

# P13 - Developing a solution to measure the height of cattle using image analysis or LiDAR

COMP3888 M15 04  
Monday 3PM

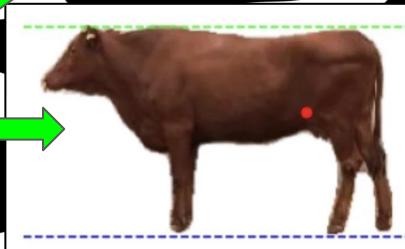
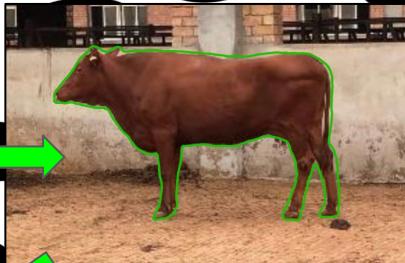
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# Project Overview



A combined hardware-software system which can:

- 1) Extract hip height of a single cow/bull passing through a confined area by the end of the development period
- 2) Provide a stream of hip height data will be available for the human observer to assess in real-time.

# System Specifications

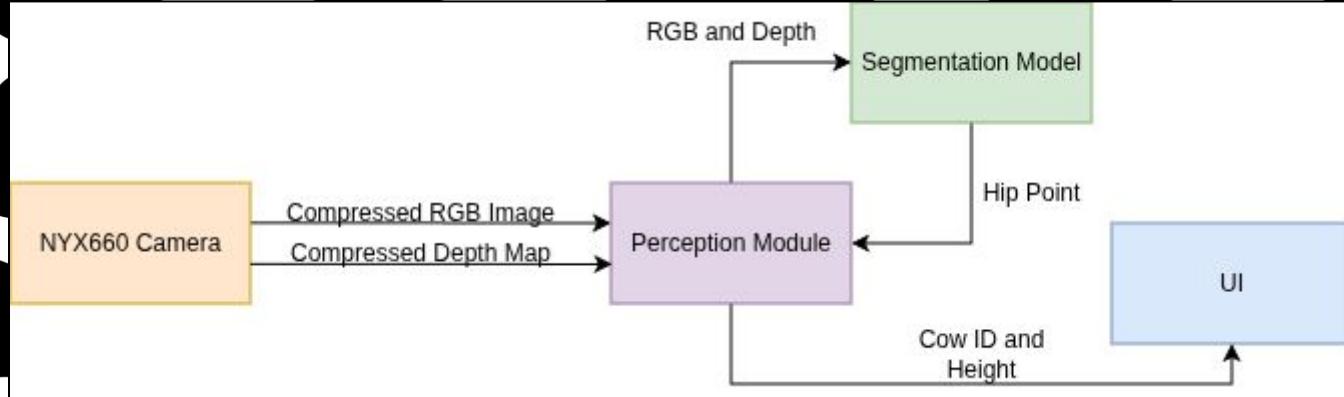
## Functional Requirements:

- Measure hip height of cow as it passes through
- Link measurements to RFID tag
- Capture data using ToF sensor
- Store results to be viewed on web app
- Operate without human intervention

## Non-Functional Requirements:

- Hip height measurements within 3cm
- Processing time of <2 seconds
- System must operate continuously for herds of cattle to pass through

# System Overview



**Hardware Module:** Physical enclosure and electrical component configuration for robustness and portability in the field

