ADVANCING RUMEN HEALTH THROUGH PRECISION VESTOCK FARMING

lobal Review of Sensor Technologies, eling, and Applications

O. TEDESCHI

SOR PHD, PAS, DIPL. ACAN
LLOR EDGES FELLOW ’19
A&M AGRILIFE RESEARCH FELLOW ’16
A&M UNIVERSITY

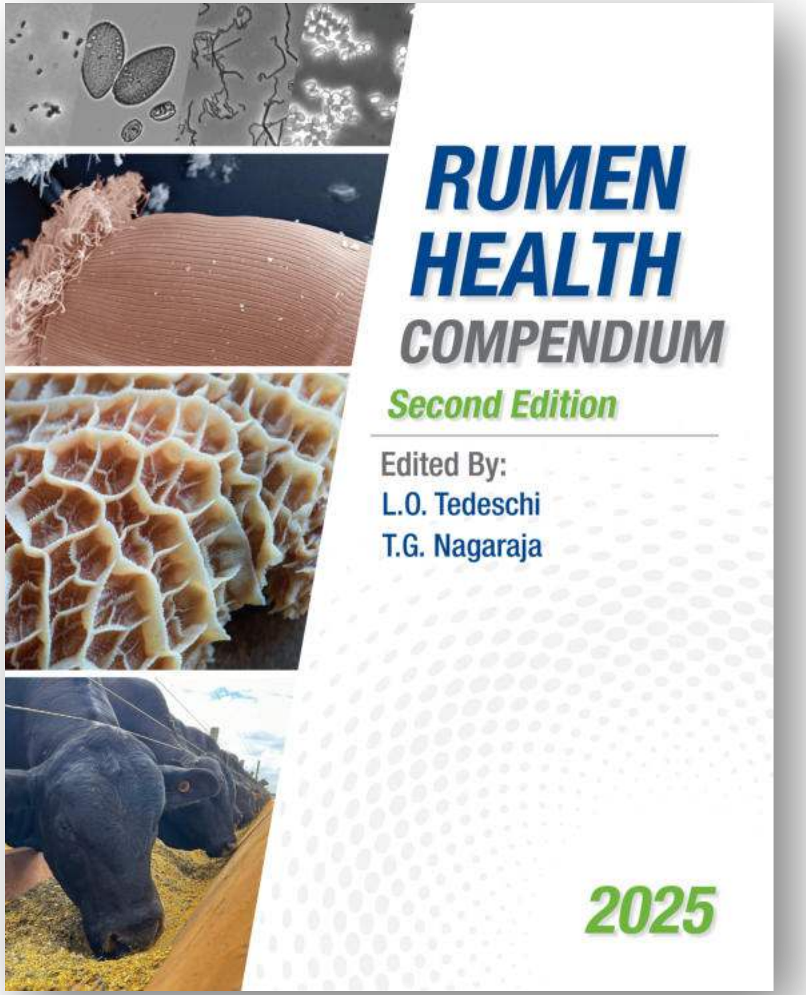
TEXAS A&M AGRILIFE RESEARCH

TEXAS A&M UNIVERSITY

Why Rumen Health?

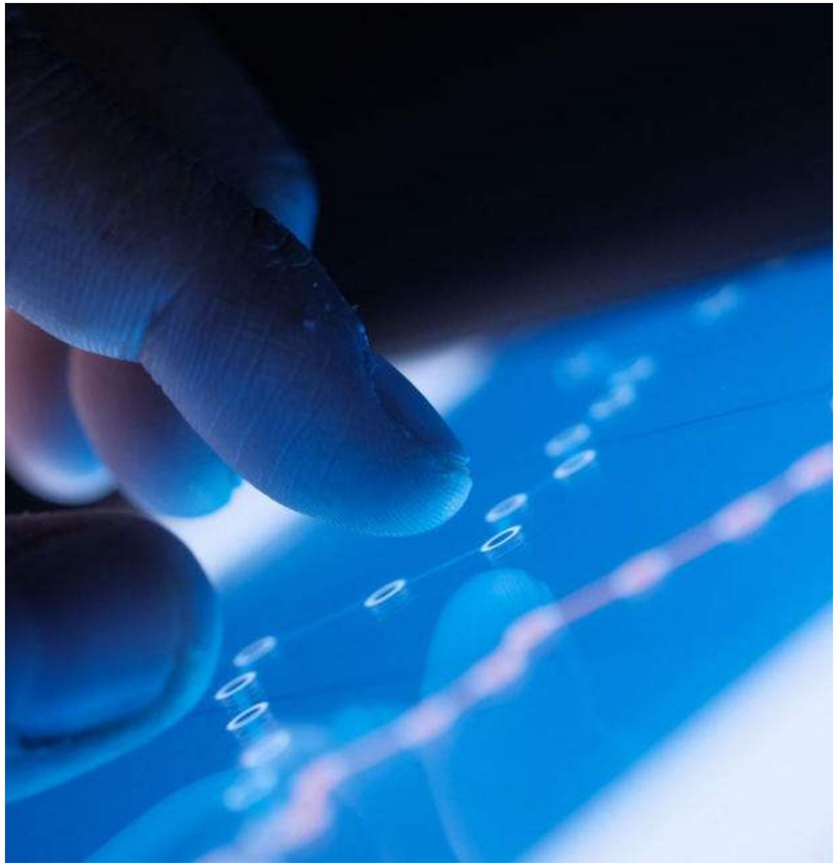
ITS HEALTH DICTATES

- **Feed Efficiency**
  - Conversion of feed into milk or meat
- **Animal Health & Welfare**
  - A stable rumen prevents metabolic diseases like acidosis, ketosis, and bloat
- **Profitability**
  - Healthy animals are productive animals. Poor rumen health is a major source of economic loss
- **The Challenge**
  - Rumen health is a delicate balance, easily disrupted by changes in diet, environment, and stress

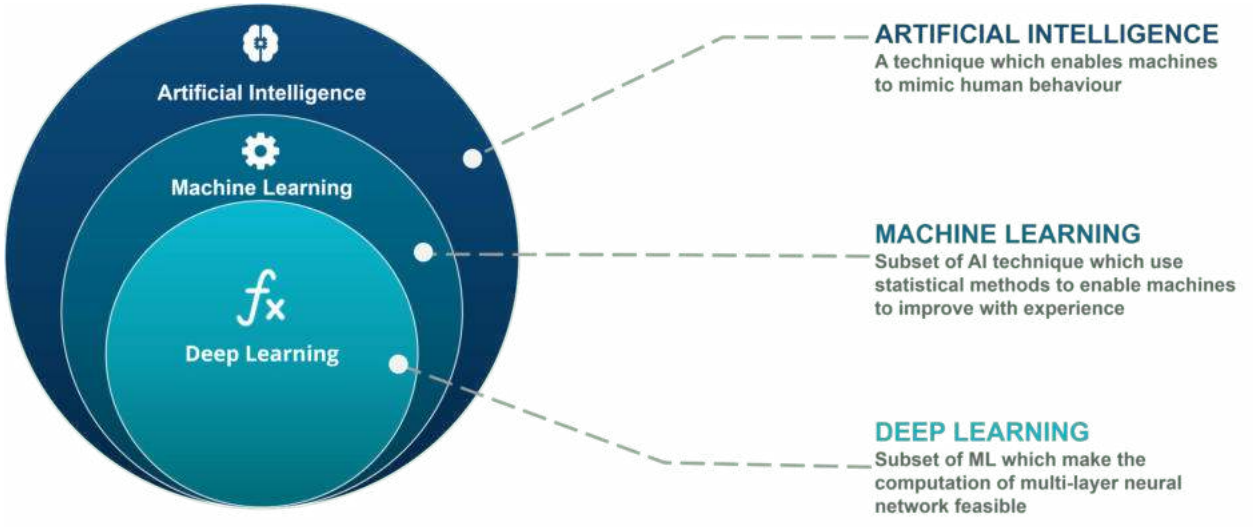


What is Precision Livestock Farming (PLF)?

- **Precision livestock farming (PLF)** uses advanced technologies to monitor and manage individual animals in real-time
- **For rumen health** PLF means moving from population-level management to **individualized animal care**
    - **Data Collection:** Continuous data from sensors on and around the animal
    - **AI-Powered Analysis:** Algorithms detect subtle patterns in data that signal potential rumen upset
    - **Automated Interventions:** Systems provide alerts or automatically adjust management (e.g., feed)
    - **The Goal:** Proactively maintain rumen stability, rather than reactively treating disease



What is Artificial Intelligence (AI)?



- **Artificial Intelligence (AI):**
The broad field that aims to replicate human-like intelligence in machines

- **Machine Learning (ML):**
A subfield of AI where systems learn from data to improve their performance without being manually programmed.
Example: Predicting disease risk in cattle based on feed intake and behavior

- **Deep Learning (DL):**
A type of ML that uses neural networks to model complex relationships, especially effective in image and video analysis.
Example: Identifying lameness in cows through posture analysis using video footage

Modeling Rumen Health with AI + PLF

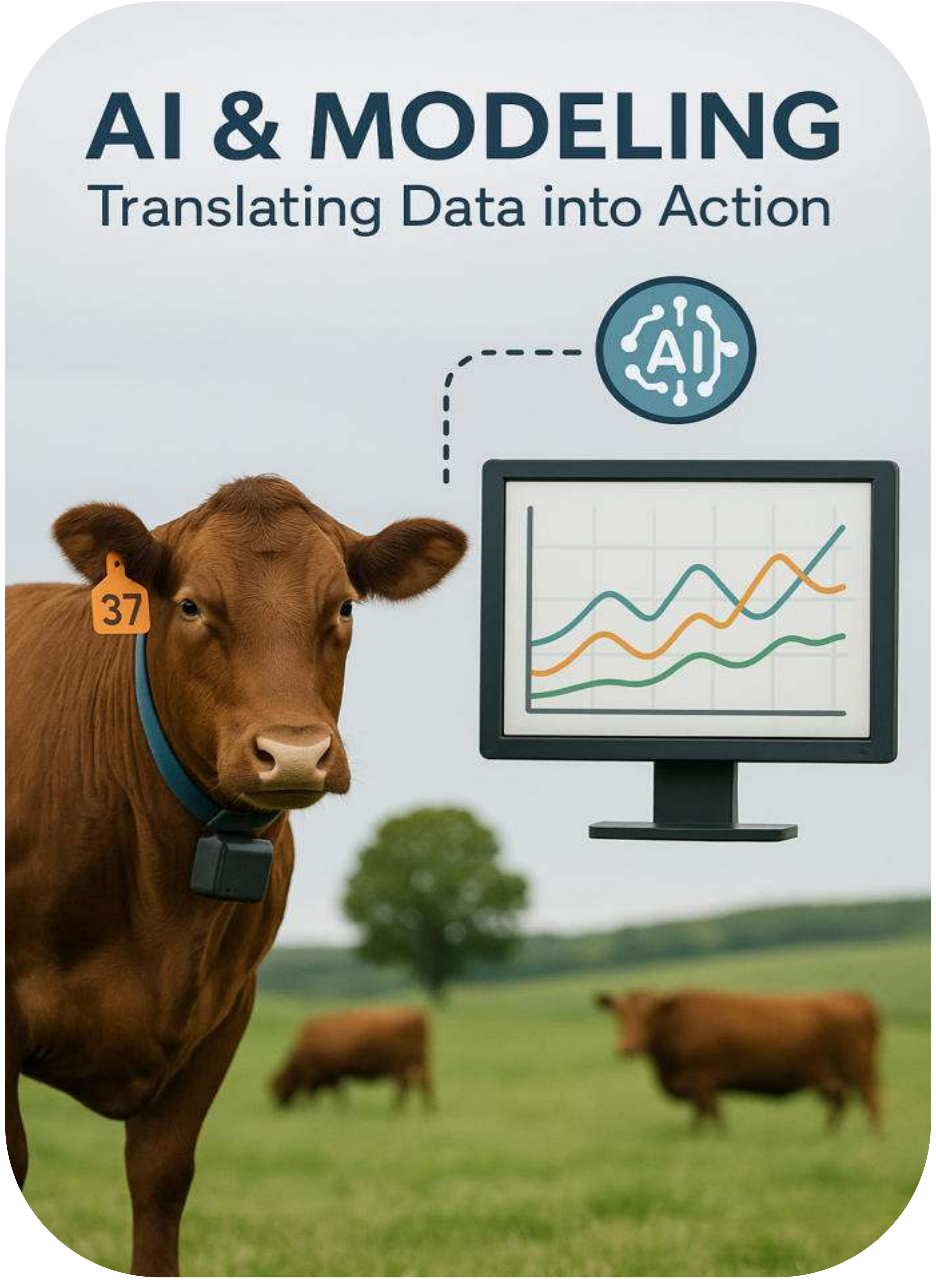
Artificial Intelligence (AI) turns this data into actionable insights

Pattern Recognition: AI algorithms identify complex patterns invisible to the human eye. Example: Detecting a slight, consistent decrease in rumination combined with altered feeding behavior over 48 hours to predict a SARA event

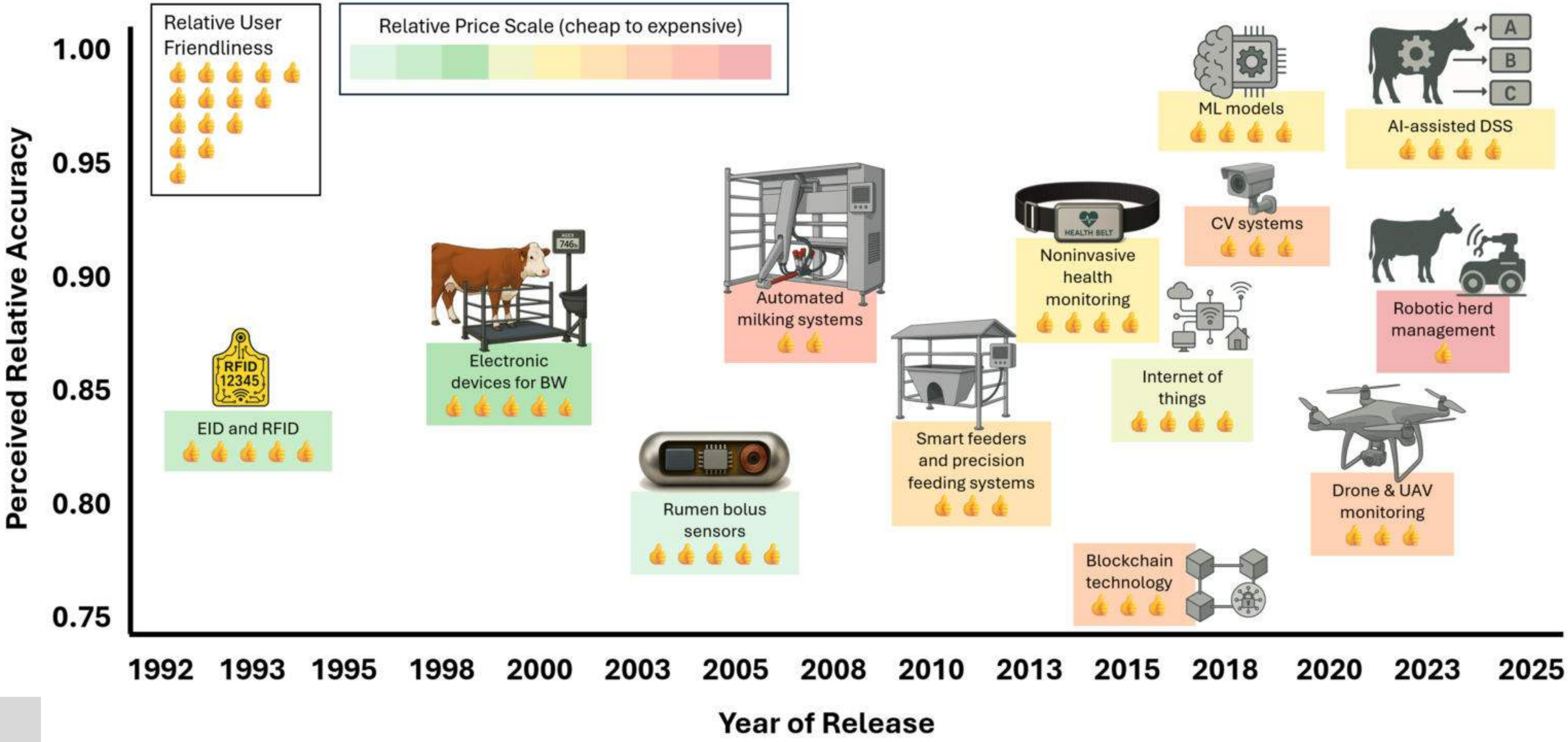
Predictive Analytics: Machine learning models can forecast the risk of metabolic disease based on current data streams, allowing for pre-emptive action

Hybrid Models: These models combine the strengths of two approaches:

- **Mechanistic Models:** Based on the biology of rumen function (e.g., predicting VFA production from feed inputs)
- **AI/Machine Learning:** Uses sensor data to fine-tune and personalize the predictions of the mechanistic model for each individual cow



AI in Livestock Farming: Evolution of Technologies



Tedeschi et al. (2025)

AI in Livestock Farming

1. Health Monitoring & Disease Detection
2. Behavior and Welfare Assessment
3. Reproductive Management
4. Weight Estimation & Growth Monitoring
5. Precision Grazing & Movement Tracking
6. Environmental Monitoring
7. Feeding and Nutrition Management

