INT: Autonomous Unmanned Aerial Robots for Livestock Health Monitoring

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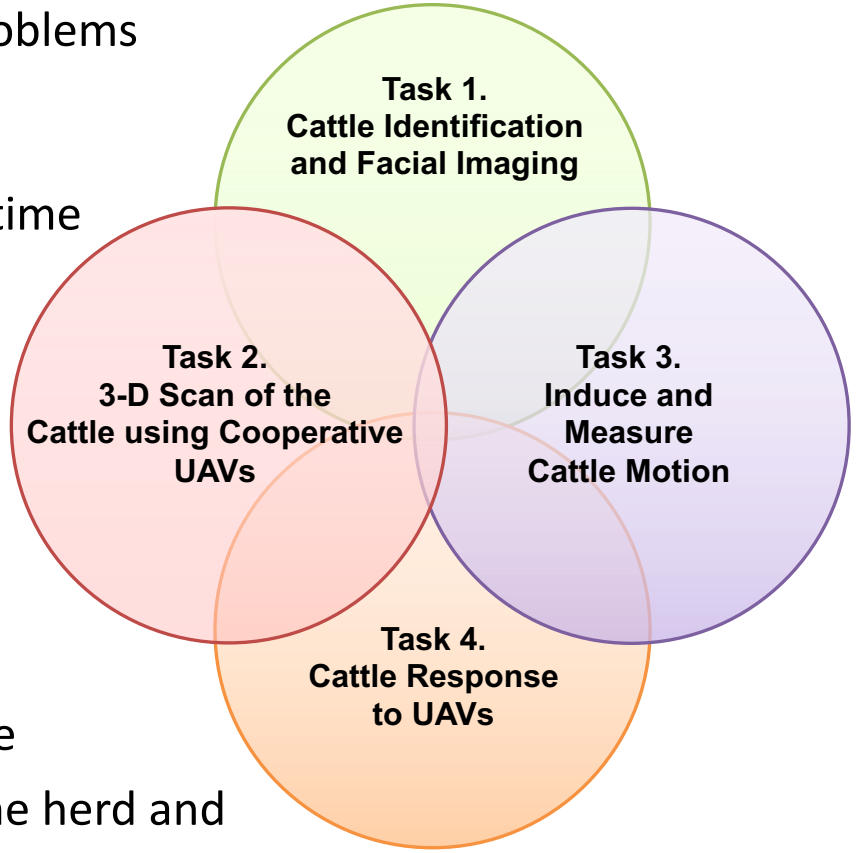
Project Motivation and Objective

Motivation:

- Poor livestock health is the most significant cause of cattle loss
- Over 2.5 million cattle ($1.5 billion value) die each year from health problems
- Only 220 thousand cattle are lost each year to predators
- Improved health monitoring can reduce herd loss
- Unlike poultry and swine, grazing cattle spend a significant amount of time outside of confinement, which makes centralized monitoring difficult

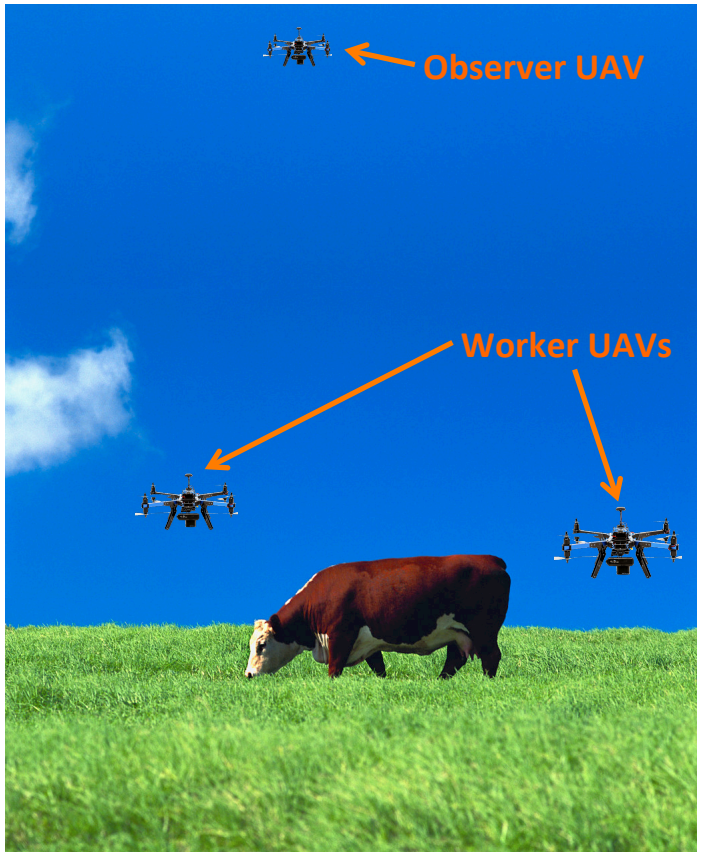
Project Objective: To develop and demonstrate a system of autonomous collaborative UAVs (rotorcraft) for monitoring the health of cattle herds

