AI BASED INSECT DETECTION AND ALERT SYSTEM USING INTERNET OF THINGS

MRS.S.BALMMAL@GEETHA
Assistant Professor
Department of ECE,
Francis Xavier Engineering College,
Tirunelveli, India

Murugesan K,
Department of ECE,
Francis Xavier Engineering College,
Tirunelveli, India

Prasanth K,
Department of ECE,
Francis Xavier Engineering College,
Tirunelveli, India

Mohamed Farith J,
Department of ECE,
Francis Xavier Engineering College,
Tirunelveli, India

Madhan M,
Department of ECE ,
Francis Xavier Engineering College,
Tirunelveli, India

Abstract – **Insect infestation is a major problem faced by farmers worldwide, causing significant damage to crops and leading to huge financial losses. In this project, we propose an AI-based insect detection system that uses computer vision techniques to detect insects in images of crops. The system uses deep learning algorithms to identify insects and classify them into different categories. The proposed system is tested on a dataset of images of crops infested with various insects and achieves high accuracy in detecting and classifying different types of insects.The proposed system can be integrated into existing farming systems to help farmers detect insect infestation early and take appropriate measures to control it.This report details the various techniques used to build the system, the dataset used for training and testing, the performance of the system, and future work.Strategic agriculture product storage strategies are required since agricultural product production is unpredictable, ensuring that there are always enough supplies available. In contrast, insects in agricultural fields result in contamination and infestation, which lower grain quality and quantity.Early detection and ongoing monitoring must be put in place to stop these issues. Numerous types of research have demonstrated the viability of acoustic technologies for insect detection and monitoring using different sound parameterization and classification methods. In our project, we employ an interrupt sensor to identify the presence of insects. then after that, we use a deep learning technique to analyze and categorize the audio.**

Keywords: Arduino UNO, ECG sensor, Temperature sensor, pulse Oximeter sensor, Node MCU (Wi-Fi Module)

I. INTRODUCTION

Pest and insects can affect the agricultural production of any country and can cause problems for any developed and developing country. Especially some of the countries of South-Asia like India where more than 60% of the population living in rural areas are dependent on agriculture for their income. Pest infected crops can create a huge setback to their economic and social planning. In the scenario of novel COVID-19 Pandemic, people are returning to their native places for earning daily needs and working in the agriculture sector. Crop infection is a crucial problem in agriculture. Recently some of the states in India like Rajasthan, Gujarat and Punjab suffered locust attack which led to more worsening of conditions. Crop pests are a significant challenge to agriculture worldwide, causing extensive damage to crops and leading to significant economic losses. Here are some of the most common crops that are affected by pests:Maize/Corn: Maize is a staple food crop for many countries and is often affected by pests such as the fall armyworm, maize stalk borer, and corn earworm. These pests can cause significant damage to the crop, leading to reduced yields and lower quality produce.Rice: Rice is a major food crop in many parts of the world and is vulnerable to pests such as the rice stem borer, rice leaf folder, and the brown planthopper. These pests can damage the crop by feeding on the leaves and stems, leading to reduced yields and lower quality produce.

II. LITERATURE SURVEY

1. "A Systematic Review on Automatic Insect Detection Using Deep Learning""Ana Cláudia Teixeira"[2023] have proposed a paper regarding insect pests are the primary reason for reduced crop yield and quality. As an alternative, integrated pest management has been devised to enhance insect pest control, decrease the excessive use of pesticides, and enhance the output and quality of crops.

2. "A Novel Resource-Constrained Insect Monitoring System based on Machine Vision with Edge AI""Amin Kargar"[2022] have proposed a paper regarding effective insect pest monitoring is a vital component of Integrated Pest Management (IPM) strategies. It helps to support crop productivity while minimising the need for plant protection products.This paper describes the development of a smart pest monitoring system, developed in accordance with specific requirements associated with the agricultural sector.
3. "An Automated Pest Identification and Classification in Crops Using Artificial Intelligence—A State-of-Art-Review" "Jose Mekha"[2022]This article presents a comprehensive report of seminal works that have been consequential in identifying infestation in crops as the in pest detection and classification by various researchers.