1. Health Monitoring & Disease Detection

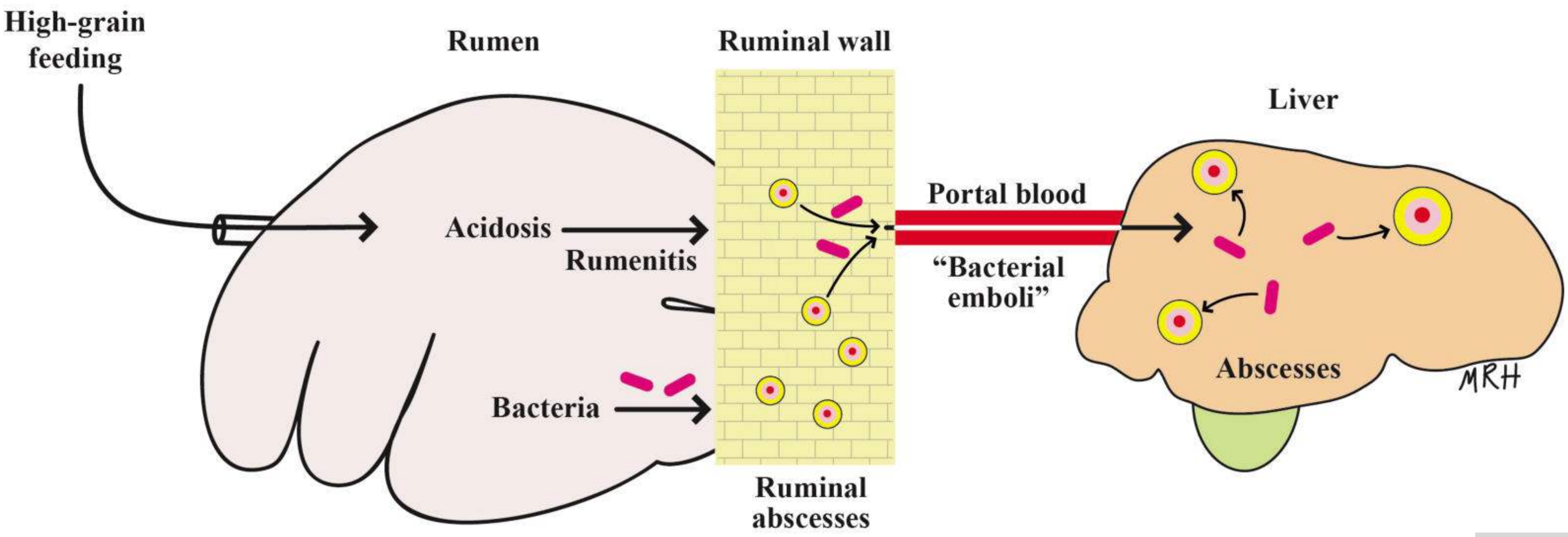
Data obtained from sensors (e.g., behavior, temperature, and feed/water intake) are analyzed using AI models to identify early signs of illness or stress

Wearable Sensors & RFID Tags:
Monitor body temperature, heart rate, rumination, feeding behavior, and movement patterns in real time

Computer Vision Systems:
Use RGB and thermal cameras to assess posture, gait (lameness detection), and physical condition remotely

Sound and Audio Analysis:
Microphones detect coughs, vocal stress, or respiratory issues—early signs of disease outbreaks

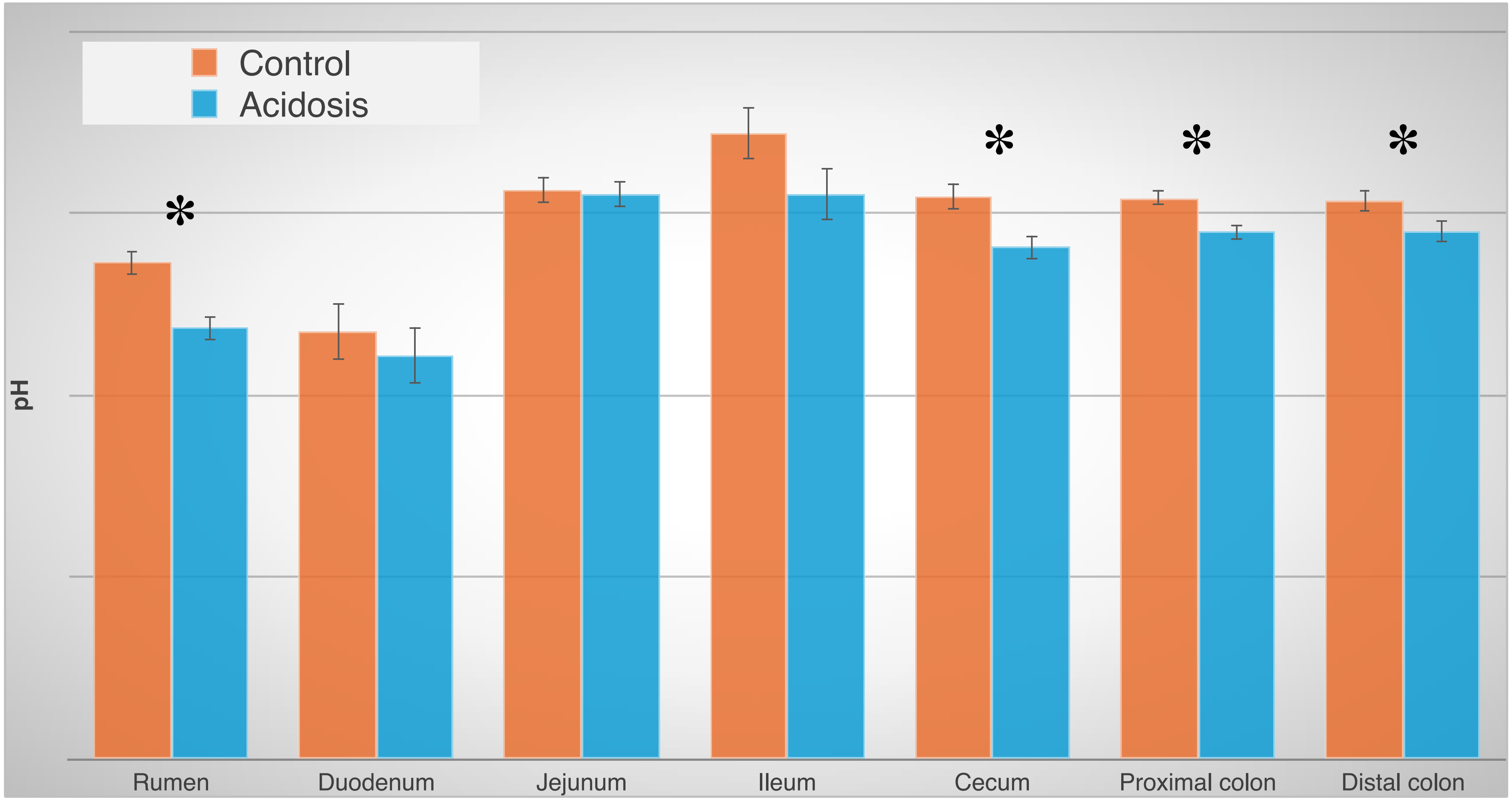
AI Algorithms:
Analyze deviations from individual animal baselines to trigger alerts for potential health concerns



Nagaraja et al. (2025)

Pathogenesis: Acidosis-Rumenitis-Liver Abscess Complex

Rumen acidosis affects more than ruminal pH



Pederzolli et al. (2018)

EXAMPLE SENSORS TECHNOLOGY - CATTLE BOLLUS

SMAXTEC pH BOLUS

smaxtec.com

MOONSYST - SMART RUMEN BOLUS

moonsyst.com/bolus

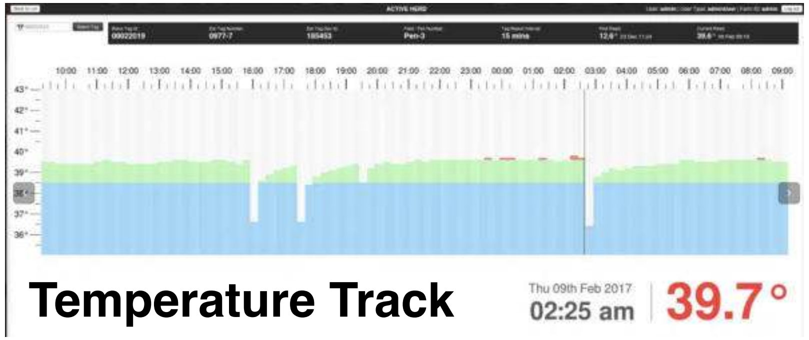
size: 100 mm × 32 mm
weight: 200g

Temperature Track

ActiveHerdTM

tracks360.com/cattle-bolus

Smarter Technologies



Cattle Scan (Canada)

cattlescan.ca

CATTLE SCAN

Evaluation of active dried yeast in the diets of feedlot steers. II. Effects on rumen pH and liver health of feedlot steers[1]

Whitney Lynn Crossland,[†,2] Caitlyn M. Cagle,[†] Jason E. Sawyer,[†] Todd R. Callaway,[‡] and Luis Orlindo Tedeschi[†,3]

[†]Department of Animal Science, Texas A&M University, College Station, TX 77843-2471; and [‡]Department of Animal and Dairy Science, University of Georgia, Athens, GA 30602

Effects of active dry yeast on ruminal pH characteristics and energy partitioning of finishing steers under thermoneutral or heat-stressed environment[1]

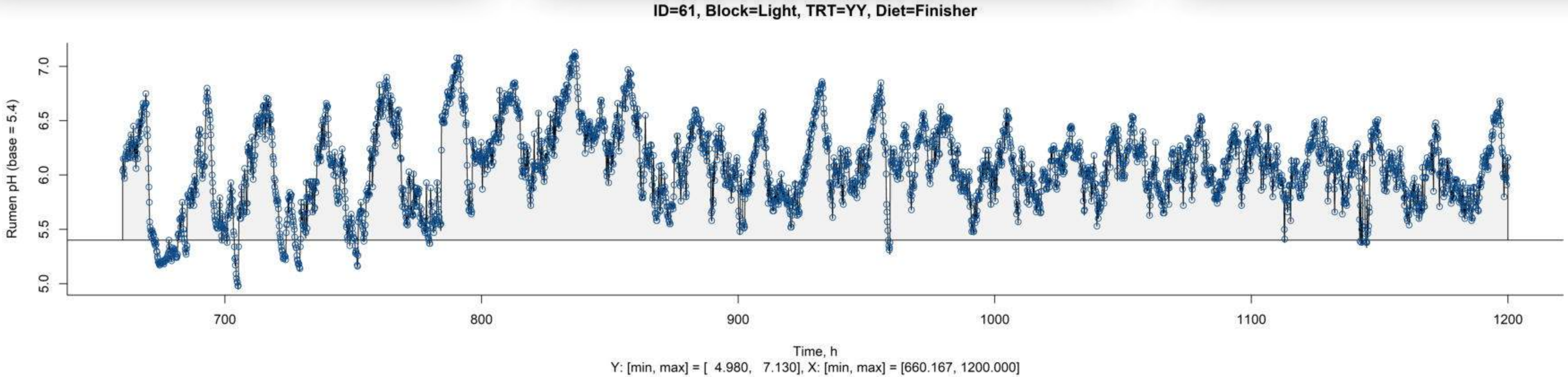
Whitney Lynn Crossland,* Aaron Bradley Norris,* Luis Orlindo Tedeschi,*[,2] and Todd Ryan Callaway[†]

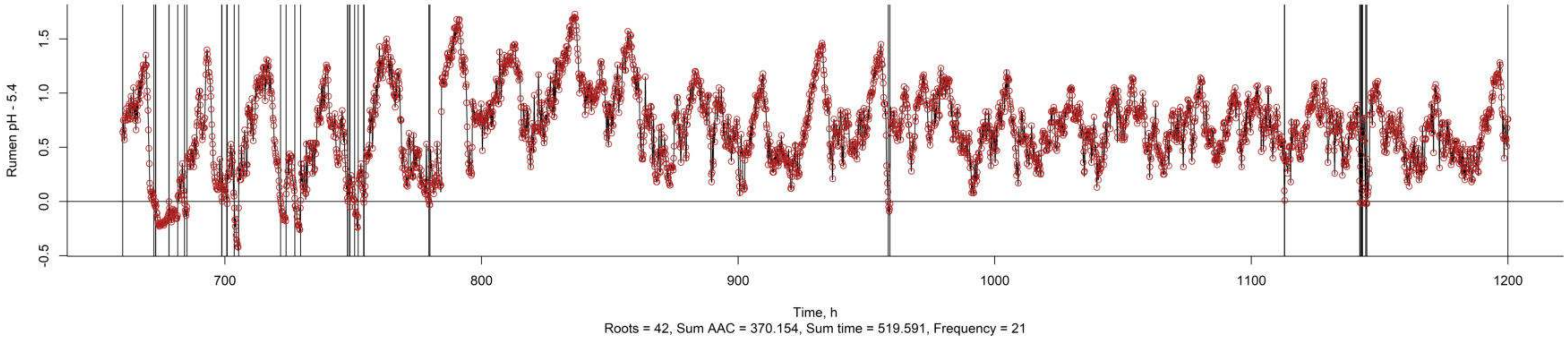
*Department of Animal Science, Texas A&M University, College Station, TX 77843-2471; and [†]Department of Animal and Dairy Science, Athens, GA 30602

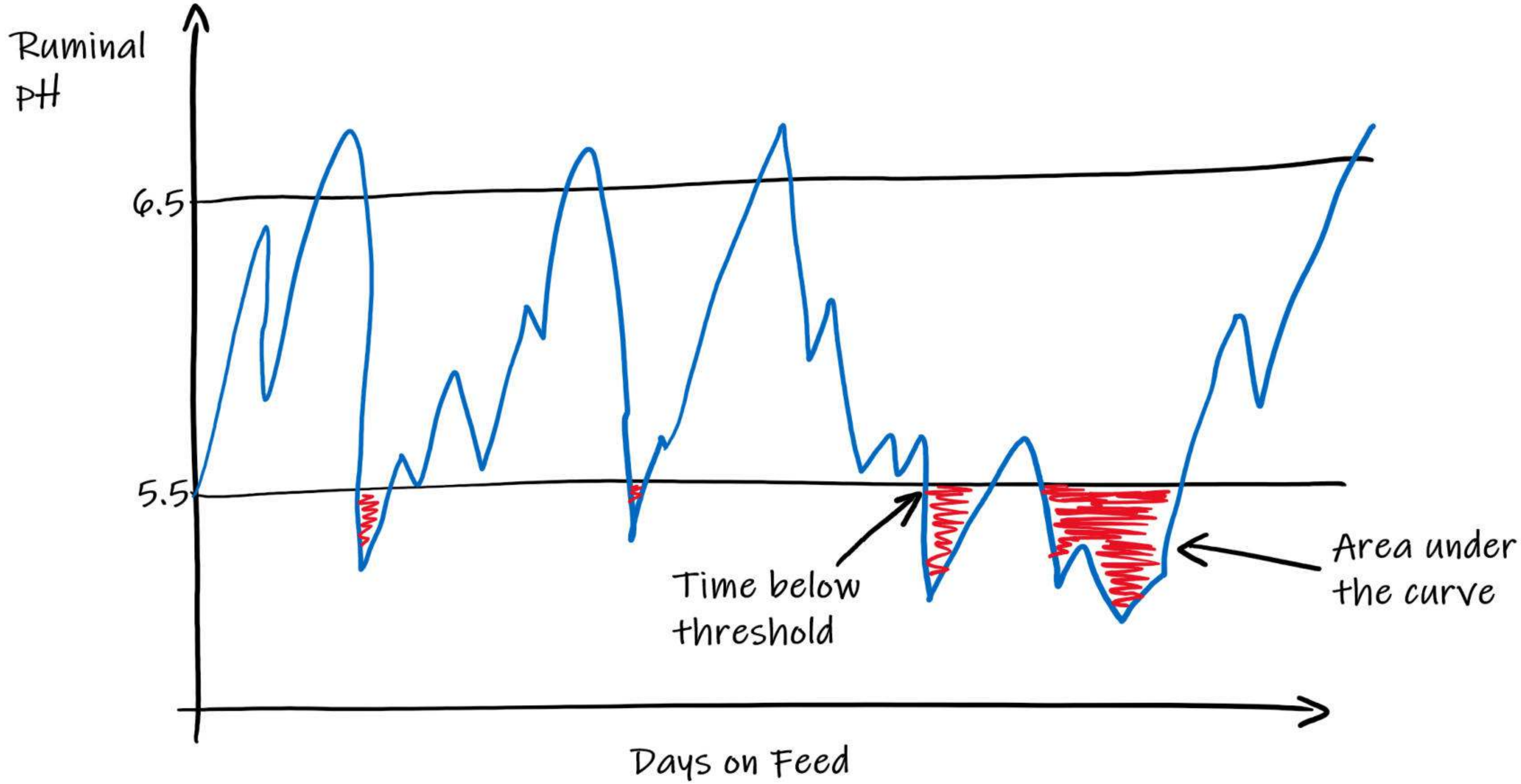
Evaluation of active dried yeast in the diets of feedlot steers. I. Effects on feeding performance traits, the composition of growth, and carcass characteristics[1]

Whitney L. Crossland,[†,2] Jillian T. Jobe,[†] Flavio R. B. Ribeiro,[‡] Jason E. Sawyer,[†] Todd R. Callaway,[||] and Luis O. Tedeschi[†,3]

[†]Department of Animal Science, Texas A&M University, College Station, TX 77843-2471; [‡]Cooperative Agricultural Research Center, Prairie View A&M University, Prairie View, TX 77446 and [||]Department of Animal & Dairy Science, University of Georgia, Athens, GA 30602







