

Sound Pollution Monitoring System and Social Awareness Creation in Modern City

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A project report submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering

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January 22, 2023

Declaration

This Final year Capstone Project report is submitted to the department of Electrical and Electronic Engineering, University of Liberal Arts Bangladesh in partial fulfillment of the requirements for the degree of Bachelor of Science. So, we hereby, declare that this report is based on the work done by us. Materials of work found by other researchers are mentioned by reference. This project report, neither in whole nor in part, has been previously submitted for any degree.

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Acknowledgement

At first, we would want to thank Almighty Allah for giving us the proper knowledge, sound health, and patience needed, to finish this Final Year Capstone Project. We also address our heartfelt thanks to our honorable supervisor Atik Jawad sir, for providing us with necessary guidelines, knowledge, ideas and precious time whenever we need it. Our gratitude to our honorable faculty members of our department, particularly Professor M. Mofazzal Hossain, PhD, Mirza Rasheduzzaman, PhD, Abul Barkat Mollah Sayeed Ud Doulah, PhD, Md Liton Hossain, PhD, Ramit Kumar Sadhukhan. We would also like to address our gratitude to Mr. Khorshed Alam, Assistant Officer, for his four years of cooperation at the university.

Lastly, we would like to express our respect, best wishes, and fondness from the bottom of our hearts Teacher Assistants, seniors, our classmates, friends, juniors, and our families who have inspired us, and supported us.

Abstract

Sound pollution has become one of the primary causes of environmental pollution in Dhaka City. Nowadays, sound intensity exceeds people's safe hearing limit. Proper assessment of sound level in Dhaka is required to properly address this pollution. To this end, this project proposes a systematic approach including an updated data set of sound levels to assess sound pollution throughout Dhaka city. Following the methodology, a survey has been conducted by selecting major locations and measuring the sound levels at those locations throughout the city. Moreover, we divided Dhaka city into two parts i.e., Dhaka North and Dhaka South. The sound level meter Lutron SL-4012 is utilized for collecting data from the selected locations choosing peak hours. The findings show that all the monitored locations are facing critical sound pollution. A few highly polluted areas such as Newmarket, Shahbagh, Paltan, Gulistan, Motijheel from Dhaka South and Mohammadpur Beribadh, Gabtoli, Farmgate, Kawran Bazar, Mohakhali from Dhaka North are also identified. Moreover, this project also proposes a potential sound mitigation approach involving device-based sound metering and displaying to reduce sound pollution. As a solution to our addressed problem, a prototype is built for the project and validated with the sound meter for accuracy checking. Machine Learning is used for sound classification, and for recognition of sound by utilizing MFCC characteristics. This project provides a significant, updated overview of sound pollution throughout Dhaka City. Furthermore, the proposed solution has the potential to raise public awareness and it can minimize sound pollution in Dhaka city upon large-scale deployment.

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Chapter 1: Introduction

1.1 Background

Along with other forms of environmental pollution, sound pollution has become a rising concern on a global scale. Consequently, noise pollution makes it strenuous for animals to utilize sound for navigation, finding food, mating, and avoiding predators, affecting many animals' potential to survive. In humans, noise acts as a stressor that may cause adverse health effects like a higher risk of cardiovascular diseases, including high blood pressure and myocardial infarction, in people chronically exposed to high levels of road or air traffic noise. People who are exposed to sound pollution develop a wide range of illnesses, which has become a global health issue [1]. The term 'sound pollution' refers to audible undesired sounds that are loud, obtrusive, and hazardous to human health [2]. Sound Pollution is a common point of problem in all industrialized countries and it polluted urban communities [3]. In many swiftly urbanizing locations, sound pollution can also create a significant environmental threat. We are morally unable to resist the man-made environmental calamity of the 2000s, which includes loud music, people chatting on phones, the traffic, and even animals barking at any time of the day [4-5]. Not only are affluent countries like the United States or Europe plagued by this pollution, but so are developing nations like Bangladesh. In Bangladesh, sound pollution is one of the talked about topics of the day. At present, the sound level in Dhaka city is estimated to be ranging from 60 to 120 dB [6]. Dhaka city has become one of the noisiest cities in the world due to the extreme exposure to sound.



Figure 1.1: Sound pollution an alarming health hazard

1.2 Literature Review

Noise pollution, particularly along major highways, is a growing hazard to Dhaka's residents along with air and water pollution. This research makes an effort to pinpoint the main noise sources at road junctions, as well as how they contribute to total noise levels and potential noise abatement strategies. Sharp and loud noise levels were noted in both instances as being mostly caused in both situations, unnecessary use of horns was identified as a prime cause of sharp and high noise levels [7]. Behavioral patterns of road users (drivers, passengers, and pedestrians) appear to be primarily responsible for the traffic noise pollution on the roads. Failure to implement the traffic and environmental laws and ignorance of general people about these laws contribute to noise pollution. Due to a rise in urbanization, industry, and cars, noise levels nowadays are higher. Along with other types of pollution including air, water, odor, waste, etc., noise pollution in Rajshahi, Bangladesh, is getting worse and worse, as in many other megacities in developing nations. Deafness, mental collapse, and other adverse impacts are only a few of the negative consequences of pollution. As a result, the main goal of this research is to measure the exceeded noise levels at particular types of sources in comparison to the norms. With the use of a sound level meter, a survey of sound level was conducted in Rajshahi city from 9 AM to 12 PM on working days in various sites, including hospitals, residential areas, schools, and colleges [8]. The observation revealed that the observed sound levels virtually everywhere consistently exceeded the DoE's recommended permissible limits (Department of Environment). The required steps that may be performed to maintain the sound level within acceptable bounds are also suggested in this study.

From March 2015 to November 2015, research was carried out at medical facilities in Bangladesh's Mymensingh city to determine the extent of noise pollution and the health consequences it has. Three hospitals Mymensingh Medical College and Hospital, Rajdhani Hospital (Pvt.) Limited, and Shawdesh Hospital (Pvt.) Limited as well as two clinics Popular Diagnostic Centre Ltd. and Safeway Diagnostic Centre Ltd. of the city of Mymensingh were all subjected to time-weighted average noise measurements for the study [9]. The Mymensingh Medical College and Hospital had the highest noise levels, whereas Shawdesh Hospital (Pvt.) Limited, on Sarda Gosh Road, had the lowest levels. All of these noise levels surpassed the government of Bangladesh's Department of Environment's (DoE) 45 dB permissible threshold [9]. Conversation, headaches, hearing issues, and elevated heart rate were found as the most prevalent issues brought on by noise pollution. In order to alleviate the issue, 28% of respondents advised using sound barriers; 25% suggested increasing doctor awareness; 22% suggested increasing visitor awareness; 13% supported restricting visits; and 4% suggested outlawing hydraulic horns.

Noise is produced by the unwelcome and unbearable sound [10]. Noise pollution resulted from all of the measured noise levels in industrial workplaces exceeding the DoE regulation (75 dB during the day and 70 dB at night). Machines and the overpopulation of workers in the sector were the main sources of noise pollution. [10] Headaches, heart conditions, and hearing problems were the most prevalent effects of noise pollution. It was recommended that in order to remedy the noise issue in industry, noisy machines should be substituted for the noise generators.

1.3 Problem Statement

Study shows that health is directly affected by sound pollution. The impacts of sound pollution are in millions. Noise-Induced Hearing Loss (NIHL) is the most common health disease caused by Sound pollution. Also, high blood pressure, heart disease, sleep disturbances, and stress are caused by loud sounds. All age groups are somewhat affected by this problem with children significantly. Traffic noise, construction sites, air traffic, and hydraulic horns are mainly responsible for sound pollution. The human hearing system can tolerate sound intensity up to 85 decibels (dB). Continuously hearing over tolerance level may cause permanent hearing loss. 60 to 70 decibels (dB) are the normal conversation range, anything over this value is considered noise. At close range, a horn emits 100 decibels (dB) of noise and it can be surmised that busy streets in Dhaka city have an average noise level of 80 to 110 decibels (dB). Therefore, Dhaka residents are prone to sound/noise pollution-related diseases, and organizations or agencies are not addressing this problem in as serious of a manner as it is in practicality.



Figure 1.2: Sources of Sound Pollution

1.4 Motivation

Sound pollution is harming people on a large scale with several diseases. Continuously hearing over the tolerance level of 85 decibels (dB) may cause permanent hearing loss. At close range, a horn emits 100 decibels (dB) of noise and it can be surmised that busy streets in Dhaka city have an average noise level of 80 to 110 decibels (dB). Therefore, Dhaka residents are prone to sound/noise pollution-related diseases, and organizations or agencies are not introducing any solution to this problem in as serious of a manner as it is in practicality.

1.5 Objectives

The objective of this project is to develop a Sound Pollution Monitoring system & create social awareness in Modern cities that will work efficiently to help in reducing sound pollution. The system comprises three significant processes that will act sequentially to mitigate our stated problem.

Data Collection: Sound intensity levels in decibels (dB) in various zones of Dhaka city is considered. Prior to this, a heatmap has been developed on basis of the accumulated data.

Prototype Implementation: A prototype system has been developed to send awareness messages among the residents to reduce noise pollution.

Sound classification: A machine learning system is used to identify sound-polluting factors.

1.6 Project Outline

This report has been divided into five chapters and every chapter has discussions on different topics related to the project. An overview of each chapter is given below:

Chapter one contains background study, literature review and objectives

Chapter two contains the and methodology of the project, sound pollution heat map.

Chapter three contains the Design and Implementation of Prototype

Chapter four This chapter contains sound classification and its result.

Chapter five This chapter contains discussion, expected outcomes.

Chapter six Contains conclusion and future work

Chapter 2: Data Collection and Analysis

This chapter contains the details of the previous research done in this field and includes the field-specific theory of Sound Pollution and its types, system parameters, and conditions of it and behind IoT-based monitoring systems as also the concept and methodology of the project.

2.1 Field-Specific Theories

2.1.1 Sound Measurement Theory

When sound exceeds the tolerable limit, it becomes pollution. Sound pollution has a destructive impact on the activity of human life. The main causes of sound pollution are urbanization, mechanized transport, horn, etc. When evaluating exposure to sound source equivalent sound level, L_{eq} , the single index indicator is used widely. This parameter is used in order to rate sounds that vary in time. A period T is defined as L_{eq} for the average sound level. For a certain period of interest, the coverage deriving from the accretion of sound level L_{eq} is regarded as its unit of measurement. For metrics, a defined time should always be used. In actual variable level over the period of interest which holds as much sound energy, L_{eq} . T may be considered persistent with that sound level. A time-varying sound level for a particular parameter is related by this method. The comparative loudness of different sounds made up of many various frequencies can be better evaluated by several filters, which are specified by acoustic community that estimate the sensitivity of vehicles. “A-weighting” filters are most suitable for environmental sound sources. The “A-weighting” curve which is weighted for corresponding continuous sound level (L_{eq}, T) is defined.

$$\frac{L_A(t)}{10} = \frac{p_{Arms}^2(t)}{p_{ref}^2} \quad (1)$$

$$L_{eq}, T = 10 \log \frac{1}{T} \int_0^T 10^{\frac{p_{Arms}^2(t)}{p_{ref}^2}} dt \quad (2)$$

Here $L_a(T)$ is the A-weighted immediate sound level, and $p_{Arms}^2(t)$ is the A-weighting sound level obtained frequency filter. In city environments, roads, railways, and industrial area, $L_a(T)$ is one of the most used indicators [11].

2.1.2 Lutron SL-4012 diagram

For collecting data, we used Lutron SL-4012 (figure 2.1) as a sound level meter. This device's quality has been assured by ISO (International Organization for Standardization). We chose this device because it has some dynamic characteristics. This device's LCD display consume low power & amp; clear read-out even in bright ambient light condition. It has dynamic memory function to store the Maximum & Minimum value. It holds functions as well. This device's microphone is used for high accuracy & amp; long-term stability. Lutron's Measurement Range is (30 – 130) dB and frequency range is 31.5 to 8,000 Hz. Lutron is durable, has long-lasting components, including a strong, light weight ABS-plastic housing case. Moreover, it is small and light weighted and its design allows one-hand operation. [12]

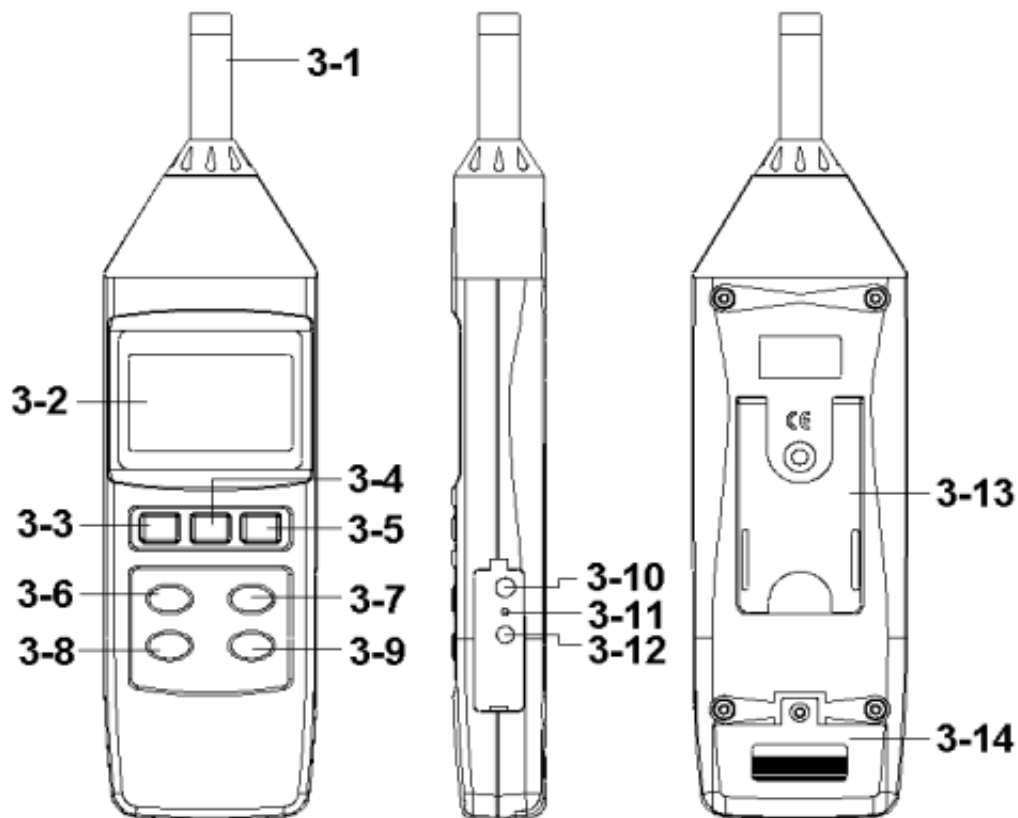


Figure 2.1: Lutron SL-4012 diagram

2.1.3 Acceptable Sound Level (dB)

There are many established effects of sound while many other effects are getting revealed by means of research [13-18]. Seven categories of disadvantageous health effects have been reported by the World Health Organization (WHO) [13]. Exposure to durable traffic sound has affiliation with poor health effects [14]. Even though the affiliations are documented to be weak, in a number of cases. However, long term exposure to sound pollution needs to be addressed due to the fact that large portions in any particular area are affected by it [15]. In numerous guidelines of sound control, sound pollution is used as a signifier of environmental sound. On the basis of anticipated critical effects of health due to sound levels, an environmental specific guideline for groups of people is provided by WHO, accordingly [16]. According to the guideline, 16-h equivalent sound level of 55 (dB) in outdoors, playground as well as at school, have the ability to create serious irritation because of sound sources which are external. The values in the guideline are specifically provided for indoor or outdoor settings [17]. Additionally, traffic on roads with intense crowds causes sound pollution which can be 75–80 (dB), specially, in the areas of developing nations considered to be urban. This triggered the governments to develop ambient sound standards so that the sound pollution problem from several sectors such as residential, commercial, industrial etc. can be dealt with [18]. The standard sound level limits regarding to Bangladesh are as follows in Table I:

Table I. Sound Level Standards in Bangladesh

Type of areas	Sound Level (dB)	
	Day Time	Night Time
Silent Zone	45	35
Residential area	50	40
Mixed area	60	50
Commercial area	70	60
Industrial area	75	70

2.2 Scope and Area of Study

In Dhaka city, the main source of sound is motorized traffic, although there are numerous other sources as well, including industries, building sites, careless loudspeaker use, public gatherings, etc. The use of banned hydraulic horns has increased by 15-25 percent on city roads. Horns are responsible for a large majority of the city's impulsive sound [20]. Anyone who is subjected to more than 100 dB sound for more than 15 minutes can experience temporary deafness and a sound of 120 decibels can cause permanent hearing loss [21]. Our data collection shows the real time actual values of sound level throughout Dhaka city.

