ASHESI UNIVERSITY

Use of Drones in Agriculture: A Bird Deterrent System

Bsc. Electrical &Electronics Engineering

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2022

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APPLIED PROJECT

Capstone Project submitted to the Department of Engineering, Ashesi University in partial fulfilment of the requirements for the award of Bachelor of Science degree in Electrical & Electronics Engineering.

Ruzvidzo Marshal

2022

DECLARATION

I hereby declare that this capstone is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

Candidate's Signature:

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Candidate's Name:

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Date:

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I hereby declare that preparation and presentation of this capstone were supervised in accordance with the guidelines on supervision of capstone laid down by Ashesi University.

Supervisor's Signature:

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Supervisor's Name:

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Date:

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Acknowledgements

To my supervisor, Mr. Kofi Adu-Labi, whose direction, encouragement and academic advice ensured the success of this project. My acknowledgement also goes to the entire Ashesi faculty for the knowledge acquired and support over the years of my bachelor's degree.

Abstract

Pest birds damage to commercial crops is a serious problem for farmers in Zimbabwe, especially for high-value crops such as maize, wheat and millet. The lack of a universally cost-effective bird deterring method has led to food insecurities in Zimbabwe. There is a need to develop a new cost-effective solution to curb bird pest problems using modern technologies complemented by bird psychology that reduce habituation. This project focuses on pest bird control in a 1-hectare maize field because of the extremely high value of the maize crop to the food security of Zimbabwe. The recent development of drone technologies has provided an autonomous pest bird management system as a potential solution. There are now available off-the-shelf bird deterring UAVs. However, the issue is to detect the presence of birds in the first place. Moreover, birds quickly habituate to simple scaring techniques, and these methods lose their effectiveness before crops are harvested. This project designed a cost-effective bird detective system using HB100 radar motion sensors dotted around the field. Different radar modules were investigated to determine their effectiveness at detecting birds at 15m from the sensor. Radar modules investigated were HB100, CMD324 and K-LCa1. HB100 proved to be better at detecting birds than other radar modules. Different prerecorded sounds for the bird deterring system were played from an mp3 player and Atmega328P. The mp3 played produced higher quality audio, which the birds can perceive as a real threat. However in terms of loudness a 5mW piezo horn twitter provided a sound that can be heard 500m away. Different UAVs were investigated for their effectiveness in carrying the predation risk system, and a UAV with autopilot performed better under windy conditions. Autopilot stabilized the drone and reduced the risk of crashing the drone. A prototype system was constructed and tested in a number of flight tests to verify its capability of deterring the birds from the field. The experiments demonstrated that the designed prototype system could detect and deter birds in the field with delayed habituation.

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Chapter 1: Introduction

1.1 Background and Context of Agriculture in Zimbabwe

Zimbabwe has five natural regions which are distinguished by annual rainfall, temperature and productive agricultural potential of the soils. Farming activities vary across these regions. Region one receives more than 1000mm of annual rain; hence the main agricultural activities in this region include farming and fruit production. Annual rainfall drops gradually from region1 to region 5. Region 5 receives 450-650mm of annual rainfall, and the main agricultural activities in this region are extensive livestock and drought-resistant crops [2].

Agriculture contributed about 9 percent of Zimbabwe's Gross domestic product (GDP) between 2012-2016. The main crops in Zimbabwe include maize, cotton, tobacco, horticultural crops and sugar. Around 70 percent of the Zimbabwean population depend on agriculture for their livelihood. About one-third of the labour force is in the agriculture industry[3]. Zimbabwe exports about 40 percent of its agricultural products, and 60 percent provide raw materials for the manufacturing sector. Hence Zimbabwe's economic growth depends mainly on the growth of the agricultural sector. However, the agricultural sector in Zimbabwe is threatened by low productivity. For the past two decades, the performance of this sector has been hindered by lack of agricultural inputs, finance and recurrent droughts.

The agricultural sector in Zimbabwe is vulnerable to changing climate conditions and pests, further exacerbating low productivity. Zimbabwe has experienced droughts for the past decade, which have negatively reduced agriculture production. In these scenarios, food shortages have been experienced in the country, and the government had to import cereals from neighbouring countries such as Zambia and Mozambique. However, due to good rainfall in the 2018/2019 season and the introduction of the government's input support scheme (command agriculture), Zimbabwe experienced a record of over 2.4 million metric tons in this season. This command agriculture has expanded to include wheat, soybeans and cotton production.

Although the Zimbabwean government is trying to ensure food security in the country by introducing the command agriculture programme, these efforts are being impeded by bird pests on cereal crops [4]. Birds cause damage to crops such as maize, rice, soybeans and sorghum in search for food. Many Zimbabwean farmers face the challenge of maintaining cereal crop quantity and quality due to bird pests. Quelea, crows, doves and guinea fowls are the bird species affecting many cereal crop farmers in Zimbabwe [6]. These bird species affect both commercial and small-scale farmers. Quelea birds move in a flock that consists of more than ten thousand birds. On the other hand, crows, doves and guinea fowls move in small numbers in a flock that consists of ten birds. All the aforementioned bird species attack seedlings and plants that are heading ready for harvest. The crops that are most affected are wheat, rice, cucurbits and maize grain. In the case of cereal crops such as rice, bird pests eat directly yellowing rice grains, decreasing the yield. In addition, birds also cause broken rice panicles. Birds cause serious damage if there is a significant difference in planting time (more than three weeks) than the surrounding rice fields. Birds are usually present in the fields two weeks before harvest. Many farmers experience a loss of about 20 percent due to bird pests [5]. Many deterrent techniques have been developed to scare away birds from farmer's fields. Other farmers have resorted to incorporating crop loss due to bird pests as part of their cost of production. Some farmers have resorted to growing crops such as tobacco that are not attractive to bird pests [6]. Tobacco is a cash crop, but it does not ensure food security in the country since it cannot be consumed directly by the people. Moreover, crops that are mainly affected by the bird pests are nutritious and drought-resistant crops that are better suited for the current changing climatic conditions. For this reason, there is a need to detect and scare birds from attacking nutritious cereal crops. Ensuring the high production of cereal crops in Zimbabwe reduces the chances of starvation and food insecurity.

1.2 Motivation

I grew up in rural areas of Zimbabwe, where the main economic activity was and is still peasant farming. Many families are earning a living through peasant farming. During the 2020/2021 farming season, I realized that many people were on the brink of starvation due to recurring droughts. To curb the effects of drought, farmers in my community resorted to grow small grain crops such as sorghum and pearl millet, which can thrive under harsh climatic conditions such as heat stress and low amount of rainfall. However, these small grains are being affected by bird pests which further reduce the yield quantity and quality. These pests are affecting about 20 percent of the crop yield. Even for those who still grow maize, bird pests are a problem to this crop too. Hence these pests exacerbate starvation risk for the people in my community. All bird deterring techniques currently being implemented, such as kids throwing stones at birds and pesticides, are ineffective and hazardous to the environment. If there is a sustainable solution to bird pests, farmers from my community can survive on small scale farming activities, thus reducing poverty, insecurity and boosting the income of the rural people

1.3 Project objectives

The aim of this project is to design and build a robust and cost-effective system that can be used for detecting and scaring birds away in a field. This project also aims to solve habituation and environmental problems caused by existing bird eterrent techniques. When successfully implemented, both small- scale and large-scale farmers can use this system to protect their crops from bird pests, thereby increasing the quantity and quality of the harvest. This ensures food security and promotes the growth of small grain crops, which are better suited for changing climatic conditions. This project will benefit the agriculture sector of Zimbabwe and the Southern African region at large.

1.4 Expected outcome

At the end of this project, expectations are to come up with a network of bird deterring techniques that are mounted on an unmanned aerial vehicle (UAV). These techniques should be able to chase birds away in a field at a reasonable time of 5 minutes. This amount of time ensures that there is less damage to the crops when birds are present in the field. The presence of the bird will be detected by ground motion detection sensors dotted around the field. These sensors will be using the Doppler effect for motion detection. When birds are detected, an alarm will be raised that informs the user about the presence and location of the birds in the field. Then the user will fly the drone towards the direction where the birds' presence has been detected. The drone will be accompanied by a horn tweeter emitting distress calls of the captured bird. This sound will be perceived as a sign of danger by other birds in the field, and they fly away from the field. The green laser mounted on the drone will also act as a visual deterrent to the birds. In addition, a camera will be mounted on the drone to capture and send the visuals of the field to the remote drone pilot.

1.5 Scope of Work

The solution will be an application of Engineering and bird psychology concepts, including but not limited to communication systems (radar sensors), drone technology, Internet of Things (IoT), embedded systems and printed circuit board (PCB) design. All these concepts, when applied successfully, a robust system for detecting and scaring birds in a field will be produced. The field size, which the system is intended to work is 2 hectares, and the types of birds to be deterred are crows, guinea fowls and doves. The system will be tested on cucurbits and maize crops. Wheat is excluded because it is affected by quelea birds, which move in tens of thousands. According to research by single UAV cannot deter a large number of birds without causing habituation in a short time [6].