Ruminal pH
6.5
5.5
Time below threshold
Area under the curve
Days on Feed

Area and Time Above and Under the Curve


Ecological Informatics 90 (2025) 103271

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Ecological Informatics

journal homepage: www.elsevier.com/locate/ecolinf

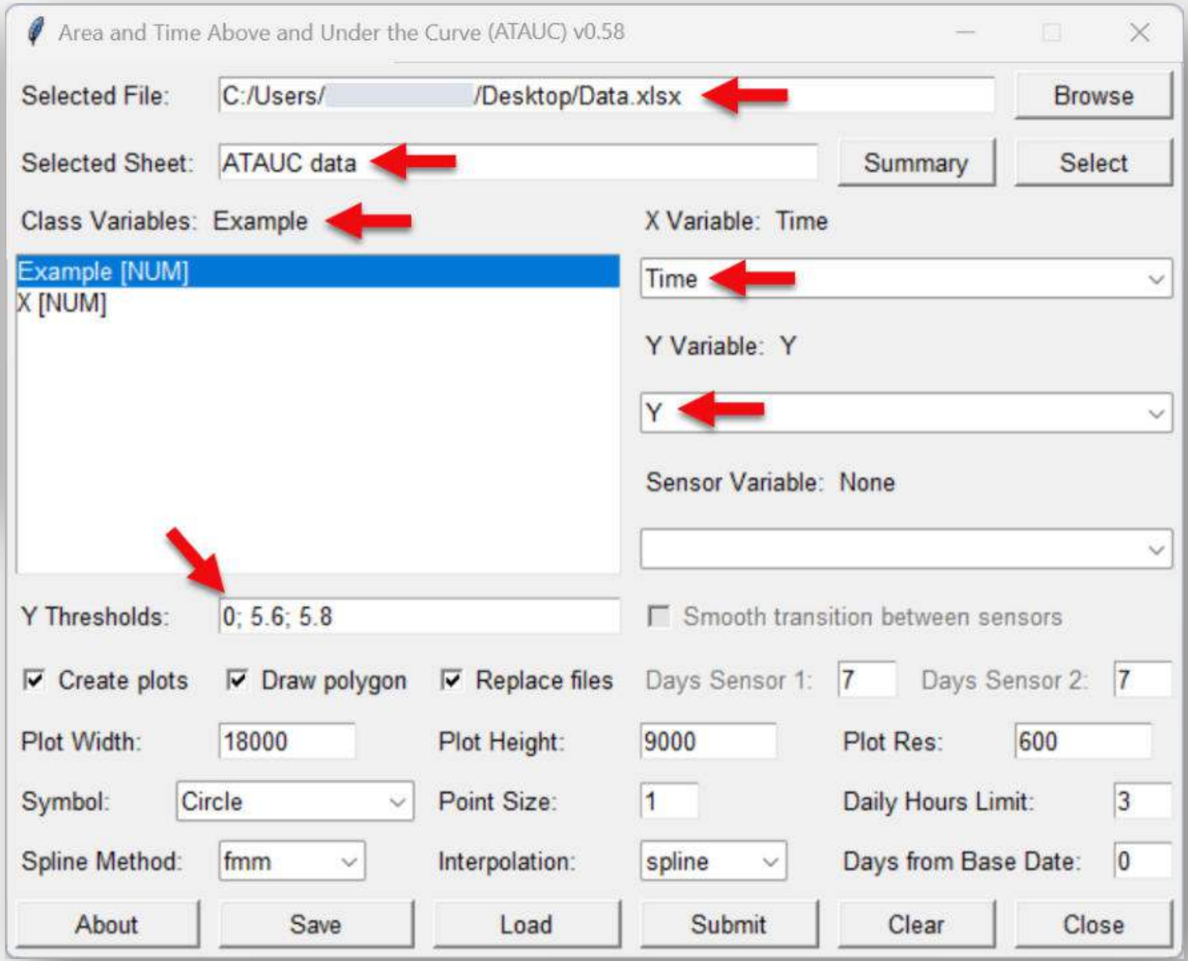
ELSEVIER

Quantifying ruminal health: A statistical review and application of area and time under the curve in animal science

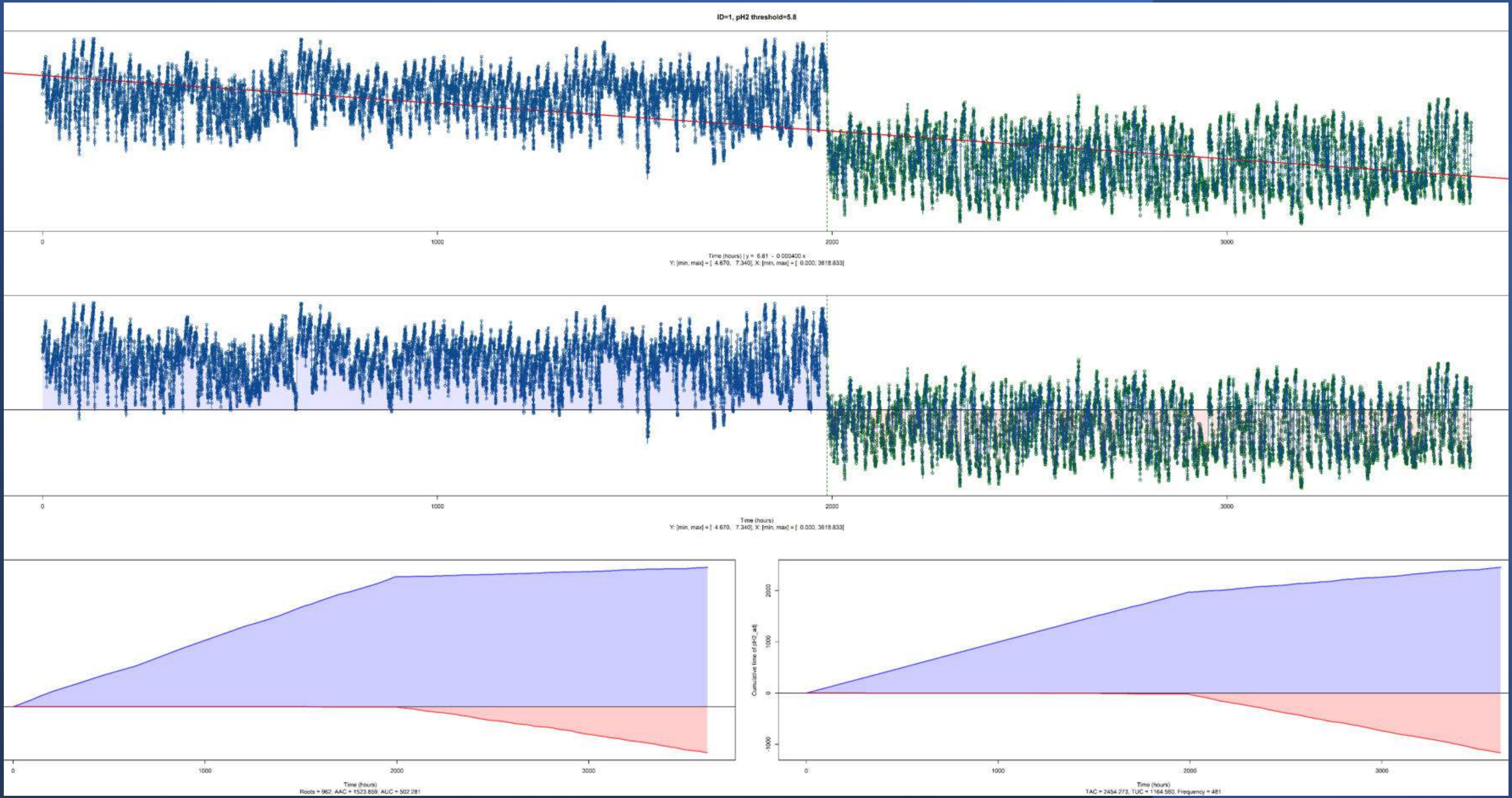
Luis O. Tedeschi

Department of Animal Science, Texas A&M University, College Station, TX 77845, USA

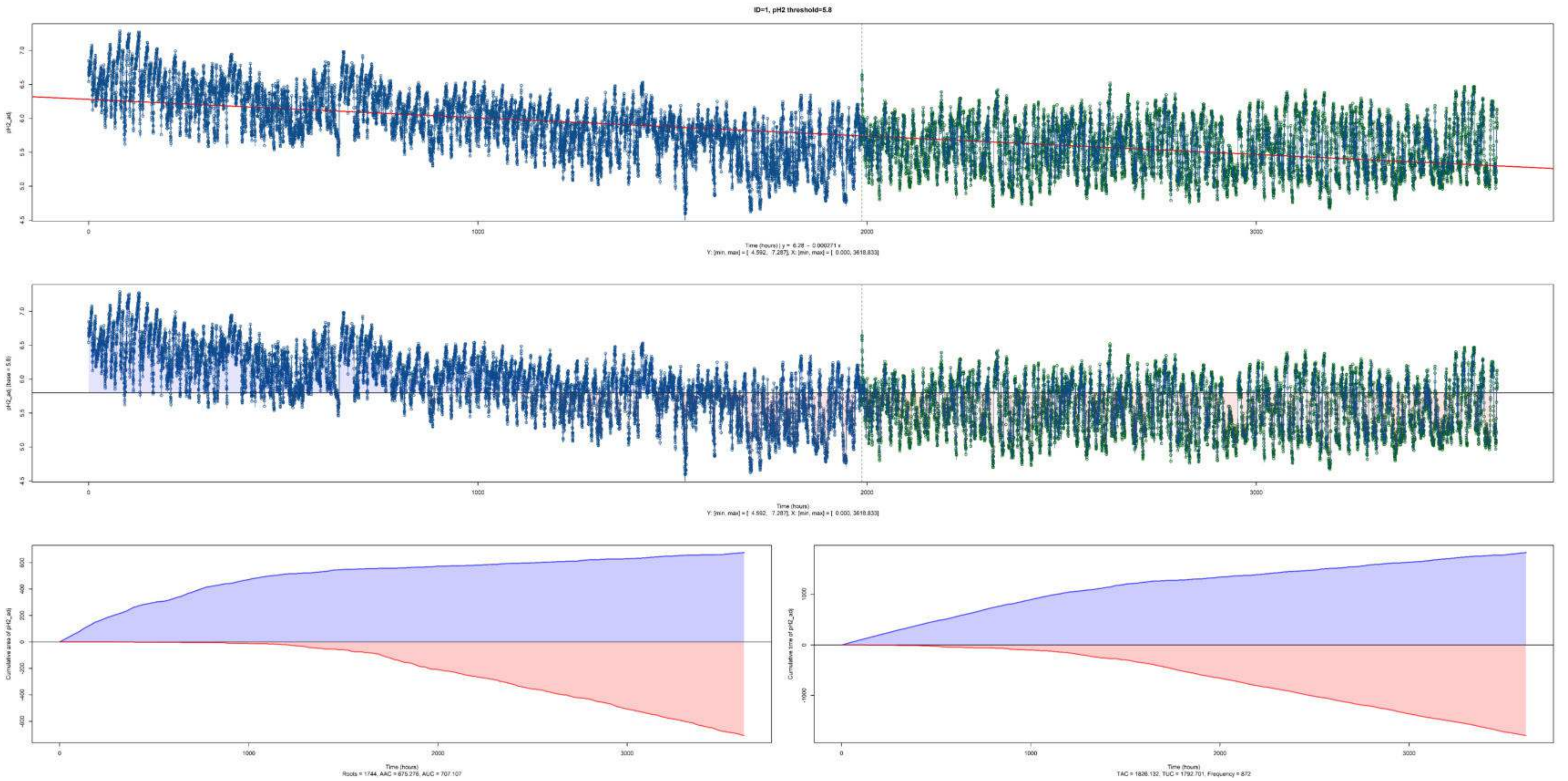
$$Adj\ pH = \begin{cases} pH + Drift_{pH4}, & pH < 4.5 \\ pH + Drift_{pH7} \times \frac{(7-4)-(7-pH)}{7-4} + Drift_{pH4} \times \frac{(7-4)-(pH-4)}{7-4} & 4.5 \le pH \le 7 \\ pH + Drift_{pH7} & pH > 7 \end{cases}$$



Tedeschi (2025)

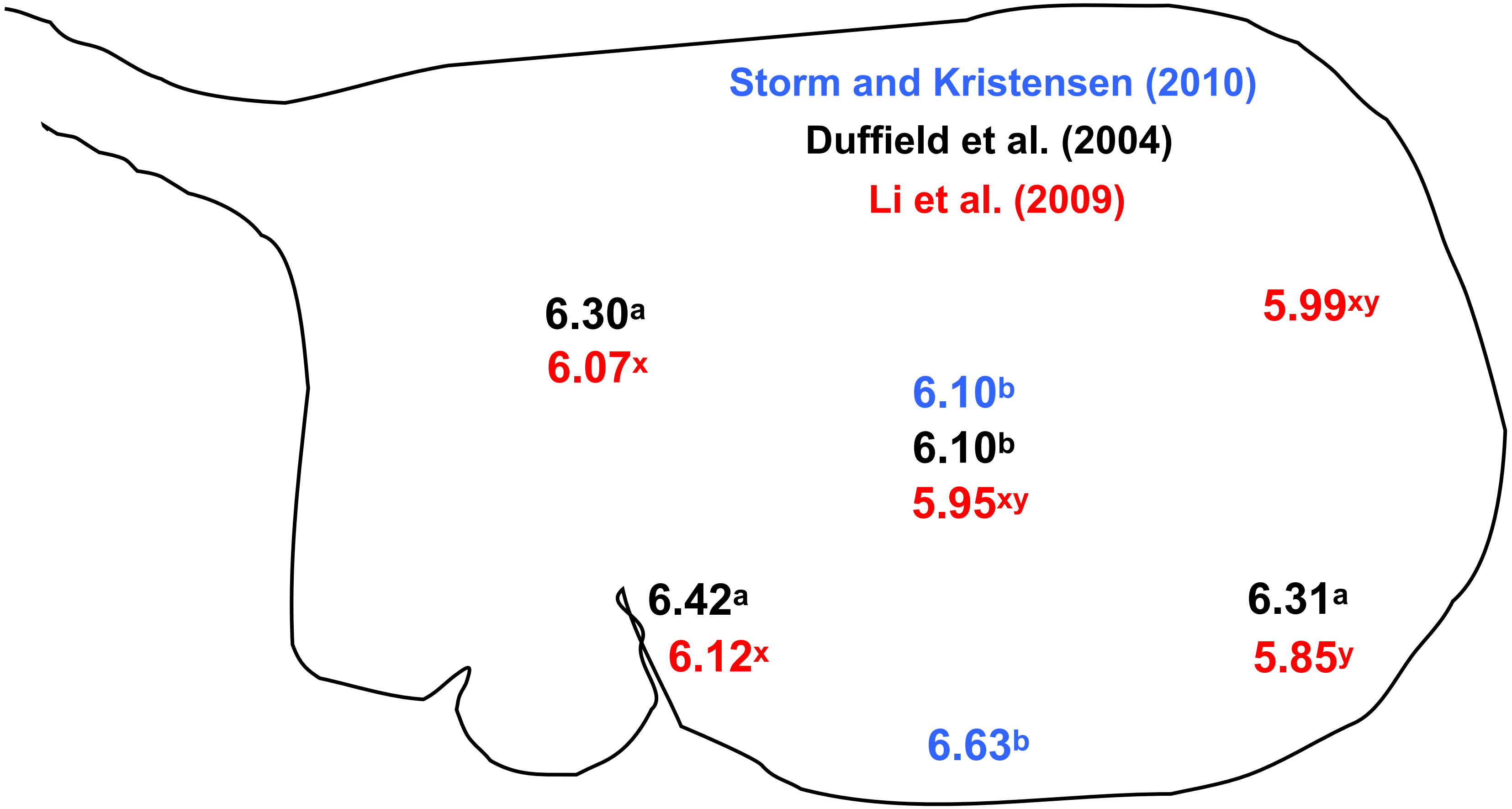


Tedeschi (2025)



Tedeschi (2025)

Stratification of pH in the rumen: A challenge for ruminal pH measurement



Penner (2025)

Which threshold should we use?

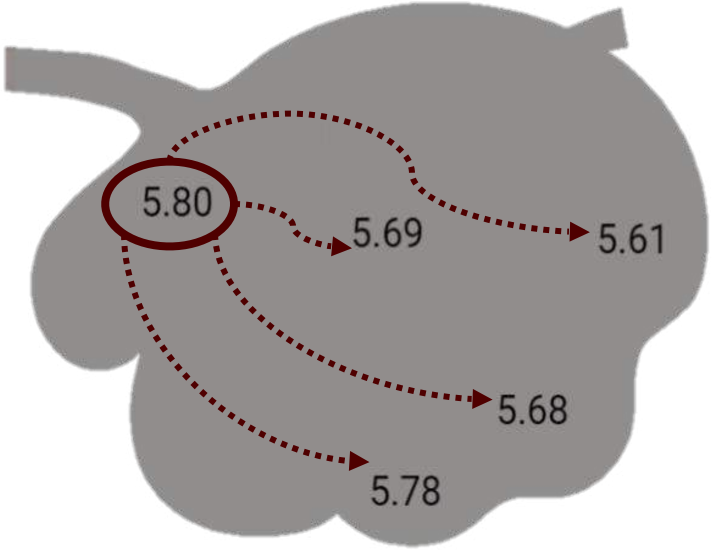
Items	Intercept[1]	Reticulum pH[1]	CT, % DM[1,2]	P-Value	R^2	RMSE[3]	N
Ruminal mean[4]	0.7238 ± 0.3609*	0.8573 ± 0.0599**	0.0339 ± 0.0237	<0.001	0.7789	0.149	64
Cranial Sac	1.1227 ± 0.3666*	0.8042 ± 0.0608**	0.0141 ± 0.0241	<0.001	0.7463	0.152	64
Ventral Sac	0.5823 ± 0.3843	0.8803 ± 0.0637**	0.0368 ± 0.0253	<0.001	0.7665	0.159	64
Dorsal Sac	0.4663 ± 0.5549	0.8874 ± 0.0920**	0.0509 ± 0.0365	<0.001	0.6199	0.230	64

* P-value : <0.05; ** P-value: <0.001
[1] Coefficients are mean ± standard error. [2] Condensed tannins inclusion in the diet, % (DM basis). [3] RMSE: root mean square error. [4] Ruminal mean is the average of the cranial sac, ventral sac, and dorsal sac.

