CDP II FINAL REPORT

UGC FAULT LOCATOR

Supervisor: Dr. Hussein Abdulrahman

1. Fanuel Petros Ghebru (H00421994)
2. Tomas Yemane Habteab (H00422004)
3. Abduselam Ahmed Nuru (H00422001)
4. Micheale Habte Tesfay (H00421998)
5. Abdulla Abdelrahim Jehan (H00351292)

2. Table of Content

Pages

2. Abstract

This research paper presents a comprehensive study on locating underground cable faults and validating transmission line parameters using data analysis. The primary focus of this study is to remove noise from acoustic signals (e.g., thumping sounds) by employing a range of methods including an LMS adaptive filter and a deep learning audio classification model. Our research involves validating transmission line parameters using data from the electric company and conducting various tests to pinpoint fault locations accurately. We emphasize the crucial role of precise fault location and validated transmission line parameters in enhancing the reliability and efficiency of power transmission networks. The proposed LMS adaptive filter technique, which is implemented on a STM32 microcontroller for efficient cost, effectively eliminates acoustic signal noise, significantly improving fault location accuracy. The other proposed solution is deploying a deep learning model on a raspberry pi, the model must differentiate the original signal from background noise. In summary, this research contributes to the development of efficient fault location methods by enhancing the acoustic detection of thumping sounds.

3. Problem Definition and Literature Review

Nowadays most of the power transmission within urban areas is transmitted using underground cable. This underground cable has advantages like less exposer to external natural disasters such as heavy rain or wind or physical damages as well as for aesthetic purposes. Though the chances of underground cable damage is lower compared to overhead transmission, still there is higher probability of damage due to cable aging, high power consumption/ power overload, or proper misplacing the cable while installing. Based on the visit we conducted in one of the stations in Sharjah water & electricity authority (SEWA) found in khorfakkan, underground cable fault happens at least once a month, especially during the summer with high rate of power demand from customers the cable may easily get damage. The main thing we concentrated in locating the underground cable system is the instrument used for hearing the frequency around the fault location because the currently used method for determining the fault location is using the acoustic method, very high frequency impulse signal is sent from one ending and then determine the distance of the fault, finally to know the exact spot various methods including analog signal processing and deep learning audio classification are used to detect that specific frequency. There are many instruments used to locate an underground cable fault such as the impulse generator (Fig1), which will generate a very high voltage anticipating a thumping sound from the fault which will enable us to hear it using many acoustic pickup methods (Fig2) but before all this we have to pre-locate the fault using a TDR (time domain reflectometer) (Fig3).

Fig.1: Impulse Generator

Fig.2: Acoustic picker

Fig.3: TDR

Finding underground cable faults using the conventional method (analog signal processing) can be a very tiresome and exhausting process, there are many challenges associated with it one of which is background noise. During this process background noise play a key role in disrupting the thumping sound coming from the cable by either mimicking the sound hence leading the engineers to the wrong fault location or by completely masking it which will result in failure of locating the fault. Currently there are some steps taken to avoid background noise which include locating the fault during the night when there is less background noise, but this system can be a waste of time and in order to combat this we are proposing two solution the first one being to design a noise reduction filter and a another one is deep learning audio classification model which will help engineers to pinpoint the exact location of the fault by cancelling the unnecessary noise that is a big obstacle of the process.

4. Need Identification

a. We have taken some requirements that will help us develop the final design of our project, the table down below explains the customer requirements:

1. Safety when detecting the noise. Safety regulations for underground cable location so as to guarantee the security of people and hardware. So we will concentrate on the insulation of the product to prevent the user from any kind of electrical shock that could lead to death.

2. Fast and efficient detection time. Before applying the LMS algorithm we are going to apply band pass filter to block all incoming signals other than the predetermined frequency of the thumping signal, by this means the operator will easily cover the whole cable range in short time.
3. Detect the fault in a way that minimizes damage to the cable. Since we are reducing the pinpointing time, we will reduce the number of times the cable is exposed to high voltage impulses, so we are not hurting the healthy cable and we are also saving cost as the pulse generation takes a lot of power.
4. Cost-effective detection The current machines used to detect the fault are a bit expensive so we will try to use a more efficient way of designing our product.

Table 1. Customer requirements

b. The engineering characteristics are listed down below in order of importance

1. Detection time: the model should be able to detect the fault in a time that is faster than the time taken by the traditional fault detector.
2. Adaptive Filtering Algorithm: To reduce this kind of noise, adaptive filtering algorithm with a fast convergence and a strong stability that dynamically adjusts filter coefficients will be used so as to properly filter out this noise.
3. Real-Time Processing: The system should be able to offer real time and noiseless cable location without delays that compromise the precision of locating cables.
4. Deep learning model: the model should be able to detect thumping sounds of different frequency and type to increase its efficiency.

4. Integration with Cable Locating Equipment: Integrating the noise cancellation system into the existing cable locating devices for improved noise cancellation capabilities.
5. Environmental Durability: Build it to resist environmental degradation and be accurate when used on-site.
6. Robustness and Reliability: Focus on making the system strong enough as well as reliable so that it can still function properly even in harsh sites like hot summer days, where it will be used for location pinning cables in order to improve safety.

Table 2: Engineering Characteristics

c. Customer assessment of computing products:

From our visit to SEWA (Sharjah Electricity and Water Authority), we have interviewed two experts Eng. Yusuf and Eng. Semir and discuss their experience on using the current and the old fault finding components. From their idea the new fault finding method have solved all the problems that they were facing from the old method, but the cost is too expensive. So we have shared our idea of solving the problem of pinpointing on the old method and still use the old equipment. They have supported our ideas and they are looking forward to testing our design to verify the solution we have come with.

d. Target Values:

Variable	Target Value
Final selling cost of the product	Below 5000 AED
Environment noise cancellation on the headphones	From 30-45 DB
Voltage impulse sent to the cable	1.5KV-2.5KV based on the cable damage
Cable Size - residential	35mm - 420 V_{LL}

Table 3. Target values

5. Design Concept

After performing all the preliminary steps of pre-locating the fault area the target is to pin out the exact fault point, so that we can tell ‘dig here’ at point x. After reaching to the faulted area one of the methods that follow is trying to hear the thumping sound generated at the fault point, the sound that is generated from the faulted point in the underground cable will be tried to be heard by excluding any additive external noise. However, the external noise is not a constant that can be predicted, it changes with the environment. So, the kind of filter that is capable of achieving this target is the adaptive filter. Adaptive filter tries to adjust its parameters with the aim of meeting some of the well-defined goal or target that depends on the state of the system as well as its surrounding [1]. The aim of this filter is to enable to reshapes the frequency components of the input to generate an output signal with the desirable features, only the output frequency from the underground faulted cable. The team proposed some of the different available options of the adaptive filters available. There are various algorithms for programming any adaptive filter, the main methods used commonly are in the below discussion. In addition to the filter there is another alternative where a deep learning audio classification model is trained to different fault thumping sounds and different kinds of noise we expect from the surrounding, this model will offer a cheaper and more effective solution to the traditional methods used in fault detection methods.

5.1 Least Mean Squares (LMS), a popular adaptive filtering technique, is number one. It uses a gradient-based approach to reduce the mean squared error between the target signal and the filter output. The filter coefficients are updated by the LMS algorithm using a stochastic gradient descent method, where the update is proportional to the error's negative gradient.

$$y(n) = \sum_{k=0}^{M-1} w_k(n)u(n-k)$$

$$\hat{\mathbf{w}}(n+1) = \hat{\mathbf{w}}(n) + \underbrace{\mu}_{\text{Step size}}\underbrace{\mathbf{u}(n)}_{\text{Filter input}}\underbrace{e^*(n)}_{\text{Error signal}}$$

5.2 Recursive Least Squares (RLS) is another adaptive filtering algorithm that is frequently employed. The filter coefficients that minimize the mean squared error between the filter output and the intended signal are estimated recursively using this method. The RLS technique is computationally more expensive than LMS since it updates the filter coefficients in a way that considers all of the historical data points.

$$\widehat{W}(n) = \widehat{W}(n-1) + \underbrace{k(n)}_{\text{Gain vector}}\underbrace{\xi^*(n)}_{\text{Prior Error}}$$

5.3 Kalman Filter: Based on erroneous measurements, the Kalman filter is a recursive algorithm that determines the state of a dynamic system. However this is frequently employed in estimating and control issues, which makes is obvious least related to our target in this project. The Kalman filter uses a mathematical model of the system dynamics and minimizes the mean squared error between the predicted and measured states to estimate the system's state.

5.4 Deep learning model: in order to create an AI model that is capable of classifying the original sound from noise can be done following different steps, the first step is data accusation, for this we can look into large data base from the internet or acquire the data ourselves. Then we should have a feature extraction, and this can follow different options including Short-Time Fourier Transform (STFT), Mel-Frequency Cepstral Coefficients (MFCCs), and many more. Then we should have a learning block, we have different kinds of learning blocks including Convolutional Neural Networks (CNNs), Recurrent Neural Networks (RNNs), and hybrid models. The figure down below illustrates deep learning audio classification model.

