

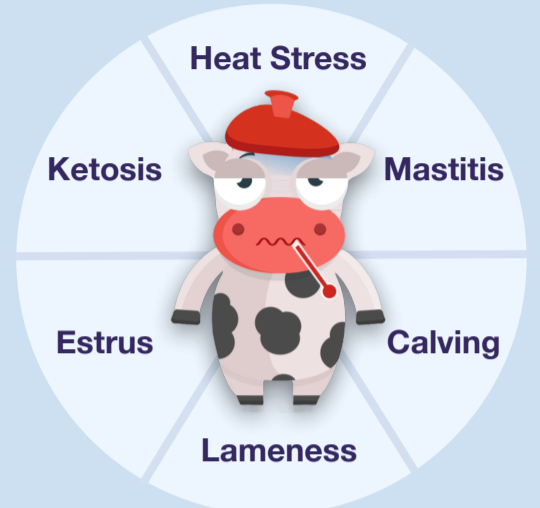


MOTIVATION

Precision livestock farming enhances productivity, animal welfare, and environmental sustainability

Multimodal and synchronized datasets are necessary for more accurate and efficient machine learning models

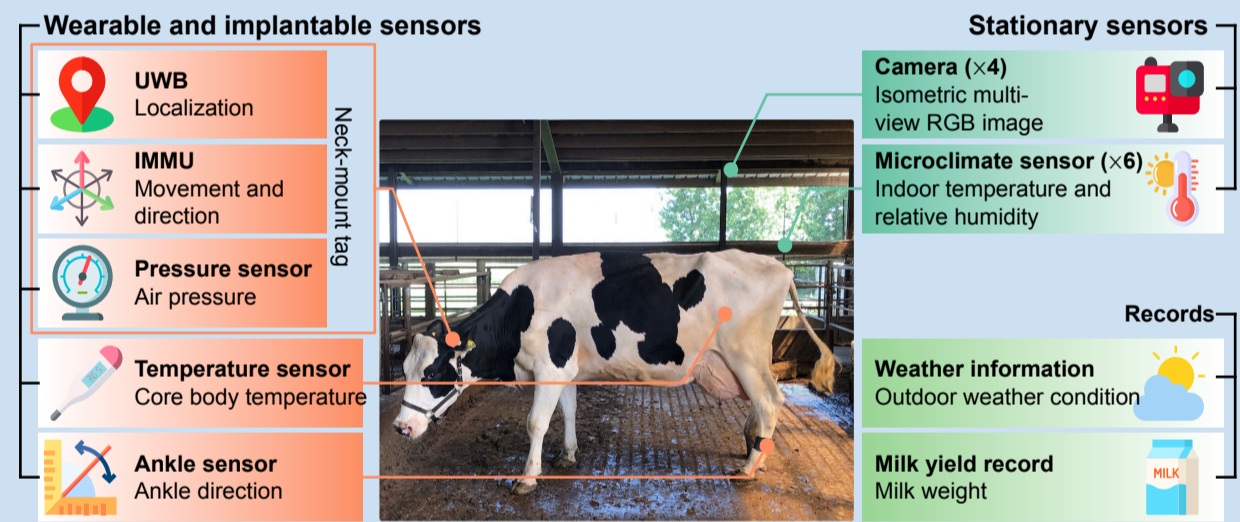
There is a lack of synchronized multimodal datasets for precision livestock farming



Common diseases & health issues

DATA COLLECTION

Nine synchronized modalities of MmCows

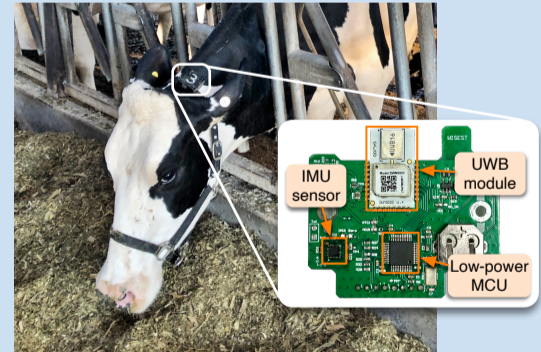


The sensor suite

1. Custom neck-mount tag:

- An ultra-wideband module (UWB) that keeps track of the location
- An inertia and magnetic measurement unit (IMMU) for measuring the head direction
- A pressure sensor that measures the elevation of the cow's neck

