UNIVERSITY OF LIVERPOOL
DEPARTMENT OF ELECTRICAL ENGINEERING & ELECTRONICS

Final Year Project

(ELEC340 / ELEC440)

Project Plan and Specifications

'Smart Sock - Project in partnership with Aintree Hospital'

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Project Supervisor: Ian Sandall

Declaration of academic integrity

The standard University of Liverpool statement of academic integrity [6] should go here as follows:

I confirm that I have read and understood the University's Academic Integrity Policy.

I confirm that I have acted honestly, ethically and professionally in conduct leading to assessment for the programme of study.

I confirm that I have not copied material from another source nor committed plagiarism nor fabricated, falsified or embellished data when completing the attached piece of work. I confirm that I have not copied material from another source, nor colluded with any other student in the preparation and production of this work.

SIGNATURE……Jiajun Guo…… DATE……27 Sep. 2023…….

Abstract

The "Smart Sock" project, initiated in partnership with Aintree Hospital, seeks to revolutionize the monitoring of heart failure (HF) patients. This report details the development of a wearable that integrates advanced sensors to detect ankle oedema, heart rate, and possibly oxygen saturation which are common markers of heart failure exacerbation. Through continuous, wireless data transmission, the device aims to alert caregivers or medical professionals to potential health risks in real time. This innovation has the potential to reduce emergency hospitalizations and improve patient care significantly. With a strong alignment to growing trends in wearable health technology and remote patient monitoring, the Smart Sock initiative embodies both industrial relevance and research potential. This report delves into the project's rationale, specifications, objectives, methodology, and preliminary results, offering a comprehensive view of its development and significance.

Contents

1. Introduction

A growing public health concern is heart failure (HF), particularly among the aging population. Over 20 million people worldwide have HF, with affluent nations having a 2% prevalence. It is alarming to see that more than half of confirmed cases will die within five years. As people get older, HF poses a significant threat to the efficient use of healthcare resources[1]. The financial burden of HF is mostly caused by the hospitalization of elderly patients, with direct expenses like hospital stays and prescription drug prices being high. Although pharmacologic treatments like β-blocker therapy have proven cost effective, the efficiency of hospital or home-based management remains debated [2]. Heart failure often presents through subtle symptoms which, if detected early, can prevent exacerbations and improve patient outcomes. In the pursuit of creating a seamless solution, the "Smart Sock" project was conceptualized. This report elucidates the journey of developing a wearable device, its industrial relevance, and the potential it holds in transforming HF patient monitoring. The subsequent sections present a detailed account of the project specifications and objectives, beginning with the conception of the anklet design and progressing through its multifaceted functionalities. The methodology section offers a structured roadmap of the project's execution, broken down into key phases and tasks. In addition, this report insights into the project's relevance in the current industrial landscape, its alignment with research trends, and the preliminary achievements to date. This report provides readers with a holistic understanding of the project, its potential impacts, and the strides made in its development.

2. Project Description

The "Smart Sock" initiative, in collaboration with Aintree Hospital, seeks to create a wearable that uses sensors to continuously monitor HF patients for ankle swelling. It aims to automatically detect the early signs of heart failure decompensation. Additionally, the sock will incorporate features to monitor atrial fibrillation and possibly measure oxygen saturation. The end goal is to offer a solution that is not only non-intrusive but also provides real-time data wirelessly, ensuring timely intervention when needed.

3. Project Specifications/objectives

3.1 Design an Anklet for Pressure Detection in a Supine Position

Develop an anklet equipped with compact and low-power sensors and microcontrollers to detect ankle pressure while lying flat. The design should ensure that the battery lasts for more than three days on a single charge and accurate detection of ankle swelling within an acceptable margin of error with an initial target of detecting a 0.1 cm increase in ankle width. Focus on sophisticated data processing and circuit design to convert sensor data into valuable insights for assessing ankle oedema. This foundational step is expected to be completed in 3 weeks, paving the way for subsequent stages upon receipt of all ordered components.

3.2 Fabricate the Anklet

Implement the design, connecting components as per the initial design to create a prototype. Ensure the device fits comfortably around the ankle, maintains low power consumption for

over three days, and offers accurate swelling detection. The verification method is that the tapered frustum simulates the gradual swelling process of the ankle joint. The accuracy of the anklet detection was verified by testing on a conical stage. Refine the design to ensure system stability and basic functionality. Allocate 5-6 weeks for this crucial phase, accounting for potential challenges in circuit design.

3.3 Integrate Heart Rate and Oxygen Saturation Sensors

Enhance the anklet by adding sensors for heart rate and oxygen saturation, ensuring they seamlessly integrate without compromising comfort or accuracy. This augmentation should not interfere with the primary function of ankle pressure detection. This simpler addition is projected to be completed within 2 weeks.

3.4 Implement Wireless Data Transmission

Equip the system for continuous measurements and data transmission, with a storage capacity of at least three days. Utilize a compact, low-power microcontroller supporting Bluetooth or other wireless protocols which should recode the data every 20 minutes. For now, I'm considering an ESP32, a low-power, integrated Wi-Fi and Bluetooth microcontroller that's perfect for wireless communication. It has enough GPIO to easily connect multiple sensors, while also supporting low-power mode, which is suitable for continuous monitoring applications and met my basic needs. Emphasize long-term data transmission stability. Allocate 4 weeks to achieve this milestone.

