Bird nest monitoring device

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Literature Review

1.1 Problem Statement

Kyle is a master's student conducting research on eagles and raptors. He requires a method to effectively monitor the martial eagle's nest through a video recording and temperature measuring. Additionally, he requires a means of knowing if this monitoring equipment is properly installed after he has either changed a battery, SD card, replaced a camera or adjusted the installation.

1.2 The purpose of bird monitoring

It is crucial to observe birds in remote areas as their habitats are being impacted by climate change and urbanization. Research has indicated that changes in bird populations and actions, such as breeding patterns, migration routes, and habitat use have resulted from climate change and urbanization [1]. To better comprehend the effects of these environmental transformations on avian species, researchers can monitor their behaviors more effectively. The significance of investigating rare or endangered bird species living specifically within remote areas cannot be overstated since they're at greater risk with regard to any further negative impact caused by climatic variations or other major industrial activities happening there; monitoring them will help us take protective measures for preserving avian biodiversity overall during this era of rapid global transformation due to consumerist human behavior leading towards natural calamities like worldwide warming, which affect all forms alive around us including vulnerable bird types who we

must work hard enough to not only preserve but also learn about so future generations inherit what nature originally bestowed upon mankind before pollution overuse took a toll beyond repair [2]. Research and studies have shown we can curtail any mishaps in the future by taking proactive steps now to learn how globalization affects the behavior of birds and take corrective action to preserve biodiversity

The feathered creatures possess an acute awareness of alterations in their surroundings, and the aftermaths of urbanization and climate change in the domains they live can result in serious implications for them. For instance, augmenting temperatures along with variations in rain patterns tend to interrupt migration schedules while the reduction of suitable nesting areas causes hindrances during breeding cycles or searching for food sources[3] . Moreover, pollution plus other kinds of stressors caused due to human intervention worsen these effects thereby intensifying the need to scrutinize bird populations residing within remote vicinities.

Studying remote regions is crucial as they are home to uncommon and endangered species that face greater susceptibility to environmental transformations. To illustrate, birds found exclusively in specific habitats or territories can be at risk of elimination due to the decline in their natural homes or other anxieties human activities cause [4]. Observing these animal groups allows researchers to gain deeper insights into their spread, number of individuals, and reproduction success- all vital information for preserving them and reducing climate change effects on urbanization.

In order to comprehensively comprehend how climate change and urbanization affect birds, researchers employ diverse techniques like bird surveys, acoustic monitoring, and bird banding [1]. Bird surveys require meticulous counting of various species in a given vicinity followed by documentation of the findings. On the other hand, capturing live specimens and then fastening distinctively identifying bands on their legs before releasing them back into nature is known as bird banding which facilitates tracking individual birds' evolution over time thus enabling discernment regarding migrations or survival rates among others [3].

It can be challenging to reach remote regions where bird populations need monitoring, necessitating specialized equipment and expertise. Nonetheless, technological advancements have simplified the process of keeping an eye on birds in such areas [5]. To illustrate: drones permit aerial surveys and allow for mapping out avian distributions; satellite imagery helps trace habitat alterations while overseeing significant bird communities.

As we conclude, it is of utmost significance to observe avian life in isolated regions.

Doing so provides us with a better comprehension of their behaviors and how they can be shielded from the effects of climate change as well as urbanization. This understanding helps scientists develop tactics that will effectively reduce negative impacts on birds caused by environmental changes.

1.3 Bird Nest Monitoring

1.3.1 Overview

Monitoring bird nests can yield useful data for ecological and conservation purposes. Nesting birds are vulnerable to changes in the environment, such as climate change [6]. Birds are an integral part of many ecosystems because of the role they play in pollination and being seed dispersers. Nest monitoring includes all the stages starting from the time the nest is being constructed and goes through all the stages of life monitoring their day-to-day movements.

1.3.2 Monitoring methods

One of the most often used techniques for monitoring bird nests is visual monitoring. It requires the observer to visit the nest on a regular basis to look for eggs or chicks, the condition of the nest, and any indications of predation. This technique is rather simple to use and offers useful data on nest success rates and reproductive efficiency. Visual surveillance, however, can be time-consuming and spook breeding birds, causing them to abandon their nest [7]. If the environment is fiddled with too much it could lead to the desertion of nests and eventually predation of birds [7]. Moreover, for certain species that are scarce or that are hard to track, visual monitoring is difficult.