Custom wearable neck-mount tag



2. Ankle sensor:

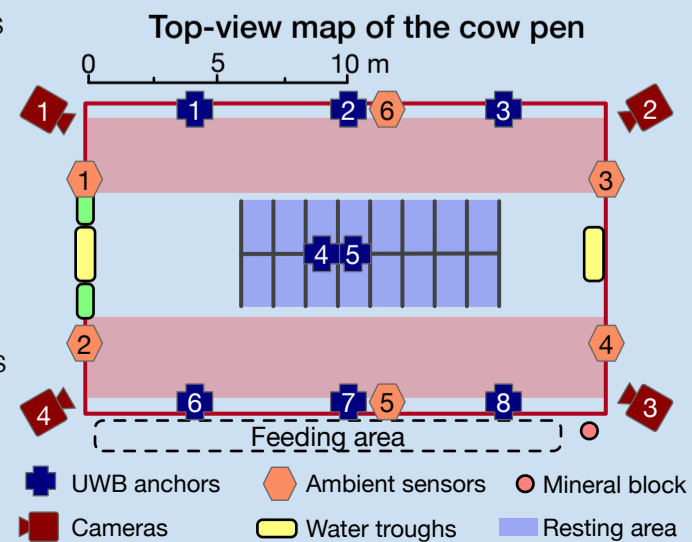
- An accelerometer attached to the cow's leg to record its lying behavior

3. Vaginal temperature sensor:

- A temperature sensor to measure the core body temperature

4. Other sensors:

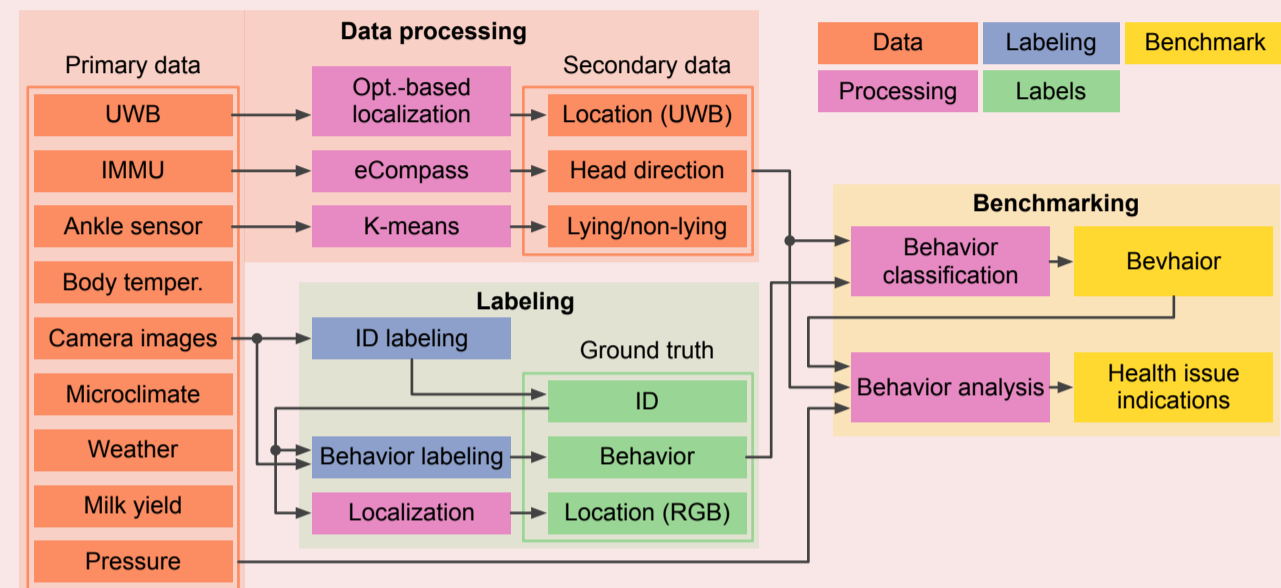
- Isometric-view cameras, microclimate sensors, outdoor weathers, and records



