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Iot-Enabled Precision Animal Trespass Identification and Deterrence System for Smart Agriculture

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Abstract: IoT technology is growing, and it works well with agricultural use cases, which makes it one of the greatest choices for making agricultural tools and gadgets. The proposed work is based on IoT technology. It is a cost-effective Arduino-based IoT prototype that enables the end user (the farmer) to protect and monitor their cropland remotely using various sensors and IoT hardware modules. This would help the farmer deal with the problem of animals trespassing into the fields more efficiently, without harming the animals, and thus avoid any major losses. It is composed of numerous separate hardware components and modules that work together. Using a PIR sensor, the project can tell when an animal is moving. If an animal is moving, a pair of Ultrasonic sensors placed in parallel look for the animal in a specific area near the border of the farmland. If an animal is detected in the area, the buzzer sounds to scare it away, and the GSM Module sends an alert message to the user (Farmer) about the animal trespassing. The system employs deterrence methods, including automated sound and light signals, as well as non-lethal methods such as mild electric shocks or water sprays, strategically placed to deter animals from entering while causing the least amount of injury. Some of the most important features of the system are that it can work with a wide range of farm types, can be expanded to accommodate farms of different sizes, and can integrate with existing farm management systems. Additionally, its cloud-based architecture enables easy monitoring and administration from a distance, providing farmers with valuable information to enhance security and optimize resource utilization.

Keywords: IoT Systems; Embedded C; Telecommunications; Smart Card; Digital Consumer Electronics; Remote Monitoring and Management; Optimize Resource Allocation.

Introduction

The use of Internet of Things (IoT) technology in farming has enabled significant improvements in farm management [63]. One such new use is the creation of a low-cost Arduino-based IoT prototype to help farmers keep animals off their crops and monitor them [32]. This system utilizes a combination of sensors and hardware modules to detect and deter animals without causing harm. For example, a Passive Infrared (PIR) sensor can detect animal movement, which then triggers Ultrasonic sensors along the edge of the farmland to ensure there are animals in a specific area [51]. When the animal is detected, a buzzer sounds to scare it away, and a GSM module sends a message to the farmer to notify them that someone is on their property. This method not only keeps crops safe, but it also keeps animals safe. Farmers can easily and affordably utilize the prototype, which features remote monitoring capabilities [56]. This helps them improve their farming operations and increase their crop yields.

There are many benefits to using IoT technology in farming [39]. Farmers can rapidly respond to potential dangers, such as animals trespassing, by keeping a close eye on their fields from a distance. This lowers the chance of crop damage and loss [35]. The IoT prototype can also provide farmers with valuable information about animal behavior and crop protection, enabling them to make informed decisions and enhance their agricultural practices. Additionally, the Arduino-based IoT prototype is affordable enough for small-scale farmers to utilize, allowing them to derive significant benefits from it [46]. Overall, the use of IoT technology in farming can transform the way farmers manage their crops, making farming more efficient, productive, and sustainable.

An embedded system is a controller programmed and controlled by a real-time operating system (RTOS) that has a specific task to perform within a larger mechanical or electrical system. It often has to deal with the processing limitations of embedded systems in real-time [30]. It is built into a complete gadget, which typically includes both hardware and mechanical components. Many of the items we use every day are controlled by embedded systems. Ninety-eight percent of all microprocessors are made to be parts of embedded systems [50]. When compared to general-purpose computers, embedded computers are typically smaller, consume less power, have a wider operating range, and are less expensive per unit. This comes at the cost of limited processing power, which makes them much harder to program and use [57]. However, by integrating intelligence into the hardware and utilizing existing sensors, along with a network of embedded units, it is possible to optimize resource management at both the unit and network levels, and add new functions that exceed current capabilities [62]. For instance, smart methods can be made to control power (Figure 1).