Our area of study is Dhaka City. As we know Dhaka City has two independent City Corporations. These are Dhaka South City Corporation (DSCC) and Dhaka North City Corporation (DNCC). We have studied 15 major locations of DSCC and DNCC, each. The locations of DSCC are Zigatola, Science Lab, New Market, Shahbagh, Ramna, Paltan, Gulistan, Bakshi Bazar, Sadarghat, Chowk Bazar, Chankharpul, Motijheel, Arambagh, Wari, Shanti Nagar. The locations of DNCC are Ulab Main Gate, Mohammadpur Bus Stand, Mohammadpur Beribadh, Gabtoli, Mirpur 10, Farmgate, Kawran Bazar, Mohakhali, Banani, Gulshan 1, Malibagh, Rampura, Progoti Sarani, Airport, Uttora.

2.3 Methodology

It is necessary to measure sound due to excessive sound pollution in Dhaka city. Hence, a methodology has been proposed to reduce sound pollution. The following steps of the methodology are mentioned:

Step 1: We have selected some major locations from Dhaka South and Dhaka North. Then we have observed these selected locations on the basis of vehicle density on a particular range of time of the day.

Step 2: Data collection begins from our selected locations. Lutron SL-4012 sound level meter is used to gather the data. The maximum and minimum sounds are documented at each location using the Lutron SL-4012 device. At each location, 10 samples of data are taken, and each data collection session lasts two minutes. Following this method, 10 data sets are gathered simultaneously from designated locations in 20 minutes.

Step 3: Examination and analysis of the collected data begins in this stage. According to World Health Organization's (WHO) sound standard, we define our selected results in three categories [13].

Step 4: When the sound level exceeds 80 dB, the locations are evaluated to be ‘Harmful’ and highlighted in red color (Harmful). If the result ranges between 80 dB and 65 dB, those locations are evaluated to be ‘Disturbing’ and highlighted in yellow color (Disturbing). Furthermore, when it is below 65 dB, those locations are evaluated as ‘Normal’ and highlighted in green color (Normal).

Step 5: We created a sound pollution heatmap of Dhaka city, including the northern and southern parts, using all of the data we collected. In general, a sound pollution heatmap will indicate which locations are ‘Harmful’, ‘Disturbing’, and ‘Normal’. The overall flowchart of this methodology is shown in figure 2.2.

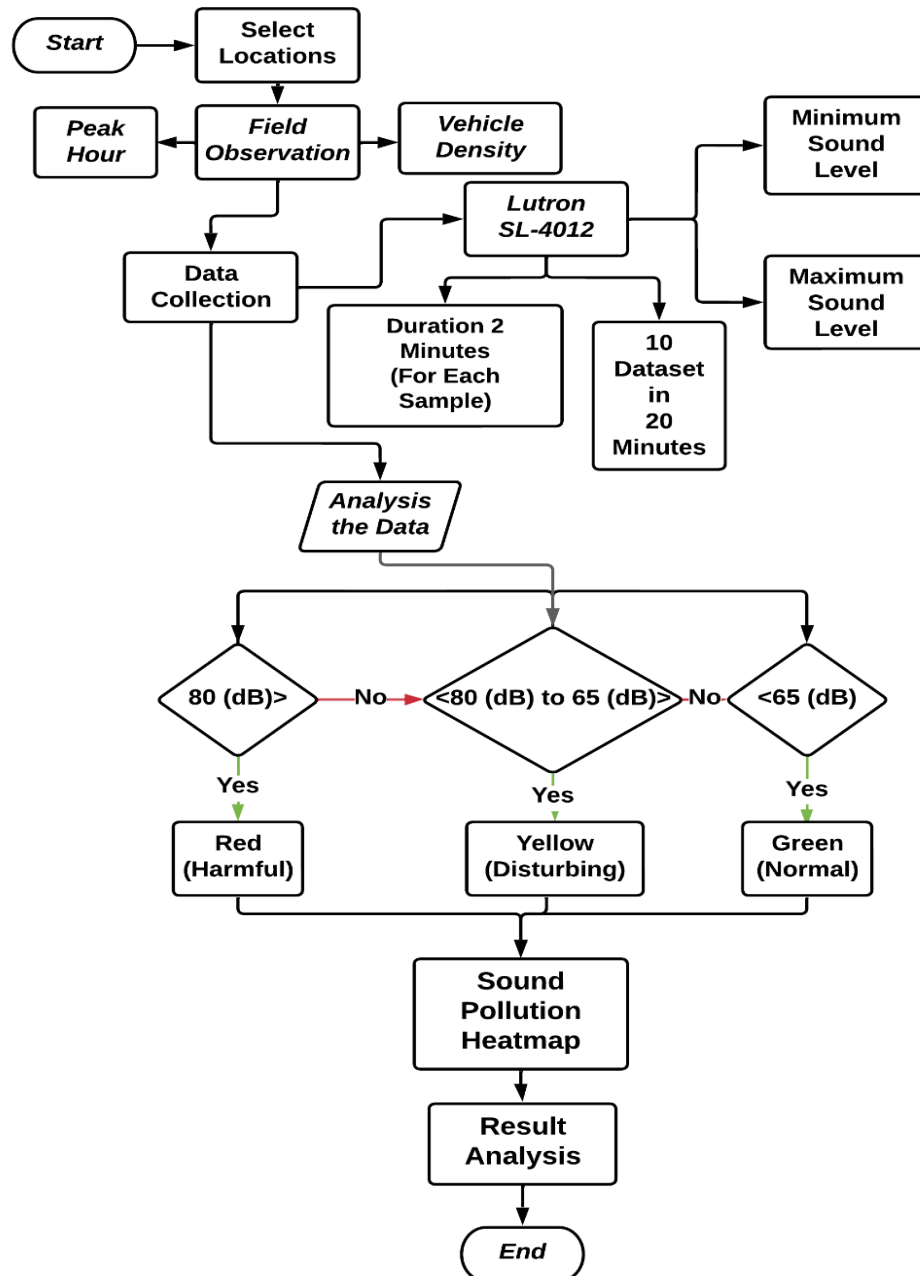


Figure 2.2: Flowchart of the proposed methodology

2.4 Data Collection

2.4.1 Dhaka South

Using the proposed methodology, we have identified some key locations of Dhaka South City Corporations. All participant data were collected between 3:00 PM and 5:00 PM. Then we observed the locations mentioned in Table II on the basis of vehicle density at a particular range of time of the day. Data was extracted from Lutron SL-4012. At each location, 10 samples of data were taken, and each data collection session lasted two minutes. All the data are shown in Table II below.

Table II. Sound Level of (dB) Dhaka South City Corporation (DSCC)

Study Area	Number Of Observation	Time (3.00 PM – 5.00 PM)		
		<i>Min Sound Level Avg. (dB)</i>	<i>Max Sound Level Avg. (dB)</i>	<i>Min & Max Sound Level Avg. (dB)</i>
Zigatola	10	76	90	83
Science Lab	10	78	96	87
New Market	10	77	99	88
Shahbagh	10	83	107	95
Ramna	10	77	91	84
Paltan	10	84	106	95
Gulistan	10	87	111	99
Bakshi Bazar	10	80	96	88
Sadarghat	10	79	95	87
Chowk Bazar	10	81	98	89
Chankharpul	10	77	95	86
Motijheel	10	79	109	96
Arambagh	10	76	94	85
Wari	10	79	93	86
Shanti Nagar	10	74	90	82

Founded on Table II, it is clear that the highest average sound level is dominant in Shahbagh 95 (dB), Paltan 95 (dB), Gulistan 99 (dB) and Motijheel 96 (dB). The lowest average sound level is in Zigatola 83 (dB) and Shanti Nagar 82 (dB). The data is plotted according to Table II. We plot the location on the x-axis and the sound level (dB) on the y-axis. With this chart, we see the average sound level in different areas of Dhaka South City Corporations. The data is shown in Figure 2.3 below.

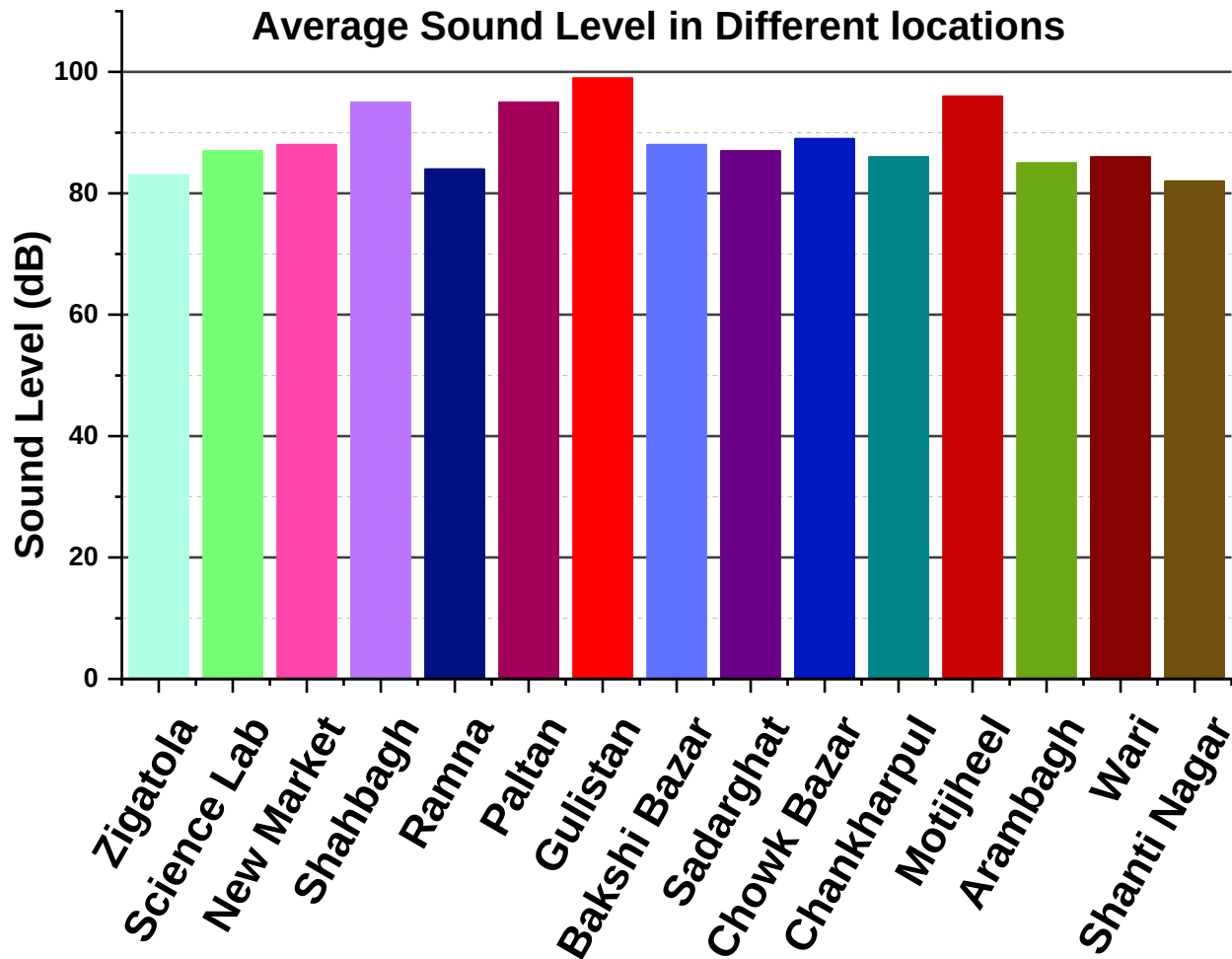


Figure 2.3: Sound Level of Intersection in DSCC

2.4.2 Dhaka North

Some of the major locations of Dhaka North City Corporation is shown Table III. All data collection of the locations, was done between 3 pm to 5 pm. The maximum, minimum, and average of 10 collected samples are portrayed. These were done in a way similar to that of Dhaka South. Here Table III represents all of the data.

Table III. Sound Level of (dB) Dhaka North City Corporation (DNCC)

Study Area	Number Of Observation	Time (3.00 PM – 5.00 PM)		
		<i>Min Sound Level Avg. (dB)</i>	<i>Max Sound Level Avg. (dB)</i>	<i>Min & Max Sound Level Avg. (dB)</i>
Ulab Main Gate	10	71	93	82
Mohammadpur Bus Stand	10	76	96	86
Mohammadpur Beribadh	10	81	107	94
Gabtolli	10	84	110	97
Mirpur 10	10	77	97	87
Farmgate	10	84	108	96
Kawran Bazar	10	82	100	91
Mohakhali	10	85	103	94
Banani	10	71	89	80
Gulshan 1	10	73	91	82
Malibagh	10	85	101	93
Rampura	10	83	95	89
Progoti Sarani	10	82	98	90
Airport	10	79	93	86
Uttora	10	73	95	84

Based on Table III, it is obvious that the highest average sound level is prevalent in Mohammadpur Beribadh 94 (dB), Gabtoli 97 (dB), Farmgate 96 (dB), Kawran Bazar 91 (dB), Mohakhali 94 (dB), Malibagh 93 (dB) and Progoti Sarani 90 (dB). The lowest average sound level is common in Ulab Main Gate 82 (dB) and Gulshan 1 82 (dB). Data by bar diagram is portrayed according to Table III. In X-axis we defined the locations and in Y-axis we defined the sound level (dB). With these

diagrams, we have got a clear view of the average sound level of different locations of Dhaka North City Corporations. The data are represented in the following in Figure 2.4.