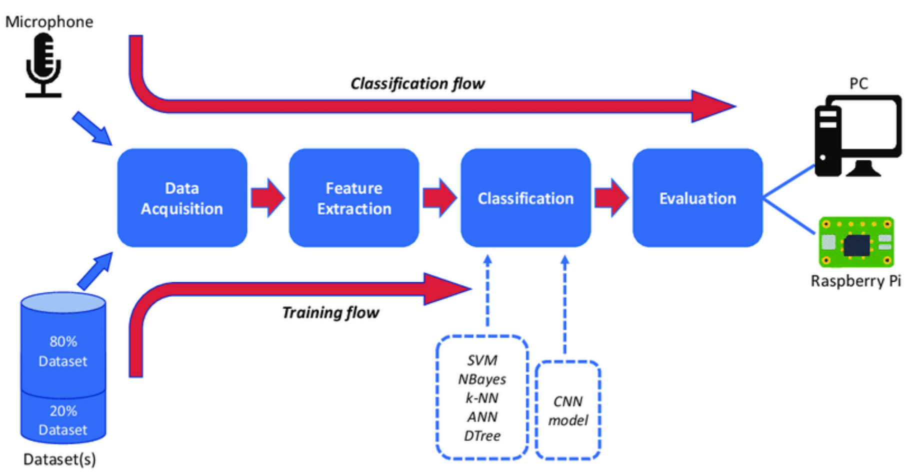


Fig4. Illustration of an audio classification model

6. Design Option Evaluation and Selection

6.1 LMS

The LMS has great advantages in its simplicity and ease of to implement with minimum cost, some of its advantages along with its limitations can be summarized as follows:
Pros:

1. Ease of Use: The LMS method is easy to use and computationally effective, making it appropriate for real-time applications.
2. Convergence: The LMS algorithm can swiftly adjust to changes in the input signal thanks to its fast convergence characteristics.
3. Robustness: The LMS method can operate in noisy conditions and is therefore appropriate for applications where noise-corrupted input signals are present.
4. Minimal memory requirements: Because the LMS algorithm updates the filter coefficients on a sample-by-sample basis, it has low memory requirements. Cons:

1. Steady-state error: Under some circumstances, the LMS algorithm may converge to a suboptimal solution, resulting in steady-state error in the filter output.
2. Sensitivity to initial conditions: The LMS algorithm's convergence behavior is sensitive to the initial circumstances, and the selection of the step size parameter can have an impact on the algorithm's stability and rate of convergence.
3. Restricted convergence rate: In some circumstances, notably for signals with significant autocorrelation, the LMS algorithm's convergence rate may be restricted.

Widely applicable for a variety of applications, the LMS algorithm is a straightforward and effective adaptive filtering technique. However, it has drawbacks in terms of steady-state error, sensitivity to beginning circumstances, and low accuracy for non-linear or time-varying signals.

6.2 RLS

The RLS has its own characteristics, summarized in the below points:

Pros

- Quick convergence compared to the LMS with high precision for the needed signal
- It has also reduced steady error as it can converge to the best outcome

Cons

- As it keeps a matrix of all the previous data points, it has high memory needs and a high computational complexity.

- Its' Sensitivity to initialization and its poor performance to noisy environment may result to inaccurate estimate in noisy environment which makes it a **big down for our project**.

Algorithm	**Performance to Noisy Environment**	**Memory requirement**	**Computational Complexity**
LMS Algorithm	Less sensitive	Less memory space	Less complex
RLS Algorithm	More sensitive	Big memory space compared to LMS	More complex

Table 4. Close look and comparison of the Two Algorithm for adaptive filtering

The microphone, as an input for the digital signal processor (DSP) is the INMP441. There are various available sound sensor components for small scale, the main and commonly used are listed in the table below. The INMP441 was selected due to its clarity and less noise susceptibility compared to others. And the market availability is good and can be shipped from local markets.

Inputs (Microphones)	**Clarity**	**AnalogDigital Conversion (ADC)**	**External Power Noise Susceptibility**	**Sound Picking Range**	**Market accessibility**
INMP441	Clear Natural	Present Inbuilt	★★★★	Near field	Easly Accessible
MAX9814	Little noisier	Absent Inbuilt	★★★	Near field	Accessible
SPH0645	Not much clearer	Present Inbuilt	★★	Near field	Accessible
INMP522	Clear Natural	Present Inbuilt	★★★★	Far field	Rare (Difficult to access and pricy)

Table 5. Close look and comparison of the sound sensors (microphones)

There are various microcontroller which can operate in real time. Some of the common options we have are mentioned in the below. The STM32 with higher clocking speed is preferred one than Arduino UNO, as higher clocking speed is crucial for faster reading and processing of the incoming signal. Raspberry pi as also another option, but due to its complexity and not being a standalone processor excluded to be put in our project as consideration.

Digital Signal Processor (DSP)	**Clock Frequency**	**Complexity**	**Price**
STM32	168 MHz	Complex for starting, uses embedded C language	Mid-range
Arduino Uno	16 MHz	Basic, simple IDE and embedded C language	Cheap
Raspberry pi	1.4 GHZ	More complex and more advance programming language	Expensive

Table 6. Close look and comparison of the possible microcontrollers for our project

6.3 The deep learning model:

When collecting data, we had limited data base as there was not enough data on the internet, so we got some data from the internet and collect some of it ourselves. We had to resort to argumentation where we changed the features of the input data such as changing the pitch. Here is some comparison between the data collection methods:

Data Collection from the internet	**Acquiring data ourselves**
There should be abundantly available	There is data scarcity on the internet
Yields to a very efficient model	Yields a model with inferior effectiveness

Table 7. Comparison between different data acquisition methods

When choosing feature extraction methods we choose MFCC method as it fits our purpose, MFCCs Extracts features from audio signals using Mel Frequency Cepstral Coefficients. Here are some comparisons between the different STFT and MFCC:

STFT	**MFCC**
Provides a representation of how the frequency content of the signal changes over time.	Represents power spectrum of the signal in the time domain.
Frequency resolution is constant across the spectrum	Frequency resolution varies across the spectrum.
High sensitivity to sudden frequency changes.	lower sensitivity to sudden frequency changes.

Table 8. Comparison between different STFT and MFCC

Convolutional Neural Networks (CNNs) excel at capturing local spectral patterns in audio for tasks like spectrogram analysis, while Recurrent Neural Networks (RNNs) specialize in modeling sequential dependencies crucial for understanding the temporal order in tasks such as speech recognition. We chose CNN as it fits our purpose.

7. The proposed Design

Based on the comparison we conducted on some of the mainly used algorithms for the adaptive filters, the advantages of the LMS outweighs the other algorithms. Therefore, the main concentration of our model will be based on the LMS filtering method. At this stage of our project we conducted the design of the adaptive filter on MATLAB. In first stage of this project the modeled was made on MATLAB Simulink we used the Normalized LMS, it is similar to LMS, but the step is varying overtime. The model design of simulation is shown in the below figure 5, for the generation of the noise the Gaussian white noise is used from MATLAB, however, the acoustic sound of the assumed faulted cable is found from external sources and uploaded as multimedia to the MATLAB.

As already discussed in this report, the fault location produces a thumping sound when it is supplied with pulses. And this thumping sound is a very important parameter that helps us to pinpoint the exact fault location. But the problem of corrupting this essential thumping sound due to passing cars sound, people walking by, machinery, and so on is what lead us to the construction of this adaptive filter.

In the LMS, by including a repeating process to perform successive corrections in the direction of the gradient vector's negative sign, as shown in the following equations, the mean square error is minimized [3].

$y(n) = F(n).\ x(n)$ ………………………….. (10)

$e(n) = d(n) – y(n)$ ………………………… (11) F

$(n + 1) = F(n) + \mu.\ x(n).\ e(n)$…………….. (12) y

(n) = filter output x (n) = input signal e (n) = error
signal d (n) = desired output
μ = step size

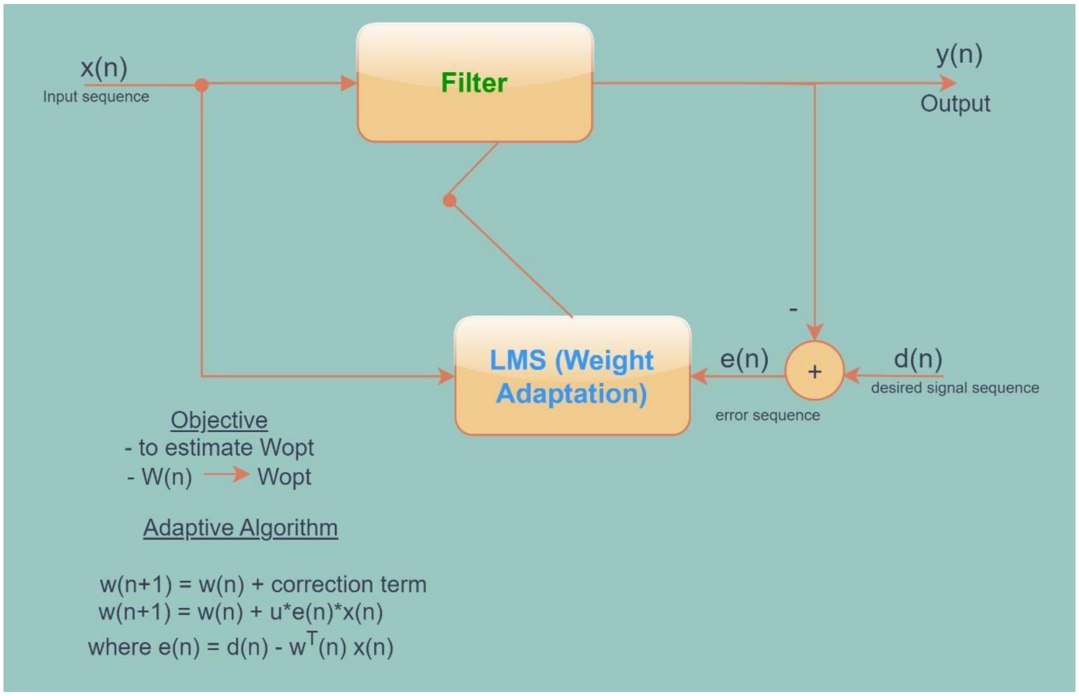


Fig 5. The block diagram of LMS Algorithm adaptive filtering Lest mean square

Then the modeled concept was tried to be implemented on a practical world using a microcontroller. The system we used for implementing the LMS filter is shown from above figure, the two inputs we require for the system are the desired audio sound we want to hear and the normal environmental or external audio signal. And based on the matching of the heard thumping sound the weights are adapted until the error is reduced to minimum.

