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Bluetooth Based Bird Detection System

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Abstract

Context. Windmills became one of main sources of energy. Since they are placed in open areas, there are many chances that birds may enter the wind farms and get killed or damaged. Some wind farms use pulse radar systems for saving the birds from windmills. In this pulse radar technology, the turbines are turned off automatically when a bird is detected. Another technology is ultrasonic "boom boxes", which are attached to turbines and produce high-frequency noises continuously to repel birds. The system we are going to propose detects the birds entering the farm using Bluetooth technology and alerts the windmill farm operator. Using Bluetooth technology can be power efficient, accurate, and mainly useful for avifauna method of protection.
Objectives. The main objective of the Bluetooth bird detection system is to make distance estimation possible with the help of signal strength that is measured between two Bluetooth devices where one is placed at the wind farm and another on bird.
Methods. Bird detection and distance measurement is done using a BGX13P Bluetooth transmitter and receiver. According to the distance to the bird, further steps can be taken to protect it. Simplicity Studio application is used to take the readings of the Bluetooth signal strength of the transmitter and receiver.
Results. As a result, the birds are detected at two distances from a windmill, the first distance is 250 m and the second is 175 m from the windmill. The windmill operator is alerted when the bird is detected at either of these distances.
Conclusions. A bird detection system is built with the help of Bluetooth technology. This system helps saving the birds from collisions with windmills. However, there is a need for further quantitative and qualitative validation of the models in full-scale industry trials.

Keywords: Bluetooth, Avifauna, Signal strength, Distance estimation.

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Contents

List of Figures

List of Tables

List of Acronyms

1. GW - Gigawatts
2. CNNs - Convolutional Neural Networks
3. LSTMs - Long Short-term Memory Networks
4. RSSI - Received signal strength indication

Chapter 1

Introduction

On this planet, there are many living beings like birds, plants, etc., who live in coexistence with humans. Here especially avifauna is one of the most affected beings by human activities and constructions like radiation, high power lines, wind turbines, etc. Wind turbines are one of these constructions which most affect avifauna. Every year many birds fatally collide with wind turbines. This is noted and taken as a problem and needs to be rectified by proper implementations.

In this research, some of the issues are solved by detecting birds to protect them from collisions with the wind turbine. The main goal of the research is to design a monitoring system based on the RSSI of the signal. The signal strength can be used to estimate the distance of the bird from the wind turbine. This research aims to observe the avifauna movement around the wind turbines.

The main issue that is considered for this research is if a bird comes near to wind turbine then an act of deterrence should be undertaken to avoid a collision. This issue is discussed and solved in this research and has been solved in such a way that a first alert is sent when the bird comes into a radius of 250 m to the wind turbine and the second alert is made when the bird comes into a radius of 175 m this is set as a danger zone.

The purpose of this thesis is to design and prototype a system for detecting birds that are approaching wind farms and notifying when the birds enter the hazardous ranges of 250 m and 175 m.

We used two BGX13P Bluetooth boards which are made by Silicon labs. Bluetooth technology has a mechanism for both transmitting and receiving signals. Here one BGX13P Bluetooth board is used as a transmitter, we have to attach it to the bird. The other board is used as a receiver, it is fixed to the windmill. If the transmitter comes in a range of the receiver, the transmitter detects the receiver, and RSSI values are observed using Simplicity studio. We have to calculate the mean and standard deviation of RSSI values observed by multiple testing at the ranges of 175 m and 250 m. We limit a set of ranges using mean and standard deviation. By these predetermined values, we can make sure that the bird is in the desired range with more than 90% accuracy.

This report consists of an introduction to the research, a survey of the related works, a description of the methodology process by implementing User Driven Design, a presentation of the implementation of the model and its validation, and finally results and their analysis.

Chapter 2

Related Works

2.1 Wind energy

The windmill is one of the most striking inventions of the middle ages. Medieval people were excited by windmills and considered them as one of the most important new development to appear in their society. As a result, within a century or so of their first appearance around 1185, windmills had spread across most of Europe [7]. At present there are many windmill farms with many wind turbines are established for renewable energy sources, which is looked as in the Figure 2.1.

Figure 2.1: Windmill farm [1]

Since then the number of windmills grew rapidly. For England alone, some 4,000 existed by the beginning of the fourteenth century [8]. This impressive achievement is a testament to the willingness of medieval people to invest in new technology [9]. In the 15th to 17th-century windmills are used as drainage pumps, further in the 16th to 17th centuries they are used to drain the land which is with water to get more dry land from the sea [10]. In the 18th century, windmills are used to pump water [11] to prepare salt in some parts of the world like Bermuda.

When coming to other parts like Greece windmills are used as flour mills and this technology is used till the 20th-century.

Wind energy has now become one of the most economical renewable energy technology [12] in recent years. Wind energy is a clean source of power. It does not cause any pollution [13]. It is a renewable source. Wind energy has low operating costs. In Europe, there were installed wind turbines with the capacity of 14.7 GW of wind energy in 2020. 80% of this energy was generated using the onshore wind mills. Europe now has 220 GW of total wind energy capacity [14].

Wind turbines, the modern equivalent of the windmill, are usually grouped into large collections of units to produce electricity. These gropus are called wind power plants, or wind farms. They are generally located in agricultural areas where large plots of land are available, and agricultural activities are undisturbed by their action. Often located in windy areas of the country, they can also be constructed offshore to make use of winds that sweep over the bodies of water. Wind-powered energy leaves no dangerous waste that can be dangerous to both people and the environment [15].

Today, electricity-generating wind turbines are tested technology and provide a secure and sustainable energy supply. It becomes an effective way to generate electricity competitive with all the other conventional energy production resources like coal, petroleum, etc. [15].

Wind energy does not cause environmental problems through greenhouse gas emissions, however, turbines can have an impact on wildlife [16], [17], [18].

Avifauna has no chance to surviving when taking a direct hit from a rotating wind turbine blade. See Figure 2.2,that shows the birds flying across windmill farm where there are chances to collide. Studies have estimated that between 140,000 and 500,000 birds die from wind turbines each year. As a comparison, collisions with buildings are estimated to kill between 365 and 988 million birds annually [19]. The study by Loss and others reported that there were 44,577 turbines in operation in 2012, while the U.S. Wind Turbine Database indicates that there are 65,548 today — an increase of 47%. Adjusting for this industry growth, approximately 538,000 wind turbine-caused bird deaths are predicted to occur in the U.S. each year [20].

Figure 2.2: Canada geese fly by a turbine [2]

2.2 Technologies for saving birds

There are many technologies applicable to save birds from colliding with wind turbines. But many of them are not enough reliable.

A color method is one of possible solutions. Most wind turbines are painted white or gray, to make them as visually inconspicuous as possible. But white paint can indirectly lure birds and bats, which was found in a 2010 study, by attracting the winged insects they hunt [21]. White and gray turbines were second only to yellow ones in attracting insects, according to the study, including flies, moths, butterflies, and beetles. Purple turned out to be the least attractive color to these insects, raising the possibility that painting wind turbines purple might alleviate some bird and bat fatalities. Even if purple paint is not practical, another line of research is investigating the use of ultraviolet light to deter birds and bats from turbines. Still, given the limitations of long-distance vision at night, some researchers think migrating bats do not always see the spinning blades, and mistake the poles of wind turbines for trees [21].