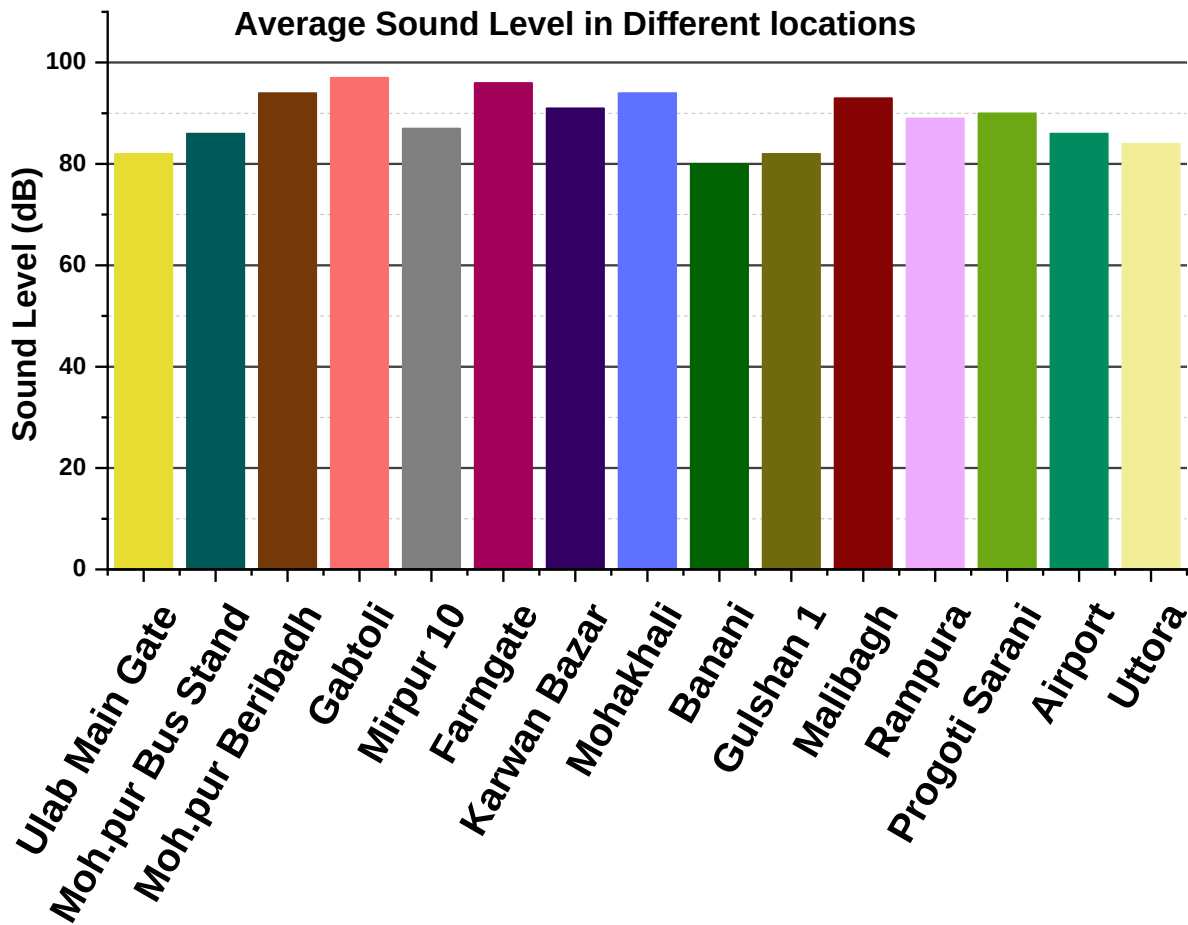


Figure 2.4: Sound Level of Intersection in DNCC

2.5 Results

2.5.1 Sound Pollution Heatmap

In order to visualize our collected data, the sound pollution heatmap is the key factor. Using the heatmap, it would be easier to determine the sound levels in different regions. It also shows the intensities of sound levels in various regions of Dhaka city. By the 'Red' circle, we defined 'Harmful' areas. The 'Yellow' circle indicates a 'Disturbing' area. By using 'Green' colors we defined 'Normal' areas. From the sound pollution heatmap, it is apparent that the regions of Dhaka North suffer from a significant number of 'Harmful' areas and the regions of Dhaka South suffer from a significant number of intolerable areas as well.

The sound pollution heatmap also clarifies that there are no 'Disturbing' and 'Normal' sound level areas. The above information is depicted in Figure 2.5

DHAKA CITY MAP

Legend:

- Red dot: Harmful (Over 80 dB)
- Yellow dot: Disturbing (Between 65 to 80 dB)
- Green dot: NORMAL (Below 65 dB)

Figure 2.5: Sound Pollution Heatmap of Dhaka City

Chapter 3: Design and Implementation of Prototype

This section contains the main work along with the descriptions of the sensor, structural apparatus which are required for the development of the monitoring system and circuits. Additionally, this section describes system software simulation and hardware implementation and IoT-based data server systems as well.

3.1 Core Model

At first, the sound level meter (dB) collects the data from the streets. For this data processing, ESP8266 was used which connected to the sound level meter (dB). A real-time code that was previously set on that ESP8266. Using the Arduino IDE tool, the real-time code was written. There is an inbuilt GSM module was attached with ESP8266 which transmits the measured data collected by the sound level meter (dB) and processed by the ESP8266 micro-controller. A pole was set up in the middle of the road divider. At the top of the pole, a large display and a box were installed. The ESP8266, sound level meter (dB), voltage converter, and an electrical circuit board were inside that box.

Secondly, the display was connected to the ESP8266 through the wire. When the sound level meter (dB) detects a value over the maximum sound tolerance level the ESP8266 micro-controller sent a command through the GSM module to display for displaying the social awareness message.

Thirdly, ESP-8266 sends the collected data to the ThingSpeak data server. We can monitor this data from anywhere in the world and also plot graphs using this data in MATLAB.

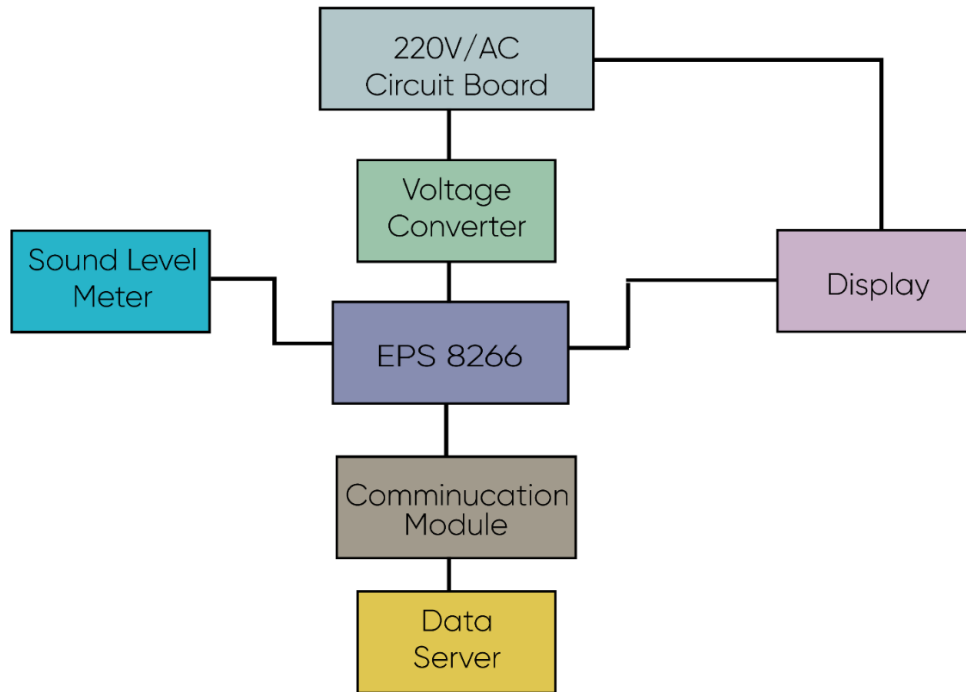


Figure 3.1: Design of Core Model

3.2 Components

3.2.1 ESP-8266

Ten silica L106, a 32-bit RISC processor with an ultra-low power need and a maximum clock speed of 160 MHz, is included inside the ESP8266 [21]. In order to build and develop user applications, 80% of the processing power is made available via the Real-Time Operating System (RTOS) and Wi-Fi stack. As self-sufficient MCUs with an RTOS-based SDK that can execute connection apps natively, ESP8266 modules may operate with ESP-AT firmware to enable Wi-Fi connectivity to external host MCUs. Also, other features like out-of-the-box cloud connection, low-power operation, and Wi-Fi security compatibility, including WPA3, in both of these operation modes. The first generation Nodemcu Dev Kit, ESP8266, is extended to include:

- D1, D10: all can be multiplexed to GPIO, PWM, 12C, 1-Wire
- AO: Route1ADC.
- USB power supply,
- USB to serial port debugging interface
- Available RAM is 20Kbyte: Currently 512Kflash is used, and users have available storage space of 150Kbyte.



Figure 3.2: ESP-8266

3.2.2 Jumper Wire

Simply said, jumper wires are cables having connector pins at each end that may be used to connect two places without soldering. With breadboards and other prototype tools, jumper wires are frequently used to make it simple to alter a circuit as required. Jumper wires are available in a number of colors, although the hues have no real significance [22]. This implies that a red jumper wire and a black one is equivalent in theory. However, you may take advantage of the colors to distinguish between different connections such as power and ground.

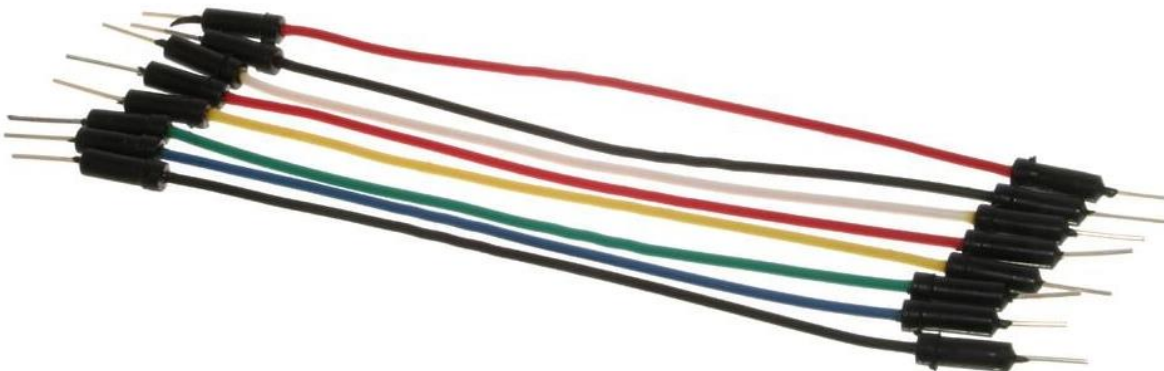


Figure 3.3: Jumper Wire

3.2.3 Breadboard (Large)

The base for building and prototyping electronics is a breadboard, often known as a protoboard. A breadboard makes it simple and quick to build temporary electrical circuits or conduct circuit design experiments [23]. The rows and columns of internally linked spring clips beneath the

perforated plastic casing of breadboards allow developers to quickly connect components or cables. Perfectly positioned spring clip holes that are 0.1" apart in both the X and Y directions make up the grid.

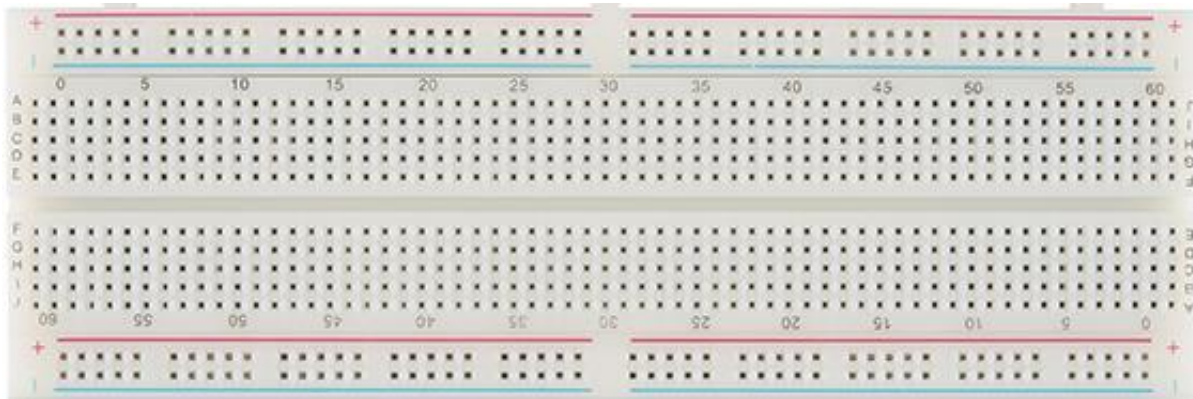


Figure 3.4: Breadboard

3.2.4 20x4 Serial LCD Display

With a 20x4 LCD, there are 4 lines that can each display 20 characters. Each character on this LCD is presented using a 5x7 pixel matrix. The Command and Data registers on this LCD are its two registers. The specifications are:

- Voltage: 5V
- Current: 2 mA
- Backlight supply voltage: 4.2V
- Backlight current: 250mA (MAX)
- Dimensions: 98mm x 60mm x 14mm



Figure 3.5: 20x4 LCD Display

3.2.5 Sound Sensor Module

An inexpensive, basic, and low-tech tool used to detect sound waves moving through the air is called a sound sensor. Additionally, it has the ability to quantify its intensity and, most significantly, turn it into an electrical signal that can be read by a microcontroller [24].