The sensor suite were deployed during 14 days at UW-Madison's Arlington Agricultural Research Station

DATA PROCESSING

Data Processing Pipeline of MmCows



Data processing:

- Extracting meaningful data: 3D neck location, 3D head direction, and lying behavior

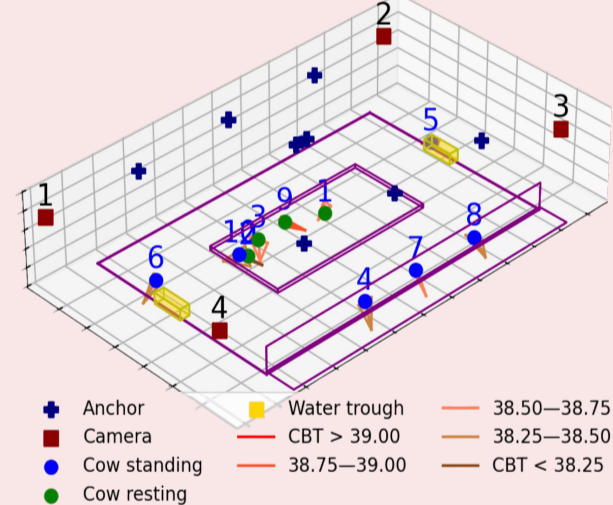
Cow identification ground truth (gt):

- Annotated 20,000 images from July 25th with 213,000 bounding boxes of 16 cows
- Utilized to derive 3D body location gt

Behavior ground truth:

- Fine-grained interval of walking, standing, feeding head up, feeding head up/down, drinking, licking, and lying behaviors

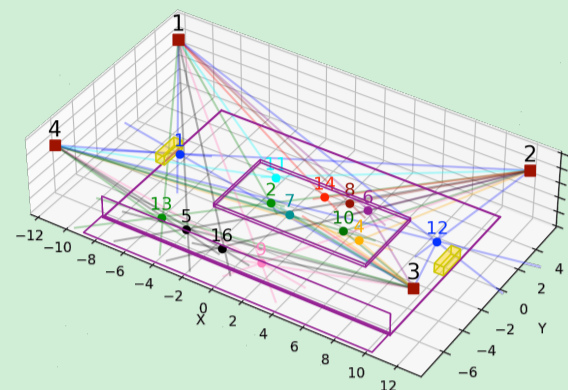
Visualization of multiple modalities in 3D view of the pen



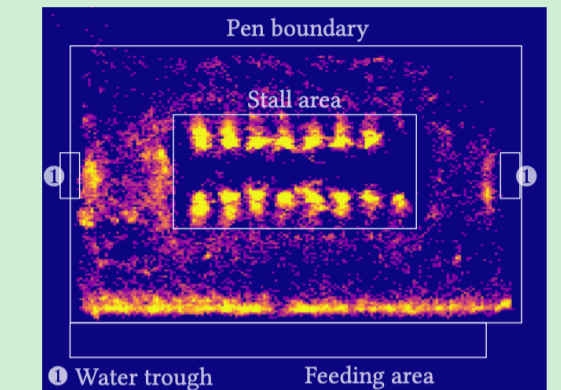
Cow ID annotations and UWB locations in multi-view images



