NRI: INT: Autonomous Unmanned Aerial Robots for Livestock Health Monitoring

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Project Timeline: February 2018 to February 2021

Motivation

The objective of this project is to develop and demonstrate a new co-robot system of autonomous unmanned air vehicles (UAVs) for monitoring the health of small-farm cattle herds in pasture, and thus, improve management practices

- Every year, over 2.5 million U.S. cattle, valued at $1.5 billion, die from health problems
- In contrast, only 220,000 cattle are lost annually to predators
- Poor livestock health is the single biggest cause of cattle loss—accounting for over 60% of all losses

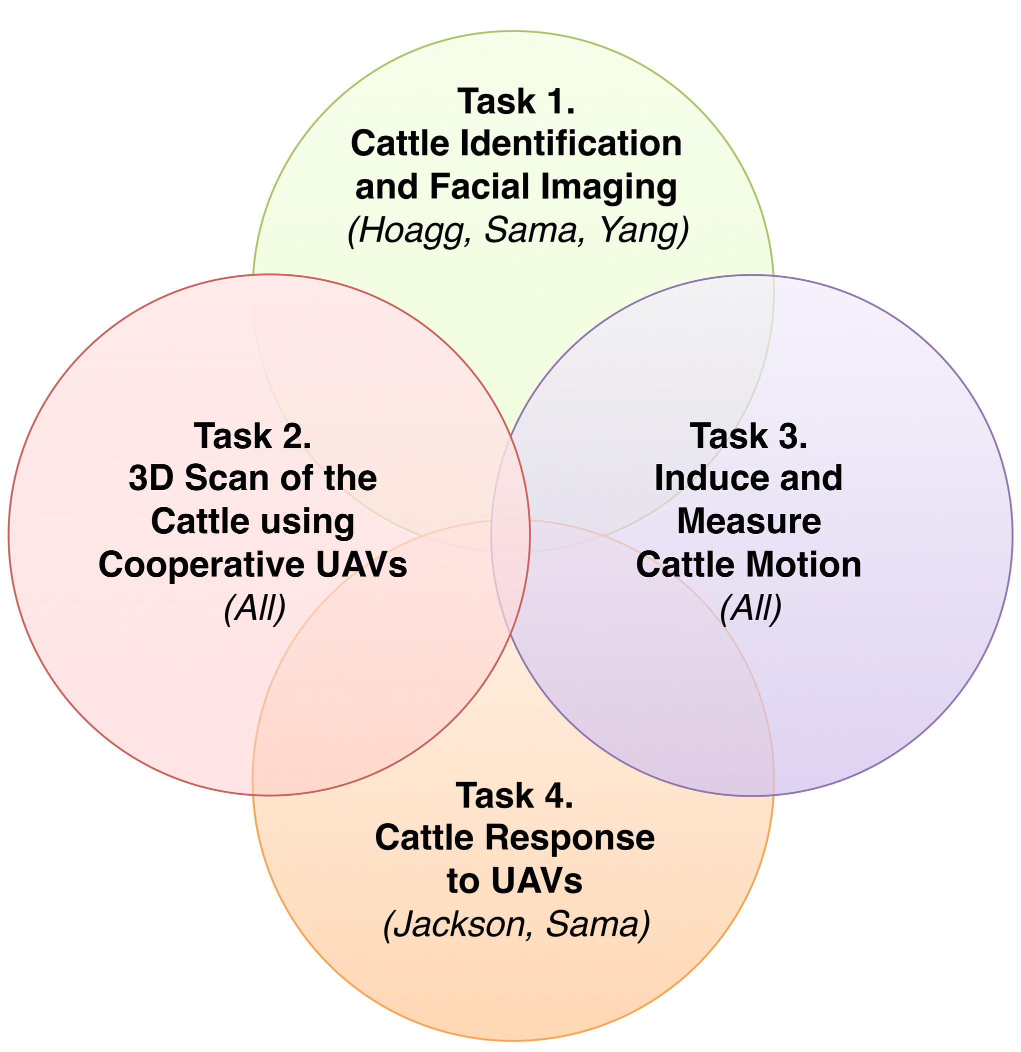
Improved health monitoring can reduce herd loss and thus, help to secure an essential source of food

- Unlike poultry and swine, grazing beef cattle spend a significant amount of time outside of confinement, which makes centralized monitoring difficult
- Although neckbands for cattle monitoring exist, these devices are expensive, cumbersome, and rarely used in practice—regardless of the size of the operation