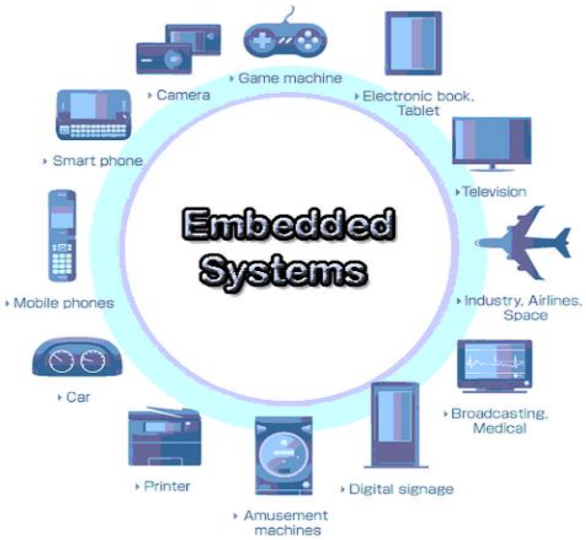

Figure 1: Embedded system

Embedded systems are widely used in various applications, including military, commercial, medical, automotive, industrial, and consumer sectors [55]. Telecommunications systems utilize numerous embedded systems, ranging from telephone switches that connect the network to cell phones used by individuals [28]. Dedicated routers and network bridges are used in computer networking to send data. MP3 players, cell phones, video game consoles, digital cameras, GPS receivers, and printers are all examples of consumer electronics [37]. Embedded systems are built into household appliances, such as microwaves, washing machines, and dishwashers, to make them more flexible, efficient, and useful (Figure 2).

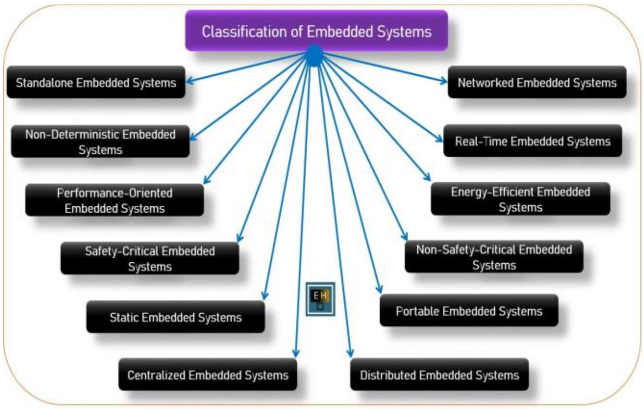

Figure 2: Classification of an embedded system

Advanced HVAC systems utilize networked thermostats to more effectively and efficiently control temperature, which can fluctuate throughout the year and day [34]. Home automation utilizes both wired and wireless networks to control various devices, including lights, climate control, security, audio, video, and surveillance. All of these things employ built-in devices to sense and control them [54]. Like traffic signals, factory controls, and highly complex systems such as MRI, avionics, and hybrid vehicles, Embedded systems can be small, like digital watches and MP3 players, or large, like a building [40]. The complexity can be modest, with just one microcontroller,

An embedded system often includes an embedded processor [29]. Embedded systems are used in various digital appliances, including microwaves, VCRs, and vehicles. Some embedded systems have an operating system built in. Some are quite specialized; thus, the entire logic is incorporated into one program [49]. These systems are built into a device for a specific reason other than to provide general-purpose computing.

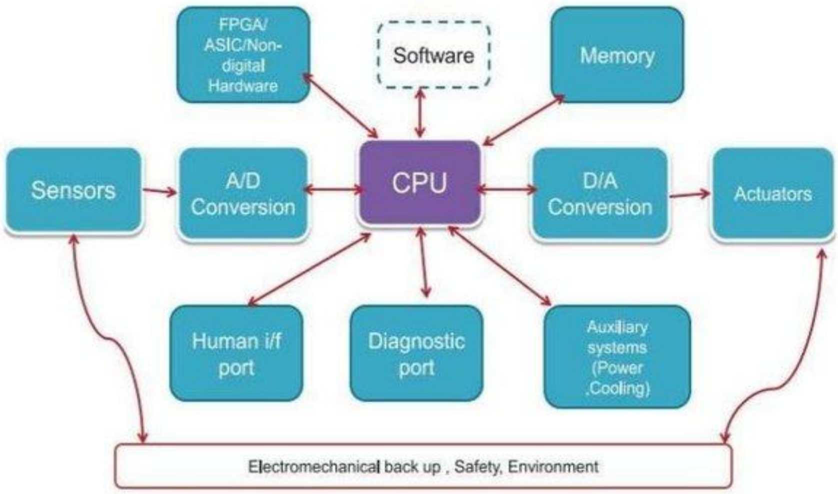

Figure 3: Block diagram of a typical embedded system

Motor control, cruise control, body safety, engine safety, robotics on an assembly line, car multimedia, car entertainment, E-com access, and mobile phones are all examples of embedded systems in cars [41]. Networking, mobile computing, wireless communications, and other things are all examples of embedded systems in telecommunications [58]. Smart cards have built-in systems for banking, phones, and security. Some examples of embedded systems in missiles and satellites include defense, communication, and aerospace applications [31]. Embedded systems in computer networking and peripherals include printers, network cards, monitors, displays, and image processing systems [44]. Digital consumer gadgets with embedded systems include digital cameras, high-definition TVs, set-top boxes, and DVDs (Figure 3).

