Wireless Applications of a Refactored Prosthesis

W.A.R.P.

Sponsored by:

Group 9

EEL 4914: Senior Design I

Daniel Mor	CpE	Dmor574@knights.ucf.edu
Brandon Ashley	CpE	Tbash@knights.ucf.edu
Niko Tubach	CpE	Ntubach@knights.ucf.edu
Harold Frech	EE	Harold.frech@gmail.com

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Statement of Work (Project Narrative)

Limbitless Solutions is a non-profit organization which designs and manufactures prosthetics for use by children at a low cost of production. Started in the Spring semester of 2014 by a small collective of students at the University of Central Florida, Limbitless has gained exposure around the globe as a philanthropic organization which provides arms for children in need. Not only do these prosthetics provide synthetic functionality of an actual arm, but they additionally provide confidence to the children who use them. Many other positive developmental effects have been proven to be attributed to using a prosthetic and this organization aims to provide cheap, effective, and functional alternatives to expensive medical grade equipment.

The prosthetics designed and produced by Limbitless Solutions have gone through many iterative improvements since its inception. The original arm which houses the electronics features three main 3D printed parts. An actual hand which is opened and closed by manipulating the tension on a cord, a housing for the electronics to hold all controllers and actuators, and lastly an interchangeable sleeve to cover the inner workings. Due to its modular design, each component can be easily redesigned for improved functionality or aesthetic appearance.

The electronics in the original design were assembled by using pre-existing prototyping boards in order to achieve the desired functionality. Electromyography (EMG) sensors are attached to the user’s bicep where the signal is amplified, filtered and lastly processed by an on-board microcontroller (MCU). The signal is analyzed in real-time by the processor and triggers an actuator, usually a servo motor, in order to activate the hand. Prototypes have come a long way since the first iterations, with current designs capable of but not limited to: controlling multiple actuators simultaneously, haptic feedback to the user and unifying the electronics on a single professionally printed circuit board (PCB). Even with all these upgrades, there are always improvements left to be made, which is where the W.A.R.P. project begins.

This project aims to advance upon the technology in the existing prosthetics, while also developing a new standalone peripheral. EMG electrodes would be placed on the bicep and interfaced with the PCB housed within a velcro cuff. The cuff would be wrapped around the bicep and battery powered to provide a free range of motion to the wearer. Onboard sensor data would be processed and transmitted wirelessly via bluetooth in real time to a nearby smartphone. A custom smart phone application would be developed to display the status of the arm and manage received data in an intuitive user-friendly manner. This application would also be used to remotely configure the electronics within the module without requiring it to be reprogrammed as is currently needed. Furthermore, the application could communicate with a remote server to send diagnostic information and receive software updates to push to the hardware.

This peripheral will serve multiple purposes, but first and foremost it will be used as a training platform. Once Limbitless approves the development of an arm, they would ship this product to the family in order to acquaint them with the technology. The children could then use the cuff as a type of training wheel before the actual arm arrives. The goal of the W.A.R.P. project would be aimed at providing a reliable and secure wireless connection, allowing for remote configuration of the hardware. Additional hardware would be added to permit features and control the power of the system in order to make the new module fully suited for use by Limbitless Solutions. Maintaining low power consumption, size, price, and weight are essential during the process of integrating additional features requested by Limbitless. Furthermore, the technology within the prosthetic should be reliable and easy to operate with limited technical knowledge. Stretch goals may include integration of the system with an already existing videogame which can be used as an educational tool and allow for self-configuration of the arms by the children who will be using them. Overall, the W.A.R.P. project will improve existing technology from the prosthetics produced by Limbitless Solutions in order to produce a standalone peripheral used as an educational tool. Lastly, this technology is planned to eventually be re-integrated and used in future designs.

Requirements Specifications

Hardware Specifications

The hardware design will involve components similar to those used in modern iterations of the technology in production by Limbitless Solutions due to the constraints imposed on the design. As such the “cuff” module will remain under 0.5kg with the electronic components composing approximately half of the total weight. This constraint is imposed in order to make using the device easier for younger children. The module is intended to have an operating lifetime of at least 10 hours, but preferably around 20 hours of active use before requiring to be charged. Furthermore, a maximum recharge time of 5 hours is required to permit the device to be fully charged overnight and better match up with a child’s daily schedule. In order to fit the entirety of the the electronics into the “cuff” the maximum dimension specifications are 150mm x 100mm x 25mm for the PCB only. Minimizing the size of the PCB will permit this technology to be utilized by more children and has a higher likelihood of being used in future iterations. The transmission of data to and from the module will take place using Bluetooth Low Energy (BLE), also known as Smart Bluetooth with a maximum transmission speed of 1Mb/s. To ensure a seamless experience with the involved interactive software a latency of 8ms - 16ms will be a necessity.