Visual localization for multiple cows



Heat map of visual location ground truth



BENCHMARKS

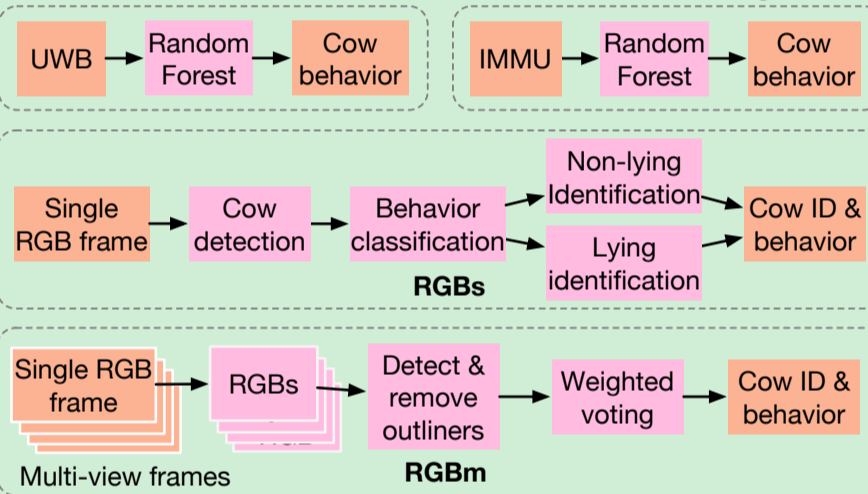
Behavior monitoring using single modality and their combinations:

- Single modality: UWB, IMMU, RGBs
- Combinations: UWB+HD, UWB+HD+AKI, RGBm

Split settings:

- Temporal split (TS) & object-wise split (OS)

Multimodal cow identification and behavior recognition



Performance comparison of behavior classification using different modalities

Modality	Set-ting	F1 score ↑							
		Walking	Standing	Feeding↑	Feeding↓	Licking	Drinking	Lying	Average
UWB	OS	.078±.027	.855±.023	.704±.077	.834±.049	.884±.054	.644±.112	.953±.017	.707±.051
	TS	.103±.040	.860±.041	.738±.026	.835±.029	.868±.066	.656±.059	.961±.008	.717±.038
IMMU	OS	.000±.000	.065±.127	.067±.084	.098±.135	.000±.000	.000±.000	.700±.760	.133±.060
	TS	.000±.000	.052±.053	.000±.000	.051±.048	.000±.000	.000±.000	.742±.126	.141±.038
RGBs	OS	.143±.036	.814±.048	.634±.063	.715±.051	.484±.193	.409±.116	.681±.032	.554±.077
	TS	.143±.036	.814±.048	.634±.063	.715±.051	.484±.193	.409±.116	.681±.032	.554±.077
UWB+HD	OS	.032±.030	.908±.015	.731±.059	.843±.046	.812±.154	.645±.136	.980±.006	.707±.064
	TS	.074±.036	.917±.022	.766±.030	.853±.026	.863±.057	.699±.049	.986±.003	.737±.032
UWB+HD+AKI	OS	.048±.040	.937±.014	.730±.057	.842±.044	.800±.183	.643±.132	.996±.001	.714±.067
	TS	.055±.026	.938±.014	.768±.032	.854±.023	.863±.060	.684±.041	.997±.001	.737±.028
RGBm	OS	.127±.053	.815±.030	.741±.044	.805±.046	.578±.172	.478±.154	.883±.027	.632±.075
	TS	.127±.053	.815±.030	.741±.044	.805±.046	.578±.172	.478±.154	.883±.027	.632±.075

Single modality results:

- UWB performs the best as the location is useful
- UWB and RGBs outperform IMMU for most behaviors except walking

Combination results:

- The best model is UWB+HD+AKI
- RGBm performed better than RGBs

Behaviors of cow #9 vs indoor THI during the deployment