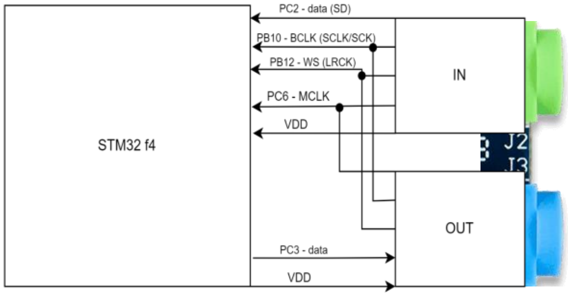


Fig 6. I2S protocol communication with the microcontroller

The interface for I2S with the microcontroller can be achieved using the pmod (I2S2) module. This protocol of communication is a three wire method that allows audio devices to communicate without the requirement of ADC or DAC and amplifiers. The input is coming from sound sensor passing to the pmod module and coming output converted to Analog from digital from the microcontroller for direct listening from wired headphone with 3.5mm jack.

Fig. 7: 3.5 mm headphone jack labels to be connected to the pmod I2S2 module for hearing audio output from the DSP

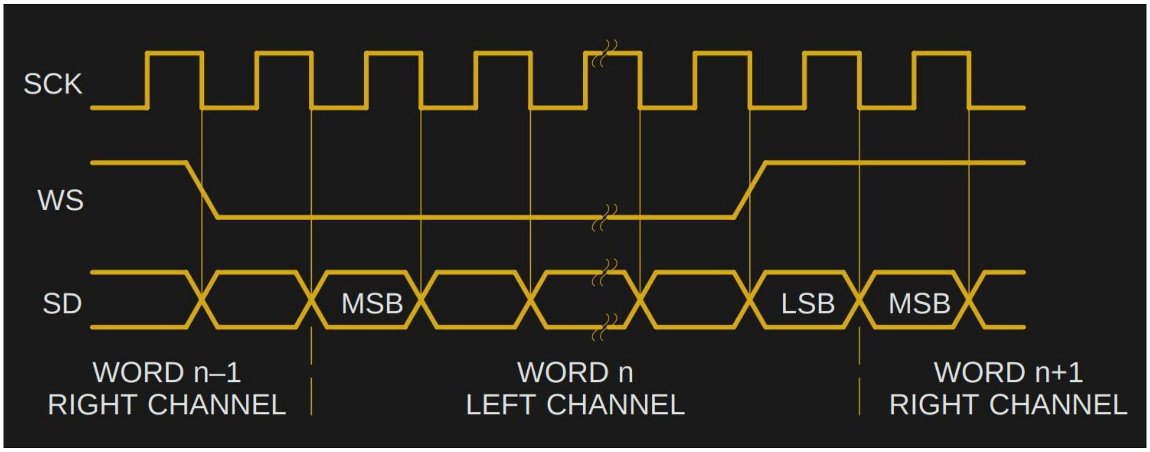


Fig. 8: Data convey between the microcontroller and I/O

The communication the Pmod links between the I/O and the DSP is through a series of clocks synchronized data transfer from left and right channels based on the word select clock (WS). In this project we used one channel only, so the L/R channel selector is connected to ground to receive only from left channel.

The second proposal is to use a deep learning audio classification method with capabilities to classify the original signal from the noise. we selected methods that fit our purpose in order to train out model, we trained our model on the Edge impulse website. The model had several layers, these layers are showed down below:

Fig. 9: the layers we used during the training.

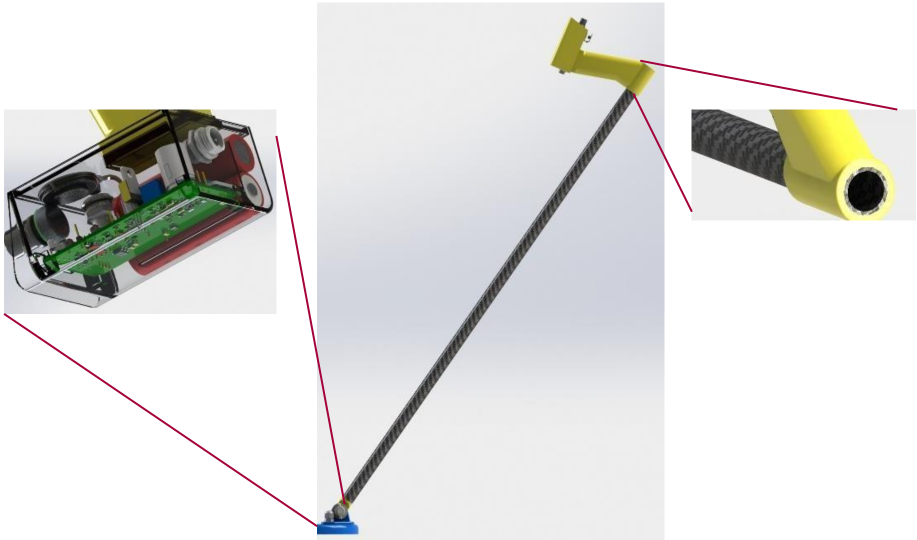


Fig.10 The proposed Sketch of the prototype

8. Design Verification Plan

During the initial stage of our project, we effectively utilized MATLAB Simulink to simulate the behavior of the acoustic faulted cable adaptive filter. As we progress into the hardware development phase, it becomes crucial to ensure that the filter meets the specified design requirements while operating in real-world environmental conditions. In order to accomplish this, we will create a thorough Design Verification Plan that outlines the goals, context, and testing procedures for the top five Evaluation Characteristics (ECs) that are vital for the adaptive filter's successful operation.

The ECs being tested are specifically tied to the filter's capacity to detect and separate acoustic sounds linked to faulty underground cables within the SEWA infrastructure. There is a significant obstacle posed by external noise, such as that coming from vehicles, human activities, and nearby machinery, which can overshadow the acoustic signals emitted by faulty cables. In the event that no faulty cable incidents happen during our project timeframe, we have alternative measures ready. These involve either simulating faulty cables in a controlled miniature model setting or utilizing pre-recorded acoustic sounds of faulty cables from external sources for testing purposes.

The final hardware model will be tested in underground locations where faulty cables are known to exist. The experiment will follow strictly the guidelines and safety regulations put across by the electric company to ensure that there is no exposure to high voltage dangers. Our team will only focus on capturing and analyzing acoustic sounds being produced by these prospective faulted cables without making any pre-location or closely ranging out to the said cables.

We have completed interaction with the SEWA electric company making visits to their sites and observing how they carry out their operations during testing phase preparation. We have identified several drawbacks to their current practice with acoustic audio filters, particularly allowing background noise interference the ability to cause issues in fault detection. To address this problem, we have established a liaison with the electric company and requested their cooperation in alerting us if any fault event occurs. This way, we shall be placing our final prototype and measuring its effectiveness under real disturbance instances.

Upon the completion of these experiments, we will provide a detailed analysis of the results and engage in a comprehensive discussion of our findings. For each test, a test plan matrix will be created and included in an appendix to ensure transparency and documentation of our verification processes. This rigorous Design Verification Plan will serve as a critical step in ensuring the reliability and effectiveness of our acoustic faulted cable adaptive filter in practical applications within the SEWA infrastructure.

9. Deliverables

In this project, we have identified several important deliverables that represent the culmination of our research and development work. First, we will write a detailed technical paper or journal article that will contain all of our findings, results, and the methods we used throughout the project. This paper will be a valuable resource for both the academic and industry communities.

Second, we will continue to develop further the simulation tool that will thoroughly test the fault location techniques we have carefully developed in the initial stage of the project. This tool will not only validate and improve the existing techniques, but it will also incorporate advanced features to enhance their accuracy and efficiency.

Our project will produce a prototype, namely an adaptive filter-based noise filtering technique. This technique, an essential element of our project, will be incorporated into a fully functional prototype. Its purpose is to minimize the negative effects of noise interference during the fault location process, leading to heightened accuracy and reliability of the system. These outcomes represent the concrete results of our project, making a valuable contribution to the progression of fault location techniques in the underground cables domain. We will incorporate additional features to our prototype, which is a deep learning model that is capable of classifying between the main signal and the background noise.