Radars are other technology used. Figure 2.3 shows the radar image from the National Weather Service's Key West facility. A massive flock of migratory birds is seen moving north. The green/yellow objects are biological objects flying north over the facility. The darker blue objects indicate rain. In [3] it is stated that "a natural phenomenon that usually goes unseen and unnoticed was seen and noticed over Key West on Monday: the massive nocturnal migration of birds was captured by the National Weather Service's radar stationed there. The field of birds was first detected around midnight and stretched over the island city, according to the Weather Service. Meteorologists said the radius of the flock measured at least 90 miles out from the center — but the actual size of the migration could have been much bigger".

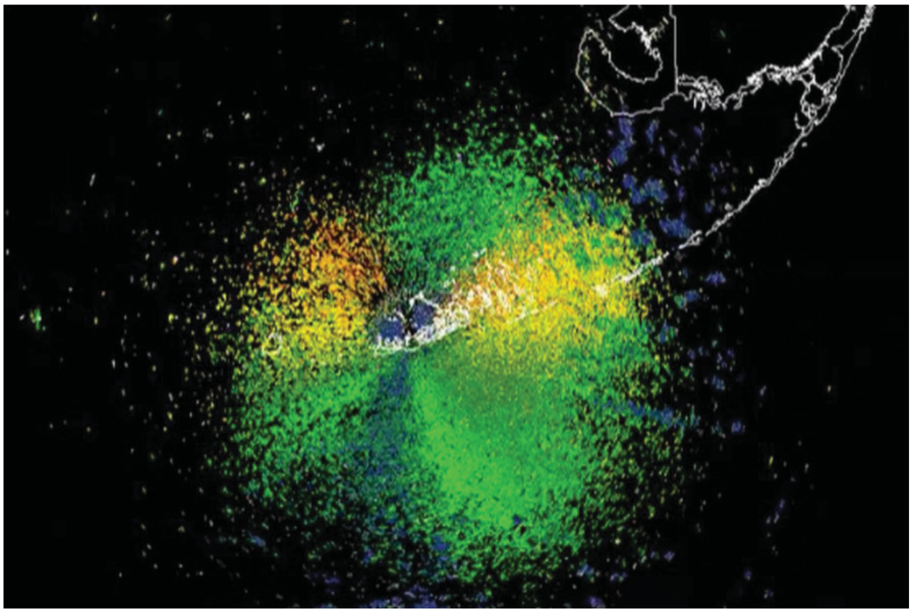

Figure 2.3: Birds detected using radar technology [3]

Radars can be used to detect the birds incoming near the wind farm. However, this method is useful rather for a massive group of birds but cannot be implemented for a small group of birds or a singular bird.

Researchers from Oregon State University are developing sensors that can tell when something hits a wind turbine blade, giving operators a chance to prevent more collisions by shutting turbines down [21]. As this process takes a long time, it is not much efficient to save birds.

Vision-and thermal-based avian detection systems are created for a wide range of applications, including ecological purposes and airport safety. There is more computer vision research pertaining to ornithological applications are shown in Figure 2.4. All birds in flight are properly recognized in subfigures (a,e) in Figure 2.4, however the dark shadows of the flying birds were not accurately detected, as illustrated in subfigure (a). All the birds in subfigures (a-h) in Figure 2.4 are detected whatever the flying altitude is. In the case of subfigures (i-p) in Figure 2.4, the images are of bird decoys which are accurately detected. However many of the techniques may translate well to birds [4].

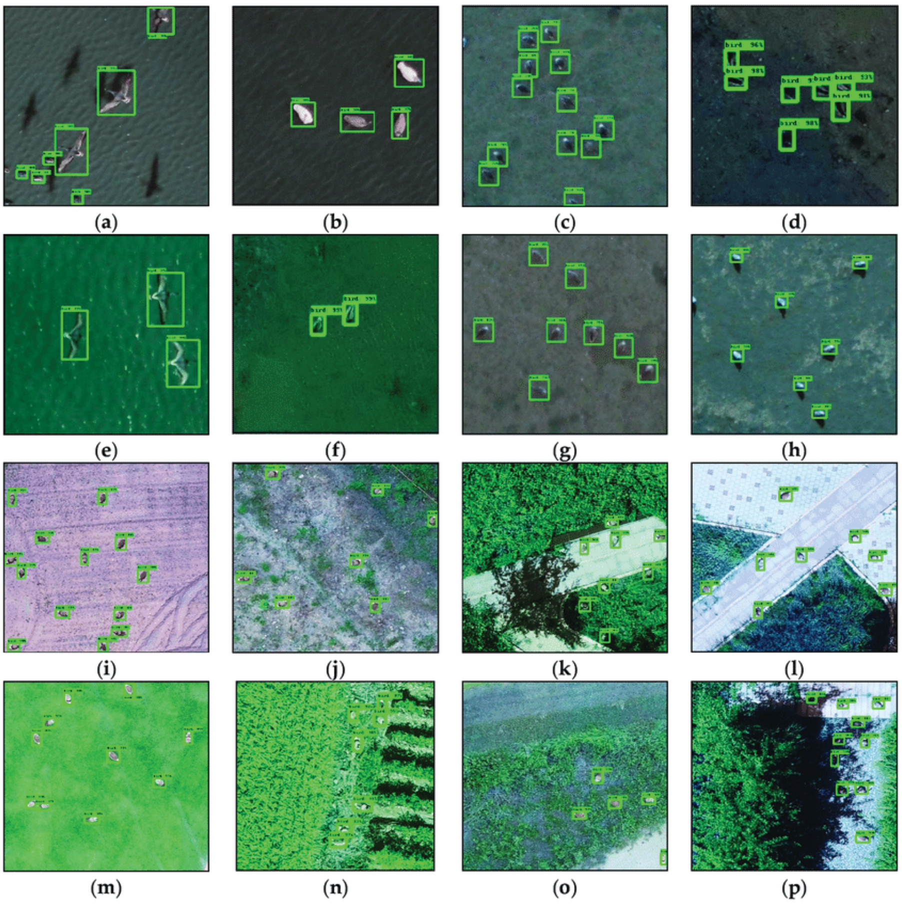

Figure 2.4: Various visual bird detection [4]

In "Hierarchical Incorporation of Shape and Shape Dynamics for Flying Bird Detection", Z. Jun, X. Qunyu, C. Xianbin, Y. Pingkun, and L. Xuelong present the design and tests of a novel bird detection system [22]. Detection is two-fold, first performing shape-based identification of the bird, followed by an analysis of bird movement. Bird's flight is categorized into four states, which comprise the entire flipping process. The hierarchical structure maintains computational efficiency by removing obvious non-bird targets via shape analysis before moving on to more process-heavy dynamic shape analysis. This method demonstrated a high detection rate and low false positive quantities, including when used with videos that incorporate noise and low contrast [22]. Webcams are a technology that can be found in a myriad of locations. By adapting computer vision techniques to be used with these affordable cameras, these devices can be used to collect data pertaining to bird migration patterns [4].