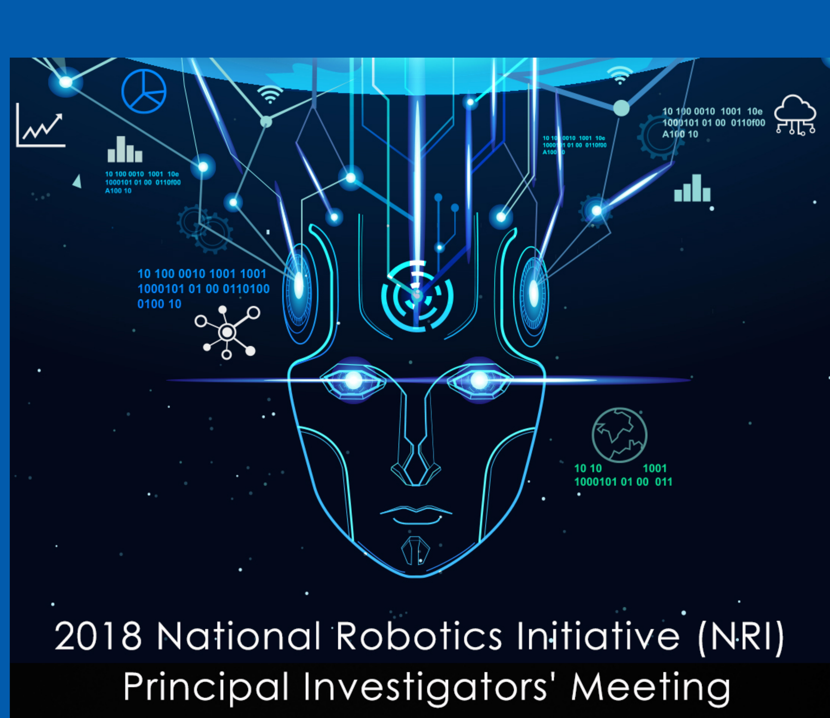
Project Overview

Objective: To develop a system of autonomous collaborative UAVs (rotorcraft) for monitoring the health of small-farm cattle herds

- Uniquely identify each cow in a herd
- Monitor each cow's physical location in pasture
- Monitor key health indicators, including facial features, volume, weight, physical activity



All of these measurements will be obtained using a group of collaborative UAVs that patrol the herd and use non-invasive measurement methods. Advances in computer science, cooperative control, agricultural engineering, and livestock systems are needed to unlock the potential of co-robot multi-UAV systems for cattle health monitoring.

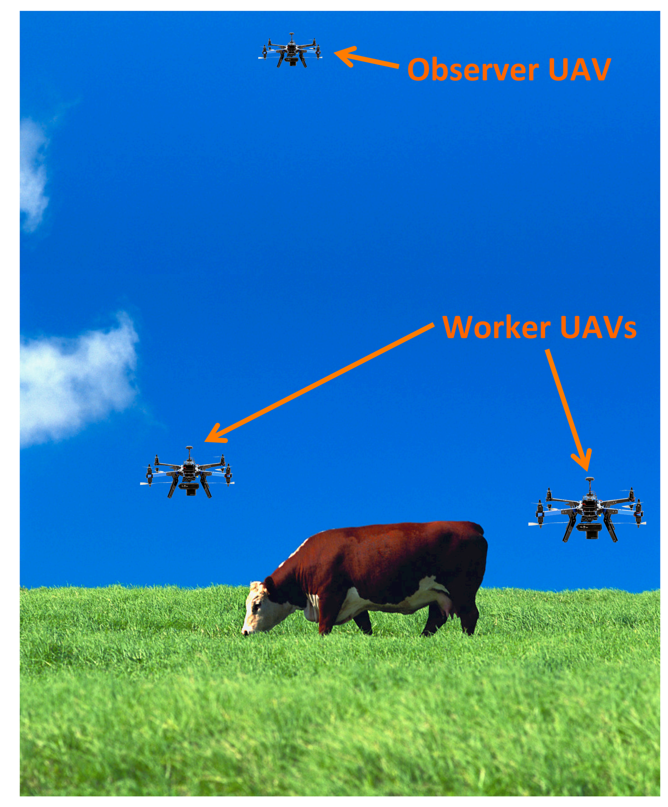


Overview of Multi-UAV System

The proposed multi-UAV system consists of 4 or 5 rotorcraft. One rotorcraft is the *observer UAV*, while the remaining rotorcraft are *worker UAVs*

