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Principal Component Analysis and Data Encryption Model for Face Recognition System

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Noise Monitoring System Development in a Library Based on The Internet of Things

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***Abstract*— a library is one of the important places for the community, especially students. However, not all visitors know the library's rules and act arbitrarily to create noise that can disturb other visitors. This research is focused on the development of classifying and monitoring the unwanted noise in the library. The system is built with the Arduino Nano 33 BLE microcontroller using the DFROBOT Analog Sound Level Meter Sense sensor and ESP32-WROOM32U. The system is equipped with classification capabilities resulting from machine training using the Convolutional Neural Network algorithm by utilizing a Feature Extraction. The system is then connected to Wi-Fi to be integrated with websites created using the PHP programming language and the Laravel framework. Data from the monitoring will be stored in the MySQL database. The system can give a noise warning when a human or cell phone sound exceeds the threshold with an average of 82.78% classification accuracy and an ideal distance from the sound source, as far as 30-100 cm.**

Keywords—Noise Monitoring System, Internet of Things, Feature Extraction, CNN.

I. Introduction

A library is needed for students, lecturers, and researchers, which makes it an alternative place to search library sources and a place for group scientific activities. But, visitors often do not understand the ethics of being in the library room. Visitors who do not understand the rules make rowdy noises and speak too loudly, causing noise to other visitors and interfering with the concentration of reading or discussions being carried out. This is one of the main reasons for complaints submitted by library visitors to librarians. Librarians, as authorized officers, need to remind visitors to be calm and not to cause noise. Librarians must also carry out their work, from collecting new book data to maintaining books in the library. Of course, continuous warnings to different visitors will significantly interfere with the librarian's work [1][2]. Therefore, a system is needed that can automatically detect and simultaneously provides a notification signal to visitors not to make noise. One way to reduce noise in the library is to use a system that alerts visitors when it reaches the specified noise threshold. However, The problem found when creating a noise monitoring system is in the noise itself.

Sound is a condition of changing pressure or can also be described as the speed of oscillations or frequencies in Units of Hertz (Hz). There are three types of sounds, namely those that have frequencies between 20Hz to 20 kHz (can be heard by human ears), above 20 kHz, and below 20Hz (both of which cannot be heard by human ears) [3].

Noise can be interpreted as unwanted, disliked, and disturbing sounds or can also be interpreted as complex sound vibrations that have various frequencies and amplitudes that are periodic/non-periodic. Noise can be measured logarithmically by units of decibels (dB) which is the energy currency of the unity of the area. Noise can be classified into three types: engine, vibration, air movement, gas, and liquid [4].

The human sense of hearing can listen to sounds within 20 Hz-20kHz. Humans can easily distinguish the types of sounds without making any additional effort. If the machine wants to have the same ability to distinguish the types of sounds, extra effort must be made because the machine has a problem that is often called *machine hearing. Feature extraction* [5] can help the machine recognize sounds.

The system must distinguish which noise is produced by visitors and which is produced by the library environment. Adding Artificial Intelligence to the system allows it to recognize the noise around it. One of the branches of Artificial Intelligence is Machine Learning. Machine Learning has now arrived at the implementation of existing embedded systems [6][7]. Several studies were done on using artificial intelligence in voice recognition, and all use CNN as the algorithm [9]–[11]. However, The application of Artificial Intelligence to embedded systems is limited when operating on devices with limited capabilities [8].

There is also a study about noise monitoring systems in the library using an Arduino Uno-based sound noise detection and warning system made at the Amikom Purwokerto University Library. In the system, the GY-MAX4466 sensor was used as a noise sensor, and a 128x64 pixel OLED screen and speakers functioned as issuing warnings in the form of sound to library visitors around it [12]. The research also built a noise detection system in Arduino-based libraries. The system is built using an LM393D sensor and is connected to an LCD that will display the text and speakers used as sound output. The research built a library visitor noise detection tool with the ES8266 microcontroller. The microcontroller is connected to a KY-037 sensor and an LCD [13]. The study also built a website as a medium for monitoring and controlling noise detection [14].

These studies are similar because they built a monitoring system using a microcontroller connected to a sound sensor. However, no one has researched how the system can distinguish the noise produced by library visitors from the noise coming from the environment around the library. For this reason, this study has the main objective of how a system built on a microcontroller can have artificial intelligence that can identify sound noise.

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Analysis of WiFi Spatio-Temporal Data for Organic Fingerprinting-based Indoor Positioning System

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***Abstract*—The mobile robot navigation is the next huge topic after positioning utilizing fingerprinting-based Wireless Positioning System (WPS). Many of recent works does not discuss this topic yet since many open problems in positioning topic are not yet solved, for instance the issues on multi-devices heterogeneity, instability of WiFi signals, granularity problems in grid-based indoor environment and many others. However, we anticipate that both positioning and navigation works must run in parallel so that the succession are guaranteed. This paper describes the analysis of spatio-temporal data of the signal obtained from the WiFi Access Point. Initial results suggest that the difference between transmitter heights have an effect on the spatio-temporal data while the handover of maximum signal strengths is inherent when three WiFi APs are used.**

Keywords—spatio temporal data, WiFi fingerprinting, indoor positioning system, wireless positioning system, mobile robot

I. Introduction

An Indoor Positioning System (IPS) is a system that is used for an agent for instance a mobile robot to positioned itself in a particular indoor environment. Conventionally used on-board sensors such as the ultrasonic, infrared, camera or a more expensive laser range finders or LIDAR are used for research platform but became cost concerns when one is talking about production along with the complex positioning algorithms. The development costs are not facilitative and often the ideas lie rest. A more cost-effective solution is to use readily and available insfrastructure such as Wireless Fidelity (WiFi) signals which act as a beacon for pinpointing a location of an agent. Moreover, many recent buildings especially in current era of the Fourth Industrial Revolution (IR4.0) already deployed WiFi Access Points with seamless connectivity to the internet. Figure 1 depicts a conceptual framework of using the WiFi insfrastructure as sensors for mobile robot positioning in an indoor environment.

An IPS system can be realized using two techniques, which are (1) geometrical-based triangulation or trilateration method or (2) signal fingerprint database method. The later are more favorable since the accuracies are proven better and simple [1][2]. Figure 2 shows the difference between the two techniques. The first method works by converting the signal strength information into distances, then the position is estimated by using geometrical computation [3]. This technique is easy to implement, however the accuracy is often disheartening since there are no exact model of signal propagation resulting incorrect distance conversion, often requires pre-processing such as Kalman filtering [4]. Fingerprinting method on the other hand, works by 'matching' an online signal to an offline signal fingerprint database or radio map built earlier. This method yields in higher accuracy compared to the trilateration method [1].

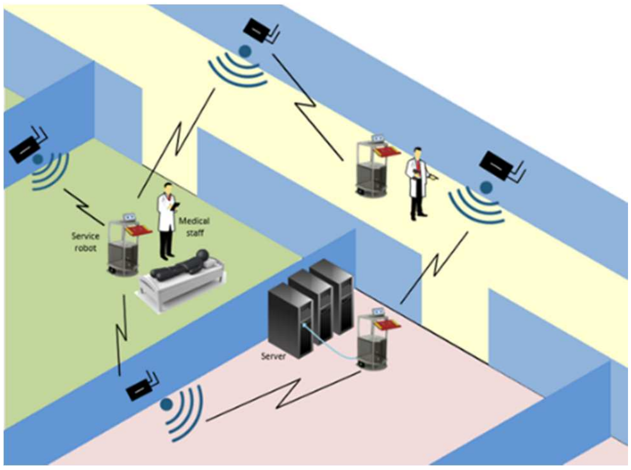

Fig 1. The concept of IPS in an indoor environment for a mobile robot application in healthcare industry [8]

The creation of signal fingerprinting database however is tedious and require extensive hours of works. Morevoer expert surveyors is needed in order to have a good and systematic database. In real application, the database must be updated regularly with respect to environment change. One feasible solution is to employ organic fingerprinting or often.

