outside the current scope.

Future work will focus on extending support for event-driven data exchange to better accommodate public health reporting requirements, implementing external notification services, and achieving full interoperability with national electronic health records. Additional efforts will include harmonizing the system with evolving national immunization schedules and conducting comprehensive usability and acceptance studies.

Overall, the project successfully delivers a secure, interoperable, and extensible foundation for digital paediatric vaccination tracking, addressing key challenges identified in the literature review and laying the groundwork for broader clinical adoption.

Project Repository: GitHub Repository

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New Projects for Master Medical Engineering & eHealth

Neonatal EIT Phantom: Breathing-Simulator Integration and Experimental Characterisation

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Summary - Electrical impedance tomography (EIT) can provide continuous, radiation-free information on regional ventilation, but robust calibration and validation tools for neonatal applications remain limited. A previous student team developed a functional, size-scalable saline-tank phantom with inflatable lung inserts, an EIT electrode interface and a standard ventilation connection. This project should expand their proof of concept into a reliable, scalable, and measurable research platform by improving the mechanical and electrical setup, integrating it with a laboratory breathing simulator, and conducting a structured experimental evaluation.

Keywords: *Electrical impedance tomography, neonatal lung phantom, breathing simulation, experimental validation, medical-device testing*

Academic Level: *Master*

Course: *MME1-PRT1/2*

1.BACKGROUND

Electrical Impedance Tomography (EIT) is a non-invasive imaging technique increasingly used for respiratory monitoring. EIT systems typically consist of a belt embedded with electrodes placed around the thorax and a monitor that continuously generates cross-sectional conductivity maps from impedance measurements between the electrodes. [2]

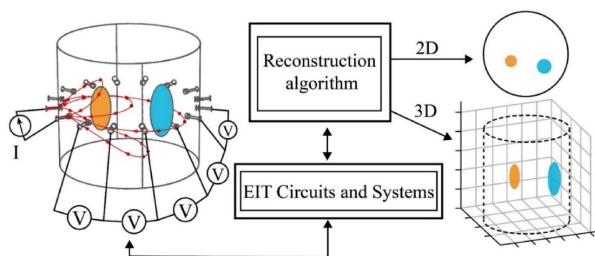


Figure 1 EIT measurement workflow [1]

Respiratory failure is a major concern in neonatal care. EIT monitors can estimate regional ventilation from changes in thoracic electrical impedance and can therefore support continuous monitoring without ionising radiation [2], [3]. Future wider use relies on measurement protocols and test objects that reproduce clinically relevant geometry, lung volume and ventilation behavior in a controlled and repeatable manner.

An existing prototype provides a strong starting point. It combines a transparent elliptical saline tank, a 50-position laminated electrode array compatible with the Sentec LuMon system, exchangeable flexible lung lobes and a norm-conforming 15 mm ventilation interface. Preliminary tests demonstrated leak-tight operation, approximately 93–96% functional electrode contact, repeated inflation and deflation, and close agreement between the measured EIT and volume waveforms [4].



Figure 1 Existing neonatal EIT phantom and ventilation setup developed by the previous student team. [4]

II. PROJECT OBJECTIVES

The objectives are to improve the setup's manufacturability, integrate it with a breathing simulator, and establish a traceable data processing workflow.

- Gain knowledge and understanding of the fundamental principles of EIT
- Gain knowledge and understanding of the human respiratory system with a specific focus on neonatal physiology
- Improve the mechanical, fluidic and electrode design while retaining scalability, exchangeable lung inserts and current compatibility with EIT systems
- Design and implement a protected and robust interface to the breathing simulator xPulm™ including sensing points and synchronised data acquisition
- Plan and perform measurements across relevant operating conditions and lung equivalents of different sizes, shapes and mechanical behaviour
- Analyse uncertainty and repeatability, compare electrical and respiratory signals, and produce a documented platform for subsequent experimental and numerical studies

III. LEARNING OUTCOMES

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

- Respiratory-system functionality, physiology and lung mechanics
- Operating principles and experimental applications of Electrical Impedance Tomography
- Parametric CAD modelling and design automation
- Design for additive and subtractive manufacturing, including 3D printing, laser cutting and CNC machining
- Design of controlled measurement protocols and structured test matrices

- Experimental data Acquisition, processing and visualisation of data; signal alignment, filtering, normalisation, as well as respiration-relevant parameters such as pressure–volume loops, compliance and resistance
- Composing technical documentation, version control, bills of materials, measurement metadata and operating procedures

IV. COORDINATION WITH PARALLEL WORK

This project might be coordinated with an internship and a master's thesis. The internship is expected to provide lung equivalents of varying shapes and sizes; these will be incorporated into the test scenarios as they become available. The thesis will numerically characterise the phantom and setup. Regular interface reviews should align geometry, material assumptions, boundary conditions and output quantities so that numerical and experimental results can be compared on a common basis. New equivalents and numerical results will extend the campaign but will not be required to complete the core deliverables for this project.

V. LITERATURE

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Development of a Modular In Vitro Airway Platform for Advanced Aerosol Deposition Research

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Summary — Experimental airway models are essential for investigating aerosol deposition and validating computational fluid dynamics (CFD) simulations. While previous student projects successfully established separate experimental platforms for the upper and lower airways, limitations in model durability, physiological realism and modularity now restrict further research.

This project aims to develop a modular in vitro respiratory platform featuring a reproducible manufacturing workflow, interchangeable airway models and an enhanced experimental setup for aerosol deposition studies. The resulting infrastructure will support future experimental research, CFD validation and the development of novel inhalation therapies.

Keywords: *Respiratory research, aerosol deposition, in vitro models, additive manufacturing, modular design, CFD*

Academic Level: *Master*

Course: *PRT*

I. BACKGROUND

The effectiveness of inhaled therapies depends strongly on where aerosol particles deposit within the respiratory tract. Experimental airway models are therefore widely used to investigate aerosol transport under controlled conditions and to validate computational simulations.

Previous student projects in our laboratory established experimental platforms for both the upper and lower airways and successfully compared in vitro measurements with CFD simulations. However, the current infrastructure has several limitations. Existing models are either manufactured from rigid PLA, which does not adequately reproduce physiological surface properties, or use Digital Anatomy printing, which provides more realistic models but suffers from limited durability and high replacement costs. Furthermore, upper and lower airway models have largely been investigated separately, limiting studies of the complete respiratory tract. The objective of this project is to overcome these limitations by developing a modular and reusable experimental platform.

Students will establish an improved manufacturing workflow for anatomically realistic airway models, design interchangeable upper and lower airway modules, and extend the existing aerosol deposition setup. The platform shall support different anatomical model types and remain compatible with standard 3D model formats (e.g., STL), creating a flexible research infrastructure for future experimental studies and CFD validation.



Figure 1: 3D Upper Airway Models in different materials.

II. PROJECT OBJECTIVES

The aim of this project is to establish a reusable experimental platform for respiratory research

rather than addressing a single scientific question. Working in a team participants will design, manufacture and validate a modular airway system that can be expanded and adapted for future research projects.