- Voltage: 3.3-5 VDC

- Outputs: one analog + one digital output
- Fixation: 1 x mounting screw hole (3 mm)
- Indicator LEDs: 1 power indicator + 1 comparator output indicator
- Frequency response: 50 Hz - 20 kHz
- Impedance: 2.2 k Ω
- Sensitivity: 45-99 dB
- Operating temperature: -40 °C to +85 °C
- Dimensions: 44 x 15 x 10 mm

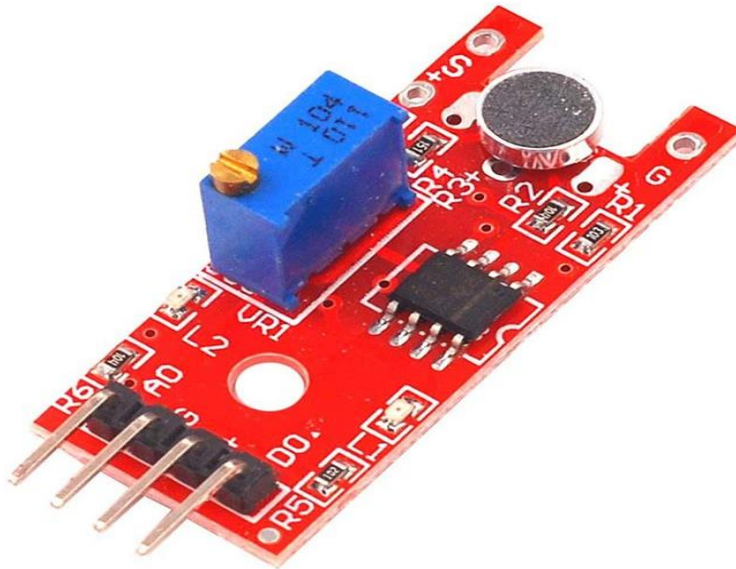


Figure 3.6: Sound Sensor Module (MOD-00214)

3.2.6 Arduino IDE

In addition to a text editor for writing code, a message area, a text terminal, a toolbar with buttons for frequently used operations, and a number of menus, the Arduino Integrated Development Environment, sometimes known as the Arduino Software (IDE), is also available [25]. It establishes a connection with the Arduino hardware and communicates with it to upload applications.

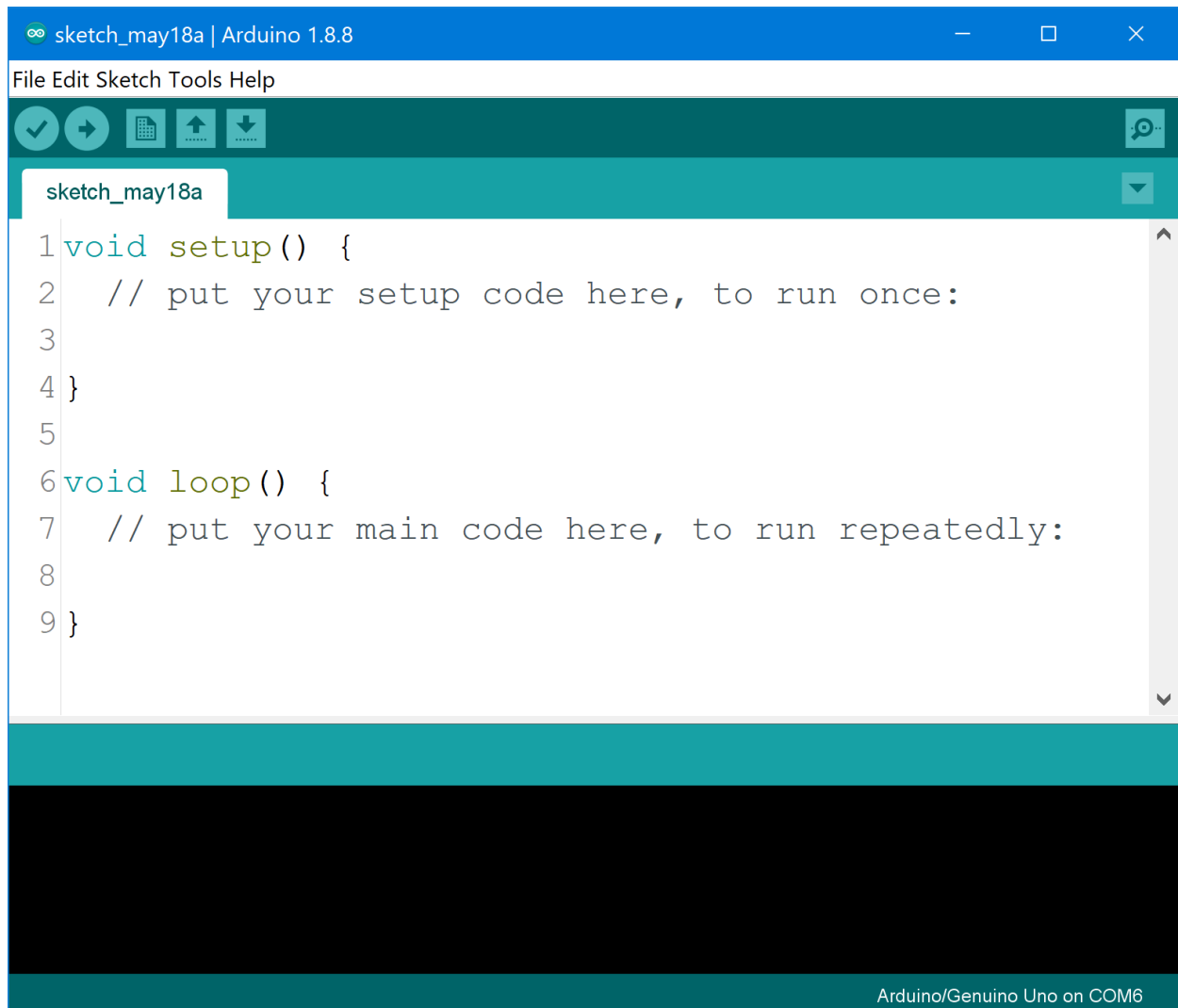


Figure 3.7: Interface of Arduino IDE

3.2.7 Proteus Design Suite

The Proteus Build Suite is a Windows tool that allows you to record schematics, simulate them, and design PCB (Printed Circuit Board) layouts [26]. It is available in a variety of configurations, depending on the size of the designs being created and the needs for microcontroller simulation. All PCB Design solutions contain an auto router as well as basic mixed mode SPICE simulation.

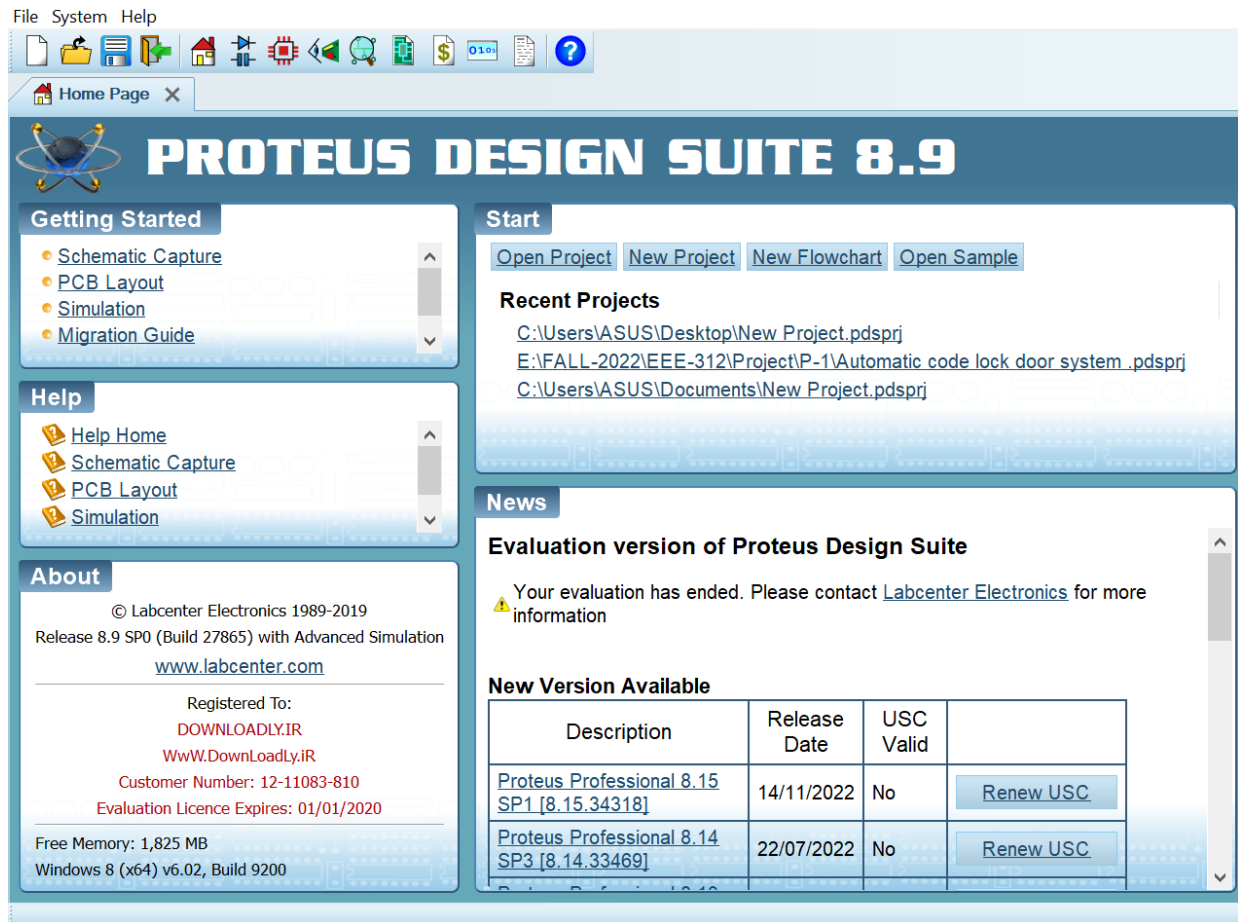


Figure 3.8: Proteus Home Page

3.2.8 IoT-Based Monitoring

The Internet of Things, or IoT, is the collective term for the billions of physical objects that are now linked to the internet and actively collecting and exchanging data. With the advent of incredibly affordable computer chips and the widespread use of wireless networks, anything may become a component of the Internet of Things, from a pill to an airplane. By connecting all these various items and equipping them with sensors, digital intelligence is added to otherwise dumb gadgets, allowing them to relay real-time data without a human being's involvement. The world around us is becoming smarter and more responsive thanks to the Internet of Things, which combines the digital and physical worlds.

3.3 Circuit Diagram

We have done our software system simulation in Proteus. In simulation we choose ESP8266 which is a micro-controller board, Sound level detect sensor, a display and a voltage source. We took 5V for voltage source. Each and every equipment are connected with the voltage source. When we connected the circuit with the voltage source, sound detect sensor started to detect the sounds and resulting it through display.

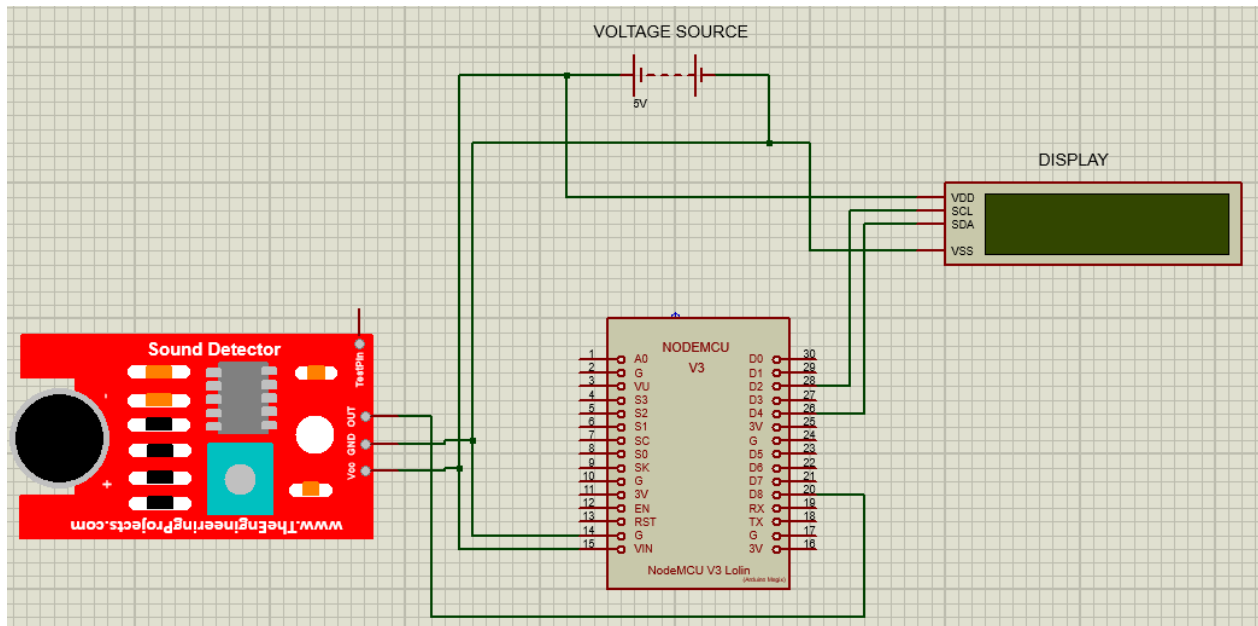


Figure 3.9: Circuit Diagram

3.4 Implementation of Prototype

Hardware implementation is as like a visual representation of software simulation. Likewise, we have connected the sound detection sensor, ESP8266, and 20*4 LCD display. The whole circuit is connected to the 5V voltage source. Here we can see visually sound levels, and awareness messages.

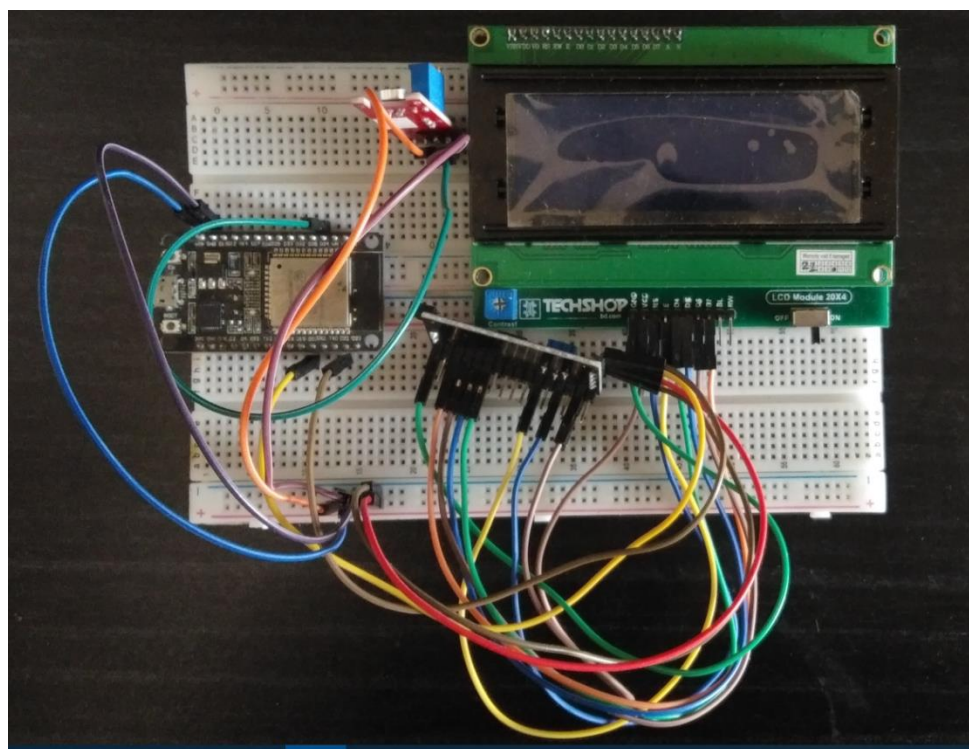


Figure 3.10: Execution of Prototype

3.5 Performance

Real time value is the most significant part of this project. Before taking real time value we have selected 10 points among the Dhaka city. These 10 points are, ULAB main gate, Mohammadpur Bus Stand, Mohammadpur Beribadh, Gabtoli, Farmgate, Zigatola, Science Lab, New Market, Gulistan, Motijheel. We have taken all the real time values through our prototype. For each point we have taken 10 maximum values and 10 minimum values. After taking all the maximum and minimum values we have calculated the average value in Table IV. In Figure 3.10 we depict it.