Chapter 2: Literature Review

Several studies have been carried out on the avian deterrents and their effectiveness. Avian deterrents can be categorized into visual, chemical, auditory and habitat modification.

Scaring birds using auditory techniques has raised complaints from the public due to noise pollution. Auditory techniques include firing gas cannons to scare birds away. However, research shows that gas canons are less effective for reducing bird damage [7]. Habituation is the main cause for the loss of effectiveness of this technique. As the continuous firing of gas canons will make birds realize that there is no real danger from the sound. Moreover, another auditory technique used is bio-acoustic deterrents. Bioacoustics are devices that produce sounds of biological relevance, such as recorded distress calls. These sounds are specific to different species. Research shows that these distress calls are more effective and more resistant to habituation than other sounds [8]. The calls can be broadcasted for about 1 minute from a stationary vehicle.

Visual techniques such as lasers have gained traction as demand for non-lethal and environmentally safe methods of bird scaring techniques is on the rise. Low power lasers are best suited for this purpose as they prolong battery life. These lasers also work under low light conditions. Birds are startled by the contrast between the ambient light and the laser beam. This method is more effective when the laser is shone in the bird's eyes. Lasers seem to be an effective method to scare birds away from the field, but some research shows that some birds are laser resistant [9]. The laser works better when there is less light, thus during dawn and at dusk.

Moreover, birds can be scared by using trained dogs to harass them. Dogs present an actual threat, not a perceived one. Habituation is highly unlikely with this method. A single border collie and its handler can keep an area of approximately 50 square kilometres free of larger birds and wildlife [10]. Dogs are useful for scaring ground foraging birds, but they are ineffective for bird species that spend time flying and perching. Furthermore, the use of dogs is labour intensive. The dogs need to be constantly directed by a trained handler.

Scarecrows mimic the predator and cause the bird to fly away to avoid predation. Many scarecrows are in the form of human-shaped effigies. On the other hand, motionless devices provide short term protection as the threat is perceived rather than real. To increase effectiveness, these devices should resemble biological significance and have high visibility or their position constantly changed to avoid habituation [11]. Ultimately, in the long run, scarecrows do not present a life-threatening technique to birds; hence birds will return to the area.

Chemical repellants is another bird deterrent technique. These repellents can be categorized into primary and secondary repellents. Primary repellents are avoided in the first place because they taste or smell offensive to the birds. Secondary repellents cause illness or unpleasant illness to the birds. Hence in the future, birds will avoid treated food. However, taste repellents are expensive to cover a large area [8]. Frequent use of vehicles and extra tractor wheeling to spray repellents reduce crop yield. Also, most of these repellents are hazardous to the environment as they end up in the food chain of human beings [12]

On the other hand, remote-controlled vehicles are being used at airports to chase away birds. Unmanned aircraft systems built to look like falcons are another option, but their implementation is being hindered by the expensiveness to build such devices that require training to operate [13]. Over the past decade, there has been a surge on the use of drones in agriculture.

Drones have been used to protect crops from pests and support the timely, efficient, and optimized use of inputs such as soil amendments, fertilizers, seeds, and water. This process leads to an increase in yields and reduces the overall cost of farm operations. Thus a drone can be used as a multi-purpose tool. Nowadays, the UAV is a low-cost option in sensing technology and data analysis systems [14]. The farmer can use UAVs to scare birds away from orchards or crops to avoid yield losses.

Research showed that UAV could prevent extensive pest birds in a 50 m radius centred on the UAV, confirming that one UAV is capable of protecting a farm smaller than 25 ha [15]. This implies that a swarm of UAV drones can be used to protect larger farms.

Chapter 3: Design

3.1 User Requirements

The user requirements comprise the user's expectations on how the system should detect and scare away birds from the field. Eight farmers in Zimbabwe and Botswana were interviewed via Whatsapp calls and social media interactions to obtain user requirements.

3.1.1 User Requirements from interviews

- Should be equipped with a loudspeaker broadcasting distress calls
- Should be equipped with taxidermy installed on the undercarriage that appears as a captured prey [The crow taxidermy should be upside down, wings open, in a vertical pose on the UAV's undercarriage. The intention of this pose is to strike the impression that the UAV has just caught the crow, and the distress call was coming from the crow in apparent danger] Birds rely on vision to navigate, find food, and detect threats. Birds are able to focus their eyes more acutely than humans, they are better able to see motion, and they are more sensitive to colour. Thus, it would be expected that visual scare devices would be effective in deterring birds from feeding on crops
- It should have a configuration that is designed to engage birds
- Provide long-term fear response towards the UAV
- One UAV should be sufficient to protect a field of 1 hectare
- To make UAVs truly effective to predators, we need to incorporate considerations of bird psychology into the design
- Easy to operate for an inexperienced user

- ❖ The UAV should be flown manually in a way such that it looks like the UAV is chasing after the birds to enhance the perceived predation risk.
- ❖ UAV should be flown to follow the movement of the flock centroid since it will be difficult to follow a single bird when they are in a flock
- ❖ The birds should be chased away in 5mins so to minimize time spent by bird-eating crops

3.2 System Requirements

This refers to the technical requirements of the bird detection and scaring system to meet user requirements. These are the needed design requirements of the system:

- ➢ The type of drone should be a multirotor because they do not need a runaway like a fixed-wing drone
- ➢ Additional hardware such as a GPS module to track the position of the UAV
- ➢ A piezo horn tweeter. The High-frequency response (3000 Hz – 17,000 Hz) is similar to the high frequency of natural bird calls. Powered by a 2-Watt amplifier, the tweeter can deliver a maximum volume of 100 dB at 1 meter
- ➢ The URI Laser Scarecrow uses a 50 mW green laser diode with a wavelength of 532 nm ± 5, a beam diameter of 14 mm and a range of 100m on flat ground
- ➢ Atmega 328p microcontroller-for controlling the sound coming out from a piezo horn tweeter
- ➢ Arduino SD card shield module to store distress calls of the birds.

3.3 Possible Solutions

To cover a field of 1 hectare, there is a need to put detection systems dotted around the field. The system will alert a remote drone pilot if there is a movement detected, assuming that every movement detected is of birds in the field. The first option for the detection system would be fixed cameras in the field. The challenge with fixed cameras at different positions is cost. One 360 degrees camera costs around $500 with a range of 100m, and to cover 1 hectare, we would need 3 of them. Moreover, each camera would require a battery unit, which raises the cost. Cameras are affected by dust which reduces their efficiency; thus, they need regular cleaning.

Secondly, another option is motion detection using low-cost radar sensors (CMD324 and HB100 sensors). Radar technology is a low cost and low power option for motion detection. Moreover, radar technology is not influenced by light and dust hence its suitability for outdoor applications. However, this low-cost option has a range of 15m is lower as compared to that of a camera (100m). The cost of seven radar sensors required to cover a range of 100m is lower than the cost of a single camera. Radar sensors consume less power (200mW) than a high-resolution camera that requires 15Watt. Hence in this project, radar technology is used for bird detection. In this project, we assume that any movement detected in the field is of birds. CMD324 /HB100 uses the doppler effect. Doppler shift is the output from the Intermediate Frequency(IF) terminal on the sensor when movement is detected. The magnitude of the Doppler Shift is proportional to the reflection of transmitted energy and is in the range of microvolts (μV). A high gain low-frequency amplifier is usually connected to the IF terminal to amplify the Doppler shift to a processable frequency. The Doppler shift is proportional to the velocity of motion. Typical human walking generates a Doppler shift below 100 Hz. Doppler frequency can be calculated by the Doppler equation below

$$f_d = \frac{2 f_0 v}{c_0} . \cos \alpha$$

Where f_d= doppler frequency

f0= frequency of the transmitted signal

v= velocity of the target

c_0= speed of light

α = angle between the emitted signal and the target object

Research has shown that low power radar modules can detect birds at a short-range [16]. Furthermore, microwave signals can be reflected by salts and metals [17]. In the blood of birds, there are salts that can reflect the microwave signals emitted by the sensor; hence the motion of birds can be detected. Objects such as leaves and twigs do not have salts; therefore, their motion cannot be detected by the radar motion sensor. Also, this project is targeting to detect medium sized birds such as owls and doves using CMD324 and HB100 sensors. This project assumes that any object detected in the field is a bird.

3.4 Bird Deterring System

To deter birds from the field, different options were considered, and these options are presented in the *Table 3.1* with Pesticides as the baseline.

