LiveStalk:

Augmented Ranching with Drones, Deep Learning and Data-Centric Thinking

Team: Whit Blodgett, Jeff Day, Omar Kapur, Ricardo Jenez, Justin Jeng

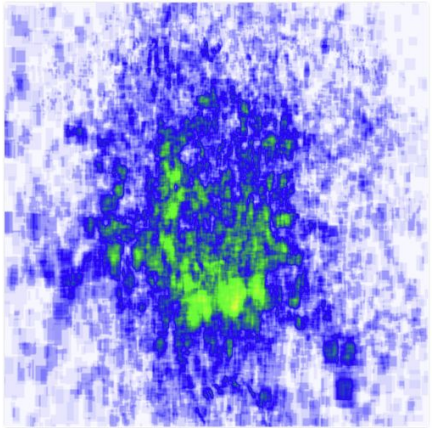
Problem we're solving

Count
"Counting cows can be difficult since they sometimes hide in ravines, especially when giving birth"

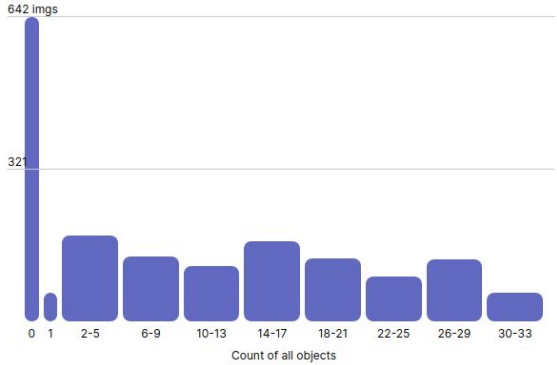
Location
"Ranches can span hundreds of square miles, while we have a general sense - we're never 100% certain where the herd is"

Data

Connolly Ranch, CA
- 1 hour filming window
- Variable image capture (height, pitch, shutter speed)



Images	Annotations	Average Image Size	Median Image Ratio
1,723	15,860	4.16 mp	2720×1530
0 missing annotations	9.2 per image (average)	from **4.16 mp**	wide
642 null examples	across 1 classes	to **4.18 mp**	



Data Collection

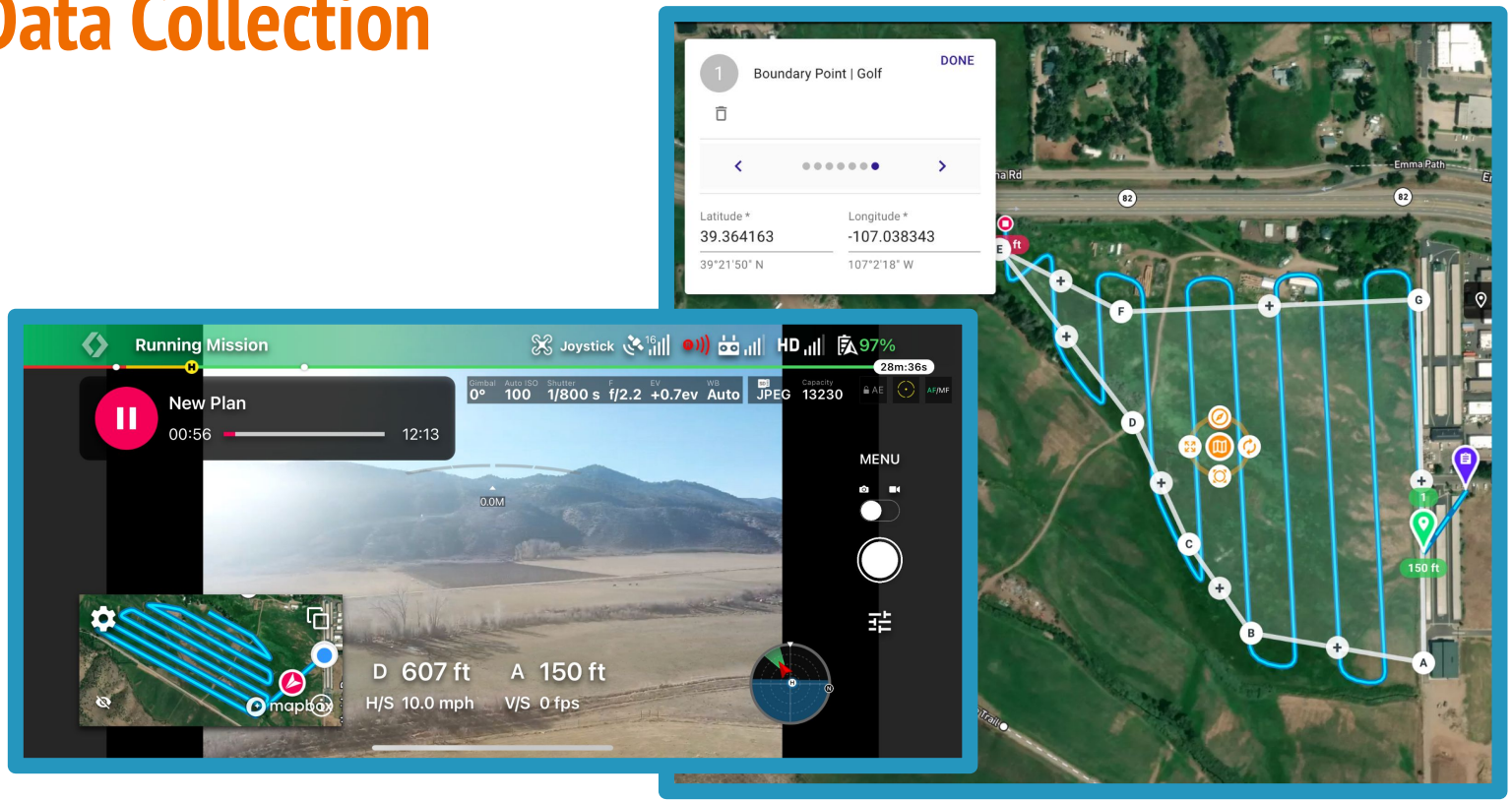
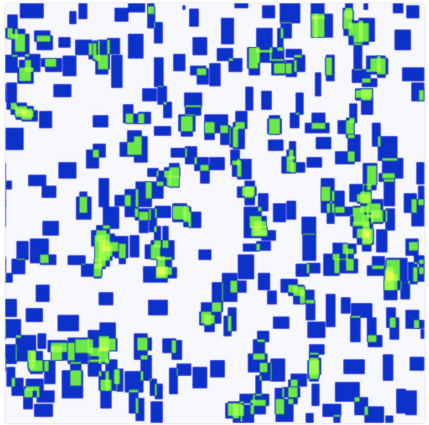