10. Project Management

10.1 Project Schedule and milestone

The project schedule and milestone are displayed down below:

Task Name	Start (Date)	End (Date)	Duration (Days)
project start	16-jan-2023	23-jan-2023	7
Team formation	24-Jan-23	30-Jan-23	6
Research Fault types and causes	1-Feb-23	7-Feb-23	6
Research fault finding process	8-Feb-23	14-Feb-23	6

Research Impulse Generator	15-Feb-23	21-Feb-23	6
Develop mathematical model	22-Feb-23	28-Feb-23	6
Develop simulations	1-Mar-23	3-7-2023	6
writing the interim Report and presentation	8-Mar-23	14-mar-2023	6
Researching how to build the prototype	15-Mar-23	28-mar 2023	13
Buying the needed parts	29-Mar-23	11-apr-2023	13
Draw the final prototype	12-Apr-23	3-may-2023	21
Review the final prototype	4-may-2023	9-may-2023	5
Building the final prototype	29-Aug-23	3-nov-2023	66
Testing and Readjusting Final Prototype	4-nov-2023	9-nov-2023	5
Submitting the final protype	10-Nov-23	15-nov-2023	5

Table 9. Project Schedule and Milestone

Here are the project schedule and milestone represented in charts

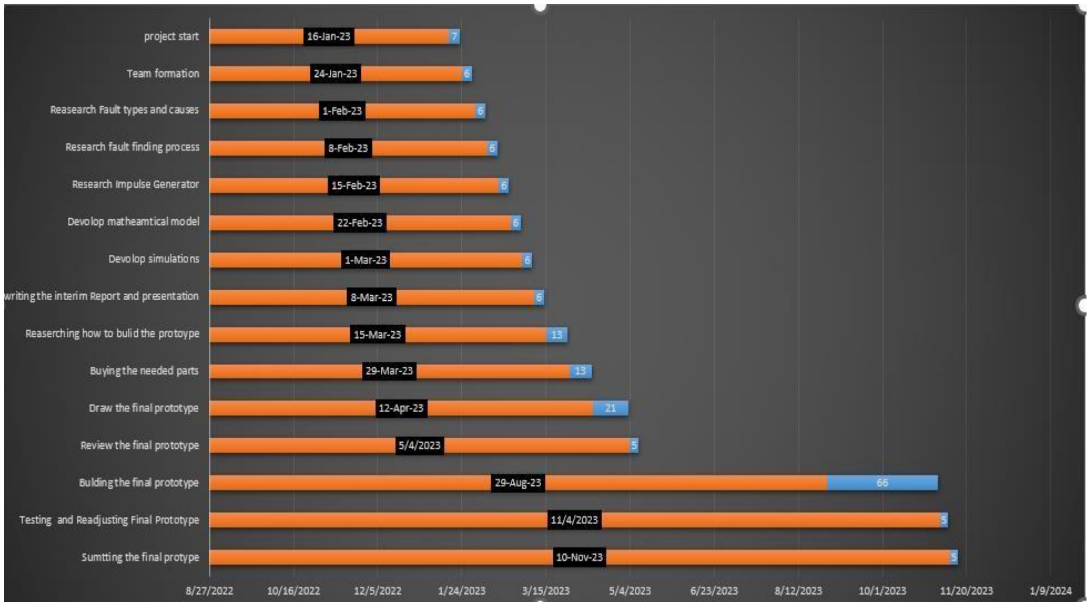


Fig. 11: Visual Representation of Project schedule and milestone

10.2 Responsibility Matrix

The responsibility of the project is displayed down below:

[RACI MATRIX]

ROLES		Fanuel Gebru	Tomas Yemane	Michaele Habete	Abduselam Ahmed	Abdulla Abdelrahim	Dr. Hussein Abdulrahman and Dr. Saher Al-batran
Project Deliverable (or Task)	**Status**	**Project Team**					**Project Mentor**
◢ Initiation Phase	Completed						
Project initialization	Completed	R	R	R	R	R	C
Team formation	Completed	A	I	I	I	I	C
task allocation	Completed	A	I	I	I	I	C
◢ Planning Phase	Completed						
Research fault types	Completed	R	R	R	R	R	C
Research fault finding process	Completed	A	R	R	I	I	C
Ressearch Impulse generator	Completed	A	R	I	I	R	C
◢ Execution Phase	Completed						
Develop Mathmatical model	Completed	R	R	R	R	R	C
Develop simulations	Completed	A	R	R	R	I	C
writing interim Report	Completed	A	R	R	R	R	I
◢ Closing Phase	Completed						
Draw prototype	Completed	R	R	R	R	R	C
write relevant codes	Completed	R	R	R	R	R	C
Purchase the required items	Completed	A	R	R	R	R	C
develop final protoype	Completed	R	R	R	R	R	C
◢ test and submit the protoype	Completed	A	R	R	R	R	I

LEGEND

R	Responsible	Responsible for getting the task done.
A	Accountable	Accountable for the task getting done in a manner that meets the required standard.
I	Informed	Team members who must be kept informed of the work. This is one-way communication.
C	Consulted	Team members who will provide input on the work. This is two-way communication.

Table 10: Responsibility Matrix

10.3 Work Breakdown Structure

We can see the work break down structure down below:

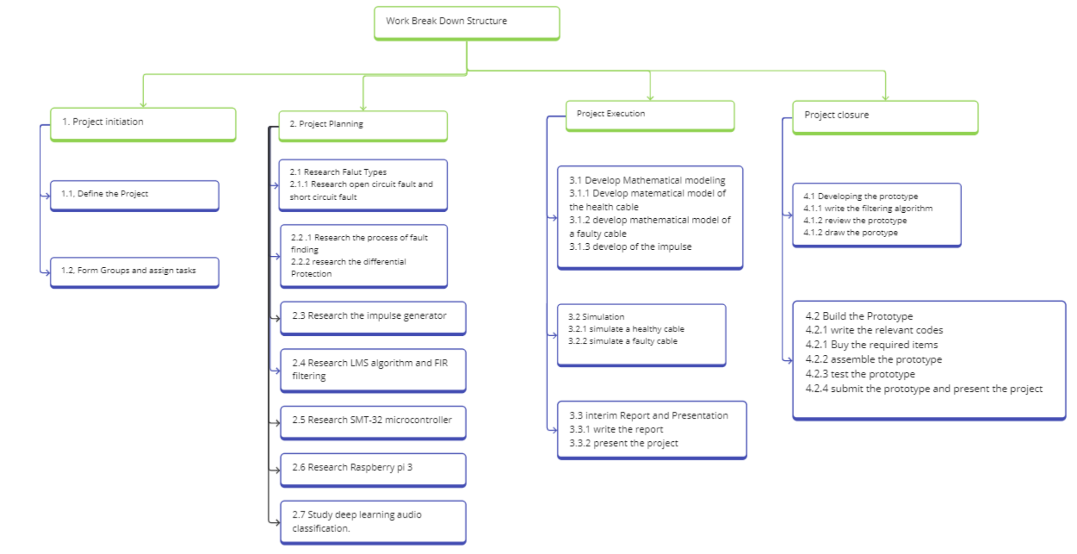


Fig. 12: Work Break down Structure

10.4 Project Communication Plan (Internal and External)

Internal Communication Plan

The internal communication plan will focus on ensuring that all team members are up to date with project progress and any issues that arise. The following methods will be used to achieve this:

- Weekly Team Meetings: The team will hold weekly meetings to discuss project status, upcoming tasks, and any issues together with our mentors Dr. Saher and Dr. Hussien.

- Progress Reports: the team member will be required to submit a weekly progress report or logbook to the mentor, outlining what we have accomplished and any challenges we have faced. And also ask Dr. Saher if there is anything unclear for us.

- Instant Messaging: the team members can use instant messaging apps like WhatsApp or Microsoft Teams or google documents to communicate and exchange information with each other quickly.

External Communication Plan

The external communication plan will focus on getting data, information, and support from our stakeholders like SEWA, FEWA, and DEWA. And this can be accomplished through email updates, site visits, and telephone updates.

10.5 Resource Planning

Resource planning for our project on fault detection in an underground transmission line through an efficient design of the fault detection bus lines and efficient signal processing design would involve several key steps. These steps include:

- ✓ Project Scope: our project is on fault detection in an underground transmission line through an efficient design of the fault detection bus lines and efficient signal processing design.
- ✓ Team Structure: team members work on the tasks collaboratively and the work is broken down equally.
- ✓ Resource Allocation: this project is being done by 5 members. And we are all from the department of electrical engineering.
- ✓ Timeframe: this project is a year-long project that will be completed next fall semester.
- ✓ Monitoring and Evaluation: Develop a monitoring and evaluation plan to ensure that progress is tracked and evaluated against the project objectives. This would involve developing performance indicators, establishing a system for data collection and analysis, and reporting on progress regularly.

By following these steps, we can effectively plan and manage the resources required for a project on fault detection in an underground transmission line through an efficient design of the fault detection bus lines and efficient signal processing design.

10.6 Develop Project Risk Management Plan

Developing a project risk management plan involves identifying potential risks to the project, assessing their likelihood and impact, and developing strategies to mitigate or manage them. The following is an example of a project risk management plan for a project on fault detection in an underground transmission line through an efficient design of the fault detection bus lines and efficient signal processing design:

1. Risk Identification: Identify potential risks to the project, including but not limited to:

- Changes in project scope or objectives
- Technical difficulties in designing the fault detection bus lines and signal processing system
- Uncertainty in the project timeline
- Budget constraints or changes in funding availability Stakeholder conflicts or changing priorities

2. Risk Assessment: we will assess the seriousness of the risks and will decide on how to mitigate the risk.
3. Risk mitigation strategies:

• Mitigation & Acceptance

4. Risk Monitoring and Control: we will regularly monitor and evaluate the effectiveness of risk
response strategies and adjust them as needed based on changing circumstances. This can include implementing early warning systems, tracking project performance metrics, and conducting periodic risk assessments.

