Intelligent Airborne Monitoring of Livestock Using Autonomous Uninhabited Aerial Vehicles

Kaya Kuru[1], Darren Ansel[1] and David Jones[1]

[1] School of Engineering and Computing, University of Central Lancashire, Preston PR1 2HE, U.K.

Abstract

Precision Livestock Farming (PLF) is one of the most promising applications showing the benefits of using drones where a lack of human element in the farming industry is becoming evident. UAV-assisted smart farming within large farms has gained momentum in managing large farms effectively by avoiding high costs and increasing the quality of monitoring. To this end, the high mobility of UAVs combined with a high level of autonomy, sensor-driven technologies and AI decision-making abilities can provide many advantages to farmers in exploiting instant information from every corner of a large farm. The key objective of this research is to develop user-friendly AI-based software that can combine the sensor data sets and accurately detect animals and health anomalies, so the information can be presented in an easy-to-understand on-demand format for livestock farmers to take targeted or preemptive action, and improve the health, welfare, and productivity of their livestock. In this research, an automated drone solution with a cross-discipline approach has been developed to periodically survey livestock in an automated manner using vision-based sensor modalities involving both standard visual band sensing and a thermal imager. The experimental results suggest that the accuracy rates of detecting livestock are very high with very high sensitivity (Se) and specificity (Sp) values. Additionally, the results regarding the animal body heat signatures obtained from the thermal imagery show promising results in detecting disease-related cases. This research is a productivity and sustainability-focused pilot to investigate and demonstrate how drones and artificial intelligence software can provide a better way to regularly inspect animals on a large farm to avoid high costs and to increase the quality of monitoring. The research demonstrates how highly integrated technologies with drones can help the farming industry to overcome the challenging issues in the management of livestock, particularly, health monitoring of livestock in very large farms in an eco-friendly and sustainable way.

Keywords: Precision Livestock Farming (PLF); livestock health monitoring; livestock management, unmanned aerial vehicles (UAV), autonomous drones, thermal imagery; active RFID, livestock image processing.

1. INTRODUCTION

To successfully operate any large farm, effective livestock management is crucial and monitoring them in large farms is a labour-intensive task and costly. Smart farming with livestock is an emerging high-tech area focused on automating production and, thus, reducing the cost of the human (manual) effort involved in daily tasks, which makes animal welfare an increased concern [1]. Vehicles are becoming increasingly automated by taking on more and more tasks [2], [3] under improving intelligent control systems equipped with enhancing sensor technologies and Artificial Intelligence (AI) techniques [4], [5], [6]. Autonomous Uninhabited Aerial Vehicles (UAVs) (A-UAVs), as flying autonomous robots, with self-learning and self-decision-making abilities by executing non-trivial sequences of events with decimetre-level accuracy based on a set of rules, control loops and constraints using dynamic flight plans involving autonomous take-off and landing are taking their indispensable parts with little or no human in the loop [7], [8] to accomplish various automated tasks [9], [10], [11], [12], [13], [14], [15]. Precision Livestock Farming is one of the most promising applications showing the benefits of using drones [16] where a lack of human element in the farming industry is becoming evident [17]. Remote detection and counting is safe, cost-effective and could be easily and frequently repeated, providing prompt information about livestock's population size and their instant location [18]. The scope of this research within this goal is to develop a fully automated decision support tool with a cross-discipline approach that can detect changes in livestock behaviour and their physiological conditions for providing early indications of potential disease outbreaks or other stress events and allowing farmers to take targeted or preemptive action, and improve the health, welfare, and productivity of their livestock.