The printed circuit board (PCB) will additionally need to meet a minimum set of safety and legal requirements. Due to stringent FCC regulations the team intends to use a pre-approved bluetooth module, which includes an antenna. Since this device will be pre-approved, the team will be able to bypass the long and expensive process of trying to get a wireless device approved by the FCC. Using a pre-approved antenna also eliminates the need for designing an antenna and having to file for approval. Aside from needing these devices, the board will also need to include hardware to monitor the health of the battery and prevent dangerous failures of the system.

Mobile Application Specification (General Users)

The mobile application will be made available to users obtaining a prosthetic device from Limbitless. Currently there is no integration with a remote device to provide feedback nor is there integration to allow remote calibration. The application will need an intuitive User Interface (UI) to allow for all individuals, adolescent or otherwise, easy accessibility to the tooling provided.

This application is set to serve multiple purposes:

1. A method to teach an individual to use the prosthetic. The application would be used as a feedback tool to visually see how the device interacts with the wearer. The user could make corrections and understand how it is working prior to receiving the actual prosthetic arm.

2. Allow a technician to remotely push updates to the on-board microcontroller.

3. Allow a user to easily calibrate the device and modify various parameters. As of now the prosthetic device requires a tethered connection for calibration which is done by reprogramming the entire chip.

4. Receive push notifications and updates from Limbitless Solutions and provide a central hub to communicate with the organization.

5. Store logged data from the cuff itself and process it before sending to the server.

Web Application Specification (Administrative Users)

The web application is intended for use by technicians and administrative users (admins). This is to provide feedback for all active systems in a single central location. Feedback is to include any useful information that can be gathered from logging the prosthetic device's movement, power consumption, response time, or errors that have occurred. This interface can be used to manage the information sent and received from the various active mobile applications.

Server Application Specification (Authenticated/Authorized Requests)

The primary goal with this service is to provide a place to store data to be accessed remotely, serving as a backup and a centralized location for all gathered data.

Each HTTP request will require the client to pass a JSON Web Token (JWT) to provide authentication and the instance of that request will need to be authorized to gain access to appropriate data and will be returned back as an HTTP response. Once a user is authorized, the mobile phone application can then access available services on the server.

Application Code Styles and Versioning Standards

To maintain code versioning and safe bug fixes introduced during production, the use of a Software Versioning Network is necessary. This application can be hosted on several private repositories provided by GitHub. Additionally a uniform coding style and branching strategy will need to be determined to allow for comprehensive development among engineers.

A secured production application will be required before the initial release, this can be achieved with the use of existing standards for handling authentication, JWT in combination with the Secure Sockets Layer/Transport Layer Security (SSL/TLS) protocols. This process would ensure a secure and reliable connection between the server and mobile application.

House of Quality

▲▲ = Strong Positive Correlation
▲ = Weak Positive Correlation
▼▼ = Strong Negative Correlation
▼ = Weak Negative Correlation

			Engineering Requirements			
			Data Analysis	Size	Development Time	Cost
			-	+	+	+
Marketing Requirements	Aesthetics	+		▲▲	▲	▲
	Power Consumption	-	▼	▼	▲▲	▼
	Ease of Use	+		▲	▲	▼
	Cost	+	▲	▲▲	▼▼	▲▲

The final goal for W.A.R.P. is to make the project a success in the eyes of the team's sponsors at Limbitless Solutions and provide a viable aid to the children that will be utilizing it in the future. Additionally, this peripheral will attempt to test the viability of various features for possible use in future iterations of the electronics within the arm. With this in mind a House of Quality (HOQ) was created to visually display the balance of the priorities when marketing the project versus designing it. Different marketing goals require various tradeoffs when developing the technology.