3.5 Establish Alert Thresholds

By detecting my heart rate and blood oxygen saturation data, which will provide “healthy data” and put the sock on the made conical frustum, moved the position of the anklet to change the height from the bottom of the conical frustum, simulated the process of ankle swelling. Analyse collected data on supine ankle pressure, heart rate, and oxygen saturation to determine alert thresholds based on the degree of ankle oedema and other health parameters. Focus on minimizing false alerts through multi-faceted analyses and comparisons. This phase, marking the preliminary completion of the “smart sock,” is expected to take 3 weeks.

3.6 Develop a Seated Mode Detection

Introduce a secondary mode for seated detection, offering the same real-time monitoring, data transmission, and alert triggering functionalities as the supine mode. Adjust detection parameters and thresholds to cater to variations in data ranges between seated and supine positions. This enhanced functionality, contributing to a multi-modal detection system, is expected to be developed within 3 weeks.

3.7 Explore the Concept of a "Digital Sock"

Post basic functionality achievement, contemplate the development of a digital sock model and a platform to receive sensor data. Aim for a user-friendly interface displaying data and alerts and consider remote monitoring for healthcare professionals. These enhancements aim to elevate user experience post-basic development.

3.8 Test All Implemented Features

Conduct comprehensive real-world testing to evaluate the smart sock's performance and accuracy, especially focusing on the needs of heart failure patients. Compare test results with traditional methods to affirm the validity and effectiveness of the developed system, leading to further optimizations.

4. Methodology

4.1 Materials and Preparation

To realize the "Smart Sock" project, the basic data information needed must first be determined, identifying sensors capable of measuring ankle oedema, heart rate, and oxygen saturation. In addition, the selection of microcontrollers that combine energy efficiency with the required computing power will play a key role. Wireless communication modules, especially those utilizing Bluetooth technology, are essential for transmitting data. Other materials include circuit components and materials used to prototype the sock itself. In addition to materials, engagement with potential users, especially patients with heart failure, can not only deepen our understanding but also improve the design to meet their unique needs. Interaction with medical professionals further provided insights from a clinical perspective.

4.2 Development and Implementation

1. Preliminary Research

Conduct a literature review on existing solutions and technologies for detecting ankle edema, heart rate, and oxygen saturation. Engage with potential users, primarily heart failure patients, and medical professionals for feedback and input.

2. Design Phase

Select appropriate sensors and microcontrollers based on size, power consumption, and performance criteria. Draft an initial circuit schematic and design a data processing algorithm to convert raw sensor data into meaningful insights.

3. Build a conical frustum

About the method of verification, by 3D printing a conical frustum, the height is about 10cm, the radius of the lower bottom is 3cm, and the upper bottom is 6cm. According to the calculation formula of the circumference of the circle, the circumference of the lower and upper bottom of this conical frustum is about 18.85 and 37.7cm, respectively. This means that we can use this conical frustum to model the degree of ankle swelling in the range of 19 to 37cm, which is 18cm. Put it into the sock from bottom to top, and slowly move the sock down. The anklet will also move down with the sock, and the circumference of the cross section of the conical frustum where the anklet is located will gradually become larger, thus simulating the phenomenon of gradual ankle swelling. By testing on conical frustum, the change of the cross-sectional perimeter from the initial position to the final detection position during the testing process can be calculated, and the accuracy of the anklet detection can be verified by comparing with the change of the perimeter detected by the anklet. The specific calculation process is shown in the results section.

4. Prototyping and Initial Testing
Source selected components and assemble an initial prototype based on the design. Conduct bench testing to validate component communication and measure the accuracy of sensors in controlled environments. Make design iterations based on test results. The pressure sensor is used to obtain pressure at the ankle, taking into account only the data detected by the sensor when the user is lying flat.

5. Integration of Additional Sensors
Add heart rate and oxygen saturation sensors to the anklet. Ensure sensors do not hinder the anklet's primary function and provide accurate readings. Update the data processing algorithm to accommodate new data inputs.

6. Data Communication and Storage
Integrate wireless communication modules (e.g., Bluetooth) into the anklet. Develop a backend system or use cloud storage solutions to store continuous data. Ensure data encryption and security protocols are in place to protect user privacy.

7. Alert System Development
Analyze collected data to determine alert thresholds. Develop an alert system that triggers based on the analyzed thresholds, ensuring minimal false alarms.

8. Multi-modal Detection
Adjust the anklet's algorithm for seated detection. Conduct tests to validate the seated mode and refine thresholds based on the different postural changes.

9. Consider other features
Design a user-friendly interface for the digital sock platform. Integrate features such as real-time data visualization and remote monitoring capabilities for healthcare professionals.

10. Real world testing and optimization
Testing in collaboration with heart failure patients. Collect feedback and make necessary adjustments based on actual test results. Improve anklet design and system based on feedback and test results.

By breaking down the approach into these specific work packages, the goal of each phase becomes clear. This approach not only ensures systematic progress, but also allows for iterative feedback, ensuring the success of the project and its relevance to the end user.

5. Project Plan

As shown in Appendix 1 and Appendix 2, the final detection accuracy of ankle changes needs to reach 0.1 cm. The recorded data can be recorded every 20 minutes through wireless transmission, and the data can be stored for at least 3 days, which also requires that the battery can meet the power supply for at least 3 days. The entire project is expected to take 20 weeks to complete, of which the production of the ankle bracelet and the test in the supine state are expected to take about one month at most. After 18 weeks, the basic functionality

of the whole project will be completed, and final testing and further improvements will be made.