In "Automatic Bird Species Detection from Crowd Sourced Videos", W. Li and D. Song designed two algorithms, one to extract avian inter-wing tip distance across time, and another to determine the wing-beat frequency and estimate the species of the avian target. An important feature of the work outlined in this paper is the use of optical flow to decipher between background and foreground, a large benefit of this method over background subtraction is the allowance of camera motion from crowd-sourced videos. Fast Fourier Transform applied to the inter-wing tip distance time series provided the wing-beat frequency, which is used to estimate the species. Experimentation showed successful extraction of inter-wing tip distance and wing beat frequency. Robustness to an error caused by foreground extraction, species prediction accuracy, and behavior when the most current inter-wing tip distance is not available was also tested [23] [4].

LiDARs have been widely used by ecologists for tasks such as fine-scale habitat mapping or assessing woodland structure and composition. However, LiDARs are also widely applied in fields such as meteorology for tasks such as measuring wind speeds and locating atmospheric boundary layers. In these contexts, the presence of flying animals, like insects, has also been detected [24]. Figure 2.5 shows the LiDAR image where the highlighted points are likely to be birds in flight. So this can also be used to detect birds from a distance, but this can be not more efficient to implement. As the LiDAR sensors' range is vast, they will gets confused between a bird and anything that looks like a bird.

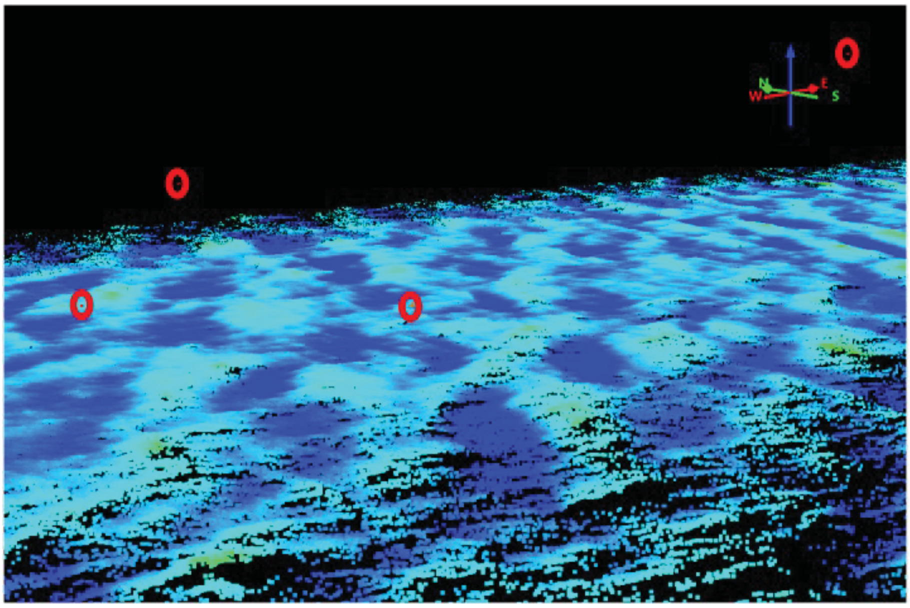

Figure 2.5: LiDAR image [5]

2.3 Bird detection methods

In the paper "Bird detection near wind turbines from high-resolution video using LSTM networks" [25], the authors proposed a detection method combining CNNs and LSTMs, which can leverage rich features extracted from CNNs and can learn long-term dependencies processed from continuous information. This detection method extracts candidate areas that might contain birds using background subtraction. It tracks these candidate objects by a robust tracker to acquire temporal as well as static information. Finally, the extracted image sequences are fed into CNN-LSTM networks to filter birds from other background objects such as turbine blades, trees, and clouds [25].

In the paper "Bird collisions at wind turbines in a mountainous area related to bird movement intensities measured by radar" [26] the authors used a dedicated bird radar, located near a wind farm in a mountainous area, to continuously record bird movement intensities from February to mid-November 2015 [26].

In research paper "Evaluation of Bird Detection using Time-lapse Images around a Wind Farm" [27], researchers use a still camera with a telephoto setup to capture a bird with a one m wing span 580 m away that in an image would cover an area of 20 pixels. This telephoto setup enables to monitor a wide area which is suitable for bird investigation and the wind turbine. The resolution of the sensor used is 5616 px $\times$ 3744 px and the field of view is $27° \times 19°$ degrees [27].

Chapter 3

Problem Statement, Objectives and Main Contributions

Wind as a clean and renewable energy source has been used by humans for centuries. However, in recent years with the increase in the number and size of wind turbines, their impact on avifauna has become worrisome due to their collision with wind turbine blades. Is there any way to reduce the death of avifauna?

The purpose of the thesis is to design and develop a Bluetooth-based system for bird detection. The rare, protected birds that nest near dangerous facilities will be equipped with Bluetooth transmitting devices, placed on the bird's back, analogical to the nowadays GPS transmitters. The signal receiver will be installed on dangerous facilities e.g. wind turbines.

Two research questions define the objective of the project

1. What is the relationship between the range of bird detection and detection accuracy when Bluetooth is used?
2. Which algorithmic methods can be implemented to improve localization accuracy with Bluetooth technology?

We come up with a system that helps to protect the lives of avifauna from wind turbines. The system contains a simple Bluetooth transmitter and receiver. The system works in such a way if the bird enters a range of 250 m of a wind turbine the receiver detects the bird which contains a transmitter. There is another detection that happens if the bird enters a radius of 175 m from wind turbine. We aim to achieve the accuracy of detection of about 90% and the real-time of detection to less than 5-6 seconds after the bird enters a 250 m radius.

The distances of 175 m and 250 m are set as boundaries for the bird detection, as it enters a 250 m radius a message is given that the bird entered 250 m, likewise if the bird enters into the 175 m crossing 250 m another message is given as the bird entered 175 m.

We use the Simplicity Studio application as a platform to connect Bluetooth transmitter and receiver from two different power sources using the USB connection. As we need to calculate the distance between the transmitter and the receiver we make multiple tests placing the two components at a distance and changing the distances.

One of us acted as a transmitter (assume a bird) and another one monitored the signal strength detected by the receiver. We keep on increasing the distance between the transmitter and receiver and we test so that we get RSSI values at the receiver end in the form of negative values. These RSSI values are used to calculate the distance between the transmitter and the receiver.

One BGX13P Bluetooth board is used as a transmitter and the other board is used as a receiver. We take the transmitter slowly in range with the receiver, the transmitter detects the receiver, and RSSI values are observed using Simplicity studio. We will calculate the mean and standard deviation of observed RSSI values by taking multiple tests at the ranges of 175 m and 250 m. Using mean and standard deviation, we can conclude a set of ranges where we can make sure that the transmitter has a radius of 250 m and 175 m to the receiver.