One example may be requiring the device to be very easy to use. Although this is possible, it certainly would increase development time due to the added complexity to the design and testing which is afforded from simplicity provided to the end user.

Block Diagrams

Brandon Ashley	Daniel Mor	Niko Tubach	Harold Frech

Diagram Legend: Each color represents a team member which is responsible for a block

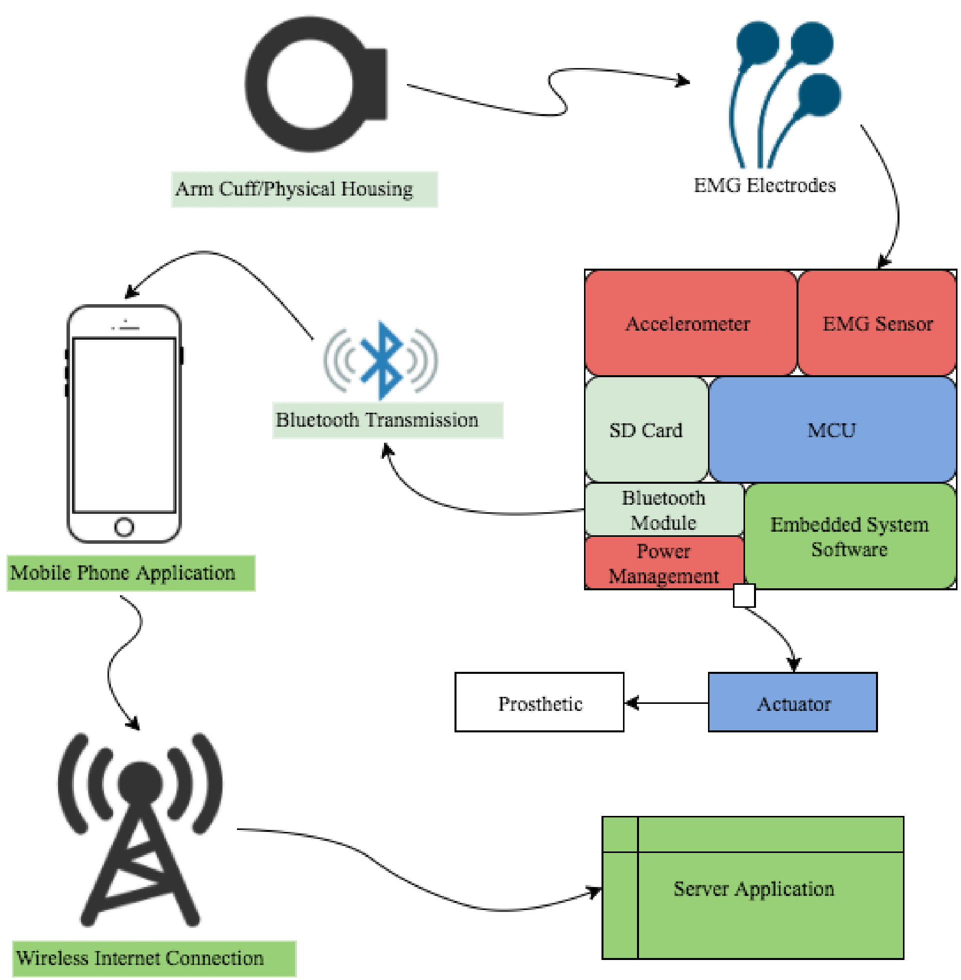

Figure 1a. High Level Overview of the System

Figure 1a describes the overview of the entire system and its various connections. Starting from the EMG electrodes which interface with the user and the cuff which houses the electronics. The PCB interfaces with various sensors, and subsystems and transmits wirelessly over bluetooth to sync with a nearby mobile phone. Using an LTE or

WiFi connection, the custom application on the phone sends and receives data as needed from a remote server. This diagram simplifies the intricacies of the connections between the sub-system and acts as a high level view of the proposed system for ease of reference.