6. Project Rationale and Industrial Relevance

Heart failure is a global health concern, affecting millions of people worldwide. Monitoring early signs of heart failure exacerbation, such as ankle oedema, is crucial for timely medical intervention, preventing potential complications and hospitalizations. Elderly or frail patients may overlook these signs or find it cumbersome to use traditional methods. The "gold standard" method now in use calls for a nurse to measure the ankle once or twice a day. This method is plainly labour-intensive and slow, making it unsuitable to use in the home or community and costly when used in medical settings as the nurse's time could be spent doing other things. The Smart Sock project, designed to monitor ankle swelling, heart rate, and oxygen saturation, addresses this need. The continuous monitoring coupled with alert systems can ensure timely medical consultations, potentially saving lives and reducing healthcare costs related to heart failure complications.

The wearable health technology market is witnessing exponential growth. With the increased focus on preventive care and the rise of health-conscious consumers, devices that provide real-time health insights are in high demand. With global demographics shifting towards an older population, there's a significant market for devices tailored towards elderly care. This segment often requires more intensive health monitoring due to a higher propensity for chronic diseases like heart failure. Recent trends in healthcare lean towards telemedicine and remote patient monitoring. The Smart Sock's capability to send real-time data wirelessly fits perfectly within this paradigm, potentially integrating with telehealth platforms for healthcare professionals to assess patients' conditions remotely. For healthcare providers, a device like the Smart Sock can potentially lead to a decrease in emergency hospitalizations due to heart failure exacerbations. This reduction not only alleviates patient suffering but also translates to significant cost savings for healthcare systems.

Health informatics, wearable health devices, patient monitoring or any related field is also one of my supervisor's research interests. The project touches upon various areas of interest, from sensor technology and data analytics to patient care and telemedicine. Furthermore, the potential for further research, such as algorithm optimization based on larger patient data sets or integration with other wearable devices, is vast.

In conclusion, the Smart Sock project is not only relevant to the industry but is poised at the intersection of several growing market segments. Its potential for improving patient care while fitting within emerging healthcare trends makes it a timely and relevant endeavour.

7. Literature Review

Heart failure is a rising epidemic, particularly among the aging population, with over 20 million affected globally. In the U.S., 5.7 million suffer from HF, leading to substantial healthcare visits and a significant mortality rate [1]. This prevalent condition, especially in those >70 years,

imposes a massive economic burden, emphasizing the urgency for innovative and cost-effective interventions [2].

The study of heart failure has been extensive, especially in terms of its impact on patients' quality of life. It's crucial for patients to self-manage and monitor symptoms. The acceptability and feasibility of continuous monitoring for HF patients, both during hospitalization and at home, have been explored [3]. Peripheral oedema is a common clinical symptom potentially impacting cardiovascular, renal, and hepatic systems, possibly leading to serious conditions like severe cardiac overload and HF. Ankle oedema, in particular, is considered a significant marker for HF [4]. Among the eight methods evaluated for peripheral oedema, water displacement and ankle circumference showed higher reliability. However, implementing the water displacement method proved more challenging and time-consuming in clinical trial settings compared to measuring ankle circumference [5]. Early studies, [4] showcasing ring-shaped finger sensors, effectively monitored heart rate, oxygen saturation, and heart rate variability, displaying the clinical potential of wearable biosensors. With technological advancements, many studies now focus on quantifying peripheral oedema continuously and accurately. [6] studied the impact of different body positions on foot and ankle volume, revealing minimal volume change in supine and seated positions, with standing showing the most significant increase.

In recent years, various wearable sensor technologies to monitor oedema have been developed. These utilize a combination of sensors like elastic strain gauges, pressure sensors like Flexiforce, elastic sensors, and IMUs to continuously and real-time monitor ankle oedema [7], [8], [9], [10], [11], [12] and [13]. Among these, [11] integrates an accelerometer with a flexible stretch sensor, utilizing a unique polymer composition rope to quantify ankle circumference, achieving an impressive 97% accuracy with the activity posture identification.

In conclusion, continuous and remote monitoring is deemed crucial for heart failure patients. wearable sensors technology has advanced to provide continuous, real-time monitoring of ankle oedema. Various studies suggest that combining sensors with smart textile technology holds promise as a vital management tool for heart failure patients.

8. Results

8.1 Preparatory work

So far, I have read a lot of literature to have a deeper understanding of my project. In addition, I have participated in and successfully passed the university ethics and integrity training, and once I successfully obtain the ethics approval, I can officially start my project. In addition,

8.2 Component selection

The materials needed for the initial start-up have been identified, including components such as sensors and microcontrollers. Pressure and Stretch Sensors include a pressure-sensitive material, Velostat, whose resistance changes when subjected to pressure. There are also Flexiforce A201 Sensors which measure externally applied pressure, change its resistance

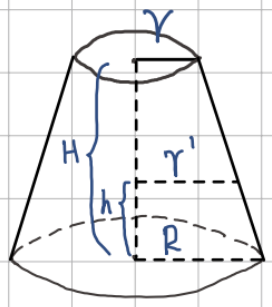
value when subjected to pressure and produce a corresponding voltage output. A simple voltage divider circuit is used with the ADC port of the microcontroller to read pressure changes. For measuring heart rate and blood oxygen saturation sensors, I considered the MAX30102, which is an integrated infrared and red LED sensor that can measure both heart rate and blood oxygen saturation. It uses PPG (Photoplethysmogram) technology to detect changes in blood flow, fixes it near the ankle joint, and measures small changes in blood flow under the skin in close contact with the skin. I chose to use the ESP32-WROOM-32 microcontroller, which has low power consumption and Bluetooth capability, allowing me to achieve wireless communication and extend usage time. The plan is to use LiPo 500mAh, a small lithium-ion battery.