11. Budget

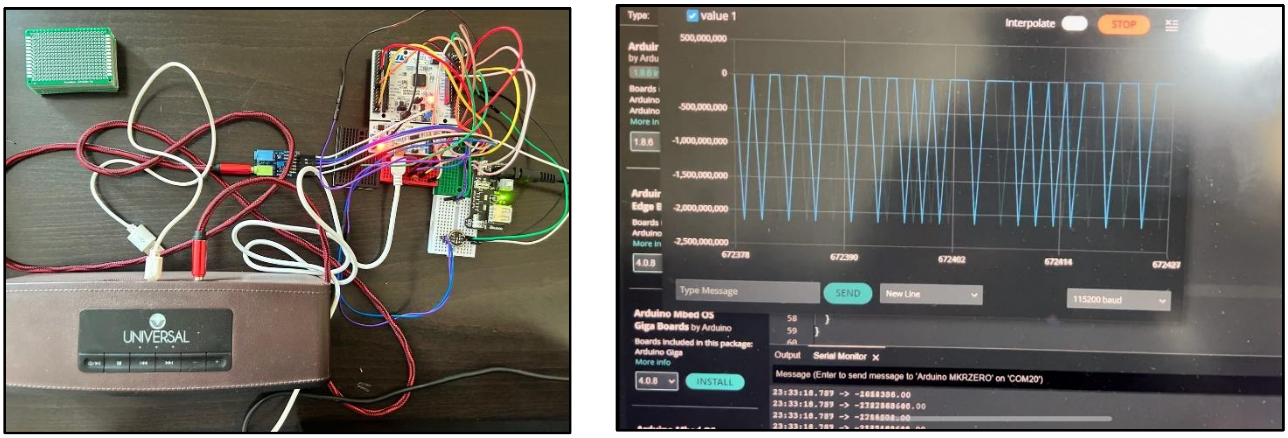
Our budget has been formulated through a comprehensive investigation and integration of the latest pricing data obtained from both domestic and global markets pertaining to the particular products we aim to acquire. Our scrupulous methodology guarantees that our budget precisely mirrors the present market circumstances and product expenditures.

Component	Price
Headphone	AED 120
Nucleo-STM32f401RE microcontroller	AED 71
2 x Microphone (INMP441)	AED 60
Pmod I2S2 module	AED 188
2 x 100 kΩ Resistors	AED 20
2 x 100 nF Capacitors	AED 10
3D Printed Case holder	AED 300
2 x 9v Battery	AED 40
Miscellaneous	AED 150
Raspberry pi screen	AED 200

Table 11. Expenses Table

12. Experimental Setup

In our project we conducted several testes before preparing the final prototype. In the first section of our design we solely depended on the embedded system setup for input and output, in order to hear the clear thumping sound of the faulted cable. Here in this method the microphone module INMP441 picks the audio input signal and the STM32 microcontroller processes the signal to be heard only the desired sound by removing the noise. This design alone had several limitations one of the reasons were the sensitivity of the INMP441 mic module. It has very low sensitivity that need to be very close to the sound source in order to pick the audio. The second limitation was the interfere of some noises with the listened output audio. Though most of the noise is reduced there is some passing through to the output.



a. b.

Fig. 13: The testing setup for detecting the external audio input from microphone and filtering, set up connection (a) and screen display of the detected input INMP441 mic (b).

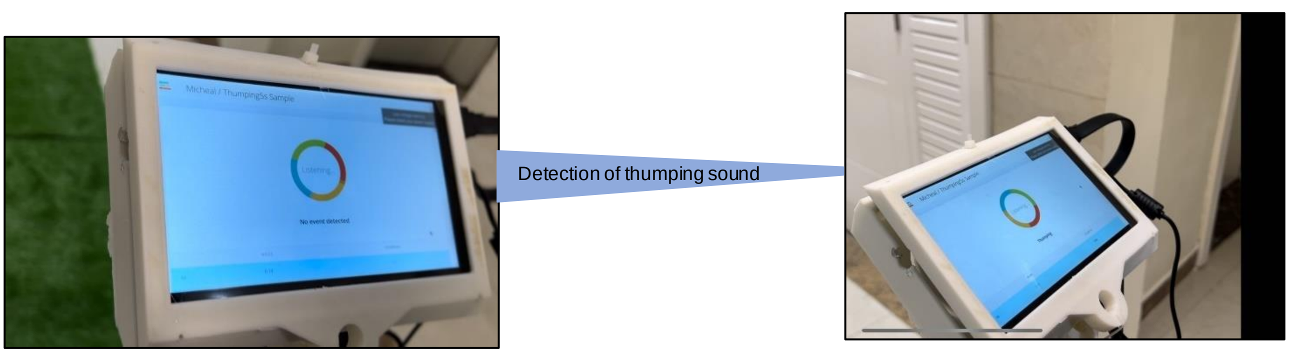
As can be shown from the figures 13, the output from the microcontroller was heard using speaker to better amplify it and clearly differentiate it from the other external coming audios, leaving the low sensitivity of the microphone module everything else works fine in the setup.

As a simulation we conducted an LMS algorithm filtering in a PC (laptop) input conducted from the microphone of the laptop and output from the headphone connected to the microphone. In this setup both a sine wave disturbed by the introducing of white noise in the MATLAB and real noise coming from an external environment was tested. As this was for simulation purpose there wasn't any application done with it. The output of the wave forms is discussed on the next section.

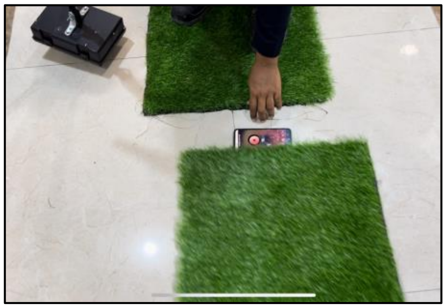
The second method we added for the project was the audio classifier. This is a Machine learning (ML) algorithm that classifies the audio coming from the filter into different categories which is one of them was the thumping. The purpose of his ML classifier algorithm is to confirm on the screen whether the thumping sound is detected among the incoming audio from the STM32 microcontroller. To perform this task a raspberry pi is used to do the classification of the incoming sound. All of our test were conducted by providing two audio source devices, one providing the noise that imitates the real environmental noise and second devices for providing the sound of the thumping in very low level that can barely be detected by the person hearing all the sounds at the same time.

Fig. 14: The prototype in action, for finding thumping sound, exact sound generating from a mobile device hidden under the carpet, this is for testing purpose.

Here the prototype as shown from the above figure, it contains all the internal components the input (mic) the stm32 microcontroller and the output audio codec is contained inside the box down to be as close as possible to the ground in order to pick audio easily. The raspberry pi which does the audio classification is at the above. The display is shown in the figures below. It gets its input audio from the microcontroller and indicates if a thumping sound is detected.



a. *b.*



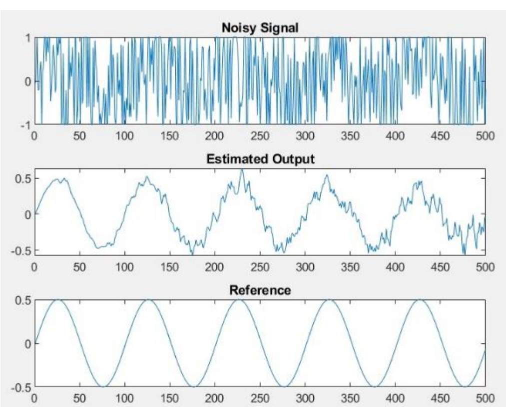
c.

Fig. 15: The testing procedure conducted for detecting the thumping sound buried under the carpet by someone else to avoid bias in finding by the individual doing the search, first absence of any detection audio (a), then at the spot the thumping playing devices is buried it is detected on the screen (b) and heard by a headset, the device was there (c)

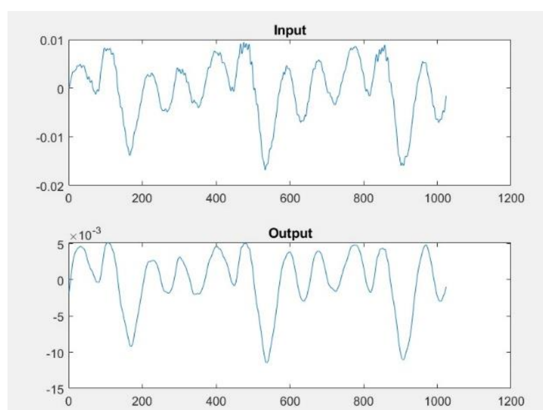
We could conduct the testing successfully and the procedure went as planned. The details of the result in discussed in the next section.

13. Results, Verification and planning

As stated in design verification plan, we had some parameters in order to evaluate our product. We had to test the functionality of our LMS filter on MATLAB simulation by using different signals in order to test its filtering capabilities. We had to use a sine wave as an input and then we tested the filter with real time audio, and we can say that the results we got we satisfactory as displayed down below:



a.



b.