**Perception Module:** Collects RGB-D data, which is triggered as cattle walks by

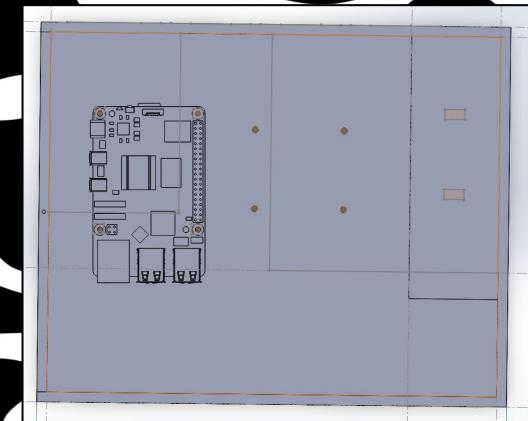
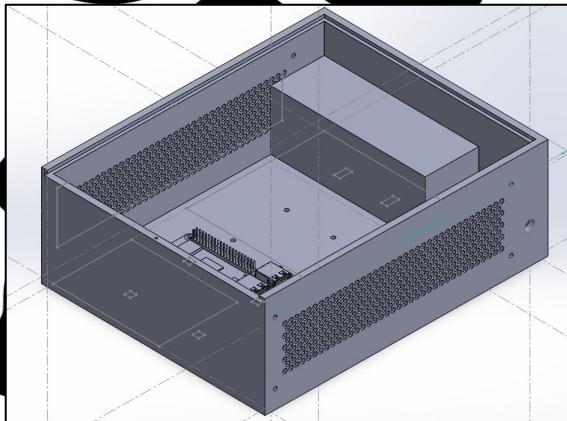
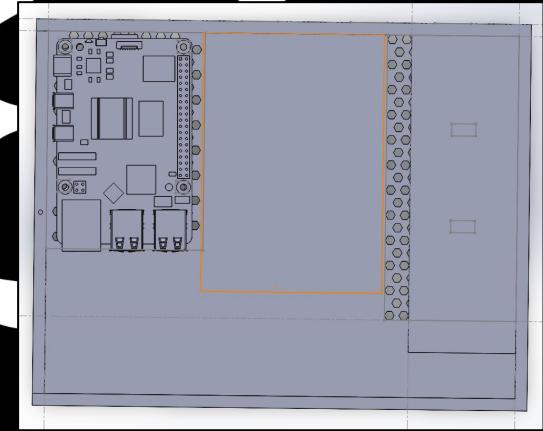
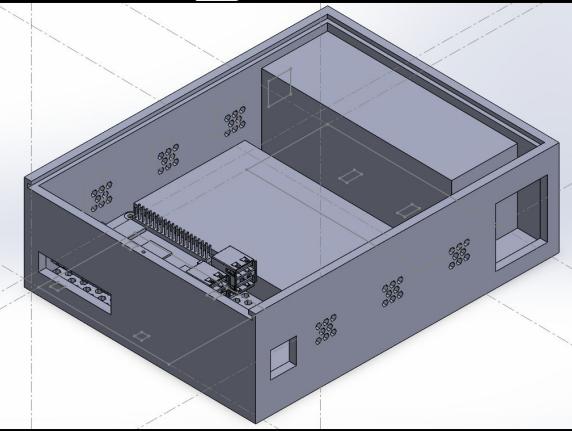
**Segmentation Model/Cow Detection Module:** Segments the cow from the image and depth map and extracts hip point

**UI/Dashboard Module:** Receives data and displays it for the farmers to see as cattle walks by

## Hardware: Sensors and Electrical Components



# Hardware: Enclosure and Prototype Configuration



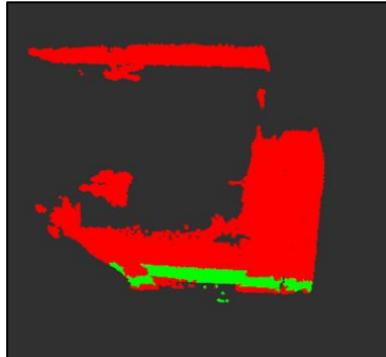
# Perception Module

## RGB to Depth Alignment

- Ensure each RGB pixel corresponds to a depth point
- Can be done live or pre-computed

## Finding Ground Plane

- Uses RANSAC to fit ground plane
- Only needs to be calibrated when moved



# Deep Learning Models Development & Design

## Segmentation Model (DeepLabV3 + ResNet-50 + ASPP)

- Identifies the **outline of the cow's body** in each frame

## Groin Keypoint Model (ResNet-50 Regression)

- Predicts the **(x, y) location** of the groin point on the cow



Input cow image of any size, pad to 224x224 with padding function, for better segmentation accuracy