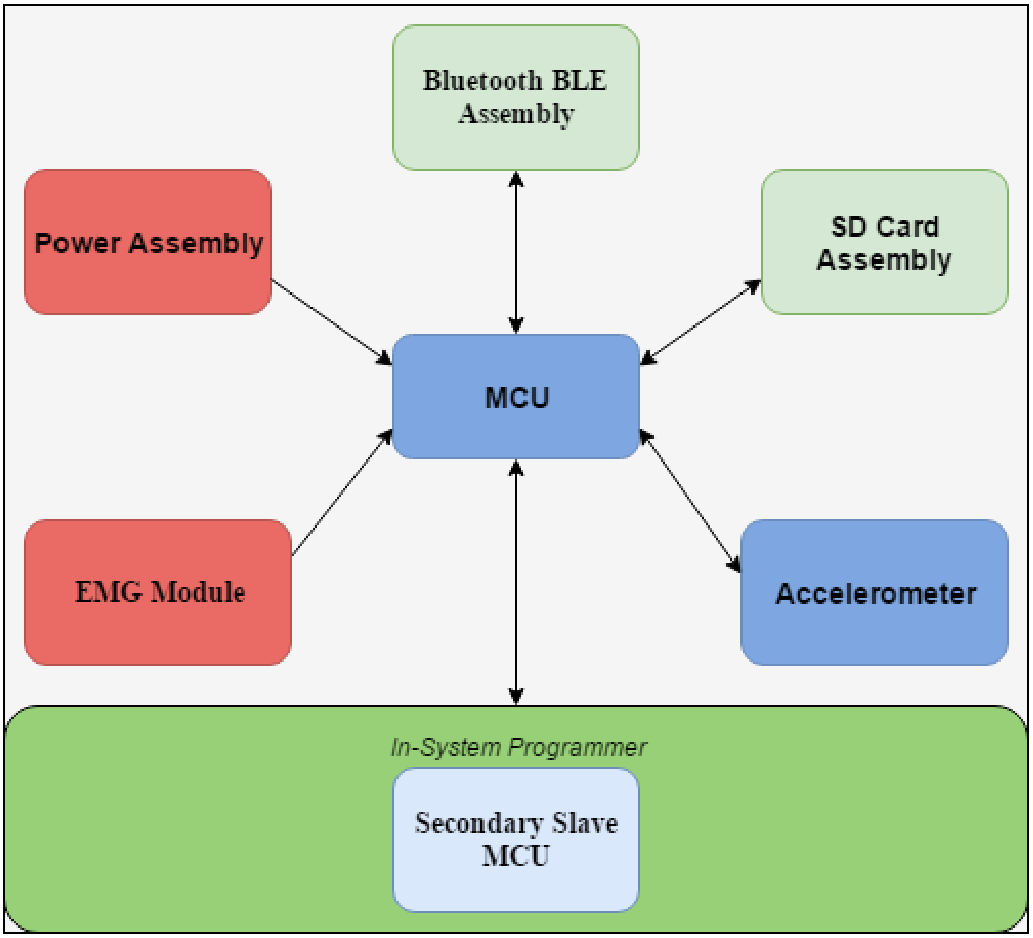

Figure 1b. High Level Overview of PCB Components

As shown in Figure 1b, a close up view of the simplified connections between the subsystems within the printed circuit board including an expected flow of power and data between the components. The color describes the focus of each team member responsible for designing the subsystem, while the team as a whole will focus on integration and testing. The microcontroller handles all processing on the device and interfaces with most other systems including the various on-board sensors and peripherals. This includes EMG sensors and the accelerometer which provide information about the outside world to the microcontroller along with the SD card reader and secondary microcontroller which would be used to reprogram the primary microcontroller wirelessly.