Timing and location affects pH

	Dairy	Beef
Subacute	5.5 – 5.8	5.2 – 5.5
Acute	<5.5	<5.2

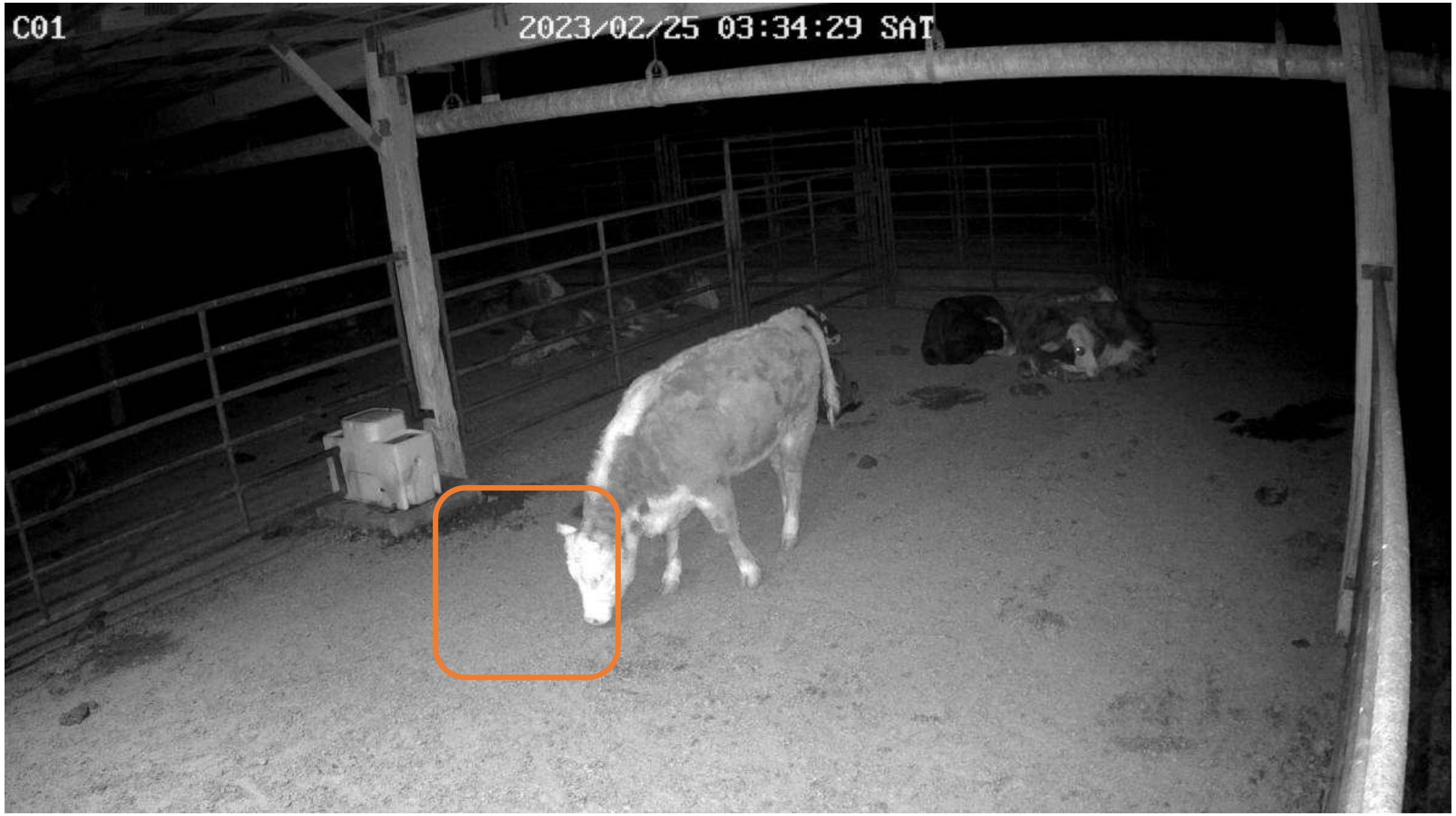
????



Tedeschi and Nagaraja (2025), Dias Batista et al. (2021)

Ground Lickers

- Detection of animals most likely to get infected with soil pathogens ➔ Liver Abscess?



Detecting Bovine Respiratory Disease and Liver Abscess via Computer Vision

A Research In Progress…

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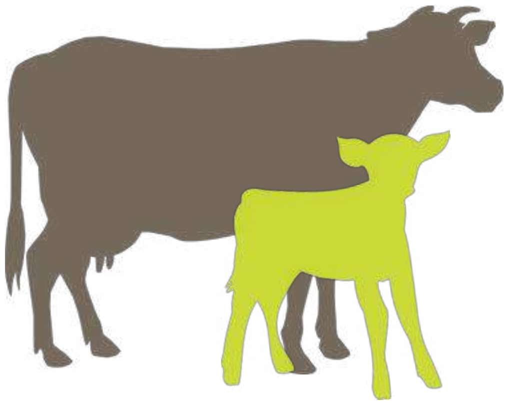
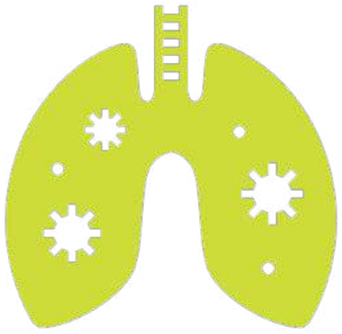
The DART Scoring to diagnose early BRD

- A visual scoring system (0 to 3) used to identify
  - **D**epression
    - Animal's general demeanor, activity level, and alertness
  - **A**ppetite
    - Animal's willingness to eat and its food intake
  - **R**espiration
    - Breathing rate, effort, and any signs of abnormal breathing (e.g., coughing, nasal discharge)
  - **T**emperature
    - Animal's rectal temperature





How to use CV to predict BRD?

Computer Vision Based BRD detection

Frames

Locate animals

- Instance Segmentation

Identify animals

- Supervised: Classification
- Unsupervised: Clustering

Predict **Activity, Temperature, and Respiration**

- Activity: Classification
- Temp.: IR footage Analysis
- Respiration: Frequency domain Analysis

Activity, Temperature, Respiration **Profiles of Individual Animals**

DART score

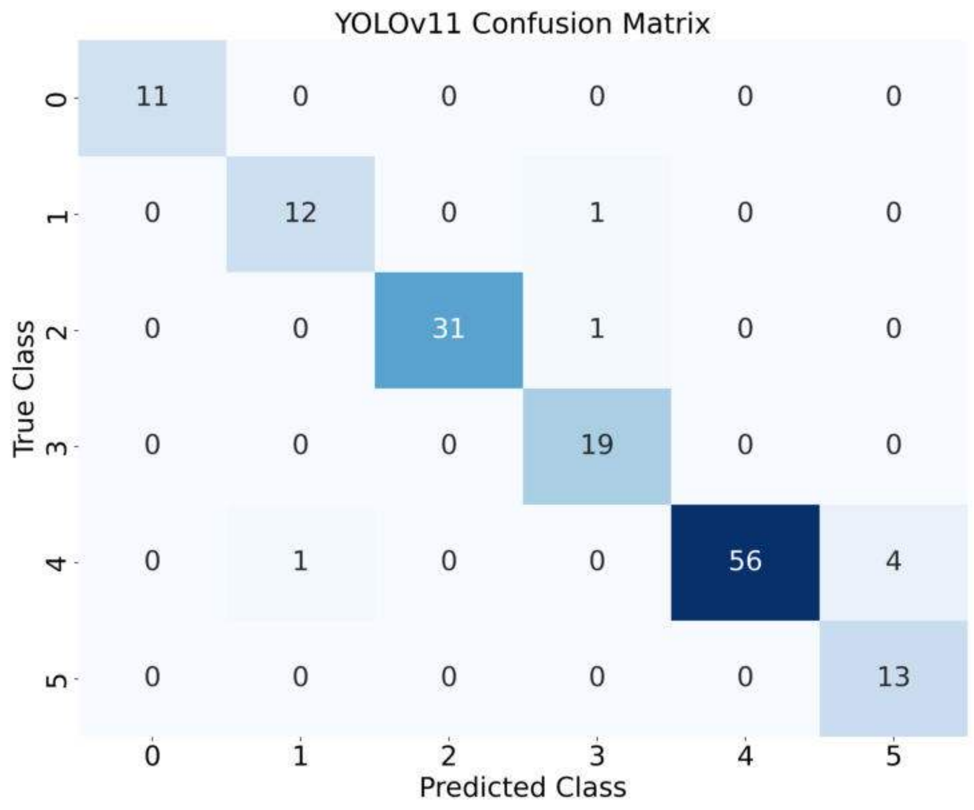
Animal Behavior: What animals do?

Number of Samples

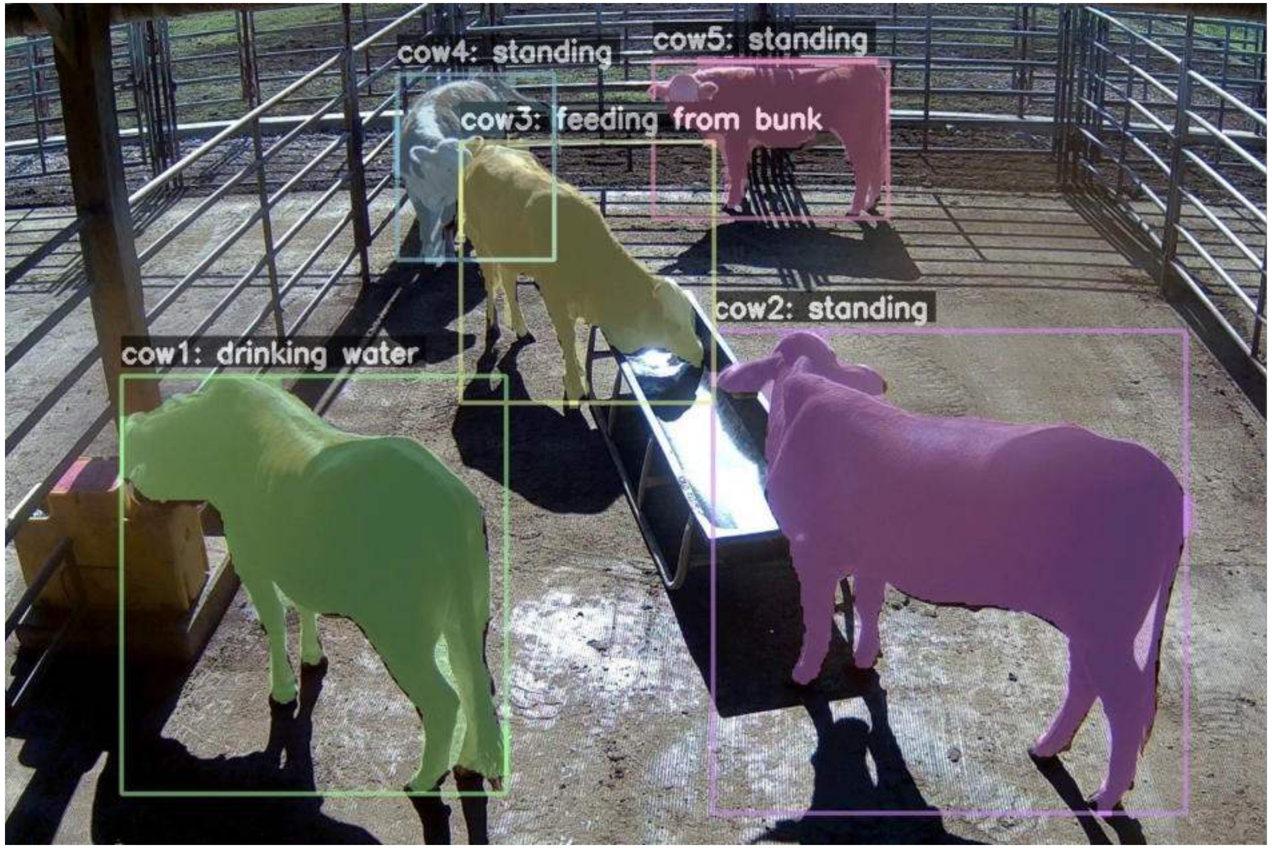
Activity	Train	Val	Test
Lying down	21	11	11
Drinking water	26	13	13
Eating - feed bunk	63	32	32
Eating - ground	38	19	19
Standing still	121	61	61
Walking	26	13	14
	295	149	148

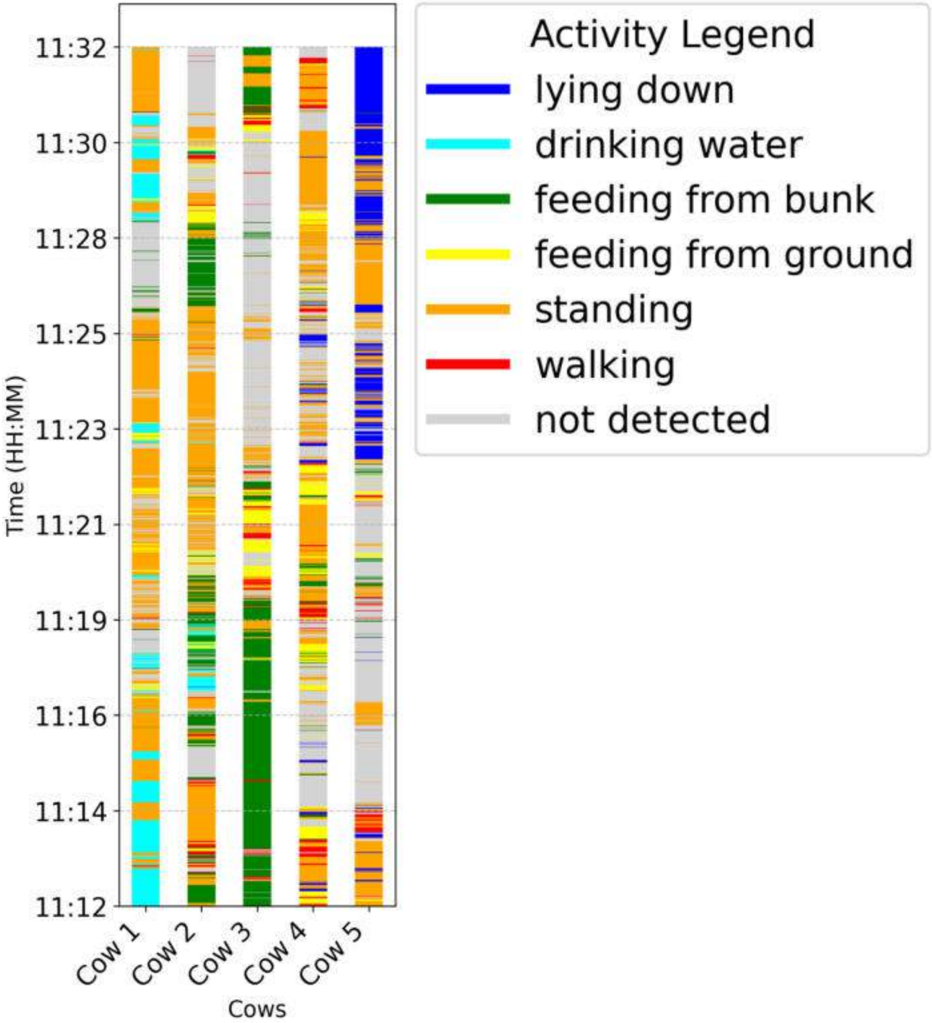
Animal Behavior: Accuracy & precision

Activity (%)	Accuracy	Precision	Recall	F1-score
Lying down	100.00	100.00	100.00	100.00
Drinking water	98.66	92.31	92.31	92.31
Eating - feed bunk	99.33	100.00	96.88	98.41
Eating - ground	98.66	90.48	100.00	95.00
Standing still	96.64	100.00	91.80	95.73
Walking	97.32	76.47	100.00	86.67
Average	**95.30**	**93.21**	**96.83**	**94.69**



Animal Behavior: Time spent doing …





2. Behavior and Welfare Assessment

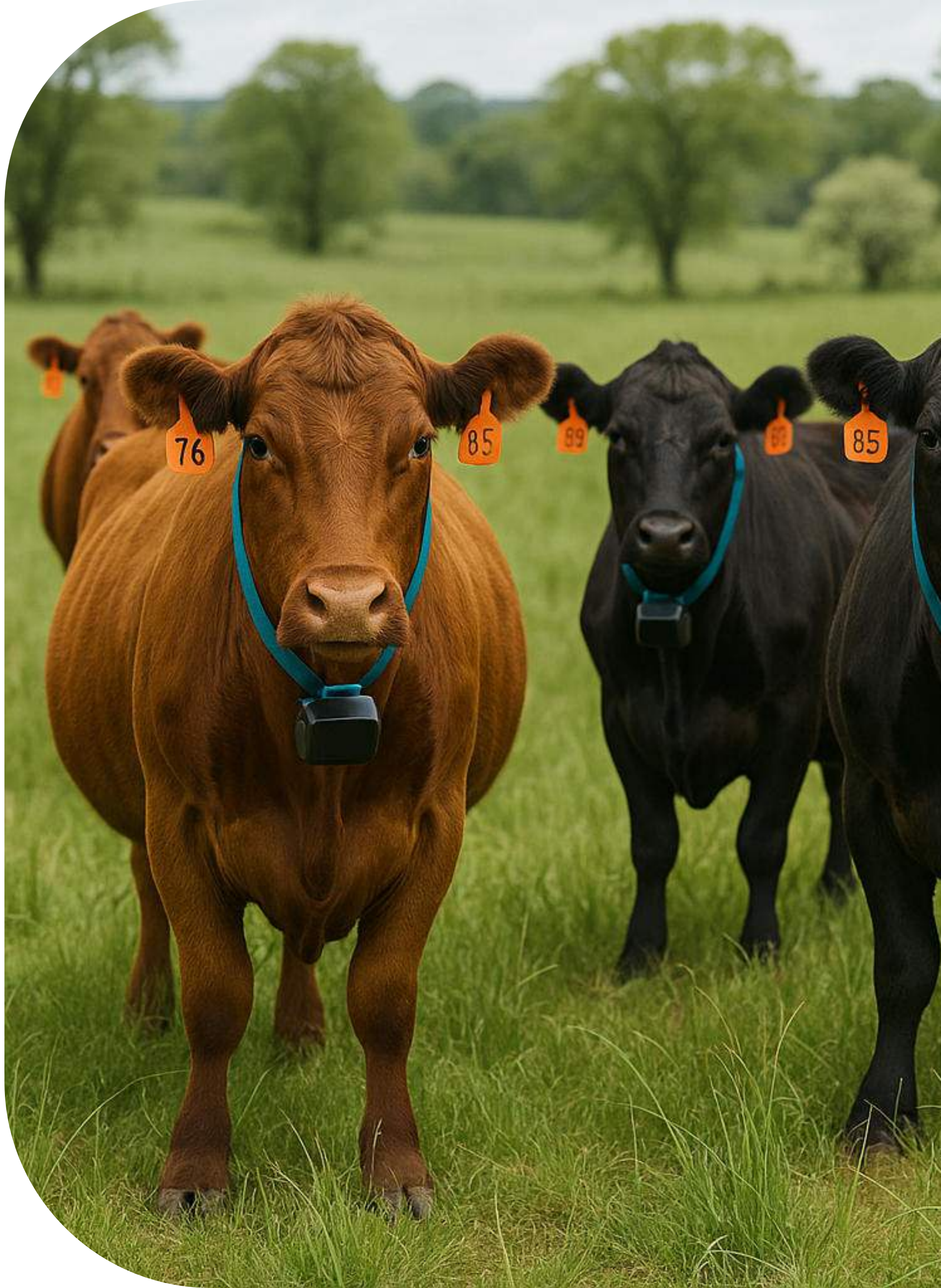
Track	**Accelerometers & Smart Collars:** Track activity patterns such as standing, lying, walking, eating, and ruminating. Changes in daily routines often indicate stress or discomfort
Detect	**Computer Vision & 3D Cameras:** Detect posture, social behavior, and gait patterns for early signs of lameness or abnormal behaviors. Example: Monitoring aggression at the bunk or isolation from the herd
Recognize	**Audio Sensors:** Recognize vocalizations linked to stress, pain, hunger, or social interactions
Monitor	**Environmental Sensors:** Monitor ambient conditions (temperature, humidity, airflow) to evaluate comfort and identify risks for heat or cold stress

