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United States Department of Agriculture
Project Initiation

Project Data for Accession Number 1032298

Project Title

Precision Livestock Management: Cattle Monitoring and Herding Using Cooperative Drones

Project Details

Sponsoring Institution National Institute of Food and Agriculture	**Project Status** ACTIVE
Funding Source NIFA Non Formula	**Grant Year** 2024
Grant No. 2024-69014-42393	**Cumulative Award Amt.** $910,000.00
Proposal No. 2023-10983	**Multistate No.** (N/A)
Project Start Date Jul 01, 2024	**Project End Date** Jun 30, 2029
Program Code [A1261] Inter-Disciplinary Engagement in Animal Systems	

Project Director

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Recipient Organization

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Performing Department

Biosystems and Agricultural Engineering

Non Technical Summary

The number of skilled laborers for monitoring and moving unconfined animals is dwindling within the US livestock industry. New technology utilizing small drones (unmanned aircraft systems or UAS) and advanced photography methods (photogrammetry) now allows for an alternative means for monitoring and moving cattle. The cost of these new technologies and the complexity of implementation are a challenge to adoption as margins are small and producers have limited time to learn complex systems.Thus, the overarching goal of this work is advancing the understanding of the UAS and beef cattle interaction in pasture and collecting physiological measurements remotely. We propose four specific objectives: 1) develop a novel multi-agent UAS control technique for semi-autonomous interaction with livestock; 2) establish UAS beef cattle reaction response; 3) quantify the accuracy of UAS based cattle volume measurements from the UAS; and 4) develop UAS economic models for the livestock industry. The outcomes of the project will offer a simplified approach for herding and monitoring livestock, provide flight recommendations

concerning animal proximity, present models for cow weight estimation, and offer insights into the optimum number of drones required.The anticipated impact for producers would be a streamlined approach to utilizing UAS for the monitoring and movement of cattle. The utilization of UAS on livestock operations will facilitate a workload reduction for producers.

Animal Health Component

Animal Health Component: 50%

Research Effort Categories

Basic	70%
Applied	30%
Developmental	0%

Classification

Knowledge Area (KA)	Subject of Investigation (SOI)	Field of Science (FOS)	Percent
307	3310	1060	100%

Knowledge Area

[307] Animal Management Systems

Subject Of Investigation

[3310] Beef cattle, live animal

Field Of Science

[1060] Biology (whole systems)

Keywords

Beef, Cattle, Drone, Cooperative-control, herding

Goals / Objectives

The overarching objective of this work is to advance the understanding of how drones can be used to improve the efficiency of cattle operations by supplementing traditional management with automated techniques. To accomplish the goals of this project, we propose four specific objectives: 1) Develop a decentralized coordinated control technique for deploying multiple drones near livestock; 2) Determine the physiological and biological response of cattle to multiple drones flying in formation; 3) Validate remotely sensed three-dimensional physical measurements of cattle, and 4) Assess the economic feasibility of integrating drone technology into U.S. beef cattle production. These objectives are built upon our previous experience in deploying drones for livestock health monitoring and are designed to bridge the gap between research-grade systems and systems that are feasible for small, medium, and large-scale production operations.

Project Methods

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Objective 1Our multi-UAV system consists of four DJI Matrice 300 quadrotors, each equipped with six pairs of stereo cameras covering all orthogonal directions (front, back, left, right, up, and down). We will develop software to process real-time point clouds from these camera pairs and use this data to track and respond to cattle motion within the R2T formation control. For example, the formation size around a cow can dynamically adjust based on its activity or task requirements. Although R2T provides local UAV collision avoidance, it doesn't address obstacles like cattle or fences. To ensure safety, we'll integrate an independent safety filter that modifies control commands when collisions are predicted. This filter uses barrier functions and quadratic programming to maintain safety while minimizing control intervention. Additionally, we'll implement a Human-in-the-Loop (HITL) mode where a human operator controls one UAV, acting as a leader for the formation. We'll leverage HITL experience to design this mode effectively. Lastly, to address sample-data effects in multi-UAV control, we'll develop a sampled-data implementation of the unified control framework, ensuring stability and performance even with slow-sample-rate feedback, using techniques developed in previous work.Objective 2UAS-naive heifers, steers, or cows will participate, requiring at least 136 animals over three years. Trials will span May to August, coinciding with the primary grazing season and graduate student availability. Similar to past studies, four-week trials will involve UAS flights on designated days (three times weekly) in morning (6-9 AM) or evening (6-9 PM) to avoid midday heat. Additionally, trials during fall and winter may occur with fewer animals and use eight two-acre pastures unless stated otherwise.Noninvasive heart rate (HR) measurement will utilize a Polar H10 sensor fastened with a Polar Equine Belt, strapped around each animal's heart girth, and logged at 1 Hz frequency using a Polar Beat app on an LG Tribute Dynasty smartphone. HR will be recorded 5 minutes preflight, preflight within the pasture, and during flight to compare baseline and in-flight HR. GPS data will be collected using a standalone Flashback GPS collar and the smartphone to log movement rates at 1 Hz, with sound frequencies also recorded. Movement rate comparisons preflight and during UAS flight will gauge changes in cattle movement. UAS visual camera footage will be analyzed with CowLog software for behavioral classification.Objective 3The study involves using imagery collected during the physiological and biological response assessment of beef cattle to multiple drones (Objective 2) as the basis for volumetric measurements. Each year of the project will involve 40 heifers, with each heifer considered a treatment and measurements replicated daily during data collection periods. Approximately 30 images distributed across 2 or 3 radii from each cow will be used to create a 3D model, with at least three image sets per treatment to assess short-term variability.The individual images will be geotagged with WGS 84 coordinates using the drone's GNSS receiver, and environmental conditions (e.g., temperature, humidity, time of day, cloud cover) will be recorded to contextualize weight estimation errors between image sets. Pix4Dmapper Pro will process the image sets into point clouds (PLY format), anticipated to exceed 1 point/cm^3 density. MATLAB will be used to isolate the cow from the ground, remove noise, and calculate its volume.Two volume calculation techniques will be explored: the first involves fitting a convex hull model to the point cloud (a coarse estimate), and the second uses Monte Carlo integration within a 3D bounding box to determine the cow's volume. This method randomly tests 3D coordinates within the box to ascertain whether they fall inside or outside the point cloud, allowing for a more accurate volume calculation.Least-squares regression analysis will fit a function relating cow volume to weight, with residuals used to assess modeling error. A random subset of weight-volume pairs will be withheld for model validation. Results will be organized by individual cow over time and by date within a year, treating each year's results as replications.Objective 4~Ten operations will be selected for on-farm herding trials, with flights conducted on five large (~100 head) and five small (~25 head) herds using up to 8 drones per operation. Data collected during these trials will be analyzed using MATLAB Simulink to optimize the drone numbers needed for different farm sizes. This data, combined with existing team data, will update enterprise analysis for UAS and create a partial budget comparing UAS with standard livestock handling practices.Additionally, a stochastic investment model will be developed to evaluate key factors driving UAS adoption in the beef cattle industry, focusing on return on investment (ROI) based on labor savings, flight frequency, herd and field size, and topography. The potential flight frequency for cattle monitoring and movement will be determined through surveys at cattlemen's meetings, considering factors like calving schedule, breeding methods, vaccination schedules, disease events, and other operational factors affecting handling facility usage.