We build a system that helps to track and detect the birds which are coming towards wind turbines and send notifications to the person operating the wind farm. We use Bluetooth technology for transmitting and receiving the Bluetooth signal. The system is 90% accurate and also the detection time is so less i.e. within seconds.

The work covers a survey of possible technologies of receivers and Bluetooth sensors, a design of the system based on User Driven Design methodology. The system should assure detection from a distance of 250 m with a reliability of 90%.

Chapter 4

Modelling

This chapter contains the description of User-driven design method used to construct the proposed system, flowchart, and block diagram of the Bluetooth-based bird detection system.

4.1 User-Driven Design (UDD)

Table 4.1 shows the User Driven Design of the system. The UDD table is divided into three main categories.

The summary of the user-driven design table:

• The table is broken down into three sections. These are the functionalities, constraints, technologies, and algorithms that could be used.

• There are two categories in the functions section: general and itemized. The project's main parameters are represented by these functionalities.

• Specific restrictions include needs such as precision, resolution, and time delay.

• The available technologies and algorithms include several implementation methods and approaches that can be applied to the project.

• General functionalities include detection and localization classification, which are the most crucial for bird detection, as illustrated in Table 4.1

• The bold font in the last column of Table 4.1 indicates which technologies were chosen to use in this project.

Table 4.1: User Driven Design

Functionalities		**Particular constraints**	**Possible technologies & algorithms**
General	**Itemized**		
Detection	Distance between Bird and transmitter up to 250m±10%	*Accuracy* $\geq$ 90%	**Bluetooth,** GPS, GSM, PDR. Wi-Fi
Localization	Outdoor (near wind farms)	250m±10% from the wind farm and 175m±10% from the wind farm	**RSSI,** Location co-ordinates

1. Functionalities: If the distance between bird and transmitter is 250 m±10% distance, then detection is done, and localization is outdoors near wind turbines.

2. Particular Constraints: The detection is accurate to $\leq$ 90% and is localized to 250 m±10% from wind turbines and 175m±10% from wind turbines.

3. Possible technologies and algorithms: We use Bluetooth for transmitting and receiving, we obtain RSSI (received signal strength indicator) values which we can extract the distance between transmitter and receiver.

4.2 Flowchart

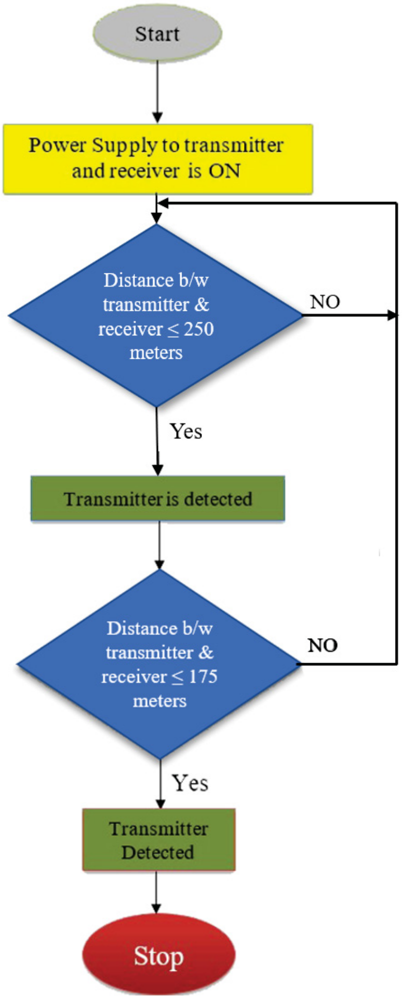

Figure 4.1: Flowchart

The flowchart describes how the entire system works in Figure 4.1, both the transmitter and receiver are given a power supply and they are ON. If the distance between transmitter and receiver is less than or equal to 250 m accurate to 10 percent then the transmitter is detected. For the distance of less than or equal to 175 m accurate to 10 percent, here if the condition is NO i.e, the distance between transmitter and receiver is more than 175 m then the flow goes back to 250 m radius because the transmitter must enter into 175 m radius or leave 250 m radius from the receiver. It cannot stay between 175 m and 250 m of radius from the receiver for a long time. If the condition is YES then the transmitter is detected again, that is how the entire flow works.

4.3 Block diagram

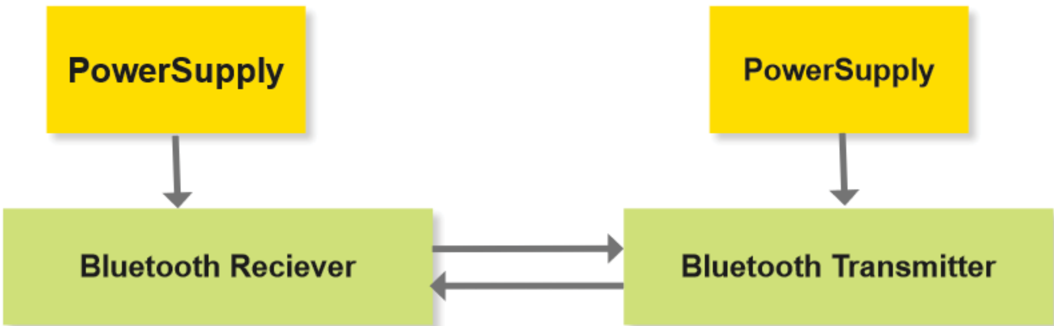

Figure 4.2: Block Diagram

Here we have a simple block diagram in Figure 4.2 where we have blocks such as power supply, Bluetooth transmitter, and Bluetooth receiver. Both the transmitter and receiver are given power supply separately so that they can establish communication between them.

Chapter 5

Implementation and Verification

5.1 Implementation

5.1.1 Component used

Silicon Labs BGX13P

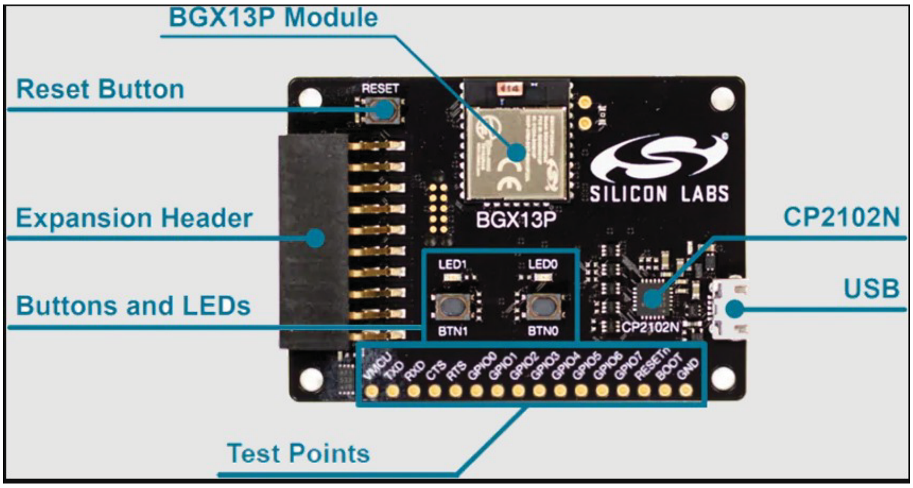

Figure 5.1: Silabs BGX13P Board [6]

The Wireless Xpress BGX13P expansion board [6] is a Bluetooth Low Energy module that has a high range of signal transmission. This has various useful features such as the BGX13P board being very small in size, it has high signal transmission power, consuming low energy, and more. The dimensions of the Wireless Xpress BGX13P expansion board are 12.9 mm × 15.0 mm × 2.2 mm [28]. The board weighs about 128.464 grams [29].