Table 3.1Pugh Matrix for bird deterring techniques

Criteria	Pesticides	UAV with mounted bird deterring techniques	Rotating reflectors	Robirds	Lasers
cost	0	+	+	-	+
Reduced habituation before two weeks	0	+	-	+	-
Environmental negative impact	0	+	+	+	+
Perimeter covered	0	+	-	+	-
Total Score	0	+4	0	+3	0
Ranking		1	3	2	3

Based on the Pugh matrix Table 3.1, the UAV mounted with other bird deterring techniques such as lasers had a higher ranking than other bird deterring techniques. A drone costs about 500 $ per piece and can cover at least 2 ha. If we used swarm drones (3 drones, for instance), they could cover a larger area and serve the farm for several years. The cost of buying the drone is recovered in the first year, and the technology could work for at least five years. Besides that, the environment is preserved when the birds are scared away instead of being killed, while no risk is posed to the food chain. The technology uses less energy compared to other traditional methods. When the drone returns from its flight, all that is required is to replace or recharge the battery before sending the drone to fly again. In an agricultural, rural setting, the stakeholder knowledge fed to the technology during the co-design processes produces an ultimate ICT-based 'African drone.' Codesign in bird scaring drone systems has a great potential to increase food security and sustainability in Africa.

3.5 Communication Design

After the movement has been detected in the field, there is a need to send the signal to the remote pilot. To avoid trailing cables in the field, communication technology between the bird detection system and the remote pilot should be wireless. Table 3.2 shows a Pugh matrix for communication technologies, with the baseline being the Bluetooth module.

Table 3.2Pugh matrix for communication technologies

Criteria	Baseline (Bluetooth)	NRF24l01	Wi-Fi 802.11	Zig bee	GSM	LORA
cost	0	+	-	+	+	-
Flexibility(number of users)	0	+	+	+	-	+
bandwidth	0	+	+		+	+
range	0	+	-	-	+	+
security	0	-	+	+	+	-
Power Consumption	0	+	-	-	-	+
Frequency range	0	+	+	-	-	+
Total	0	+5	3	1	1	+4
Ranking		1	3	4	4	2

To interpret the Pugh matrix above, the row highlighted in red means that the GSM and WIFI 802.11 technologies consume more power than Bluetooth technology. The GSM, Wi-Fi and Zigbee consume more power than the required specification. Based on the above Pugh matrix, the NRF24l01 communication technology is the best option because it has desirable specifications according to the Pugh Matrix criteria, which meet our design requirements.

Chapter 4: Methodology

4.1.1 4.1 Implementation

Figure 4.1 below shows a signal conditioning circuit that acts as a bandpass filter with a bandwidth of 3Hz- 999Hz.

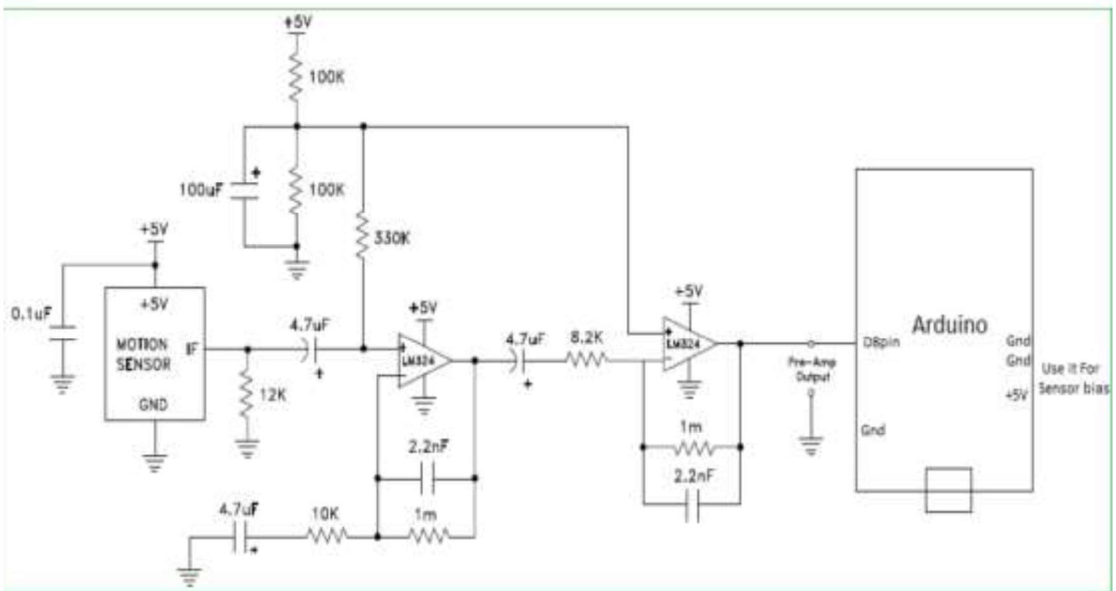

Figure 4.1 Signal Conditioning circuit

Below are the equations for the bandpass filter

$$Voltage\ gain = \frac{-R_2}{R_1}$$

$$fc_1 = \frac{1}{2\pi R_1 C_1}$$

$$fc_2 = \frac{1}{2\pi R_2 C_2}$$

Where R1= 8.2KΩ, R2=1MΩ, C1=4.7µF and C2= 2.2nF

The motion sensors CMD324 and HB100 (Figure 4.2) are both Continuous Waves (CW) radar modules, and they operate under the same principles. One of the differences between them is that HB100 operates at 10.525Ghz, and CMD324 operates at 24.125GHz. The working principle of CW radar modules is that they transmit and receive signals simultaneously using separate receiving and transmitting antennas. The transmitter generates a continuous sinusoidal signal at a frequency of $f_{t,}$ and when a moving target reflects this signal, the transmitted signals are shifted by the Doppler effect f_d. The Doppler effect is the change in frequency of a sound or light wave produced by a moving target relative to the observer.[18]. The CMD324 and HB100 sensors can retrieve the velocity from the target object's velocity by detecting the phase difference between the transmitted signals and the received echoes. To distinguish different objects in the field, there is a need to generate a unique signature of the target. Frequency modulated Continuous Waves (FCMW) can achieve this purpose. In FCMW, a systematic variation of the transmitted frequency or a unique time stamp is placed on the transmitted signal at every instant. The time delay between the transmission and reception is measured to determine the range of the target object [19]. CW radar sensors are used for an application that requires the ability to sense movement but not the target range, whilst FMCW radar modules offer micro-doppler signatures[20]. Micro- doppler are additional signatures imparted onto the reflected signal back to the radar. These signatures are in addition to the bulk velocity and are created by vibration, rotation and other subtle movements of the target. Micro doppler can be used for target recognition and imaging. In this project, FMCW K-LCa1 was used in an attempt to generate the unique signature of the birds.

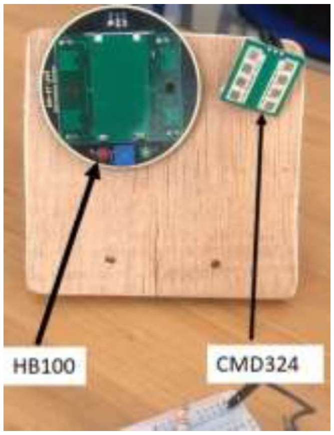

Figure 4.2Motion detection sensors

Another setup of FMCWK-LCa1 with FRDM K64f development board was tested. The K64f MCU was selected because it is based on a Cortex M4 microprocessor, which supports a DSP library. The DSP library was needed to perform a Fast Fourier Transform (FFT) on the IF signal from the sensor. The spectrum of the frequency generated is unique to each target object. This process generates unique signatures of the target objects.