8.3 Perimeter calculation

The process of ankle swelling was simulated by a conical frustum with a height of 10cm and a radius of 3 and 6cm on the upper and lower bottom surfaces, respectively. During the test, the anklet is placed on the upper edge of the conical frustum as the initial position, and then the position of the anklet is moved. According to formula 1, through the height of the anklet to the bottom of the conical frustum, the "ankle" circumference at this time can be calculate, and the "ankle swelling" can be obtained compared with the circumference of the initial position. Formula 1 gives the method of calculating the cross section at the anklet position by the height of the it distances from the bottom of the conical frustum. Formula 2 gives the difference when measured by different heights, so it is easy to calculate how much the circumference has changed. The value calculated by these two formulas is convenient to verify with the measured value of the ankle bracelet. The following is the specific calculation process.

$$C' = 12\pi - 0.6h \tag{1}$$

$$\Delta C' = 0.6\pi(h_0 - h_1) \tag{2}$$



height : $H = 10$ cm

the height of the anklet : h, $0 \le h \le 10$ cm

the radius of the lower bottom : $R = 6$ cm

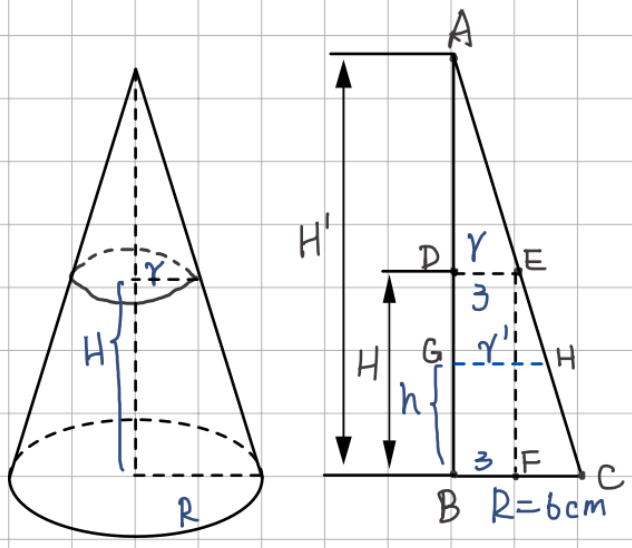
the radius of the upper bottom: $r = 3$ cm

circumference: $C = 2\pi r$

the radius of the cross section : r'

$3\text{cm} \le r' \le 6\text{cm}$

The relationship between the radius of the cross section r' and the height of the anklet h :



$R = 2r = 6$ cm

$AD = EF = DB = H = 10$ cm

$H' = AB = 20$ cm

$h' = AG = H' - h = 20 - h$ cm

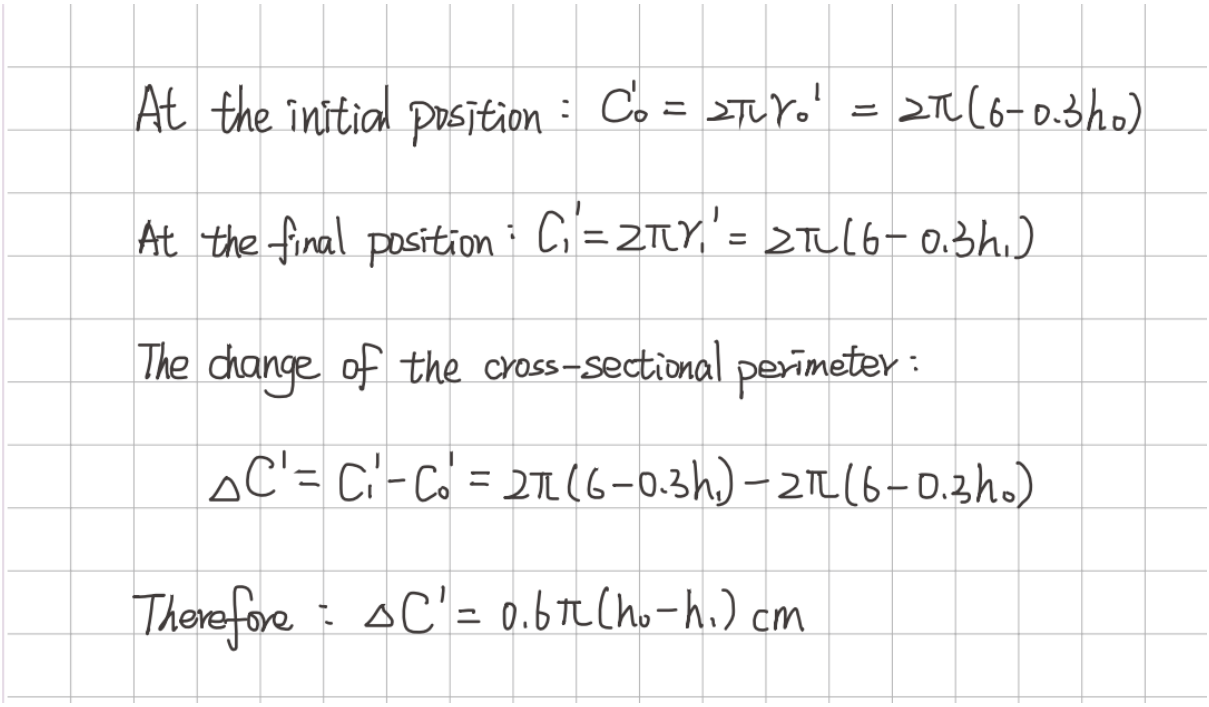
$\triangle AGH \sim \triangle ABC$

$$\frac{AG}{AB} = \frac{GH}{BC} \Rightarrow \frac{H'-h}{H'} = \frac{r'}{R} \Rightarrow \frac{20-h}{20} = \frac{r'}{6}$$