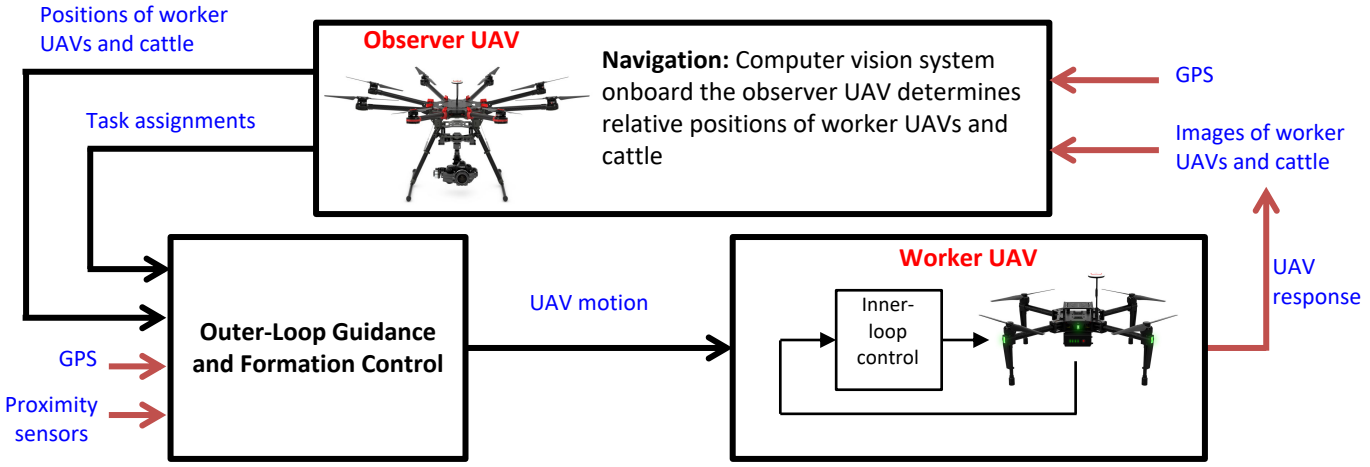
- Uniquely identify each cow in a herd
- Monitor each cow's location in pasture
- Monitor key health indicators, including: facial features, volume and weight (for a 3D image scan), physical activity, temperature
- All measurements will be obtained using a group of UAVs that patrol the herd and use non-invasive measurement methods



Overview of Collaborative Multi-UAV System

- *Observer UAV*
  - Hovers above cattle and worker UAVs
  - Uses downward-facing stereo cameras to track motion
  - Determines relative positions and orientations of cattle and worker UAVs
- *Worker UAVs*
  - Rely on relative position and orientation estimates provided by observer UAV in combination with GPS
  - Cooperatively perform cattle imaging and health monitoring tasks