4. "Artificial Intelligence in Agriculture: A Literature Survey""Starlin Daniel Raj"[2022] have proposed the maximising the yield with high quality and lesser chemical influence, have been the hopes from consumer perspective. Such an application of AI in Agriculture, will prevent lives from natural disasters, can alert or warn about the calamities and take the safest route

5. "A Deep-Learning-Based Detection Approach for the Identification of Insect Species of Economic Importance""Michael Tannous"[2021] have proposed a paper regarding Artificial Intelligence (AI) and automation are fostering more sustainable and effective solutions for a wide spectrum of agricultural problems.

6. "Plant diseases and pests detection based on deep learning""Xuewei Wang"[2021] have proposed a paper regarding deep learning has made breakthroughs in the feld of digital image processing, far superior to traditional methods. How to use deep learning technology to study plant diseases and pests identifcation has become a research issue of great concern to researchers

7. "Research on Recognition Model of Crop Diseases and Insect Pests Based on Deep Learning in Harsh Environments""Y.Ai,C.Sun,J.Tie and X.Cai"[2020] have proposed a paper regarding agricultural diseases and insect pests are one of the most important factors that seriously threaten agricultural production. Early detection and identification of pests can effectively reduce the economic losses caused by pests. In this paper, convolution neural network is used to automatically identify crop diseases. The data set comes from the public data set of the AI Challenger Competition in 2018, with 27 disease images of 10 crops. In this paper, the Inception-ResNet-v2 model is used for training. The cross-layer direct edge and multi-layer convolution in the residual network unit to the model.

8. "Remote Insects Trap Monitoring System Using Deep Learning Framework and IoT""Balakrishnan Ramalingam"[2020] have proposed the paper a real-time remote insect trap monitoring system and insect detection method using IoT and Deep Learning (DL) frameworks. The remote trap monitoring system framework is constructed using IoT and the Faster RCNN (Region-based Convolutional Neural Networks) Residual neural Networks 50 (ResNet50) unified object detection framework.

9. "A Research on Application of Human-Robot Interaction using Artifical Intelligence""L.Mary Gladence, Vakula C.K , Mercy Paul Selvan, T.Y.S.Samhita"[2019]This paper centers around a training technique dependent on the common human-PC communication. The task is to teach the Robot to compose by giving three unique information sources like Voice order, Camera based Video info or utilizing MEMS equipment interface utilizing Zigbee. Voice direction can be perceived utilizing Android application. Motion will perceived utilizing framework camera, utilizing PCA calculation framework will order the pictures. MEMS sensor is wired equipment hardware which will contain the quantity of likelihood blend to order the robot.

10. "Home and Office Automation System Using Human Activity Recognition""Mary Gladence.L, Hari Haran Sivakumar, Gobinath Venkatesan and Shanmuga Priya.S"[2017] have proposed the paper regarding motion detection like if a person enters into the room and sits/stands/lies down then the fan or AC should be automatically turned on. If a person comes and walks away or keeps roaming around, then they should not be turned on thus saving energy.

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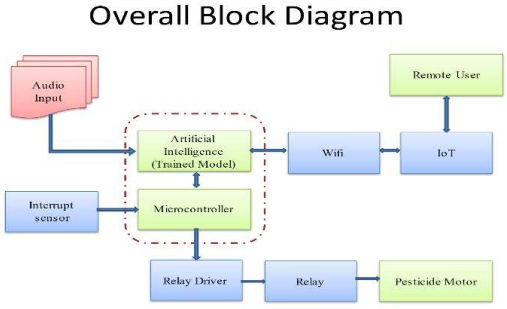
II. METHODOLOGY