Rewrite : $r' = 6 - 0.3h$ cm

Because : $C = 2\pi r \Rightarrow C' = 12\pi - 0.6\pi h$ cm

The circumference of the cross section of the conical frustum where the anklet is located is : $C' = 12\pi - 0.6\pi h \quad (0 \le h \le 10\text{cm})$



9. Conclusion

The "Smart Sock" project epitomizes the confluence of technology and healthcare, aiming to provide an invaluable solution for heart failure patients worldwide. This endeavour underscores the significance of early detection and timely medical intervention, seeking to minimize complications associated with heart failure decompensation. By leveraging advanced sensor technology, data analytics, and wireless communication, this project endeavours to develop a wearable that is both functional and non-intrusive. The exponential growth and demand in the wearable health technology market, coupled with the shifting global demographics, bolster the project's industrial relevance. From component selection to ethics and integrity training, the preliminary phases have been successfully navigated. As the project progresses, it is expected that in the future this project will improve patient care, reduce healthcare complications, and subsequently, create a solution that resonates with both healthcare professionals and the patients they serve.

Appendix 1. Key Specifications

Parameter	**Verification**
Ankle swelling was detected with an acceptable margin of error of 0.1cm	Check the accuracy of the equipment in the test verification phase by using conical frustum
Record data every 20 minutes	Use a timer to measure the data rate
Data can be stored on removable memory for at least 3 days	Review calculation
The data is transmitted wirelessly	Demonstration
Battery powered for up to 3 days	Measure the current and extrapolate

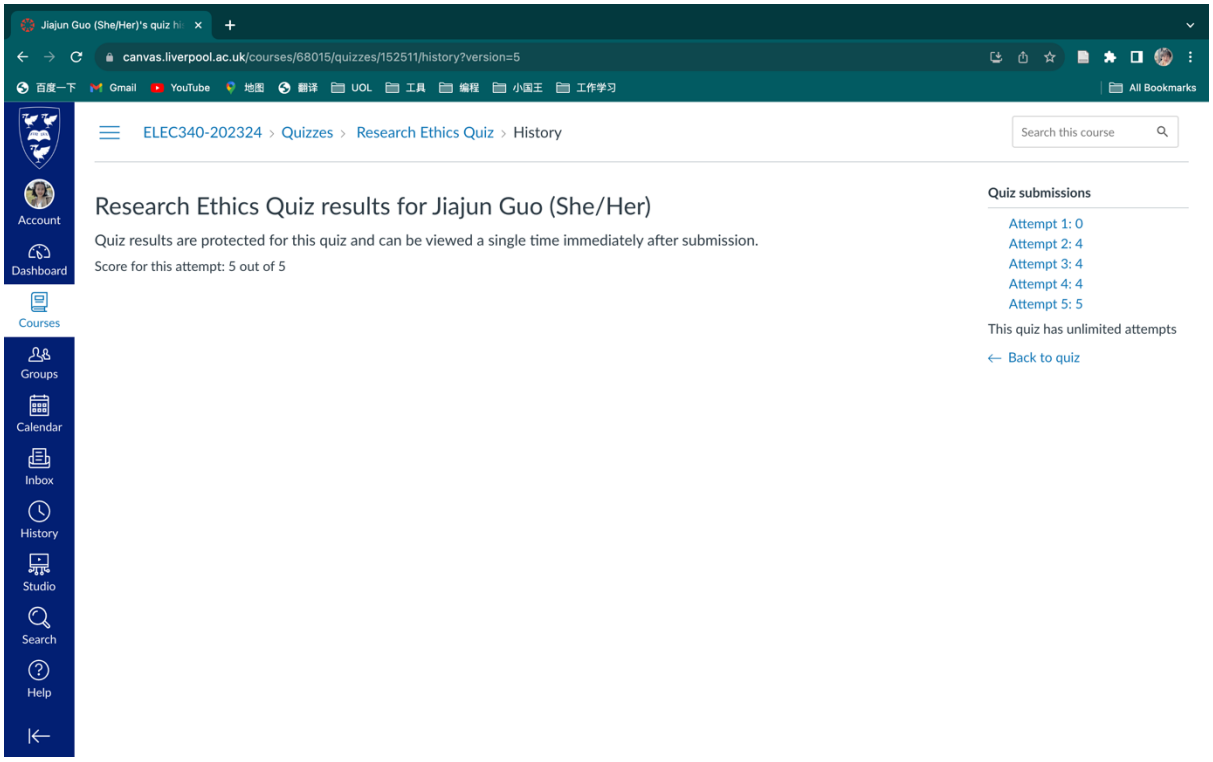
Appendix 2. A Gantt chart

Task	W0	W1	W2	W3	W 4~6	W 7~10	W11	W12	W 13,14	W 15~17	W18	W 19,20
Study the literature												
Conduct risk and ethical assessments												
Apply for ethics approval												
Submit Project Plan/Specifications												
Design an Anklet for Pressure Detection in a Supine Position												
Fabricate the Anklet												
Integrate Heart Rate and Oxygen Saturation Sensors												
Implement Wireless Data Transmission												
Establish Alert Thresholds												
Develop a Seated Mode Detection												
Explore the Concept of a "Digital Sock"												
Test All Implemented Features												

Appendix 3. List of work packages, milestones and deliverables.