4.2 Block Diagram of Bird Detection System

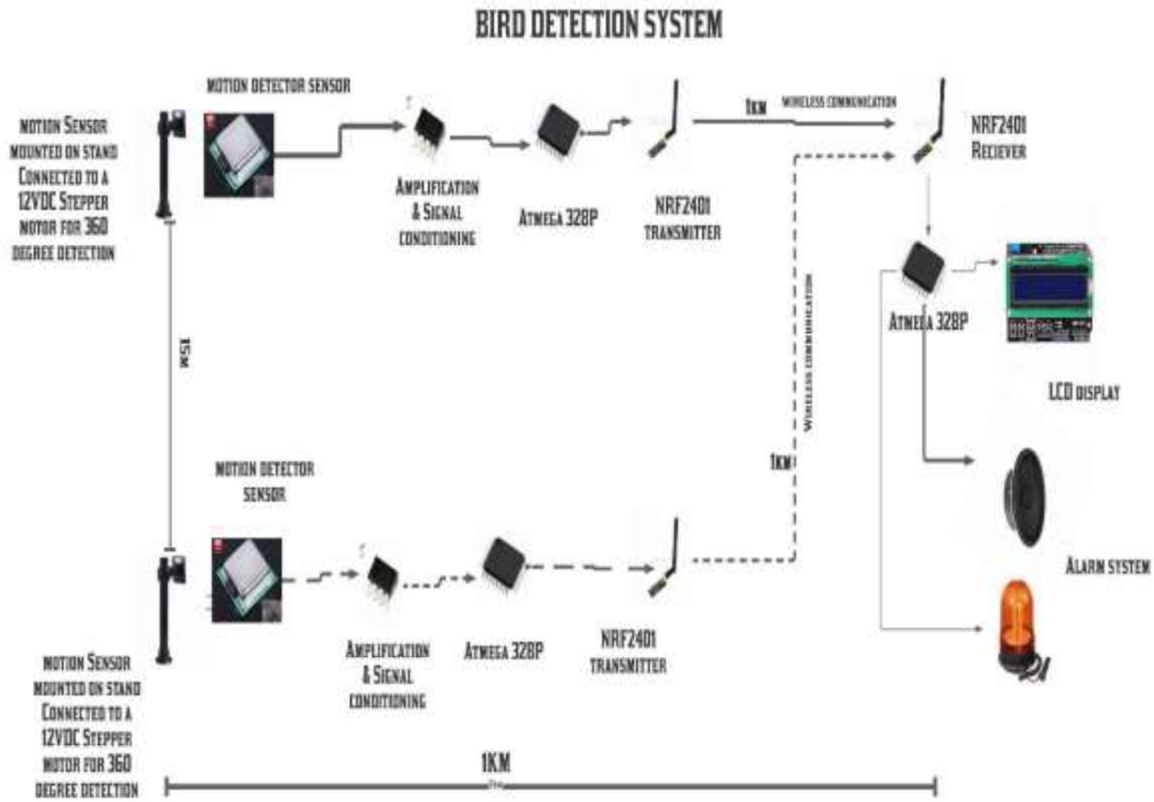

Figure 4.2 Bird detection system

4.3 FPV racing drone

Figure 4.3 Storm A racing drone

The drone was mounted with the Predation Risk generating system, which is a system for generating falcon sounds that are perceived as a threat by other birds. Two methods were compared in this project. The first approach was generating predation sounds using Atmega328P, SD card module and an 8ohm speaker. The SPI pins on Atmega328P were connected to the SD card module.

Sounds from Arduino pin 9 were too low hence the need for an audio amplifier. In this project, a low-cost LM386 audio amplifier was used. The circuit design of the amplifier is shown in Figure 4.4

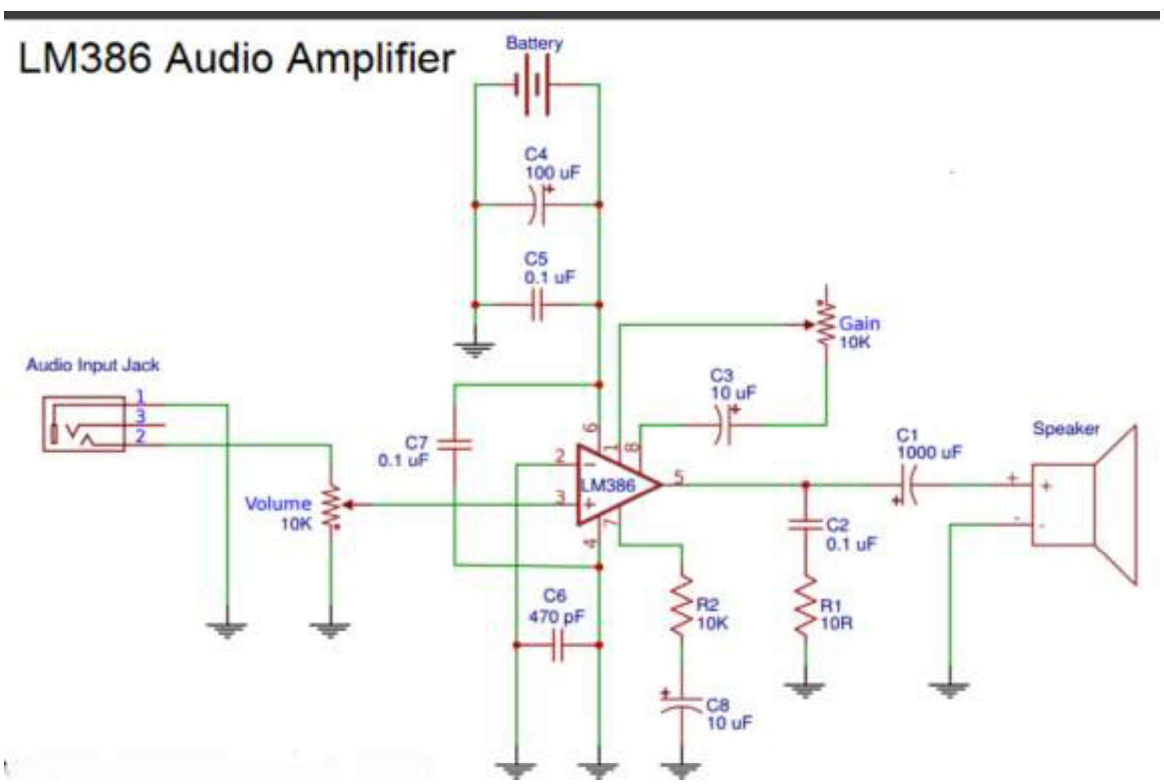

Figure 4.4Amplification circuit

For the second approach, the predation risk was generated by an mp3 player. The Predation risk generating system is shown in *Figure 4.5*

***4.4* MP3 player Setup**

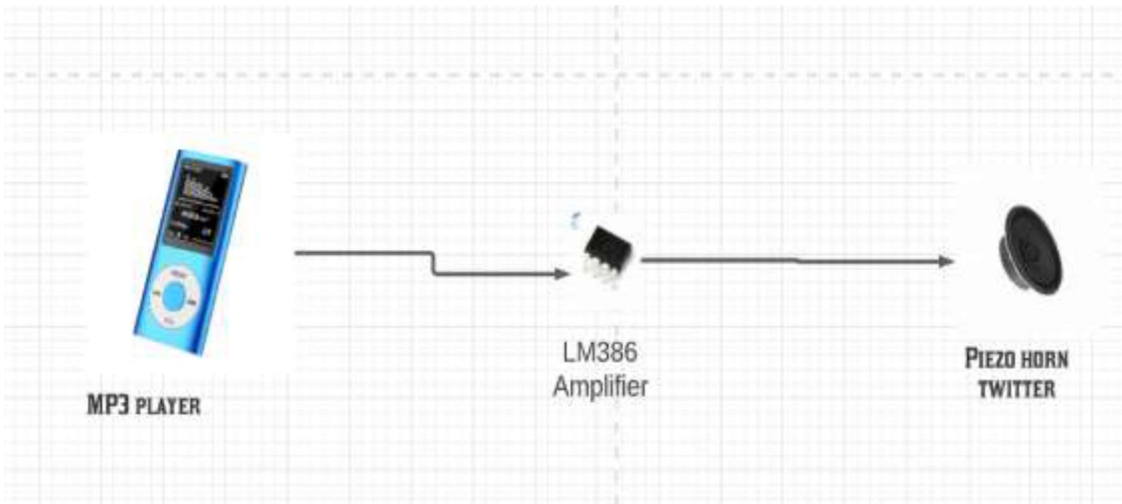

Figure 4.5 Predation risk generating system

Also, the green laser was connected to one of the channels on the Radio link receiver (Radio link R9D) mounted on the drone. This enables controlling the turning on and off of the laser from the ground.