Go through segmentation model, output cropped image, 224x224 at most



Pad the cropped image back to 224x224, better for groin model accuracy

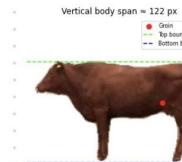


Identify groin with groin model, then go vertically up&down for height in pixel

Device: rps  
Loaded shape: (224, 224, 3)  
Predicted groin: (164, 102)

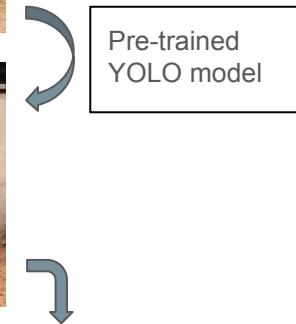
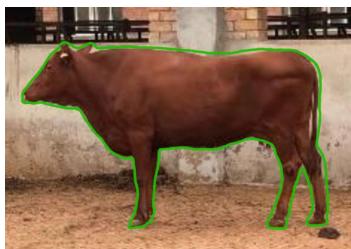


Use pixel height to calculate actual height, using camera distance etc.



# Manual Data Creation

## Segmentation

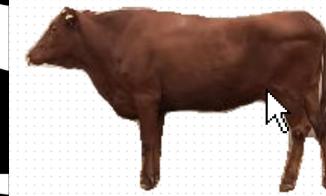
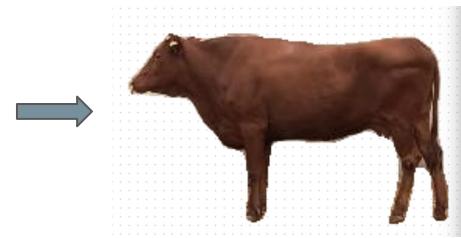


```
df_seg.head()
```

	image_file	coords
0	00000005.jpg.rf.b12008ae7a0ee055e479f8557a4c7f...	[[[44, 41], [44, 42], [44, 42], [43, 42], [43, ...
1	00000014.jpg.rf.0c957d1300b1bfaa1d79a6214f6d76...	[[[37, 79], [37, 80], [37, 80], [36, 80], [36, ...
2	00000014.jpg.rf.ddc9ed1a4a8c8fbb1981e27ae2f96d...	[[[66, 80], [66, 81], [65, 82], [65, 82], [64, ...
3	00000014.jpg.rf.e4ca1cdc0185f914900d3aaa71d2fd...	[[[65, 80], [65, 81], [64, 82], [64, 82], [64, ...
4	00000018.jpg.rf.15569f04614ae4b82273a08ae288da...	[[[48, 48], [48, 49], [47, 49], [47, 49], [47, ...

## Groin Detection

Pre-trained  
YOLO model



```
df_groin.head()
```

0	00000005.jpg.rf.b12008ae7a0ee055e479f8557a4c7fde.png	523x399	(422,195)	(181,110)
0	00000005.jpg.rf.b12008ae7a0ee055e479f8557a4c7f...	523x399	(418,193)	(179,109)
1	00000014.jpg.rf.0c957d1300b1bfaa1d79a6214f6d76...	463x276	(137,171)	(66,128)
2	00000014.jpg.rf.ddc9ed1a4a8c8fbb1981e27ae2f96d...	468x276	(326,174)	(156,129)
3	00000014.jpg.rf.e4ca1cdc0185f914900d3aaa71d2fd...	468x272	(325,166)	(156,126)
4	00000018.jpg.rf.15569f04614ae4b82273a08ae288da...	507x344	(114,181)	(50,116)

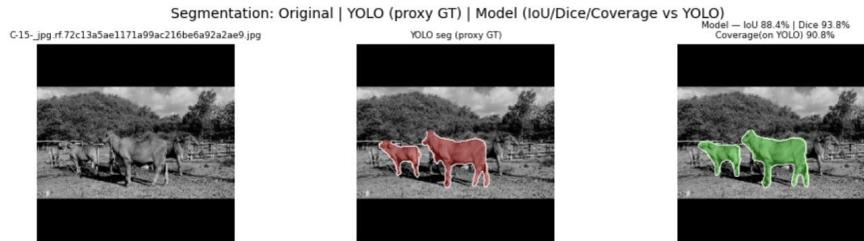
# Model Training and Results

## Dataset

- (1) ~3,800 manually labeled cow side-view images (2) Dataset split: **80% training / 20% testing**