Measures To Enhance The Characterization Of Internet Exchange Points

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***Abstract*—The reliability of data transport on the Internet is one of the objectives of researchers in the field of computer science. Data such as videos and audio is becoming increasingly large. Therefore, transporting them over the Internet is becoming difficult. It has therefore been important to establish a method of locally interconnecting autonomous systems (AS) with each other to facilitate the exchange of traffic: Internet Exchange Points (IXP). They play an important role, there is much to be done to understand their impact on the Internet, and IXP characterization is an important step in this direction. An AS will choose to connect to an IXP based on some characteristics, and identifying relevant characteristics remains a challenge. They provide an almost complete status of an IXP while detailing its evolution, which is very important for the members of the IXP and possibly for other actors such as ISPs who would like to connect to it. In this paper, we propose six measures to enhance IXP characterization. There is the attraction rate, the peering rate, the number of IXP interconnections (national, regional and international), the objective rate, an IXP's resistance rate, and attraction failure rate. These measures provide more relevant characteristics than the previous ones. They allow one to have an almost complete status of an IXP while detailing its evolution, which is very important for the IXP members and eventually for other actors such as Internet access providers who would like to connect to it.**

***Index Terms*—Characteristic; Autonomous System; Internet Service Provider; Internet eXchange Point; Rate.**

I. Introduction

A large amount of data to be transported on the Internet and the search for efficiency in data traffic have forced computer network operators to introduce many traffic techniques, including Internet Exchange Points (IXPs). An IXP is an infrastructure where multiple networks interconnect to exchange traffic.

IXPs are today's central exchange points for Internet traffic. Indeed, they are a key component of the Internet ecosystem [1]–[3]. Much of the research on IXP characteristics focus on the characteristics of traffic at Internet Exchange Points (IXPs) [4]–[13].

So, the pertinent question is, what measures can be taken to better characterize Internet exchange points? Or what characteristics reflect the effectiveness of IXPs?

To answer this question, we need to consider some basic metrics like the number of ASes connected to the IXP (degree), the number of IXPs, the number of AS disconnected per year (i.e., they cease to be members of the IXP), the number of new connected AS per year, and the size of internet traffic through an IXP.

We use these metrics to define six rates: the attraction rate (τ_{attr}) the peering rate (τ_{peer}), number of IXP interconnections (τ_{in}, τ_{ir}, τ_{ii}), the objective rate (Obj_{att}), an IXP's resistance rate (τ_{eff}), and attraction failure rate (τ_f). We applied our proposed measures to characterize IXP using real data.

We used the data from PeeringDB [14].

We computed these rates on a set of IXP and the results match the formal definition targets. For example, the interconnection rate depends on the geographic spread of the IXP. The measures show the effectiveness of IXPs as intended.

The rest of the paper is articulated as follows: in Section II, we discuss the work related to the question addressed; Section III presents the methodology adopted and the dataset; Section IV presents the results, and Section VI presents the conclusion.

II. Related work

In this section, we discuss several contributions that have already addressed the characteristics of IXPs.

The authors of this paper [13] have shown that the largest European IXP is a location where abundant peering takes place. Indeed, the member of ASes established 67% peering. They characterize the IXP by peering fill rate or peering rate, which is the number of peer-to-peer links established and used for peering and the rate of peering through the IXP. Regional interconnection between Internet exchange points facilitates peering over a wider area. Indeed, the interconnection between IXPs promotes a wider coverage of IXPs and therefore attracts more operators. This will contribute enormously to the improvement of the ecosystem [4].

According to **Arnold Nipper** [6], for the IXP interconnection technique, the simplest approach is to set up a single

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Detection and tracking of honeybees using YOLO and StrongSORT

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***Abstract*—Understanding the behavior of honey bees is essential for maintaining a healthy bee colony. Hive monitoring systems are crucial for this purpose. In the last few years, computer vision and deep learning have become widely used in such systems. This paper uses a deep learning approach for detecting and tracking honey bees. Firstly, for detection, we employed the YOLO model using a data set of 1000 ground truth images. Secondly, for tracking, we used the StrongSORT approach. Results show that the detector performs well in both classes of honey bees (with or without pollen). The models based on this approach provide considerably good average tracking accuracy with low latency. Thus, this procedure is reliable and can be used in the future for real-time monitoring systems.**

***Index Terms*—HoneyBee, Detection, Tracking, YOLO, StrongSORT**

I. Introduction

Honeybees are incredibly vital all over the world, and they are one of the most important elements of the ecosystem. Honey bees are not only important for the honey they produce but also for their pollination abilities. Additionally, pollination is aided when beekeepers move their beehives from one farm to another [1]. In fact, *Apis mellifera* offer around 14% of the entire pollination services in agriculture [2].

To keep the bee hives healthy, beekeepers must routinely verify them. Some of these activities can be hazardous to bees. Researchers have proposed various methods for monitoring the inside and outside of the hive.

In hive monitoring systems, computer vision is frequently employed [3] such as automatic tracking, and behavior analysis [4] [5], and 3D real-time stereo vision-based monitoring of flying honeybees [6]. With the emergence of deep learning [7], accurate object detection and recognition became possible, encouraging many researchers to use both deep learning and computer vision in their projects, particularly the benefits of extracting information from image data other than honey bees [8] [9] [10], and build honey bees hive monitoring systems for flight activity and background mortality [11] [12].

The Convolutional Neural Network (CNN) has progressed pretty fast in the last decade. In the realm of honeybees, we can find CNN-based approaches, identifying bees according to whether they are carrying pollen or not [13], concentrating on the observation of bees exiting and entering the hive [14], even the usage of CNN provides outstanding detection results, but that is insufficient for the immediate inference, especially when it aims to identify and locate bees that are carrying pollen. Using a Faster-R CNN object detector, the performance is much better than old approaches based on CNN [15].

Other deep learning approaches for object detection have emerged recently, such as Single Shot Multi-Box Detector (SSD) [16] and You Only Look Once (YOLO) [17], and these detection approaches have been applied in real-time bee hive monitoring systems.

The work in [18] focuses on tracking a single bee in a captured scene and plotting its path in a 2D plane using the background subtraction technique and YOLOv2 [18]. Another work in [19] employed a colony flow monitoring system with a one-way multi-frame detector SSD and the Faster R-CNN. Authors in [20] detect Varroa destructor mite using YOLOv5 and SSD. Another study in [21] used YOLOv3 tiny architecture to detect bees and identify pollen sacks with a Kalman filter and the Hungarian algorithm for tracking [21]. In [22], YOLOv4 and DeepSORT algorithms are used in the honeybee in-out monitoring system for tracking.

Unfortunately, the study in [22] has not provided an analysis of the designed system in terms of tracking. To that effect, our current work deals with this issue. In this paper, we use YOLOv5 and StrongSORT to detect and track honey bees and provide the detection and inference time analysis. Data is collected using honeybees videos available online. The frames of these videos clearly show honeybees and pollen sacs. We use these frames to create our data set. After that, we use our YOLOv5 model for detection, and we transfer the detected images to the input of StrongSORT, which combines motion and appearance information to track detected objects.

The paper begins with an introduction, followed by an explanation of the methodology we utilized for detection and tracking, how these approaches function, how we labeled our data, and where we used it. Finally, we discuss the obtained results of the used approach.

II. Materials and Methods

In our work, we use both detection and tracking. After the image is detected using YOLOv5, StrongSORT is used to track it.