The board contains the BGX13P module, Expansion header, Test points, and CP2102N parts as shown in Figure 5.1

Hardware:

The setup of the BGX13P kit has the following steps:

1. By using a micro USB cable connect one end to the BGX13P board and

another end to PC.
2. We should make sure that the green light is turned on near the USB connector.
3. The connection bridge should be established to CP2102N USB to UART successfully. This is observed in the windows device manager as "Silicon Labs CP210x USB to UART bridge (COMx)", where x is the COM port number.

Software(Simplicity Studio):

Simplicity Studio is the software platform that has tools used to configure and estimate BGX13P.

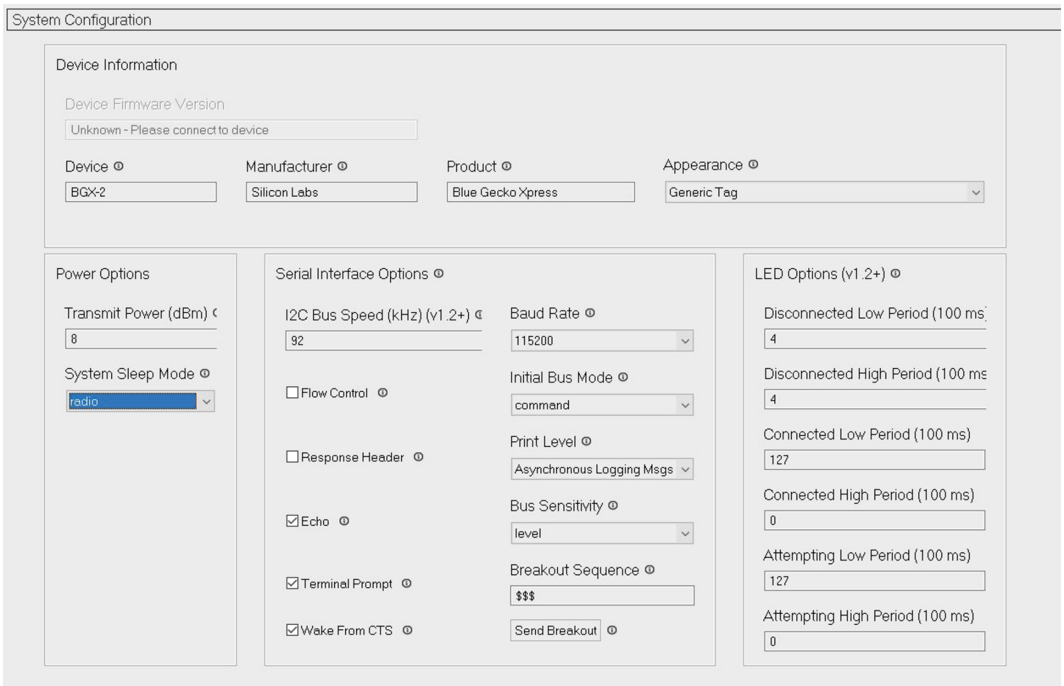

Figure 5.2: Simplicity Studio System configuration

The image referred to Figure 5.2 shows the system configuration of the board BGX13P, there are some pre-configuration settings like Power options, Serial interface options, LED options, etc., that are needed to be changed to increase the efficiency of the system.

The main change that was made is system sleep mode, the pre-configured setting is Deep sleep mode which is changed into Radio which helps to increase the range and transmitting power of the system.

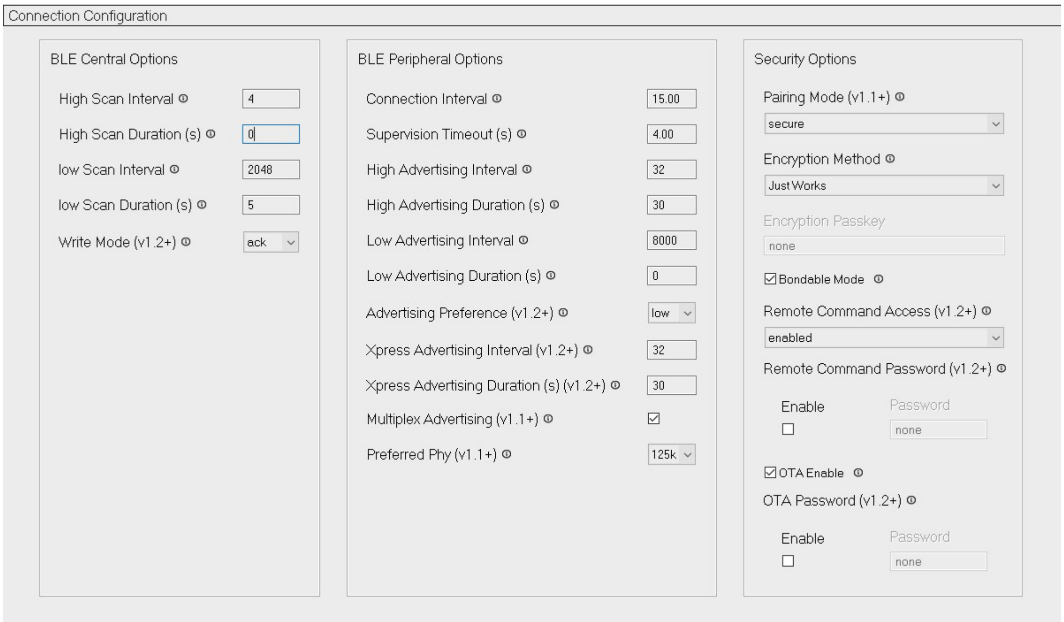

Figure 5.3: Simplicity Studios connection configuration

In this Figure 5.3, the connection configuration settings are changed that are required for the efficient connection between transmitter and receiver. Different changes can be made like BLE (Bluetooth low energy) central options, BLE peripheral options, and Security options.

5.1.2 Hardware Implementation

The BGX13P board can be used as both transmitter and a receiver. The beacons are equipped with a transmitter, let us assume BGX13P as one. This transmitter transmits signals which can be detected by the receiver.

Here, the RSSI(Received signal strength indication) values are obtained by using Simplicity Studio and two BGX13P boards where one of them is used as a transmitter and the other as a receiver. Both boards are connected to high-power sources to transmit high-range signals. The receiver board is connected to the control unit to receive the RSSI values of the transmitter.

BGX13P is scanned using the command "scan high" in simplicity Studio, this command scans only the BGX devices that are in range.

As this BGX13P are attached to birds the "scan high" command scans all the birds around the range and gives the RSSI values, these RSSI values are used to calculate distance approximately.