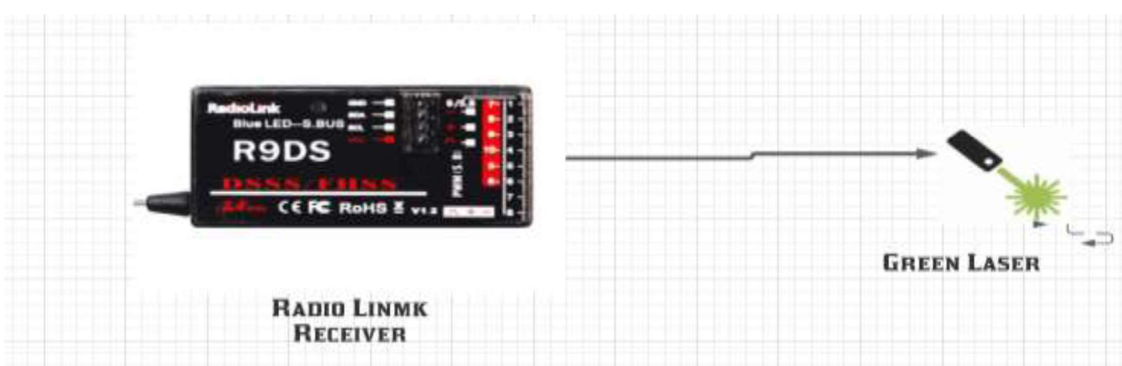

Figure 4.6Green laser

4.5 **Overall Block Diagram System**

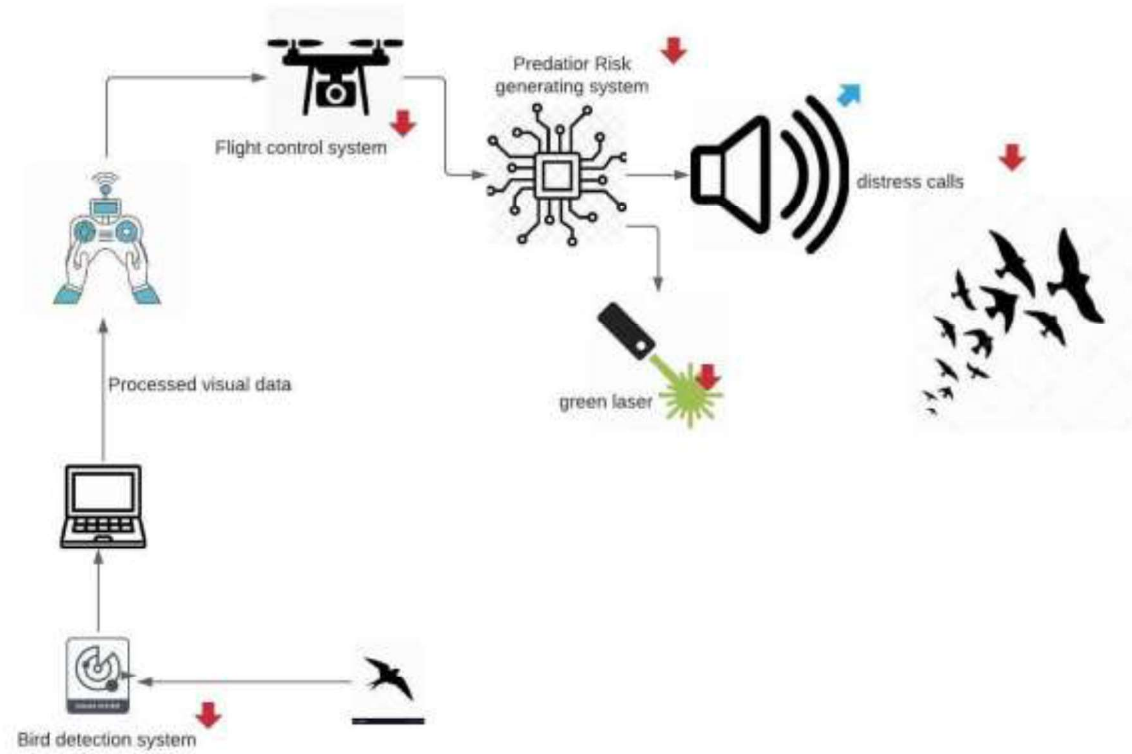

Figure 4.7Overall block diagram

4.6 Design Concerns for Major components

Microcontroller [Atmega328P].

Microcontrollers are often used in systems that need to operate automatically following a fixed sequence of steps in a repetitive way. A microcontroller will be controlling the predation risk generator system through a piezo horn tweeter. This approach offers a solution that has a small size, has much greater flexibility, lower circuit complexity, and a very quick development time, Atmega328P microcontroller will be used both in bird detection systems and bird scaring systems. In the detection system, the microcontroller will be used to control the rotation of the motor, process information from the motion sensor and send it to the user wirelessly via the Nrf2401 module. In the deterring system, the microcontroller will be used to control the sound coming from the piezo horn tweeter. The ability to vary the predation sounds using the ATMEGA 328P reduces habituation in the long term [7]. The receiver will control the laser on mounted on the drone

URI green Laser was used as a visual scare device to deter birds. For laser, the best option would be the one with minimum power consumption and is effective in distracting birds. Research has shown that green laser performs better in deterring birds than the red laser [8].

A piezo horn tweeter was chosen because it has a high-frequency response (3000– 17,000 Hz) which is the frequency range of natural bird calls. Powered by a 2-Watt amplifier which ensures lower power consumption, the tweeter can deliver a maximum volume of 100 dB at 1 meter, which is quite audible for birds in the range of the drone and also not loud enough to cause noise pollution to nearby farms which had been a past problem.

CMD324 and HB100 sensors are low-cost devices to detect the presence of birds in the field using radar technology. Other methods to detect birds include using cameras which are way more expensive and consume a lot of power.

A Global Positioning System (GPS) with a compass module is a security feature in case the UAV runs out of power. The drone can be easily found with the aid of the GPS location

4.7 Specifications of components used

1. CMD324 radar motion sensor

Table 4.1CMD324 radar motion Sensor

PARAMETER	RATINGS	UNIT
Range	15	m
Output power	5	mW
Operating frequency	24	GHz
Operating Voltage	5.5	V
Operating temperature	Min 20- max 60	Degrees Celsius
Radiated Power	15	dBm
Maximum Operating Current	40	mA

2. HB100 radar motion sensor

Table 4.2 HB100 radar motion sensor

PARAMETER	RATINGS	UNIT
Range	15	m
Radiated power	15	dBm
X band frequency	10.525	GHz
Operating Voltage	4.75-5.25	V
Operating temperature	Min 20- max 60	Degrees Celsius
Operating Current(max)	30	mA

3. Atmega328P

Table 4.3 Atmega328P microcontroller (MCU)

PARAMETER	RATINGS	UNIT
Speed	16	Mhz
Program memory size	32	Kb
Operating Voltage	1.8-5.5	V
RAM	2	K Bytes
Operating Current(max)	40	mA

4. NRF24L01 module

Table 4.4 NRF24L01 module

PARAMETER	RATINGS	UNIT
Range	1	km
Communication protocol	SPI	-
Band rate	0.250-2	Mbps
Channel range	125	-
Maximum nodes	6	-
Operating Voltage	3.3	V
Operating Current	50-250	mA

FPV Storm A racing drone:

Table 4.5 FPV storm racing drone

Features	RATINGS	UNIT
Integrated camera range	300	m
CC3D flight controller	SPI	-
Video transmission frequency	5.8	GHz
2204 brushless motors	2300	Kv
Receiver frequency	2.4	GHz
LiPo Battery	11.1	V
Battery energy Density	2200	MAH
Transmitting distance	4000	m

4.8 Circuit Schematics

For the ground system, a single universal circuit was made, making it easier to use one PCB design for both the transmitter and receiver circuit; hence the cost of PCB fabrication was reduced**.**