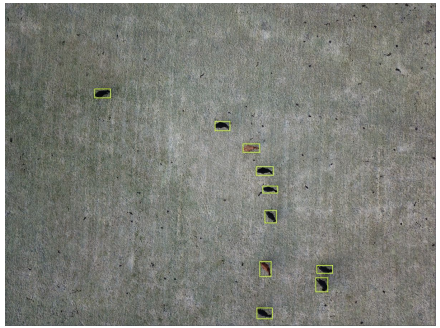
Image Annotation - Small Dataset

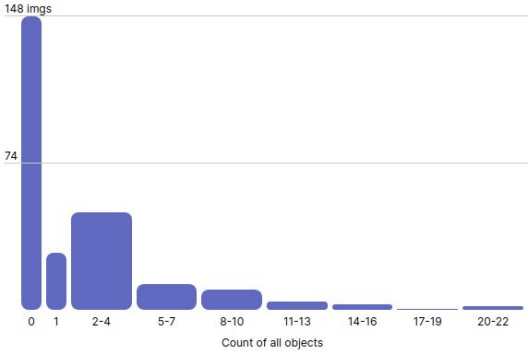
Carbondale, CO assorted ranches,

- 15 individual photo sessions across 5 days in 7 locations
- Consistent image capture
- No overlap images

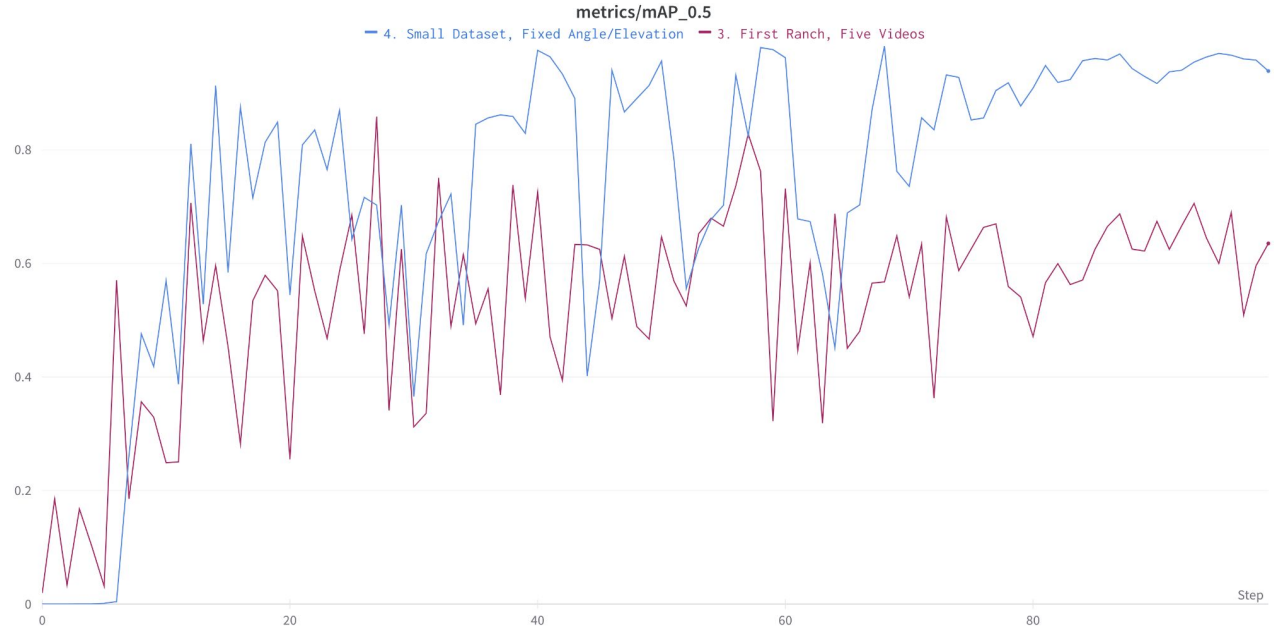


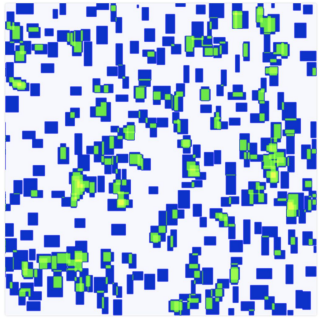
Images	Annotations	Average Image Size	Median Image Ratio
258	464	12.00 mp	4000×3000
0 missing annotations	1.8 per image (average)	from 12.00 mp	wide
148 null examples	across 1 classes	to 12.00 mp	



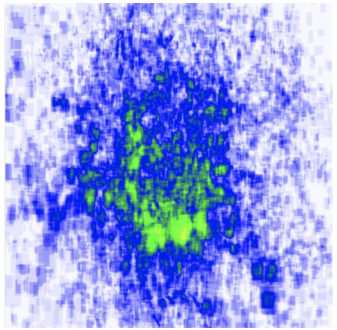


Data Centric





Carbondale
(464 cows)



Connelly
(15,860 cows)

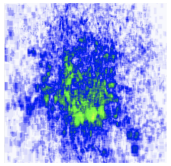
Experimentation

- Four experiments, each using **YOLOv5s** trained on a different dataset
  - #1-3 trained on initial run (increasing size)
  - #4 trained on a small dataset with fixed angle and elevation
- All experiments tested against a holdout test set of 59 images

Experiment	mAP (IoU of 0.5)
1) First Ranch, One Run	0.3629
2) First Ranch, Two Runs	0.4429
3) First Ranch, All Runs	0.6351
4) **Small Dataset (fixed angle/elevation)**	**0.9388**

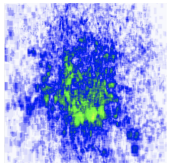
Experiment 1:
First Ranch, One Run

Training images: 439



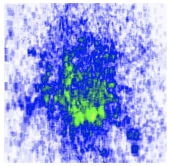
Experiment 2:
First Ranch, Two Runs

Training Images: 701



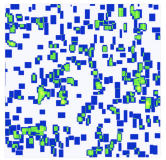
Experiment 3:
First Ranch, All Runs

Training Images: 1137



Experiment 4:
Fixed Angle / Elevation
(Small Dataset)