Table IV. Results from Prototype

Study Area	Number of Observation	Time (3.00 PM – 5.00 PM)
		Average Sound Level (dB)
Ulab Main Gate	10	78
Mohammadpur Bus Stand	10	82
Mohammadpur Beribadh	10	90
Gabtoli	10	91
Farmgate	10	89
Zigatola	10	76
Science Lab	10	82
New Market	10	81
Gulistan	10	94
Motijheel	10	92

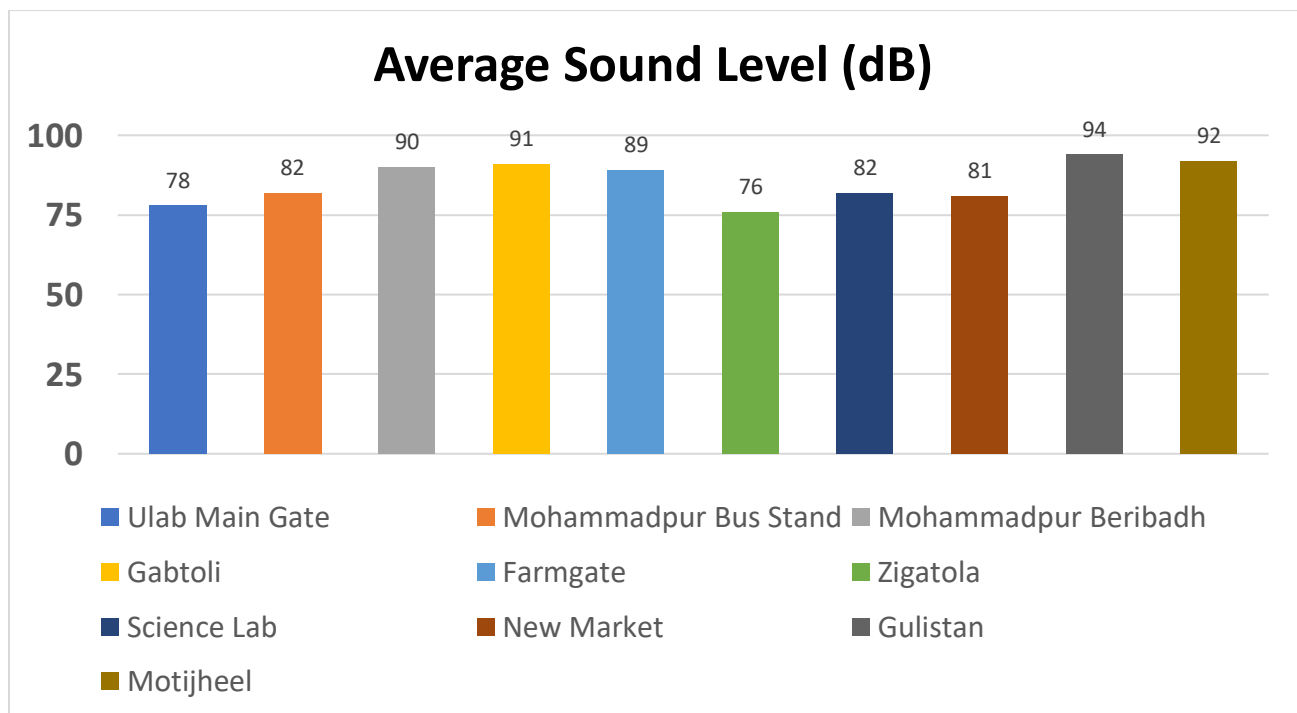


Figure 3.11: Sound Level of Intersection in DNCC and DSCC from Prototype

3.6 Sound Level with Awareness Messages

As mentioned in section 2.4 that there are three different messages for three different sound levels. The awareness messages are already stored in ESP-8266 memory. After powering up the prototype, the sound sensor detects the sound and sends it to the microcontroller of ESP-8266. Then microcontroller process the value in the dB. After processing the value, the microcontroller sends this data to display with required awareness message (Table V) that was previously stored.

Table V. Sound Level with Awareness Messages

Sound Level (dB)	Awareness Messages
≤ 60 dB	Reduce Chaos and Stay Safe
> 60 to < 85	Please Reduce Sound Save Your Ear
≥ 85	Reduce Sound Now Prevent Deafness

We have selected all the three section ethically. All the sections have been chosen by evaluation and calculation of the real time data. While it is ≤ 60 dB, we considered it as a quiet place. As an awareness message we have mentioned that, “Reduce Chaos and Stay Safe” Secondly, > 60 to < 85 , we considered that place as moderate. As an awareness message we have mentioned that, “Please Reduce Sound Save Your Ear” Finally, ≥ 85 , we considered that place as high noisy area. As an awareness message



Figure 3.12: Message for Sound Level-Quite



Figure 3.13: Message for Sound Level-Moderate



Figure 3.14: Message for Sound Level-High

3.7 ThingSpeak Data Server

ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize, and analyze live data streams in the cloud. You can send data to ThingSpeak from your devices, create instant visualization of live data, and send alerts.

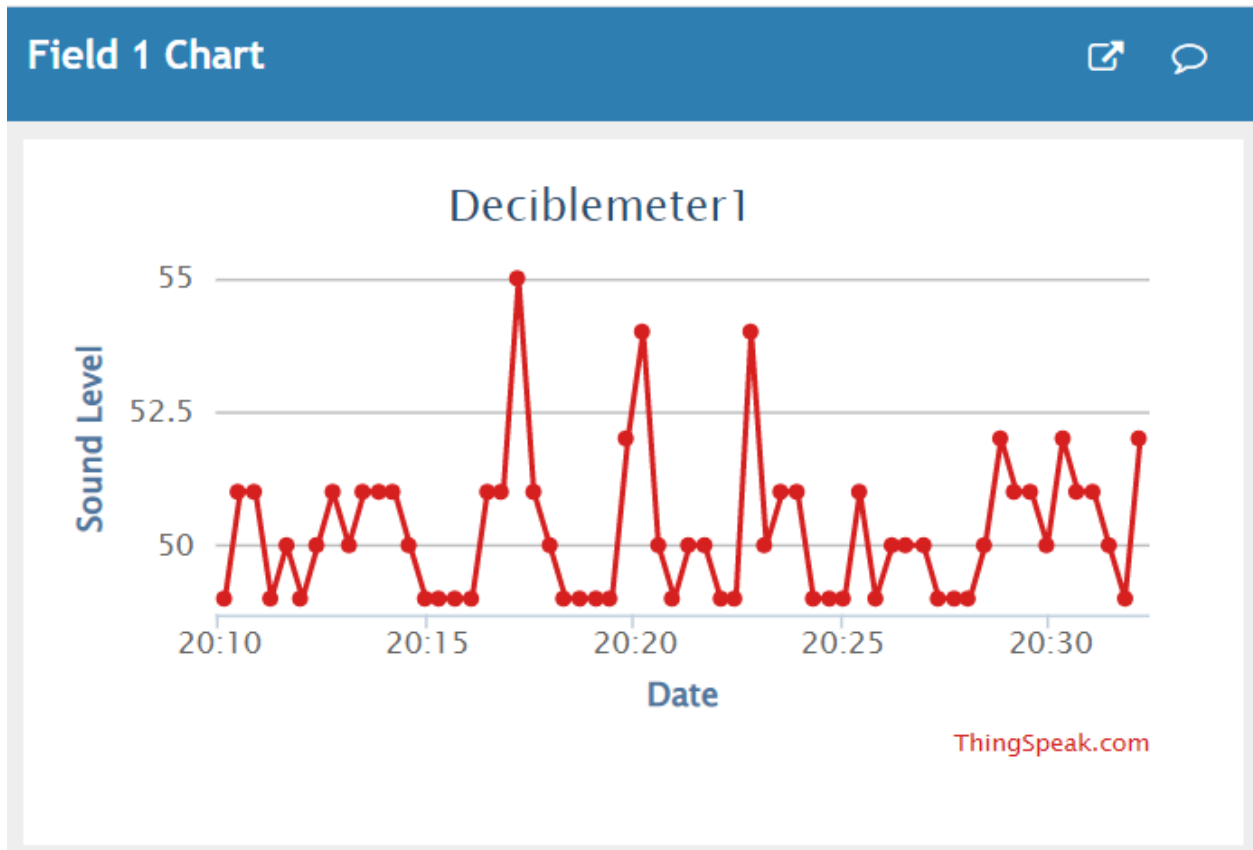


Figure 3.15: Data Visualization in ThingSpeak

3.8 Performance Evaluation of Prototype

As we mentioned earlier that we have taken data from Lutron and our prototype. After that, we evaluated the performance between Lutron and our prototype. We have observed that there is only 4-7% error while we are evaluating are shown in figure 3.16 and 3.17. So, this error performance shows that all the real-time data we have collected through our prototype is much more accurate.

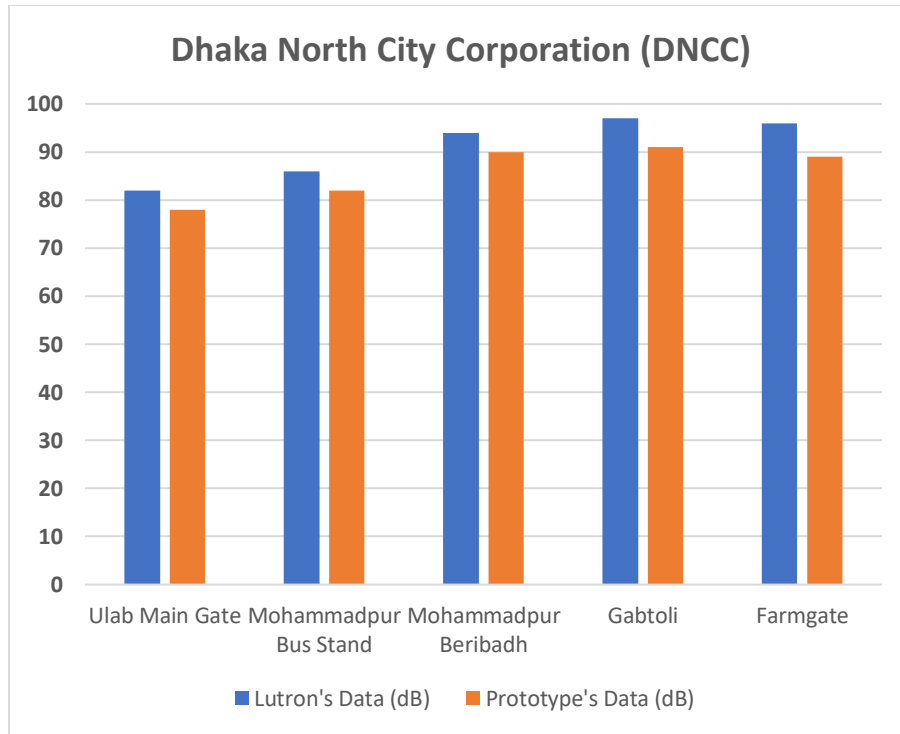


Figure 3.16: Comparison between Lutron SL-4012 and Prototype Data in DSCC

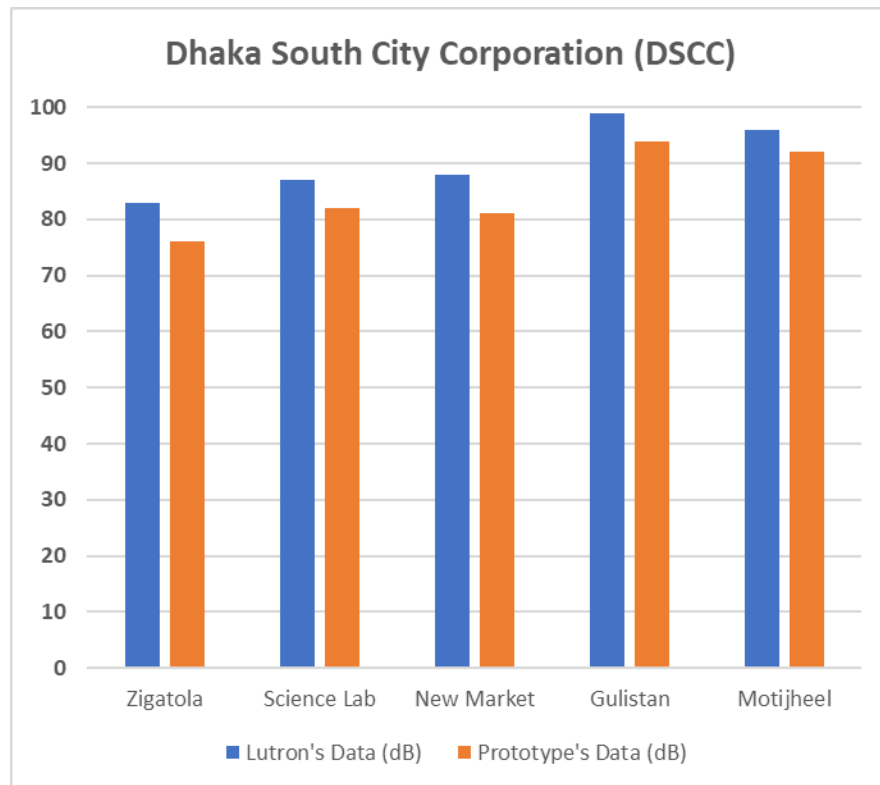


Figure 3.17: Comparison between Lutron SL-4012 and Prototype Data in DNCC

Chapter Four: Sound Classification

We use machine learning for classification of various type of sound which makes this project more concise. At the beginning, we have taken sound data form Leguna, bus, car, bike, CNG. We have done MFCC visualization for car, CNG, bus, bike, Leguna sound dataset. For performance visualization we built ANN model which is containing on Loss per Epoch and Accuracy per Epoch.

4.1 Machine Learning for more specific monitoring system

To make our monitoring system more concise we can go for machine learning method. Machine learning algorithm will show precisely which vehicle produce more noise.

Machine learning (ML) is a field of inquiry devoted to understanding and building methods that 'learn', that is, methods that leverage data to improve performance on some set of tasks. It is seen as a part of artificial intelligence.