Vision systems, accelerometers, and audio sensors help detect abnormal behaviors such as reduced rumination, excessive lying time, or vocalizations

AI enables continuous, unbiased monitoring for welfare compliance

SMART COLLARS AND EAR TAGS

- **How they work**
  - GPS and accelerometers in collars or ear tags track specific motion patterns
- **Key Metrics & Their Meaning**
  - **Rumination Time:** A healthy cow ruminates 450-550 minutes/day. A significant drop is a primary indicator of rumen upset, stress, or illness
  - **Eating Time:** Reduced time at the bunk can signal acidosis or other health issues
  - **Activity:** Lethargy or excessive restlessness can be correlated with metabolic distress
- **AI Integration**
  - Machine learning models analyze deviations from an individual animal's baseline behavior to generate high-accuracy health alerts



EXAMPLE SENSORS TECHNOLOGY - TRACKING - GPS - TAG - COLLARS

CERES TAG
cerestag.com

SMART PADDOCK
smartpaddock.com

701x
701x.com

CHIPSAFER
chipsafer.com

INNOGANDO
innogando.com

MOOVEMENT
moovement.com.au

VENCE - Virtual Fence
vence.io

GALLAGHER - Virtual Fence
gallagher.com

NOFENCE - Virtual Fence
nofence.no

HALTER - Virtual Fence
halterhq.com

ANIMAL SCIENCE
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Utilizing Unmanned Aerial Vehicles (UAV) to Track and Monitor Cattle on Pasture

Contents lists available at ScienceDirect

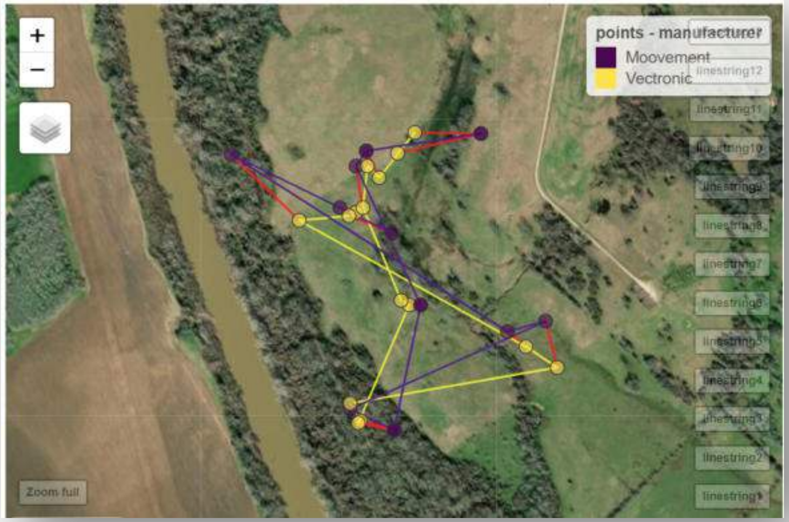
Smart Agricultural Technology

journal homepage: www.journals.elsevier.com/smart-agricultural-technology

Comparison of GPS Collars and Solar-Powered GPS Ear Tags for Animal Movement Studies

Dylan G. Stewart [a,*], Egleu D.M. Mendes [b], Kiju Lee [c,d], Marcus E. Blum [e], Luis O. Tedeschi [b], Stephen L. Webb [a,e]

[a] Department of Rangeland, Wildlife, and Fisheries Management, Texas A&M University, College Station, TX 77843, USA
[b] Department of Animal Science, Texas A&M University, College Station, TX 77843, USA
[c] Department of Engineering Technology & Industrial Distribution, Texas A&M University, College Station, TX 77843, USA
[d] Department of Mechanical Engineering, Texas A&M University, College Station, TX 77843, USA
[e] Texas A&M Natural Resources Institute, College Station, TX 77840, USA

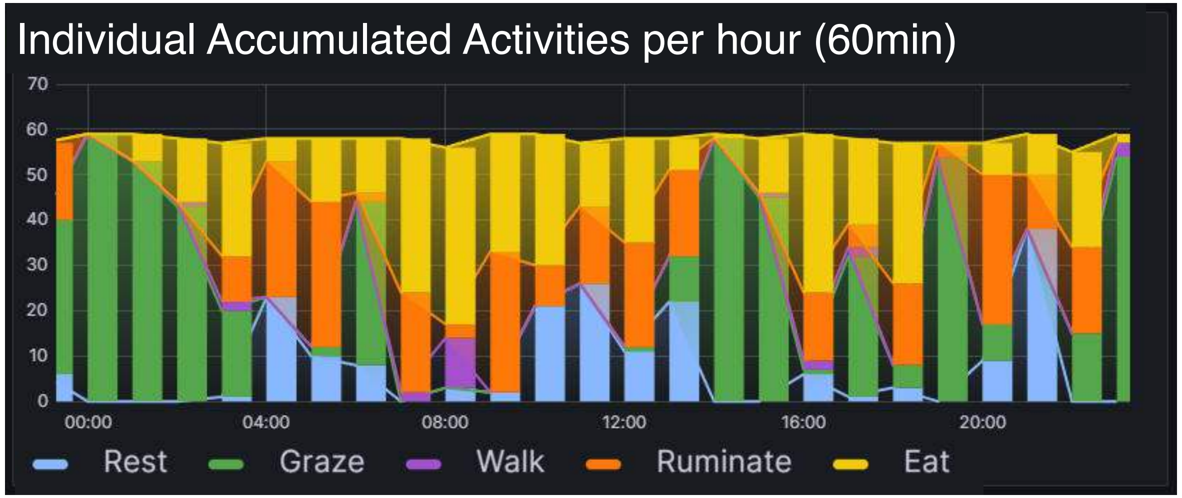


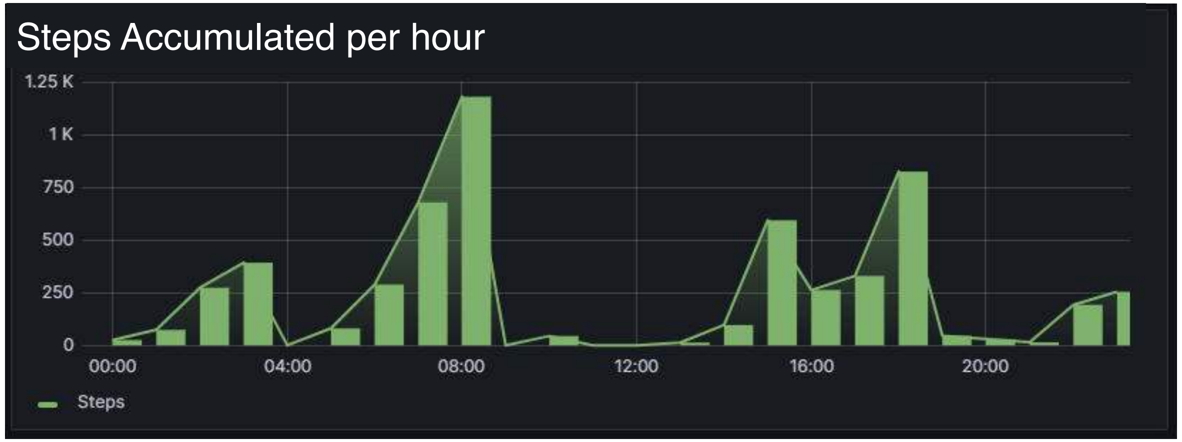
GPS Evaluation: Static versus Pasture Trials

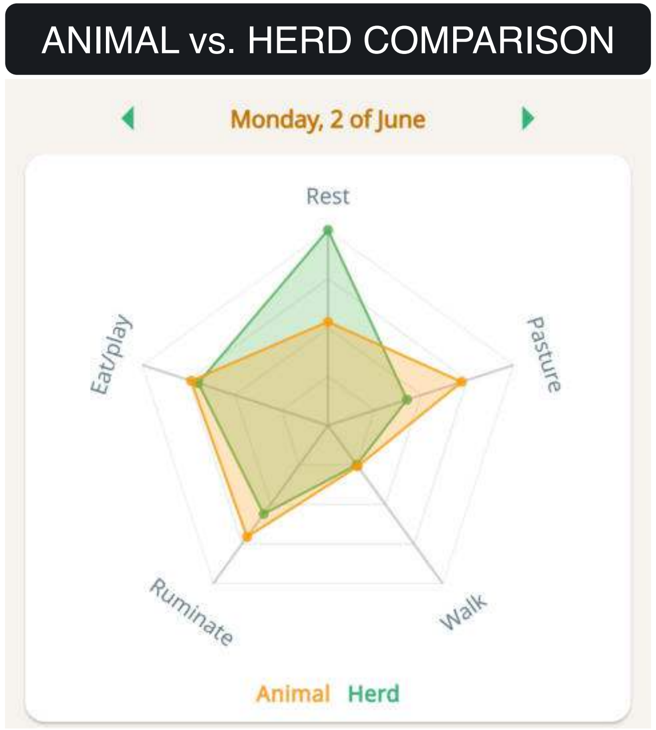
STATIC TEST

PASTURE TRIAL

Grazing Animal Behavior Output







EXAMPLE SENSORS TECHNOLOGY - TRACKING - TAG - COLLARS

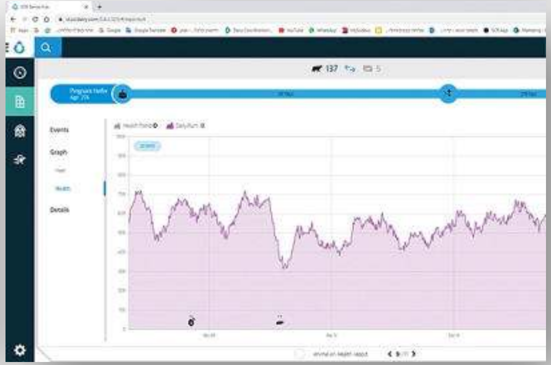
MERCK - SENSE HUB

merck.sensehub.com
allflex.global/blog/most-effective-health-monitoring-systems

SenseHub™

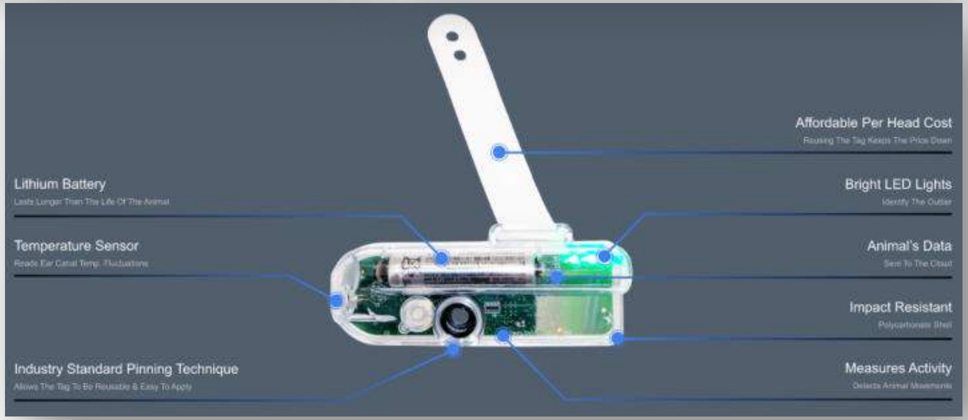
SenseHub™
COW CALF

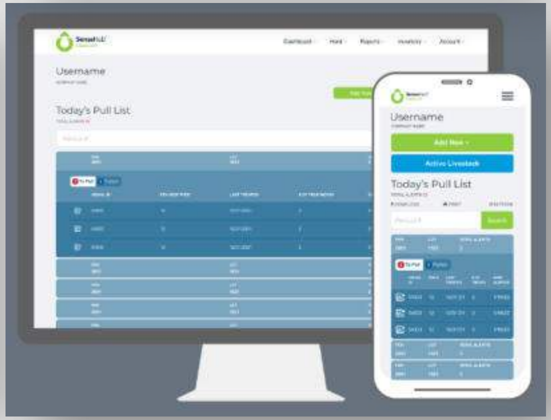
merck.sensehub.com/sensehub-cow-calf



SenseHub™
DAIRY

merck.sensehub.com/dairy

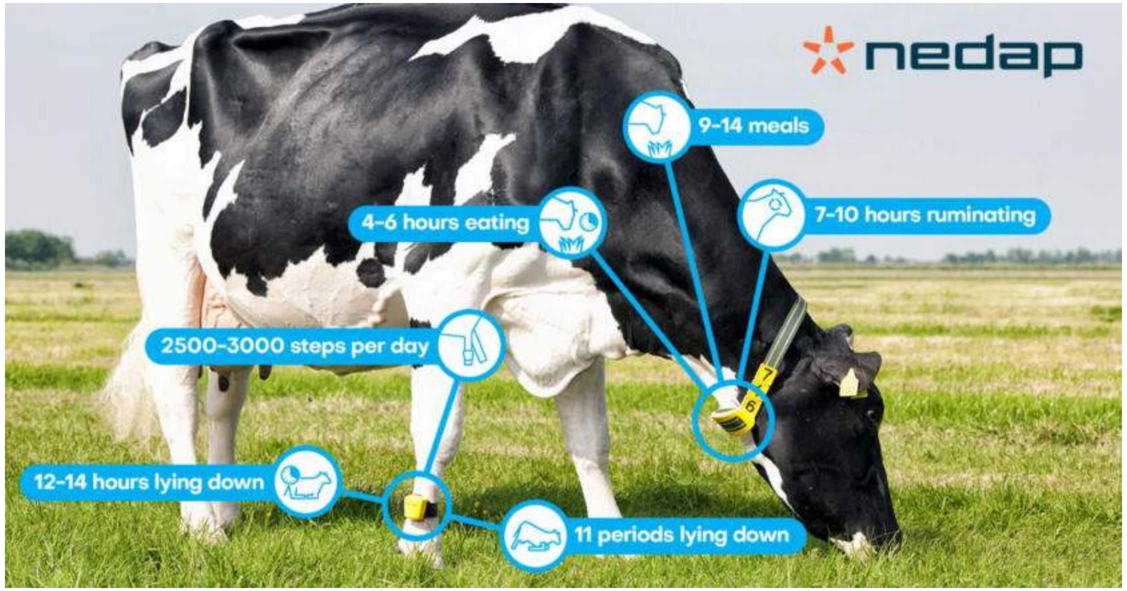


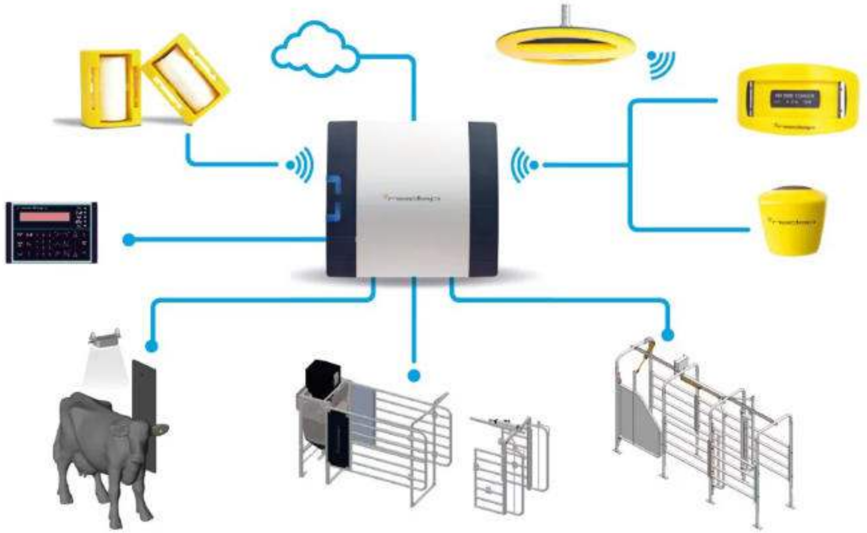


SenseHub™
FEEDLOT

SENSOR INTEGRATION IN DAIRY CATTLE

nedap-livestockmanagement.com





AUTOMATED COW FEEDING STATION + SORTING

3. Reproductive Management

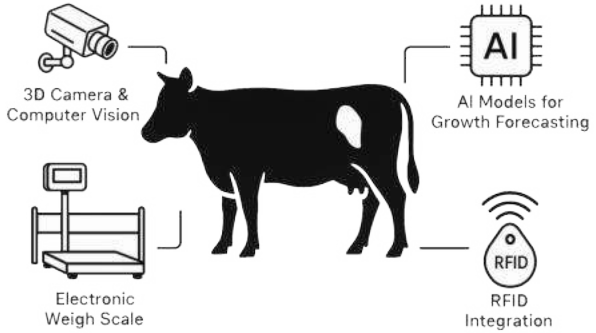
Activity Monitors & Smart Collars:
Detect increased movement and restlessness during estrus.
Some systems measure mounting behavior and step count for precise heat detection.