The project objectives are to:

- Develop a reproducible manufacturing workflow for anatomically realistic airway models, evaluating fabrication methods that improve durability while maintaining physiologically relevant surface properties.
- Design a modular airway platform allowing interchangeable upper and lower airway models with different anatomical representations and branching depths to be connected seamlessly or used independently.
- Extend the existing experimental setup by integrating the modular airway platform with the aerosol collection chamber and developing concepts for temperature and humidity control for future liquid aerosol experiments.
- Validate the functionality and reproducibility of the platform through representative aerosol deposition experiments and ensure compatibility with standard 3D model formats (e.g., STL) for future CFD studies.
- Document the manufacturing workflow, modular interfaces and experimental procedures to establish a sustainable research infrastructure for the laboratory.

III. LEARNING OUTCOMES

This project exposes students to the complete development cycle of a biomedical research platform, from concept development and mechanical design to manufacturing, experimental validation and documentation. Students will work in an interdisciplinary environment combining biomedical engineering, additive manufacturing and respiratory research.

By completing the project, students will gain experience in:

- Additive manufacturing and alternative fabrication techniques for biomedical applications.
- CAD design and development of modular engineering systems.
- Design and validation of experimental respiratory research platforms.
- Aerosol deposition measurements and experimental data analysis.
- Development of reproducible laboratory workflows and engineering documentation.
- Collaborative engineering within a multidisciplinary research team.

The completed platform will become a long-term research infrastructure supporting future Master's theses, CFD validation studies and the laboratory's ongoing research into aerosol transport and respiratory therapies.



Figure 2: Previously manufactured upper and lower airway models in different material and shape configurations.

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Project R.E.S.C.U.E.

(Realistic Eye Simulation for Cataract to Upgrade IOL Evaluation)

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Summary — Cataract is the most common cause of blindness worldwide, nowadays treatable with surgically implanted intraocular lenses (IOLs). The model eye developed by the FHTW is a unique system designed to test IOLs in a more realistic scenario through the inclusion of tilt and decentration actuators as well as wave-front sensing. This project has for objective to characterize, document, repair when necessary and further develop the model eye and use it to test intraocular lenses to improve the treatment of cataract.

Keywords: Cataract, Eye, Optics, Artificial organ model

Academic Level: Master – Medical Engineering and e-Health

Course: PRT

1. BACKGROUND

Vision is the most developed human sense accounting for 80% of the external information processed by the brain. [1] Any impairment to visual acuity therefore leads to a worsened quality of life through increase injury risk, loss of personal independence and limited social participation, especially in older individuals. [2]

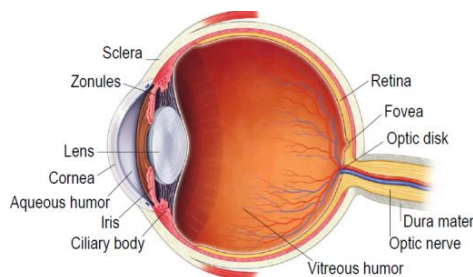


Figure 1: Drawing of the human eye and its component parts. [5]

The human eye is a sophisticated optical system that focuses the incoming light on the retina where it is converted into neural signals for the brain to process. This imaging system is composed of two main optical elements: the cornea, the stiff outer surface of the eye which provides most of the focusing power, and the crystalline lens, a soft internal structure that deform to fine-tune the focus and ensures sharp

image formation on the retina. Cataract, the age-related clouding of the crystalline lens, is the leading cause of blindness worldwide, affecting over 20 million people and accounting for 50% of all blindness cases. [3] Cataract is thankfully treatable with a surgical procedure where the clouded lens is replaced by an artificial intraocular lens (IOL) made out of biocompatible material. Nowadays, this is one of the most common and successful medical procedures, with more than 100 000 interventions each year in Austria alone. [4]

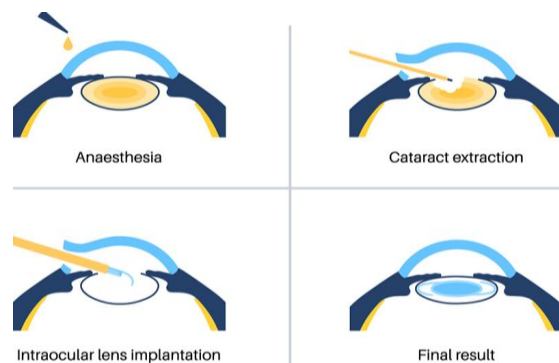


Figure 2: Drawing describing the steps of cataract surgery. [6]

However, post-operative complications can arise when IOLs tilt or decenter from the optimal axis. These small displacements, introduce perceptible optical aberrations that degrade vision quality for

the patients. These displacements are difficult to predict and remain the largest source of error in IOL selection. Current testing standards focus on the optical characterization of the IOL isolated from the rest of the eye in an ideal scenario that fails to account for these displacements, leaving a critical gap in how IOLs are evaluated.

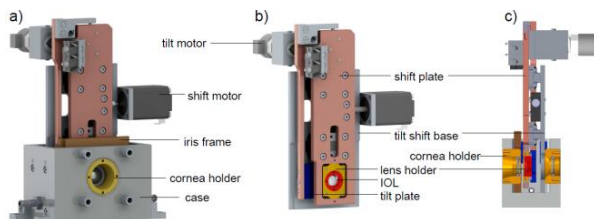


Figure 3: CAD rendering of the FHTW model eye. [7]

Here at the FHTW, a unique testing system was developed to address this gap by testing IOL performance under realistic, non-ideal conditions in an optomechanical model eye. [7] The system includes a saline-filled housing for the IOLs, better replicating the internal eye environment; a custom lens simulating the human cornea, to test the IOLs as part of a more realistic imaging system; automated tilt and decentration actuators to simulate postoperative IOL displacements and measure their effect on vision; and a digital wavefront sensor to measure optical aberrations and describe effects that go beyond simple refractive errors.

Unfortunately, the system is currently not in use, and critical know-how has been lost. This project offers you the chance to restore, validate, and document this unique system, and contribute to improving IOL testing and thus patient outcomes.

II. PROJECT OBJECTIVES

The objectives of this project are to:

- Collect the know-how from previous student projects.
- Diagnose and repair the hardware, update the software and transfer it to a more permanent platform.
- Operate the model eye and document the performances on test samples.
- Deliver a hand-over manual and come-up with possible further developments for the system.

The project will start with an in-depth review of L. Traxler's doctoral thesis [7] as well as previous students' these on the subject. This will be complemented by a study of the optometry of eye models, as well as wavefront aberrometry. Then, the state of the system will be assessed, spare parts will be ordered and implemented and the codebase will be migrated to a Git repo. Finally, if time permits IOLs will be tested and the performance of the system will be calibrated and recorded for future use.

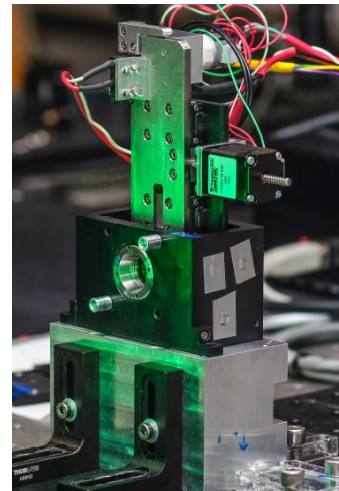


Figure 4: Picture of the model eye in the FHTW optics lab. [7]

III. LEARNING OUTCOMES

In this project, you will get familiar with:

- Graphical user interfaces in Matlab
- Opto-mechanical actuator and drivers
- Basics of optical design and aberrometry

IV. LITERATURE

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Project Ra.D.I.U.S.