Work packages	Milestones	Deliverables
Design an Anklet for Pressure Detection in a Supine Position	Ankle swelling was detected with an acceptable margin of error of 0.1cm.	A preliminary ankle ring that can detect ankle swelling was successfully made. Battery powered for up to 3 days.
Fabricate the Anklet		
Integrate Heart Rate and Oxygen Saturation Sensors		
Implement Wireless Data Transmission	Data is transmitted wirelessly, and alerts are enabled when a threshold is reached.	The data is transmitted wirelessly, Record data every 20 minutes. Data can be stored on removable memory for at least 3 days.
Establish Alert Thresholds		
Develop a Seated Mode Detection	Develop a Seated Mode and add extensions.	Optimize the already implemented features and try to add new features, including standing mode, and build a visual interface to display virtual socks for easy observation.
Explore the Concept of a "Digital Sock"		
Test All Implemented Features		

Appendix 4. The Research Ethics Quiz on Canvas



Appendix 5. The risk assessment form

UNIVERSITY OF LIVERPOOL

SINLGE USER BEng, MEng, MSc GROUP PROJECT RISK ASSESSMENT FORM - REPORT ONLY SIGNIFICANT HAZARDS
Unsafe working methods will lead to a reduction in your final project mark! ALL hardware work must be completed within the laboratory

Students are encouraged to come on site to perform their lab work but are advised that in some circumstances (Adriano, raspberry Pi and micro-controller boards which operate at <20V) equipment is allowed to be brought home. Students removing any other equipment from the lab needs to be authorised in writing by your supervisor - supervisors please confirm with HOD/safety team to confirm.

NAME- Jiajun Guo **Student ID Number- 201676348**	**LOCATION-** **Final year Laboratory**
SCHOOL/DEPARTMENT: Electrical Engineering & Electronics **Undergraduate year of study: Year 3**	**BUILDING: Electrical Engineering and Electronics, A-Block**
TITLE OF PROJECT: Smart Sock - Project in partnership with Aintree Hospital	
Description of Work: Develop socks with sensors to monitor frail/elderly heart failure (HF) patients for the development of ankle swelling.	

Select a category for this project: **Category 1**	**Category 1 – Projects based on specialist equipment:** Projects requiring equipment available in the electronics laboratories (such as power supplies, multimeters, oscilloscopes, etc.) or any other specialist equipment that requires specific health and safety considerations (such as drones, etc.) that students would not normally be allowed to take home.
	Category 2 – Projects based on "home-friendly" equipment: Projects requiring small pieces of equipment that do not require specific health and safety considerations and students can safely use at home (Raspberry Pi's, Arduinos and other similar low-voltage boards with double insulated power supplies).
	Category 3 – Projects based on software only: Projects fully based on software that can be completed using only a computer, without requiring any other equipment.

If students are in an observation capacity only when experiment is being performed

- please state this on form as well as risk in being observers - i.e. possible distracting experimentalist,
- State risk if they could be injured in this respect and how. Significant risks only should be stated.
- Class of any laser is required

State voltage & current values of all power sources being used. Any power supplies that have the ability to generate current and voltages > 10mA AND >20V respectively can be regarded as potentially extremely hazardous:

Voltage 5V Current 2A

HAZARDS (Location, equipment and substances, activities)	WHO CAN BE HARMED?	CURRENT CONTROLS	Likelihood (L) × Consequence (C) = RISK SCORE (R)		
			L	C	R
Power sources in the laboratory, electrical systems working live, etc., can cause injuries such as electric shocks, fires, and explosions.	People in areas where a fire or explosion may occur in the laboratory.	Note the low voltage (< 5V). Before using laboratory instruments, check the equipment for damage or failure, and follow the equipment manufacturer's safety recommendations during use to avoid potential risks. Turn off the power after use and store as required.	1	5	5
Injuries caused by soldering, including toxic gases that may be generated during use.	Personnel in the soldering work area.	Use the accompanying tools, follow the correct steps, and use the extractor fan to remove the smoke from the soldering process.	1	3	3
Slips and falls	With anyone nearby	Always keep the workbench clean and tidy, and place wires and personal items properly. Pay attention to the surrounding environment to avoid collisions with other workers around.	2	1	2
Lithium batteries can cause fires or explosions.	Worker	Use lithium batteries with product qualification certificates, production processes in line with quality control requirements, and design safety in line with relevant safety specifications. A detailed laboratory test of the battery is required before the experiment to assess its safety. In addition, ensure that the storage temperature of the battery is between -5 ° C and 35 ° C to use the battery in the right environment to ensure that it has a good safety record and meets all safety regulations.	1	4	4
Muscle damage from working long hours.	Worker	After working for a period, take a moderate rest, such as moving the wrist and cervical spine, to avoid excessive fatigue.	3	1	3
The hazards of display screens on the eyes.	Worker	Avoid looking at the screen for too long. For example, protective glasses such as those that block blue light can be used to reduce the harm of the display screen to the eyes.	4	1	4

- **For work using only Raspberry Pi and/or Arduino boards or other hardware connected via USB cable the main hazards are Display Screen Equipment (DSE) related, e.g. Repetitive Strain Injury, Carpal Tunnel Syndrome. L=1, C=1, R=1**

Training table - All boxes must be ticked in the following section to indicate either YES or NO.			
	NO	YES	If you have ticked YES please follow the hyperlinks in the attached document, complete and return supplementary paperwork and/or implement and adhere to the guidance given.
Use of tenon saw/hacksaw	✓		**Read Safe Operating** Procedure and other documentation on hand tools
Will work require the lifting of weights (>15kg)	✓		Manual Handling
Laser – If yes please input class of laser. Laser documents and hazard should be described on page 2 if laser is **NOT** class 1	✓		Please read all documents in the following link README : Laser: information and registration Guidance on the Safe Use of Lasers in Education & Research