Remote sensing is a popular technique used to track birds. While drones can deliver high-resolution photographs of nests and the surrounding ecosystem, camera traps can record images of the nest and nesting behavior [8]. The monitoring of bird nests can be conducted non-intrusively using remote sensing techniques, which also enables the collection of more precise data. There are several shortcomings when it comes to remote sensing such as the high cost of equipment and the need for advanced knowledge of tools and equipment [9].

Acoustic monitoring is a method which uses sound to study wildlife. The technology ranges from handheld sound detectors to state-of-the-art technology. From animals such as birds and bats to marine mammals, fish and amphibians, sound is produced by a wide variety of creatures for communication and locomotion [10]. The technology surrounding acoustic sensors has been growing at a rapid pace due to the steep advances in technology that humans have made in recent history. Therefore, more reliable, and accurate sensors have been made which significantly help wildlife monitoring and have made them more cost effective [11].

GPS Tracking allows for portable tracking systems which account for three-dimensional movement, allows for various measurements strategies, and also transfers data remotely [12]. This provides a muti-scale approach to track bird movements and monitoring behavior in real-time. The devices need to be as small as possible to not have a significant influence on the day-to-day life of the birds. It has been found that tracking devices have a natural tendency to compromise the value of the movement data obtained by lowering survival rates, reducing reproductive success, and causing other undesirable changes in behavior [13].

1.4 Bird nest monitoring technologies

Bird nest monitoring devices are becoming increasingly important among ornithologists, bird enthusiasts, and conservationists. These devices can provide valuable information about bird behaviour, breeding success, and habitat use, and can help identify factors that may be affecting bird populations.

There are several types of cameras that can be used for bird nest monitoring, including trail cameras, security cameras, and specialized bird nest cameras. Trail cameras such as the Q-A258 Trail Camera shown in figure 1.1 are popular choices because they are weather-resistant, have long battery life, and can take high-quality photos and videos.

Figure 1.1: Q-A258 Trail Camera
Source: Adapted from [14]

Security cameras are also a good option because they are typically Wi-Fi-enabled and can be accessed remotely using a smartphone app. Specialized bird nest cameras, like the Bird Box Camera with Wireless Transmission shown in figure 1.2, are designed specifically for monitoring bird nests and often include features such as infrared night vision and weatherproof housing.

Figure 1.2: Bird Box Camera
Source: Adapted from [15]

The existing devices are either too expensive, have unnecessary features, lack necessary features, hard to mount, are not easily accessible, or are hard to maintain.

1.5 Temperature monitoring technology

1.5.1 Overview

Temperature monitoring of animals is a useful tool to analysing the behavioral patterns of animals. This information clarifies health problems such as stress or pain, reproductive patterns and animal welfare [19]. There are multiple ways of obtaining temperatures of wild animals which is decided by the necessary requirements of the data that is needed.

1.5.2 Methods of temperature monitoring

Rectal thermometers are a technique which involves a thermometer being inserted into the animals rectum to measure the internal temperature. Although, it is one of the most accurate methods to measure body temperature, the procedure is and intrusive and upsetting for the animal [20]. This method of temperature monitoring can be cost effective, but it is a more difficult procedure to implement, not mention the privacy invasion and uncomfortable experience for the bird [20].

Infrared technology is a well-known and advanced way of receiving body temperatures of animals. This method involves measuring the animal's surface temperature. Although less invasive than rectal thermometers, this method might not be as accurate as the environment could have impacts on the readings [21]. The advantage of using infrared technology allow observers to gather thermal properties of many surfaces of the body which all show different temperatures such as head and body [20]. Although thermal imaging cameras have become more accessible recently due to technological improvements, infrared thermometers offer the chance to collect non-invasive readings of surface temperature at a far lower cost [20].