(Roughness Analysis via DIY Interferometry for Universal Surfaces)

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Summary — Around 20% of medical implants fail within 15 years, often due to poor surface integration with the biological substrate. Surface roughness plays a critical role: too smooth and implants fail to bond with the bone, too rough and they accelerate wear. Commercial White Light Interferometry (WLI) systems provide nanometer-scale topographic measurements of these surfaces, but their cost makes them inaccessible. This project aims to develop a low-cost WLI system based on a Linnik interferometer with off-the-shelf components and open-source software to measure the 3D surface topography of medical implants.

Keywords: *Medical Implants, Optics, Low-cost Interferometry, Surface Metrology*

Academic Level: *Master – Medical Engineering and e-Health*

Course: *PRT*

1. BACKGROUND

Medical implants are among the most impactful interventions in modern medicine, with 3 million knee and hip replacements performed annually in Europe. Yet, to this day, around 20% of joint replacements fail within 15 years, leading to dangerous and painful revision surgeries, prolonged disability, and high additional costs. These failures stem from a complex interplay of biological and mechanical factors, but a recurring issue is the mismatch between the implant's surface properties and the biological substrate. [1]

Surface roughness is especially important for implant acceptance. Controlled micro-roughness enhances bone anchorage, regulating the distribution of mechanical stress, and osteoblast activity, whereas overly smooth surfaces promote fibrous encapsulation rather than stable bone contact. On the other hand, overly rough surfaces accelerate abrasive wear, and can act as crack initiation sites. Implant manufacturers must therefore quantify standardized roughness and

textural parameters to guarantee biocompatibility.

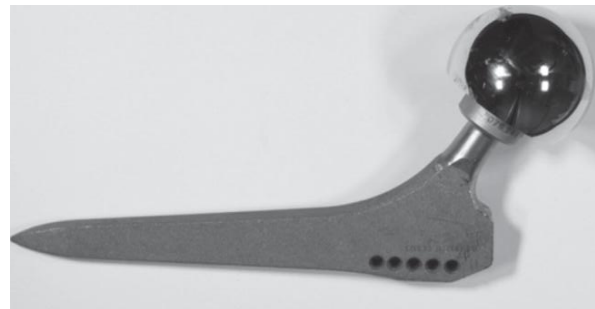


Figure 1 Hip implant stem (Zimmer) The titanium surface interfacing with the femur was grit-blasted to a 3 μm - 5 μm nonporous finish. Adapted from [1]

White Light Interferometry (WLI) has emerged as a standard tool for surface roughness characterization in implant metrology, offering non-contact, high-resolution 3D topography. Recent studies demonstrate WLI's ability to resolve micro-roughness features (0.5–5 μm Ra) critical for osseointegration, while also detecting manufacturing defects that could compromise implant performance. Unlike stylus profilometry, WLI avoids surface contact, minimizing damage and contamination, and can measure high-slope and porous surfaces making it particularly

valuable for modern implant designs based on additive manufacturing. [2]

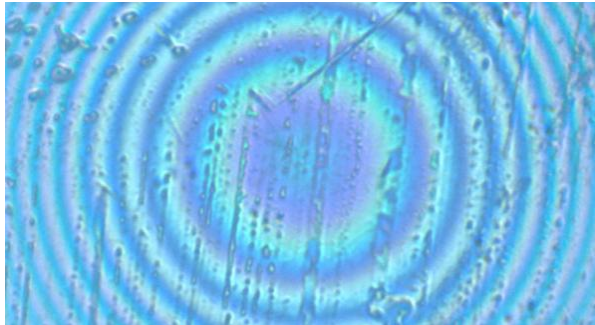


Figure 2 Surface characterization of a steel ball bearing with WLI. The multi-color interference pattern is very visible. Adapted from [3]

WLI is based on coherence scanning, a technique that measures surface roughness and topography by analyzing interference patterns created when light reflects off the sample and a reference mirror are combined on a detector. Commercial WLI systems typically rely on Mirau or Michelson interferometer geometry integrated directly into the objective. This provide sub-nanometer vertical resolution and millimeter-scale fields of view, but their very high cost makes them inaccessible for educational institutions. The goal of this project is to develop a low-cost alternative based on a Linnik interferometer, off-the shelf components and simple electronics and software.

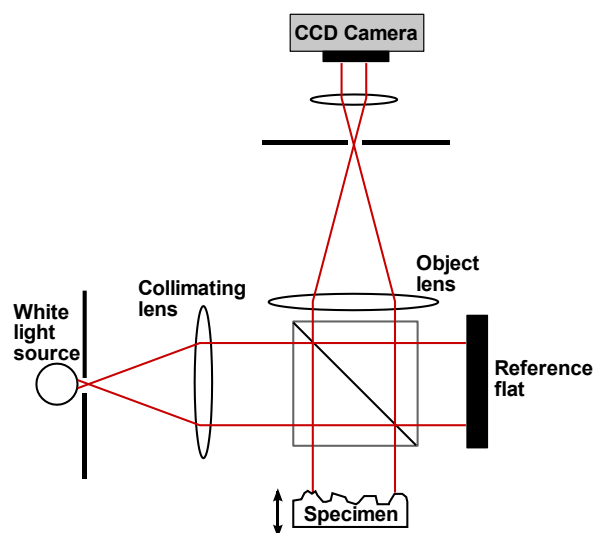


Figure 3 Twyman-Green (similar to Linnik) interferometer set up as a white light scanner. Adapted from [4]

In a so-called Linnik geometry, the output of a white LED is split into two beams: one beam

travels to the sample surface, while the other reflects off a reference mirror. When these beams recombine, they create bright and dark fringe patterns that shift as the reference mirror scans the optical path length. By capturing these fringe shifts with a CCD camera and processing them, a 3D map of the surface can be reconstructed.

II. PROJECT OBJECTIVES

The first phase of the project will focus on a comprehensive literature review to identify existing low-cost interferometric systems and their applications in surface metrology. The team will need to understand key design principles, such as light source and camera selection, fringe analysis algorithms. The team will produce a literature review and a bill of materials.

After procuring the materials, the system development itself can start. It will be separated into 3 sub-goals:

1. Optics: Assemble the Linnik interferometer, optimize imaging of the sample, and ensure fringe visibility.
2. Mechanics/electronics: Integrate the stepper stage for the reference mirror, and ensure stable scanning. Integrate the LED and the camera into the optical system.
3. Software: connect to the motors, cameras and light-source, develop fringe analysis algorithms and a user-friendly GUI.