Collecting sound data: The first step is to collect sound data using a sound sensor. The sound sensor can be placed in the area where the insects are likely to be found. The sensor will capture the sound made by the insects, which will be used as input data for the ANN network.
Preprocessing the sound data: The sound data collected by the sensor needs to be preprocessed before it can be used by the ANN network. This preprocessing involves filtering out any noise or background sounds that may interfere with the insect sounds.
Training the ANN network: Once the sound data has been preprocessed, it can be used to train the ANN network. The network will be trained to recognize the specific sound patterns made by different types of insects. This training process involves feeding the ANN network with labeled sound data and adjusting the weights and biases of the network until it can accurately classify the sounds.
Testing the ANN network: After the ANN network has been trained, it needs to be tested to see how well it can classify new insect sounds. This involves using a set of test data that the network has not seen before and evaluating its accuracy.
Implementing the system: Once the ANN network has been trained and tested, it can be implemented in a system for insect detection. This system will use the sound sensor to capture insect sounds, process the sound data, and use the trained ANN network to classify the sounds and identify the type of insect.

BLOCK DIAGRAM



III. EXIXTING SYSTEM

A deep learning-based object detection algorithm is trained to identify the insects on the trap. Generally, most of the insects are small in size. So, insect detection algorithms need a small object detection capability. In terms of detecting insect presence in an image, the insects cover only a small number of pixels in an image, i.e., the area of interest in an image when detecting an insect is very small.

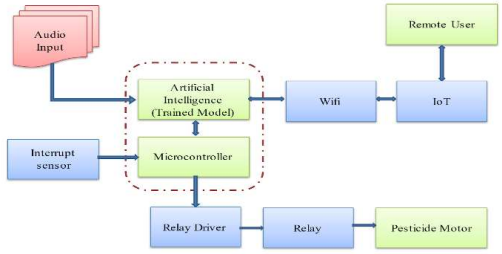
In any object detection algorithm, extracting the features from small objects is particularly challenging because there is a good chance that smaller objects might get overlapped or too pixelated to extract any useful information. Moreover, information extracted from smaller objects could be lost as it is passed on through multiple layers of feature extractor [36]. Furthermore, the information extracted about smaller objects is very limited as these objects appearance is very restricted in a training image. Small objects' limited appearance leading to an incomprehensible feature extraction process could contribute to additional errors in detection results.analog values that are sensed by the different sensors are then given to a microcontroller attached to it. The microcontroller processes these analog signal values of health parameters separately and converts it to digital values using ADC converter. Now, the digitalized values from more than one microcontroller are sent to the central PMS. Each of the sensors attached microcontroller with a transceiver will act as a module which has its own unique ID. PC of the Central PMS. The gateway is attached to the PC i.e. Central PMS which is situated in the medical center, is capable for selecting different patient IDs and allowing the gateway to receive different physical parameter values the patient specified by the ID. The software designed using Graphical User Interface (GUI) can operate on different physical parameters of each patient, consecutively with a specified time interval for each patient.

Some of the drawbacks are :Limited Scalability: Although an AI-based insect detection system can be deployed on a large scale, it may be challenging to scale up the system without encountering technical issues. This can limit its usefulness in large-scale agricultural operations.High Cost: Implementing an AI-based insect detection system using images can be expensive, particularly if deployed on a large scale. The cost of purchasing and maintaining the required equipment, as well as the cost of training the AI algorithm, can be significant.Using camera for insect detection may high cost for implementation but insect detection using sound sensor makes the implementation cost low and it give accurate result.We use IR sensor for insect motion detection and relay for triggering the pesticide machine automatically when the insect detected. Environmental Factors: Cameras are sensitive to environmental factors such as lighting, weather conditions, and image distortion, which can affect the accuracy of the system. These factors may also interfere with the transmission of image data to the central processing unit.

IV.PROPOSED SOLUTION

An AI-based insect detection system using IoT and sound sensors is a technology that can revolutionize the way we detect and manage insect populations in various settings. The system works by using sound sensors to detect the sounds produced by insects in a specific area and then analyzing them using an artificial intelligence algorithm to identify the specific type of insect.This system has many potential benefits, including the ability to detect and identify insects quickly and accurately, which can help prevent crop damage and reduce the use of pesticides. Additionally, the use of IoT technology allows for remote monitoring and real-time data collection, which can help farmers and pest control professionals make more informed decisions about pest management.The AI-based algorithm used in this system is trained on a large dataset of insect sounds, allowing it to identify the unique sound patterns produced by different types of insects. This helps ensure accurate and reliable insect detection, even in noisy or challenging environments.