Vaginal or Body Temperature Sensors:
Subtle changes in temperature can signal estrus or calving.

Computer Vision:
Monitors behavioral signs of heat (e.g., mounting, tail raising, isolation).
Can also detect calving behaviors like circling or frequent lying/standing.

Automated Alerts:
Mobile or cloud-based systems notify producers of optimal insemination timing or impending calving.

AI analyzes activity data to detect heat cycles and optimize breeding schedules
Some systems predict calving events or post-partum recovery time



4. Weight Estimation & Growth Monitoring

3D Cameras & Computer Vision Systems
Capture depth and body shape from multiple angles to estimate body weight without physical contact.
Algorithms use image-based features like body length, width, and volume for prediction.

Electronic Weigh Scales (e.g., walk-over or drinker-mounted)
Capture real-time weight each time the animal visits a waterer or feeder—without human intervention.
Example: C-Lock SmartScales or similar systems.

AI Models for Growth Forecasting
Predict future weight trajectories and detect deviations from expected gain (e.g., for early detection of illness or nutritional issues).

CV and depth cameras are used to estimate live weight non-invasively and track average daily gain (ADG) trends
Helps optimize market timing and nutrition plans

EXAMPLE OF COMMERCIAL TECHNOLOGY AVAILABLE

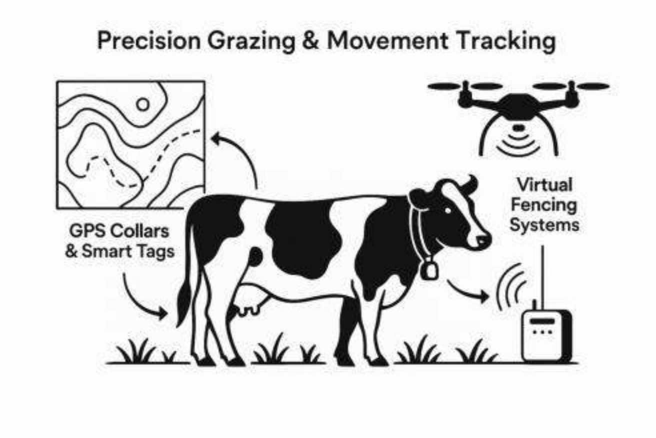
OPTIWEIGHT - IN-PADDOCK PARTIAL BW SYSTEM
optiweigh.com.au

C-LOCK - SMART SCALE PARTIAL BW SYSTEM
c-lockinc.com

GALLAGHER - AUTO WEIGHER - PARTIAL BW SYSTEM
gallagher.com

VYTELLE SENSE (GrowSafe) - PARTIAL BW SYSTEM
vytelle.com

INTERGADO - FULL BW SYSTEM
intergado.com



5. Precision Grazing & Movement Tracking

GPS Collars & Smart Tags
Track animal position, walking patterns, and activity levels in real time.
Useful for mapping pasture use, detecting lameness, or monitoring lost or isolated animals.

Virtual Fencing Systems
Use GPS and audio/electric cues to confine animals to designated zones without physical barriers. Systems like eShepherd and Nofence allow remote pasture management.

Drones & UAVs (Unmanned Aerial Vehicles)
Monitor herd behavior and pasture condition from above. Help detect injured or calving animals in remote areas.

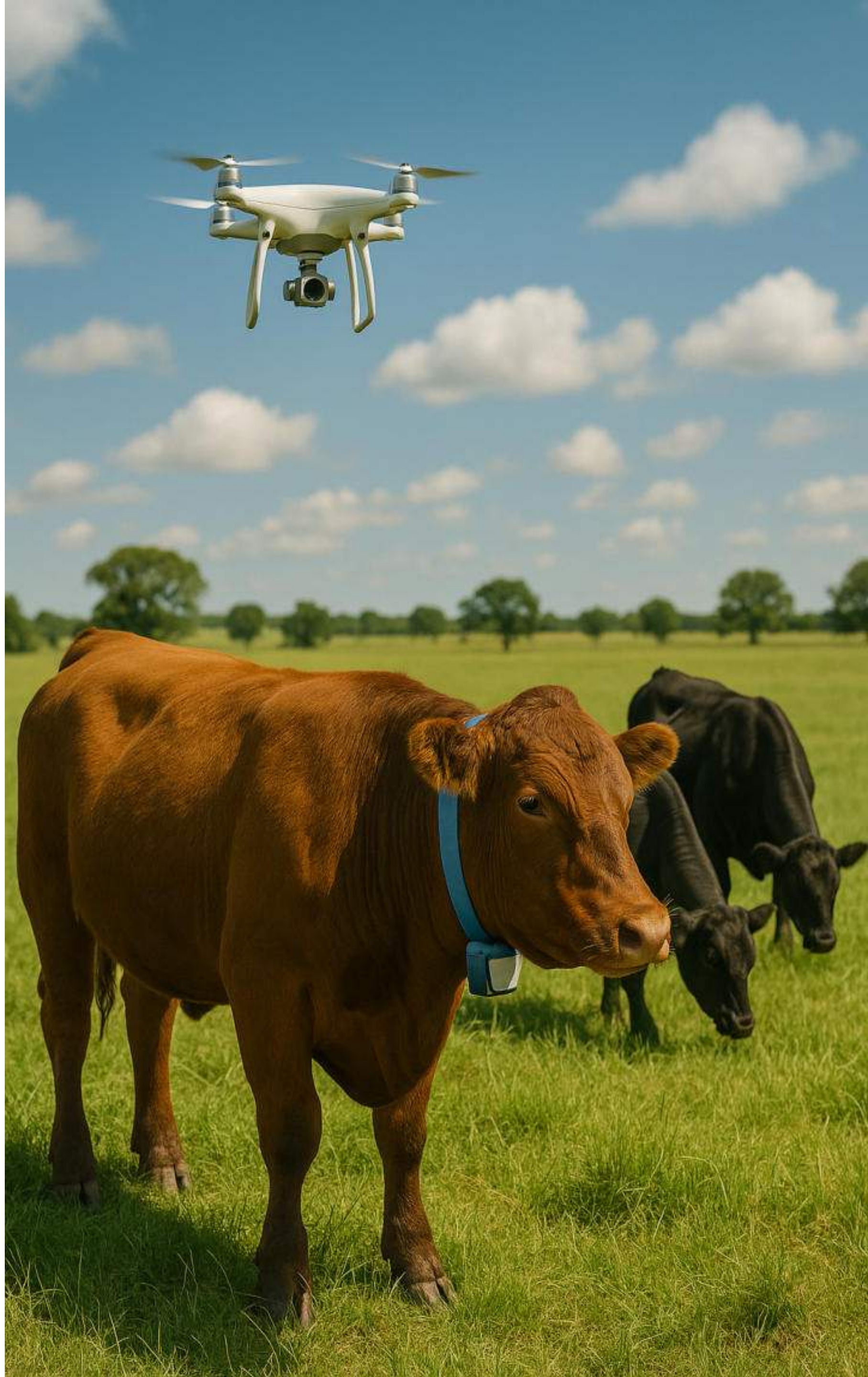
Grazing Analytics Platforms
Integrate data from GPS, weather, and forage growth models to suggest grazing rotations and rest periods.

GPS-based collars and drones combined with AI manage rotational grazing, prevent overgrazing, and optimize forage

AI-POWERED PASTURE & GRAZING MANAGEM

Optimizing grazing for rumen health using remote sensing, from collars or tags, and using virtual fencing solutions

- **SATELLITE & DRONE IMAGERY**
  - AI analyzes NDVI (Normalized Difference Vegetation Index) data to map pasture quality, identifying areas with excessively rich or poor forage
- **Virtual Fencing (e.g., Halter, Nofence, eShepherd, Vence, etc.)**
  - GPS collars are used to confine the herd to specific grazing zones without physical fences
- **Integrated Management**
  - The AI system guides grazing rotation, moving cattle to new areas to ensure balanced nutrient intake and prevent overconsumption of high-risk forage



6. Environmental Monitoring

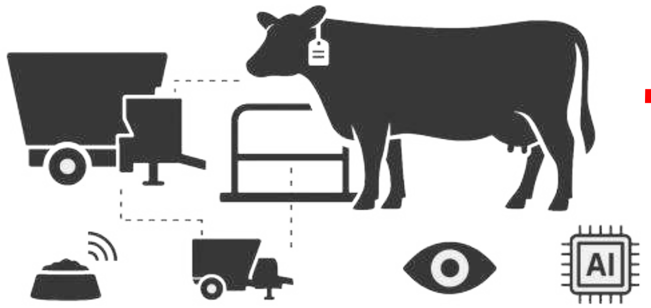
Climate Sensors
Measure temperature, humidity, air velocity, and light inside barns or pastures.
Help prevent heat stress, frostbite, or poor ventilation conditions.

Gas & Air Quality Sensors
Monitor ammonia, CO_2, methane, and dust levels—critical for respiratory health and environmental compliance.
Especially important in confined housing or feedlots.

Thermal Cameras & Imaging Systems
Detect hotspots and monitor surface temperatures of animals and equipment.
Early detection of heat stress or machinery overheating.

Data Dashboards & Alerts
Real-time visualization and remote alerts allow quick response to unfavorable conditions.
Integration with mobile apps or farm management software.

AI tools assess barn conditions like temperature, humidity, air quality, and ammonia levels, making real-time recommendations to improve animal comfort and reduce emissions



7. Feeding and Nutrition Management

Smart Feeders & Intake Monitoring Systems
Record individual intake data using RFID-linked stations.
Detect under- or over-consumption, illness, or feed refusal.
Example: GrowSafe, Insentec, or C-Lock Smart Feeders.

Automated Feed Mixers & Dispensers
Ensure accurate ration delivery with real-time weighing, mixing, and distribution.
Reduce human error and improve consistency.

Computer Vision for Feeding Behavior
Monitors time spent eating, visits to the feed bunk, and competition/aggression.
Helps assess welfare and detect early signs of health issues.

AI-Based Nutritional Modeling
Combines intake, weight gain, and environmental data to adjust diets dynamically.
Predicts the best feeding strategy for maximum gain and minimal waste.

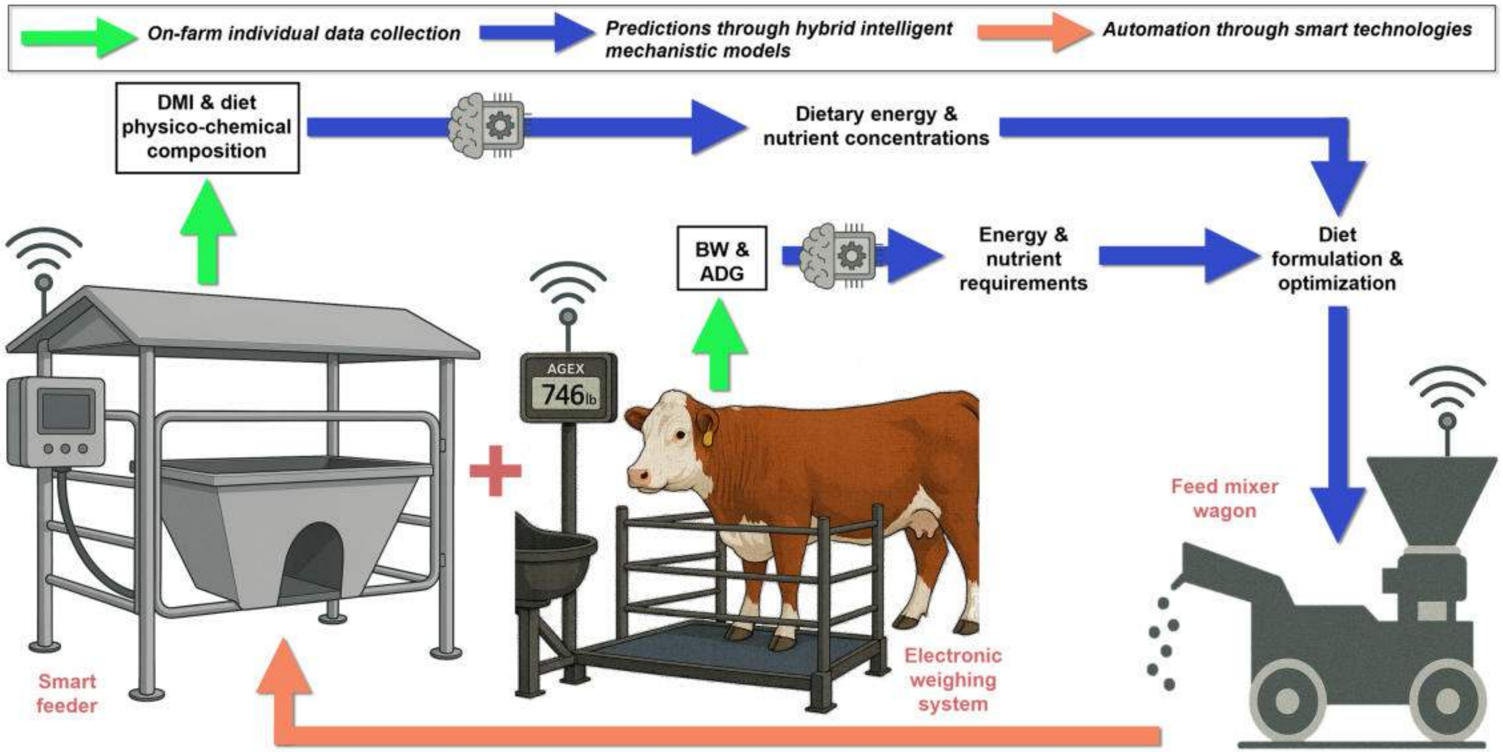
AI-integrated feeders track intake at the individual level, adjust rations dynamically, and alert managers about underfeeding or overconsumption
Smart blending systems ensure balanced, cost-effective diets

Precision Nutrition & Automated Feeding

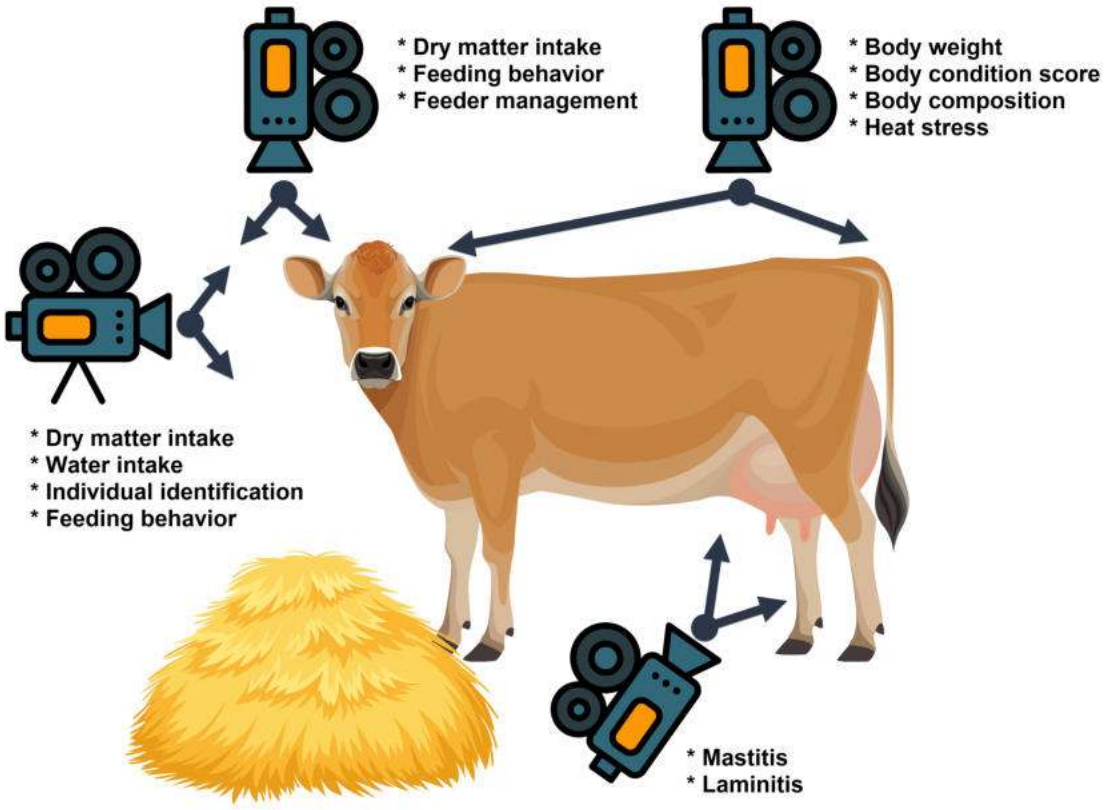
Connecting sensor data directly to feeding intake systems creates a powerful feedback loop