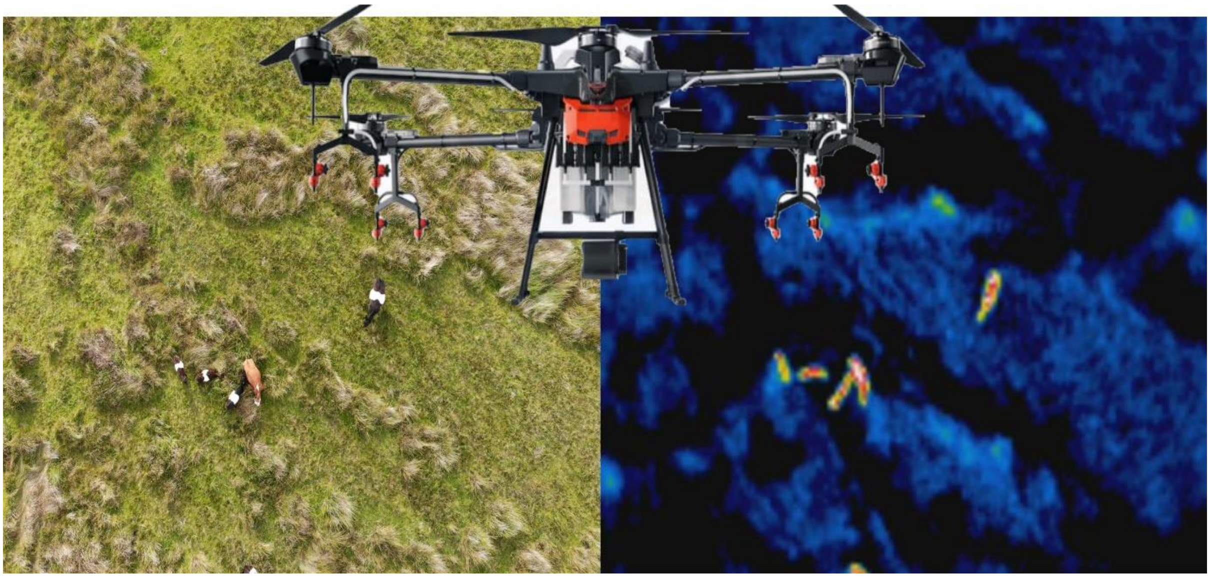

Figure 1: Main interface of the application

2. METHODS

The key objective of this research is to develop user-friendly AI-based software that can combine the sensor data sets and accurately detect the animals and health anomalies, so the information can be presented in an easy-to-understand on-demand format for livestock farmers to take targeted or preemptive action, and improve the health, welfare, and productivity of their livestock. In this research, an automated drone solution (Fig. 1) with a cross-discipline approach within the concept of Automation of Everything and Internet of Everything [19], [20] has been developed to periodically survey livestock in an automated manner using vision-based sensor modalities involving both standard visual band sensing and a thermal imager. The images/videos are aimed to be processed using artificial intelligence (AI) based software to detect stock numbers, and individual animal temperatures to indicate the presence of infection or stage in the fertility cycle. A number of supervised and unsupervised [21] Machine Learning (ML) and Deep Learning (DL) techniques were examined through data fusion based on the features of the datasets (videos, images) collected in both visible band wavelengths and thermal imagery. As an essential physiological index, animal body surface temperature can be used to accurately evaluate the physiological state of animals under stress, fertility, welfare, metabolism, health, and disease [22]. An AI-based application using an ensemble of AI techniques was established to perform image classification and clustering to achieve the objectives of animal analytics in this research. The onboard IoT platform with the developed application enables the drone to be operated consistently and reliably by automating many key functions that could otherwise be subject to human error. The application aims to report any abnormal situation to the farmers to improve the adverse conditions.

3. RESULTS

The experimental results suggest that the accuracy rates of detecting livestock are very high with very high sensitivity (Se) and specificity (Sp) values of over 97%. Additionally, the results regarding the animal body heat signatures obtained from the thermal imagery show promising results in detecting disease-related cases. Using drones with highly automated flights provides on-demand accurate information to the farmer that enables early interventions with high-accuracy detection and classification of livestock should an animal go missing or need attention on the grounds of animal health and welfare. The research demonstrates how highly integrated technologies with drones can help the farming industry to overcome the challenging issues in the management of livestock, particularly, health monitoring of livestock in very large farms in an eco-friendly and sustainable way. The research team is currently examining the correlation of thermal measurements with known health-related conditions for mapping the fused sensor inputs to particular diseases, which provides early indications of potential disease outbreaks or other stress events.