The Internet of Things (IoT) is a concept that describes situations where everyday objects, sensors, and other devices that aren't typically considered computers can connect to the internet and perform computing tasks. This enables these devices to create, share, and utilize data with minimal human involvement [42]. However, there isn't a single definition that works for everyone. The concept of integrating computers, sensors, and networks to monitor and control equipment has been around for a long time. However, several recent advances in the technology sector are pushing the Internet of Things closer to becoming a reality for everyone [53]. These are some of the things: Ubiquitous Connectivity, Widespread Adoption of IP-based Networking, Computing Economics, Miniaturization, and Advances in Data [27]. Connectivity Models: There are numerous distinct technical communication models that IoT implementations utilize, each with its own unique features [60]. The Internet Architecture Board discusses four popular methods of communication: Device-to-Device, Device-to-Cloud, Device-to-Gateway, and Back-End Data Sharing [45]. These models demonstrate the flexibility of IoT devices in their interaction and the value they provide to users.

Hardware and software parts are used to make IoT devices work. Dedicated hardware components are used to connect to the real world and perform operations that are more complex from a computational perspective [47]. Microcontrollers run software that reads inputs and controls the system. This module discusses the functions of the hardware and software components of the system [59]. It explains what typical hardware components do and how the microcontroller connects the software and hardware. An operating system is typically used by IoT devices to enable the software and microcontroller to communicate with each other [52]. We will discuss what an operating system does for an IoT device and how an IoT operating system differs from a traditional one.

Smart gadgets that can connect to the internet and utilize built-in processors, sensors, and communication hardware to gather, transmit, and respond to data from their surroundings comprise an IoT ecosystem. IoT devices link to an IoT gateway or other edge device to exchange the sensor data they collect. The data is then either transferred to the cloud for analysis or examined locally [36]. These gadgets can communicate with other devices connected to them and perform actions based on what they learn from each other. People can engage with the devices, such as setting them up, providing instructions, or accessing data, but the gadgets do most of the work on their own [43]. The precise IoT apps employed with these web-enabled devices have a significant impact on how they connect, network, and communicate.

The Internet of Things (IoT) has numerous real-world applications, including consumer IoT, commercial IoT, manufacturing IoT, and industrial IoT. IoT apps can be applied in various fields, including automotive, telecommunications, energy, and others [38]. For example, in the consumer market, smart homes equipped with smart thermostats, smart appliances, and connected heating, lighting, and electronic devices can be remotely managed using computers, smartphones, and other mobile devices [61]. Wearable gadgets equipped with sensors and software can gather and analyze user data, then transmit information to other technologies about the users [33]. The goal is to make users' lives easier and more comfortable. People also employ wearable safety devices [48].

Literature Survey

Indian farmers face numerous challenges that farmers in wealthy countries do not. One of the biggest challenges Indian farmers face is animals getting onto their farms [4]. Animal trespassing occurs frequently, especially on farms located near forests and hills. Animals have frequently invaded farms, damaging crops and causing farmers significant trouble and financial loss [22]. The poorest farmers, who rely on farming for their income, were the most affected. This poses a significant threat to many farmers, as they would lose substantial amounts of money [12]. Many farmers rely on government compensation, but acquiring it is a lengthy and stressful process.

In most cases, the amount of money the government provides is significantly less than the amount they lost [18]. To deter animals from entering their land, farmers employ a few old-fashioned tactics, such as setting off crackers, digging trenches, and installing electric fences [9]. These methods are not very effective and can harm the animals. Therefore, we require a new method to prevent animals from entering our property that is effective and humane [14]. Because technology is growing and spreading so quickly, it's easy and inexpensive to utilize the latest technologies to prevent animals from entering agriculture.