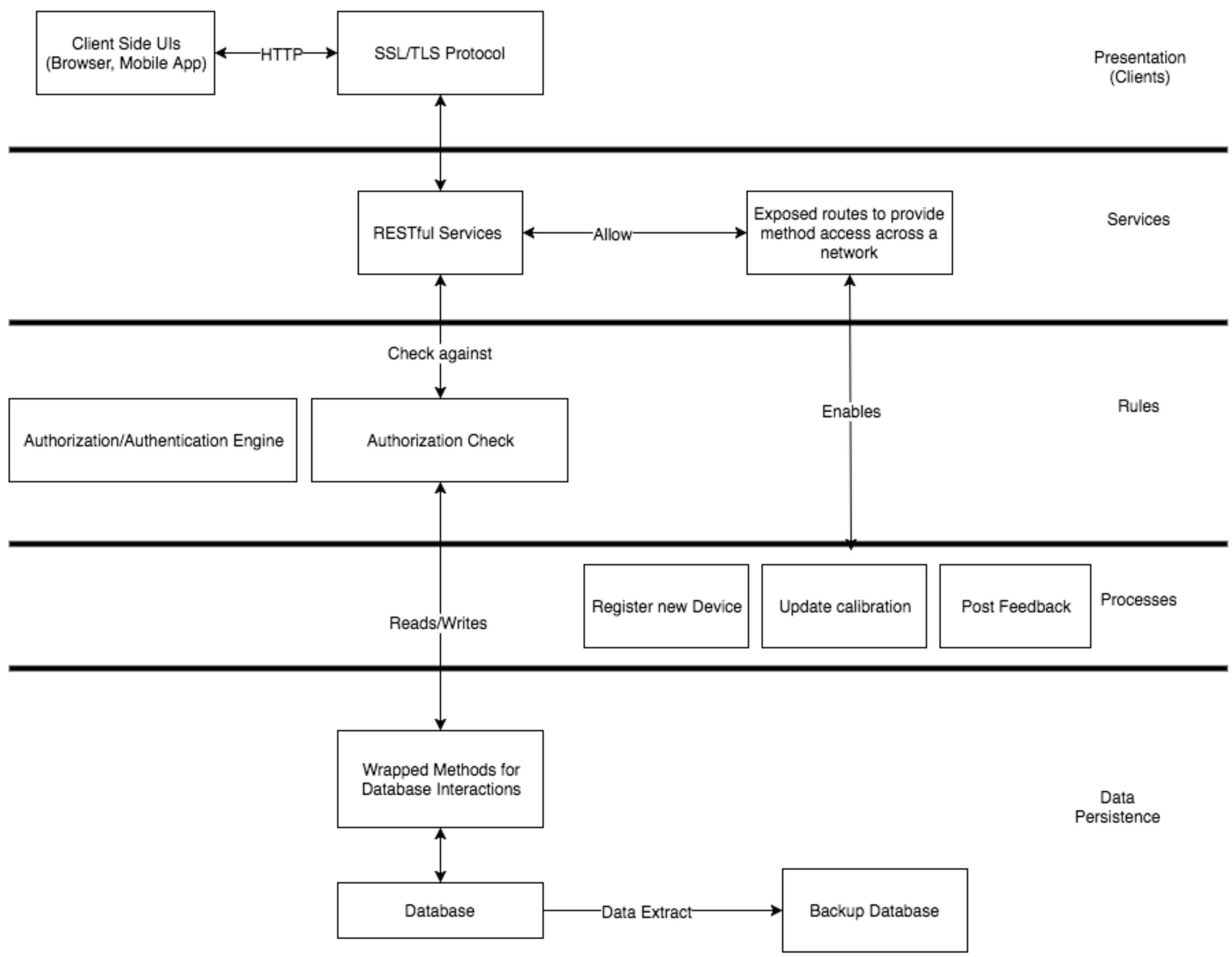

Figure 1c. High level architectural overview of the application layers.

Figure 1c showcases the proposed system's architectural view from a software analysis standpoint. Specifically, it utilizes a customised layered architectural model to convey a better understanding of how the software components used within the system will interact with one another. The presentation layer includes the mobile application and internet protocols utilized on the client-side to interact with the software of the server side system. The services and rules (security) layers work together to enable and limit the processes of the system which provide authorized actions for a user. The final layer of the model is data persistence which describes the database layout as well as the wrappers used to interact with it in the effort of preserving data for future use.

Project Budget

Under the project goals reviewed and approved by Limbitless Solutions the team has been allotted up to $1000 for research and development in order to produce a functional prototype of W.A.R.P. To meet this monetary constraint component price approximations have been laid out in the chart below. The majority of the cost associated with the project is involved in sending the board to be manufactured along with the overall cost of prototyping the designs. In order to further reduce the costs, free samples and evaluation modules will be requested from known contacts within the organization. With respect to the final cost of the circuit board, it is expected that the cost reflected throughout this project will not be the same for mass production. As such, the goal will be to produce a PCB which will cost below $50 per board in orders of higher quantity.

Additionally, the team will utilize spare parts which are available from the University engineering labs, personal possession, and additionally already purchased equipment from the sponsoring organization. This will vastly reduce the price to produce a working prototype and additionally reduce the lead time when waiting on parts to be shipped.