Machine learning algorithms build a model based on sample data, known as training data, in order to make predictions or decisions without being explicitly programmed to do so. Machine learning algorithms are used in a wide variety of applications, such as in medicine, email filtering, speech recognition, agriculture, and computer vision, where it is difficult or unfeasible to develop conventional algorithms to perform the needed tasks.

4.2 Data Set and Preprocessing

Data preprocessing is a method for transforming unclean data into clean data sets. Every time data is obtained from various sources, it is done so in a raw manner that makes analysis impossible. We took 20 different samples of each vehicle. Then make these 20 samples in a duration of 3 seconds and make it 100 samples are shown in figure 4.1.

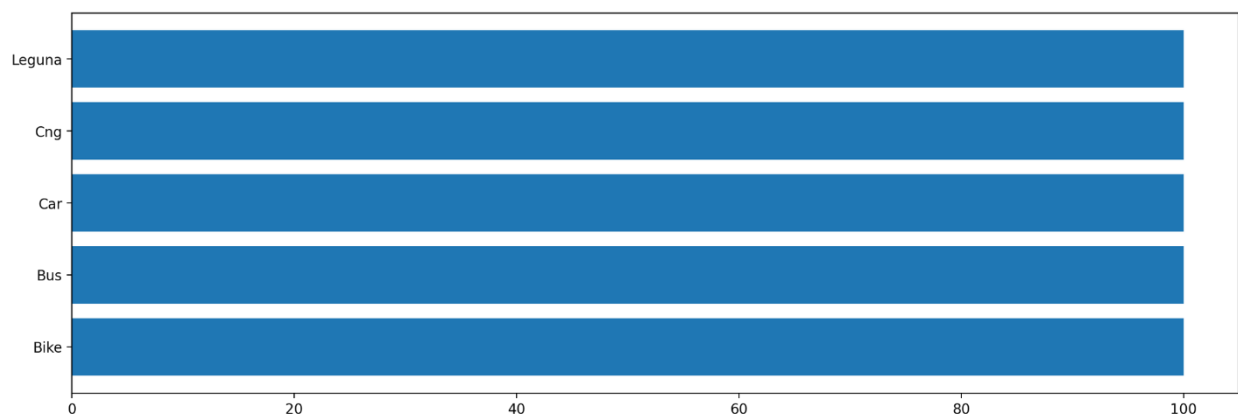


Figure 4.1: Sound Sample category

4.3 MFCC Visualization

Mel-frequency cepstral coefficients (MFCCs) are coefficients that collectively make up an MFC. They are derived from a type of cepstral representation of the audio clip (a nonlinear "spectrum-of-a-spectrum"). The difference between the cepstrum and the Mel-frequency cepstrum is that in the MFC, the frequency bands are equally spaced on the Mel scale, which approximates the human auditory system's response more closely than the linearly-spaced frequency bands used in the normal spectrum. This frequency warping can allow for better representation of sound, for example, in audio compression that might potentially reduce the transmission bandwidth and the storage requirements of audio signals. MFCCs are commonly used as features in speech recognition systems, such as the systems which can automatically recognize numbers spoken into a telephone. MFCCs are also increasingly finding uses in music information retrieval applications such as genre classification, audio similarity measures, etc.

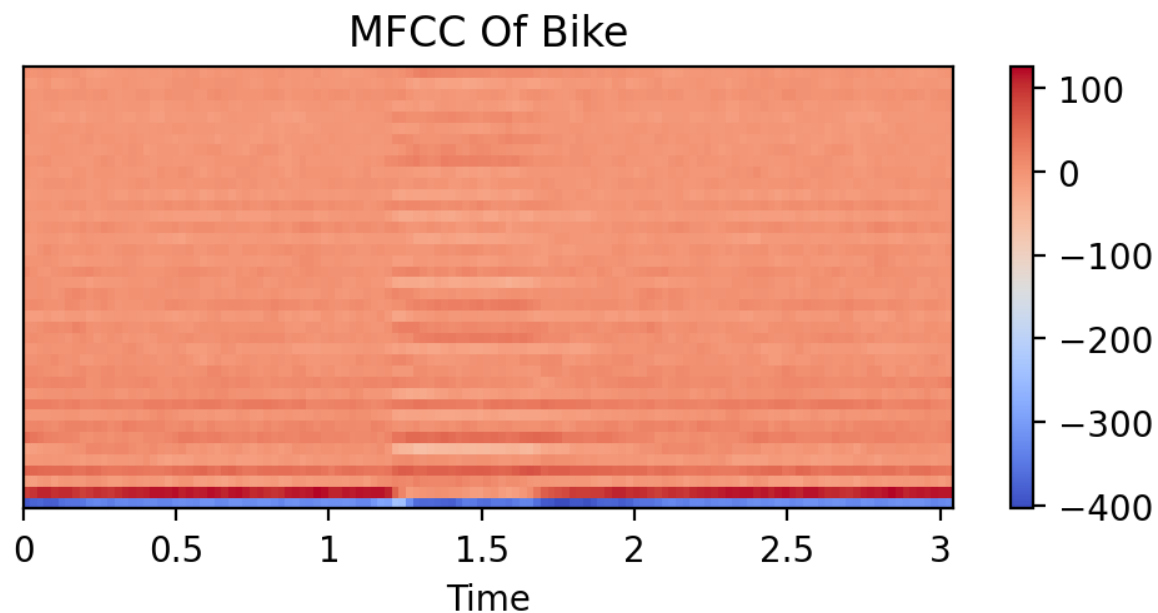


Figure 4.2: Visualization of Bike

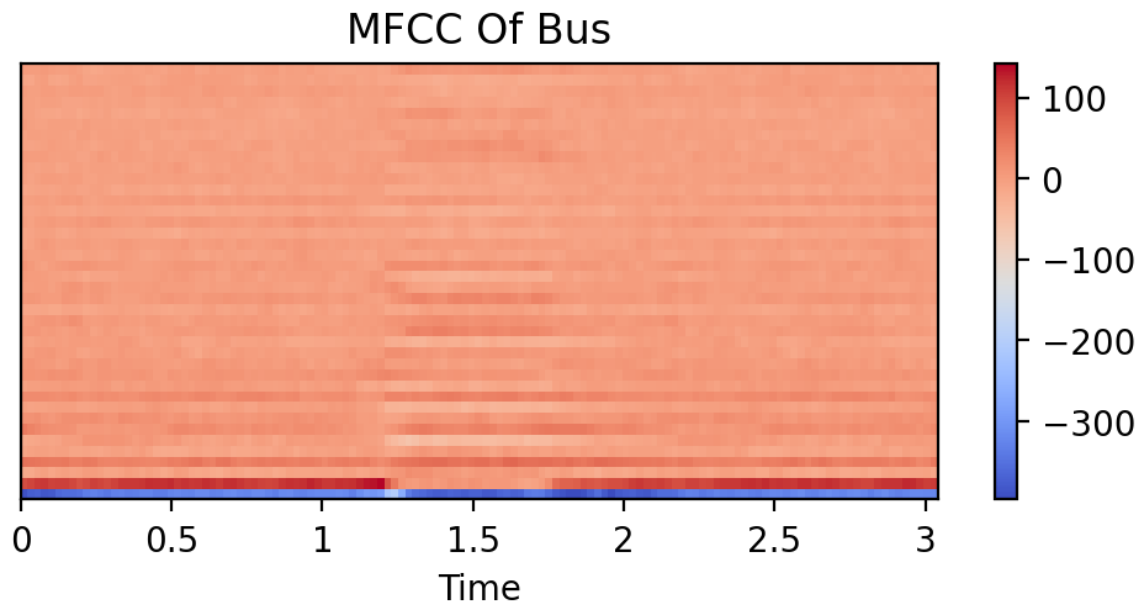


Figure 4.3: Visualization of Bus

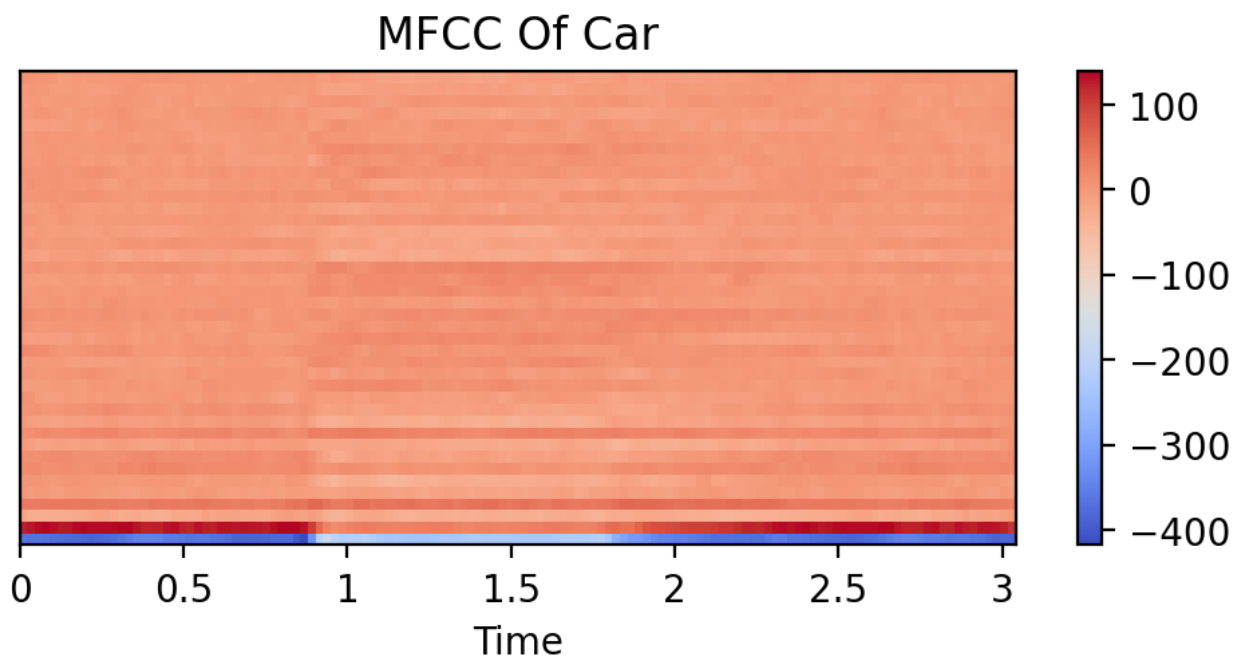


Figure 4.4: Visualization of Car

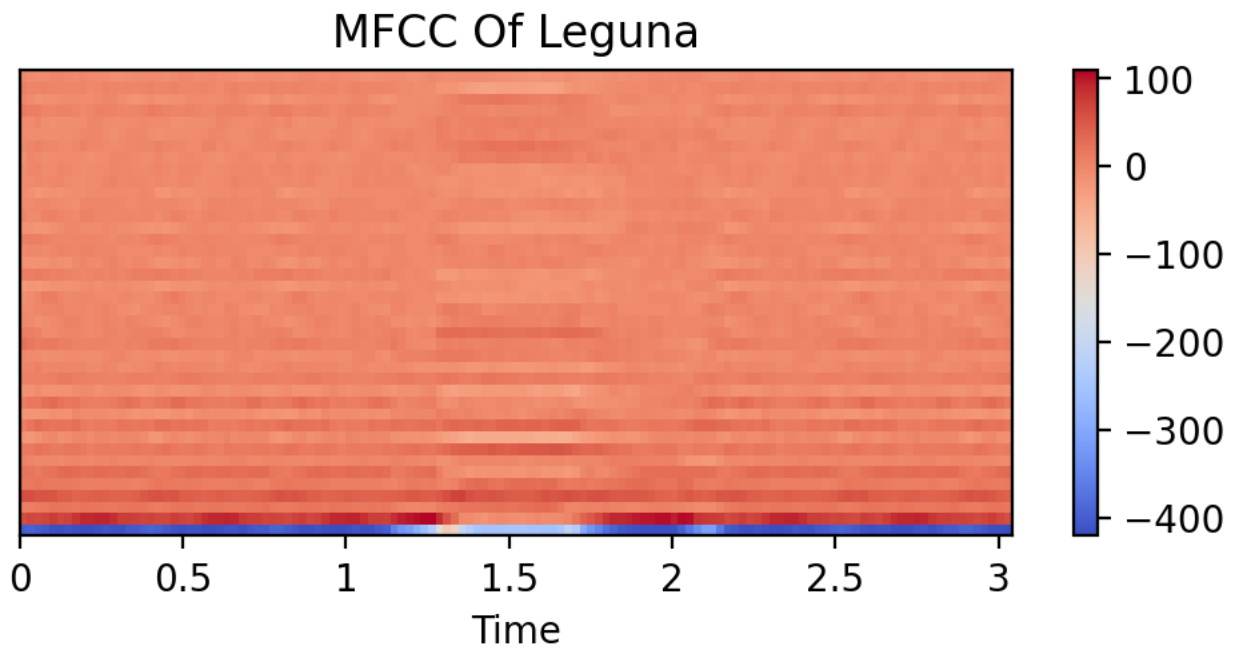


Figure 4.5: Visualization of Leguna

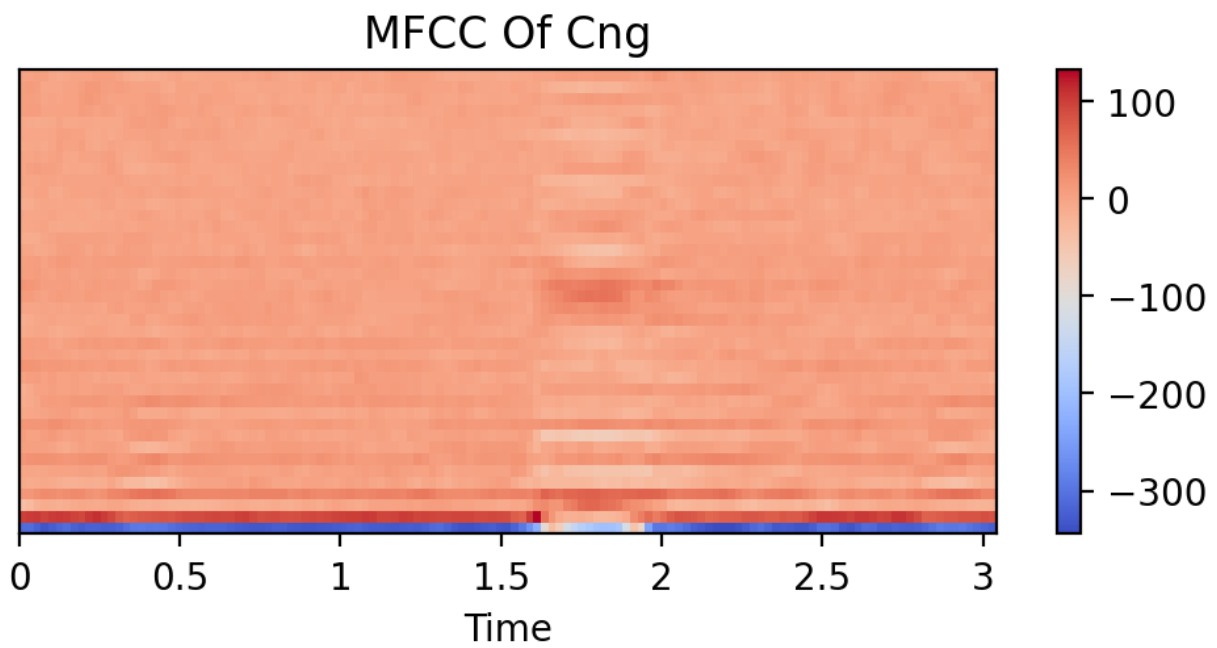


Figure 4.6: Visualization of CNG

4.4 Definition of Sound Classification

Epochs are defined as the total number of iterations for training the machine learning model with all the training data in one cycle. In Epoch, all training data is used exactly once. Further, in other words, Epoch can also be understood as the total number of passes an algorithm has completed around the training dataset. A forward and a backward pass together counted as one pass in training. Iteration is defined as a total number of batches required to complete one epoch, where a number of batches are equal to the total number of iterations for one epoch. Before starting the introduction of Batch in machine learning, you must have one thing in your mind that the batch size and the batch are two separate entities in machine learning. Batch size is defined as the total number of training examples that exist in a single batch. Let's understand the concept of mixing up an Epoch and iteration with the below example where we have considered 1000 datasets as shown in the below figure.

