EEE4113F Draft Literature Review

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Chapter 1

Literature Review

1.1 Data acquisition

Wireless vs. Wired data transmission in Wildlife studies, Data acquisition in wildlife research has numerous challenges, one of which is choosing between wireless and wired methods for data transmission. Traditionally, wired communications are usually employed. However, they introduce problems like cable management issues and animal interference. Gula, Roman, et al. [1] detail how different coaxial cable thicknesses are required to transmit different data types over a set length without any additional amplification, between the sensors and control unit. This results in a cluster of cables running between the subsystems. Another concern in the study was that animals, such as rats, end up chewing the cables over time [1]. Li, N. et al. [2] speaks about the cost of deploying a wired system compared to a wireless system for surveillance, and that deploying a wireless system will reduce the overhead that comes with maintenance when the connections get damaged. Their findings suggest that implementing a wireless communication system will present a more cost-effective solution for wildlife research [2].

Despite the improvements of wireless communication capabilities, wired communications have served as an industry standard due to its advantages. Huynh's study on general communication protocols [3] 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. The study 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 [3].

Given the challenges associated with wired communications in wildlife research, wireless data transmission becomes a promising alternative. Adsumilli, C et al. [4] talks about the '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.' The successful video coding standards used were H.263 and MPEG-4, which were implemented to achieve error control for both reception and transmission of video in error prone environments [4].

In exploring alternative wireless connectivity modules for low power IoT devices, Peng, Y. et al. [5] 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 battery less 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. [5] reported a maximum packet detection range of 50 m, making it a possible solution for smaller data transmission needs.

1.2 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' [6]. The wide versatility of a device like the Raspberry Pi makes it ideal for implementation of customisable video monitoring solutions. Jolles [6] 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 [7]. Prinz et al. [8] 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.

[6] 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. [9] 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. [9] 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. [10] implement a remote visual surveillance based on an ESP32 microcontroller, demonstrating a successful microcontroller-based implementation under slightly different circumstances to [9]. [6] 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.

[6] 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.

1.3 Motion detection for camera traps

Meek and Pittet [11] identify that 'Motion detection is of prime importance for any camera trap to be effective'. Importantly, Rovero et al. [12] 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 [11] 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. [12] 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 [13] 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' [13].

Welbourne et al [14] 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. [12] 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. [8] 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.

1.4 Night or low-light visibility

Rovero at al. [12] discuss the use of infrared or LED flash, to enable camera visibility at night.

Bibliography

[1] R. Gula, J. Theuerkauf, S. Rouys, and A. Legault, "An audio/video surveillance system for wildlife," *European Journal of Wildlife Research*, vol. 56, pp. 803–807, 2010.

[2] N. Li, B. Yan, G. Chen, P. Govindaswamy, and J. Wang, "Design and implementation of a sensor-based wireless camera system for continuous monitoring in assistive environments," *Personal and Ubiquitous Computing*, vol. 14, pp. 499–510, 2010.

[3] A. Huynh, "Study of wired and wireless data transmissions," Ph.D. dissertation, Linköping University Electronic Press, 2010.

[4] C. Adsumilli and Y. H. Hu, "Adaptive wireless video communications: Challenges and approaches," in *Proceedings of International Workshop on Packet Video*, 2002, pp. 1–11.

[5] Y. Peng, L. Shangguan, Y. Hu, Y. Qian, X. Lin, X. Chen, D. Fang, and K. Jamieson, "PLoRa: A passive long-range data network from ambient lora transmissions," in *Proceedings of the 2018 conference of the ACM special interest group on data communication*, 2018, pp. 147–160.

[6] J. W. Jolles, "Broad-scale applications of the Raspberry Pi: A review and guide for biologists," *Methods in Ecology and Evolution*, vol. 12, no. 9, pp. 1562–1579, 2021. [Online]. Available: https://besjournals.onlinelibrary.wiley.com/doi/abs/10.1111/2041-210X.13652

[7] S. Hofmeyer and S. Cunningham, personal communication.

[8] A. C. B. Prinz, V. K. Taank, V. Voegeli, and E. L. Walters, "A novel nest-monitoring camera system using a Raspberry Pi micro-computer," *Journal of Field Ornithology*, vol. 87, no. 4, pp. 427–435, 2016. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1111/jofo.12182

[9] L. Camacho, R. Baquerizo, J. Palomino, and M. Zarzosa, "Deployment of a set of camera trap networks for wildlife inventory in western Amazon rainforest," *IEEE Sensors Journal*, vol. 17, no. 23, pp. 8000–8007, 2017.

[10] B. Cardoso, C. Silva, J. Costa, and B. Ribeiro, "Internet of things meets computer vision to make an intelligent pest monitoring network," *Applied Sciences*, vol. 12, no. 18, 2022. [Online]. Available: https://www.mdpi.com/2076-3417/12/18/9397

[11] P. Meek and A. Pittet, "User-based design specifications for the ultimate camera trap for wildlife research," *Wildlife Research*, vol. 39, no. 8, pp. 649–660, 2012.

[12] F. Rovero, F. Zimmermann, D. Berzi, and P. Meek, "Which camera trap type and how many do i need? a review of camera features and study designs for a range of wildlife research applications," *Hystrix, the Italian Journal of Mammalogy*, vol. 24, no. 2, pp. 148–156, 2013. [Online]. Available: https://doi.org/10.4404/hystrix-24.2-8789

[13] A. Rico-Guevara and J. Mickley, "Bring your own camera to the trap: An inexpensive, versatile, and portable triggering system tested on wild hummingbirds," *Ecology and Evolution*, vol. 7, no. 13, pp. 4592–4598, 2017. [Online]. Available: https://onlinelibrary.wiley.com/doi/abs/10.1002/ece3.3040

[14] D. J. Welbourne, A. W. Claridge, D. J. Paull, and A. Lambert, "How do passive infrared triggered camera traps operate and why does it matter? breaking down common misconceptions," *Remote Sensing in Ecology and Conservation*, vol. 2, no. 2, pp. 77–83, 2016. [Online]. Available: https://zslpublications.onlinelibrary.wiley.com/doi/abs/10.1002/rse2.20