IoT technology is growing quickly, and it works well with agricultural use cases. This makes it one of the greatest choices for making agricultural instruments and gadgets [7]. The proposed work is based on IoT technology. It is a cost-effective Arduino-based IoT prototype that enables the end user (the farmer) to protect and monitor their cropland remotely using various sensors and IoT hardware modules. This will help address the issue of animals entering the fields more efficiently, without harming them, and will prevent any major losses [17]. It is composed of numerous separate hardware components and modules that work together. A PIR sensor detects animal movement. If movement is detected, a pair of Ultrasonic sensors looks for the animal in a certain area near the edge of the farmland [2]. If an animal is detected in that area, the buzzer sounds to scare it away, and the GSM Module sends a message to the user (the farmer) to notify them that an animal has crossed the border [23]. The Farmer can request images of the field at any time, which is very helpful in understanding the field situation better when an animal trespasses. The photos are delivered to them via Telegram. The ESP32 Camera Module is responsible for capturing images. It takes a picture of the field, sends it to the user (the Farmer), and also takes a picture of the field, saving a backup on the SD card connected to it [15]. The prototype of the project works perfectly according to the order of functions listed above, and the test run results are as we expected.

The traditional database paradigm lacks sufficient storage capacity for the data generated by Internet of Things (IoT) devices, necessitating the use of cloud storage. Big Data mining techniques are used to look at this data [13]. Cloud-based big data analytics and IoT technology are essential for the feasibility assessment of smart agriculture. Smart or precise agricultural technologies are considered crucial for enhancing farming practices. Everyone, including farmers, uses mobile devices extensively [25]. In this regard, Information and Communication Technologies (ICT) are crucial for farmers to access agricultural information. In the field of Digital Agriculture, the IoT can be utilized for various purposes, including monitoring crop growth, selecting the optimal fertilizer, and aiding in irrigation decisions [5]. This paper discusses the usage of IoT devices to collect agricultural data and store it in a Cloud database. Big data analysis in the cloud is used to examine data such as the amount of fertilizer required, the crops that need to be grown, and the market and stock needs for these crops. Then, a prediction is made using data mining, and the information is sent to the farmer using a mobile app [11]. Utilizing this expected knowledge, our primary objective is to enhance crop productivity and maintain the cost of agricultural goods at a manageable level.

The Internet of Things (IoT) plays a crucial role in smart farming [20]. Smart farming is a new concept that utilizes IoT sensors to gather information about agricultural fields. The study aims to utilize advanced technologies, specifically IoT and automation, in smart agriculture. Monitoring environmental factors is crucial to maximizing crop yields [3]. This paper's primary focus is on utilizing the CC3200 single-chip microcontroller to monitor temperature and humidity in an agricultural area using sensors [8]. The camera is connected to the CC3200, allowing it to take pictures and send them to farmers' phones over Wi-Fi.

Smart agriculture, based on the Internet of Things (IoT), can help farmers increase their crop yields by providing them with real-time information about their crops. This technology is helpful because it enables farmers to track their farm activities, which in turn helps them make informed decisions about their crops and farming practices [10]. The suggested solution utilizes a soil moisture sensor to determine the soil's moisture level, and then activates or deactivates the pump accordingly [24]. As technology improves and makes it harder for criminals to access the farm, surveillance systems also need to be updated to stay ahead of the curve [1]. The suggested fix combines an IR sensor with the ESP32 Cam. This way, if motion is detected within the farm's perimeter, the ESP32 Cam will take a picture of the scene and send an email to notify you [26]. Also, flame sensors will provide recorded audio alerts to farm users when they see fire or flames on the property. This can help farmers stay safe while they grow crops [19]. Arduino controls these sensors, and the server gets new data from them.

Smart farming is a new concept that utilizes information and communication technology in machinery, equipment, and sensors to facilitate network-based, high-tech farm supervision cycles [16]. The Internet of Things (IoT), cloud computing, and other emerging technologies are expected to drive growth and lead to the increased use of robots and artificial intelligence in farming. These revolutionary changes are disrupting the current agricultural practices, and they also raise numerous concerns [6]. This article examines the instruments and equipment used in IoT agriculture that utilize wireless sensors, as well as the challenges that are anticipated to arise when technology is integrated with traditional agricultural practices [21].

Methodology

In farming areas, wild animals can enter crops and harm cattle, posing a significant problem [69]. Farmers lose a significant amount of money since traditional methods of keeping animals away generally don't work well and don't respond quickly enough [82]. We need a dependable and effective system that can quickly and accurately identify trespassing animals and initiate deterrent actions immediately [73]. Farmers also need a way to monitor their fields remotely and receive real-time notifications to help them manage and mitigate the hazards associated with wildlife infiltration [66]. To address these issues, we require a novel IoT-based solution specifically designed to detect and prevent animals from trespassing in smart agriculture. A machine learning technique, such as a Convolutional Neural Network (CNN) or a similar approach, is used to accurately and intelligently identify animals from webcam photos [76]. You can use TensorFlow or PyTorch frameworks to design and train the machine learning model (Figure 4).