Observer UAV:

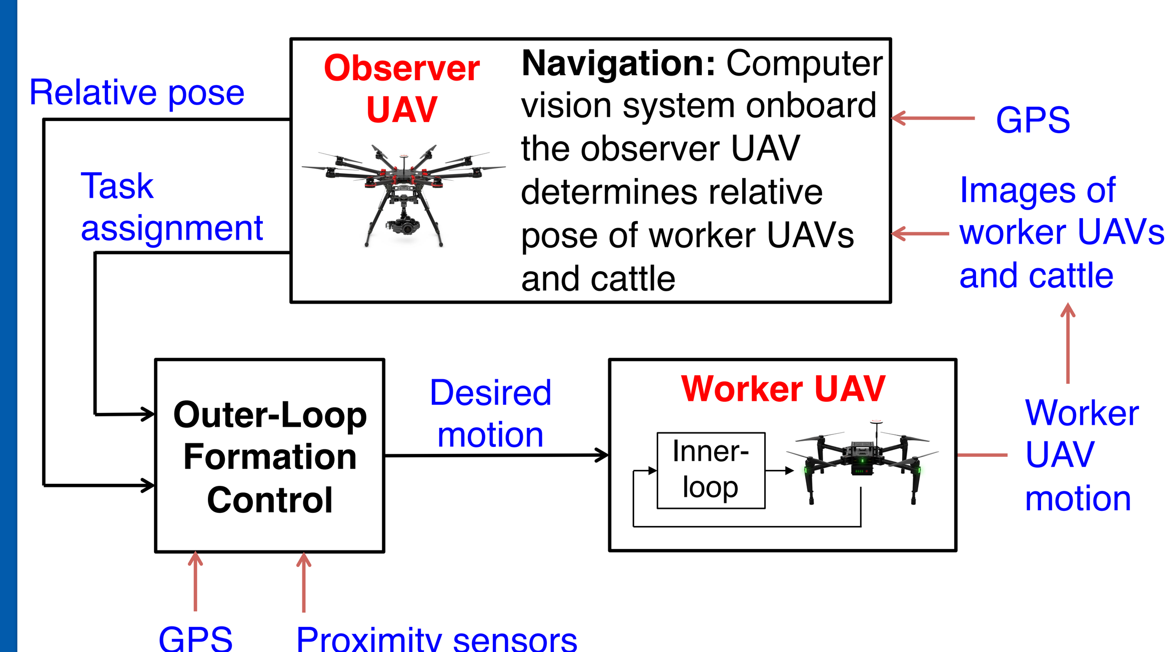
- Hovers 30 to 90 m above the cattle and worker UAVs
- Uses downward-facing stereo cameras to track motion
- Determines the relative pose (i.e., location, orientation) of the cattle and worker UAVs



Worker UAVs:

- Cooperatively perform cattle imaging and health monitoring tasks
- Rely on relative position and orientation estimates provided by the observer UAV

Control system is a multi-loop architecture with outer-loop discrete-time relative-to-target (DT-R2T) formation control for cooperative imaging

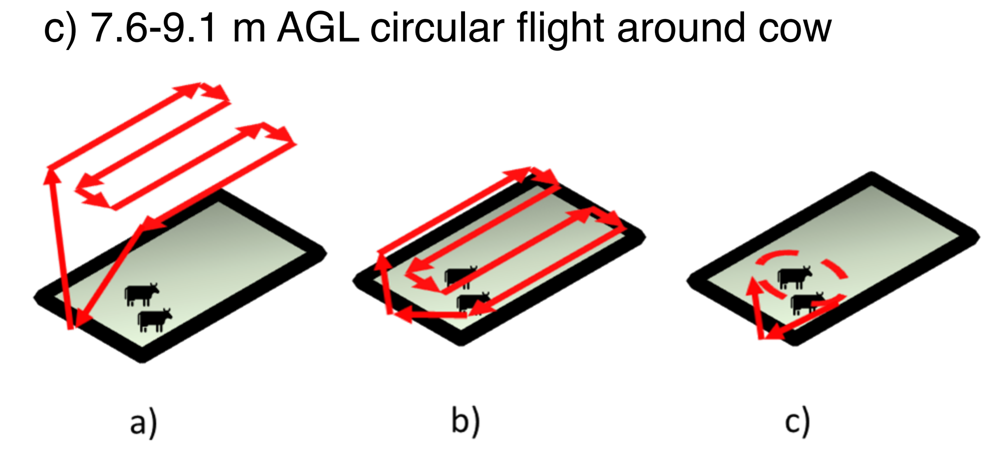


Cattle Response to UAVs

Objective: Evaluate the potential stress induced by UAVs flying near cattle

Methods: Three flight treatments on 20 dairy heifers (2 heifers per 2 acre pasture)

a) 18 m AGL grid over field (pasture monitoring)
b) 7.6-9.1 m AGL grid over field (lower altitude)
c) 7.6-9.1 m AGL circular flight around cow