III. LEARNING OUTCOMES

In this project, you will get familiar with:

- Graphical user interfaces in Matlab
- Opto-mechanical actuator and drivers
- Basics of optical design

IV. LITERATURE

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Evaluation of Markerless Motion Capture Systems for Functional Movement and Mobility Assessment: Comparison of markerless systems, validation and OpenSim-based analysis

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Summary — This project investigates the potential and limitations of markerless motion analysis for functional movement assessment. Students will compare at least two markerless systems, including OpenCap, validate estimated ground reaction forces against synchronized PASCO force-plate measurements, and investigate further biomechanical analysis using OpenSim. The methods will be evaluated within a literature-based application scenario. A Python-based pipeline will integrate data processing, analysis, visualization, and automated reporting.

Key learning outcomes include motion analysis, data processing, validation of biomechanical measurements, and the application of programming in healthcare.

Keywords: *Markerless Motion Analysis, OpenCap, OpenSim, Ground Reaction Forces, Functional Movement Assessment, Biomechanics*

Academic Level: *Master*

Course: *PRT*

I.BACKGROUND

Flexibility and mobility are fundamental components of physical health and functional independence. Reduced joint mobility, restricted range of motion, muscular shortening, asymmetries, and altered movement patterns can contribute to musculoskeletal problems and may increase the risk of injury or functional limitations. In older adults, reduced mobility is additionally associated with an increased risk of falls and loss of independence. In younger and athletic populations, limitations in mobility and altered movement strategies may contribute to overuse injuries or musculoskeletal complaints.

From a healthcare and prevention perspective, the early identification of functional limitations enables targeted interventions such as physiotherapy, mobility and strength training, or adaptation of rehabilitation programs. Objective assessment of human movement is therefore relevant for rehabilitation, injury prevention,

sports science, and general functional assessment.

Traditional motion analysis technologies, such as marker-based three-dimensional motion capture combined with force plates, provide detailed kinematic and kinetic information and are widely used in biomechanical research. However, such systems are expensive, time-consuming, require specialized laboratory environments and trained personnel, and are therefore difficult to transfer into broader healthcare, rehabilitation, or field applications.

Despite this promise, validation remains essential. While OpenCap provides estimates of ground reaction forces, the accuracy of these outputs must be systematically compared against gold-standard force plate data. PASCO plates, available in the laboratory environment, allow direct measurement of GRFs and thus provide the necessary benchmark for evaluating the performance of markerless tracking. This project therefore investigates markerless motion analysis from measurement to

biomechanical interpretation. Students will compare different markerless systems, investigate measurement repeatability, validate estimated GRFs against PASCO force plates, and explore further biomechanical modelling using OpenSim. All components will be investigated within a literature-based functional application scenario.

II. PROJECT OBJECTIVES

Comparison of Markerless Motion-Analysis Systems

Students will practically investigate OpenCap and at least one additional markerless system, such as Orhelligent® VISION. A standardized movement routine will be recorded and corresponding biomechanical parameters identified and compared.

Research Question 1

How comparable are biomechanical parameters obtained from different markerless motion-analysis systems?

Deliverables

- Comparison of at least two markerless systems, including OpenCap.
- Optimization of camera setup (best-practice distances, angles, fields of view, individual markers) to improve reliability of markerless tracking and GRF estimation.
- Testing reliability in outdoor conditions.
- Documented and reproducible recording setup.
- Identification and quantitative comparison of suitable biomechanical parameters.
- Evaluation of system differences, practical limitations, and suitability for the selected application.
- Understanding the technology and algorithms of markerless movement systems.
- Optional: Developing a mobile tracking camera system for extending duration

Validation of Estimated Ground Reaction Forces

A central component of the project is the validation of estimated GRFs. OpenCap recordings will therefore be performed simultaneously with measurements using PASCO force plates.

Students will develop a suitable synchronization procedure and compare estimated and measured force data. Relevant parameters may include force-time curves, peak vertical GRF, impulse, loading characteristics, or contact time (depending on the developed scenario). Appropriate error and agreement measures shall be selected and justified.

Research Question 2

How accurately do markerless estimates of ground reaction forces reproduce simultaneously measured force-plate data?

Deliverables

- Documented synchronization method for OpenCap and PASCO.
- Dataset containing simultaneous markerless and force-plate measurements in a simple GUI
- Processing workflow for aligning and comparing GRF data.
- Quantitative comparison using appropriate error and/or agreement measures.
- Interpretation of the observed deviations for the selected application.

Standardized Assessment and Repeatability

Based on scientific literature, students will select approximately 3–5 functional movements or assessments and develop a standardized measurement protocol and mobility index. Pilot and repeated measurements will be used to optimize the protocol and investigate the stability of selected biomechanical parameters.

Research Question 3

How repeatable are selected biomechanical parameters obtained from markerless motion analysis under standardized measurement conditions?

Deliverables

- Literature-based application scenario and selection of suitable movements and parameters.
- Standardized protocol including movement instructions, repetitions, camera setup, and calibration.
- Pilot testing and refinement of the protocol.
- Quantitative analysis of the repeatability of selected parameters.
- Identification of relevant sources of measurement variability.
- Generate an interpretive report that highlights muscle shortening and joint movement limitations, with a GUI to control report content.

Application Scenario and Automated Reporting

All project components shall be combined within one coherent functional application scenario related to mobility, flexibility, rehabilitation, injury prevention, or functional movement assessment.

Students are expected to select and justify the scenario, movement tasks, relevant biomechanical parameters, and analysis methods based on scientific literature.

A Python-based processing pipeline shall integrate the collected data and automate relevant analysis steps. It should support data import, synchronization, calculation of selected parameters, statistical comparison, visualization, and automated report generation.

The final report should translate biomechanical measurements into understandable information relevant to the selected application, rather than simply presenting raw data. The exact implementation and report design remain open. An interpretable report with a simple GUI is needed.

Optional Extension: OpenSim-Based Biomechanical Modelling

As an optional extension, OpenSim may be used to investigate whether differences between estimated and measured ground reaction forces affect further biomechanical analyses.

Markerless kinematic data may be combined with estimated or PASCO-measured force data to derive additional parameters, such as joint moments. This allows students to explore whether errors identified during GRF validation also influence the biomechanical interpretation.

Optional Research Question

How do differences between estimated and measured input data affect biomechanical parameters derived from musculoskeletal modelling?

Deliverables

- Implementation of an OpenSim-based analysis workflow.
- Comparison of selected biomechanical parameters using estimated versus measured input data.
- Evaluation of the influence of GRF estimation errors on biomechanical interpretation.

III. DELIVERABLES OVERVIEW

The completed project shall provide:

- a standardized, literature-based functional assessment protocol.
- evaluation and comparison of at least two markerless systems.
- analysis of measurement repeatability.
- synchronized PASCO measurements and quantitative GRF validation.
- a documented OpenSim workflow.
- a functional Python-based analysis pipeline.
- an automatically generated assessment report.
- documentation of limitations and recommendations for future use.

Detailed deliverables are listed in the previous section corresponding to the topic. Three iPads and PASCO force plates can be borrowed from UAS Technikum Wien for conducting the measurements.

IV. Learning Outcomes

By the end of this project, students will be able to:

- conduct and critically evaluate markerless motion analysis.
- design standardized functional movement assessments.
- synchronize different data acquisition platforms.
- process and analyze biomechanical time-series data.
- understand and apply fundamental OpenSim workflows.
- develop Python-based workflows for biomechanical data analysis and reporting.
- critically interpret biomechanical parameters in a practical application context.