5.2 Validation and Verification

While validating the performance of the proposed system, some of the possible test cases are performed which are explained below.

Test case 1: Here, in this case, a low-power source i.e a laptop is used to give power to the transmitter (BGX13P), on the other hand, the receiver is connected to another laptop, at a distance up to 150 m of distance the RSSI values are obtained as shown in the Table 5.1.

The Bluetooth signal strength value differs according to the position of the Bluetooth board. So we take the signal strength readings by placing boards in two different positions i.e., placing both Bluetooth boards in the vertical position and placing both Bluetooth boards in the horizontal position.

For the distances greater than 150 m and less than 200 m the RSSI values are around -80 dBm as shown in Table 5.1. For the distances greater than 200 m the receiver failed to to receive the signal from the transmitter.

Distance (m)	**RSSI values in vertical (dBm)**	**RSSI values in horizontal (dBm)**
25	(-59, -56, -60, -53, -56,) (-56, -56, -61, -56, -60)	(-59, -57, -58, -57, -58,) (-62, -62, -56, -58, -58)
50	(-62, -58 , -63, -59, -61,) (-60, -60, -61, -60, -61)	(-66, -68, -70, -67, -70,) (-71, -67, -70, -66, -64)
75	(-65, -69, -64, -66, -64) (-65, -66, -68, -66, -68)	(-74, -77, -72, -77, -74) (-78, -75, -76, -73, -77)
100	(-75, -72, -73, -73, -74) (-74, -76, -76, -76, -77)	(-74, -74, -76, -74, -76) (-77, -74, -78, -75, -75)
125	(-83, -77, -73, -82, -77) (-76, -78, -78, -79, -78)	(-76, -79, -84, -80, -79) (-78, -80, -79, -81, -80)
150	(-74, -73, -77, -78, -70) (-78, -77, -71, -74, -77)	(-79, -79, -80, -81, -81) (-80, -78, -84, -80, -79)
175	(-79, -78, -80, -83, -81) (-81, -79, -85, -74, -82)	(-85, -87, -88, -82, -87) (-80, -79, -80, -79, -84)
200	(-80 -79, -78,-79,-81) (-81,-81,-78,-77,-79)	(-80, -81, -82, -81,-79) (-82, -80, -79, -81, -81)

Table 5.1: RSSI values upto 200 m (low power)

Test case 2: In this test case the transmitter is supplied with a high power source i.e a power bank having 18 W capacity is used. In the other end the receiver is connected to a laptop. We observed that the range of transmission has increased to a distance up to 350 m. The RSSI values that are obtained at the distances less than 300 m are shown in Table 5.2. For the distances greater than 300 m the values obtained are same and near to -86 dBm. RSSI values at range of 500 m were not obtained as the receiver failed to receive the transmitted signal.

In this process, different RSSI values are received based on the positioning of the boards as shown in Table 5.2. So this scenario is taken into consideration and tested by placing the boards in two different positions i.e., placing both boards in vertical and horizontal positions. In the first scenario, both the transmitter and receiver are placed horizontally, in the other both the transmitter and receiver are placed vertically. By applying these conditions there is a change in RSSI values.

Distance (m)	**RSSI values in vertical (dBm)**	**RSSI values in horizontal (dBm)**
50	(-64, -64, -67, -64, -64)	(-70, -69, -65, -70, -66)
100	(-69, -70, -71, -72, -68)	(-75, -78, -76, -81, -77)
150	(-73, -73, -72, -72, -71)	(-79, -80, -76, -75, -81)
200	(-79, -80, -81, -80, -81)	(-82, -84, -83, -79, -83)
225	(-84, -81, -83, -86, -87, -82)	(-85, -84, -86, -84, -82)
250	(-85, -82, -81, -84, -86)	(-85, -87, -88, -87, -88)
275	(-89, -88, -88, -85, -86)	(-86, -84, -86, -87, -90)

Table 5.2: RSSI values upto 275 m (sufficient power supply)

The Tables 5.4 and 5.3 show the RSSI values when boards are placed in a different position, mean and standard deviation are calculated for every distance of 25 m. Range of 175 m and 250 m are taken into consideration as boundaries for detection. As we can see the RSSI values keep on decreasing as the distance between the transmitter and receiver increases. The mean and standard deviation are calculated for every distance.

Mean is defined as a type of average. It is the sum of all the values in a set of data, such as numbers or measurements, divided by the number of values on the list. μ is the mean, and N is the number of elements in the list.

The equation for the mean value μ is:

$$\mu = \frac{1}{N}\sum_{i=1}^{N} x_i \tag{5.1}$$

Standard deviation is the measure of the dispersion of a set of data from its mean. It measures the absolute variability of a distribution

The standard deviation σ is defines as:

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2} \tag{5.2}$$

In the vertical position of both the boards, RSSI values are taken, and then the mean and standard deviation are calculated for the values at each distance as shown in Table 5.3. As for in particular both 175 m and 250 m are taken as boundaries, the mean of RSSI values at 175 m is -80.7 dBm and the standard deviation of RSSI is 2.0 dBm, the mean of RSSI values at 250 m is -85.4 dBm and the standard deviation of RSSI is 2.7 dBm. Considering these values, if the boards are in the vertical position, we can consider that at 175 m, the RSSI values are -80.7 dBm ±2.0 dBm, and at 250 m, the RSSI values are -85.4 dBm ±2.7 dBm.

Table 5.3: Mean of RSSI values taken up to 250 m(vertical position, sufficient power Supply)

Distance in m	**RSSI in vertical (dBm)**	**RSSI mean vertical (dBm)**	**RSSI standard deviation vertical (dBm)**
25	-53,-53,-53,-55,-55,-55,-55, -56,-56,-56,-56,-56,-56,-57,-57	-55.3	1.3
50	-58,-58,-59,-59,-59,-60,-60, -60,-61,-61,-61,-61,-62,-62,-63	-60.3	1.4
75	-63,-63,-64,-64,-65,-65,-65, -65,-66,-66,-66,-66,-66,-66,-66	-65.1	1.1
100	-67,-67,-68,-68,-68,-69,-69, -69,-69,-70,-70,-70,-70,-71,-71	-69.1	1.2
125	-69,-72,-72,-72,-73,-73,-73, -73,-74,-74,-74,-76,-76,-77,-77	-73.7	2.1
150	-76,-76,-77,-77,-77,-77,-78, -78,-78,-79,-79,-79,-79,-81,-81	-78.1	1.5
175	-78,-78,-79,-79,-79,-79,-80, -81,-81,-82,-82,-82,-83,-84,-84	-80.7	2.0
200	-79,-79,-79,-79,-80,-80,-80, -80,-81,-81,-81,-81,-83,-86,-86	-81	2.2
225	-81,-82,-82,-82,-83,-83,-84, -84,-84,-84,-84,-86,-86,-87,-87	-83.9	1.8
250	-82,-82,-82,-82,-84,-84,-84, -85,-86,-87,-88,-88,-88,-89,-90	-85.4	2.7

Table 5.4: Mean of RSSI values taken up to 250 m(horizontal position, sufficient power supply)