A. Data-set

For our experiment, we listed many public honeybee data sets. However, none of them provided the suitable data set we

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Optimizing the energy consumption of WSN by using Energy efficient routing protocol using Dijkstra Algorithm

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Abstract— **Wireless Sensor Networks (WSNs) are ensembles consisting of many spatially distributed sensor nodes connected via wireless medium to look at and record physical information from the environment. These battery-powered nodes lose all their energy after a given period. Knowing that the energy constraint affects the lifetime of the network, it is, therefore, appropriate to direct our research to optimize it. Therefore, the objective of this study is to mitigate the overall energy consumption and maximize the lifetime of the network. Currently, routing algorithms are widely used in WSNs to improve network lifetime. In this study. The Dijkstra (DA) algorithm identifies the shortest paths between the cluster head (CH) and the base station by determining their cost based on the residual energy of the neighboring CH, the energy consumption of the neighboring CH, the distance of the neighboring CH, and the degree of neighboring CH. To measure the performance of the proposed approach, the number of alive nodes and data packets received by the base station are considered. The results are tested on 100 nodes for 4000 transmission rounds, the amount of data transported is 5 million bits a little more than the other methods. The proposed methodology results are compared with the traditional LEACH, DEEC and TEEN approaches.**

Keywords- Dijkstra Algorithm, Energy consumption, Network lifetime, and Wireless sensor networks

I. INTRODUCTION

Several applications such as defense, weather forecasting, medical, and various commercial and industrial applications require WSNs. Several compact and inexpensive sensor nodes with higher sensing, processing, and information transmission capabilities compose a WSN. These sensor nodes are dispersed in the environment and detect, evaluate and receive data. Having a limited non-rechargeable energy source, the energy of the sensors must be used efficiently because the battery cannot be exchanged due to the placement of the sensor in a hostile environment and out of reach of humans. WSN sensor nodes act as repeaters to transmit information to other sensors and the sink. The sensor collects data using an analog-to-digital converter (ADC) and processes the data for transmission to the central aggregator known as the sink node, also known as the base station (BS). At the sink node, data analysis is important for application decision-making. Sensing data from an environment and transmitting data from any node to the sink node are two factors that lead to the depletion of sensor energy in a WSN. The energy consumed to transmit data in a WSN is higher [1]. The major challenge of a WSN is energy autonomy, therefore the failure of the network is related to the failure of the nodes. So, having a WSN made of sensors with insufficient power is a problem. The direct transmission of data from the sensor nodes to a BS is not recommended because of the high energy loss. So, a routing protocol uses the best route to the BS to reduce its energy consumption, because a direct transmission requires more energy. These routing protocols also improve the fault tolerance level, enhance reliability, facilitate data accumulation, and promote scalability [2]. The main research objective is to decrease the energy consumption of a WSN. This study, it is sought to limit the energy consumed during data transmission, which allows for increasing the number of packets transmitted to the BS. Graph theory is used to solve the shortest path problem. The Dijkstra algorithm is used to identify the shortest path between a CH and a BS. The choice of this path is based on the distance between a CH and a BS based on graph theory. Dijkstra's algorithm relies on an efficient implementation for fast solution discovery in WSN. Optimal route generation is used to reduce the energy consumption of the nodes during the transmission of data packets. Therefore, this study contributes to increasing the network lifetime. The rest of the paper includes a literature review regarding clustering and routing techniques presented in the second part. The problems highlighted in the existing research and the solution is discussed in the third part. The preliminary steps for the implementation of this solution are illustrated in the fourth part. Further clarification on the use of Dijkstra's algorithm for choosing the shortest path between CH and BS is provided in part five. A comparative study of

Control of Master-Slave Microgrid Based on PR and PI Controllers in Islanded Mode

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***Abstract*—This paper presents a unique control scheme to improve the active and reactive power sharing between two parallel inverters in a microgrid based on a master-slave scheme. The implemented control scheme comprises outer and inner loops that are controlled by a Proportional Integral (PI) controller. Moreover, the novelty of the overall suggested control scheme is the addition of a Proportional Resonant (PR) controller in both master and slave inverters, where a PR controller can further enhance the robustness and stability of the system. The microgrid understudy consists of three parallel 3-level diode clamped inverters (master and two slaves) connected to a common load in standalone mode. The results are carried out using MATLAB/Simulink, where the suggested control scheme is compared to the same system, but without a PR, controller to validate its robustness and effectiveness. The simulation results demonstrate that active and reactive power sharing has been enhanced when the PR controller is added to the inverter circuit.**

***Index Terms*—Microgrids, parallel inverters, master-slave, inner and outer loops, PR controller**

I. Introduction

Over the past few decades, rising demand for energy and the decline of fossil fuels has pushed the world toward Renewable Energy Resources (RERs') [1]–[3]. Recently, RERs' technologies such as wind turbines and PV panels, have gained much attraction by integrating them through a concept called Distributed Generation (DG) [4]. Nonetheless, power quality issues such as harmonics or over-voltages, and stability issues in the network functionality are all technical and operational challenges that arise because of the high penetration of DG units in a distribution network. Therefore, the microgrid concept was germinated to overcome the aforementioned problems in the DG [5].

A discrete energy system composed of loads and renewable energy resources that can operate with or without the primary grid is the definition of a microgrid [6]. The existence of a central control unit with a specified area and a Point of Common Coupling (PCC) to connect and disconnect the microgrid from the utility grid, distinguishes microgrids from distribution network control. When the microgrid is disconnected from the primary grid, the mode of operation is called islanded/standalone mode, while the second mode is when the microgrid is connected to the primary grid through the PCC, and this mode is called grid-connected [6], [7].

However, the microgrid's implemented power-sharing control scheme must provide a stable operation in both microgrid modes. The control schemes of microgrids based on the power-sharing control strategies can be classified into two main categories with respect to their inverters: communication-based (centralized) [8], and communication-less (decentralized) methods [9]. Decentralized (communication-less) are methods/schemes related to droop control and its variations [10]. While centralized (communication-based) methods are various, such as concentrated control, current distribution, master-slave, etc. [11]. Nevertheless, the droop control strategies suffer a substantial disadvantage which is the voltage and frequency (VaF) deviation of the microgrid from the main grid, which can be tackled by the communication-based methods, especially the master-slave control scheme. In this control scheme, the master unit is responsible for controlling the voltage at the PCC (outer loop control). At the same time, slaves are directed to only supply current (inner loop control), hence, injecting active (P) and reactive (Q) powers to the connected loads throughout the PCC [12].

Previous papers presented the microgrid-based master-slave scheme only with a simple controller for instance PI controller, or an advanced nonlinear controller such as sliding mode control, to control either inner, outer, or both loops [13]–[17]. However, the novelty of this work is to add a (PR) controller within each of the connected parallel inverter schemes in the microgrid system, so that the system can have accurate power sharing among slave units. To the best of the authors' knowledge, this is the first paper that added the PR controller to the inverter circuits in the implemented power system.

The purpose behind adding a PR controller in each inverter circuit is to further stabilizes the voltage at the PCC when the is controller added to the master inverter. In addition, enhancing the power-sharing among the slave units by adding the aforementioned controller to the slaves' inverters; in order to inject reliable/constant active (p) and reactive (Q) powers to the connected loads. The effectiveness of the proposed system has been assessed in MATLAB/Simulink, relying on a model of a microgrid with three DG units (one master and two slaves). This paper is organized as follows: Section I is the introduction and background about the microgrid. Section II depicts the structure and parameters of the microgrid based on the master-slave scheme. Section III demonstrates the proposed control schemes of both master and slave units. Simulation results are illustrated in Section IV. Section V is the conclusion and future work.

Optimization Microgrid System with Symbiotic Organisms Search Algorithm

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Abstract — With the policy of prioritizing the development of renewable energy sources, the total capacity of renewable energy sources in Vietnam is increasing day by day. However, there are a few issues that need to be resolved. Wind and solar energy sources are highly dependent on weather conditions, but the weather is inherently erratic, so these energy sources are always unstable with changes in weather. Because solar and wind power systems are non-inertial power systems, so it is necessary to have inertia power systems such as thermal power (coal, LNG), hydroelectricity, atomic electricity to maintain a stable continuous power supply. The problem is to moderate these power sources to meet the economic and emission optimization goals. This paper focuses on researching optimization algorithms to find the best solutions for the economic and emission problem in Microgrid system including 2 generators, 1 Combined heat and power (CHP), 1 Photovoltaic (PV), 1 WT (Wind Turbine).

Applying Symbiotic Organisms Search Algorithm to search for optimal solutions for the above problems, the paper gives better results than other algorithms up to 20%.