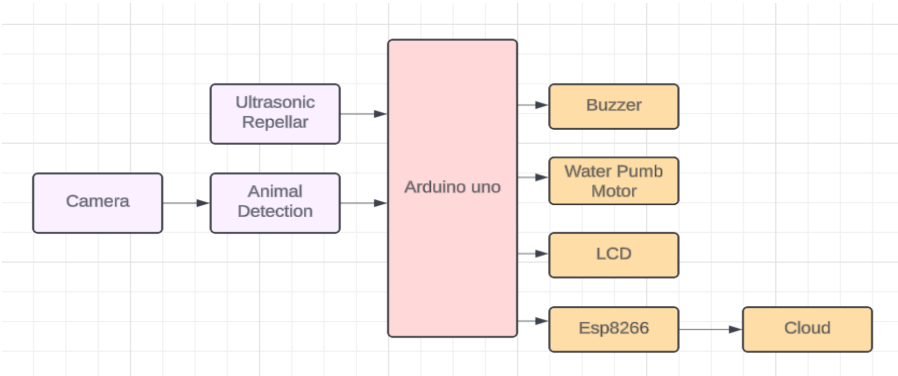

Figure 4: block diagram

The Uno PCB measures 2.7 inches in length and 2.1 inches in width at its widest points [75]. The USB connector and power jack stick out past the longest point. Four screw holes on the board let you attach it to a surface or case. Keep in mind that the space between digital pins 7 and 8 is 160 mil (0.16"), which is not a multiple of the 100-mil spacing between the other pins [65]. A power supply, sometimes referred to as a power supply unit (PSU), is a device or system that provides electrical or other types of energy to an output load or group of loads. Most of the time, people use the term to refer to electrical energy supplies [81]. Less often, they use it to talk about mechanical energy supplies, and even less often, they use it to talk about other types of energy suppliers.

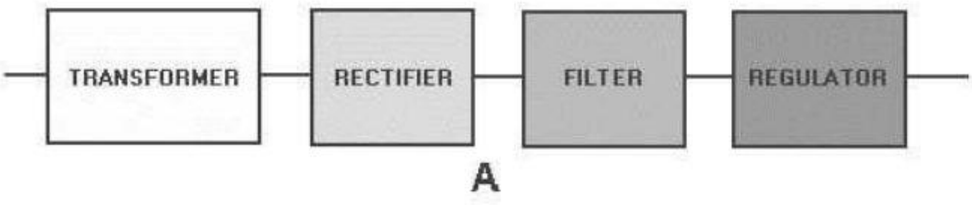

Figure 5: power supply

The transformer changes the voltage of the input line and separates the power supply from the power line [72]. The rectifier part changes the input signal from alternating current to pulsing direct current. But as you read this chapter, you will learn that pulsing DC is not good [83]. This is why a filter section is employed to convert pulsing DC into a cleaner, more stable form of DC electricity. The last part, the regulator, performs exactly as it says it will. It maintains the power supply's output at a steady level, even when the load current or input line voltages fluctuate significantly [67]. Let's follow an AC signal through the power supply now that you know what each part accomplishes [74]. Now, you need to examine how this signal changes in each part of the power supply. You will see how these modifications happen later in the chapter. In view B of Figure 4-1, the transformer gets an input signal of 115 volts AC. The transformer is a step-up transformer with a 1:3 turns ratio [79]. To find the output of this transformer, we can multiply the input voltage by the ratio of turns in the primary to the ratio of turns in the secondary. For example, 115 volts AC × 3 = 345 volts AC (peak-to-peak) at the output [68]. The rectifier's output will be one-half, or approximately 173 volts of pulsing DC (Figure 5), because each diode in the rectifier section only conducts for 180 degrees of the 360-degree input cycle.