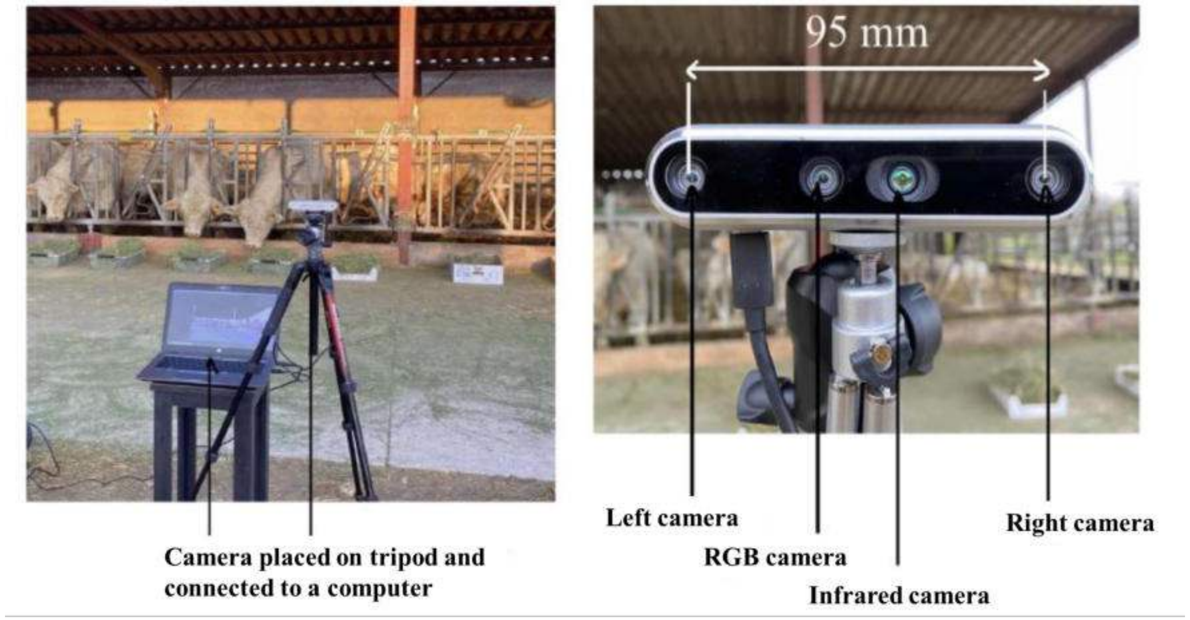
- **AUTOMATED RATION ADJUSTMENT**
  - An AI system can detect a group of cows is at high risk for SARA based on bolus pH data
  - It automatically communicates with the **robotic TMR mixer** to slightly increase the proportion of effective fiber in their next ration
- **INDIVIDUALIZED SUPPLEMENTATION**
  - Smart feeders identify an individual cow with low rumination via her RFID tag
  - The system can dispense a targeted dose of a buffer (e.g., sodium bicarbonate) or other supplements into her personal feed bin
- **BENEFITS**
  - Reduces metabolic disease incidence, improves feed efficiency, and lowers feed costs

Feeding and Nutrition Management



Tedeschi et al. (2025)



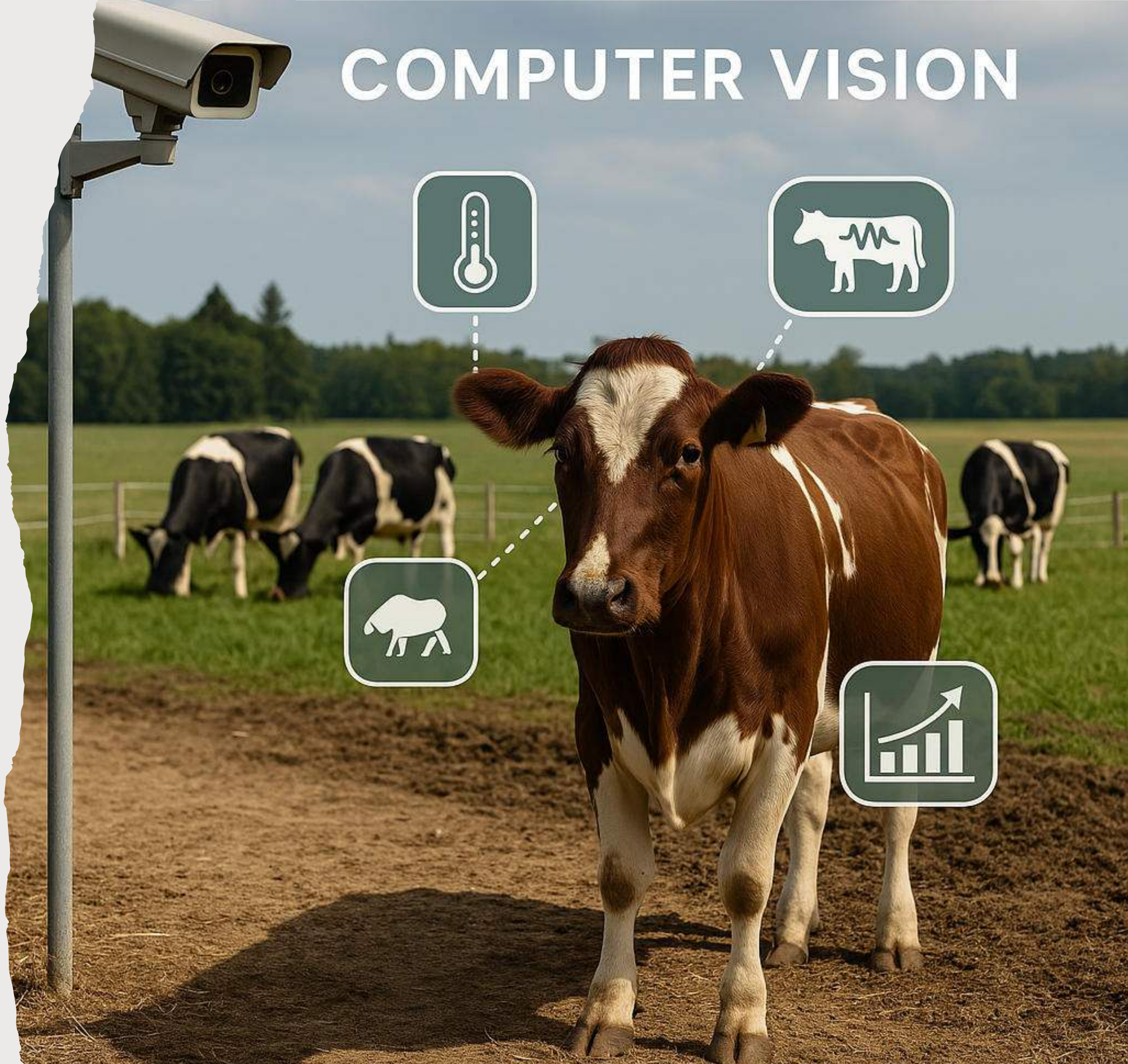


AI + Computer Vision

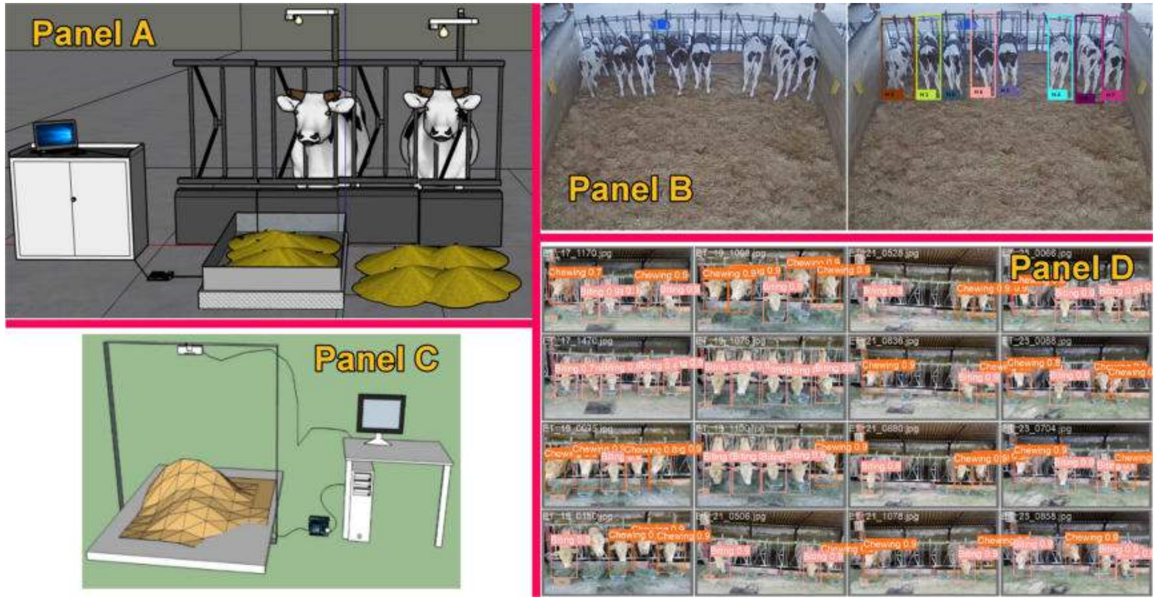
Guarnido-Lopez et al. (2024; doi: 10.1093/af/vfae028)

Computer Vision as a Potential Technology to help Decision-Making of Cattle Production

- **Non-Invasive & Stress-Free**
- **Scalable & Passive**
- **Rich Data Collection**
- **Automated & Continuous Monitoring**
- **Integration with AI**
- **Cost Efficiency Over Time**
- **Low maintenance effort**

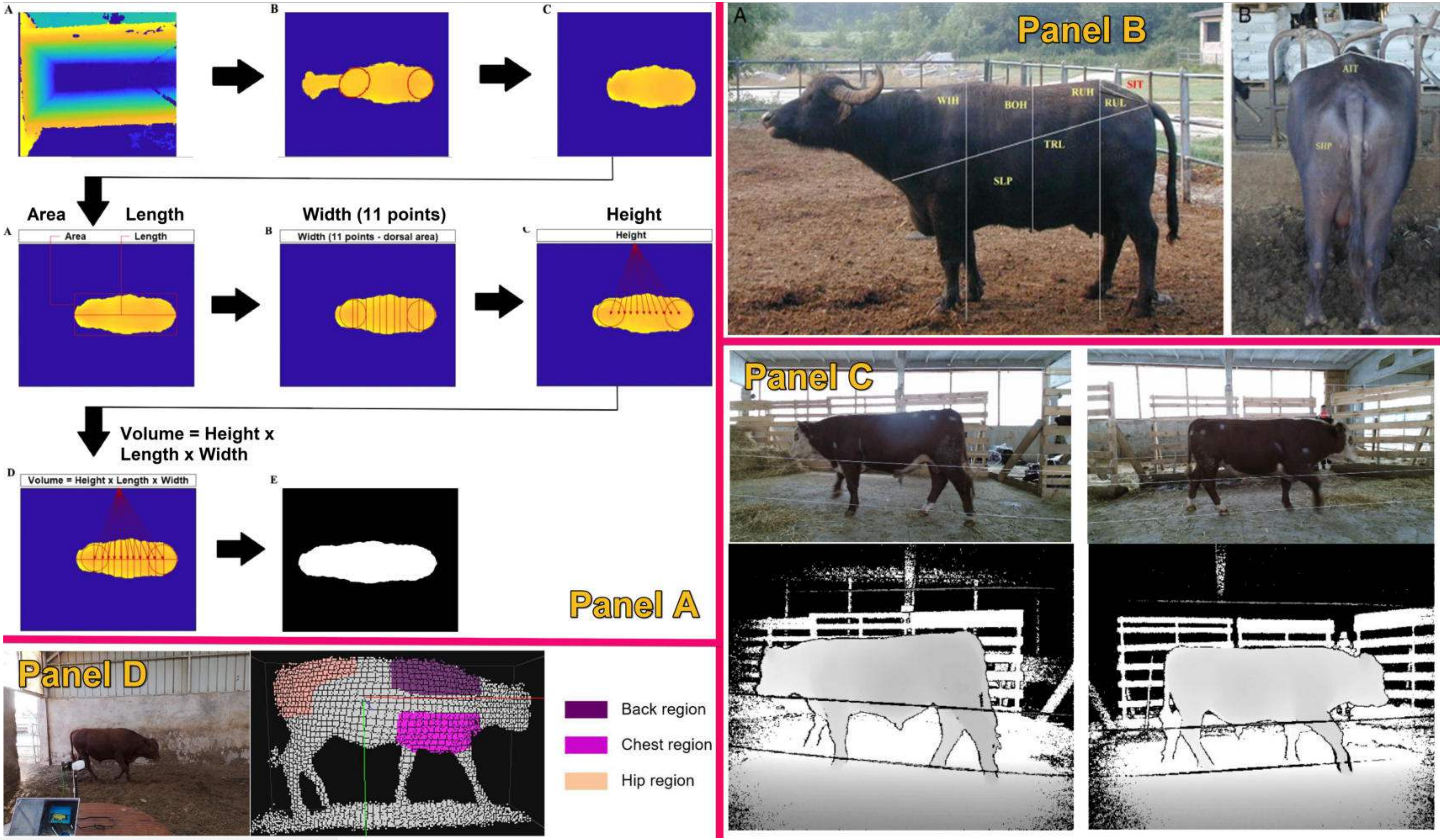


CV for Feed Intake



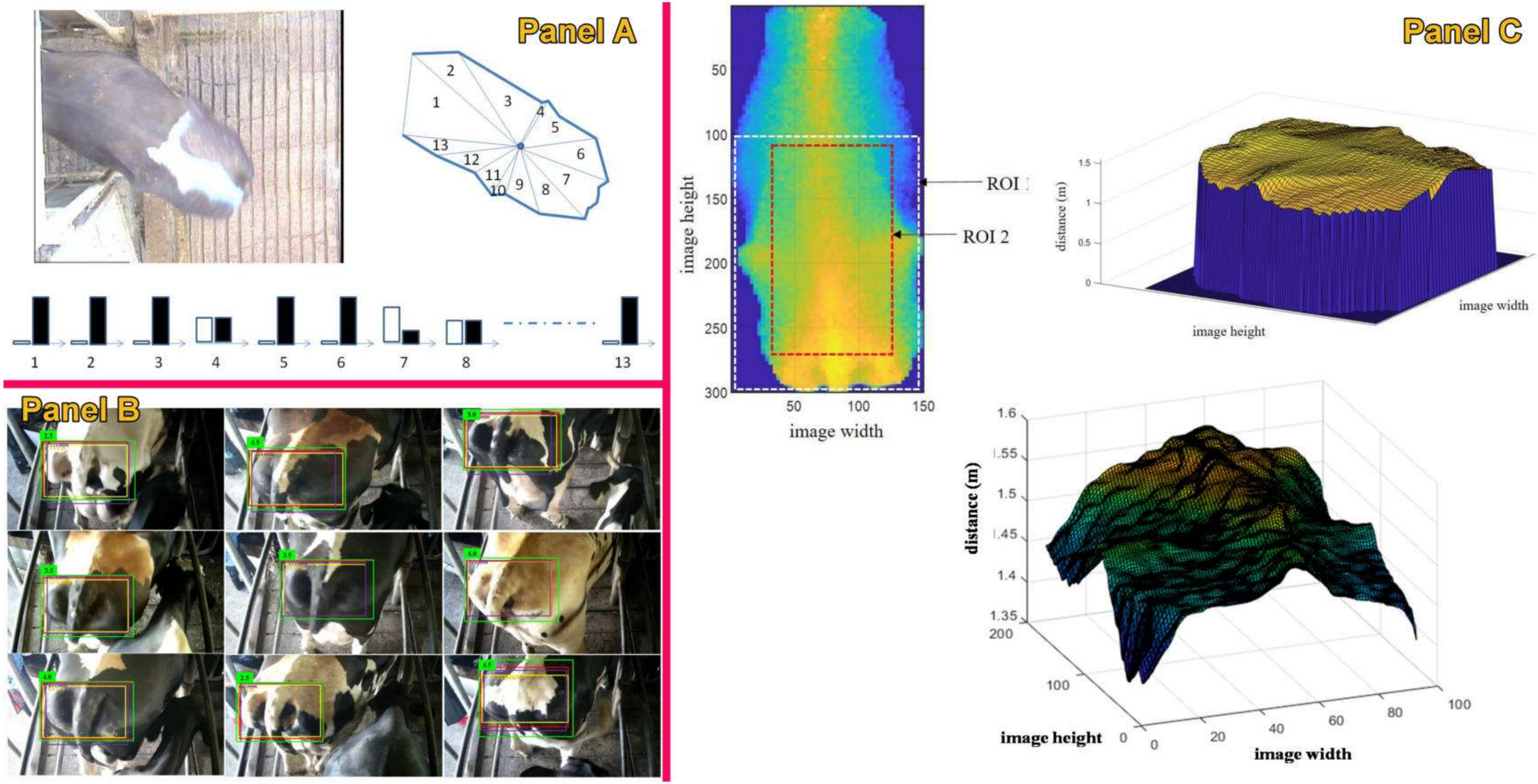
Guarnido-Lopez et al. (2024; doi: 10.1093/af/vfae028)

CV for Body Weight



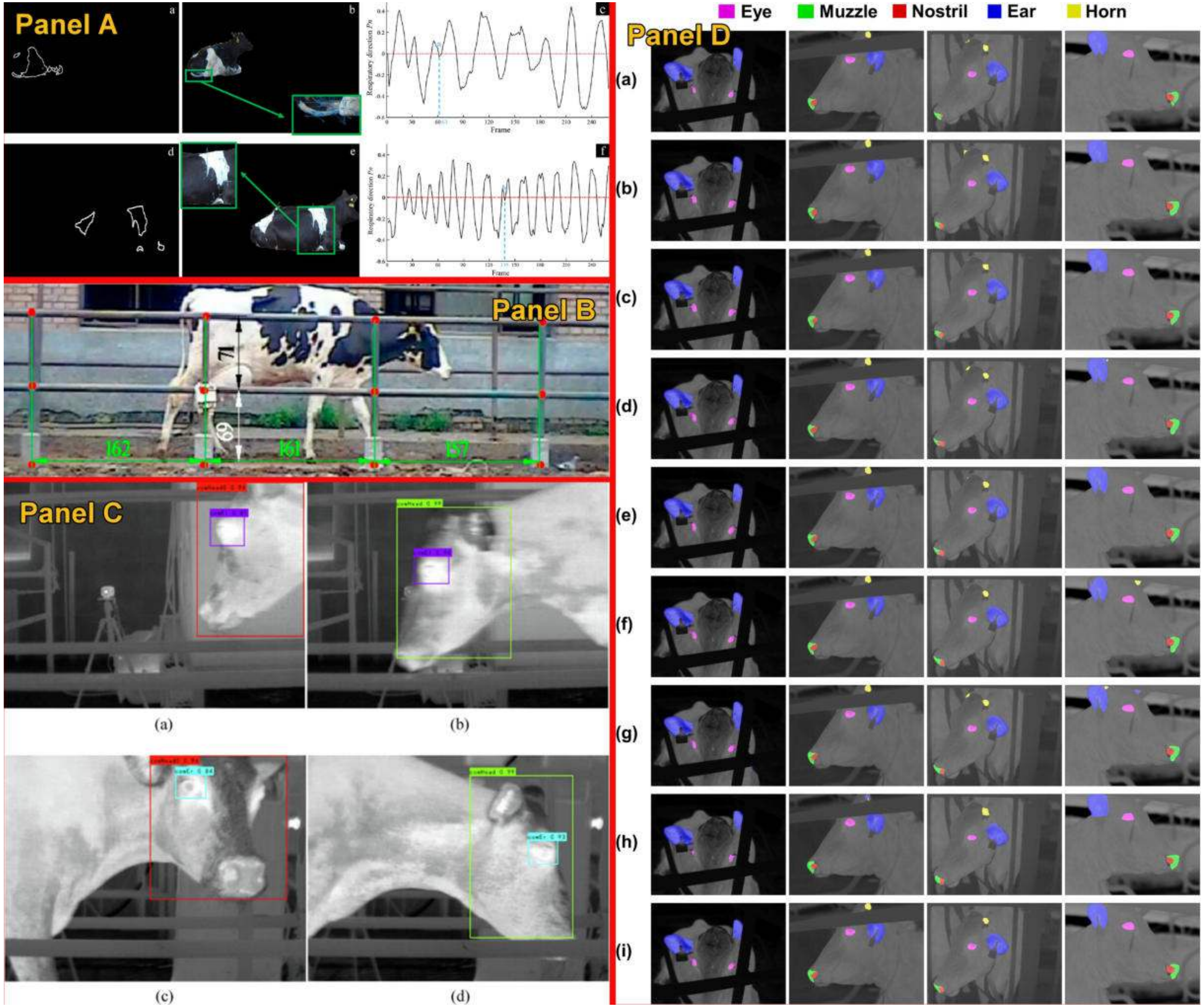
Guarnido-Lopez et al. (2024; doi: 10.1093/af/vfae028)