Keywords – Economic emission dispatch, micro-grid, symbiotic organisms search algorithm, renewable energy

I. INTRODUCTION

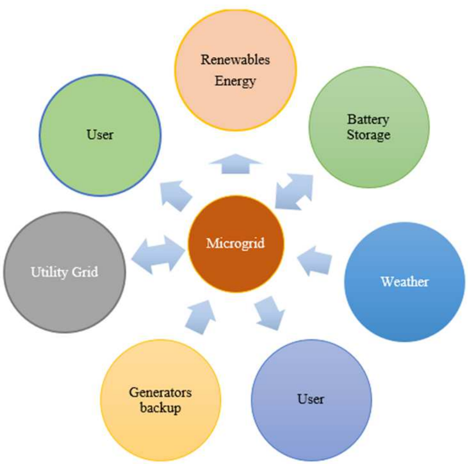

Fig 1: Microgrid model overview

The United States Department of Energy [1] defined "Micro-grid as a group of interconnected loads and distributed energy resources (DERs) within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A micro-grid can connect and disconnect from the grid to enable it to operate in both connected or island-mode" The special feature of the micro-grid is that it is possible to control the opening and closing of this system with just one button and make this system isolated from the entire common grid. This is a specific use for the grid-connected system during a power failure of the entire system. [2] [3].

In operation process of micro-grid system, the load demand required flexible-adaptation ability of distributed sources. However, the problem is that it is necessary to moderate the DERs reasonably to achieve the requirements of the system. Depending on the requirements, the moderation problem in Microgrid is complex or simple.

In general, the problem revolves around how to make the Microgrid system work efficiently with the least resources. One of them is the problem of economic emissions dispatch (EED) optimization. To solve this problem, many researchers have focused on using different methods to find the optimal solution. With the development of computers and computing technology, many algorithms have been born to meet the goals of researchers. And in that, algorithms based on artificial intelligence increasingly promote the ability to provide quick and accurate solutions. Algorithms are used for problems in economic moderation with complex input parameters such as modified harmony search algorithm (MHSA) [4]; Reduced Gradient Method (RGM) [5]; Summation based multi-objective evolutionary algorithm (SMODA) [6]; non-dominating sorting genetic algorithm II (NSGA II) [7] [8]; multi-objective evolutionary algorithm (MOEA) [9], multi-objective particle swarm optimization (MOPSO) [10] [11]

For this paper, to solve the EED optimization problem for Microgrid system with generators including 2 DG, 1 PV, 1WT and 1 CHP, we used the SOS algorithm to find the best results. The algorithm is applied in 4 cases: all sources, only fossil energy sources, not using solar energy, not using wind energy. The results are compared with other algorithms such as Modified harmony search Algorithm (MHSA) [4], Interior Search Algorithm ISA [12], Cuckoo Search Algorithm (CSA) [12],Improved Harmony Search Algorithm (IHSA) [13], Ant Colony Optimization Method (ACO) [5], Improved and Adaptive Harmony Search (IAHSA) [14].

Noise Monitoring System Development in a Library Based on The Internet of Things

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***Abstract*— a library is one of the important places for the community, especially students. However, not all visitors know the library's rules and act arbitrarily to create noise that can disturb other visitors. This research is focused on the development of classifying and monitoring the unwanted noise in the library. The system is built with the Arduino Nano 33 BLE microcontroller using the DFROBOT Analog Sound Level Meter Sense sensor and ESP32-WROOM32U. The system is equipped with classification capabilities resulting from machine training using the Convolutional Neural Network algorithm by utilizing a Feature Extraction. The system is then connected to Wi-Fi to be integrated with websites created using the PHP programming language and the Laravel framework. Data from the monitoring will be stored in the MySQL database. The system can give a noise warning when a human or cell phone sound exceeds the threshold with an average of 82.78% classification accuracy and an ideal distance from the sound source, as far as 30-100 cm.**

Keywords—Noise Monitoring System, Internet of Things, Feature Extraction, CNN.

I. Introduction

A library is needed for students, lecturers, and researchers, which makes it an alternative place to search library sources and a place for group scientific activities. But, visitors often do not understand the ethics of being in the library room. Visitors who do not understand the rules make rowdy noises and speak too loudly, causing noise to other visitors and interfering with the concentration of reading or discussions being carried out. This is one of the main reasons for complaints submitted by library visitors to librarians. Librarians, as authorized officers, need to remind visitors to be calm and not to cause noise. Librarians must also carry out their work, from collecting new book data to maintaining books in the library. Of course, continuous warnings to different visitors will significantly interfere with the librarian's work [1][2]. Therefore, a system is needed that can automatically detect and simultaneously provides a notification signal to visitors not to make noise. One way to reduce noise in the library is to use a system that alerts visitors when it reaches the specified noise threshold. However, The problem found when creating a noise monitoring system is in the noise itself.

Sound is a condition of changing pressure or can also be described as the speed of oscillations or frequencies in Units of Hertz (Hz). There are three types of sounds, namely those that have frequencies between 20Hz to 20 kHz (can be heard by human ears), above 20 kHz, and below 20Hz (both of which cannot be heard by human ears) [3].

Noise can be interpreted as unwanted, disliked, and disturbing sounds or can also be interpreted as complex sound vibrations that have various frequencies and amplitudes that are periodic/non-periodic. Noise can be measured logarithmically by units of decibels (dB) which is the energy currency of the unity of the area. Noise can be classified into three types: engine, vibration, air movement, gas, and liquid [4].

The human sense of hearing can listen to sounds within 20 Hz-20kHz. Humans can easily distinguish the types of sounds without making any additional effort. If the machine wants to have the same ability to distinguish the types of sounds, extra effort must be made because the machine has a problem that is often called *machine hearing. Feature extraction* [5] can help the machine recognize sounds.

The system must distinguish which noise is produced by visitors and which is produced by the library environment. Adding Artificial Intelligence to the system allows it to recognize the noise around it. One of the branches of Artificial Intelligence is Machine Learning. Machine Learning has now arrived at the implementation of existing embedded systems [6][7]. Several studies were done on using artificial intelligence in voice recognition, and all use CNN as the algorithm [9]–[11]. However, The application of Artificial Intelligence to embedded systems is limited when operating on devices with limited capabilities [8].

There is also a study about noise monitoring systems in the library using an Arduino Uno-based sound noise detection and warning system made at the Amikom Purwokerto University Library. In the system, the GY-MAX4466 sensor was used as a noise sensor, and a 128x64 pixel OLED screen and speakers functioned as issuing warnings in the form of sound to library visitors around it [12]. The research also built a noise detection system in Arduino-based libraries. The system is built using an LM393D sensor and is connected to an LCD that will display the text and speakers used as sound output. The research built a library visitor noise detection tool with the ES8266 microcontroller. The microcontroller is connected to a KY-037 sensor and an LCD [13]. The study also built a website as a medium for monitoring and controlling noise detection [14].

These studies are similar because they built a monitoring system using a microcontroller connected to a sound sensor. However, no one has researched how the system can distinguish the noise produced by library visitors from the noise coming from the environment around the library. For this reason, this study has the main objective of how a system built on a microcontroller can have artificial intelligence that can identify sound noise.

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II. Research Method

This research was built using several steps. Which are system concept, analysis of requirements, system design, system implementation, and system testing.

A. System concept

The system has a working principle of being able to receive sound input from the surroundings. The sound enters through 2 components, namely the noise sensor and microphone. The typical conversation or the minimum audible sound level is 60dB [15][16]. When the sound around the device exceeds the threshold of 60 dB, the system will run the microphone sensor and perform sound classification. Sounds will be classified into five categories: falling object, horn, human, cell phone, and siren. When the classification indicates a category of human or mobile phones, the notification LED will light up to commemorate the people around it. All tool readings in decibel values and classification results will be sent to the database, and a data summary will be displayed on the website.

B. Analysis of requirement

This system is built using two microcontrollers, Arduino Nano BLE Sense [17] as a classification microcontroller and ESP32-WROOM32U [18] as a microcontroller that connects with databases. Arduino Nano BLE Sense which already has a microphone type MP34DT05, is also connected to a noise sensor made by DF Robot with an Analog Sound Level Meter type and an indicator LED that functions as an indicator when the device is on and a warning LED for users around it. DF Robot Analog Sound Level Meter is a decibel measuring sensor produced by DF Robot. This sensor is also known as a decibel meter or *noise meter,* which measures the noise around the sensor [19]. The feature extraction results will be used for input in training using the Convolutional Neural Network (CNN) algorithm [10]. The data received from these sensors will enter the Arduino communication serial, which will be forwarded to the ESP32.