The filter section, comprising resistors, capacitors, and inductors, determines the rate at which the signal rises and falls. So, the signal stays at a more stable DC level [77]. When we discuss the actual filter circuits, we can see the filter process more clearly. The filter's output is a 110-volt DC signal with an AC ripple superimposed on it. We shall explain why the voltage is lower (average voltage). The electronic equipment (also referred to as the load) utilizes the regulator's output, which is always 110 volts DC [64]. This circuit is a small power supply that gives out +5V. It's excellent for trying out digital devices. You can readily find those transformers, but their voltage regulation is usually not very good, which makes them not very useful for digital circuit experimenters unless they can find a means to improve it [70]. The output of this circuit is +5V at approximately 150 mA, but it can be increased to 1 A if sufficient cooling is added to the 7805 regulator chip. There is protection against overload, and terminals are included in the circuit [80].

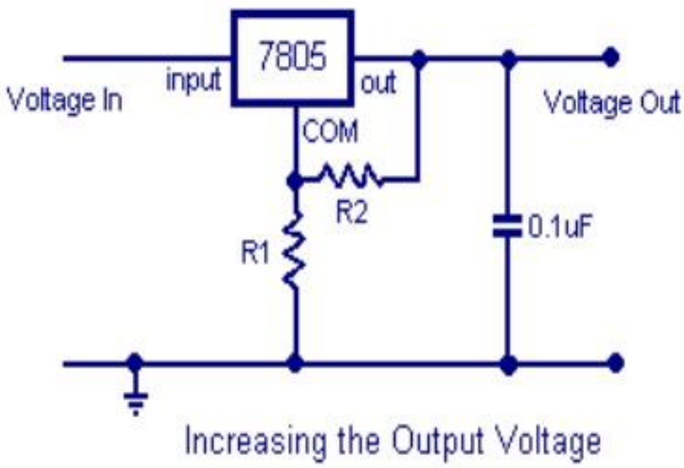

Figure 6: More output current

We can modify the circuit by replacing the 7805 chip with another regulator from the 78xx chip family that has a different output voltage, if we need more than +5V [78]. The last digits of the chip code indicate the output voltage [71]. The input voltage must be at least 3V higher than the output voltage of the regulator (Figure 6).

Result and Discussion

The idea behind LCDs is that as an electric current flows through the liquid crystal molecules, they tend to untwist. This changes the angle of the light that goes through the polarized glass molecule and the angle of the top polarizing filter [90]. Because of this, a small amount of light can pass through the polarized glass in a specific portion of the LCD. So, that area will be darker than the others [103]. The LCD operates by blocking light. When making the LCDs, a mirror is placed at the rear to reflect light. An indium-tin oxide electrode plane is located on top of the device, and a polarized glass with a polarizing film is positioned at the bottom [97]. A common electrode must cover the entire area of the LCD, and the liquid crystal material must be above it (Figure 7).

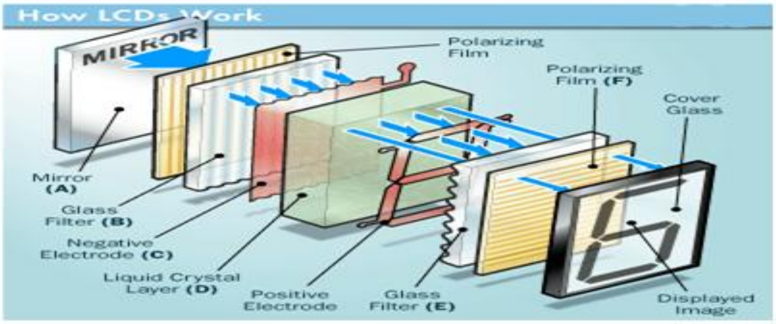

Figure 7: LCD layer diagram

The second piece of glass has an electrode in the shape of a rectangle on the bottom and another polarizing film on top. It is essential to note that both parts are perpendicular to each other. If there is no current, the light will go through the front of the LCD, hit the mirror, and bounce back [91]. The liquid crystals between the common-plane electrode and the rectangular-shaped electrode will untwist when the electrode is linked to a battery. So, the light can't get through. That rectangular region looks empty [102]. Ultrasonic pest repellers are electrical devices that emit high-frequency sounds intended to deter, harm, or repel pests in the home, such as insects and rodents. Testing labs and the U.S. Federal Trade Commission (FTC) have disagreed on whether or not they genuinely work [96]. Rodents and insects can spread diseases such as salmonella and hantavirus, and cause significant damage to buildings if they aren't kept in check.