- 5 min flight per pasture at 2.3 m/s average speed
- Behavioral response measured with Land Air Sea® trackers
- Heart rate response measured with Polar® H10 and Polar® Equine electrode set

Preliminary Results: No behavioral changes across treatments due to UAVs. Heart rate was equivalent prior to and during flight

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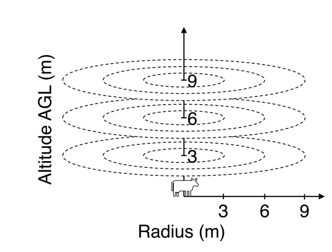
3D Scan of Cattle from UAVs

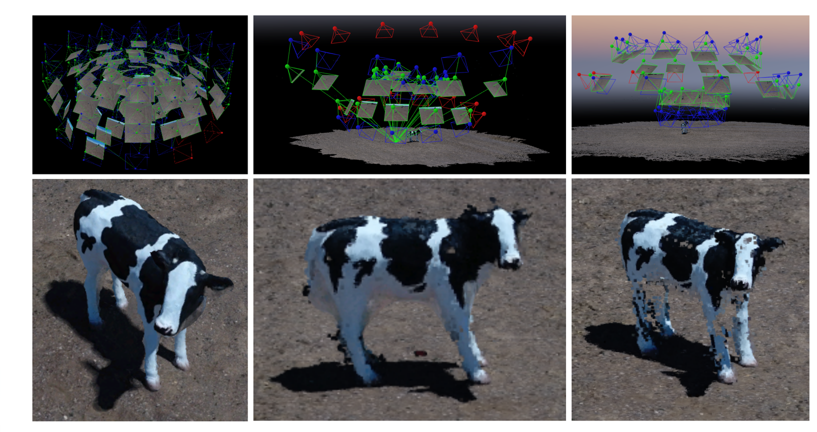
Objective: Determine optimal flight paths for 3 UAVs to simultaneously image a cow

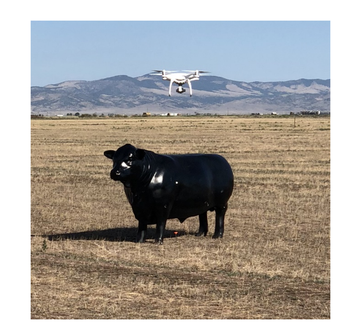
Methods: 108 images were collected along 9 flight paths. Flight paths were programmed into the UAV autopilot and the flight was repeated 3 times. 3D models were generated using Pix4Dmapper. Three paths were chosen from the 9 to form an individual treatment.

Preliminary Results: 3D model degrades if the number of images is reduced. Certain combinations resulted in entire sets of images being dropped from analysis because of an inadequate number of tie points.