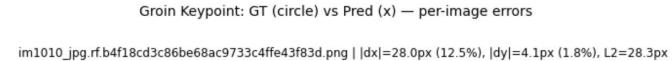
### Segmentation Model (DeepLabV3 + ResNet-50 + ASPP)

- Input images resized to **224 × 224**, normalized
- Trained for **25 epochs**
- **Performance: 86.88%** (compared to YOLO baseline)



### Groin Keypoint Model (ResNet-50 Regression Head)

- Input images also **224 × 224**, normalized
- Trained for **10 epochs**
- **Performance: 86.0%** (normalized diagonal metric)



# Dashboard

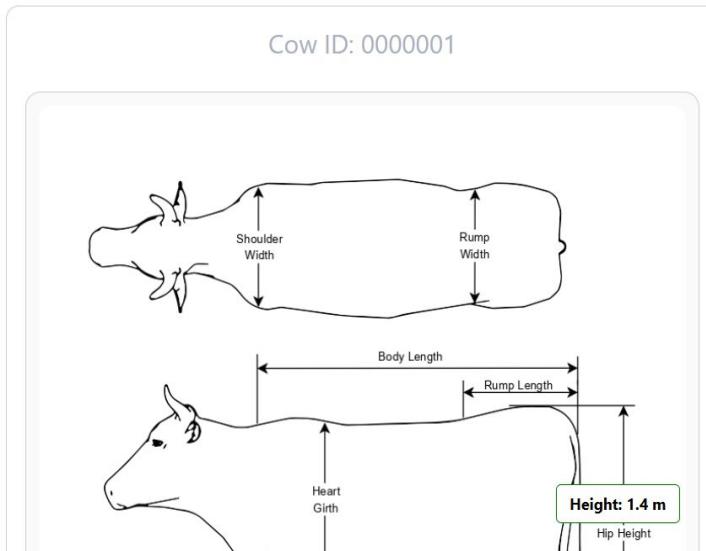
[CowCam](#)[Realtime Dashboard](#)[Download Data](#)[Calibrate](#)[Restore All](#)Show  entriesSearch: 

Cow ID	Height (m)	Action
0000001	1.4	<a href="#">Delete</a>
0000002	1.3	<a href="#">Delete</a>
0000003	1.6	<a href="#">Delete</a>
0000004	1.4	<a href="#">Delete</a>
0000007	1.7	<a href="#">Delete</a>