Distance in m	**RSSI in horizontal (dBm)**	**RSSI mean horizontal (dBm)**	**RSSI standard deviation horizontal (dBm)**
25	-57,-57,-58,-58,-58,-58, -59,-59,-60,-61,-62,-62,-62	-59.3	1.8
50	-62,-62,-63,-64,-64,-65, -66,-66,-66,-67,-67,-67,-67	-65.1	1.8
75	-65,-66,-66,-66,-66,-69, -69,-70,-70,-72,-72,-74,-74	-69.2	3.1
100	-70,-71,-72,-74,-74,-74, -74,-75,-75,-76,-76,-77,-81	-74.5	2.7
125	-72,-72,-75,-76,-77,-78, -79,-79,-79,-80,-80,-80,-81	-77.5	2.9
150	-78,-78,-79,-79,-79,-79, -79,-79,-81,-81,-81,-83,-84	-80.0	1.8
175	-79,-79,-80,-80,-82,-83, -84,-84,-84,-85,-86,-86,-86	-82.9	2.6
200	-81,-81,-81,-82,-82,-82, -82,-82,-87,-87,-87,-87,-89	-83.8	2.9
225	-84,-84,-84,-85,-86,-86, -86,-86,-86,-88,-89,-89,-89	-86.3	1.8
250	-85,-85,-86,-86,-86,-87, -87,-88,-88,-88,-88,-88,-89	-87.0	1.2

In the horizontal position of both the boards, RSSI values are taken and then the mean and standard deviation are calculated for the values at each distance as shown in Table 5.4. As for in particular both 175 m and 250 m are taken as boundaries, the mean at 175 m is -82.9 dBm and the standard deviation is 2.6 dBm, the mean at 250 m m is -87.0 dBm and the standard deviation is 1.2 dBm. Considering these values, if the boards are in the vertical position, we can consider that at 175 m, the RSSI values are -82.9 dBm $\pm$2.6 dBm, and at 250 m, the RSSI values are -87.0 dBm $\pm$1.2 dBm.

5.2.1 Simplicity Studio Software Validation

The receiver board is kept constant in the middle of the field and the transmitting board is placed in the movement where it is approaching the receiver board from an initial distance of 300 m. Using Simplicity Studio, while the transmitting board is in movement, the signal strength values between transmitter and receiver are taken and recorded in a text file as shown in Figure 5.4. In this project, it is proved that the distance can be estimated by using Bluetooth technology. The recorded data contains the time of the signal detected, the signal strength of the transmitting board (values in negative), and the remaining board details.

```
10:51:10:# 1 -089 ec:1b:bd:22:8b:62 BGX-8B62
10:51:16:# 1 -091 ec:1b:bd:22:8b:62 BGX-8B62
10:51:24:# 1 -088 ec:1b:bd:22:8b:62 BGX-8B62
10:51:30:# 1 -085 ec:1b:bd:22:8b:62 BGX-8B62
10:51:35:# 1 -087 ec:1b:bd:22:8b:62 BGX-8B62
10:51:42:# 1 -084 ec:1b:bd:22:8b:62 BGX-8B62
10:51:56:# 1 -082 ec:1b:bd:22:8b:62 BGX-8B62
10:52:17:# 1 -083 ec:1b:bd:22:8b:62 BGX-8B62
10:52:20:# 1 -083 ec:1b:bd:22:8b:62 BGX-8B62
10:52:23:# 1 -081 ec:1b:bd:22:8b:62 BGX-8B62
10:52:27:# 1 -079 ec:1b:bd:22:8b:62 BGX-8B62
10:52:31:# 1 -080 ec:1b:bd:22:8b:62 BGX-8B62
10:52:36:# 1 -078 ec:1b:bd:22:8b:62 BGX-8B62
10:52:42:# 1 -074 ec:1b:bd:22:8b:62 BGX-8B62
10:52:44:# 1 -075 ec:1b:bd:22:8b:62 BGX-8B62
10:52:48:# 1 -071 ec:1b:bd:22:8b:62 BGX-8B62
10:52:51:# 1 -068 ec:1b:bd:22:8b:62 BGX-8B62
10:52:54:# 1 -072 ec:1b:bd:22:8b:62 BGX-8B62
10:52:56:# 1 -065 ec:1b:bd:22:8b:62 BGX-8B62
10:53:15:# 1 -064 ec:1b:bd:22:8b:62 BGX-8B62
10:53:17:# 1 -069 ec:1b:bd:22:8b:62 BGX-8B62
10:53:21:# 1 -062 ec:1b:bd:22:8b:62 BGX-8B62
10:53:24:# 1 -065 ec:1b:bd:22:8b:62 BGX-8B62
10:53:31:# 1 -060 ec:1b:bd:22:8b:62 BGX-8B62
10:53:33:# 1 -063 ec:1b:bd:22:8b:62 BGX-8B62
10:53:40:# 1 -065 ec:1b:bd:22:8b:62 BGX-8B62
10:53:43:# 1 -069 ec:1b:bd:22:8b:62 BGX-8B62
10:53:46:# 1 -072 ec:1b:bd:22:8b:62 BGX-8B62
10:53:49:# 1 -075 ec:1b:bd:22:8b:62 BGX-8B62
10:53:50:# 1 -078 ec:1b:bd:22:8b:62 BGX-8B62
10:53:53:# 1 -081 ec:1b:bd:22:8b:62 BGX-8B62
10:53:55:# 1 -084 ec:1b:bd:22:8b:62 BGX-8B62
10:53:58:# 1 -087 ec:1b:bd:22:8b:62 BGX-8B62
10:55:15:# 1 -089 ec:1b:bd:22:8b:62 BGX-8B62
10:59:45:# 1 -091 ec:1b:bd:22:8b:62 BGX-8B62
```

Figure 5.4: RSSI values which were taken when the transmitter board is approaching and leaving the receiver

5.3 Python Code Validation

The Python program is constructed in such a way that not only detects when the bird enters the ranges (175 m and 250 m) but also detects when the entered bird leaves the ranges (175 m and 250 m). Figure 5.5 shows the python code to import each value that is recorded in the text file to print the signal strength value.

```python
with open(filepath,'r') as regis:
    for line in regis:
        for text in line:
            print("RSSI:"+line[12:17]+"dBm")
            rssi=int(line[13:17])
```

Figure 5.5: File import and values reading

The range of signal strength values for 175 m and 250 m is calculated by using the mean and standard deviation at the respective position. By using those ranges, considering both horizontal and vertical positions of the board, if the RSSI value ranges between -89 dBm to -85 dBm, it can be considered that there is more than a 90% chance that the bird containing a particular device is entered 250 m of range of receiver board. Similarly, ranges of RSSI values are calculated in each zone. Figure 5.6 shows the Python code that notifies when the bird with transmitter enters the 250 m range from the receiver.

```python
            if -89<rssi<-85 and x==0:
                if a==0 and b==0 and c==0:
                    print("Bird entered into 250 meters of range")
                    a=1
                    x=1
```