Flight paths



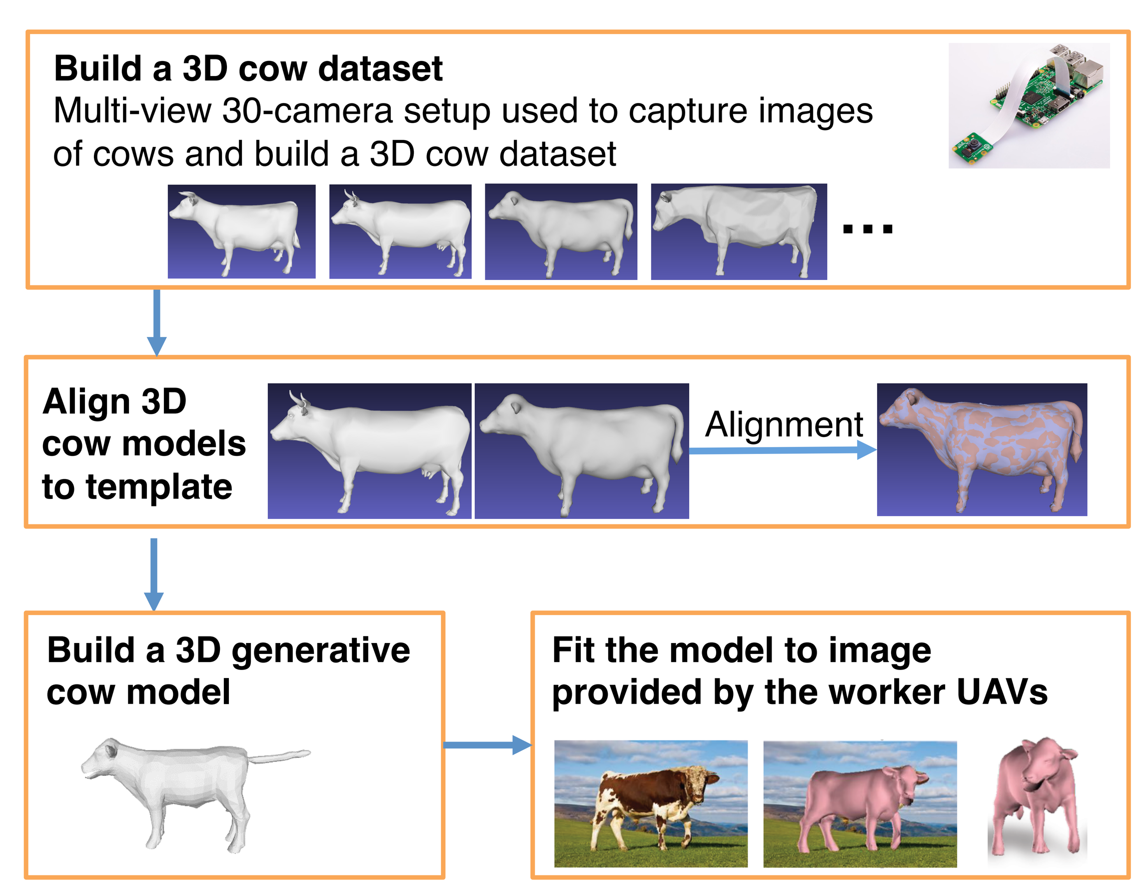


3D model quality degrades if the number of images is reduced. Camera locations (top) and resulting 3D model (bottom) from 9 flight paths (left) and 2 different combinations of 3 flight paths (center, right)

Generative 3D Cow Model

Objective: Build generative 3D cow model that will be used to estimate cow volume and weight

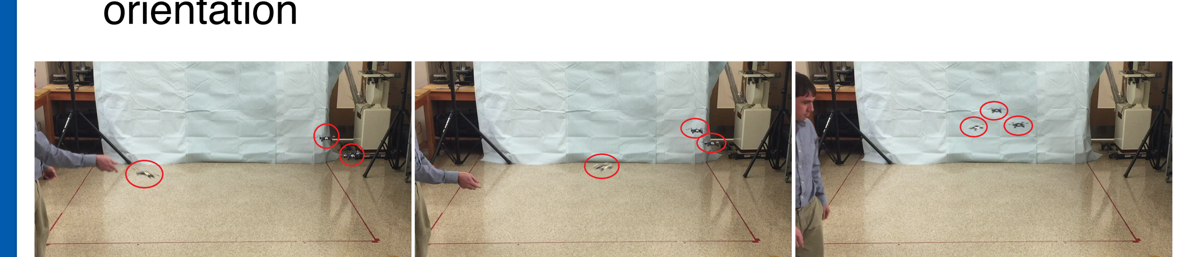
- Collecting 3D cow image dataset from multi-camera imaging setup to build generative cow model
- Generative model will be able to generate a variety of cow shapes and poses with relatively few tuning parameters



DT-R2T Formation Control

Objective: Develop and test the discrete-time relative-to-target (DT-R2T) formation control algorithm that positions UAVs in a desired formation around a cow to obtain images simultaneously from different angles

- Approach is discrete time because recent results show that some continuous-time formation control methods may not perform well with slow-sample-rate feedback (e.g., vision-based feedback)
- Relative-to-target approach allows the formation to rotate as the imaging target (e.g., cow) changes its orientation



Indoor discrete-time formation control experiments. The red circles highlight the UAVs. From left to right: a UAV is released to join the formation (left); the UAV autonomously joins the formation (center left and center right); the UAVs maintain a triangle formation and follow a circular leader trajectory (right).