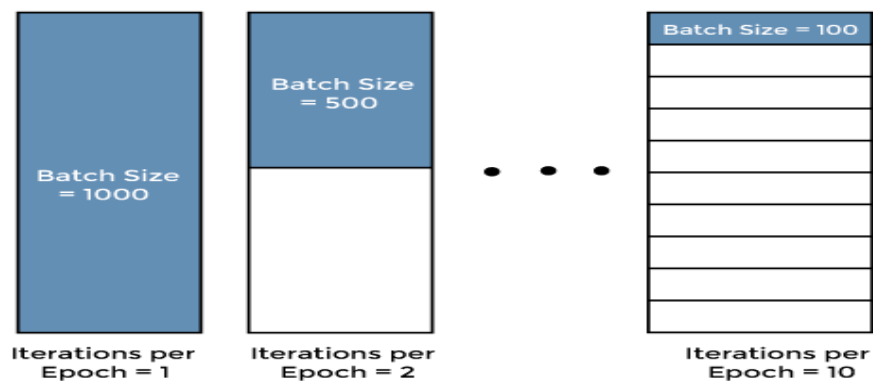


Figure 4.7: Epoch and iteration

4.5 Architecture of the ANN Model

The training loss is a metric used to assess how a deep learning model fits the training data. That is to say, it assesses the error of the model on the training set. Note that, the training set is a portion of a dataset used to initially train the model. Computationally, the training loss is calculated by taking the sum of errors for each example in the training set. Another non-linear activation function that has grown in prominence in the deep learning field is the ReLU function. Rectified Linear Unit is referred to as ReLU. The ReLU function's primary advantage over other activation functions is that it won't simultaneously activate all of the neurons. Dense Layer is simple layer of neurons in which each neuron receives input from all the neurons of previous layer, hence called as dense. Dense Layer is used to classified image based on output from convolutional layers.

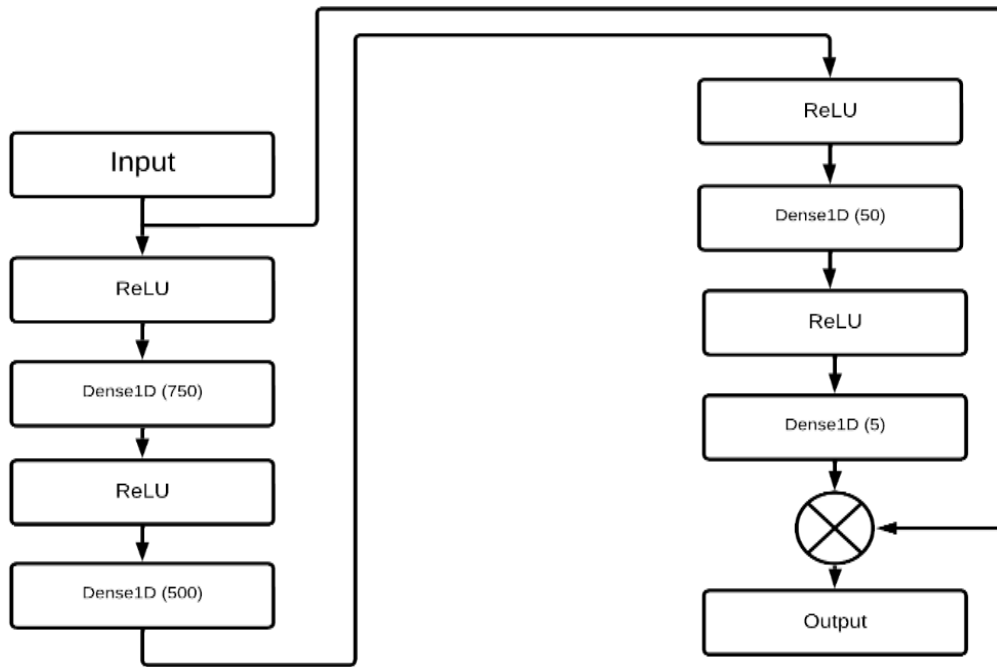


Figure 4.8: Data Classification Flowchart

4.5.1 ANN Model Losses

Validation loss is a metric used to assess the performance of a deep learning model on the validation set. The validation set is a portion of the dataset set aside to validate the performance of the model. The validation loss is similar to the training loss and is calculated from a sum of the errors for each example in the validation set.

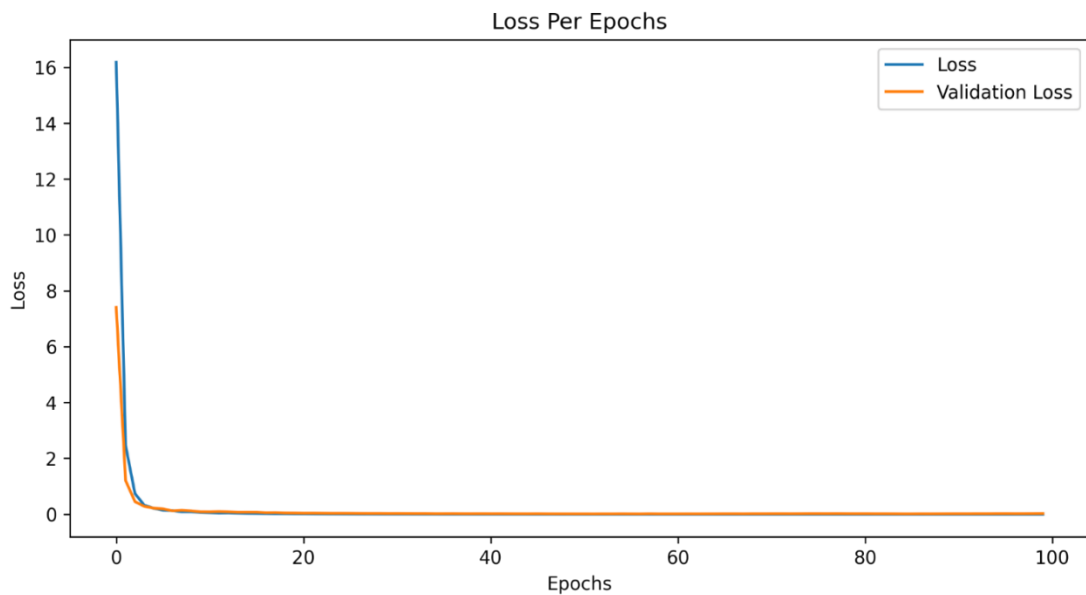


Figure 4.9: Loss Per Epochs

4.5.2 Accuracy of ANN Model

Loss is a value that represents the summation of errors in our model. It measures how well (or bad) our model is doing. If the errors are high, the loss will be high, which means that the model does not do a good job. Otherwise, the lower it is, the better our model works. Accuracy is more straightforward. It measures how well our model predicts by comparing the model predictions with the true values in terms of percentage.

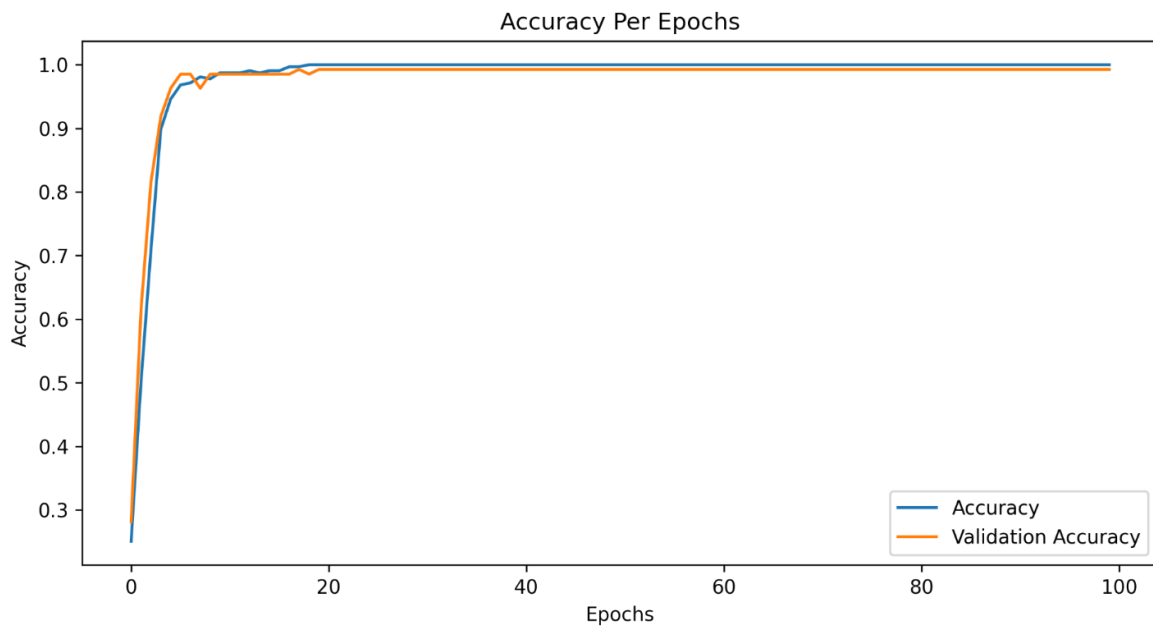


Figure 4.10: Accuracy Per Epochs

Chapter Five: Discussion

5.1 Discussion

5.1.1 Potential Sound Pollution Mitigation Approach

Awareness about the environment among the common folk can have a substantial impact in diminishing the sound level. People themselves will follow the rules regarding the management of the environment and traffic and also make moves against high-level sound stimulation if their knowledge focusing on the dangers of sound pollution is increased by means of general training, mass media and other ways which are effective.

A possible solution can be made if we place a device that can detect sound and give the awareness message simultaneously. This device could be cost-effective and innovative. In order to restrain sound pollution, a set of strategies known as sound mitigation is implemented. The techniques presented in Figure 5.1 can be deployed to reduce the amount of sound pollution.



Figure 5.1: Possible Sound Pollution Mitigation Approach

5.1.2 Expected Outcomes

We expect that this project will create evolution in people's minds about the effect of sound pollution. We also expect all the people in the street to read our social awareness message which is shown on display so they obey the maximum sound tolerance level. All the vehicle drivers on the street don't use unnecessary horns. It alerted those people who play loudspeakers to reduce the volume of their devices.

The overall impact of this project is people get rid of sound problems related to disease if they read our social awareness messages.

Finally, our primary aim is to reduce sound pollution in the street of Dhaka city as well as the whole world.

5.1.3 Expected Impacts

The impacts of the implemented project on societal, health, safety, legal and cultural issues. We expect that the Impacts of the Project of this project are lifelong. It'll release the upcoming generations from sound pollution-related diseases.

The project is fully safe and eco-friendly. It'll not release any CFC gas. But there is a problem and the problem is the display connected pole was installed in the middle of the road divider or beside the road. So, it may distract the vehicle drivers when they drive. Also, if any vehicle is high over 25 feet and moves beside the pole, there is a probability of clashing with the display.

As we all know natural disasters happen habitually so, there is a risk of a chance of affecting the pole during the disaster's time.

5.1.4 Sustainability

The proposed sound monitoring project is reliable in terms of performance and longevity. As well there are no conflicting chances with the environment, human and animal welfare. If we think about a sustainable city with less sound pollution, we have to reduce sound pollution. If we implement this project on large scale, we think this will create a remark regarding the reduction of sound pollution. Moreover, our future work will make this project more sustainable. The equipment's of the prototype we used is maintainable. Furthermore, display, ESP 8266, Sound sensor are legitimate. Additionally, using of the renewable energy system will make this project more supportable.

5.1.5 Ethical point of view

As sound pollution is a bioethical issue. Some noise is necessary, but much noise in modern life is unnecessary, and people who create noise risk harming the physical and mental health of others, whether or not that noise is necessary. Ethical decision-making is based on core character values like trustworthiness, respect, responsibility, fairness, caring, and good citizenship. Ethical decisions generate ethical behaviors and provide a foundation for good living practices. All of the work regarding this project is only for the less polluted city, society and world as well. This project is ethically enriched because this project is applicable to public health, communities, the environment and welfare. If we create awareness through this project for the mass people then this project significantly and ethically remarkable.

Chapter Six: Conclusion and Future Work

6.1 Conclusion

Hardware implementation gives the structural depiction of the project. Before implementation, we created a core model, containing ESP8266 which is a micro-controller, 20x4 LCD display, breadboard and also Arduino IDE. For storing real time data, we created an IoT based data server named Thingspeak. For checking the performance of the prototype, we have collected real time data through this prototype. Subsequently, all the data set stored in IoT based data server system. Another aim was to provide awareness messages through this prototype. So that, we need to breakdown data set in classified way. For classification of all data set we breakdown data sets in three parts, and each of the breakdown contains awareness messages. After the processing with real time data, awareness messages were shown in the display immediately. Moreover, we have done performance evaluation between our prototype and Lutron where we found 4-7% error. Which indicates the vast accuracy of our prototype. Besides, we also implement a simulation version in Porteous. Where we created a circuit diagram including all the equipment's which we used in hardware implementation. The project's hardware implementation also includes appropriate equipment. All equipment is effective and environmentally friendly. Additionally, applying machine learning gives the project new supervision. Machine learning is primarily used to categorize sounds. In the machine learning section, we develop a model. so that we can determine the data's quality, precision, and recall. We employ the Mel-frequency cepstral coefficient (MFCC) to facilitate visualization. There are 5 different types of vehicles in our data set (BUS, CAR, BIKE, LEGUNA, CNG). By utilizing MFCC, we were able to visualize each sort of car. ANN model gives the vast depiction of the losses and accuracy of the sound classification. We have mentioned briefly including the epoch of losses and accuracy. The sound level may subsequently be easily categorized, providing us better assess of the precision, accuracy, and recall on our data set. In chapter 4, briefly discussion have been given including figures and graphs. These findings imply that Dhaka's sound pollution condition is extremely concerning. Therefore, it is essential to reduce noise pollution to ensure a sustainable city.