Figure 5.6: Bird entering 250 m zone

So obviously it can be considered that if the signal strength is less than -90 dBm, it can be concluded that the bird entered and exited 250 m radius. Figure 5.7 shows the Python code that notifies when the bird leaves the range.

```python
            if rssi<-90:
                if a==1:
                    print("Bird out of zone")
                    a=0
                    x=0
```

Figure 5.7: Bird exiting 250 m zone

Figure 5.8 shows the program where it is notified when the bird is between the 175 m and 250 m of the zone. It may be the bird coming toward the receiver or leaving from the receiver.

```
if -85<rssi<-82 and y==0:

    if a==1 and b==1 and c==1:
        print("Bird is between 175 meters and 250 meters")
        c=0
        y=0
        z=0

    if a==1 and b==1 and c==0:
        b=0
        y=1
        x=0

    if a==1 and b==0 and c==0:
        #print("Bird enters zone 2")
        b=1
        y=1
        x=0
```

Figure 5.8: While the bird is in the zone between 250 m and 175 m

And finally, if the bird enters the range within 175 m of the receiver, a warning is sent. Figure 5.9 is the Python program that handles the warning.

```
if rssi>-81 and z==0:
    if a==1 and b==1 and c==0:
        print("Warning :Bird enters 175 meters of range")
        c=1
        z=1
        y=0
break
```

Figure 5.9: When the bird enters 175 m of range

As 175 m range is set as one of the boundaries, as the bird enters there is a message showing "Bird entered the radius". When the bird (transmitter) is moving away from the windmill (receiver) and if the bird (transmitter) is in the range of 175 m to 250 m distance from the windmill (receiver), then the "Bird is between 175 and 250" message is shown.

If the bird moves 250 m away from the windmill, "Bird out of zone" message is shown. But if the bird again moves towards the windmill and enters the 175 m range, the "Warning: Bird enters 175 meters of range" message is again shown.

Chapter 6

Results and Analysis

```
RSSI: -089dBm
RSSI: -091dBm
RSSI: -088dBm
Bird entered into 250 meters of range
RSSI: -085dBm
RSSI: -087dBm
RSSI: -084dBm
RSSI: -082dBm
RSSI: -083dBm
RSSI: -083dBm
RSSI: -081dBm
RSSI: -079dBm
Warning :Bird enters 175 meters of range
RSSI: -080dBm
RSSI: -078dBm
RSSI: -074dBm
RSSI: -075dBm
RSSI: -071dBm
RSSI: -068dBm
RSSI: -072dBm
RSSI: -065dBm
RSSI: -064dBm
RSSI: -069dBm
RSSI: -062dBm
RSSI: -065dBm
RSSI: -060dBm
RSSI: -063dBm
RSSI: -065dBm
RSSI: -069dBm
RSSI: -072dBm
RSSI: -075dBm
RSSI: -078dBm
RSSI: -081dBm
RSSI: -084dBm
Bird is between 175 meters and 250 meters
RSSI: -087dBm
RSSI: -089dBm
RSSI: -091dBm
Bird out of zone
```

Figure 6.1: Output

Figure 6.1 shows the output values that are obtained from Python code that alerts the windmill operator based on the received RSSI values from the Bluetooth transmitter. The Python code imports a text file as input where the text file consists of RSSI values that are taken between two Bluetooth devices by changing the distance between them, where one Bluetooth device is considered as a transmitter and the other as a receiver. The range is declared in such a way if RSSI values are between -89 dBm and -85 dBm there is a maximum chance that the bird enters into 250 m range as the RSSI values are low.

In the other case if RSSI values are between -85 dBm and -82 dBm there is a chance of the bird entering into the range of 175 to 250 m.

In the last case if RSSI values are less than -81 dBm there is a chance of the bird entering into the range of 175 m.

The defined ranges of RSSI values given in the code are taken from the common mean and standard deviation of both the horizontal and vertical positions so that there will be more accurate.

So when we equip the bird with small size low-energy Bluetooth devices such as beacons and by having high range signal transmitting Bluetooth receiver at the wind farm, we can detect the bird incoming towards the wind farm from a distance of 250 m from the wind farm. We do not know if the bird is still coming towards the wind farm or changing its track. So when we notify the operator that the bird is 250 m far, he will be ready to take certain measures to save the bird from the collision. And when we noticed that the bird approached 175 m from the wind farm, the operator can perform the required action to save the bird. When notified that the bird leaves the zone, the operator can switch attention and monitor for any other incoming birds.

Chapter 7

Conclusions and Future Work

Birds are essential in our real world. They own all complete rights to live along with us they help us to survive better because they prey on the insects that destroy our food. So bird life is essential in our real world to maintain an eco-friendly environment. Similarly, windmills are very useful on farms, they act as a mechanical source for the movement of water. These windmills are used to lift the water from the aquifer and irrigate the crops or to pipe the water from one location to another. Wind energy is the most economical renewable energy technology and a clean source of power.

There are many instances where birds on farms are died due to windmills. It is very essential to protect those birds dying because of windmills. So the Bird Detection System is developed which saves the birds from getting died because of windmills. Signal strength between a pair of Bluetooth devices is used to detect the birds surrounding the windmills.

From 250 m the bird is detected and the further direction of the bird is not known, so an alert message is received when the bird is at 175 m. So immediately the windmill operator takes measures to prevent the bird from entering the windmill for collision.

The design of the proposed system is verified with real-time scenarios to get the efficient output of the system. The complete workflow of the system are shown using the block diagram and the flowchart of the system. The proposed system alerts the windmill operator if there is any bird on the farm that is likely to move toward the wind farm and get hurt.

This device can be further used in all the areas where the birds are accidentally getting hurt. The device alerts the windmill operator of the bird's presence in a dangerous area, and therefore the windmill operator can take measures to prevent the damage to the bird. This device not only can be used for this purpose but also in any field where distance estimation is required.

Appendix A

Python Programming

The Python program (Figures A.1) given is used to detect using RSSI values

```python
filepath = "data.txt"
text="BGX-8B62"
a=0
b=0
c=0
x=0
y=0
z=0
with open(filepath,'r') as regis:
    for line in regis:
        for text in line:
            print("RSSI:"+line[12:17]+"dBm")
            rssi=int(line[13:17])
            if -89<rssi<-85 and x==0:
                if a==0 and b==0 and c==0:
                    print("Bird entered into 250 meters of range")
                    a=1
                    x=1
            if rssi<-90:
                if a==1:
                    print("Bird out of zone")
                    a=0
                    x=0
            if -85<rssi<-82 and y==0:

                if a==1 and b==1 and c==1:
                    print("Bird is between 175 meters and 250 meters")
                    c=0
                    y=0
                    z=0

                if a==1 and b==1 and c==0:
                    b=0
                    y=1
                    x=0

                if a==1 and b==0 and c==0:
                    #print("Bird enters zone 2")
                    b=1
                    y=1
                    x=0

            if rssi>-81 and z==0:
                if a==1 and b==1 and c==0:
                    print("Warning :Bird enters 175 meters of range")
                    c=1
                    z=1
                    y=0
            break
```

Figure A.1: Python Program

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