ESP32 will be connected to a previously determined WIFI so that it can communicate with the server. The data from Arduino nano sent to ESP32 is in the form of noise sensor reading data, and the classification results will be forwarded to the server to be stored in the database. So, data from the tool that has entered the database will be able to be displayed on the website. On the website, data can be displayed by year, month, and day. There is also an option to display reading data directly.

C. System design

Based on the analysis of requirements before, the system is shown in Fig. 1. When the device is connected to a power source, it immediately reads the required library. Next, the initialization of the pins, serial communication, and required variables will be carried out. Then, it is also checked whether the microphone is working or not. Otherwise, it will display an error warning. Then, the pin connected to the LED indicator will be turned on as long as the tool is on. It will then read the data from the noise sensor and go into conditioning. When the noise sensor reading exceeds the threshold of 60 decibels, a voice reading will be carried out through the microphone. Then the noise level reading and classification will be sent to the communication serial to be accepted on the ESP32. If the noise is not more than 60 decibels, then only the noise level measurement results are transmitted to the communication serial. This Noise Measurement and Sound Classification software will be embedded on the Arduino Nano 33 BLE Sense board with a flowchart, as shown in Fig. 2.

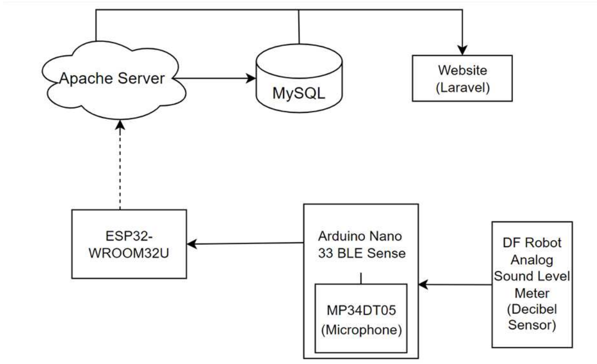

Fig. 1 Diagram Block

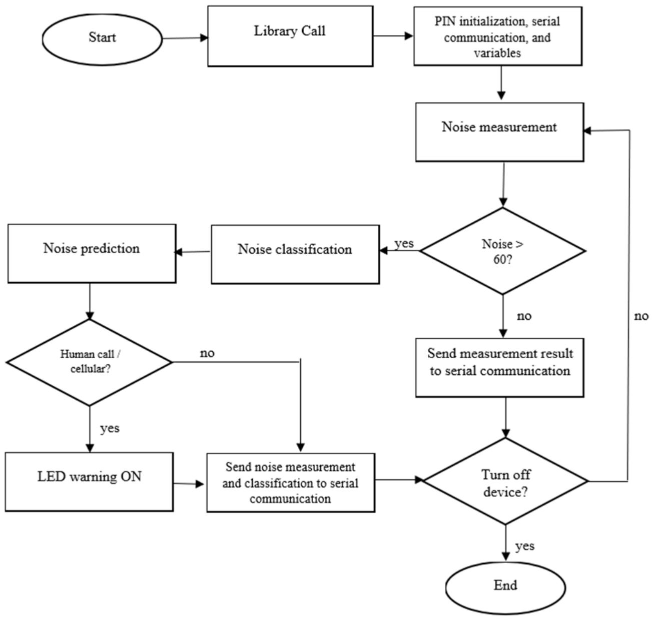

Fig. 2 Noise measurement and classification system

The AudioClassification library was created using Edge Impulse Studio [20]. This library is generated from machine training that generates a classification model based on the training carried out. In creating a classification model, a prior invocation of libraries is required in training. Then, a dataset will be loaded with 1071 sound samples divided into five categories called falling objects containing 216 sound samples representing the sounds of falling objects. Human contain 246 sound samples that represent noises coming from humans. A cell phone contains 225 sound samples, a collection of noise sounds from a cell phone. The horn contains 198 sound samples which are a class containing noise sounds caused by vehicle horns. The siren contains 186 sound samples, a type of sound produced by the sirens of ambulance, police, or fire engines. The fallingObj category contains sounds obtained from live recordings of falling objects by the author. The Phone category contains mobile phone voices obtained from open media such as YouTube. The Siren, Human, and Horn categories contain sounds taken from the UrbanSound8K dataset by sorting out sounds relevant to library conditions. Furthermore, sound wave extraction will be carried out aimed at improving the accuracy of the training results. The sound waves used for classification training are not recommended to be used directly because they will result in poor accuracy [21]. Then, after the extraction of sound waves, training is immediately carried out using the Convolutional Neural Network algorithm. The algorithm is made from several hidden layers to make it easier for the machine to recognize the type of sound expected. The hidden layers used are reshaped layer, two Conv/pool layers, flatten layer, a dropout, a dense layer, and drop out again. The flatter layer is true, the epoch used is 1000, and the learning rate parameter used is 0.005. After the training and testing are completed, the model will finally be saved and converted into a C++ library for easy use in programming on hardware.

In the data storage system, this will be done by ESP32-WROOM32U. First, the invocation of the libraries necessary for the running of the program is carried out. After calling the library, a serial communication initialization will be carried out to retrieve data from the Arduino Nano 33 BLE Sense, and initialize the variables and functions needed to be able to connect with WIFI such as SSID and password from the WIFI you want to connect. Furthermore, ESP32 will wait for the data sent from Arduino Nano until the data is received then the data will be sent to the server that was initialized at the beginning. The device will keep repeating the previously mentioned stages until the device is turned off. In addition to the configuration performed on the ESP32, it also needs configuration for the server to save the data to the database.

The database needs to be initialized to configure the MySQL database's table name, username, and password. In addition, there is also a variable initialization that will store data from ESP32. Furthermore, it will wait for a request from the hardware; when there is a POST request, it will be checked whether the API key owned is appropriate or not. This is necessary to avoid the entry of unwanted data from other parties. The received data will be sent to the MySQL database if the key is appropriate. Monitoring Website is a website that functions to display data statistics obtained from noise monitoring and classification.

III. Result and Analysis

The website functions to display data statistics obtained from noise monitoring and classification. A summary of the data will be displayed on the website. The dashboard of the website is shown in Fig. 3.

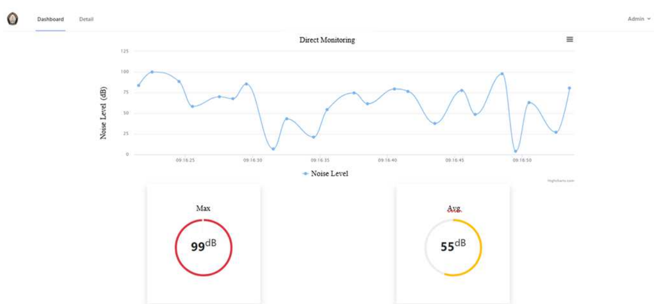

Fig. 3 Dashboard View of The Website

The monitoring system provides a login page used by admin and dashboard page to see a graph of the monitoring being carried out, the maximum data, and the average monitoring of the day. It also has a detailed page to see a summary graph of all monitoring carried out and the maximum, average, and highest-year data of the entire monitoring. Users can also see the details per year, month, week, and day.

A. Noise Monitoring System Distance Testing

Testing the noise monitoring system aims to see how it performs in monitoring the noise around it. Noise monitoring is done by taking noise measurements against the distance from the sound source. This test aims to determine how the DFRobot Analog Sound Level Meter sensor can measure sound noise at varying distances. One sound sample will be used, compared to the percentage loss from the initial noise read at a distance of 0 cm until a specific distance change is made. The calculation of the loss percentage can be defined by equation 1.

$$Loss = \frac{noise\ with\ x\ distance}{noise\ starting\ point} \times 100\% \qquad (1)$$

TABLE I. Noise Monitoring Systems Distance Testing

No.	Volume	Distance	Noise	Loss
1.	20 %	0 cm	90.4 dB	0%
2.		10 cm	78.5 dB	13,1%
3.		20 cm	69.6 dB	23,0%
4.		30 cm	64.5 dB	28,7%
5.		40 cm	60.6 dB	32.9%
6.		50 cm	60.3 dB	33,3%
7.		60 cm	59.9 dB	33,7%
8.		70 cm	59.8 dB	33,8%
9.		80 cm	58.7 dB	35,1%
10.		90 cm	58.3 dB	35,6%
11.		100 cm	57.7 dB	36,1%

The trial was conducted using one constant sound sample with a speaker volume of 20%, as seen in Table I. From the test, the initial noise at a distance of 0 cm was 90.4 dB. Then a shift of length of 10 cm is carried out. This can be used as a reference for the optimal measurement distance that can be done by the DFRobot Analog Sound Level Meter sensor.