Fig. 16: The MATLAB simulation result for Sine wave with white nosie as an input (a), and external sound input with environmental noise in real-time filtering (b) plots.

Then we had to test the deep learning model we designed before deploying it on the Raspberry Pi, this model is supposed to be tasked with separating the noise we get from the real signal it should be displaying the results in real-time indicating if the sound heard is noise or the real thumping signal. To train the model we needed data and it was not as abundant as we wanted it to be, so we resorted to augmentation techniques and this created some constraints for us as the data wasn't enough to train our system. However, we were able to train the model, and the results of the training are displayed below:

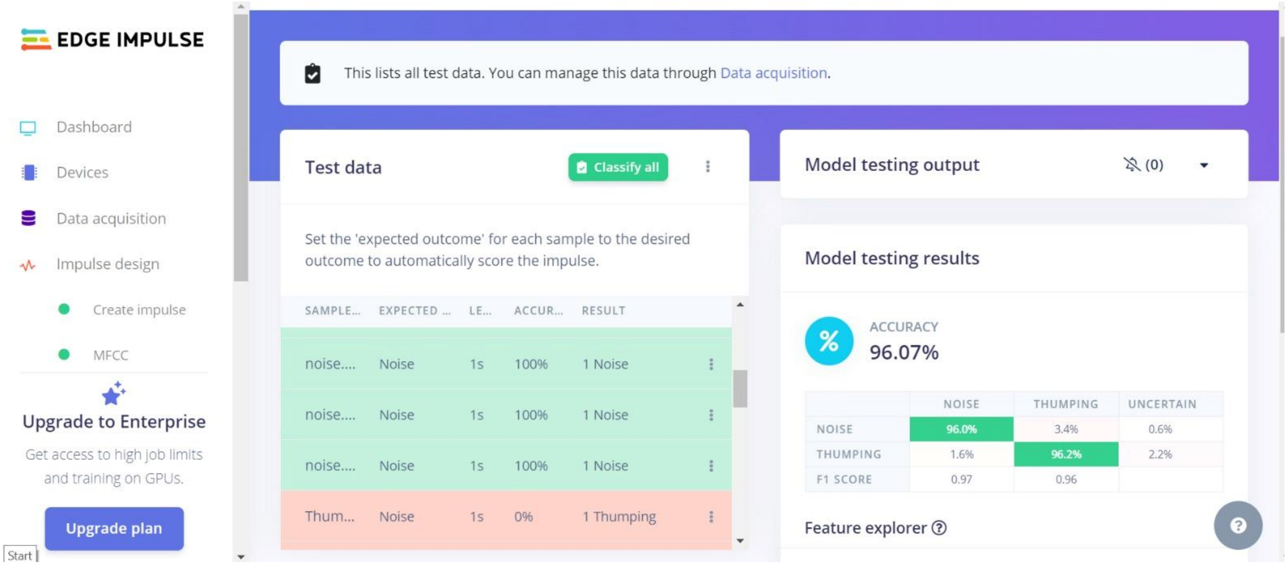


Fig. 17: The training Results, showing an accuracy of 96%.

The final results that we got from the prototype were satisfactory, as the prototype was working the photos below show how the prototype was classifying between the different signals:

Fig. 18: The detection of thumping at the exact spot with a percentage of 86% confidence.

There were some constraints we faced during the training phase of the deep learning model, these constraints we caused due to the scarcity of training data as we don't have many thumping sounds coming out of a faulty cable on the internet. Overall we can say that we were going according to the project plan, and we finalized the deliverables on time according to the timeline. Additionally, we didn't exceed the budget we set at the start of the project and the time management of the project was perfect.

14. Bussines Plan

The Bussiness Plan document can be accessed from here. To avoid more than 21 pages long document to be included here.

15. Conclusion and Future work

We showed our prototype to our peers, asking them about their feedback on the design of the product. We concluded that our peers can be target customers is because they are electrical engineering students, so they had prior knowledge of our design. We provided them a list of the customer requirements that we had at the start of the designing process; these requirements are as follows:

- ✓ Frequency Filtering: The filter should be capable of isolating and amplifying specific frequency ranges associated with cable fault signals.

- ✓ Real-time Signal Analysis: The filter system should provide real-time signal analysis capabilities, enabling instant identification and differentiation of fault signals from Background noise.

- ✓ Adaptability to Cable Types: The filter should be designed to accommodate various types of underground cables, including different insulation materials and sizes.

- ✓ Integration with Fault Location Equipment: Seamless integration with existing underground cable fault location equipment is a key requirement.

- ✓ User-friendly Interface: The filter system should feature an intuitive and user-friendly interface for operators. This includes a graphical user interface (GUI) that allows easy adjustment of filter parameters, clear visualization of filtered signals, and the ability to store and recall settings.

Our peers then had to evaluate the product based on the customer requirements, their rating we overall the prototype is good, and it can be deployed in real time fault location tasks. What they liked about the prototype was the innovative approach that we used in order to separate the real thumping sound from background noise, the approach in question is applying deep learning to separate the fault thumping sound from background noise. When they were asked about the improvements they wanted to see their reply was as follows; it would be better if the user can adjust filter parameters, The accuracy of the model is okay but if it was increased, it will improve the overall efficiency of the prototype, and when the prototype was displayed we didn't see its adaptability to different cable type so improve the way you present the product. From the feedback we got we can say that there are plenty of thing in our prototype that are open to an improvement, we can improve the product in the future as follows:

- ✓ Training the deep learning model using abundant data to increase the efficiency.
- ✓ Improve the user interface by adopting touch screen display and this can eliminate the need for peripherals such as mouse and keyboard when operating the prototype.
- ✓ We need to demonstrate to the customers the application of the filter with different cable types, so we need to update our simulation environment.

Finally we can say that the final product is open to improvements, we can work on them to make it more efficient product and most importantly to give our prototype a fighting chance in the competing market.

Reference

[1] J. S. H. W. R.W. Deltenre, "Underground Cable Fault Location," New Mexico, 1977.

[2] ProdigyTechnovations, "Difference between I2C vs I2S," [Online]. Available: https://shorturl.at/alRW3.

[3] A. S. R. P. Deepak Pandey, "Real time active noise cancellation using adaptive filters following RLS," *International Research Journal of Engineering and Technology (IRJET),* vol. 03, p. 5, 2016.

[4] S. M. I. M.-S. C. M. I. S.-J. L. M. I. Xia Yang, "Fault Location for Underground Power Cable," IEEE, 2008.

[5] E. Tutorial, "Filters," 2020. [Online]. Available: https://www.electronicstutorials.ws/filter/filter_2.html.

[6] Circuits4you, "Underground cable fault detection," Circuits4you, 2016. [Online]. Available: https://circuits4you.com/2016/05/17/arduino-based-underground-cable-fault-detection/. [Accessed 2023].

Appendix: Team charter

Team Charter

Team's values, standards, and goals for effective teamwork

Team Members	**Abdulla Abdelrahim:** **Skills: Good diplomacy and Inter-communication with external parties.**	**Abduselam Ahmed:** **Skills: Good interaction with different internet platforms. And awareness about engineering devices.**	**Fanuel Petros:** **Skills: 3D designing, electrical devices repairing. Team leading.**	**Micheale Habte:** **Skills: MATLAB simulink, machine learning.**	**Tomas Yemane:** **Skills: different embbeded microcontrollers familiarity, C code , MATLAB simulink.**
Roles and Responsibilities	Communicate with third parties for site visiting Communicate with SEWA or FEWA for observation on their fault finding procedure	Utilize different platforms for researching about project.	Team managing and monitoring. 3D models for project. Final prototype assemble Look for the completion of assigned tasks on time	Understanding the Algorithm for audio filtering on MATLAB and Implementing there.	Researching about different microcontroller compatible for porject. Implementing the right algorithm in embedded system. Peform SImulink model
Shared Values	Communicating on time.	Perfoming assigned task on time.	Daily communication with team members. And receive feedback from team members.	Bringing and looking good model on time.	Working with other members and updating new finding.
Guidelines for Communication	Call and Whatsup	Face to face, Microsfot Teams and whatsapp	Face to face, Microsoft Teams	Face to face, Microsoft Teams	Face to face, Microsoft Teams

Quality Standards	Working by communicating with each other and updating the progressing to members	Accomplishing given task on time Updating with Mentor the tasks accomplished on time	Respecting the idea of others and receiving feedback without complain from other members
Team Goals	Provide reliable and proved design to final prototype	managing and finishing all planes before given deadline.	gaining skills and sharing together what found by each member for together growth.
Goals Evaluation	Is the expecte result found and Is it above expectation?	Does the design perform well to solve the needed problem?	Are all the ideas generated and recorded incorporated in the design?