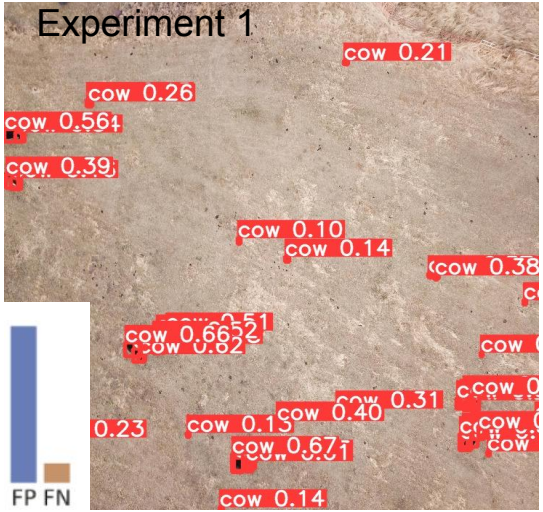
Training Images: 258

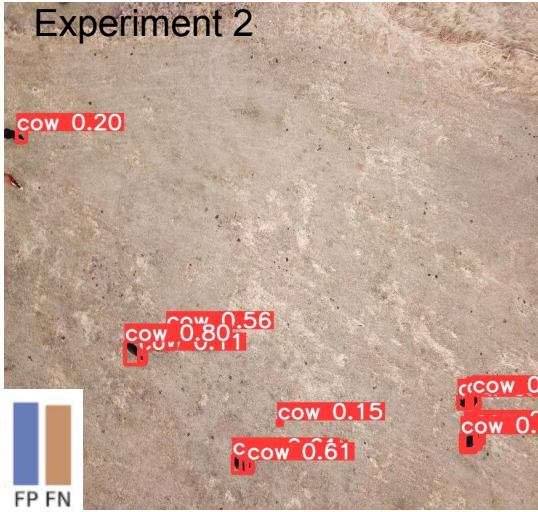


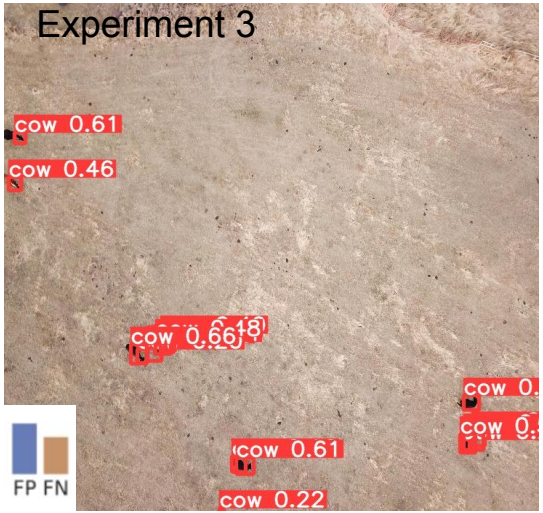
Error Analysis

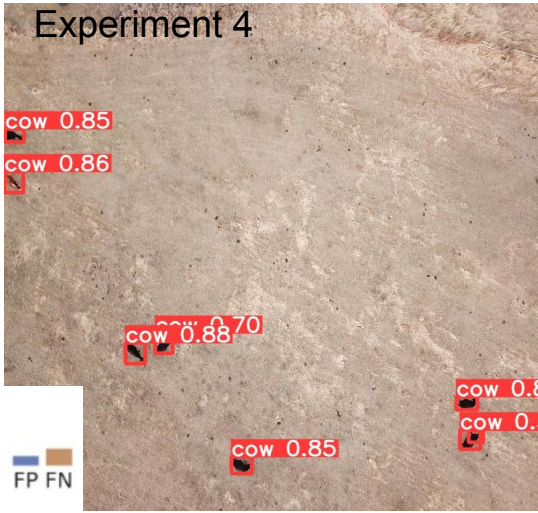
The same test image, with detection results from each experiment (there are 7 cows labeled in the image)