B. Noise Monitoring System Data Delivery Testing

In testing the IoT system, measurements of the performance of receiving and sending data to the server will be carried out on the ESP32-WROOM32U board. Some aspects that will be tested include the accuracy and delay of data transmission. Data transmission accuracy can be defined as how much data is sent versus the amount of data received. Delivery accuracy can be formulated in equation 2

$$Accuracy = \frac{data\ accepted}{data\ delivered} \times 100\% \qquad (2)$$

Delivery accuracy testing needs to be done because when serial communication is carried out between Arduino Nano BLE Sense and ESP32-WROOM32U, there is a condition called lag that causes some data sent by Arduino to be received simultaneously by ESP32 which causes only 1 data to be sent to the server.

Delay is the time distance from data transmission to being received by the time during the data transmission process. Delay can also be defined as the time it takes from the sender to get to the recipient. Calculating the average delay can be done by dividing the total delivery time by the data received by the destination device with equation 3. The results of the accuracy and delay tests can be seen in Table II.

$$Delay = \frac{total\ time\ for\ sending\ data}{total\ accepted\ data} \times 100\% \quad (3)$$

TABLE II. DATA DELIVERY IN IOT SYSTEM TESTING

No.	Time Interval	Total Data Sent	Data Received	Accuracy (%)	*Delay* (ms)
1.	1 Minute	30	20	50%	3000 ms
2.	10 Minutes	300	159	53%	3774 ms
3.	30 Minutes	900	475	53%	3789 ms
4.	60 Minutes	1800	932	52%	3863 ms
Average				52%	3607 ms

Table II shows an average of 52% data accuracy and an average 3607 ms delay in the data delivery testing. Based on the delay column, sometimes there is a delay of approximately 3-4 seconds from the data send until the data received.

C. System-Wide Testing

This testing mechanism consists of two parts; the first is to check the CNN algorithm used in the library monitoring system in classifying the noise. The second one is to check the system's data flow from the input to the noise monitoring system.

In the first testing process, after the system builds using the CNN, the accuracy, F1 score, precision, and recall will be calculated based on the five noise categories in edge impulse studio, as shown in Table III.

TABLE III. ACCURACY, F1, PRECISION, AND RECALL RESULT

Confusion Matrix Parameter	Falling Object	Horn	Human	Cell Phone	Siren
Accuracy	68.3%	90.8%	93.8%	93%	68%
F-1	0.8	0.92	0.78	0.8	0.85
Precision	0.96	0.94	0.67	0.98	0.81
Recall	0.68	0.91	0.93	0.68	0.9

The test result showed that the system's average accuracy is 82.78%. As shown in Table III, horn, human, and cell phone sounds have a high accuracy value compared to falling objects and siren sounds.

The second testing process is testing the system built with two microcontrollers. The test was carried out by simulating the activities that occurred in the library with the distance of the tool to the user is 50 cm and it carried out for approximately 1 minute for each simulation. Testing is used to determine the system's capabilities starting from monitoring noise, classifying, storing, and displaying data, as shown in Table IV.

Fig. 4 also shows one of the scenarios where the system will notify the user when the sound input is greater than the threshold given. In the scenario, given one of the human sound which level is greater than the threshold. The system will process the input and provide a warning in the red LED.

Fig. 4 The Library Noise Monitoring System's Warning Sign

TABLE IV. NOISE MONITORING SYSTEMS TESTING

Simulation	Qualitative Conditions	Noise Monitoring	Classification	Data Retention	*Website*
Silent state, there is only the sound of buzzing fans and air conditioners.	Calm	35-43 dB	-	The majority of important data is stored	Data may appear on the *website*
Chat in a fairly small voice	Calm	41-55 dB	-	The majority of important data is stored	Data may appear on the *website*
Laughs loud enough	Noisy	55-73 dB	Man, Falling Objects	The majority of important data is stored	Data may appear on the *website*
Coughing sound	Quite Noisy	53-68 dB	Humans, Falling Objects, Cell Phones	The majority of important data is stored	Data may appear on the *website*
Dropping objects	Quite Noisy	51-65 dB	Falling Objects, Cell Phones	The majority of important data is stored	Data may appear on the *website*
Horn sound	Noisy	58-85 dB	Horns, Sirens, Cell Phones	The majority of important data is stored	Data may appear on the *website*
Chat quite loudly	Noisy	57-75 dB	Man, Phone, Falling Object	The majority of important data is stored	Data may appear on the *website*
Phone ringing	Noisy	58-77 dB	Phone, Siren	The majority of impor-	Data may appear on the

				tant data is stored	*web-site*
Siren sound	Noisy	55-78	Sirens, Telephones, Horns	The majority of impor-tant data is stored	Data may appear on the *web-site*

Based on Table IV, from those 1 minute, some conditions are not right. However, the main function of recognizing human noise sounds is good enough because it can recognize some sounds produced by humans and cell phone.

IV. Conclusion

From the research that has been carried out, the system can give a noise warning when a human or cell phone sound exceeds the threshold with an average of 82.78% classification accuracy and an ideal distance from the sound source, as far as 30-100 cm. It is also able to monitor the noise in its surroundings. In IoT systems that utilize ESP32-WROOM32U hardware, they have excellent capabilities in transmitting data. Still, for data receipt from serial communication, there is a delay of approximately 3-4 seconds. Improving the accuracy of delivery can be done by increasing the delivery lag time performed by Arduino Nano 33 BLE Sense. Still, it will make noise monitoring less accurate due to the long lag.

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Noise Monitoring System Development in a Library Based on The Internet of Things

by Adian Fatchur Rochim

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***Abstract*— a library is one of the important places for the community, especially students. However, not all visitors know the library's rules and act arbitrarily to create noise that can disturb other visitors. This research is focused on the development of classifying and monitoring the unwanted noise in the library. The system is built with the Arduino Nano 33 BLE microcontroller using the DFROBOT Analog Sound Level Meter Sense sensor and ESP32-WROOM32U. The system is equipped with classification capabilities resulting from machine training using the Convolutional Neural Network algorithm by utilizing a Feature Extraction. The system is then connected to Wi-Fi to be integrated with websites created using the PHP programming language and the Laravel framework. Data from the monitoring will be stored in the MySQL database. The system can give a noise warning when a human or cell phone sound exceeds the threshold with an average of 82.78% classification accuracy and an ideal distance from the sound source, as far as 30-100 cm.**

Keywords—Noise Monitoring System, Internet of Things, Feature Extraction, CNN.

I. Introduction

A library is needed for students, lecturers, and researchers, which makes it an alternative place to search library sources and a place for group scientific activities. But, visitors often do not understand the ethics of being in the library room. Visitors who do not understand the rules make rowdy noises and speak too loudly, causing noise to other visitors and interfering with the concentration of reading or discussions being carried out. This is one of the main reasons for complaints submitted by library visitors to librarians. Librarians, as authorized officers, need to remind visitors to be calm and not to cause noise. Librarians must also carry out their work, from collecting new book data to maintaining books in the library. Of course, continuous warnings to different visitors will significantly interfere with the librarian's work [1][2]. Therefore, a system is needed that can automatically detect and simultaneously provides a notification signal to visitors not to make noise. One way to reduce noise in the library is to use a system that alerts visitors when it reaches the specified noise threshold. However, The problem found when creating a noise monitoring system is in the noise itself.

Sound is a condition of changing pressure or can also be described as the speed of oscillations or frequencies in Units of Hertz (Hz). There are three types of sounds, namely those that have frequencies between 20Hz to 20 kHz (can be heard by human ears), above 20 kHz, and below 20Hz (both of which cannot be heard by human ears) [3].

