EEE4113F Draft Literature Review

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Chapter 1

Literature Review

1.1 An overview of existing full camera trap systems

Efficient wildlife surveillance systems rely on complex technologies, with infrared sensing emerging as a superior choice, as pointed out by Meek et al. [1], who emphasises the key advantages such as cost effectiveness, speed, space and weight saving, usability, and versatility as being critical in developing an efficient wildlife surveillance system in comparison to other systems out there. Additionally, Rovero, Francesco, et al. [2] emphasises the importance of establishing a selection criterion when choosing amongst off-the-shelf products, especially in niche environments like nesting areas. Swann et al. [3] further argued that while choosing from a selection of camera traps designed for generalised use cases may be complex, it becomes essential to refine a module designed for nest ecology researchers. Aguiar-Silva, Francisca Helena, et al. [4] agreed on the use of infrared sensors because of the prevalence of nocturnal predators that attack nesting areas of birds. This will make it easier to analyse activity regardless of night or day in confined areas.

Wireless data transmission and automation emerge as crucial requirements in modern camera trap modules, according to Glover-Kapfer et al. [5]. However, they make note of the fact that availability of good camera traps, i.e., those that are relevant to the researchers' requirements, is often dictated by the novelty task at hand, which may limit the available options for studies in nest ecology. In a study regarding nest predation, Ribeiro-Silva, Lais, et al. [6] again stress the importance of infrared cameras but warn against positioning them too far away from the nest to reduce overexposure of the captured footage. A Bushnell TrophyCam, which captures both videos and photos, was found to provide more intuitive data for distinguishing between different birds within the same species through analysing their behaviour from short video intervals. Challenges experienced involved low detection efficiencies with motion sensors and a need for managing the video lengths to optimise data storage [6].

Recent studies highlight the ongoing efforts to improve camera trap systems in wildlife research by addressing issues of detection reliability, data cataloguing, and remote communication capabilities, while also revealing challenges in power consumption, weight, and cost. Nazir, Sajid, et al. [7] introduced the "WiseEye" camera trap system, which aimed to address frustrations of existing camera systems. The "WiseEye" system, consisting of a Raspberry Pi and passive infrared sensors, promised and showed an improvement in detection reliability, reduced data cataloguing time, and remote communication capabilities. With this solution came many drawbacks such as lower power efficiency, weight, and cost. This indicates potential areas that can be simplified and optimised to suit nest ecology research. Rico-Guevara et al. [8] contributed by confirming the importance of having a PIR sensor in their study that involved capturing pictures of hummingbirds. They also had issues when it came to power consumption and weight. This is a recurring issue among existing designs. Green, Sian, et al. [9] explored the integration of artificial intelligence with existing camera trap solutions, in a bid to offer advancements in data processing and analysis. This brought upon its own issues such as increased power consumption and greater computational requirements that would only be fixed if the whole system is redesigned.

1.1.1 Challenges and limitations of consumer camera traps

Addressing operational challenges and efficiency issues in nest monitoring systems are important when designing effective wildlife research modules, as indicated by Ribeiro-Silva, Lais, et al. [6], who identified the various shortcomings in existing solutions and proposed strategies for improvements. In the pursuit of effective nest monitoring, Ribeiro-Silva, Lais, et al. [6] noted operational challenges and efficiency problems with existing solutions. They found that problems like insufficient storage, wind displacement, weather damage, and false detection of animals outside the intended field of view led were caused by poor efficiency, loss of data, and missed predation lists. This study suggests improvements in camera positionings, increased storage, regular inspection, and the use of more than one camera to progressively monitor the activity around the nest.

The use of camera data in wildlife research brings about challenges because of limitations in existing camera trap modules, as indicated by Jorge A Ahumada et al. [10], who discussed the importance of establishing hardware standards to the specific requirements of a research task. They go on to further suggest that existing camera trap modules may not meet the standards that are expected for scientific and conservation purposes. The study stresses the necessity of laying groundwork to establish hardware standards tailored to each study, challenging the feasibility of adopting off-the-shelf modules for diverse researching tasks.

1.2 Data transmission techniques

1.2.1 Comparison of wired and wireless data transmission

Despite the improvements of wireless communication capabilities, wired communications have traditionally served as the industrty standard. Huynh's study on general communication protocols [11] sheds light on several key advantages of wired data transmission. These include implementation of parallel data transfer techniques, with the speed can be adjusted by the number of parallel cables, provided the transfer rate per cable is maintained and the cables are shieled to minimise cross talk. [11] also made note of differential lines being utilised instead of single-ended lines, to improve data speeds, lower the power consumption and reduce electromagnetic interference, all pertinent to the scope of the design.

Gula et al. suggest that wired solutions may introduce problems such as cable management and animal interference. [12] details how different coaxial cable thicknesses are required to transmit different data types over a set length without any additional amplification, resulting in a cluster of cables running between subsystems. [12] also noted concerns that animals, such as rats, end up chewing the cables over time.

Given the challenges associated with wired communications in wildlife research, wireless data transmission becomes a promising alternative. Adsumilli, C et al. mention that 'error resilience and error concealment were the most important aspects of current research for successful realization of transmission and reception of image/video signals over bandwidth limited fading wireless networks/channels.' [13].

Li et al. [14] suggest that implementing a wireless communication system will present a more cost-effective solution for wildlife research. [14] further stipulares that deploying a wireless system will reduce the overhead that comes with maintenance when the connections get damaged.

[13] H.263 and MPEG-4 encoding standards, which were implemented to achieve error control for both reception and transmission of video in error prone environments [13].