Appendix: Engineering Drawings

Engineering Sketch

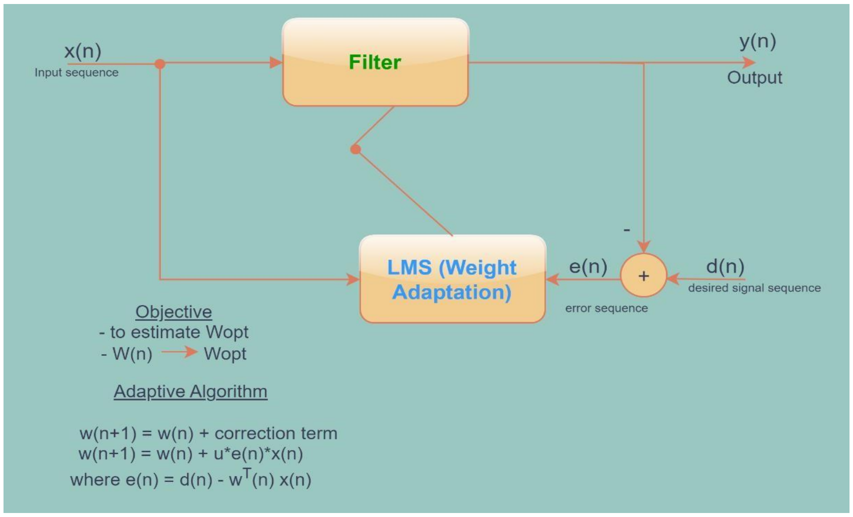


Fig. 4: The block diagram of LMS Algorithm adaptive filtering Lest mean square

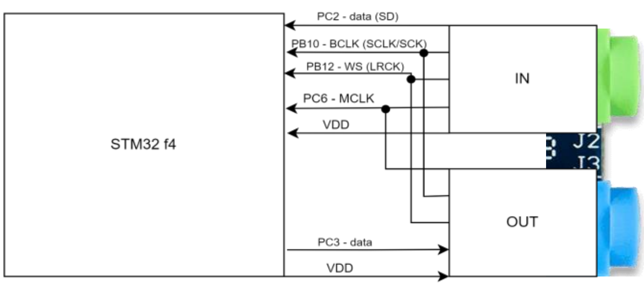


Fig. 5: I2S protocol communication with the microcontroller

Fig. 6: 3.5 mm headphone jack labels to be connected to the pmod I2S2 module for hearing audio output from the DSP

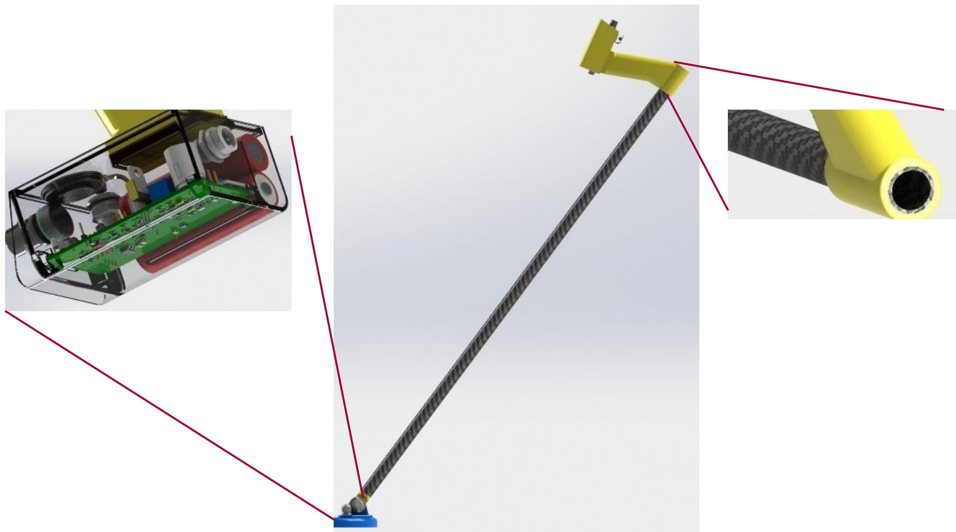


Fig. 8: The proposed Sketch of the prototype

Appendix: Prototype Test Matrices

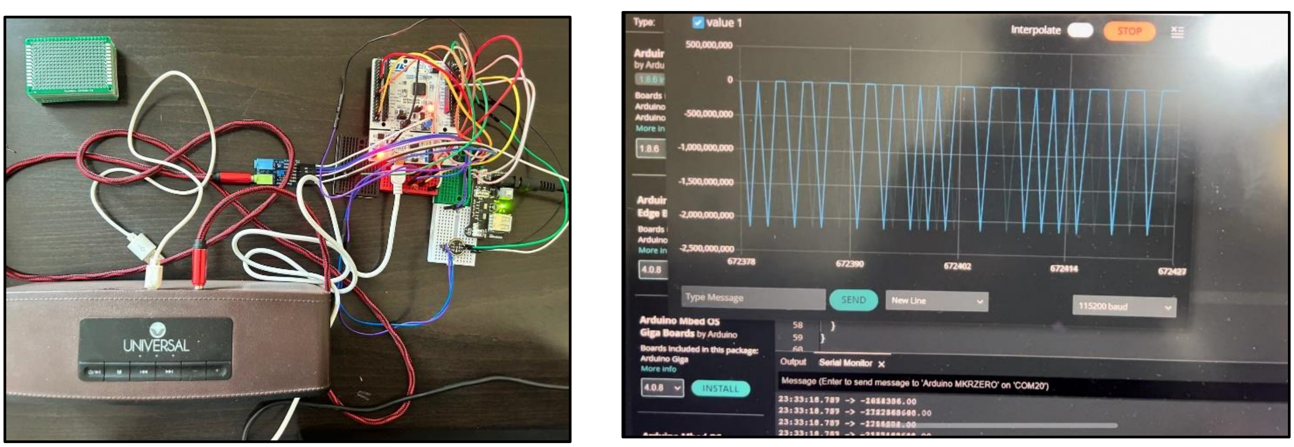
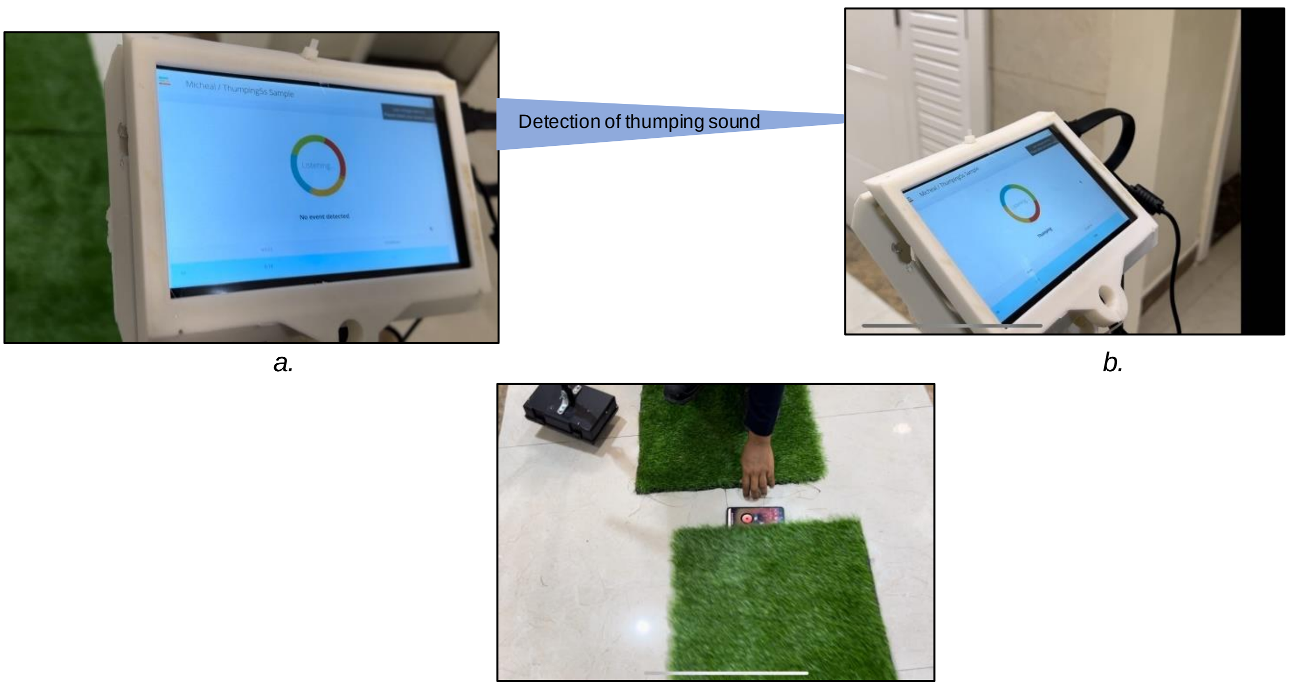


Fig. 13: The testing setup for detecting the external audio input from microphone and filtering, set up connection (a) and screen display of the detected input INMP441 mic (b).

Fig. 14: The prototype in action, for finding thumping sound, exact sound generating from a mobile device hidden under the carpet, this is for testing purpose.



a. *b.*

c.