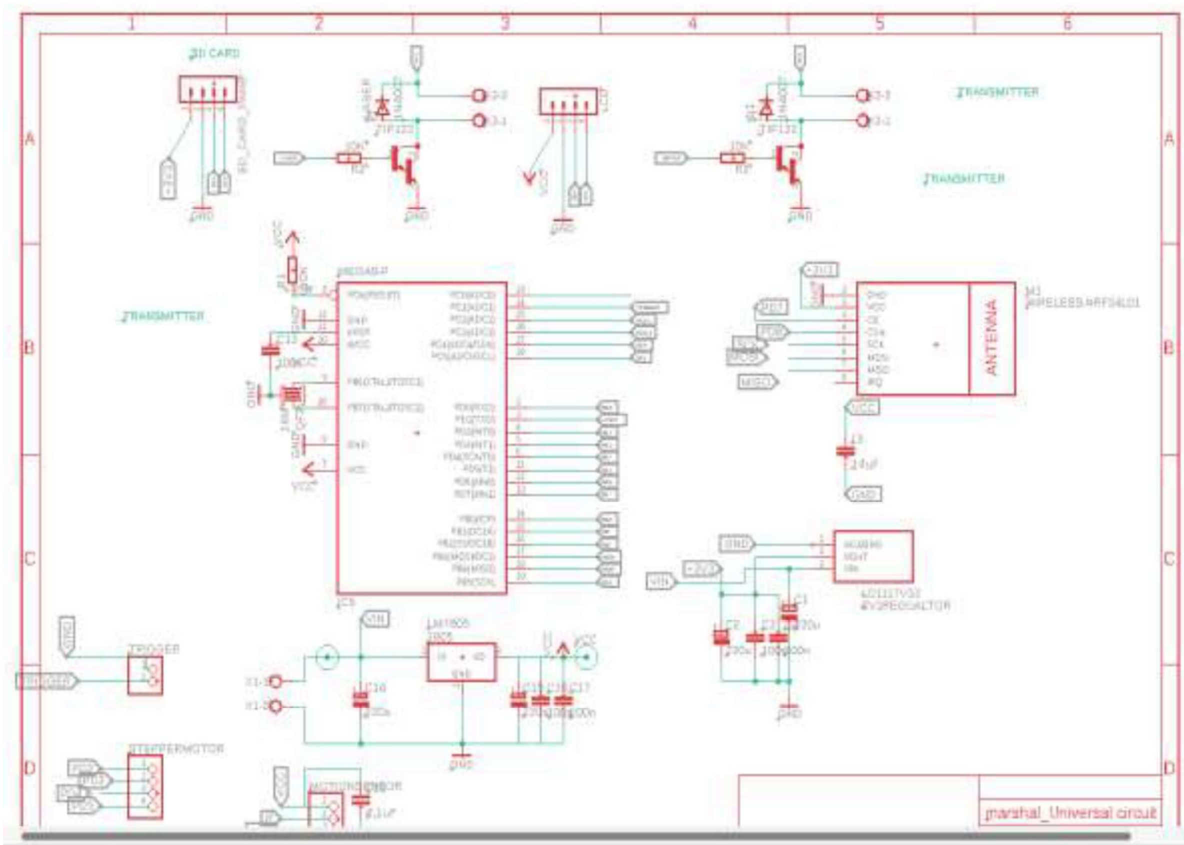

Figure 4.8 Universal Circuit

4.9 PCB View of the Universal circuit

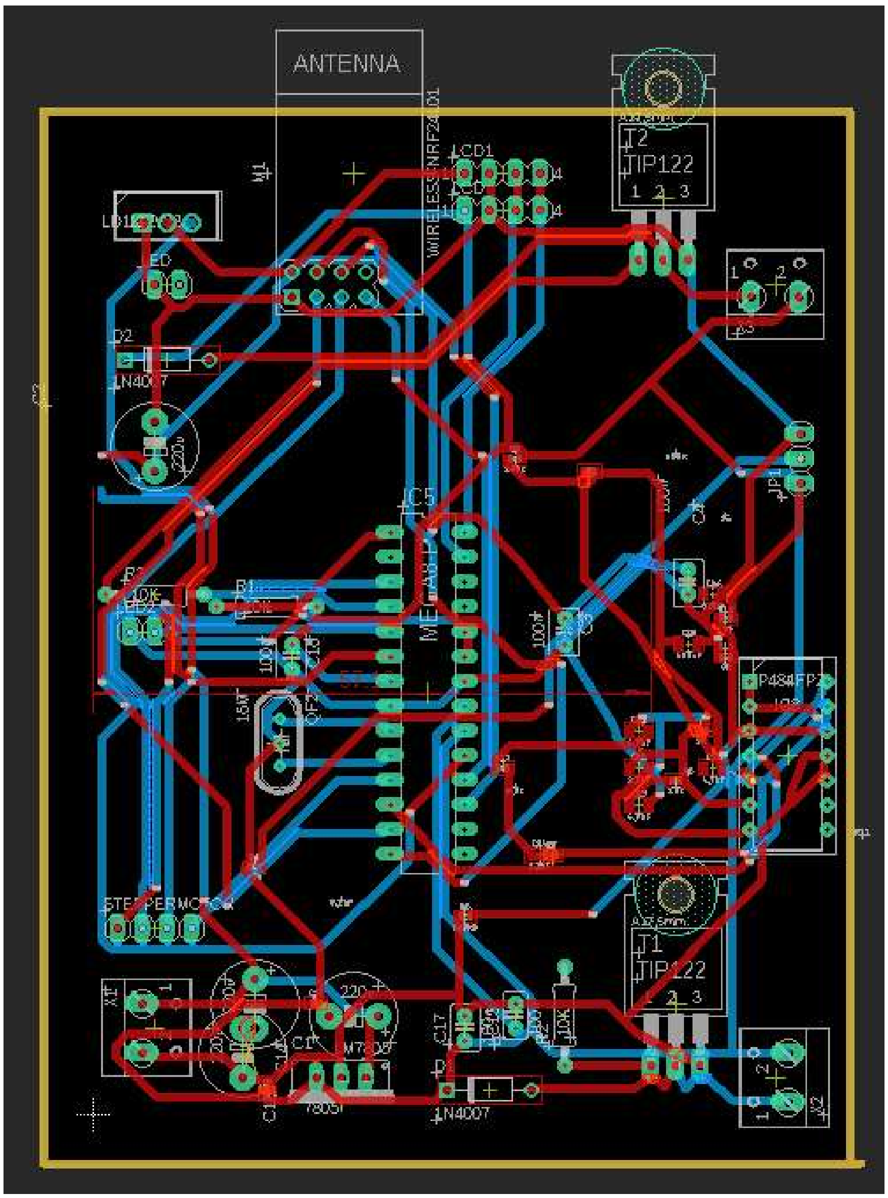

Figure 4.9 PCB view

Figure 4.9 shows the PCB with a trace diameter of 32mm. If the diameter is less than 32mm, the circuit oscillates, which affects performance. The PCB design was made to be a two-layer board with Atmega 328P at the centre of the board. Since the circuit is not complicated, a two-layer board can reduce the cost of fabrication whilst the circuit is performing as expected. Also, placing the Atmega 328P at the centre makes the routing of wires easier. The NRF24L01 were placed far away from the terminals of the motion sensor to avoid interference, which affects the performances of these two devices. Decoupling capacitors were placed close to the power supply terminal blocks to smoothen the power supply voltages. The routing wires on the PCB were routed in the form of a polygon to avoid sharp curves, which introduce noise in the circuit.

4.10 Bird Deterring system circuit Schematics

The Sound generating system schematic is shown in Figure 4.10

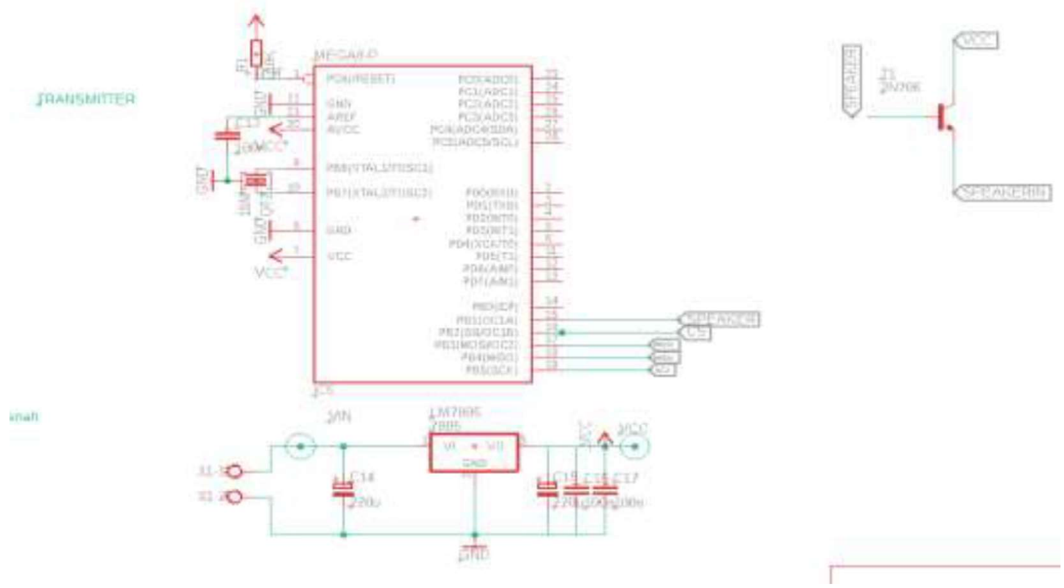

Figure 4.10 Sound generating system schematic

The Audio amplification circuit is shown in Figure 4.11. LM386 was used as the audio amplifier

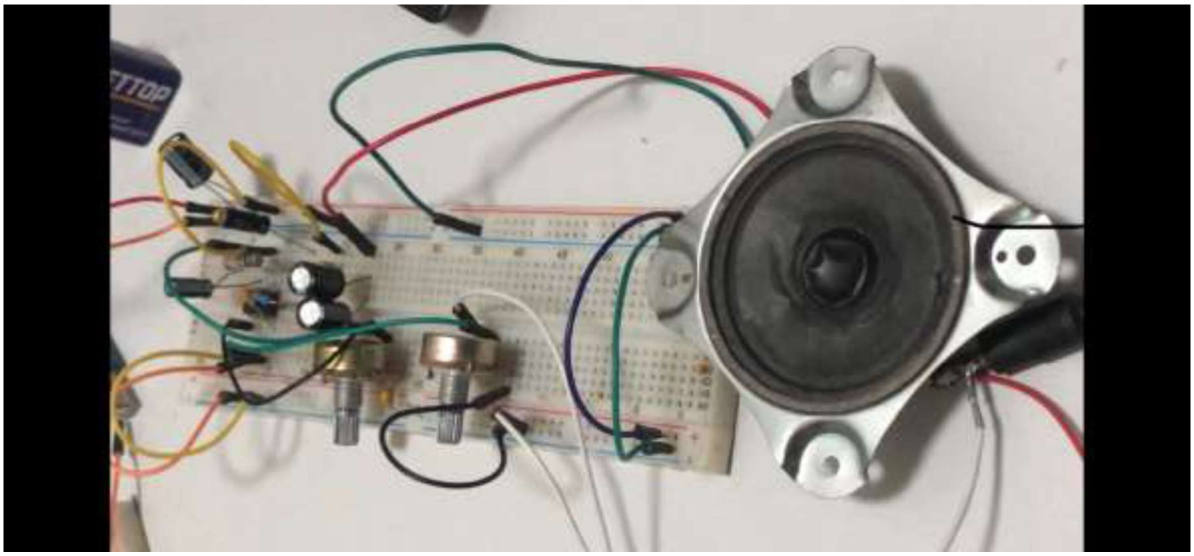

Figure 4.11 Audio amplification

4.11 Power Consumption table

Table 4.6 Power consumption table

Component	Voltage rating(V)	Current Rating(A)	Quantity	Power rating(W)
Atmega 328P	5	26uA	3	130u
HB100	5	45m	1	0.2
CMD324	5	40m	1	0.2
NRF24L01	3.3	50m	2	0.165
Speaker	5	0.02	1	0.01
LM386 audio amplifier	9	0.1	1	1
Drone	12	23.33	1	280
Total Power consumption				281,375

Chapter 5: Testing and Results

5.1 Bird Detection System.

The HB100 and CMD324 sensors were able to detect the motion of moving objects. The smallest size of the detected objects was an index finger of an average finger at a distance of 12 meters. From this observation, it can be implied that a single bird can be detected with this system since a single bird is larger than a human index finger. The HB100 came with an inbuilt amplification circuit, and it showed a green light when a movement had been detected. The HB100 and CMD324 had similar connections to the Atmega 328P, which performs signal processing and computes the speed of the moving object. The Atmega 328P communicated wirelessly with another Atmega 328P through the nrf24l01 wireless communication module. At the receiver end, a buzzer was configured to turn on when a moving object was detected, and the speed was shown on the OLED screen. During the testing, HB100 was more responsive as compared to CMD324. Figure 5.1 shows the testing of the bird detection system.