Overall Block Diagram



This project proposes Many different technologies were used to control the pests. Previously it was very difficult to determine the pest using camera's because it has only get the images from certain range but it became very easy to detect the insect by using IR SENSOR and SOUND SENSOR along with ANN (Artificial Neural Networks) architecture.We have already get the binary data of the insects sounds and store it in dataset file.Once the insect movement is detected through the IR sensor then sound sensor looks for the insects sound and get the insect data and it send to the training python code to make the comparison using ANN architecture once the sound matched with the predefined binary sound then it trigger the pesticide motor using relay module and it also shows the insect name in 16x2 LCD display. This project proposes Many different technologies were used to control the pests. Previously it was very difficult to determine the pest using camera's because it has only get the images from certain range but it became very easy to detect the insect by using IR SENSOR and SOUND SENSOR along with ANN (Artificial Neural Networks) architecture.

V.HARDWARE REQUIREMENT

A. Arduino UNO

The Arduino UNO is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins, 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header, and a reset button. The board is programmed using the Arduino software (IDE) and can be used to control a variety of devices and sensors. It is commonly used in projects such as robotics, home automation, and internet of things (IoT) applications.
The Arduino UNO is the board to get started with electronics and coding. If this is your first experience tinkering with the platform, the UNO is the most robust board you can start playing with. The UNO is the most used and documented board of the whole Arduino famil. The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller and developed by Arduino.cc and initially released in 2010.

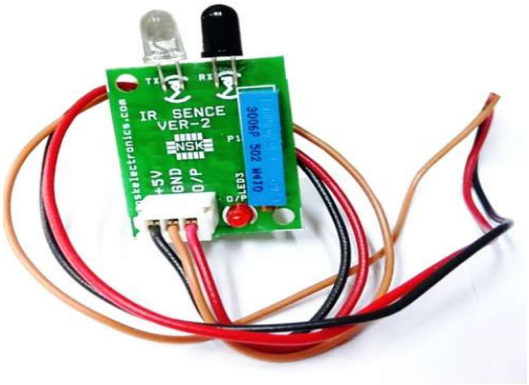
B.Atmega328P

ATmega328P is a high performance yet low power consumption 8-bit AVR microcontroller that's able to achieve the most single clock cycle execution of 131 powerful instructions thanks to its advanced RISC architecture. It can commonly be found as a processor in Arduino boards such as Arduino Fio and Arduino Uno

C.IR Sensor

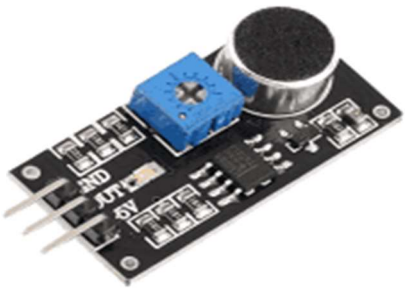
IR sensor is a multipurpose infrared sensor which can be used for obstacle sensing, line sensing, etc. and also as an encoder sensor.The sensor provides a digital output (1 or 0).The sensor outputs a logic one (+3.5V) at the digital output when an object is placed in front of the sensor and logic zero (5V), when there is no object in front of the sensor - 0v.An IR sensor consists of an IR emitter and an IR receiver. The emitter emits infrared radiation, which is then reflected or absorbed by objects in its path. The

receiver detects the reflected or absorbed radiation and produces an electrical signal that is proportional to the intensity of the received radiation.IR sensors are commonly used in a variety of applications such as proximity sensing, object detection, and temperature sensing. For example, they can be used to detect the presence of objects in automated doors, to measure the temperature of a room, or to detect the presence of people or animals in a security system.In addition to their wide range of applications, IR sensors are relatively inexpensive and easy to use. They can be integrated into electronic devices with minimal additional components and can be programmed to respond to specific types of radiation or to trigger certain actions when certain radiation thresholds are reached.