Radio Telemetry is a technique that comes up often in new technology when measuring temperatures of animals. In order to get continuous temperature measurements, this method entails implanting a temperature-sensitive radio transmitter within the animal. Although it is intrusive it can deliver extremely accurate data and it can be pricey [19] [22]. Another way is radio-tag a birds' lower back using a harness [23]. Once attached, observers will be able to see the bird's location without physically seeing the bird. Disadvantages of radio tags show that they are expensive to implement, and tracking is limited because observers need to be within a close distance of the tagged birds [23].

1.6 Power Supply Design

1.6.1 Energizing the raspberry pi

The prevalence of the Raspberry Pi computer is due to its compact nature, existing solely on a single board that requires external power. There are several means by which we may energize these systems, each option carrying its own benefits and drawbacks.

Utilizing a Raspberry Pi in remote areas warrants attention to various challenges. One such challenge pertains to the power source as conventional options may not be accessible, depending on your location. Therefore, exploring alternative resources like batteries, solar panels and wind turbines becomes imperative for charging up the device at hand. Another challenge to conquer is the power consumption of Raspberry Pi. Despite its minimal energy usage, enhancing its productivity requires disabling unnecessary components and choosing an operating system that aligns with your goals [24].

Recently, many have been interested in off-grid energy supply systems because of their ability to provide sustainable power in remote areas. These systems can function alongside various electronic devices like the Raspberry Pi and other similar products.

1.6.2 Photovoltaic(PV) systems

The use of photovoltaic (PV) systems has significantly increased as they are efficient in converting solar energy into electrical power [24]. This has led to their widespread installation at remote locations, ranging from small rooftop units to large-scale solar farms. However, tracking the performance of these systems can be challenging when access is restricted in distant areas. A resolution can be achieved by establishing a surveillance mechanism, utilizing the photovoltaic method. Such an exceptional scheme provides instant real-time updates on PV system performance from any vicinity. With this approach, it becomes possible to pinpoint potential mishaps while also diagnosing and streamlining overall functionality adeptly with ease.

It's possible to operate a remote monitoring system with the help of a Raspberry Pi [26]. This nifty gadget is an affordable, small single-board computer that can be easily integrated into such setups. Combining it with both solar panels and batteries enhances its suitability for areas situated in remote places - or isolated from conventional power

sources. Several studies have looked into the possibility of using a Raspberry Pi to develop a tool that can supervise photovoltaic systems from afar.

These researches involved examining whether utilizing this kind of technology was feasible, monitoring different parameters whilst collecting data, and developing an easily manageable interface for remote supervision accessibility. Furthermore, some surveys investigated machine learning algorithms as potential tools in scrutinizing the collected information acquired through these surveillance mechanisms [25]. In its entirety, the utilization of Raspberry Pi as a tool for distant photovoltaic surveillance has brought forth opportunities and may augment the yield of PV structures in remote areas.

1.7 The gaps and limitations present in technology utilized in the tracking of birds.

1.7.1 Limited battery life in bird monitoring devices

Several remote surveillance devices utilised in bird monitoring have batteries or secondary power sources to power the devices. However, these batteries tend to have a limited battery life which results in more time spent maintaining bird monitoring devices. Developing more efficient batteries that can last longer and increase the lifespan of bird monitoring devices is one of the missing technological aspects in this field. Multiple studies have highlighted the problem of limited battery life in bird tracking devices, and its impact on data collection efforts. For instance, researchers have found that short battery life leads to data gaps, which in turn can undermine the accuracy of findings [27]. Furthermore, the shorter battery life also reduces the overall data collection period, which limits the amount of information that can be generated from tracking data.

Other researchers have attempted to address this problem by developing innovative ways to extend the battery life of tracking devices. In one study, solar-powered GPS transmitters were used to increase battery life while maintaining tracking capabilities [28]. While others have resorted to managing the power consumption of components used and improving battery capacity to improve the battery life with an aim to reduce disrupting the birds when the batteries must be replaced [29]. Despite these efforts, limited battery life remains a significant challenge for bird-tracking devices. As tracking technology continues to evolve and improve, developments of new strategies that balance tracking capabilities with battery life need to be explored

1.7.2 Poor accuracy of location data in bird monitoring

A conventional way to animal tracking uses limited range global positioning system (GPS) trackers that can store location coordinates locally, however, these tracking devices then require transceiver from the biologist or researcher to transfer location history when in out-of-range areas [36]. The accuracy of these devices is heavily reliant on the environmental factors. Other tracking devices such as geolocators also rely on signals from satellites and global systems for mobile communication (GSM). The accuracy of these devices can be affected by signal interferences, battery life and environmental factors, resulting in errors of up to several hundred kilometers in some cases [30].