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Reactivation and Evaluation of a Biodex System for Functional Force Assessment

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Summary — This project aims to reactivate an existing Biodex system 2 and establish a reproducible workflow for biomechanical force and functional assessments. Students will identify and document the available hardware and interfaces, restore data acquisition including appropriate A/D conversion, and develop a graphical user interface (GUI) for configuring measurements, displaying signals in real time, and storing measurement data. The system will then be characterized using suitable test procedures. Finally, selected functional application scenarios and different measurement positions will be implemented to evaluate the system and demonstrate its future use in teaching and research.

Keywords: *Biodex, Force Measurement, Functional Assessment, Biomechanics, A/D Conversion, Data Acquisition, user interface*

Academic Level: *Master*

Course: *PRT*

I. BACKGROUND

Quantitative assessment of muscular strength and function is important in rehabilitation, sports science, biomechanics, and clinical research. Measurements of force, torque, and joint-specific muscular performance can be used to characterize functional limitations, investigate asymmetries, monitor rehabilitation progress, and evaluate interventions.

Dynamometry systems such as Biodex Systems have been widely used for standardized strength and functional assessments. Depending on the system configuration, measurements can be performed at different joints, body positions, and movement conditions. This enables the investigation of muscular function under controlled and reproducible conditions.

An older Biodex system 2 (Biodex Medical Systems, Inc., Shirley, NY, USA) is currently available at UAS Technikum Wien but is no longer in active use. Information regarding its exact configuration, available components, interfaces, data acquisition, and previous measurement workflows is limited. Before the

system can again be used for teaching or research, its technical setup and measurement capabilities need to be systematically investigated, updated and documented.

A particular challenge is the acquisition, visualization, and processing of the measurement signals. Existing analog outputs may require appropriate signal conditioning and analog-to-digital (A/D) conversion before data can be recorded, displayed through a graphical user interface (GUI), and further processed using current software.

The aim of this project is therefore not simply to switch the existing system back on, but to establish a documented, reproducible, and usable measurement setup and demonstrate its functionality using meaningful biomechanical application scenarios.

II. PROJECT OBJECTIVES

System Reactivation and Technical Characterization

The first step is to identify the available Biodex system 2, its components, sensors, interfaces, and

current operational status. Existing documentation shall be collected where available, while missing information may need to be reconstructed through systematic testing.

The goal is to determine which functions of the existing system can be restored and how the system can be operated safely and reproducibly.

Research Question 1

How can the existing Biodex system be technically reactivated and established as a reproducible measurement system for future teaching and research applications?

Deliverables

- Identification and documentation of the available Biodex system and components.
- Technical overview of sensors, mechanical components, interfaces, and available outputs.
- Assessment of the current functionality and identification of missing or non-functional components.
- Reactivation of the relevant measurement functions.
- Documented setup and operating procedure.
- Identification of technical limitations and recommendations for future use.

Data Acquisition and A/D Conversion

central technical component is to establish access to the Biodex measurement signals independently of the outdated acquisition infrastructure from a previous project.

The existing A/D converter and its documentation shall first be reviewed and evaluated. Its technical suitability, compatibility with the available Biodex signals, and limitations shall be assessed. If necessary, the converter shall be adapted, supplemented, or replaced by a suitable current data-acquisition solution.

Available analog signals shall be identified and characterized regarding parameters such as signal type, voltage range, sampling requirements, and calibration. An appropriate A/D conversion and digital data-acquisition workflow shall then be implemented based on the existing documented system and the requirements of the current project.

The resulting data should be accessible for further processing and analysis, preferably using an open and reproducible workflow such as Python.

Research Question 2

How can signals from the existing Biodex system 2 be reliably acquired, digitized, calibrated, and processed using a data-acquisition workflow?

Deliverables

- Identification and characterization of relevant analog output signals.
- Selection and implementation of a suitable A/D conversion and data-acquisition approach.
- Definition of appropriate sampling and signal-processing parameters.
- Calibration or verification of relevant measurement channels.
- Implementation of a reproducible workflow for recording, storing, and processing measurement data.
- Visualization and export of relevant force, torque, position, or other available signals.

Functional Testing and Measurement Positions

Once the system and data acquisition are operational, its functionality shall be evaluated using suitable biomechanical test cases.

Based on literature and the technical possibilities of the available system, students shall select meaningful strength or functional assessments. Measurements should include different positions or configurations to investigate how positioning and measurement setup influence the obtained results.

Possible applications may include isometric strength measurements, joint-specific force or torque assessment, agonist/antagonist comparisons, side-to-side comparisons, or other functional strength assessments supported by the system.

Research Question 3

Can the reactivated Biodex system provide reproducible and interpretable force or functional measurements across selected test conditions and measurement positions?

Deliverables

- Selection and justification of suitable test cases/application scenarios.
- Standardized protocols for participant positioning and measurement execution.
- Implementation of measurements in different relevant positions or configurations.
- Repeated measurements to assess measurement consistency.
- Analysis and visualization of relevant force/torque and functional parameters.
- Evaluation of the influence of measurement position and setup on the results.

III. APPLICATION AND FINAL OUTCOME

The final goal is to establish the Biodex system as a usable measurement platform for future teaching and research projects.

Students shall combine the technical reactivation, data acquisition, and functional testing into one documented workflow. The selected application scenarios should demonstrate not only that signals can be recorded but also that the resulting data provide meaningful biomechanical information.

Where appropriate, a Python-based processing workflow should be developed to automate data import, signal processing, parameter extraction, visualization, and export. Relevant parameters may include peak force or torque, average force, force-time characteristics, side-to-side differences, or other measures appropriate for the selected application.

Final Deliverables

The completed project shall provide:

- a reactivated and operational Biodex measurement setup.
- complete documentation of the available hardware, interfaces, and measurement possibilities.
- a functional A/D conversion and digital data-acquisition workflow.

- verification/calibration of relevant measurement channels.
- standardized protocols for selected force or functional assessments.
- measurements in different relevant positions or configurations.
- an evaluation of measurement consistency and practical usability.
- a reproducible workflow for data processing, visualization, and export.
- a concise Get Started / User Guide enabling future students and researchers to operate the system.

The exact measurement protocols, technical implementation of the data acquisition, and selected biomechanical application scenarios shall be developed and justified by the project team.

IV. LEARNING OUTCOMES

By the end of this project, students will be able to:

- systematically analyze and reactivate an existing biomechanical measurement system.
- understand sensors, analog measurement signals, interfaces, and A/D conversion.
- design and implement a digital data-acquisition workflow.
- calibrate and verify biomechanical measurement signals.
- develop standardized protocols for force and functional assessment.
- perform and analyze biomechanical force and torque measurements.
- process and visualize biomechanical time-series data.
- document a technical measurement system for reproducible future use.