I.D.	Part Name	Estimated Cost
1	PCB Fabrication	$250
2	Microcontroller	$8
3	Bluetooth Module	$15
4	Power Assembly	$100
5	Human Interface	$50
6	SD Card Module	$10
7	Accelerometer Module	$5
9	Server	$0
10	Discrete Components	$75
11	Backup Funds	$200
Total Cost		**$713**

Milestones

Objective	Description	Start Date	End Date	Duration
Senior Design I	Design, Plan, and Prototype	05/16/2016	08/02/2016	12 Weeks
Project Paper		05/17/2016	07/15/2016	9 Weeks
1	Initial Project Idea	05/17/2016	05/20/2016	3 Days

2	Initial Proposal - Divide and Conquer	05/24/2016	06/03/2016	2 Weeks
3	Table of Contents	06/04/2016	07/01/2016	4 Weeks
4	Rough Draft Document	06/04/2016	07/08/2016	5 Weeks
5	Final Document	06/04/2016	07/15/2016	6 Weeks
Research		05/30/2016	06/30/2016	4 Weeks
6	Bluetooth Comm.	05/30/2016	06/30/2016	4 Weeks
7	PCB	05/30/2016	06/30/2016	4 Weeks
8	Mobile Application	05/30/2016	06/30/2016	4 Weeks
9	Database-Management System	05/30/2016	06/30/2016	4 Weeks
10	Accelerometer	05/30/2016	06/30/2016	4 Weeks
11	SD Storage	05/30/2016	06/30/2016	4 Weeks
12	In-System Programming	05/30/2016	06/30/2016	4 Weeks
13	Physical Case Design	05/30/2016	06/30/2016	4 Weeks
14	Power Assembly Design	05/30/2016	06/30/2016	4 Weeks
Order Prototyping Components		07/15/2016	07/22/2016	1 Week
Prototyping		07/22/2016	08/05/2016	2 Weeks
15	Breadboard and Testing	07/22/2016	07/29/2016	1 Week
16	Proto-Board and Testing	07/29/2016	08/05/2016	1 Week
PCB Acquirement		08/06/2016	08/15/2016	1 Week
17	Finalize PCB design	08/06/2016	08/13/2016	1 Week
18	Place PCB and Components Order	08/13/2016	08/15/2016	2 Days
Senior Design II	Develop, Implement and Test	08/22/2016	12/02/2016	15 Weeks
Development		08/24/2016	09/23/2016	4 Weeks
19	Physical Cuff Housing	08/24/2016	09/23/2016	4 Weeks
20	Mobile Application	08/24/2016	09/23/2016	4 Weeks

21	Database System	08/24/2016	09/23/2016	4 Weeks
Implementation		09/23/2016	10/07/2016	2 Weeks
22	Solder PCB components	09/23/2016	10/07/2016	2 Weeks
23	Mobile Application	09/23/2016	10/07/2016	2 Weeks
24	Database System	09/23/2016	10/07/2016	2 Weeks
Testing		10/07/2016	10/21/2016	2 Weeks
Integration		10/21/2016	11/04/2016	2 Weeks
[Extra] Cushion Time		11/04/2016	11/18/2016	2 Weeks
Prepare Presentation		11/18/2016	11/25/2016	1 Week

The schedule laid out in the above table is intended as a reference and is the team's optimistic plan of finishing the tasks within the given timeframe of the project. Noteworthy assumptions include an estimated lead time to receive the PCB after ordering, two weeks time to send the board to a company to "pick-and-place" the components on the PCB and two weeks time to properly test the device. In addition, an early deadline for the finished document and product have been set for three weeks and two weeks in advance of their respective due dates to account for unforeseen circumstances during the research and development process.

Decision Matrix

The team unanimously decided to work towards the completion of the W.A.R.P. project proposal from the beginning of the group's formation, as such it is unnecessary to include other project considerations. The reasons for this decision are due mainly to the team wanting its contributions through Senior Design to positively impact the community. The team also felt that this project would involve a well rounded set of challenges which match the skillsets of the members. Lastly, the availability of funding when working with Limbitless Solutions would allow the team to create a more intricate project, and gain experience in the fields of software development, electrical engineering and embedded systems.