In exploring alternative wireless connectivity modules for low power IoT devices, Peng, Y. et al. [15] put forward a solution that is suitable for long-range transmission of low-rate data, which offers a simplification of camera modules in wildlife research. The study goes into the wireless device designed for batteryless IoT devices (passive devices), that are capable of transmitting data over long distance. While this is unsuitable for video or image transmission, the device will allow for the user to wirelessly obtain logs on the status of the module even when power has run out. [15] reported a maximum packet detection range of 50 m, making it a possible solution for smaller data transmission needs.

Conversations with the researchers for the project at hand [16] WiFi-based communication may be hampered by a lack WiFi connectivity at many of the red-winged starling nesting sites.

1.3 Integration of camera traps with the Internet of Things (IOT)

Single-board microcomputers can be a valuable tool for biological research. Jolles argues that '[T]he Raspberry Pi [is] a great reserach tool that can be used for almost anything. This can range from ... video recording of laboratory experiments, to long term field measurement stations' [17]. The wide versatility of a device like the Raspberry Pi makes it ideal for implementation of customisable video monitoring solutions. Jolles [17] also argues that the small footprint of the Rasbperry Pi aids in its use in research, and versatile options for the provision of power allow it to be used with minimal human intervention over long time periods. These benefits align strongly with the needs of the project at hand, further emphasizing the Raspberry Pi as a viable platform around which to base the project.

Data storage and retrieval has been identified as a key limitation in the application of camera traps to monitor Red-Winged starlings [16]. Prinz et al. [18] implement a project for video surveillance of Acorn Woodpecker nests. They justify the Raspberry Pi as useful resource owing to its small size and variety of storage and connectivity options. The particular project uses a WiFi connection to upload footage to cloud storage on Google Drive. They further identify that the onboard SD card has sufficient storage for around 3 days worth of footage, but also identify the strength of the Raspberry Pi in its ability to leverage 3G/4G connectivity or external flash drives and hard drives as alternative means of data storage. The variety of footage collection and/or storage options make it likely that a suitable option can be found in the case of Red-Winged starlings.

[17] acknowledges the existance of other microcomputer systems, argues that the use of these systems is hampered by lack of hardware and software maintanence, alongside generally poorer user support

compared to the widespread Raspberry Pi.

Microcontrollers, including options from ST Microelectronics, Espressif, and Atmel offer an alternative to full microcomputers. Camacho et al. [19] discuss a custom design based on the ATMEGA2650 microcontroller. They use a customised circuit design to allow for advanced power management, with the goal of limiting power draw. [19] further describe difficulties with using commonly available prototyping board, which are not necessarily as capable of achieving power draw requirements as custom circuit designs. Cardoso et al. [20] implement a remote visual surveillance based on an ESP32 microcontroller, demonstrating a successful microcontroller-based implementation under slightly different circumstances to [19]. [17] also identifies that microcontrollers may have even less stringent power requirements than the Raspberry Pi and argues that simple, repetitive tasks are often better suited to microcontrollers. Microcontroller based solutions may offer more customisability and lower costs compared to microcomputer solutions such as the Raspberry Pi.

[17] also identifies that microcontrollers and microcomputers can be used in tandem in some instaces. This would allow the benefits of both systems to be realised, such as allowing for exceptionally low power draw the majority of the time, but allowing for the advanced connectivity options of the Raspberry Pi when required.

Both microcontroller and single-board microcomputers have varying price, typically depending on processing power and available peripherals. Local market prices may make higher-end devices too costly to be viable, and microcontrollers are generally significantly cheaper than microcomputers.

1.4 Motion detection for camera traps

Meek and Pittet [1] identify that ‘Motion detection is of prime importance for any camera trap to be effective’. Importantly, Rovero et al. [2] discuss that the camera field of view does not correspond directly to the detection zone. Motion detection is often a separate process from video or image recording, and must be thoroughly considered to make for a viable solution.

Meek and Pittet [1] identify that most commercial camera traps use passive infrared (PIR) sensors to detection motion of wildlife, but are prone to false detections, resulting in images that don’t feature any wildlife. The sensitivity of a PIR motion detector ‘depends on many factors, including the distance of the moving target, the temperature differential, the size of the animal, its speed and background light.’ Rovero et al. [2] add to this by identifying that PIR sensors can be triggered by pockets of hot air or vegetation. The prevalence of PIR based motion detection seems to indicate that it is a workable and useful solution, but evidence shows that there are also difficulties associated with the technology.

Rico-Guevara and Mickley [8] chose to use PIR motion sensors because they ‘were cheap and easy to deploy, and successfully detected hummingbirds.’ Their study found that detection of even the smallest species of hummingbirds was adequate for their application. They chose to combat the issue of false detections by intentionally positioning the sensors away from objects that could trigger unwanted detections, and mitigated the consequently limited scope of an individual sensors by triggering from multiple differently positioned sensors. A separate standalone trigger was also developed which included an adjustable sensistivity, allowing ‘fine tuning by optimizing the trade-off between increased sensitivity and false positives' [8].

Welbourne et al [21] identify that the functioning of PIR sensors is often misunderstood, leading to 'flawed inferences or expecatations of camera performance.' A thourough understanding of PIR sensors would help in the development of a robust and well-functioning solution.

Rovero et al. [2] discuss that older comercial camera traps from the 1980s were triggered by a break in an infrared beam. However, newer models come in 'self-contained package including sensors and camera.'

Prinz et al. [18] use an alternative technique which detects changes in the pixels from the camera output. This was achieved using the open-source program motion-MMAL. This alternative technique minimises the hardware requirements of the system.

1.5 Night or low-light visibility

Rovero at al. [2] discuss the use of infrared or LED flash, to enable camera visibility at night.

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