Noise can be interpreted as unwanted, disliked, and disturbing sounds or can also be interpreted as complex sound vibrations that have various frequencies and amplitudes that are periodic/non-periodic. Noise can be measured logarithmically by units of decibels (dB) which is the energy currency of the unity of the area. Noise can be classified into three types: engine, vibration, air movement, gas, and liquid [4].

The human sense of hearing can listen to sounds within 20 Hz-20kHz. Humans can easily distinguish the types of sounds without making any additional effort. If the machine wants to have the same ability to distinguish the types of sounds, extra effort must be made because the machine has a problem that is often called *machine hearing. Feature extraction* [5] can help the machine recognize sounds.

The system must distinguish which noise is produced by visitors and which is produced by the library environment. Adding Artificial Intelligence to the system allows it to recognize the noise around it. One of the branches of Artificial Intelligence is Machine Learning. Machine Learning has now arrived at the implementation of existing embedded systems [6][7]. Several studies were done on using artificial intelligence in voice recognition, and all use CNN as the algorithm [9]–[11]. However, The application of Artificial Intelligence to embedded systems is limited when operating on devices with limited capabilities [8].

There is also a study about noise monitoring systems in the library using an Arduino Uno-based sound noise detection and warning system made at the Amikom Purwokerto University Library. In the system, the GY-MAX4466 sensor was used as a noise sensor, and a 128x64 pixel OLED screen and speakers functioned as issuing warnings in the form of sound to library visitors around it [12]. The research also built a noise detection system in Arduino-based libraries. The system is built using an LM393D sensor and is connected to an LCD that will display the text and speakers used as sound output. The research built a library visitor noise detection tool with the ES8266 microcontroller. The microcontroller is connected to a KY-037 sensor and an LCD [13]. The study also built a website as a medium for monitoring and controlling noise detection [14].

These studies are similar because they built a monitoring system using a microcontroller connected to a sound sensor. However, no one has researched how the system can distinguish the noise produced by library visitors from the noise coming from the environment around the library. For this reason, this study has the main objective of how a system built on a microcontroller can have artificial intelligence that can identify sound noise.

II. Research Method

This research was built using several steps. Which are system concept, analysis of requirements, system design, system implementation, and system testing.

A. System concept

The system has a working principle of being able to receive sound input from the surroundings. The sound enters through 2 components, namely the noise sensor and microphone. The typical conversation or the minimum audible sound level is 60dB [15][16]. When the sound around the device exceeds the threshold of 60 dB, the system will run the microphone sensor and perform sound classification. Sounds will be classified into five categories: falling object, horn, human, cell phone, and siren. When the classification indicates a category of human or mobile phones, the notification LED will light up to commemorate the people around it. All tool readings in decibel values and classification results will be sent to the database, and a data summary will be displayed on the website.

B. Analysis of requirement

This system is built using two microcontrollers, Arduino Nano BLE Sense [17] as a classification microcontroller and ESP32-WROOM32U [18] as a microcontroller that connects with databases. Arduino Nano BLE Sense which already has a microphone type MP34DT05, is also connected to a noise sensor made by DF Robot with an Analog Sound Level Meter type and an indicator LED that functions as an indicator when the device is on and a warning LED for users around it. DF Robot Analog Sound Level Meter is a decibel measuring sensor produced by DF Robot. This sensor is also known as a decibel meter or *noise meter,* which measures the noise around the sensor [19]. The feature extraction results will be used for input in training using the Convolutional Neural Network (CNN) algorithm [10]. The data received from these sensors will enter the Arduino communication serial, which will be forwarded to the ESP32.

ESP32 will be connected to a previously determined WIFI so that it can communicate with the server. The data from Arduino nano sent to ESP32 is in the form of noise sensor reading data, and the classification results will be forwarded to the server to be stored in the database. So, data from the tool that has entered the database will be able to be displayed on the website. On the website, data can be displayed by year, month, and day. There is also an option to display reading data directly.

C. System design

Based on the analysis of requirements before, the system is shown in Fig. 1. When the device is connected to a power source, it immediately reads the required library. Next, the initialization of the pins, serial communication, and required variables will be carried out. Then, it is also checked whether the microphone is working or not. Otherwise, it will display an error warning. Then, the pin connected to the LED indicator will be turned on as long as the tool is on. It will then read the data from the noise sensor and go into conditioning. When the noise sensor reading exceeds the threshold of 60 decibels, a voice reading will be carried out through the microphone. Then the noise level reading and classification will be sent to the communication serial to be accepted on the ESP32. If the noise is not more than 60 decibels, then only the noise level measurement results are transmitted to the communication serial. This Noise Measurement and Sound Classification software will be embedded on the Arduino Nano 33 BLE Sense board with a flowchart, as shown in Fig. 2.

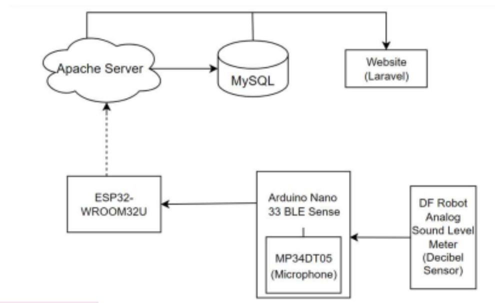

Fig. 1 Diagram Block

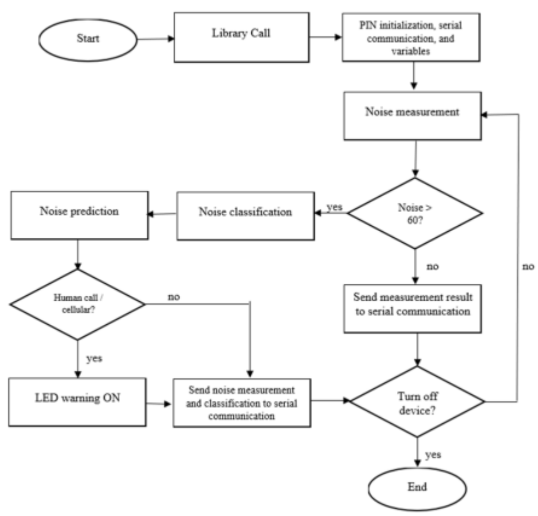

Fig. 2 Noise measurement and classification system

The AudioClassification library was created using Edge Impulse Studio [20]. This library is generated from machine training that generates a classification model based on the training carried out. In creating a classification model, a prior invocation of libraries is required in training. Then, a dataset will be loaded with 1071 sound samples divided into five categories called falling objects containing 216 sound samples representing the sounds of falling objects. Human contain 246 sound samples that represent noises coming from humans. A cell phone contains 225 sound samples, a collection of noise sounds from a cell phone. The horn contains 198 sound samples which are a class containing noise sounds caused by vehicle horns. The siren contains 186 sound samples, a type of sound produced by the sirens of ambulance, police, or fire engines. The fallingObj category contains sounds obtained from live recordings of falling objects by the author. The Phone category contains mobile phone voices obtained from open media such as YouTube. The Siren, Human, and Horn categories contain sounds taken from the UrbanSound8K dataset by sorting out sounds relevant to library conditions. Furthermore, sound wave extraction will be carried out aimed at improving the accuracy of the training results. The sound waves used for classification training are not recommended to be used directly because they will result in poor accuracy [21]. Then, after the extraction of sound waves, training is immediately carried out using the Convolutional Neural Network algorithm. The algorithm is made from several hidden layers to make it easier for the machine to recognize the type of sound expected. The hidden layers used are reshaped layer, two Conv/pool layers, flatten layer, a dropout, a dense layer, and drop out again. The flatter layer is true, the epoch used is 1000, and the learning rate parameter used is 0.005. After the training and testing are completed, the model will finally be saved and converted into a C++ library for easy use in programming on hardware.

In the data storage system, this will be done by ESP32-WROOM32U. First, the invocation of the libraries necessary for the running of the program is carried out. After calling the library, a serial communication initialization will be carried out to retrieve data from the Arduino Nano 33 BLE Sense, and initialize the variables and functions needed to be able to connect with WIFI such as SSID and password from the WIFI you want to connect. Furthermore, ESP32 will wait for the data sent from Arduino Nano until the data is received then the data will be sent to the server that was initialized at the beginning. The device will keep repeating the previously mentioned stages until the device is turned off. In addition to the configuration performed on the ESP32, it also needs configuration for the server to save the data to the database.