Low-Code Medical VR: From DICOM Scans to Quest 3

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Summary — Visualizing complex, three-dimensional anatomical data from standard medical imaging techniques like CT or MRI remains a cognitive bottleneck when using traditional 2D monitors. This project focuses on developing an interactive Virtual Reality (VR) application for the Meta Quest 3 that allows users to visualise, scale, and inspect segmented patient-specific 3D anatomical models. Using a simplified, beginner-friendly pipeline, students will process real DICOM data set from the Cancer Imaging Archive (TCIA) using the open-source clinical software 3D Slicer, import the optimized 3D meshes into the Unity game engine, and apply low-code VR interactions using Meta's XR SDK blocks. The finalized application could serve an effective tool for pre-operative surgical planning and medical education.

Keywords: Medical Image Segmentation, Virtual Reality (VR), 3D Slicer, Unity, Meta Quest 3

Academic Level: Master

Course: PRT1

I. BACKGROUND

In clinical settings, radiologists and surgeons work with 3D datasets acquired via Computed Tomography (CT) or Magnetic Resonance Imaging (MRI). However, interpreting these volumes on standard monitors requires significant spatial visualization skills and could limit collaborative surgical planning [1]. Virtual Reality and Mixed Reality technologies offer an immersive alternative, placing anatomically accurate, life-sized 3D reconstructions directly in the user's physical space [2].

Historically, deploying complex volumetric medical data to standalone mobile headsets presented major bottlenecks due to strict frame rate requirements (e.g., maintaining a stable 90 FPS to avoid cybersickness) and limited mobile GPU processing power [3]. This project addresses these challenges through a low-code, asset-optimized system integration. By using free open-source software '3D Slicer' for medical image segmentation, students can convert clinical

DICOM slices into optimized, low-polygon 3D meshes (.fbx or .obj files) rather than writing complex rendering shaders from scratch [4].

Using Unity (configured with the Universal Render Pipeline) and Meta's modular XR Building Blocks, students will build a user interface allowing natural grab and scale interactions, clipping-plane cross-sections, and customizable color/transparency maps.

Finally, students can test the app's performance and usability on Quest 3 to prove that medical scans could be turned into interactive VR models.

II. PROJECT OBJECTIVES

- **Analyze Requirements & Literature:** Conduct a state-of-the-art review on TCIA dataset and choose a suitable image modality, as well as conducting research on medical visualization in VR and define technical requirements.

- **Design the Segmentation Pipeline:** Establish a workflow using 3D Slicer to segment anatomical targets (e.g., bones, organs) from the previous Dataset DICOM repositories and optimize them for real-time performance.
- **Develop the VR Application:** Implement the optimized 3D models in Unity URP and configure Quest 3 standalone deployment (including hand-tracking, grab/scale interactions, and visual clipping planes).
- **Evaluate System Usability:** Conduct a baseline usability study using standardized frameworks to evaluate user experience and measure performance metrics (frame rate stability).

III. LEARNING OUTCOMES

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

- **Medical Image Processing:** Segmenting 3D DICOM volumes, handling density thresholds (Hounsfield Units), and exporting optimized surface meshes using 3D Slicer.
- **Game Engine Basics (Unity):** Working with the Universal Render Pipeline (URP), organizing 3D environments, and deploying Android packages (.apk) onto standalone mobile VR headsets.
- **Virtual Reality Interaction Design:** Setting up the **Meta XR Core SDK** and utilizing modular "Building Blocks" for grab-and-scale physics, hand-tracking, and basic 3D UI.
- **Academic Writing & Usability Testing:** Structuring a scientific paper, formulating an engineering-based research question, and conducting quantitative usability evaluations.

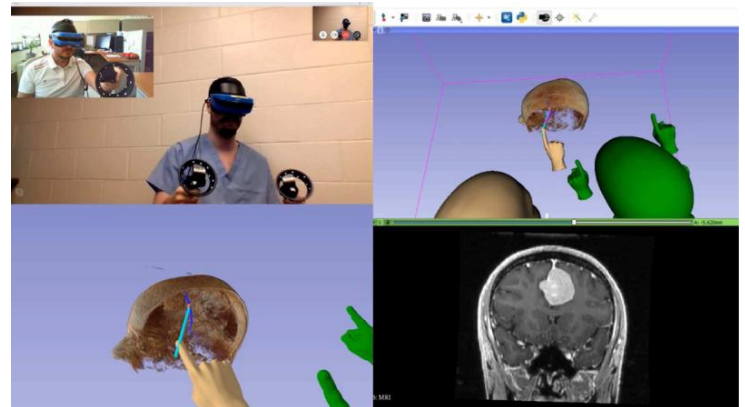


Figure 1 Collaborative brain surgery in virtual reality using real-time tractography

Literature

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Meta Quest 3 Hand-Tracking Upper-Limb Rehabilitation Prototype

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Summary: *This project aims to develop and evaluate an upper-limb rehabilitation prototype for the Meta Quest 3 using hand tracking. The system will implement three use cases featuring at least three simple reaching and grasping exercises to record user movement performance and analyze how collected metrics respond to variations in task difficulty. Additionally, real-world goniometer measurements will be conducted to compare the VR tracking accuracy against traditional assessment methods. The aim of the project is to provide a proof-of-concept for basic rehabilitation using VR exercises for the upper limb, and to provide the know-how for the students.*

Keywords: *Rehabilitation, Meta Quest 3, Upper Limb*

I. BACKGROUND

Virtual Reality (VR) is increasingly used to support rehabilitation exercises by providing interactive, repeatable tasks and objective movement measurements. Recent work with Meta Quest 3 shows that hand tracking can be used for upper-limb and that basic kinematic measures can be extracted from tracked hand positions. A 2026 study with 39 healthy participants reported small tracking errors and moderate-to-good reliability for most tested kinematic measures compared with laboratory motion capture, although some more complex measures were less reliable (Campos et al., 2026).

Recent Quest 3 rehabilitation prototypes have implemented simple activities such as reaching, gripping, carrying, and moving targets, with task parameters such as target distance and time limits (Türe et al., 2026). Earlier Unity-based upper-extremity VR work also used reaching and grasping exercises with hand or controller interaction (Tokgöz et al., 2023). These examples suggest that a limited hand-tracking-based prototype is technically feasible without external sensors.

This project is not meant to act as a complete clinical rehabilitation program, but rather to serve

as a basic test for a specific set of upper-limb exercises. Because of this, it is not intended to measure EMG, diagnose illnesses, or prove medical effectiveness. Instead, the goal is to show that Quest 3 hand tracking can accurately capture these movements and provide reliable, repeatable performance data.

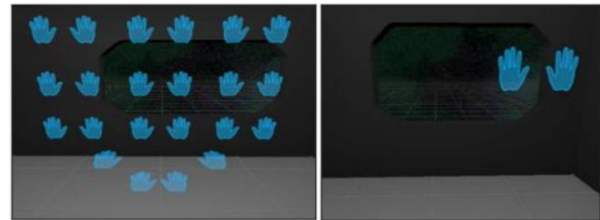


Figure 1: Forward-reaching movement pattern used in a virtual upper-extremity rehabilitation exercise, illustrating the presentation of bilateral target positions and the corresponding bimanual reaching task, taken from (Tokgöz et al., 2023).

II. PROJECT OBJECTIVES

The objectives of this project are to:

- Develop a VR prototype: Implement Unity application/ Game using hand tracking to support upper limb rehabilitation exercises targeting the shoulder, elbow, and hand.