On the other circuit set up to generate the unique signature of objects, the sensor used could not create signals that can be used for radar imaging. Moreover, on performing FFT on the signal from the K-CLa1 sensor, we only managed to get a spectrum of frequencies that was not unique. Hence, in the end, the HB100 sensor module produced better results than K-CLa1. Figure 5.2 shows doppler images from the K-LCa1 test results using a phone and a hand as the target objects. The target objects were moved towards and away from the sensor.

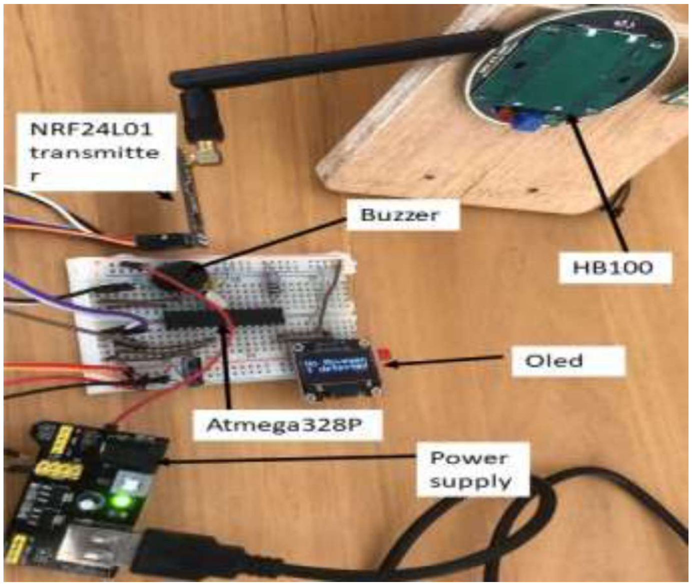

Figure 5.1 Bird detection system

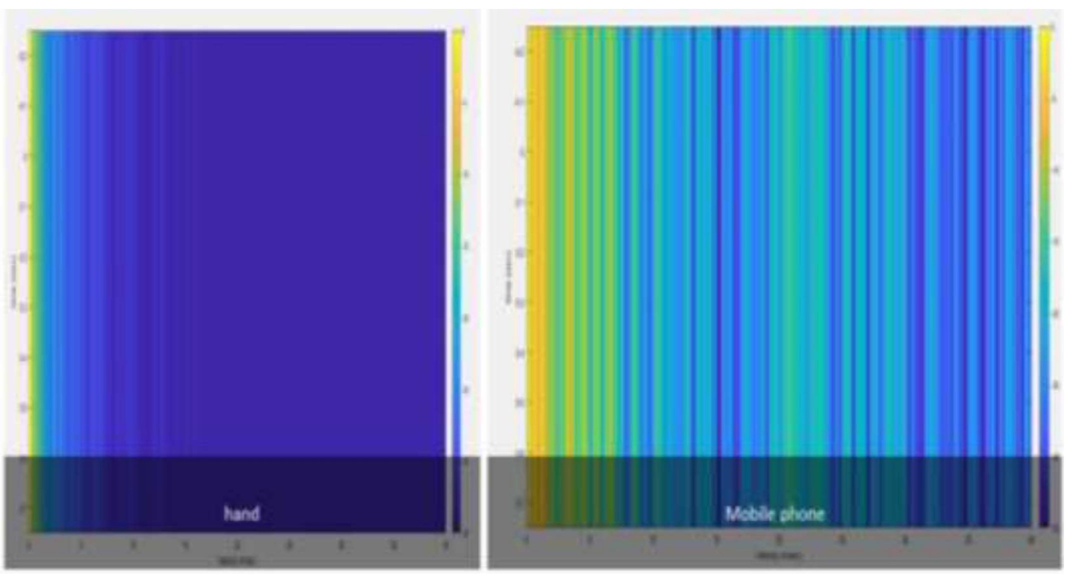

Figure 5.2 K-CLa1 doppler images

5.2 Bird Deterring System

The first technique to deter birds was using prerecorded falcon sounds stored in a memory card. The sounds were successfully generated with Atmega328P, SD card module, 16-ohm speaker and an LM386 audio amplifier with a gain of 200. The sounds were audible within the range of 2m. The falcon sounds from Arduino were not as loud as expected because the library used to play WAV files had a maximum volume of 5 on a scale of 0 to 7.

The FPV Storm racing drone did not perform as expected to carry the bird deterring system. The drone required more manual control, making it difficult to stabilize, especially under windy conditions. Hence this presented the risk of damaging the payload when the drone crashed several times. It required more practice to land the drone successfully. Also, the drone had a short flight time of 10 minutes because the battery had a lower energy density. The drone was able to fly a distance of 200 meters in this flight time. The CC3D flight controller on the FPV Storm A acing drone was replaced with the Arducopter flight controller to carry out further tests. Ardupilot was selected because of its autopilot and stabilization modes. The drone became easier to fly and land in a stabilized mode. The drone was no longer crashing, which reduced the number of times we had to replace the propellers. Figure 5.3 shows the drone under test flight.

Figure 5.3 Drone test flight

After successfully testing the drone, the payload of a piezo horn tweeter was mounted on the drone. The sound from the piezo horn tweeter was audible in the range of 500m. the frequency was too high such that the operator had to wear headphones to shield the ears from the high-pitched sound. The blue and red LEDs were mounted to the front and the back of the drone to act as a visual deterrent in place of the green laser in the original design. Figure 5.4 shows the LEDs and a piezo horn tweeter mounted on the drone.

Figure 5.4 Drone with LEDs and piezo horn tweeter

Chapter 6: Conclusion

6.1 Summary

The main goal of this project was to design a robust system that detects birds in a field and uses a network of techniques mounted on the drone to deter the birds. The system was designed to reduce crop loss due to bird pests and reduce the habituation of birds to the deterring techniques. The system used low-cost radar sensors for motion detection and prerecorded falcon sounds to deter birds. The motion sensor used was HB100 with a range of 20 meters. A drone with a camera was mounted with a predation risk generating system and was flown towards the birds in the field. The purpose of the ground system was to save drone power such that a drone is operated when a bird has been detected in the field.

6.2 Limitations

Due to the time factor, the PCB design, which was sent for fabrication, did not arrive in time; hence all the circuit testing was done on the breadboard. A low-cost perf board did not work as the circuit did not transmit wirelessly using the NRF24L01 module. Some of the components in the design, such as the green laser and mp3 player were ordered, but they did not arrive in time due to delays in shipment process. There were no alternatives components that could meet the design requirements

The HB100 sensor had a limited range of 12 meters upon testing as compared to the 20 m stated in its documentation. Also, the use of NRF24L01 has the challenge of working in open-air conditions only. There is a need to use other wireless communications that work around the buildings, and obstacles though this might increase the cost of the system. On the bird deterring system, the use of a racing drone presented some challenges because there is a need for an experienced drone pilot to fly it. Our system is designed for farmers who might not have experience with drones; hence, a racing drone is not suitable because it is difficult to balance during flight time. Also, this drone cannot operate under windy conditions and at higher altitudes. Under these conditions, the drone lost control and crashed. Although the CC3D flight controller was replaced with Ardupilot/Arducopter, the new flight controller had a low response time and sometimes lost control. The drone would roam around the place aimlessly. Furthermore, Atmega 328P has a resolution of 8 bit; hence, the system's sound quality was low and obscured by the sound of the drone propellers. In order for the birds to perceive our system as a threat, there is a need to make the sounds from the speaker as natural and audible as possible.

6.3 Future Works

To help improve the system, there is a need to continue a series of testing and use alternative components and compare their efficacy. Another component that can be implemented for bird detection system is a camera to detect birds in the field. Though the camera might increase the cost significantly but with the development of technology, some cameras with a range of about 300m will become much cheaper. A camera with this range can cover a 3-hectare field(0.03km^2). The camera will be assisted with image recognition algorithms to recognize birds in the field. Additionally, other FMCW radar sensors with high resolution, such as FMCW KMD2, can be implemented to generate the unique signature of birds by performing FFT on the IF signal.