Signs of a rodent infestation include droppings, especially near food sources and under sinks, food packages that have been eaten or gnawed on, and holes in building materials that could allow rodents to enter the house [98]. Cockroach infestations are arguably the most common and difficult to eradicate type of pest infestation, especially in cities and industrial and commercial kitchens. You can identify cockroaches by their droppings, which resemble pepper flakes and are typically found in kitchen cupboards. Their egg sacs are often located in hard-to-reach areas, such as cracks and crevices in kitchen cabinets, drains, and behind dishwashers and refrigerators [84]. Some people claim that ultrasonic pest repellers can eliminate even these types of bugs in the home. A water pump is a type of pump that combines both mechanical and hydraulic principles to move water through a piping system and provide enough force for future usage [104]. They have been in one form or another for a long time, dating back to early civilization. These pumps are currently used in many different types of homes, farms, cities, and factories [92]. There are various types of water pumps, so when choosing one that is robust and reliable, consider what you need it for.

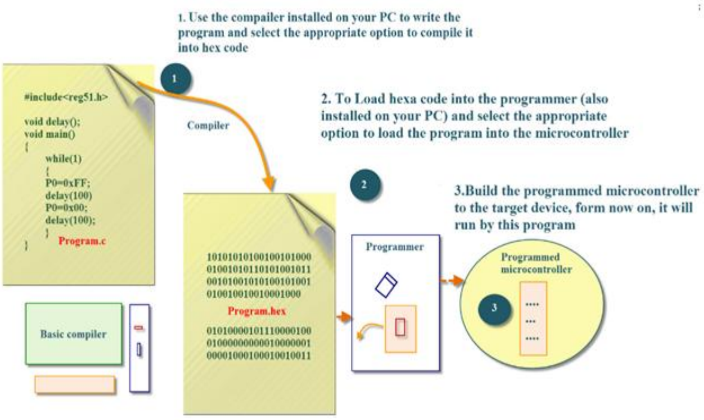

Figure 8: Block diagram of Embedded C

The Embedded C code in the block diagram above makes the LED linked to Port 0 of the microcontroller blink. A function is a group of statements that work together to do a certain job. A programming language is a group of one or more functions [89]. Many people are familiar with application software that enables computers to perform tasks. Embedded software, on the other hand, is typically harder to see but just as intricate. Embedded software has specific hardware requirements and capabilities, and adding third-party hardware or software is strictly limited [105]. This is not the case with application software. At the time of production, embedded software must include all necessary device drivers, which are written for the specific hardware. The CPU and the chips you choose have a significant impact on how well the software performs. Most embedded software engineers know how to read schematics and data sheets for parts to figure out how to use registers and the communication system [99]. It's helpful to know how to change between decimal, hexadecimal, and binary, as well as how to change bits. People don't use web apps very often, although they can send XML files and other output to a computer to be shown (Figure 8).

SQL databases and file systems with directories are usually not present. A cross compiler is needed for software development. It operates on a computer but creates code that can be run on the target device [100]. To debug, you need to use an in-circuit emulator, JTAG, or SWD. A lot of the time, software developers can see the whole kernel (OS) source code. Convolutional Neural Networks (CNNs) have revolutionized the way computers perceive images, enabling them to automatically and accurately recognize objects [87]. Because they can learn and automatically extract complex features from raw image data, NN-based image classification algorithms have become increasingly popular. This article discusses the concepts, techniques, and applications of CNNs for image categorization. We will examine the architecture, training procedure, and metrics for evaluating CNN image categorization in more detail [95]. By understanding how CNNs function for image classification, we can unlock numerous new ways to recognize objects, comprehend scenes, and analyze visual data.

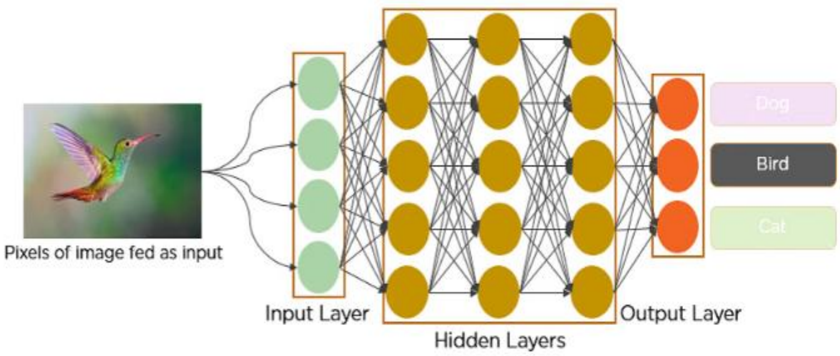

Figure 9: CNN diagram

A feed-forward neural network, specifically a convolutional neural network, is often used to analyze images by processing data with a grid-like structure. Another name for it is ConvNet [85]. A convolutional neural network identifies and categorizes objects in an image [93]. This neural network can distinguish between two types of flowers: orchids and roses (Figure 9-11).