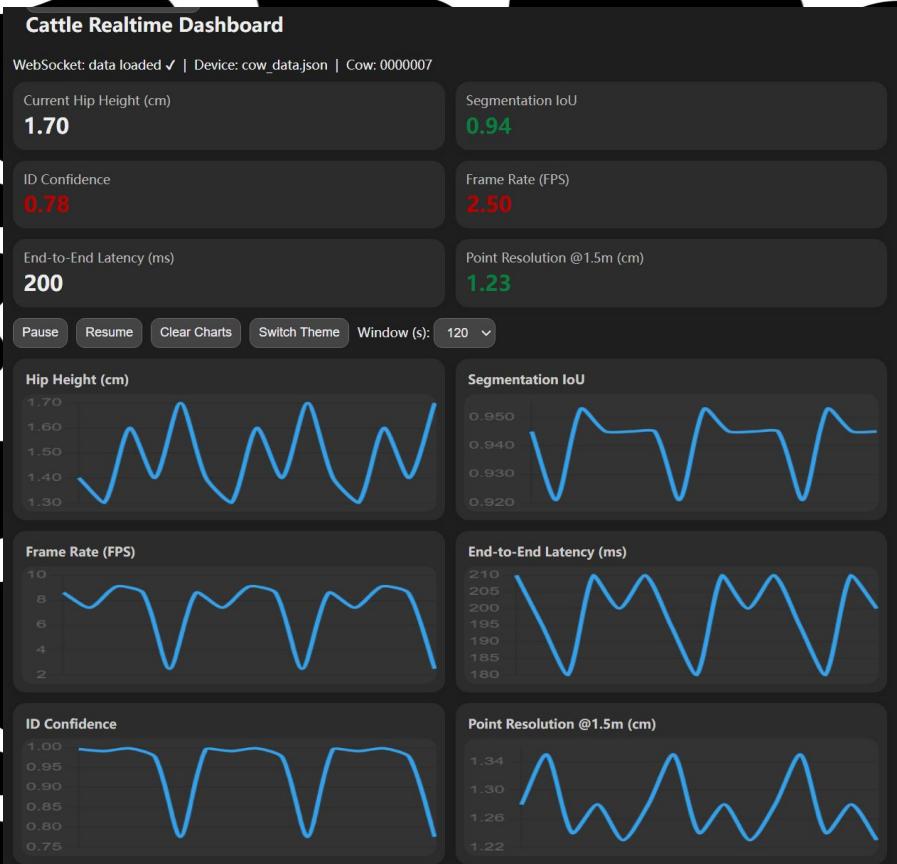
Showing 1 to 5 of 5 entries

Previous  Next

Cow ID: 0000001



# Dashboard real-time-monitoring



## Summary Metrics:

- Current Hip Height — HAR.1.0
- ID Confidence — DAT. 1.0
- End-to-End Latency — MES.1.0
- Segmentation IoU — SEN.1.1
- FPS — SEN.1.1
- Point Resolution — SEN.1.0

Realtime page is dynamically updated by the JSON file at the back end. So all data are determined according to the changes of the home page

# Test 1: Segmentation Model Normal Test - Quality of Work



## Segmentation (User Story 1) — “Outline full cow body automatically”

- Regression Acceptance test: Overlay predicted segmentation on YOLO -> accuracy percentage
  - Directly validate model output with standard segmentation metrics: IoU
  - Other Related Aspects: (1) Workflow Latency: 0.2s (2) Seed
- Mean IoU: 86.88% | Median IoU: 89.51%  
Mean Dice: 92.55% | Median Dice: 94.46%  
Mean Coverage (ModelnYOLO / Model): 93.42%
- User Consistency: Cow-outlining reliability | 20% validation portion + not from dataset < 200 | Result: ~86.88%
  - Limitation: (1) YOLO is not human GT (2) Domain shift (bars/cages) could affect performance (3) 224x224 inputs affects robustness



## Test 2: Groin Model Normal Test - Quality of Work

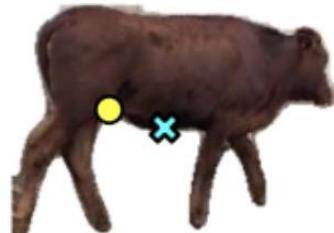
### Groin Keypoint (User Story 2) — “Provide hip/groin point for measurement”

- Regression/Integration Test: Per-axis MAE(dx,dy), % accordingly, normalized accuracy
- Per-axis MAE exposes systematic bias and visualization ensure interpretability
- Other Aspects: (1) Resolution handling (2) Reproducibility
- Consistency with User: Test return a single (x,y) | 20% validation portion + some not from dataset < 200 | Result: ~86.0%
- Limitations: (1) Noticeable x-axis bias (2) sensitivity to non-224 inputs (3) possible degradation under domain shift

Per-axis MAE: dx=43.45px, dy=5.01px | Average per-axis MAE=24.23px  
Mean L2 error: 44.21px  
Accuracy within 5px: 0.0%  
Accuracy within 10px: 0.0%  
Normalized accuracy (1 - L2/diag): 86.0%



im0302.jpg.rf.c128255948323e598b2c1fa389133fff.png | |dx|=34.6px (15.4%), |dy|=10.7px (4.8%), L2=36.2px