Fig. 15: The testing procedure conducted for detecting the thumping sound buried under the carpet by someone else to avoid bias in finding by the individual doing the search, first absence of any detection audio (a), then at the spot the thumping playing devices is buried it is detected on the screen (b) and heard by a headset, the device was there (c)

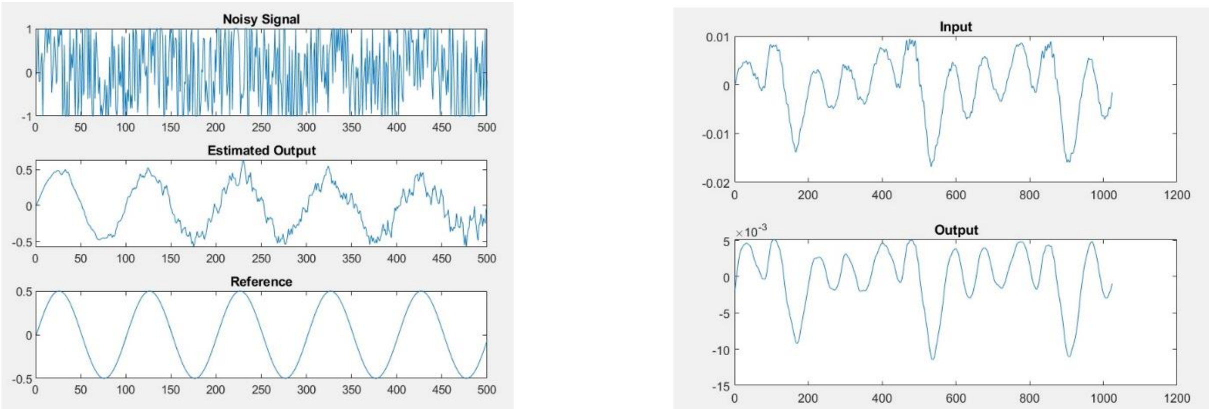


Fig. 16: The MATLAB simulation result for Sine wave with white nosie as an input (a), and external sound input with environmental noise in real-time filtering (b) plots.

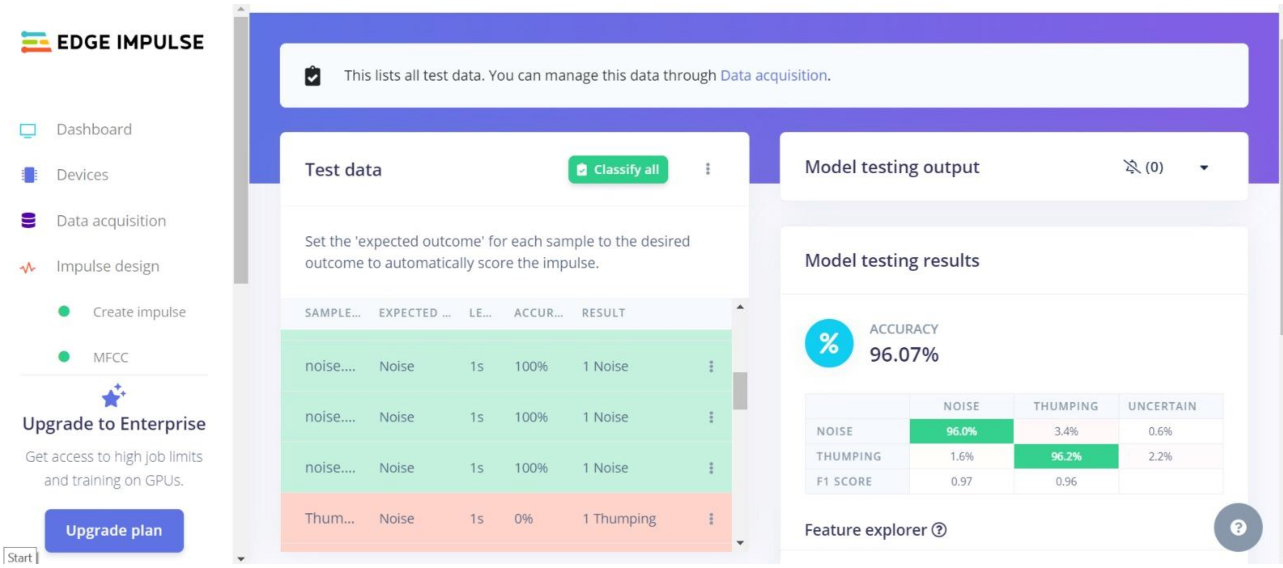


Fig. 17: The training Results, showing an accuracy of 96%.

Appendix: Clouse out memos

Abdelrahim A.

As a member of the capstone design project team, I played a crucial role in our ultimate success. My primary responsibilities included extensive research on the underground electrical fault-finding process and acting as a liaison between our team and different companies such as FEWA and SEWA. This project offered me a valuable opportunity to dive into the complexities of underground cable fault identification and gain practical knowledge about the use of various filters. Additionally, I gained a thorough understanding of project management techniques, including the RACI matrix, resource planning, and work breakdown structure, which were fundamental to our team's efficiency and success. Furthermore, this experience sharpened my communication and collaboration skills, giving me invaluable experience working within a team-oriented project setting. While reflecting on this project, I have identified areas where I could have improved, and if given the opportunity, I am eager to incorporate these lessons into future projects.

For the next class, I strongly advise dedicating plenty of time and energy towards the project, with a focus on truly enjoying the process. Regarding the references I used, I found great value in seeking support and guidance from my peers, whose wealth of knowledge and personal experiences proved invaluable. Furthermore, I also utilized online resources such as YouTube videos and textbooks to deepen my understanding of the subject matter. Ultimately, this capstone design project served as a highly enriching learning opportunity. I am eager to put the knowledge and skills gained to use in future pursuits.

Ahmed A.

During our capstone design project, I played a pivotal role by conducting extensive research on surge generators, utilizing the Raspberry Pi, exploring various types of faults, and making significant contributions to the design of the LMS filter. As a result, I seamlessly collaborated with my team and gained valuable insights into the challenges and opportunities involved in the underground fault location process. Furthermore, my involvement in the LMS filter design further enhanced my skillset in adaptive filtering techniques and signal processing. This project provided me with valuable learning experiences, including navigating the complexities of adaptive filtering, diving into the realm of artificial intelligence for audio classification, and understanding the importance of effective project management practices.

As I look back on my role in the project, I can confidently say that my efforts were in line with our team's charter, but I am also aware of areas where I can improve. If I were to approach the project again, I would prioritize starting the prototype design phase earlier and invest in a dedicated course on Raspberry Pi microcontrollers to increase adaptability. Moving forward, I propose that future teams carefully consider project choices based on available resources, team capabilities, and overall expertise.

Throughout our project, we found great success in utilizing a variety of resources, including research papers, YouTube videos, books, and online coding forums. These tools were instrumental in overcoming challenges and achieving our goals. Overall, this capstone design project has greatly enriched my engineering skills.

Habte M.

Throughout the project, my main role was on simulating our ideas on MATLAB. Starting from CDP1, I was working on mathematical model for a single line to ground fault of underground cable using MATLAB. It was intended to solve the locating problem using mathematical equation of the cable parameters however it was not validated as we couldn't find historical data from the electricity authority. While in the CDP2, I was working on simulating the LMS and NLMS algorithm using MATLAB. It was initiated using sample sin wave then progressively developed to real time adaptive noise enhancement. My last role was training and deploying embedded machine learning for the audio recognition feature of our project on Edge Impulse. From the project, I have learned how to approach a problem and solve through progressive, and I gained the importance of effective collaboration within a team. Looking back, before the start of the project I would have spent more time choosing my project including clearly defining the final stage and the possibility of success of my project. For future teams, I would like to remind them to use their CDP1 on completely finish their on simulation that have more possibility to be easily deployed. Finally, regarding my role MATLAB and EDGE IMPULSE software were my main simulation tools and accommodate us by simplifying the simulation process.

Petros F.

In my capacity as the team leader for the capstone design project, my official duties encompassed cooperating in designing the LMS filter, 3D model design and printing, prototype assembly, and electronics assembly and soldering. Beyond these roles, I undertook the responsibility of managing team performance and facilitating communication with our mentor. Through this experience, I gained substantial insights into engineering, project management, and team dynamics. Specifically, the hands-on application of theoretical knowledge in designing intricate systems and integrating various components into a functional prototype provided a profound understanding of engineering principles. Moreover, the challenges of managing the team highlighted the significance of effective communication, time management, and adaptability in the realm of project management. These lessons learned when compared to my initial personal statement in the team charter, reflect a direct and practical application of theoretical concepts to real-world scenarios, showcasing a tangible evolution in my understanding of these disciplines. If given the opportunity for a different approach, I would focus on narrowing down project objectives and achieving them incrementally, providing a clearer path to success. My advice to the next class is to concentrate intensely on Capstone Design Project I, dedicating time to study and discuss every minute detail early on, ensuring a more seamless implementation of the prototype. Valuable resources during this journey included online platforms(courses, videos, and articles), research papers, and power systems distribution books.

Yemane T.

During the whole project time that took more than six months, I participated mainly in two activities, at first, especially during the CDP 1, I made some research on underground cable fault types and looked closely into the market available current method of underground cable fault detection. I looked also into the different audio filtering algorithms as such I came up with LMS algorithm for our project. During the CDP 2 I highly worked on the microcontroller selection and interfacing the inputs and outputs of it, and along with that incorporating the LMS inside IDE to run in the STM32f401RE. Throughout this project I learned technical skills, one among them is the microcontroller STM32, this project gave me excuse to look into it, apart from that, my knowledge on DSP was deepened due to this project. In addition, I gained soft skills like teamwork, group communication, and sharing knowledge with work mates. There was some constraints in time management as the whole project is leaded by the group leader in our case Fanuel. I would like to improve the time management, and early testing stage for our project. To the next class I would love to give advice to not look at each other while working and everyone to be responsible and not to expect order or request to do specific task, at last but not least to manage their time and widen their view in doing the projects.