Use of drones	✓		Prior to the purchase of any drone equipment, please consult the safety team – even if the devices purchased are not intended to be flown. Please refer to drones
Use gas cylinders or compressed gas?	✓		Gas Cylinder safety : Email local safety team to verify if training is required
Use hazardous Chemicals only? If stated on the form, description of hazard is required.	✓		COSHH - Use on-line EEE COSHH system to create COSHH risk assessment. Email local safety team to verify if training is required
Use voltages over 30V DC/AC If hazard has been previously described this	✓		Electrical Safety/Electricity – Includes reading the Sch. of EEE & CS dangers of electricity document
Use Power tools or rotating motors and machines	✓		SCR15-4 PUWER
Use Cryogenic Liquids/gases	✓		Cryogenic liquids and solids – Email local safety team to verify if training is required
Use Vacuum Systems and pressurised vessels	✓		Pressure systems : Email local safety team to verify if training is required
Use Radiation (UV, x-rays, microwaves)	✓		UV radiation (including links to local rules & safety advisor website)

LEVEL of Supervision? c	**A** = Work May not be started without direct supervision
	B = Work may not start without Supervisor advice or approval
	C = No specific extra supervision requirements
Other relevant specific assessments (Local rules, Ethic approval forms)- Ethic approval forms	

Disclaimer

- *The University of Liverpool ensures as far as is reasonably practical the health and safety of its staff and students.*
- *All equipment used by the students for their project must be safety tested and approved by the laboratory technicians before use. This includes but is not limited to, soldering irons, oscilloscopes, power supplies, probes and multimeters.*
- *Students **MUST NOT** undertake hazardous experimental/development work associated with their project outside of their designated laboratory space.*
- *ALL equipment that is used in the laboratory space & project MUST be purchased through the departments purchasing procedures.*
- *No equipment to be plugged into the mains supply unless circuit has been approved by technician or supervisor.*
- *Failure to abide by these conditions can result in the project receiving 0%.*
- ***Submission of this form implies acknowledgement by all the students named below.***

I can confirm that Hazards identified and precautions specified are appropriate for the task :-

Acknowledgement by Student 1 Name.....Jiajun Guo.....Signature.....Jiajun Guo.....Date.....5, October, 2023

Academic supervisor Name.....Ian Sandall..... Signature.....Date.....

Common reasons for previously rejection of the form

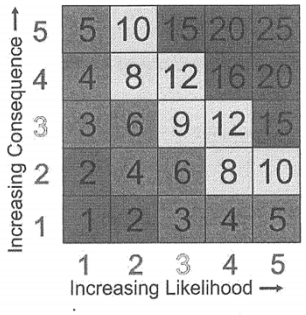
- Project category was not stated on the assessment.
- Contradiction of hazards listed on page 2 compared those identified in training table. Users inserted description of hazards such as chemicals & live working but failed to insert yes in hazard table. Only hazardous chemicals should be described. Only significant hazards observed in experimental process should be described.

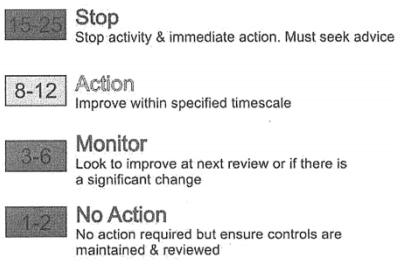
- Missing supervisor signature – risk assessment is invalid & students cannot enter the laboratory area
- Additional hazards noted in training table that are not described in hazard section. Lasers were described in training table required but hazard was not described in main assessment. Laser users should refer to risk assessment template document to identify how these should be described.

GUIDANCE TO COMPLETE THIS RISK ASSESSMENT FORM (LIKELIHOOD / CONSEQUENCE / RISK SCORE)

Likelihood		Consequence		Risk score	ACTION TO BE TAKEN
1	Very unlikely	1	Insignificant – no injury	1-2 NO ACTION	No action required but ensure controls are maintained and reviewed.
2	Unlikely	2	Minor – minor injuries needing first aid	3-9 MONITOR	Look to improve at next review of if there is a significant change
3	Fairly likely	3	Moderate – up to seven days absence	8-12 ACTION	Reduce risk if possible, within specified timescale
4	Likely	4	Major – more than seven days absence; major injury	15-25 STOP	Stop activity and immediate action
5	Very likely	5	Catastrophic – death; multiple serious injury		

- For work using only Raspberry Pi and/or Arduino boards (i.e. no other hardware connected using additional power supplies) the only hazards are Display Screen Equipment (DSE) related, e.g. Repetitive Strain Injury, Carpal Tunnel Syndrome. L=1, C=1, R=1





Appendix 4. Ethical approval questionnaire

UNIVERSITY OF LIVERPOOL

DEPARTMENT OF ELECTRICAL ENGINEERING AND ELECTRONICS

Ethics Self-Assessment 2023-2024

Final Year BEng (ELEC340) and Year 3 MEng (ELEC440)

Student Name: Jiajun Guo_____ Module: ELEC340

Supervisor: Ian Sandall _____ Student ID No: 201676348_____

Project Title: Smart Sock - Project in partnership with Aintree Hospital

Formal ethical approval must be obtained for all research projects '*involving research on human subjects or human tissues or databases of personal information to be carried out by University staff or students on University premises, or at any location, where there is no other acceptable provision for ethical consideration*'. Final year projects (ELEC340) and year 3 MEng projects (ELEC440) involving human participation must be undertaken in a way that safeguards the dignity, rights, health, safety, and privacy of those involved.