All detections with confidence > 0.1 shown for comparison purposes

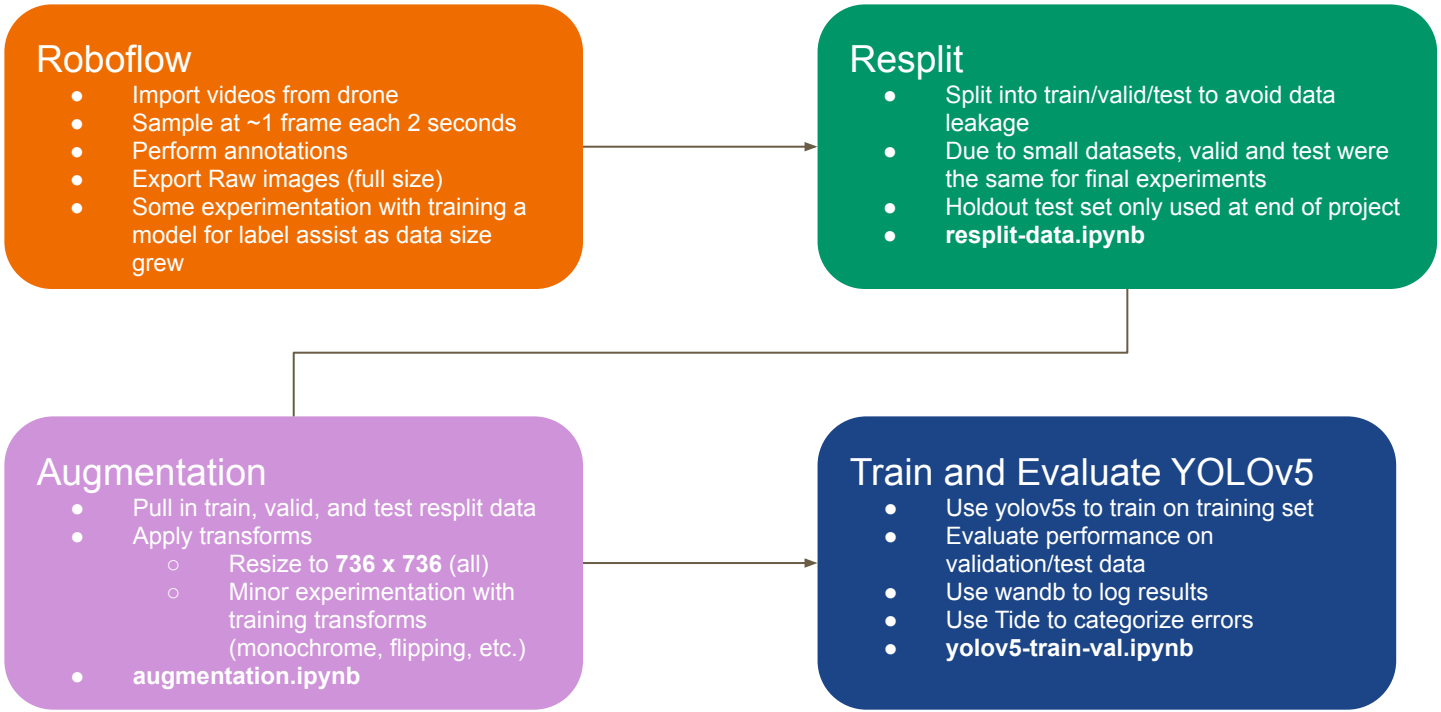




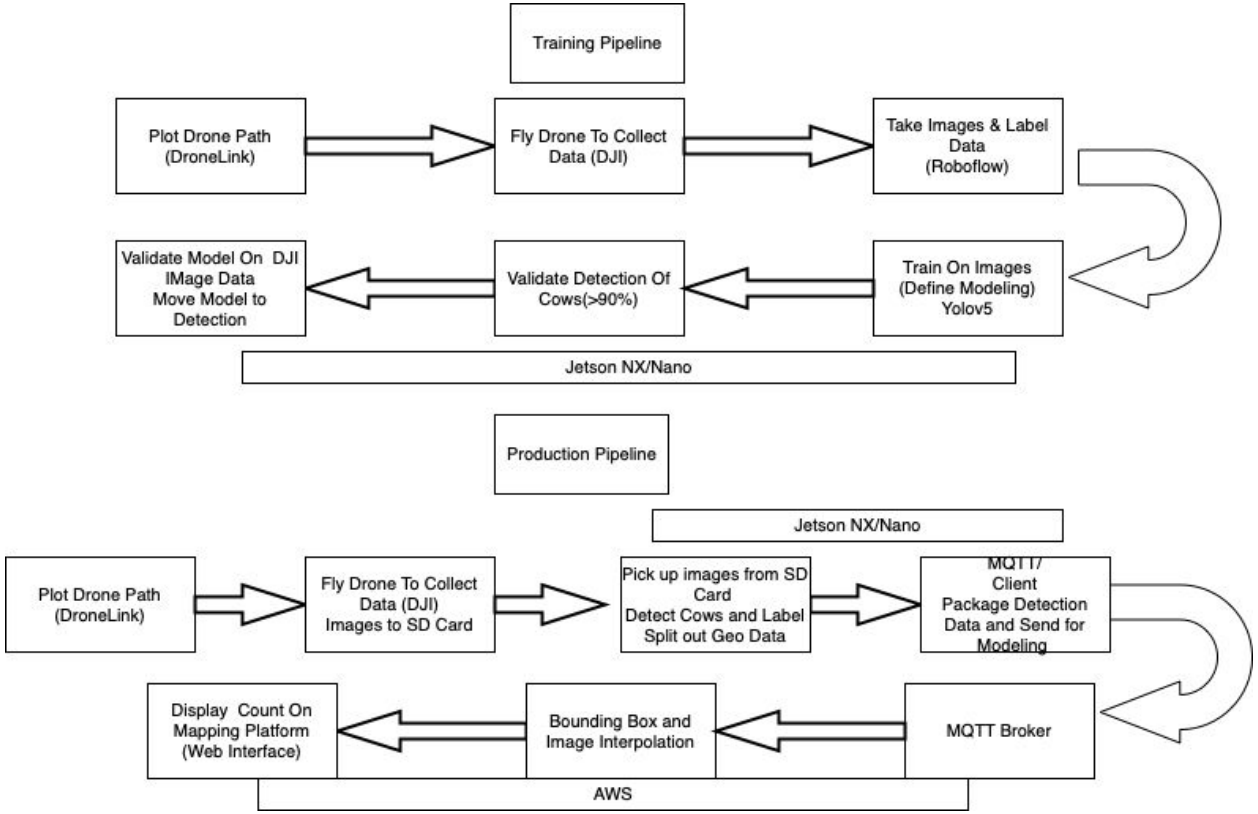




Model Training Pipeline

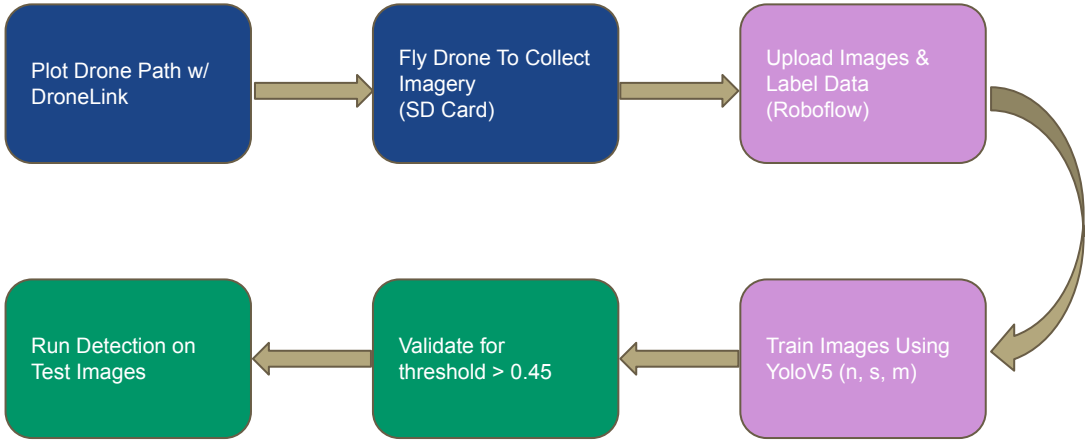


LiveStalk Flow:



LiveStalk Flow: Image Capture And Analysis

Training Pipeline And Model Setup



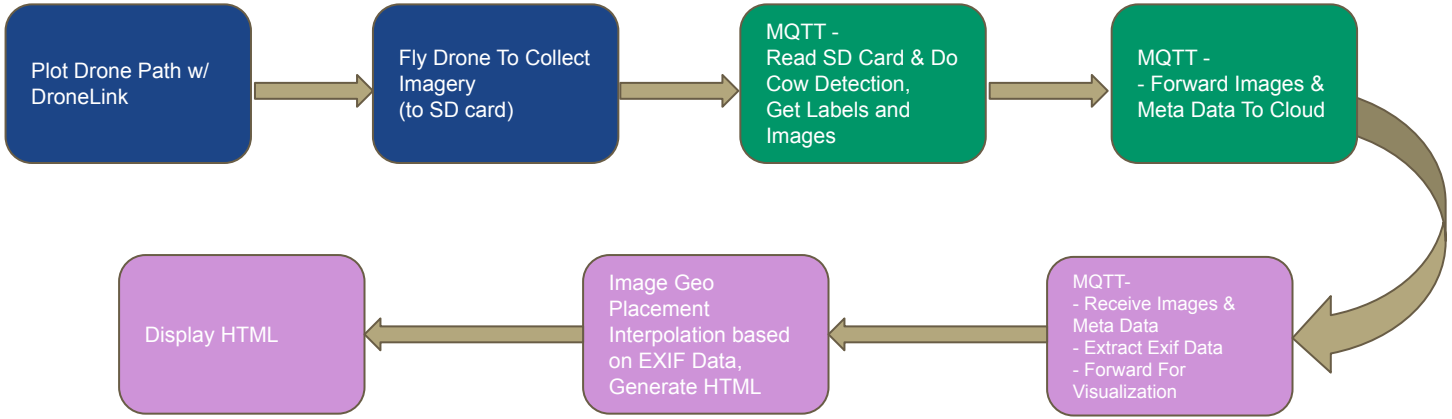
DJI Mavic Drone

Cloud

Jetson Nano/NX

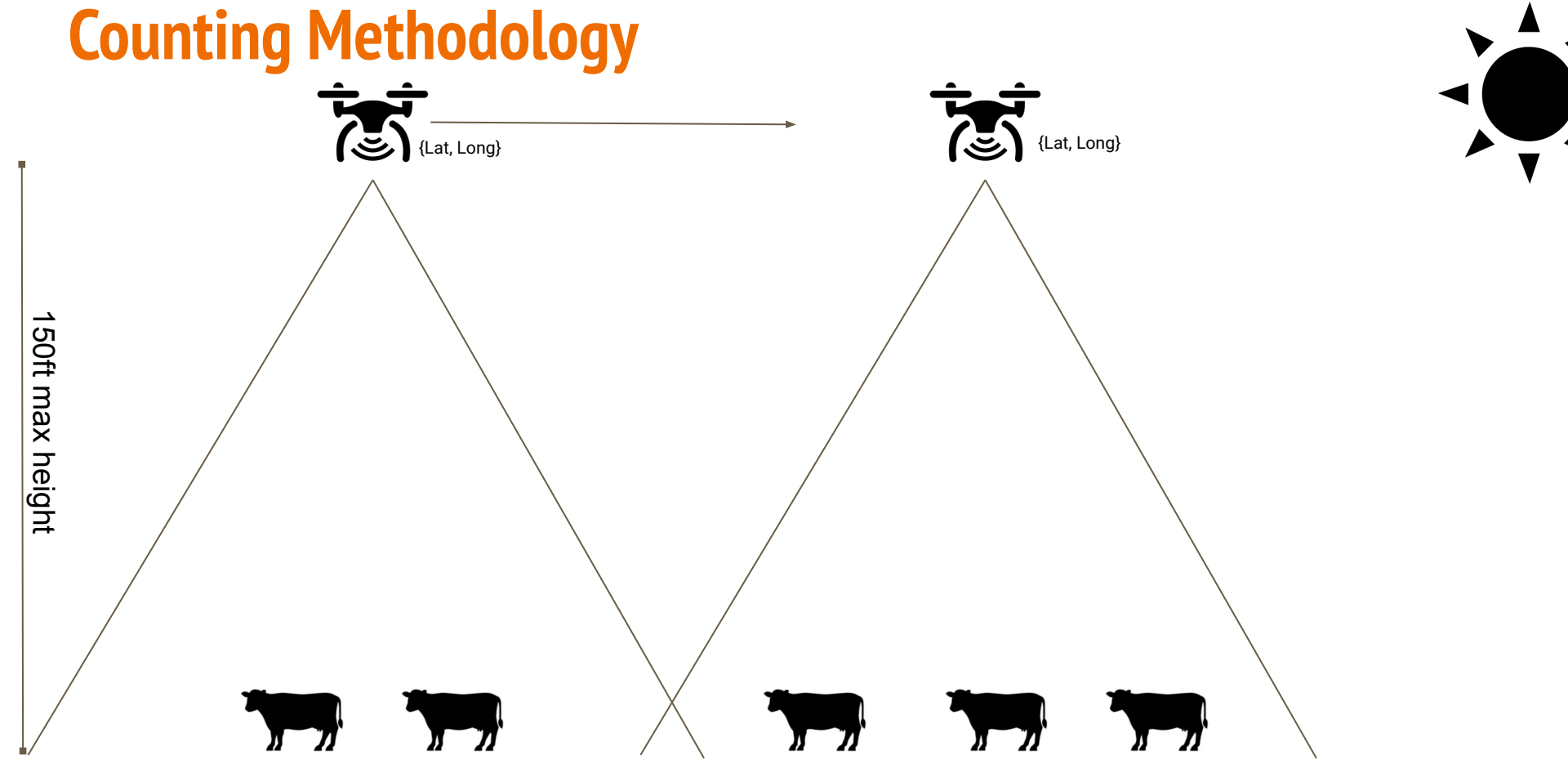
LiveStalk Flow: Production Pipeline

Current Deployment Approach

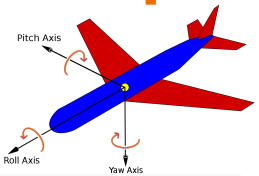


Next Step Will be To Eliminate the SD Card and Send Live Images For Detection To The Nano/NX w/ Potential For Changing Drone Path

Counting Methodology

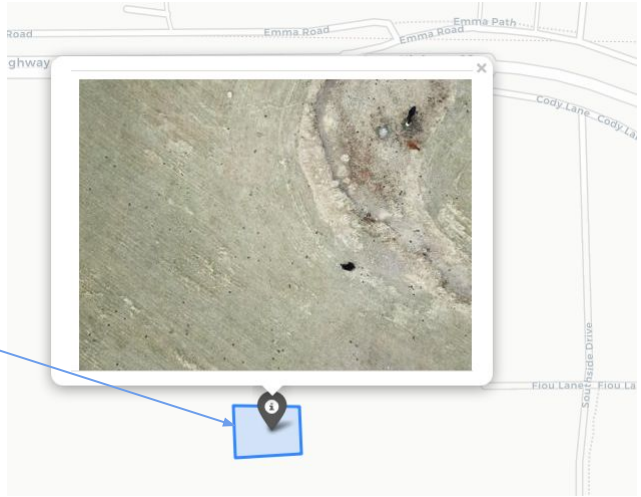


Georeferencing & Map Visualization



Example metadata [Exif]:

```
latitude: 45.6426621388889
longitude: -94.5975223611111
AbsoluteAltitude: 332.743835
FlightPitchDegree: 0.3
FlightRollDegree: 3
FlightYawDegree: 89
GimbalPitchDegree: -90
GimbalRollDegree: 0
GimbalYawDegree: 7.8
RelativeAltitude: 40.700001
TlinearGain: 0
altitude: 332.7
altitude_ref: 0
aperture: 1.25
f_number: 1.25
focal_length: 13
image_make: "DJI"
image_model: "FLIR"
```

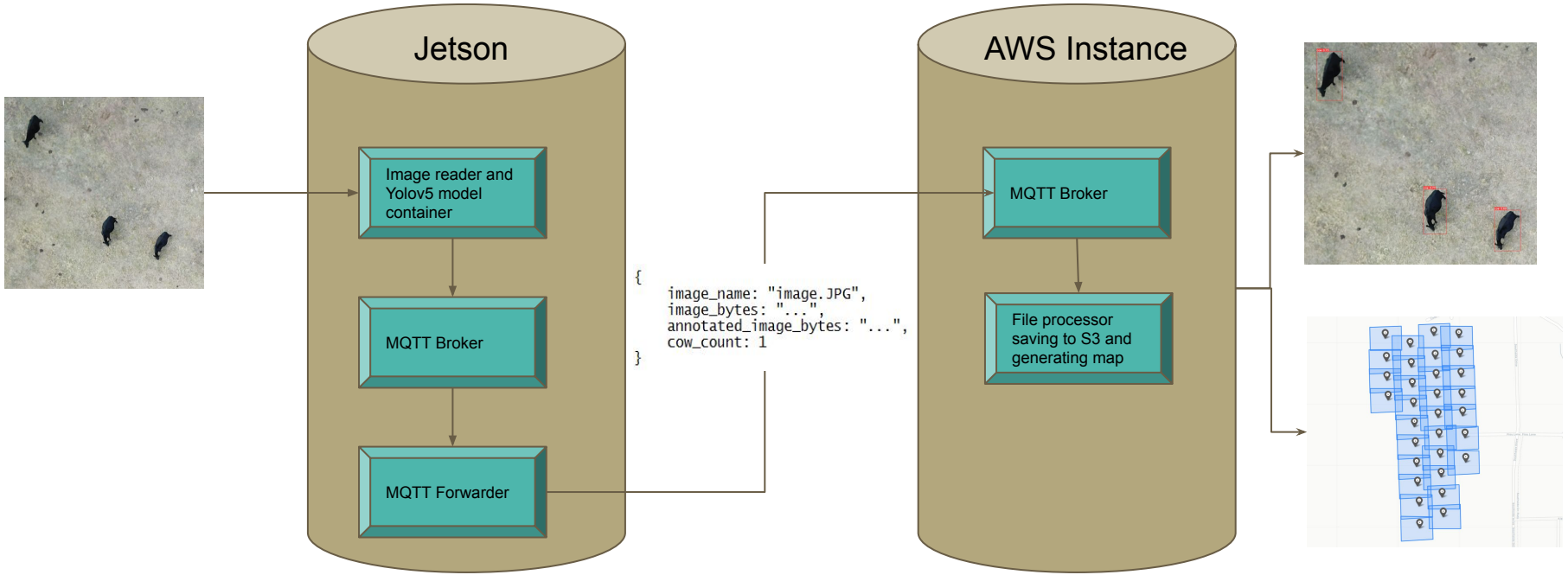


- Image field of view to bounding box conversion
  - Georeferenced_fov = f(fov_h, fov_v, cam_pitch, cam_yaw, cam_roll, rel_altitude, cam_lat, cam_long)
  - Further discussion here
- Final UI: map of cow counts and bounding boxes
  - Geospatial stack: folium, shapely, geopandas, pyproj