4. CONCLUSION

This research is a productivity and sustainability-focused pilot to investigate and demonstrate how drones and artificial intelligence software can provide a better way to regularly inspect animals on a large farm to avoid high costs and to increase the quality of monitoring. The incorporation of A-UAVs into the management of large farms is imperative. UAV-assisted smart farming has gained momentum in managing large farms to avoid high costs and to increase the quality of monitoring. The integration of UAVs embedded with IoT applications that are equipped with sensor-driven technologies can help survey large farms regularly in a timely manner with advanced AI tools, improve the early diagnosis of livestock diseases and reduce disease-related deaths significantly. To this end, the high mobility of UAVs combined with a high level of autonomy and AI decision-making abilities can provide many advantages to farmers in exploiting instant information from a large farm. Through a combination of experimentation studies, we demonstrate significant improvements in livestock health monitoring within large farms using drones equipped with intelligent monitoring systems. Not only does the use of drones reduce our reliance on fossil-fuelled vehicles, but there are also labour cost savings from a reduced labour requirement so we can free up more time and valuable resources to spend on other tasks that will boost productivity. The potential benefits of the developed farm technology can be summarised as fuel use savings, productivity improvements, cost savings and the value of additional animal health information gathered.

REFERENCES

[1] Jukan, A., Carpio, F., Masip, X., Ferrer, A. J., Kemper, N., & Stetina, B. U. (2019). Fog-to-Cloud Computing for Farming: Low-Cost Technologies, Data Exchange, and Animal Welfare. In Computer (Vol. 52, Issue 10, pp. 41–51). https://doi.org/10.1109/mc.2019.2906837

[2] Kuru, K. *et al*. (2023). Toward Mid-Air Collision-Free Trajectory for Autonomous and Pilot-Controlled Unmanned Aerial Vehicles. In IEEE Access (Vol. 11, pp. 100323–100342). https://doi.org/10.1109/access.2023.3314504

[3] Kuru, K. (2021). Planning the Future of Smart Cities With Swarms of Fully Autonomous Unmanned Aerial Vehicles Using a Novel Framework. In IEEE Access (Vol. 9, pp. 6571–6595). https://doi.org/10.1109/access.2020.3049094

[4] Kuru, K. (2023). Sensors and Sensor Fusion for Decision Making in Autonomous Driving and Vehicles. Sensors.

[5] Kuru, K. (2022). TrustFSDV: Framework for Building and Maintaining Trust in Self-Driving Vehicles. In IEEE Access (Vol. 10, pp. 82814–82833). https://doi.org/10.1109/access.2022.3196941

[6] Kuru, K. *et al*. (2021). A Framework for the Synergistic Integration of Fully Autonomous Ground Vehicles With Smart City. In IEEE Access (Vol. 9, pp. 923–948). Institute of Electrical and Electronics Engineers (IEEE). https://doi.org/10.1109/access.2020.3046999

[7] Kuru, K. (2021). Conceptualisation of Human-on-the-Loop Haptic Teleoperation With Fully Autonomous Self-Driving Vehicles in the Urban Environment. In IEEE Open Journal of Intelligent Transportation Systems (Vol. 2, pp. 448–469). https://doi.org/10.1109/ojits.2021.3132725

[8] Kuru, K. *et al*. (2023). AITL-WING-HITL: Telemanipulation of autonomous drones using digital twins of aerial traffic interfaced with WING. In IEEE Access (Vol. 11).