- **Exercise Implementation:** Design and implement 2–3 standardized functional tasks (e.g., point-reaching, reach-and-grasp, and path-following) with three adjustable levels of difficulty. These task should follow standardized clinical assessment protocol called the Action Research Arm Test (ARAT).
- **Capture movement data:** Record hand position and timestamps during each trial.
- **Calculate basic metrics:** Measure success/failure, movement time, reach distance, trajectory length, average speed, and optionally movement efficiency.
- **Conduct Physical Goniometer Baseline:** Measure shoulder, elbow, and hand angles using a digital goniometer while participants perform the exact same exercise protocols in a virtual Reality setting.
- **Feasibility Evaluation & Comparative Validation:** Conduct a pilot feasibility study with 10–15 healthy participants (pending institutional approval) across three task difficulty levels. Evaluate user performance and system usability in VR and perform a comparative analysis between Meta Quest 3 hand-tracking data and real-world goniometer joint measurements.

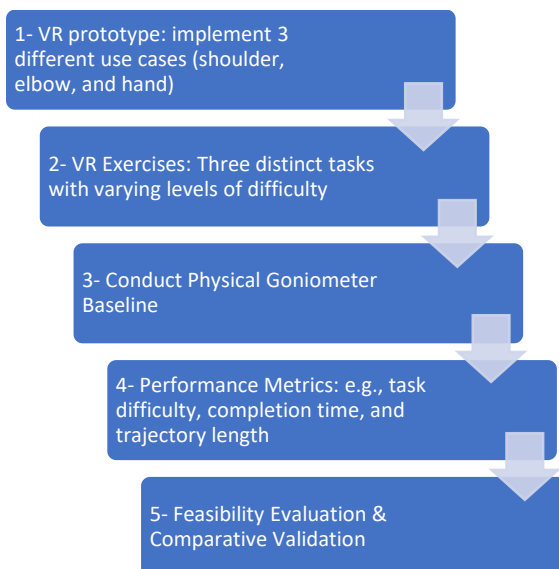


Figure 2: Proposed Project Workflow (Quest 3)

III. LEARNING OUTCOMES

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

- Develop a hand-tracked VR application in Unity for Meta Quest 3.
- Design simple rehabilitation-oriented interaction tasks and adjust their difficulty.
- Work with tracked 3D hand-position data and timestamps.
- Implement basic movement and performance metrics such as completion time, trajectory length and movement efficiency.
- Design and conduct a small technical usability/feasibility evaluation and analyse the resulting data.
- Write a comprehensive project report following the standardized IMRD structure.

IV. LITERATURE

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FHTW-EMR: Electronic Medical Record for Learning and Research

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Summary — The laboratory infrastructure at UAS Technikum Wien includes the Intensive Care Unit and the Health & Care Data Center. New in 2026, an Electronic Medical Record system (EMR) is available, based on open source software components. This now enables us to explore and optimise the digital landscape of health care professionals and patients with close insight into the daily routines. A series of student projects will over time add functions to the EHR to collect, exchange and use data, e.g. to render views on trends and patient journeys, and to provide support to patients and healthcare providers based on available data and knowledge. The projects will use HL7 FHIR resources, from specifications for the European Health Data Space (EHDS). They will also connect to partner institutions from industry and healthcare, to assure that user requirements are met in the best possible way.

Keywords: *Electronic Medical Record, EU Health Data Space, HL7 FHIR,*

Academic Level: *Master / Bachelor*

Course: *PRT/leave empty*

I. BACKGROUND

For many, digitalization offers great potential for continuing to provide high-quality care within existing healthcare systems. Over the last decades substantial progress was made in digital technologies, including mobile applications, semantic interoperability and smart use of data. However, there is only weak evidence about benefits of digitalization in clinical care on large scales so far, e.g. [1]. Further work is therefore necessary to better transfer technological progress into medical practice and patient journeys [2]. This will have to address organizational, regulatory and technical issues.

In our study programs at UAS Technikum Wien we traditionally provide the basic skills required for digitalization in healthcare, including hands-on experience throughout development life cycles. So far, we were not able to demonstrate professional digital environments like electronic medical record systems (EMRs) and Picture Archive and Communication Systems (PACS) in our courses, and to provide them to students for hands on practice. EMRs are typically complex, individually tailored and costly. In academic

environments they are available only within selected funded projects. On the other hand, open source software is already in intensive use locally, [3], [4], [5]. Using these, the EMR was built at UASTW, see Figure 1 and Figure 2. Significant progress was also made in standards based data sharing, e.g. in the EURIDICE initiative [6], connected to the EU Health Data Space (EHDS) [7], [8].

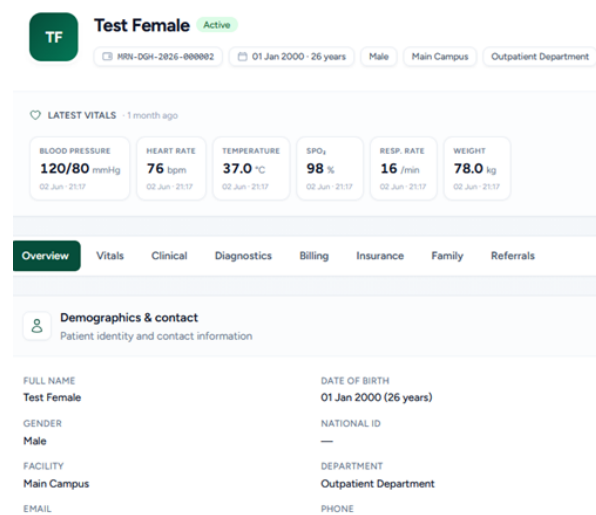
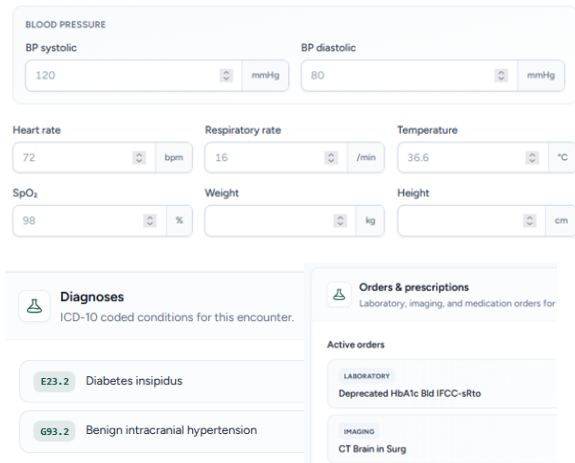


Figure 1 Patient view in the EMR system of UASTW

The goal of the series of projects described here is therefore to explore and enhance functionalities of the EMR at UASTW, with the goal to better support digitalization in healthcare on larger scales. We want to consider the results of cross border initiatives like e.g. EHDS and translate them into tangible benefits for users in medicine.



The screenshot displays a user interface for an EMR system. It features several input fields for vital signs: Blood Pressure (systolic 120, diastolic 80), Heart rate (72 bpm), Respiratory rate (16 /min), Temperature (36.5 °C), SpO2 (98 %), Weight, and Height. Below these, there are sections for 'Diagnoses' (listing ICD-10 coded conditions like Diabetes insipidus and Benign intracranial hypertension) and 'Orders & prescriptions' (listing active orders like Deprecated HbA1c Bld IFCC-sRto and CT Brain in Surg).