The database needs to be initialized to configure the MySQL database's table name, username, and password. In addition, there is also a variable initialization that will store data from ESP32. Furthermore, it will wait for a request from the hardware; when there is a POST request, it will be checked whether the API key owned is appropriate or not. This is necessary to avoid the entry of unwanted data from other parties. The received data will be sent to the MySQL database if the key is appropriate. Monitoring Website is a website that functions to display data statistics obtained from noise monitoring and classification.

III. Result and Analysis

The website functions to display data statistics obtained from noise monitoring and classification. A summary of the data will be displayed on the website. The dashboard of the website is shown in Fig. 3.

Fig. 3 Dashboard View of The Website

The monitoring system provides a login page used by admin and dashboard page to see a graph of the monitoring being carried out, the maximum data, and the average monitoring of the day. It also has a detailed page to see a summary graph of all monitoring carried out and the maximum, average, and highest-year data of the entire monitoring. Users can also see the details per year, month, week, and day.

A. Noise Monitoring System Distance Testing

Testing the noise monitoring system aims to see how it performs in monitoring the noise around it. Noise monitoring is done by taking noise measurements against the distance from the sound source. This test aims to determine how the DFRobot Analog Sound Level Meter sensor can measure sound noise at varying distances. One sound sample will be used, compared to the percentage loss from the initial noise read at a distance of 0 cm until a specific distance change is made. The calculation of the loss percentage can be defined by equation 1.

$$Loss = \frac{noise\ with\ x\ distance}{noise\ starting\ point} \times 100\% \quad (1)$$

TABLE I. Noise Monitoring Systems Distance Testing

No.	Volume	Distance	Noise	Loss
1.	20 %	0 cm	90.4 dB	0%
2.		10 cm	78.5 dB	13,1%
3.		20 cm	69.6 dB	23,0%
4.		30 cm	64.5 dB	28,7%
5.		40 cm	60.6 dB	32.9%
6.		50 cm	60.3 dB	33,3%
7.		60 cm	59.9 dB	33,7%
8.		70 cm	59.8 dB	33,8%
9.		80 cm	58.7 dB	35,1%
10.		90 cm	58.3 dB	35,6%
11.		100 cm	57.7 dB	36,1%

The trial was conducted using one constant sound sample with a speaker volume of 20%, as seen in Table I. From the test, the initial noise at a distance of 0 cm was 90.4 dB. Then a shift of length of 10 cm is carried out. This can be used as a reference for the optimal measurement distance that can be done by the DFRobot Analog Sound Level Meter sensor.

B. Noise Monitoring System Data Delivery Testing

In testing the IoT system, measurements of the performance of receiving and sending data to the server will be carried out on the ESP32-WROOM32U board. Some aspects that will be tested include the accuracy and delay of data transmission. Data transmission accuracy can be defined as how much data is sent versus the amount of data received. Delivery accuracy can be formulated in equation 2

$$Accuracy = \frac{data\ accepted}{data\ delivered} \times 100\% \quad (2)$$

Delivery accuracy testing needs to be done because when serial communication is carried out between Arduino Nano BLE Sense and ESP32-WROOM32U, there is a condition called lag that causes some data sent by Arduino to be received simultaneously by ESP32 which causes only 1 data to be sent to the server.

Delay is the time distance from data transmission to being received by the time during the data transmission process. Delay can also be defined as the time it takes from the sender to get to the recipient. Calculating the average delay can be done by dividing the total delivery time by the data received by the destination device with equation 3. The results of the accuracy and delay tests can be seen in Table II.

$$Delay = \frac{total\ time\ for\ sending\ data}{total\ accepted\ data} \times 100\% \quad (3)$$

TABLE II. DATA DELIVERY IN IOT SYSTEM TESTING

No.	Time Interval	Total Data Sent	Data Received	Accuracy (%)	*Delay* (ms)
1.	1 Minute	30	20	50%	3000 ms
2.	10 Minutes	300	159	53%	3774 ms
3.	30 Minutes	900	475	53%	3789 ms
4.	60 Minutes	1800	932	52%	3863 ms
Average				52%	3607 ms

Table II shows an average of 52% data accuracy and an average 3607 ms delay in the data delivery testing. Based on the delay column, sometimes there is a delay of approximately 3-4 seconds from the data send until the data received.

C. System-Wide Testing

This testing mechanism consists of two parts; the first is to check the CNN algorithm used in the library monitoring system in classifying the noise. The second one is to check the system's data flow from the input to the noise monitoring system.

In the first testing process, after the system builds using the CNN, the accuracy, F1 score, precision, and recall will be calculated based on the five noise categories in edge impulse studio, as shown in Table III.

TABLE III. ACCURACY, F1, PRECISION, AND RECALL RESULT

Confusion Matrix Parameter	Falling Object	Horn	Human	Cell Phone	Siren
Accuracy	68.3%	90.8%	93.8%	93%	68%
F-1	0.8	0.92	0.78	0.8	0.85
Precision	0.96	0.94	0.67	0.98	0.81
Recall	0.68	0.91	0.93	0.68	0.9

The test result showed that the system's average accuracy is 82.78%. As shown in Table III, horn, human, and cell phone sounds have a high accuracy value compared to falling objects and siren sounds.

The second testing process is testing the system built with two microcontrollers. The test was carried out by simulating the activities that occurred in the library with the distance of the tool to the user is 50 cm and it carried out for approximately 1 minute for each simulation. Testing is used to determine the system's capabilities starting from monitoring noise, classifying, storing, and displaying data, as shown in Table IV.

Fig. 4 also shows one of the scenarios where the system will notify the user when the sound input is greater than the threshold given. In the scenario, given one of the human sound which level is greater than the threshold. The system will process the input and provide a warning in the red LED.

Fig. 4 The Library Noise Monitoring System's Warning Sign

TABLE IV. NOISE MONITORING SYSTEMS TESTING

Simulation	Qualitative Conditions	Noise Monitoring	Classification	Data Retention	*Website*
Silent state, there is only the sound of buzzing fans and air conditioners.	Calm	35-43 dB	-	The majority of important data is stored	Data may appear on the *website*
Chat in a fairly small voice	Calm	41-55 dB	-	The majority of important data is stored	Data may appear on the *website*
Laughs loud enough	Noisy	55-73 dB	Man, Falling Objects	The majority of important data is stored	Data may appear on the *website*
Coughing sound	Quite Noisy	53-68 dB	Humans, Falling Objects, Cell Phones	The majority of important data is stored	Data may appear on the *website*
Dropping objects	Quite Noisy	51-65 dB	Falling Objects, Cell Phones	The majority of important data is stored	Data may appear on the *website*
Horn sound	Noisy	58-85 dB	Horns, Sirens, Cell Phones	The majority of important data is stored	Data may appear on the *website*
Chat quite loudly	Noisy	57-75 dB	Man, Phone, Falling Object	The majority of important data is stored	Data may appear on the *website*
Phone ringing	Noisy	58-77 dB	Phone, Siren	The majority of impor-	Data may appear on the

				tant data is stored	*website*
Siren sound	Noisy	55-78	Sirens, Telephones, Horns	The majority of important data is stored	Data may appear on the *website*

Based on Table IV, from those 1 minute, some conditions are not right. However, the main function of recognizing human noise sounds is good enough because it can recognize some sounds produced by humans and cell phone.

IV. Conclusion

From the research that has been carried out, the system can give a noise warning when a human or cell phone sound exceeds the threshold with an average of 82.78% classification accuracy and an ideal distance from the sound source, as far as 30-100 cm. It is also able to monitor the noise in its surroundings. In IoT systems that utilize ESP32-WROOM32U hardware, they have excellent capabilities in transmitting data. Still, for data receipt from serial communication, there is a delay of approximately 3-4 seconds. Improving the accuracy of delivery can be done by increasing the delivery lag time performed by Arduino Nano 33 BLE Sense. Still, it will make noise monitoring less accurate due to the long lag.

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