Technical Infrastructure

- Container based approach to development
  - Jetson Nano/Xavier NX container with MQTT & Yolov5
  - AWS EC2 containers with MQTT Broker and MQTT Client w/ PIL Imaging, EXIF tools, Geo library'
- Reliable delivery mechanisms using MQTT
- Image detection using trained model from Yolov5s on Nano/NX
- HTML generation using XXX Geo Library

Technical Infrastructure



Solution Demo

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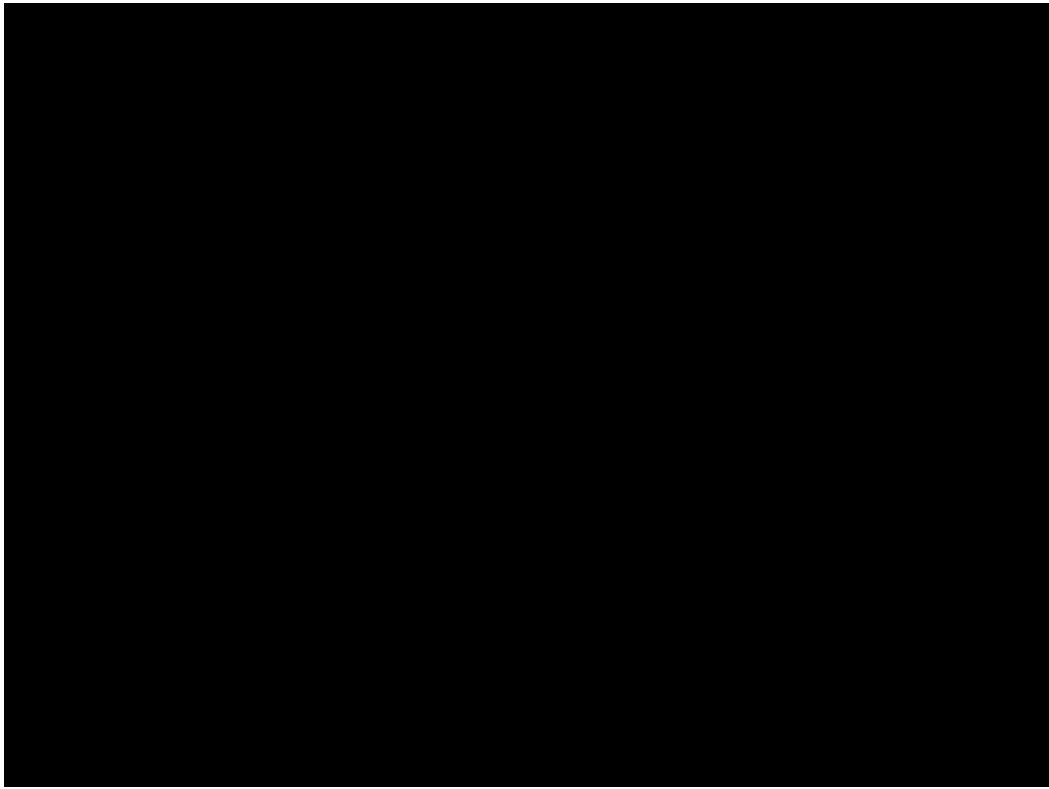


Deployment

- Telemetry we have: (?) Heading, speed, Lat/Long

Where is the inference run? How do we send model to drone?