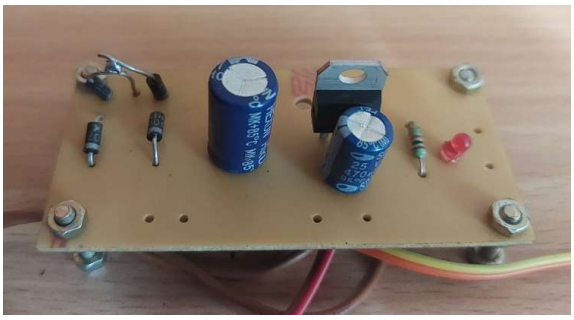
D. Sound Sensor

A sound sensor, also known as a microphone sensor, is a device that can detect sound waves in the surrounding environment. It converts sound waves into an electrical signal that can be processed by electronic circuits or systems.The sensor usually consists of a diaphragm that vibrates in response to sound waves, and a transducer that converts the vibrations into an electrical signal. Sound sensors can be used to detect a wide range of sounds, from low-frequency sounds like thunder to high-frequency sounds like bird songs.In the context of an AI-based insect detection and alert system using IoT, sound sensors can be used to detect the unique sounds that different insect species make. For example, the sound of a mosquito is different from that of a bee.The system can use machine learning algorithms to analyze the sounds and identify the type of insect and its behavior.Overall, sound sensors are useful in a wide range of applications, from detecting the presence of insects to monitoring noise pollution in urban areas. They are commonly used in electronic devices such as smartphones, laptops, and voice assistants.



E.Bridge Rectifier

A bridge rectifier is an electronic component used to convert AC (alternating current) voltage to DC (direct current) voltage. It is made up of four diodes arranged in a bridge configuration, hence the name "bridge rectifier".The bridge rectifier works by allowing current to flow in only one direction through the load, which is typically a capacitor or a load resistor. The diodes in the bridge rectifier are arranged so that when the input AC voltage is positive, current flows through two of the diodes, and when the input voltage is negative, current flows through the other two diodes. This allows the current to always flow in the same direction through the load, resulting in a DC voltageThe output of a bridge rectifier is not a pure DC voltage, but a pulsating DC voltage with ripple. To reduce the ripple, a filter capacitor is usually connected in parallel with the load. The filter capacitor stores charge during the periods when the input voltage is higher than the output voltage, and then discharges during the periods when the input voltage is lower than the output voltage, resulting in a smoother DC voltage.Bridge rectifiers are commonly used in power supplies for electronic devices, as well as in automotive and other applications where DC voltage is required. They are efficient, reliable, and relatively inexpensive, making them a popular choice for a wide range of applications



F.Stepdown Transformer

A step-down transformer is a type of transformer that is designed to reduce the voltage of an AC (alternating current) power source. It works by using two coils of wire wound around a magnetic core. The coil that is connected to the AC power source is called the primary coil, and the coil that is connected to the load is called the secondary coil.When AC voltage is applied to the primary coil, it creates an alternating magnetic field in the core, which in turn induces a voltage in the secondary coil. The ratio of the number of turns in the primary coil to the number of turns in the secondary coil determines the voltage transformation ratio.Step-down transformers are commonly used in electronic devices, power supplies, and electrical appliances to reduce the voltage of the AC power source to a level that is suitable for the device or appliance. They are also used in industrial applications to reduce the voltage of high-voltage power sources to a level that is safe for use in machinery and equipment.Step-down transformers are provide a safe and efficient way to reduce the voltage of AC power sources to a level that is suitable for a wide range of applications.