Technology that has been designed to improve tracking and collection of location data is an Automated Radio-Telemetry System (ARTS) [30]. The ARTS was designed to monitor animals constantly and is situated on 40-meter towers featured with directional antennas. This allows for real-time tracking and analysis of data and has been used to track birds, mammals, and reptiles [30]. Strategies such as the use of multiple tracking devices, data validation, advancements in satellite navigation, and improved reporting protocols and positioning technology may help to reduce errors and improve the quality of data.

1.7.3 Lack of wireless communication devices in bird monitoring

Wireless communication devices are common in monitoring bird characteristics and movements. However, there has been limited research on the lack of wireless communication devices in bird monitoring. The studies showed that about 70% of bird species still cannot be tracked while on the move and several bird tracking devices require physical retrieval of data, and this impacts the study negatively due to constant disruption of the bird's environment [31]. The challenge with implementing wireless communication devices is the limited range of some wireless devices. This makes it difficult to track birds that migrate over long distances. Although research has discovered better ways to design lightweight, waterproof and durable devices that can be attached to birds without affecting their behavior, communicating with these devices wirelessly remains a challenge [[32].

To mitigate these challenges, researchers have conducted studies where GPS tracking devices were attached to songbirds to monitor their movements and behavior [30]. Another used radio telemetry to monitor the breeding behavior of a threatened species of bird in Germany [32]. To reduce disruptions to the natural environment, some researchers use

basic wireless sensors to monitor the bird's speech [33]. The limited research on the lack of wireless communication devices in bird monitoring highlights the need for further exploration and investment in these technologies. By utilizing wireless communication devices, bird monitoring programs can gain more accurate and reliable data, leading to a better understanding of bird populations and ecological health.

1.7.4 Lack of Data Analysis Tools/ Technologies

The processing of animal tracking data has forever relied on the availability of data analysis tools, such that their unavailability has limited the full exploitation of tracking data. Given that animal tracking involves the acquisition of large data of quantities, managing these data can be challenging, thereby leading to an increased chance of errors in data analysis. [31] While the last few years have seen an increase in the availability of large datasets, this has also brought with it several challenges such as the need for appropriate analytical techniques. For instance, animal tracking systems that rely on global positioning system (GPS) technology collect substantially more data than common software tools can effectively handle. Consequently, there remains a need for data scalability, particularly in cases where continuous tracking is performed, long-term storage is required, multi-user support is needed across research groups and institutions and cost-effective software tools are necessary [34]. New advanced technology development, however, has been made to fill some of the previously existing gaps in animal tracking, these include, automation of processes, virtual storage capacity, backup and recovery, and data integrity through the database management systems.

1.7.5 Cost Considerations in Animal Tracking

Choosing wildlife tracking systems present multiple trade-offs to scientists, enthusiast, etc, the main trade-off that has existed for decades is the high cost, high-quality data and vice versa. According to [35], conventional camera-based systems are not scalable and cost-effective to cover multiple animals [35]. The researchers have made breakthroughs in the miniaturization of wildlife tracking systems, however, this also comes at higher costs and about 11 of on-board stored data could never be retrieved [31].

GPS can collect large datasets, as the cost of this technology is decreasing, it creates an increase in the number of individual animals being tracked which is good for wildlife tracking, however, this also means storage of such datasets requires virtually unlimited

data storage capacity and backup and so the cost has shifted to data storage [31]. GSM is still one of the most expensive form of data transmission despite it being the most used in various parts of the world. Other options available for long-range communication like cellular networks 2G/4G/5G for smaller reserves but the increase in size of the reserve increases with costs and setup [36].

Wildlife tracking will always present trade-offs for the researchers, these include but are not limited to costs, size, and type of dataset accuracy. Studies have been done to assist guide researchers, enthusiasts, academics, etc in navigating around these trade-offs.

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