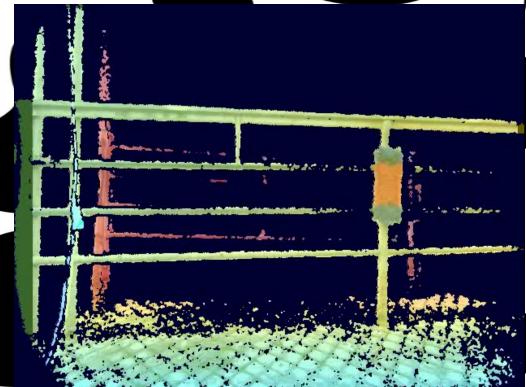


## Test 3: Perception/Measurement - Quality of Work

### Perception/Measurement (User Story 2) — “Provide hip height measurement”

- Hip index used to determine hip point
- Distance from hip point to ground plane gives height
- Average heights taken while cow is in frame
- Limitations: Limited depth range (0.5-4m), susceptible to occlusion, susceptible to poorly reflective surfaces,

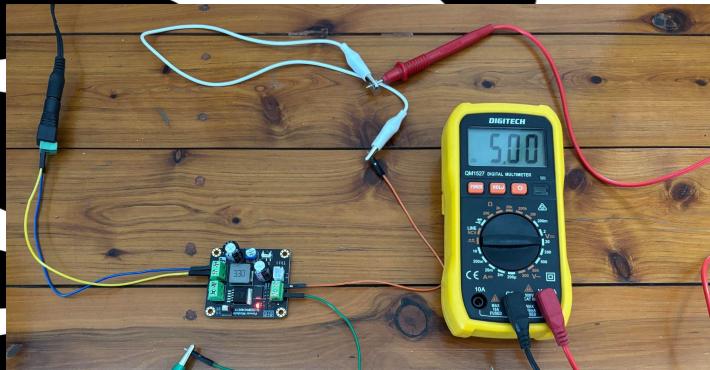
3, 314, 194  
The depth at 314 and 194 is 3056  
The cow is 1.6478784651886142 tall!!!!



## Test 4: Hardware - Quality of Work

### Hardware (User Story 3) — “Enabling developers”

- All hardware is contained within a transportable box. No extra hardware needed.
- Powered using mains. Buck converter and laptop power supply provides the required +12V and +5V.
- RGB and Depth images streaming reliable at >20 FPS.
- Limitations: **(1)** No protective circuitry (e.g. fuses, TVS diode), **(2)** No active cooling, **(3)** Relatively untested.



```
root@xps15-9520:/home/user# ros2 topic hz /nyx660/depth/image_raw/compressedDepth
average rate: 23.495
    min: 0.030s max: 0.276s std dev: 0.04346s window: 30
average rate: 26.343
    min: 0.030s max: 0.276s std dev: 0.03118s window: 60
average rate: 24.658
    min: 0.029s max: 0.276s std dev: 0.03708s window: 81
average rate: 23.264
    min: 0.028s max: 0.280s std dev: 0.04117s window: 100
average rate: 23.063
    min: 0.027s max: 0.280s std dev: 0.04129s window: 123
^Croot@xps15-9520:/home/user#
```

# Demonstration



# Current Limitations and Future Work

## Limitations

- ◎ **Hardware Constraints** - Due to the limited memory size of the AI Hat, the preferred (and better) Cow Segmentation Model is unable to put into the system
- ❖ **Plane Fitting** - The method used to determine the ground plane can sometime be calibrated wrong, resulting in inaccurate heights recorded
- ❖ **Compute Power** - The compute power of the RPi5 is limited, so the system does often work at 2FPS, requiring cows to move slower in order to obtain multiple hip height points for better accuracy

## Future Work

- ◎ **Smaller Model** trained on larger datasets including cattle within a race
- ❖ **Multi-Cow** detection and height capabilities
- ❖ **Optimised/Better Performance** to allow for cattle to move at higher speeds while maintaining high accuracy

## Project Deliverables

- ◎ Integrated Hardware/Software Setup, with CAD schematics and Instructions
- ❖ All developed code - Inclusive of AI Models, Training Scripts, Training Data and Code Documentation
- ✿ System Specifications and Requirements Future Integration/Futher Work