[9] Kuru, K. *et al*. (2019). Analysis and Optimization of Unmanned Aerial Vehicle Swarms in Logistics: An Intelligent Delivery Platform. In IEEE Access (Vol. 7, pp. 15804–15831). Institute of Electrical and Electronics Engineers (IEEE). https://doi.org/10.1109/access.2019.2892716

[10] Kuru, K. *et al*. (2023). WILDetect: An intelligent platform to perform airborne wildlife census automatically in the marine ecosystem using an ensemble of learning techniques and computer vision. In Expert Systems with Applications (Vol. 231, p. 120574). https://doi.org/10.1016/j.eswa.2023.120574

[11] Kuru, K. *et al*. (2023). Intelligent airborne monitoring of irregularly shaped man-made marine objects using statistical Machine Learning techniques. In Ecological Informatics (Vol. 78, p. 102285). Elsevier BV. https://doi.org/10.1016/j.ecoinf.2023.102285

[12] Kuru, K., & Ansell, D. A. (2023). Vision-Based Remote Sensing Imagery Datasets From Benkovac Landmine Test Site Using An Autonomous Drone For Detecting Landmine Locations [dataset]. IEEE DataPort. https://doi.org/10.21227/PTSA-QJ43

[13] Kuru, K. *et al*. (2023). Intelligent, automated, rapid and safe landmine and Unexploded Ordnance (UXO) detection using Maggy. IEEE Transactions on Geoscience and Remote Sensing.

[14] Kuru, K. *et al*. (2023). Intelligent automated, rapid and safe landmine and Unexploded Ordnance (UXO) detection using multiple sensor modalities mounted on autonomous drones. IEEE Transactions on Geoscience and Remote Sensing.

[15] Kuru, K. *et al*. (2023). IoTFaUAV: Intelligent remote monitoring of livestock in large farms using Autonomous uninhabited aerial vehicles. In Computers and Electronics in Agriculture.

[16] Bacco, M., Berton, A., Gotta, A., & Caviglione, L. (2018). IEEE 802.15.4 Air-Ground UAV Communications in Smart Farming Scenarios. In IEEE Communications Letters (Vol. 22, Issue 9, pp. 1910–1913). Institute of Electrical and Electronics Engineers (IEEE). https://doi.org/10.1109/lcomm.2018.2855211

[17] Grogan, A. (2012). Smart farming. In Engineering & Technology (Vol. 7, Issue 6, p. 38). Institution of Engineering and Technology (IET). https://doi.org/10.1049/et.2012.0601

[18] Kalmukov, Y., & Evstatiev, B. (2022). Methods for Automated Remote Sensing and Counting of Animals. In 2022 8th International Conference on Energy Efficiency and Agricultural Engineering (EE&AE). 2022 8th International Conference on Energy Efficiency and Agricultural Engineering (EE&AE). IEEE. https://doi.org/10.1109/eeae53789.2022.9831239

[19] Kuru, K., & Yetgin, H. (2019). Transformation to Advanced Mechatronics Systems Within New Industrial Revolution: A Novel Framework in Automation of Everything (AoE). In IEEE Access (Vol. 7, pp. 41395–41415). Institute of Electrical and Electronics Engineers (IEEE). https://doi.org/10.1109/access.2019.2907809

[20] Kuru, K. (2021). Management of geo-distributed intelligence: Deep Insight as a Service (DINSaaS) on Forged Cloud Platforms (FCP). In Journal of Parallel and Distributed Computing (Vol. 149, pp. 103–118). Elsevier BV. https://doi.org/10.1016/j.jpdc.2020.11.009

[21] Kuru, K., & Khan, W. (2018). Novel hybrid object-based non-parametric clustering approach for grouping similar objects in specific visual domains. In Applied Soft Computing (Vol. 62, pp. 667–701). Elsevier BV. https://doi.org/10.1016/j.asoc.2017.11.007

[22] Zheng, S., Zhou, C., Jiang, X., Huang, J., & Xu, D. (2022). Progress on Infrared Imaging Technology in Animal Production: A Review. In Sensors (Vol. 22, Issue 3, p. 705). MDPI AG. https://doi.org/10.3390/s22030705