VI.SOFTWARE REQUIREMENTS

A. Android Studio

Android Studio is the official integrated development environment (IDE) for Google's Android operating system. It is based on the IntelliJ IDEA Java IDE and is built specifically for Android development. Android Studio provides a complete set of tools for developing, testing, and deploying Android apps, including a visual layout editor, code editor, and debugging tools. It also includes a built-in emulator for testing apps on different Android devices and versions. Additionally, it includes a software development kit (SDK) manager, which makes it easy to download and install the latest Android SDKs and other tools. Android Studio also offers built-in support for version control systems such as Git and Subversion, making it easy for developers to collaborate on projects. It is free and open-source and available for Windows, macOS, and Linux.

B .Arduino IDE

The Arduino IDE is open-source and available for Windows, Mac, and Linux operating systems. It is widely used by hobbyists, students, and professionals for a variety of projects, including robotics, home automation, and Internet of Things (IoT) devices. The ease of use and accessibility of the Arduino IDE make it a popular choice among those interested in learning about electronics and programming, and the wide range of projects that can be created using the platform makes it a versatile tool for professionals as well.

One of the key features of the Arduino IDE is the library manager, which allows users to easily import and use pre-existing libraries for specific functions and devices. These libraries provide a set of predefined functions that can be easily called in the code, eliminating the need to write complex code for specific functionality. This feature makes it easy for users to add functionality to their projects, such as connecting to sensors or controlling motors.

C. python IDE

Python is a popular programming language that is widely used in AI-based insect detection using sound sensors. Some of the ways Python can be used in this context are:
Data preprocessing: Python can be used to preprocess the audio data collected from sound sensors. This includes filtering the audio signals to remove noise and extracting relevant features from the audio signals, such as frequency, amplitude, and duration.
Machine learning: Python is widely used for machine learning, which is an essential component of AI-based insect detection systems. Machine learning algorithms can be used to train models that can detect insect sounds in the audio data.
Deep learning: Deep learning is a subfield of machine learning that is particularly useful for processing audio data. Python can be used to implement deep learning algorithms such as convolutional neural networks (CNNs) and recurrent neural networks (RNNs) for detecting insect sounds.
Visualization: Python has many powerful data visualization libraries such as Matplotlib and Seaborn, which can be used to visualize the audio data and the results of the insect detection algorithms.
Integration: Python can be easily integrated with other tools and frameworks used in AI-based insect detection systems, such as TensorFlow, Keras, and scikit-learn. This makes it a popular choice for developing end-to-end insect detection systems.

D.ANN(Arificial Neuron Network)

Artificial Neural Network (ANN) architecture can be used in AI-based insect detection using sound sensors by training the network to classify insect sounds. Insects produce different sounds that are unique to their species, and an ANN can learn to identify these patterns by analyzing a large dataset of insect sounds.The following are some potential uses of ANN architecture in AI-based insect detection using sound sensors:
Insect Classification: ANNs can be trained to classify different insect species based on their sound patterns. By analyzing the frequency, duration, and amplitude of the sound signals, the ANN can learn to distinguish between different types of insects.
Pest Detection: ANNs can be used to detect and identify pest species that are harmful to crops or buildings. By using sound sensors to detect the presence of insects, the ANN can quickly determine whether a pest is present and take appropriate action.
Monitoring and Surveillance: ANNs can be used to monitor and track insect populations over time. By analyzing the changes in the sound patterns, the ANN can detect changes in the insect population, such as an increase or decrease in the number of insects.
Early Warning System: ANNs can be used as an early warning system for insect infestations. By monitoring sound patterns over time, the ANN can detect changes that indicate the presence of an insect infestation before it becomes widespread.
Overall, ANN architecture can be a valuable tool in AI-based insect detection using sound sensors. By analyzing large datasets of insect sounds, an ANN can learn to classify, detect, and monitor insect populations, providing important information for pest control and management.

VII.. FLOW OF OUR PROJECT

The Working methodology of our proposed project is in detailed manner in the below

Gather sensor data: Collect data from both IR sensors and sound sensors placed near the area where you want to detect insects

Preprocess data: Preprocess the sensor data by converting it into a suitable format that can be used by the ANN algorithm.

Train ANN model: Train an Artificial Neural Network (ANN) model using the preprocessed sensor data. The ANN should be designed to classify the sensor data as either insect activity or non-insect activity.