This project proposes a novel methodology to determine and resolve the issue of sound pollution. Additionally, this research includes real-time sound-level data for the entire Dhaka city. Sound pollution in 30 locations throughout Dhaka city (both north and south) have been observed. The results of the project depict the current scenario of Dhaka city regarding sound pollution.

This project concluded that intersections of busy roads in Dhaka city are exposed to a sound level that is above the limit of tolerance at all times. Among our surveys, Gulistan in DSCC has a maximum sound level of 99 (dB) and Gabtoli in DNCC has a maximum sound level of 97 (dB). On the other hand, Shanti Nagar in DSCC has a minimum sound level of 82 (dB) and Banani in DNCC has a minimum sound level of 80 (dB). Note that, both maximum and minimum values of all areas are above the acceptable sound level (80 dB). To mitigate this issue, a systemic prototype has been developed to reduce sound pollution in society. This prototype will have the scope to trace sound intensity levels in situ. Upon detection of noise pollution, it will spread social

awareness among people and this prototype will take an approach to distinguish the sound-producing factor to assist people in effectively taking respective actions on that factor. Ultimately, this prototype holds a greater value for social development on a global scale.

6.2 Scope of Future Development

Renewable Energy for the monitoring system: Nowadays, the use of Renewable energy is almost a prerequisite in the development of energy-consuming systems. Renewable energy is a newer safe path that is achieved from natural sources and causes no pollution to the planet. Therefore, solar energy/PV cells can potentially be used to power up the entire system. This can also minimize the carbon footprint and can be energy-efficient, cost-effective, sustainable, and environmentally friendly.

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Appendix

Appendix A:

```
#include <LiquidCrystal_I2C.h>

#include <HTTPClient.h>

#include <Wire.h>

#include <WiFiManager.h>

LiquidCrystal_I2C lcd = LiquidCrystal_I2C(0x27, 20, 4);

//display config

const int sampleWindow = 50;

unsigned int sample;

unsigned long lastTime = 0;

unsigned long timerDelay = 10000;

//pin config

#define SENSOR_PIN 34 //sensor

//cloud config

WiFiClient client;

WiFiManager wifiManager;

String api_key = "G75W0B9G6PJ0D9JL"; //cloud api key

const char *server_name = "http://api.thingspeak.com/update"; //cloud data api

void setup ()

{

    pinMode (SENSOR_PIN, INPUT);

    Serial.begin(115200);

    Wire.begin();

    lcd.begin();

    lcd.backlight();

    lcd.setCursor(0, 0);

    lcd.print("WIFI Connecting.....");

    lcd.clear();

    lcd.setCursor(0,0);

    if(Serial.available() > 0){

        lcd.print("Serial connected successfully");
```

```

lcd.setCursor(0,1);

  lcd.print("please look for wifi");

  lcd.setCursor(0,2);

  lcd.print("Shohan-Project");

  lcd.setCursor(0,3);

  lcd.print("ip: 192.168.4.1");
}

else{

  lcd.print("serial connection failed");

  lcd.setCursor(0,1);

  lcd.print("try again");

}

if(wifiManager.autoConnect("Shohan-Project") == HIGH)
{

  lcd.clear();

  lcd.setCursor(0,0);

  lcd.print("WiFi Connected to.....");

  lcd.setCursor(0, 1);

  lcd.print(wifiManager.getConfigPortalSSID());

  delay(4000);

  lcd.setCursor(0,2);

  lcd.print("process begin");

}

else{

  lcd.clear();

  lcd.setCursor(0,0);

  lcd.print("WiFi Connection failed");

}

//wifiManager.startConfigPortal("Shohan-Project");

  lcd.clear();

}

void loop ()

```

```

{
    unsigned long startMillis= millis();
    float peakToPeak = 0;
    unsigned int signalMax = 0;
    unsigned int signalMin = 1024;
    while (millis() - startMillis < sampleWindow)
    {
        sample = analogRead(SENSOR_PIN);
        if (sample < 1024)
        {
            if (sample > signalMax)
            {
                signalMax = sample;
            }
            else if (sample < signalMin)
            {
                signalMin = sample;
            }
        }
    }
    peakToPeak = signalMax - signalMin;
    int db = map(peakToPeak,20,900,49.5,90);
    lcd.clear();
    lcd.setCursor(0, 0);
    lcd.print("Loudness: ");
    lcd.print(db);
    lcd.print("dB");
    Serial.printf("Loudness: %d dB\n", db);
    if (db <= 60)
    {
        lcd.setCursor(0, 1);
        lcd.print("Level: Quite");
    }
}

```

```

Serial.println("Level: Quite");
lcd.setCursor(0, 2);
lcd.print("REDUCE CHAOS");
lcd.setCursor(0, 3);
lcd.print("STAY SAFE");
}
else if (db > 60 && db<85)
{
  lcd.setCursor(0, 1);
  lcd.print("Level: Moderate");
  Serial.println("Level: Moderate");
  lcd.setCursor(0, 2);
  lcd.print("PLEASE REDUCE SOUND");
  lcd.setCursor(0, 3);
  lcd.print("SAVE YOUR EAR");
}
else if (db>=85)
{
  lcd.setCursor(0, 1);
  lcd.print("Level: High");
  Serial.println("Level: Moderate");
  lcd.setCursor(0, 2);
  lcd.print("REDUCE SOUND NOW");
  lcd.setCursor(0, 3);
  lcd.print("PREVENT DEAFNESS");
}
Serial.println("Cloud Connecting...");
if ((millis() - lastTime) > timerDelay)
{
  if(WiFi.status()== WL_CONNECTED)
  {
    WiFiClient client;

```

```

    HTTPClient http;
    http.begin(client, server_name);
    http.addHeader("Content-Type", "application/x-www-form-urlencoded");
    // Data to send with HTTP POST
    String httpRequestData = "api_key=" + api_key + "&field1=" + String(db);
    int httpCode = http.POST(httpRequestData);
    if(httpCode > 0){
        if(httpCode == HTTP_CODE_OK)
        {
            Serial.println("data send successfully");
        }
        else {
            Serial.println("Something Else");
        }
    }
    else
    {
        Serial.printf("HTTP Request failed, exception: %s\n", http.errorToString(httpCode).c_str());
    }
    http.end();
}
else {
    Serial.println("WiFi Disconnected");
}
lastTime = millis();
}
delay(1000);
lcd.clear();
}

```

Appendix B:

```
import IPython.display as ipd
import librosa
import librosa.display
import pandas as pd
import os, time, warnings
import seaborn as sns
import numpy as np
from tqdm import tqdm
import matplotlib.pyplot as plt
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import LabelEncoder
from tensorflow.keras.utils import to_categorical
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import (
    Dense,
    Conv1D,
    MaxPooling1D,
    BatchNormalization,
    Dropout,
    Flatten,
    Conv2D,
    MaxPool2D,
)
warnings.filterwarnings("ignore")
log_cols = ["model", "accuracy", "train_time", "pred_time"]
log = pd.DataFrame(columns=log_cols)

from google.colab import drive
drive.mount('/content/drive')
# reading the files
audio_dataset_path = "/content/drive/MyDrive/Research/Sound/Latest/All 1/"
meta_data = pd.read_excel('/content/drive/MyDrive/Research/Sound/Latest/Excel.xlsx')
meta_data.groupby("Class")["Class"].unique()
x = meta_data["Class"].unique()
y = meta_data["Class"].value_counts(ascending=True)
ind = np.arange(len(y))
# plt.figure()
fig, ax = plt.subplots(figsize=(15, 5))
ax.barh(ind, y)
ax.set_yticks(ind)
ax.set_yticklabels(x)
ax.bar_label(ax.containers[0])
plt.gcf().set_dpi(500)
plt.title("Number of Audio Samples per Category")
```

```

plt.xlabel("Number of Samples")
plt.ylabel("Category")
plt.show()
plt.rcParams["figure.figsize"] = (5, 2.5)
plt.rcParams["figure.dpi"] = 200
audio_path = audio_dataset_path + "Sample1.wav"
(xf, sr) = librosa.load(audio_path)
mfccs = librosa.feature.mfcc(y=xf, sr=sr, n_mfcc=40)
librosa.display.specshow(mfccs, x_axis="time")
plt.colorbar()
plt.tight_layout()
plt.title("MFCC Of Bike")
plt.show
audio_path = audio_dataset_path + "Sample2.wav"
(xf, sr) = librosa.load(audio_path)
mfccs = librosa.feature.mfcc(y=xf, sr=sr, n_mfcc=40)
librosa.display.specshow(mfccs, x_axis="time")
plt.colorbar()
plt.tight_layout()
plt.title("MFCC Of Bus")
plt.show
audio_path = audio_dataset_path + "Sample3.wav"
(xf, sr) = librosa.load(audio_path)
mfccs = librosa.feature.mfcc(y=xf, sr=sr, n_mfcc=40)
librosa.display.specshow(mfccs, x_axis="time")
plt.colorbar()
plt.tight_layout()
plt.title("MFCC Of Car")
plt.show
audio_path = audio_dataset_path + "Sample4.wav"
(xf, sr) = librosa.load(audio_path)
mfccs = librosa.feature.mfcc(y=xf, sr=sr, n_mfcc=40)
librosa.display.specshow(mfccs, x_axis="time")
plt.colorbar()
plt.tight_layout()
plt.title("MFCC Of Cng")
plt.show
audio_path = audio_dataset_path + "Sample5.wav"
(xf, sr) = librosa.load(audio_path)
mfccs = librosa.feature.mfcc(y=xf, sr=sr, n_mfcc=40)
librosa.display.specshow(mfccs, x_axis="time")
plt.colorbar()
plt.tight_layout()
plt.title("MFCC Of Leguna")
plt.show

```

```

# list containing all the features
extracted = []
# for each row in the csv
for index_num, row in tqdm(meta_data.iterrows()):
    # get the file
    file_name = os.path.join(
        os.path.abspath(audio_dataset_path),
        str(row["Title"])+str(".wav"),
    )
    # get file label
    final_class_labels = row["Class"]
    # load the audio file
    audio, sample_rate = librosa.load(file_name, res_type="kaiser_fast")
    # extract the features
    feature = librosa.feature.mfcc(y=audio, sr=sample_rate, n_mfcc=128)
    # feature scaling
    scaled_feature = np.mean(feature.T, axis=0)
    # store it in a list
    extracted.append([scaled_feature, final_class_labels])
    #print(sample_rate)
# create a new dataframe
extracted_df = pd.DataFrame(extracted, columns=["feature", "class"])
# Storing the dataframe to pickle for further processing
extracted_df.to_pickle("extracted_df.pkl")
extracted_df.head()
feature.shape
import pickle
with open('extracted_df.pkl', 'rb') as f:
    data = pickle.load(f)
print(data)
# create a new dataframe
final = pd.DataFrame(extracted, columns=["feature", "class"])
X = np.array(final["feature"].tolist())
y = np.array(final["class"].tolist())
# label encoding to get encoding
le = LabelEncoder()
# transform each category with it's respected label
Y = to_categorical(le.fit_transform(y))
# split the data to train and test set
X_, X_test, y_, y_test = train_test_split(
    X, Y, test_size=0.1, random_state=42
)
X_train, X_val, y_train, y_val = train_test_split(
    X_, y_, test_size=0.3, random_state=42
)

```

```

# print the details
print("Number of training samples = ", X_train.shape[0])
print("Number of training samples = ", X_val.shape[0])
print("Number of testing samples = ", X_test.shape[0])
# Construct model
num_labels = Y.shape[1]
ANN_Model = Sequential()
ANN_Model.add(Dense(750, activation="relu", input_shape=(128,)))
ANN_Model.add(Dense(500, activation="relu"))
#ANN_Model.add(Dense(500, activation="relu"))
#ANN_Model.add(Dense(250, activation="relu"))
#ANN_Model.add(Dense(100, activation="relu"))
ANN_Model.add(Dense(50, activation="relu"))
ANN_Model.add(Dense(num_labels, activation="softmax"))
ANN_Model.summary()
ANN_Model.compile(optimizer="adam", loss="categorical_crossentropy", metrics=["accuracy"])
)
num_epochs = 100
num_batch_size = 32
t0 = time.time()
ANN_Results = ANN_Model.fit(
    X_train,
    y_train,
    batch_size=num_batch_size,
    epochs=num_epochs,
    validation_data=(X_val, y_val),
)
ANN_Model.save("Model1.h5")
print("ANN Model Saved")
train_hist_m1 = pd.DataFrame(ANN_Results.history)
train_m1 = round(time.time() - t0, 3)
plt.figure(figsize=(10, 5), dpi=300)
plt.plot(train_hist_m1[["loss", "val_loss"]])
plt.legend(["Loss", "Validation Loss"])
plt.title("Loss Per Epochs")
plt.xlabel("Epochs")
plt.ylabel("Loss")
plt.show()
plt.figure(figsize=(10, 5), dpi=300)
plt.plot(train_hist_m1[["accuracy", "val_accuracy"]])
plt.legend(["Accuracy", "Validation Accuracy"])
plt.title("Accuracy Per Epochs")
plt.xlabel("Epochs")
plt.ylabel("Accuracy")
plt.show()

```

```

acc_m1 = ANN_Model.evaluate(X_test, y_test, verbose=0)
t0 = time.time()
y_pred_m1 = ANN_Model.predict(X_test, verbose=0)
pred_m1 = round(time.time() - t0, 3)
log_entry = pd.DataFrame(
    [{"ANN", acc_m1[1] * 100, train_m1, pred_m1}], columns=log_cols
)
log = log.append(log_entry)
# function to predict the feature
def ANN_Prediction(file_name):
    # load the audio file
    audio_data, sample_rate = librosa.load(file_name, res_type="kaiser_fast")
    # get the feature
    feature = librosa.feature.mfcc(y=audio_data, sr=sample_rate, n_mfcc=128)
    # scale the features
    feature_scaled = np.mean(feature.T, axis=0)
    # array of features
    prediction_feature = np.array([feature_scaled])
    # get the id of label using argmax
    predicted_vector = np.argmax(ANN_Model.predict(prediction_feature), axis=-1)
    # get the class label from class id
    predicted_class = le.inverse_transform(predicted_vector)
    # display the result
    print("ANN has predicted the class as --> ", predicted_class[0])
# File name
#file_name = audio_dataset_path + "Sample438.wav"
file_name = "/content/drive/MyDrive/Research/Sound/All/" + "Sample 30.wav"
# get the output
ANN_Prediction(file_name)
# play the file
ipd.Audio(file_name)

```