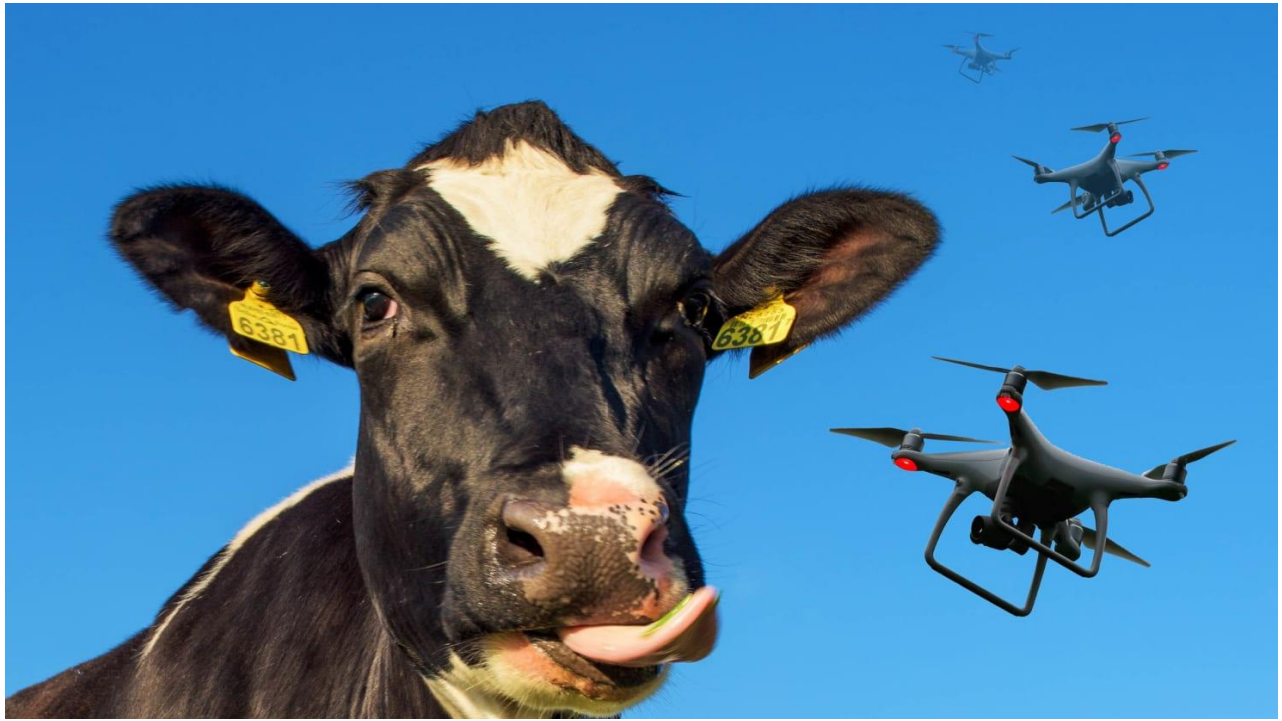
Error analysis

Monitoring Model Drift/Change for anomalies

Data Feedback Loop

Drone Mission Planning: DroneLink

Conclusion - Drones With Smarts At The Edge Is Real



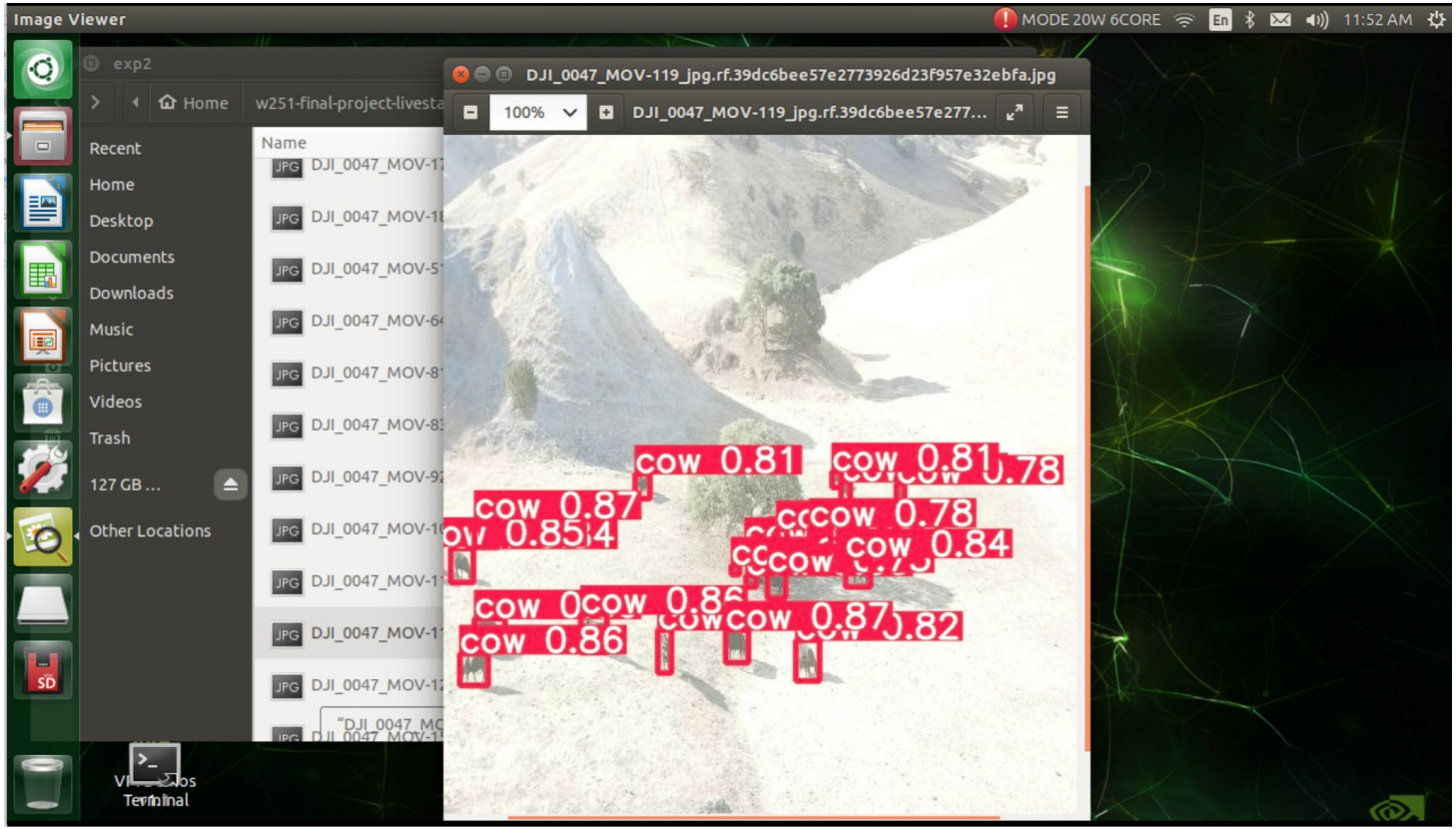
We Demonstrated A Practical Application Of Image Detection At The Edge Using All the Techniques From This Class.

This The Beginning Of Operational Automation Of Drones For Everyday Use With Smarts On The Drone.

Thank You

Any Questions?

Training And Detection on NX



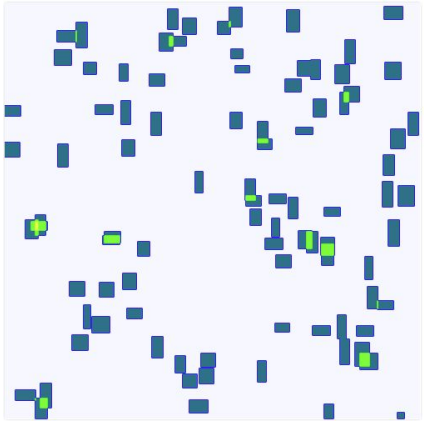
Error Analysis

Sample images from Experiment 4 (best results)

Blue boxes - actual
Red boxes/text - predicted

Image Annotation - Test Holdout Set

- Images taken from a single pass over a pasture
- Consistent elevation (~45m above ground) and camera angle (90° down)
- Dataset size:



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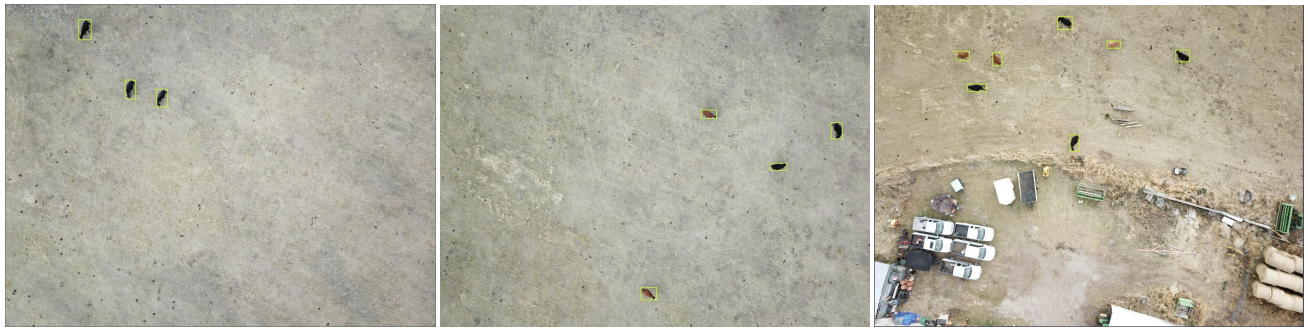
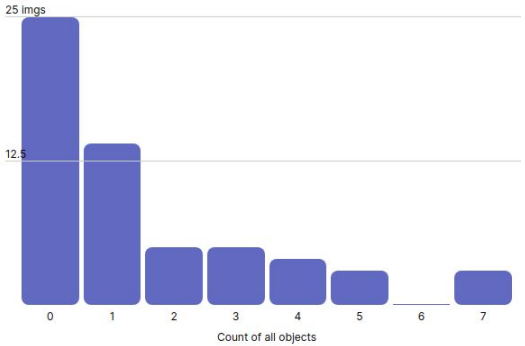
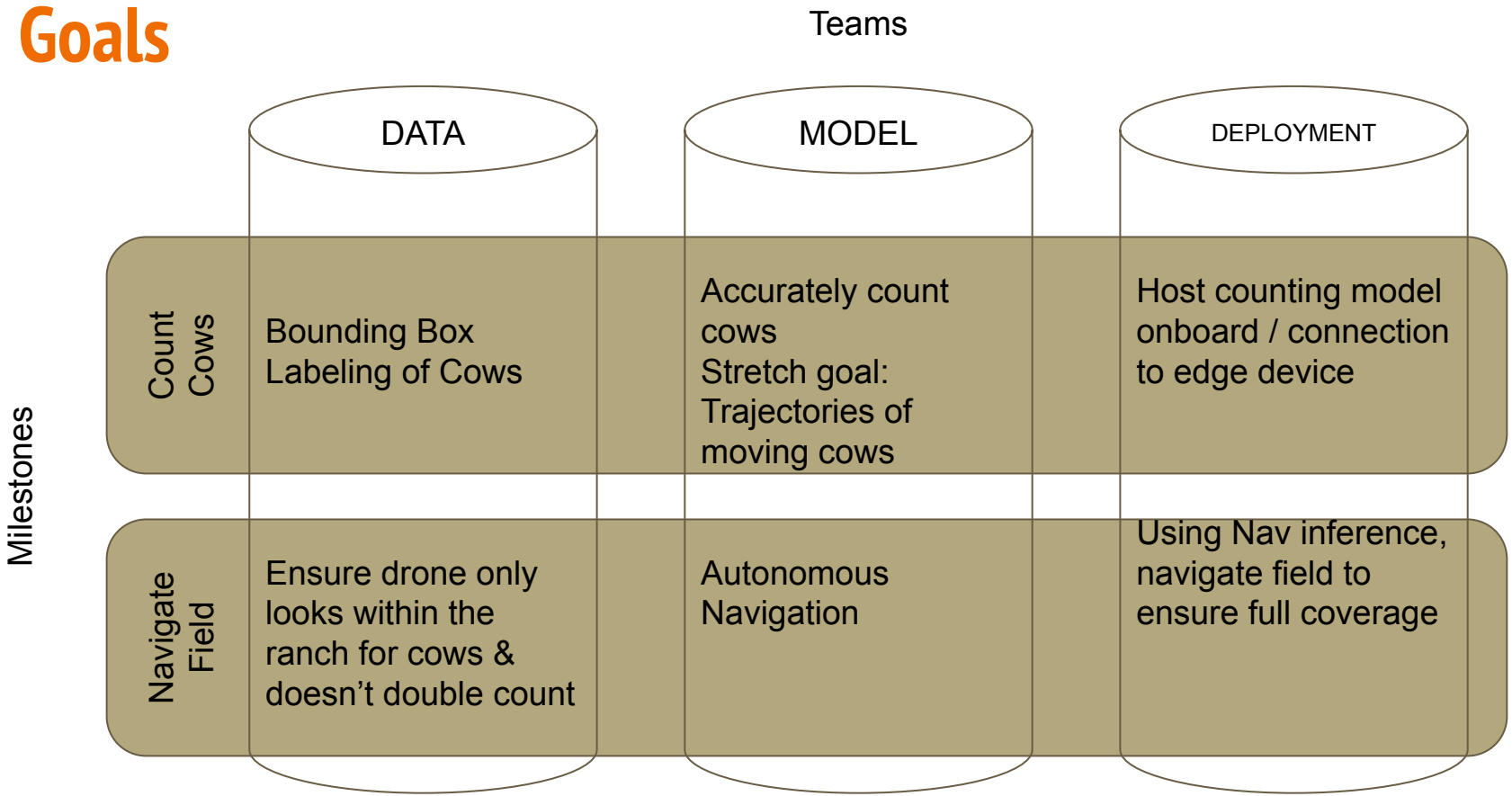




Goals


Teams
DATA
MODEL
DEPLOYMENT
Milestones
Count Cows
Bounding Box Labeling of Cows
Accurately count cows
Stretch goal: Trajectories of moving cows
Host counting model onboard / connection to edge device
Navigate Field
Ensure drone only looks within the ranch for cows & doesn't double count
Autonomous Navigation
Using Nav inference, navigate field to ensure full coverage

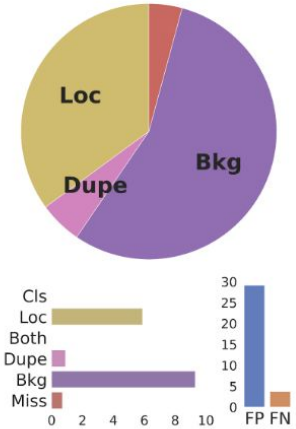
Error Analysis

Analysis using TideCV
(https://github.com/dbolya/tide)

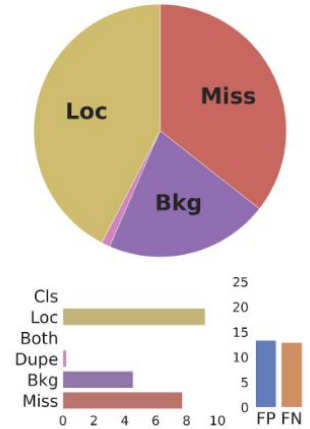
Key:

- Loc: Localization
- Dupe: Duplicate Detection
- Bkg: Background Error
- Miss: Missed Error
- FP: False Positive
- FN: False Negative

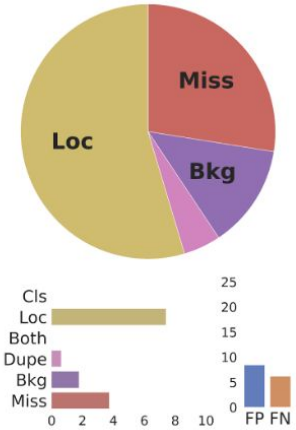
1. First Ranch, One Run



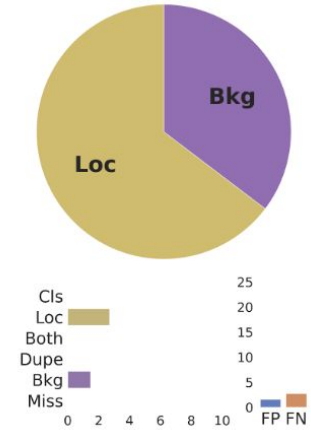
2. First Ranch, Two Runs



3. First Ranch, All Runs



4. Fixed Angle/Elevation



Results

Experiment	mAP (IoU of 0.5)
1) First Ranch, One Run	0.3629
2) First Ranch, Two Runs	0.4429
3) First Ranch, All Runs	0.6351
4) **Small Dataset (fixed angle/elevation)**	**0.9388**

Experiment #4 (small dataset with fixed angle and elevation, blue line) is the clear winner!