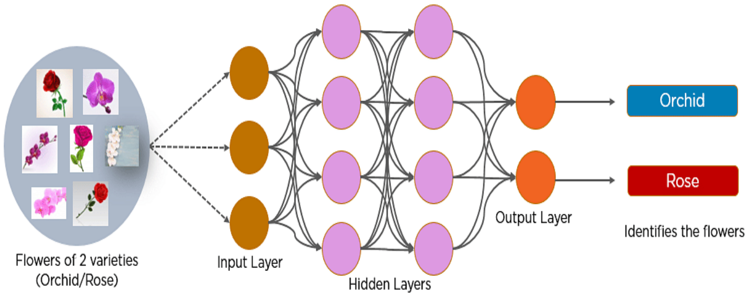

Figure 10: CNN workflow

In CNN, every image is represented as an array of pixel values.

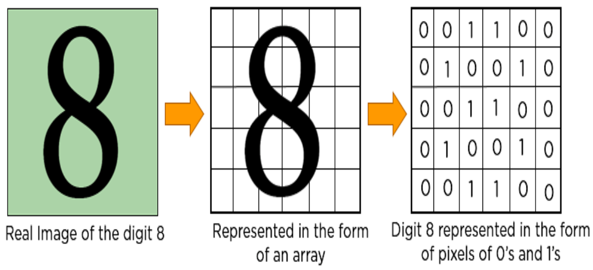

Figure 11: CNC imaging

The convolution operation is what makes up a convolutional neural network [94]. Let's use two 1D matrices, a and b, to help us comprehend the convolution operation.

a = [5, 3, 7, 5, 9, 7]

b = [1,2,3]

When you do a convolution operation, you multiply the arrays element by element and then add them together to make a new array that shows a*b [88]. The elements of matrix A are multiplied by the first three elements of matrix B. To find the answer, add the product (Figure 12).

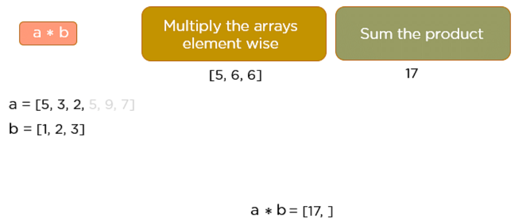

Figure 12: Fusion of Arrays

The next three elements from the matrix a are multiplied by the elements in matrix b, and the product is summed up.

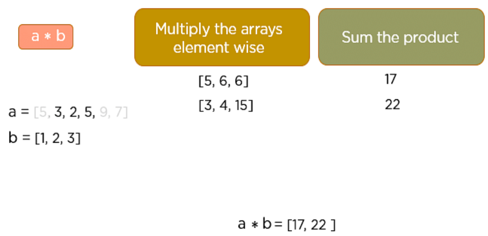

Figure 13: Summation of Split Products

The suggested project would be a very good, useful, and economical way to prevent animals from entering the farmlands [86]. The project is easy to operate, can prevent animals from trespassing without harming them, and can also help if animals cause damage to crops or property on the farm (Figure 13) [101].

Conclusion and Future Enhancement

The IoT-based Animal Trespass Identification and Prevention System, utilizing Arduino, can detect animals in real-time and take precise steps to prevent them. It allows farmers to monitor their crops remotely and receive notifications promptly, making their farms safer. Future upgrades will feature enhanced machine learning algorithms, GPS monitoring, the ability to grow and save energy, a mobile app interface, and data analytics for improved farm management. Adding weather monitoring devices would enable the system to provide real-time information about factors such as rainfall and temperature, which would help farmers make more informed decisions. Creating a mobile app that enables farmers to receive warnings, view sensor data, and remotely control the system would make it easier to use and more beneficial. To make the system more sustainable and less dependent on grid electricity, think about using solar power. Make the system easy to integrate with, allowing for the addition of other sensors or features in the future. Using data analytics can help farmers make better decisions and manage their crops more effectively by providing them with useful information.

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