Figure 2 Vital signs, diagnoses and orders in the EMR system of UASTW

II. PROJECT OBJECTIVES

This group of projects will target one or more of the following objectives:

- Support specific medical workflows and patient journeys
- Enable the EMR to access and share data via available HL7 FHIR APIs and with the PACS (DCM4CHE)
- Connect the EMR to national IT infrastructures, e.g. ELGA, eCard / GIN
- Select and present available data as required for specific tasks
- Integrate smart and AI functionality as required for specific tasks, including secondary use based on OMOP
- Connect to partner universities and other (open source) communities in sustained collaborations
- Take part in external connectathons, hackathons and projectathons to demonstrate and optimise the EMR

III. LEARNING OUTCOMES

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

- Defining requirements based on clinical workflows and patient journeys
- Design, implementation and testing of software components within the EMR landscape
- Engaging in large scale open source software projects
- HL7 FHIR implementations based on the EHDS specifications

Literature

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GEN-DOCK - Genomic Triggered Automated Docking

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Summary — Modern precision medicine integrates patient genomic data with computational drug discovery to enable tailored therapeutic strategies. This project introduces GenDock, a cloud-based, high-throughput virtual screening pipeline that bridges a simulated Hospital Information System (HIS) with structural bioinformatics tooling through FHIR interoperability. A Python microservice monitors clinical events (via JSON/MQTT). Upon detecting a predefined disease-associated genomic variant or protein target (e.g., BRAF/EGFR in oncology, viral/bacterial targets, or metabolic mutations), the service automatically retrieves target protein structures from the Protein Data Bank (PDB), prepares the receptor, and executes automated molecular docking using AutoDock Vina. Predicted binding affinities (ΔG) are parsed, ranked, and mapped into standardized FHIR Observation resources, which are then transmitted via REST APIs to an Electronic Medical Record (EMR) at FHTW. This demonstrates a seamless, event-driven link between clinical systems and computational decision support.

Keywords: *eHealth Infrastructure, High-Throughput Virtual Screening, AutoDock Vina, FHIR,*

Academic Level: *Master/ Bachelor*

Course: *PRT/leave empty*

I. BACKGROUND

Clinical decision support increasingly depends on integrating heterogeneous biomedical data sources. Although hospitals routinely store diagnoses, laboratory results, and genomic reports in electronic medical records, computational screening tools remain disconnected from healthcare infrastructures. HL7 FHIR offers a standardized REST-based framework for exchanging healthcare information, enabling computational outputs to become part of clinical workflows. This project demonstrates an event-driven architecture where patient-specific genomic information triggers automated docking experiments. The workflow includes protein retrieval from the Protein Data Bank, ligand library screening, parsing docking scores, and generation of standardized FHIR Observation resources for downstream clinical applications. In oncology contexts, specific target variants such as mutated BRAF or EGFR kinases

require targeted therapeutic strategies. Traditional workflows require bioinformaticians to manually download target structures, configure grid boxes, and run docking software, followed by custom reporting. By automating this pipeline via cloud microservices and connecting it to clinical triggers, treatment options or small-molecule binding predictions can be delivered directly to oncologists via the Electronic Medical Record (EMR) system.

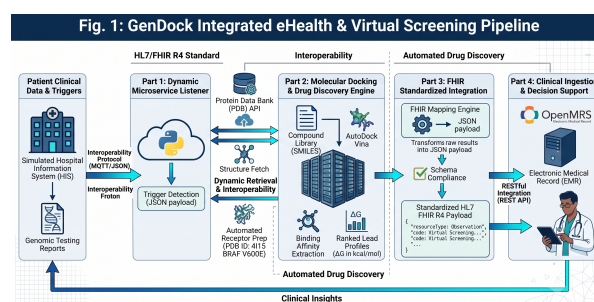


Figure 1: GenDock end-to-end pipeline, demonstrating event-driven clinical workflow triggering, automated docking, and standardized FHIR ingestion into OpenMRS for multi-disease personalized medicine.



II. PROJECT OBJECTIVES

The core technical and methodological objectives of this project are structured as follows:

1. **Interoperability:** Design an event-driven cloud architecture (JSON/MQTT) connecting HIS triggers to computational microservices.
2. **Dynamic Pipeline:** Automate real-time PDB structure retrieval and receptor/grid preparation based on patient variant triggers.
3. **Molecular Docking:** Execute high-throughput AutoDock Vina screening, parsing and ranking ligand binding affinities (ΔG).
4. **FHIR & Drug Discovery:** Convert docking results into valid HL7 FHIR Observations and ingest them into EMR at FHTW via REST APIs.

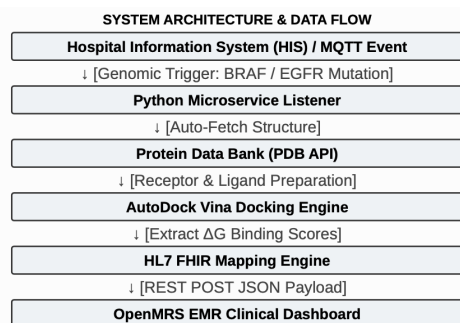


Fig. 1. End-to-end event-driven architecture bridging clinical EMRs with computational drug screening.

III. LEARNING OUTCOMES

Students engaging in this project will acquire advanced interdisciplinary competence across software engineering, bioinformatics, and healthcare informatics. Specifically, key learning outcomes include:

- **Python Microservice Engineering:** Mastery in building robust, event-driven RESTful services and socket/MQTT listeners.
- **Structural Bioinformatics & Docking:** Hands-on experience with molecular structure manipulation, PDB parsing, ligand/receptor preparation, and AutoDock Vina execution.

- **eHealth Standards & Interoperability:** Deep expertise in FHIR R4 schema design, coding systems (LOINC, SNOMED CT), and JSON resource serialization.
- **EMR Systems & RESTful Integration:** Practical integration experience with OpenMRS and enterprise healthcare APIs.
- **Collaborative Development & DevOps:** Practical application of Git version control, continuous integration, Docker containerization, and automated testing frameworks.
- **Scalable eHealth System Design:** Understanding architectural patterns required for high-throughput, HIPAA/GDPR-aware clinical decision support systems.

Sample FHIR R4 Observation Snippet

```
{
  "resourceType": "Observation",
  "status": "final",
  "category": [{ "coding": [{ "system": "http://terminology.hl7.org/CodeSystem/observation-category", "code": "exam" }] }],
  "code": { "text": "Virtual Screening Binding Affinity (Delta G)" },
  "subject": { "reference": "Patient/SIM-ONCOL-042" },
  "valueQuantity": {
    "value": -9.4,
    "unit": "kcal/mol",
    "system": "http://unitsofmeasure.org",
    "code": "kcal/mol"
  },
  "component": [{
    "code": { "text": "Target Protein / Variant" },
    "valueString": "BRAF V600E (PDB: 4115)"
  }]
}
```

Fig. 2. Standardized FHIR R4 JSON payload representing molecular docking results for clinical ingestion.

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