It should be noted that this policy covers **all** research methodologies including such activities as informal interviews, accessing personal files in an archive, or on-line data gathering. The requirement to obtain ethical review applies with equal force to projects undertaken by undergraduate students. For these projects, it is the responsibility of the supervisor to ensure that the ethical issues of the research are fully assessed and that formal ethical approval is obtained before the project commences.

Does your project involve any human participants (including situations where you are a participant as well as the investigator)?	YES	
Does your project involve any human tissues (including your own)?		NO
Does your project involve any databases of personal information (including your own personal information)?		NO
Does your project involve experiments using animals?		NO

Delete either YES or NO on each line above

If any of the answers given above are YES then you, along with your project supervisor, must investigate the requirement to apply for ethical approval. Filling in this form does not give any approval to your project and you are responsible to obtain approval before commencing your project Details of how to apply for ethical approval can be found at https://www.liverpool.ac.uk/intranet/research-support-office/research-ethics/ (for human participation) and at https://www.liverpool.ac.uk/research-integrity/animal-research/ (for use of animals).(Intranet links may not work off-campus)

Student Signature: Jiajun Guo Date: 5, October. 2023

Supervisor's Signature: _____ Date: _____

Appendix 5. References

[1] S. M. George, B. D. Langley, E. M. B. Weaver, S. R. Hardin, and J. Yao, 'Design of peripheral edema measurement device for home use', in *2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, Aug. 2016, pp. 4387–4390. doi: 10.1109/EMBC.2016.7591699.

[2] W. C. Lee, Y. E. Chavez, T. Baker, and B. R. Luce, 'Economic burden of heart failure: A summary of recent literature', *Heart & Lung*, vol. 33, no. 6, pp. 362–371, Nov. 2004, doi: 10.1016/j.hrtlng.2004.06.008.

[3] T. A. Floegel, K. D. Allen, and M. P. Buman, 'A pilot study examining activity monitor use in older adults with heart failure during and after hospitalization', *Geriatric Nursing*, vol. 40, no. 2, pp. 185–189, Mar. 2019, doi: 10.1016/j.gerinurse.2018.10.001.

[4] H. H. Asada, P. Shaltis, A. Reisner, S. Rhee, and R. C. Hutchinson, 'Mobile monitoring with wearable photoplethysmographic biosensors', *IEEE Engineering in Medicine and Biology Magazine*, vol. 22, no. 3, pp. 28–40, May 2003, doi: 10.1109/MEMB.2003.1213624.

[5] K. G. Brodovicz, K. McNaughton, N. Uemura, G. Meininger, C. J. Girman, and S. H. Yale, 'Reliability and Feasibility of Methods to Quantitatively Assess Peripheral Edema', *Clin Med Res*, vol. 7, no. 1–2, pp. 21–31, Jan. 2009, doi: 10.3121/cmr.2009.819.

[6] I. O. W. Man, K. Glover, P. Nixon, R. Poyton, R. Terre, and M. C. Morrissey, 'Effect of body position on foot and ankle volume in healthy subjects', *Clinical Physiology and Functional Imaging*, vol. 24, no. 6, pp. 323–326, 2004, doi: 10.1111/j.1475-097X.2004.00578.x.

[7] J. Skřivan, T. Blecha, R. Soukup, J. Řeboun, and V. Resl, 'Sensors in Textiles for Monitoring Patients with Edema', in *2018 41st International Spring Seminar on Electronics Technology (ISSE)*, May 2018, pp. 1–5. doi: 10.1109/ISSE.2018.8443667.

[8] T. Kawano, S. Nishida, and M. Hashimoto, 'Development of Measuring Device for Lower Leg Swelling Using a Strain Gauge', *JSME International Journal Series C Mechanical Systems, Machine Elements and Manufacturing*, vol. 48, no. 4, pp. 592–597, 2005, doi: 10.1299/jsmec.48.592.

[9] J. A. Healey, 'Method and apparatus for measuring lower extremity volume', US7484408B2, Feb. 03, 2009 Accessed: Oct. 10, 2023. [Online]. Available: https://patents.google.com/patent/US7484408B2/en

[10] L. Lucangeli, E. D'Angelantonio, V. Camomilla, and A. Pallotti, 'SISTINE 2.0: Sensorized Socks for Postural Telemonitoring', in *2022 IEEE International Workshop on Metrology for Industry 4.0 & IoT (MetroInd4.0&IoT)*, Jun. 2022, pp. 283–288. doi: 10.1109/MetroInd4.0IoT54413.2022.9831630.

[11] R. Fallahzadeh, M. Pedram, and H. Ghasemzadeh, 'SmartSock: A wearable platform for context-aware assessment of ankle edema', in *2016 38th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, Aug. 2016, pp. 6302–6306. doi: 10.1109/EMBC.2016.7592169.

[12] S. Zhang and R. Rajamani, 'Sensors on instrumented socks for detection of lower leg edema - An in vitro study', in *2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC)*, Aug. 2015, pp. 3153–3156. doi: 10.1109/EMBC.2015.7319061.

[13] R. Fallahzadeh, M. Pedram, R. Saeedi, B. Sadeghi, M. Ong, and H. Ghasemzadeh, 'Smart-Cuff: A wearable bio-sensing platform with activity-sensitive information quality

assessment for monitoring ankle edema', in *2015 IEEE International Conference on Pervasive Computing and Communication Workshops (PerCom Workshops)*, Mar. 2015, pp. 57–62. doi: 10.1109/PERCOMW.2015.7133994.