For the Bird deterring system, there is a need to use drones with better autopilot flight controllers, which helps the farmer to operate the drone easily. With the autopilot mode, the farmer will input the coordinates, and the drone will fly autonomously. This will reduce the need for an experienced drone pilot and reduce the risk of damaging the drone when it crashes. Moreover, the drone of choice should be equipped with an obstacle avoidance mechanism to avoid damaging the drone when it is close to an obstacle. With autopilot flight mode, a farmer is supposed to create the mission path of the drone on a computer; however, without obstacle avoidance, the drone might not reach its destination when it encounters an obstacle. Hence, it is important to use a drone that can navigate its way around obstacles.

For the predation risk generation, an mp3 player with a better audio amplifier than LM386 can be used to play higher quality falcon sounds. Also, an mp3 player comes as a low-cost option for the sound generating system. A green laser, a visual deterrent, should be mounted on the drone to add to the network of deterring birds in the field. Moreover, the whole system should be rigorously tested for about a month to investigate its effectiveness towards the habituation of birds. Additional components such as a green laser and a piezo horn tweeter should also be tested for their effectiveness. To design a proper system that resets itself when unexpected conditions occur, a Watchdog Timer needs to be included in the code so that the system restarts under such conditions.

6.4 Conclusion

The designed system is a good start towards detecting and deterring birds in the field using modern technology. The system is not ready yet for deployment in the field, but further testing can guarantee its success. There is a need to investigate other low-cost techniques to detect and deter birds in the field. Compared to conventional methods of detecting birds in the field, such as pesticides and firing canon guns, the designed system performs much better and is less prone to habituation as it includes bird psychology in the design. The designed system managed to detect the movement of birds and compute their speed. Lower speed movements (below 1km/hr) were filtered as they included noise or small disturbances of the motion sensor itself. This made the system robust at eliminating noise. A buzzer was triggered when a noticeable movement had been detected in the field, and the remote user could see the computed speed of the target object. In terms of deterring the birds, the system managed to vary falcon sounds at random times, and the drone flew at different angles, making it more effective in scaring birds away from the field for a long time. The sounds generated were loud enough to be audible for birds in the range of 1m to 500m.

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Appendix

Code for the receiver

```
 #include <Wire.h>

#include <Adafruit_GFX.h>

#include <Adafruit_SSD1306.h>

#include <avr/wdt.h>


#define SCREEN_WIDTH 128 // OLED display width,  in pixels

#define SCREEN_HEIGHT 64 // OLED display height, in pixels

#define Buzzer 6

// declare an SSD1306 display object connected to I2C

Adafruit_SSD1306 oled(SCREEN_WIDTH, SCREEN_HEIGHT, &Wire, -1);




#include "Arduino.h"

#include <SPI.h>

#include <RF24.h>


// This is just the way the RF24 library works:

// Hardware configuration: Set up nRF24L01 radio on SPI bus (pins
10, 11, 12, 13) plus pins 7 & 8

RF24 radio(7, 8);


byte addresses[][6] = {"1Node","2Node"};
```

```
// ---------------------------------------------------------------
---------------
// SETUP   SETUP   SETUP   SETUP   SETUP   SETUP   SETUP   SETUP
SETUP
// ---------------------------------------------------------------
-----------

void setup() {



  Serial.begin(9600);
wdt_enable(WDTO_8S);
 pinMode(Buzzer, OUTPUT);
Serial.println("THIS IS THE RECEIVER CODE - YOU NEED THE OTHER
ARDUINO TO TRANSMIT");

  // Initiate the radio object
  radio.begin();

  // Set the transmit power to lowest available to prevent power
supply related issues
  radio.setPALevel(RF24_PA_MIN);
```

```
        // Set the speed of the transmission to the quickest available
        radio.setDataRate(RF24_2MBPS);

        // Use a channel unlikely to be used by Wifi, Microwave ovens
etc
        radio.setChannel(124);

        // Open a writing and reading pipe on each radio, with opposite
addresses
        radio.openWritingPipe(addresses[0]);
        radio.openReadingPipe(1, addresses[1]);

        // Start the radio listening for data
        radio.startListening();


      // ---------------------------------------------------------------
---------------
        // initialize OLED display with address 0x3C for 128x64
        if (!oled.begin(SSD1306_SWITCHCAPVCC, 0x3C)) {
          Serial.println(F("SSD1306 allocation failed"));
          while (true);
        }
```

```
    delay(2000);         // wait for initializing
    oled.clearDisplay(); // clear display

    oled.setTextSize(2);          // text size
    oled.setTextColor(WHITE);     // text color
    oled.setCursor(0, 10);        // position to display
    //oled.println("Gena is online   TODAY TOMORROW"); // text to
display
    oled.display();               // show on OLED

  }

  void loop() {

   // This is what we receive from the other device (the transmitter)
    unsigned char data;

    // Is there any data for us to get?
    if ( radio.available()) {

      // Go and read the data and put it into that variable
      while (radio.available()) {
        radio.read( &data, sizeof(char));
      }
```

```
          // No more data to get so send it back but add 1 first just
for kicks
          // First, stop listening so we can talk
          radio.stopListening();



          // Now, resume listening so we catch the next packets.
          radio.startListening();




        }


        Serial.print(data);
           Serial.println("km/hr ");
           oled.clearDisplay();
           digitalWrite(Buzzer, LOW);
           if (data>80){
             oled.clearDisplay();
         oled.setCursor(0, 10);        // position to display
        //oled.println(data); // text to display
        oled.println("No Movement detected ");
        digitalWrite(Buzzer, LOW);
```

```
      }

    else {
       oled.clearDisplay();
      oled.setCursor(0, 10);        // position to display
   oled.println(data); // text to display
   oled.println("km/hr");
  digitalWrite(Buzzer, HIGH);

    }
      oled.display();
    delay(1000);

}
```

Appendix C – code for the transmitter and

HB100/CMD324 sensor

```
 #include <Stepper.h>



const int stepsPerRevolution = 200;  // change this to fit the number of steps per revolution

// for your motor



// initialize the stepper library on pins 2 through 5:

 Stepper myStepper(stepsPerRevolution, 2, 3, 4, 5);



#include <SPI.h>

#include <RF24.h>
```

```
#include <RF24_config.h>

#include <nRF24L01.h>


RF24 radio(7, 8); // CE, CSN


const byte address[6] = "00001";


long randNumber=0;
```

```
// Below: pin number for 6 for OUT

#define PIN_NUMBER 6

// Below: number of samples for averaging

#define AVERAGE 10

// Below: define to use serial output with python script

//#define PYTHON_OUTPUT

unsigned int doppler_div = 44;

unsigned int samples[AVERAGE];

unsigned int x;
```

```
void setup() {
  Serial.begin(9600);
  pinMode(PIN_NUMBER, INPUT);


/// transmission setup
  radio.begin();
  radio.openWritingPipe(address);
  radio.setPALevel(RF24_PA_MIN);
  radio.stopListening();


// stepper motor
  // set the speed at 60 rpm:
  myStepper.setSpeed(60);
```

```
}

void loop() {

//Serial.print(speed_calc());

Serial.print("\r\n");

transmitter(speed_calc);

stepper_motor();

}

//functions

//stepper motor

void stepper_motor() {
```

```
  // step one revolution  in one direction:

  myStepper.step(stepsPerRevolution);

  delay(500);

  // step one revolution in the other direction:

  myStepper.step(-stepsPerRevolution);

  delay(500);

}

// transmitter
```

```
void transmitter (unsigned int x) {

Serial.print(x);



   char buffer[300];

     sprintf(buffer, "speed  %d km/h", x);




 radio.write(&buffer, sizeof(buffer));

 //radio.write(&text, sizeof(text));

  //delay(3000);



}
```

```
// motion sensor

 unsigned int speed_calc(){/// probe pin dig 6

 // noInterrupts();

  pulseIn(PIN_NUMBER, HIGH);

  unsigned int pulse_length = 0;

  for (x = 0; x < AVERAGE; x++)

  {

    pulse_length = pulseIn(PIN_NUMBER, HIGH);

    pulse_length += pulseIn(PIN_NUMBER, LOW);

    samples[x] =  pulse_length;

  }
```

```
interrupts();



// Check for consistency

bool samples_ok = true;

unsigned int nbPulsesTime = samples[0];

for (x = 1; x < AVERAGE; x++)

{

  nbPulsesTime += samples[x];

  if ((samples[x] > samples[0] * 2) || (samples[x] < samples[0] / 2))

  {

    samples_ok = false;

  }

}
```

```
if (samples_ok)

{

  unsigned int Ttime = nbPulsesTime / AVERAGE;

  unsigned int Freq = 1000000 / Ttime;



  #ifdef PYTHON_OUTPUT

   // Serial.write(Freq/doppler_div);

  #else

  if ((Freq/doppler_div)>3000){

return Freq/doppler_div;}

else

return 0;
```

```
    #endif
  }
  else
  {
    #ifndef PYTHON_OUTPUT


    #endif
  }


}
```