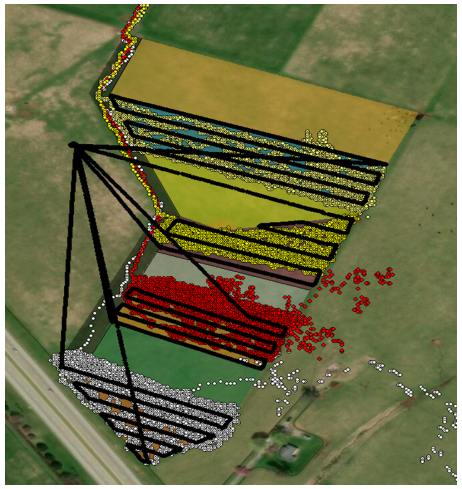
Cattle Response to UAVs

Objective: Evaluate cattle response and potential stress induced by UAVs

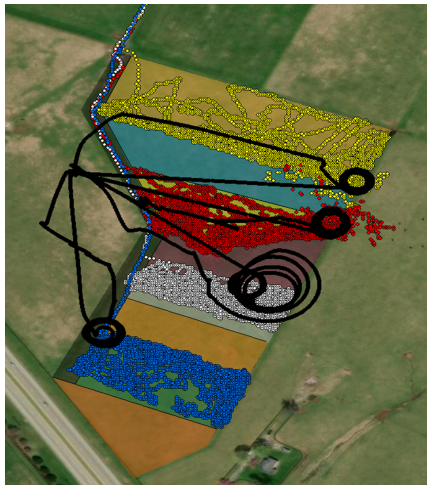
Method: Perform UAV flights near cattle in pasture and measure behavioral and physiological response. Details of most recent experiments are:

- Two groups of Angus females (32 heifers per group)
- 5 min flights per pasture at 2.3 m/s average speed
- 5 flights/day for 3 days/week
- Use grid and circular pattern flights at 7.6 to 9.1 m above ground level
- Measure behavioral response (i.e., cow's physical motion) with GPS trackers
- Measure heart-rate response with Polar® H10 and Polar® Equine electrode set

Grid Flights



Circular Flights



Cattle Response to UAVs

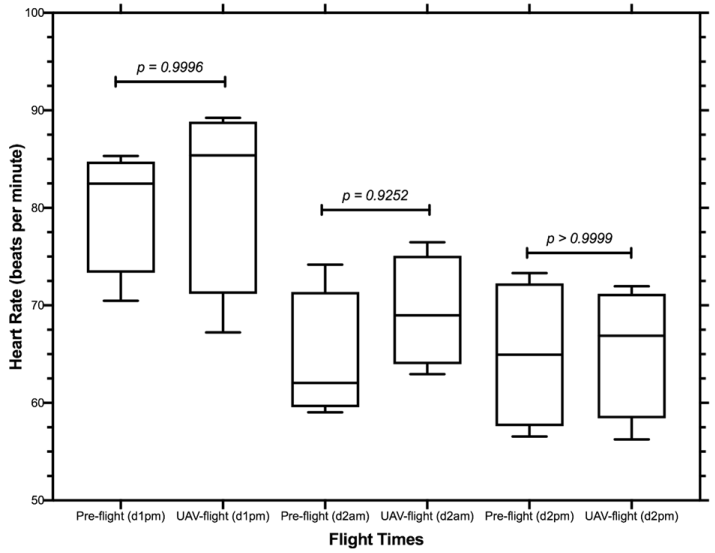
Result: No statistically significant difference in response measured 5-minutes before flight in comparison to during flight

- No change in cattle motion
- No change heart rate
- No differences between grid and circular flight patterns

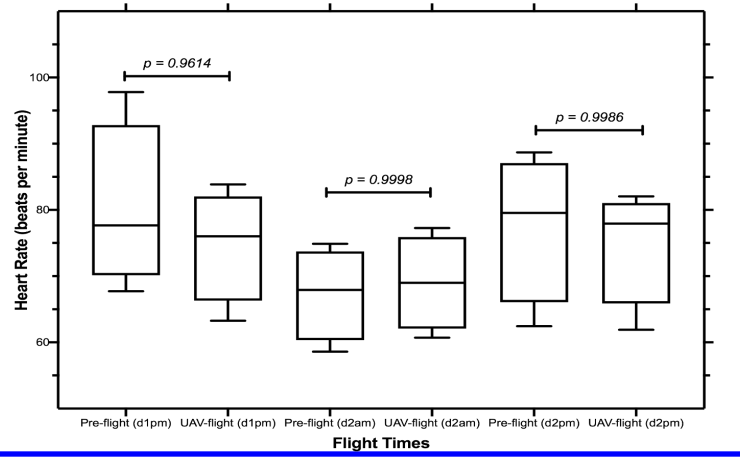
Future Work:

- Examine impact of multiple UAVs
- Measure head motion response during flight
- Determining minimum UAV distance that causes animal response
- Examine impact of direction of UAV approach

Week 1 Grid Flights



Week 1 Circular Flights



Relative-to-Target UAV Formation Control

Objective: Develop and test relative-to-target (R2T) formation control

- R2T positions UAVs in desired formation around a cow to obtain images simultaneously from different angles
- R2T allows the formation to translate and rotate as the imaging target (e.g., cow) changes its position and orientation
- Indoor experiments successfully demonstrated R2T with 3 UAVs
- Outdoor experiments currently underway

Future Work:

- Develop observer UAV for improved outdoor feedback measurements
- Incorporate collision-avoidance barrier function
- Improve worker UAV hardware platform

UAV-Based Scan of Cattle for Volume Estimation

Objective: Determine UAV flight patterns that can be used to image a cow for accurate volume estimation

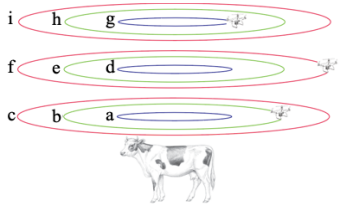
Method:

- Use UAVs to capture images of 2 cow statues
- Use subsets of those images to construct 3D models and evaluate accuracy of volume estimated from 3D model
- Collected images along 9 flight paths
- 3D models generated using all 3-flight-path combinations

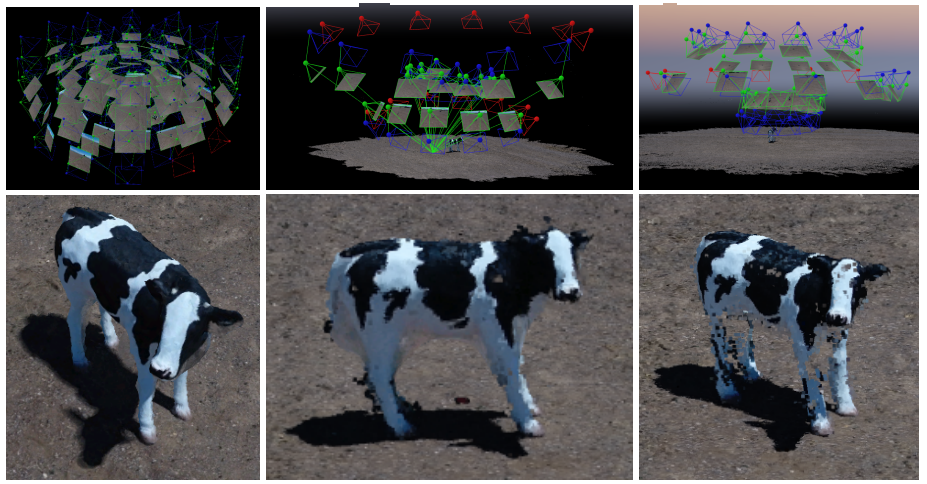
Result: Can use a reduced image data-set (images from 3 flight paths) to estimate volume with no significant difference from the full data-set estimate

Future Work: Develop improved methods for volume estimation and validate methods

Flight Paths



Post-Processing to Estimate Volume



3D Reconstruction Using a Generative Cow Model

Objective: Develop a generative 3D cow model that can reconstruct a cow using limited images

- Thirty-camera setup used to capture an image set for training the generative model
- Model can generate a variety of shapes and poses using relatively few tuning parameters

Thirty-Camera Cattle Imaging Setup

Result: Model can generate visually acceptable reconstruction from short video of images

Input Video

Reconstructed Cow

Future Work:

- Obtain more extensive image set (of real cattle) to improve generative model
- Evaluate generative model with real cattle

Acknowledgements

Graduate Students:

Zack Lippay—UAV formation control

Gabriel Abdulai—Cattle response

Felipe Pampolini, Ladino Karla—3D scan from UAVs

Xinxin Zuo, Shunnan Chen—Generative cow model

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Press: Recently featured in CNET video documentary “Drones on the Farm”

For more information, please come to Poster #104 on Thursday 6pm to 8pm