Deploy the ANN model: Deploy the ANN model to the Arduino Uno board, which will allow the model to make real-time predictions on incoming sensor data.

Connect the pesticide machine: Connect the pesticide machine to the Arduino Uno board, which will enable the system to trigger the machine when insects are detected.

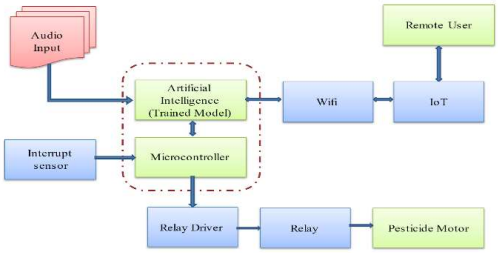
Continuously monitor: Continuously monitor the sensor data and make predictions using the deployed ANN model to detect any insect activity in the area.

Determine insect presence: If the ANN model detects insect activity from both the IR sensors and sound sensors, the system will determine that there are insects present in the area.

Trigger the pesticide machine: If insects are detected, the system will trigger the pesticide machine to dispense the pesticide to eradicate the insects.

Continue monitoring: After the pesticide machine is triggered, the system will continue to monitor the sensor data to ensure that the insect activity has been eliminated.

Overall Block Diagram



VIII. EXPERIMENTAL RESULT

Our paper explains about the system used to monitor the insect detection and enables the sound sensor and get the insect sound data and send to the arduino uno to the python code it compares using ANN Architecture the actual sound with predefined sound when the match is success it throws the name of the insect which we predefined in the dataset and triggers the pesticides motor.This ensures the experimental result of our project

Then the conclusion of the system is given in the next page of this paper.

IX. CONCLUSION

AI-based insect detection using sound sensors is a promising approach to accurately identify and track insects based on their unique sound signatures. By leveraging machine learning algorithms, AI-based insect detection can classify insect species and behaviors in real-time, making it an essential tool for early detection of insect infestations and disease vectors.

However, there are still some challenges and limitations that need to be addressed for AI-based insect detection using sound sensors to reach its full potential. One of the main challenges is the variability of insect sounds in different environments, which can affect the accuracy and generalizability of machine learning models. Additionally, there may be background noise and other factors that can interfere with the detection of insect sounds, making it challenging to distinguish insect sounds from other sounds in the environment.

Future work in this area could focus on improving the quality and diversity of sound datasets used to train machine learning models, including data from different environments and insect species. Additionally, efforts could be made to develop more robust algorithms that can account for variability in insect sounds and background noise, as well as new hardware and sensors that can capture more accurate and detailed sound data.

X .REFERENCES

[1] "Deep Learning-Based Insect Sound Classification Using Environmental Acoustic Recordings" by Chen et al, 2022.

[2] "Insect sound classification using an ensemble deep learning model" by Yang et al. in Ecological Indicators, 2022.

[3] "Insect sound recognition based on wavelet packet transform and convolutional neural network" by Chen et al. in Ecological Indicators, 2022.

[4] "Automated insect sound detection and classification using deep learning models" by Bhagat et al. in Insects, 2021.

[5] "Insect sound recognition using machine learning algorithms and Mel frequency cepstral coefficients" by Wang et al. in Ecological Informatics, 2021.

[6] "Automatic classification of insects based on the sound signals using deep learning techniques" by Goswami et al. in Journal of Ambient Intelligence and Humanized Computing, 2021.

[7] "Insect sound recognition using convolutional neural network and continuous wavelet transform" by Zheng et al. in International Journal of Agricultural and Biological Engineering, 2020.

[8] "Deep learning based insect classification using acoustic signals: A comparative study" by Kumar et al. in International Conference on Computer Vision and Image Processing, 2020.

[9] "Insect species classification using convolutional neural networks with feature transfer" by Li et al. in Journal of Bionic Engineering, 2020.

[10] "Deep learning-based insect classification using acoustic signals with transfer learning" by Liu et al. in Ecological Informatics, 2019.