CV for Body Condition Score



Guarnido-Lopez et al. (2024; doi: 10.1093/af/vfae028)

CV for Health Status

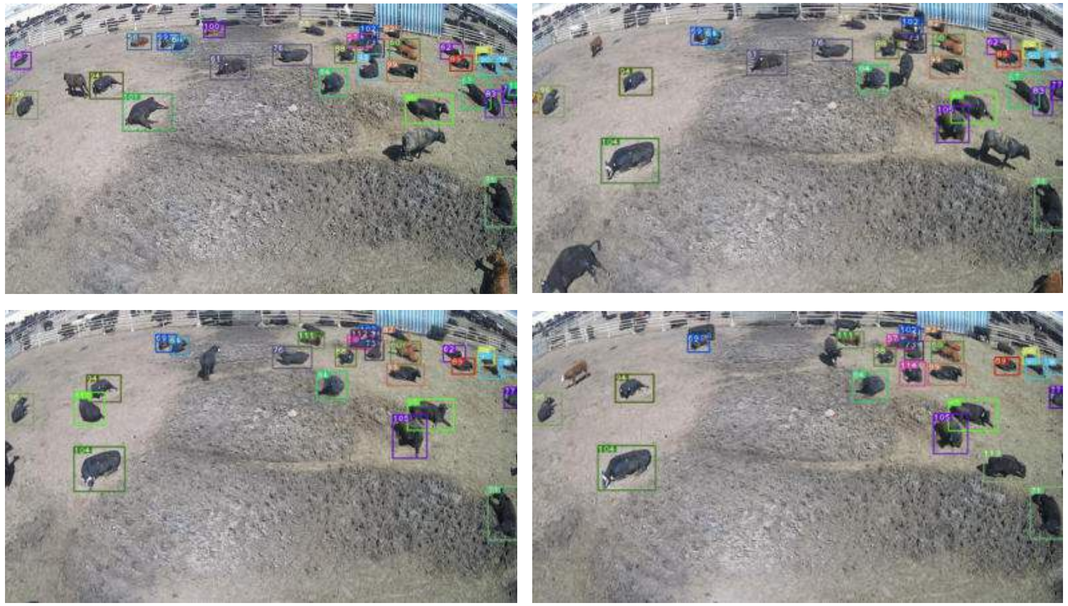


Guarnido-Lopez et al. (2024; doi: 10.1093/af/vfae028)

COMMERCIAL TECHNOLOGY AVAILABLE

PRECISION LIVESTOCK TECHNOLOGIES

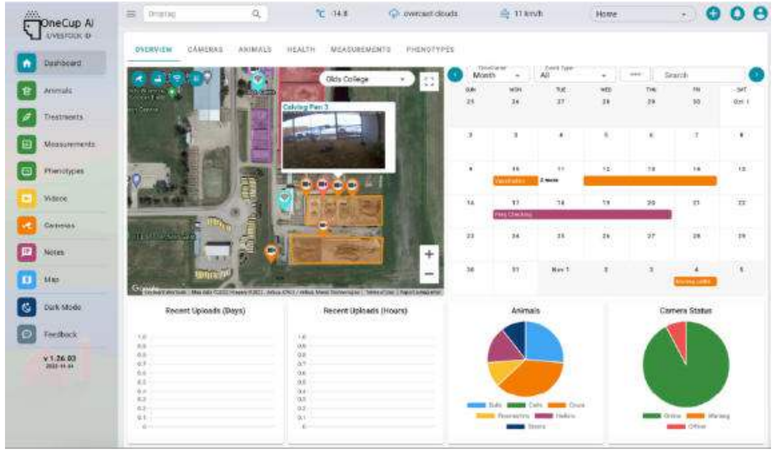
precision-livestock.com

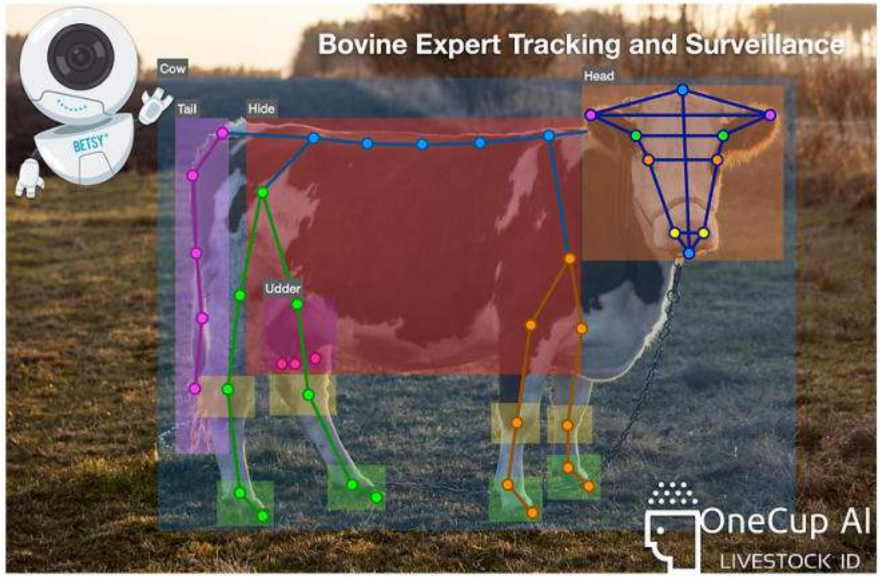


COMMERCIAL TECHNOLOGY AVAILABLE

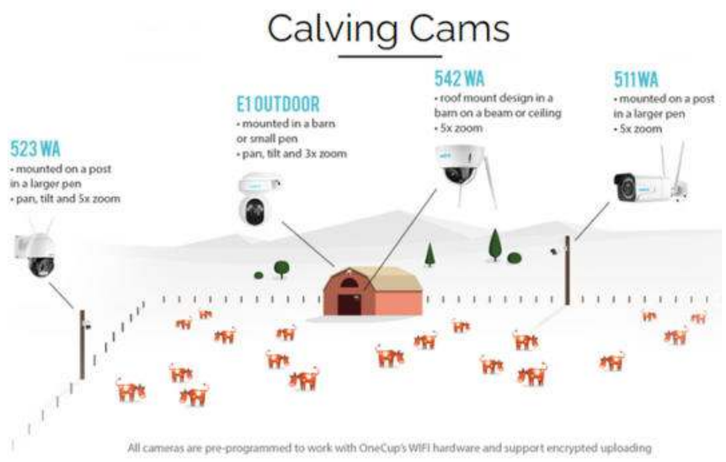
OneCup AI

onecup.ai





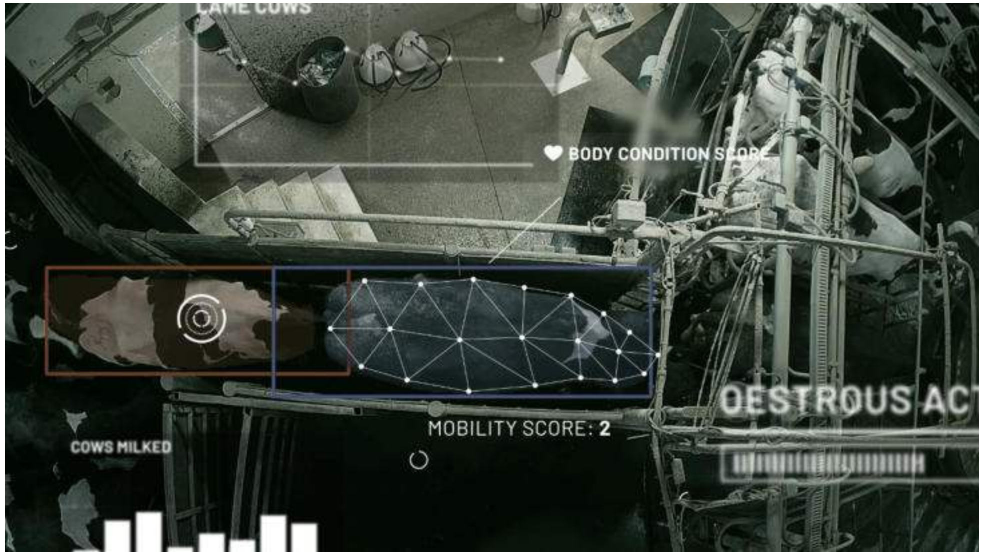
Training Model with a Digital Twin

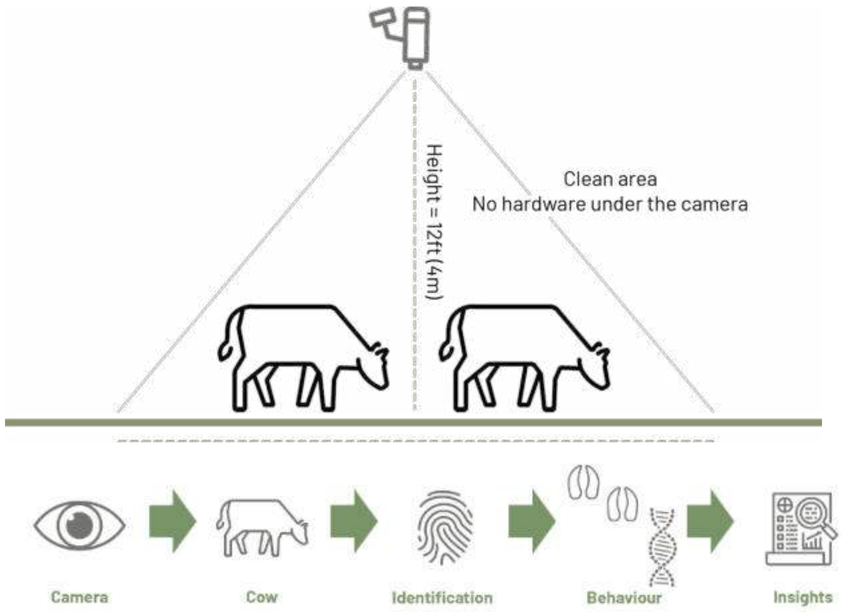


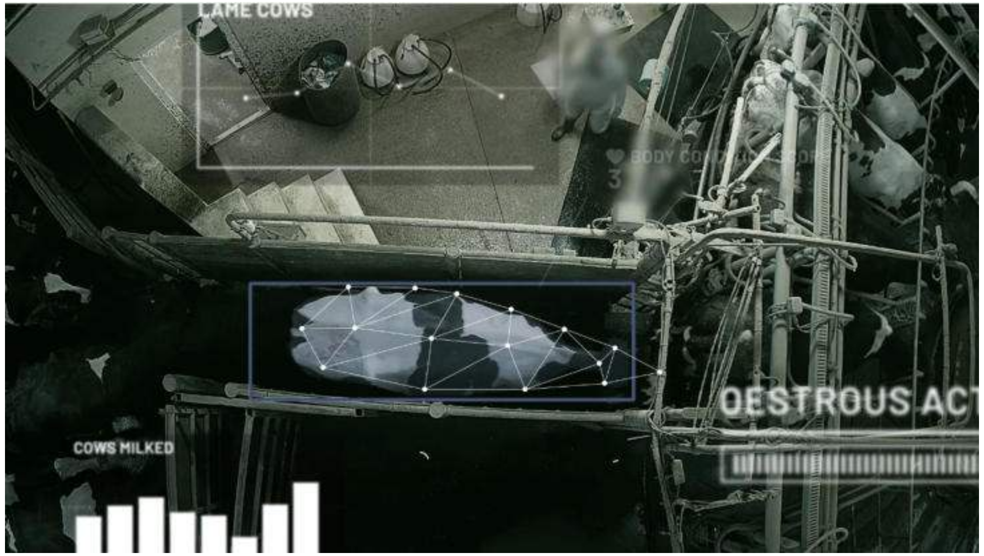
COMMERCIAL TECHNOLOGY AVAILABLE

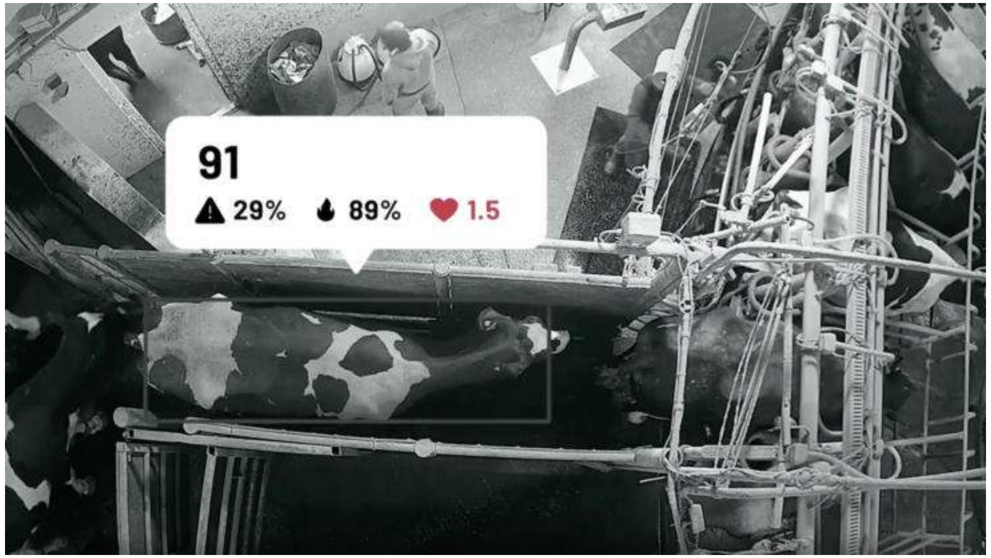
CattleEye
cattleeye.com

FOR DAIRY COWS







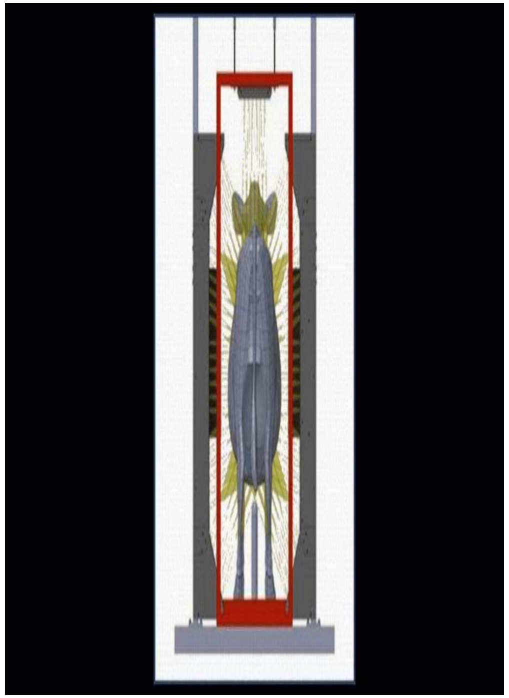


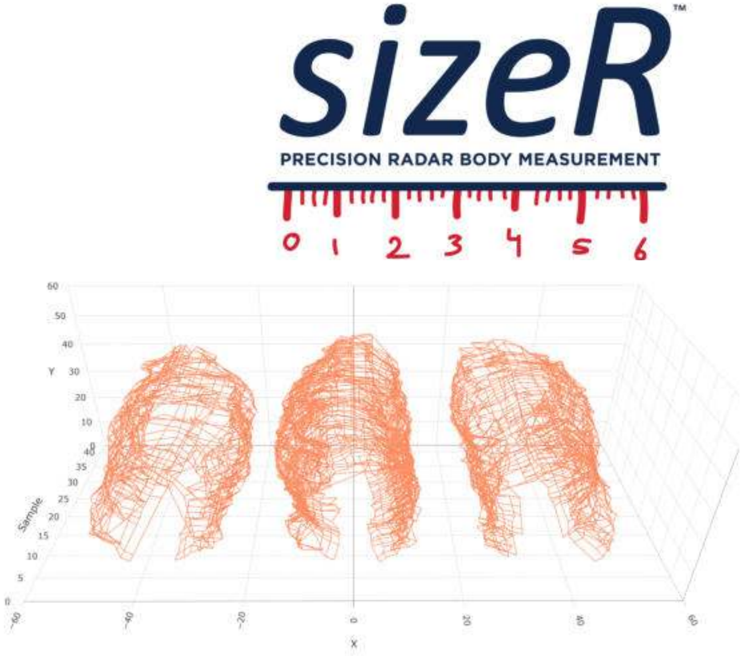
Precision Measurements of Body Biometrics

APPLICATIONS FOR PRECISION LIVESTOCK FARMING

PRECISION RADAR BODY MEASUREMENT

- Challenge: precise body measurement of animals
  - System captures and creates a 360° "blueprint" of the entire animal body
    - E.g., hip height, hip width, heart girth, shoulder height, etc.
    - Combines the metrics to provide
      - Body Surface Area, Volume, Body Condition Scores, and Weight Estimates.

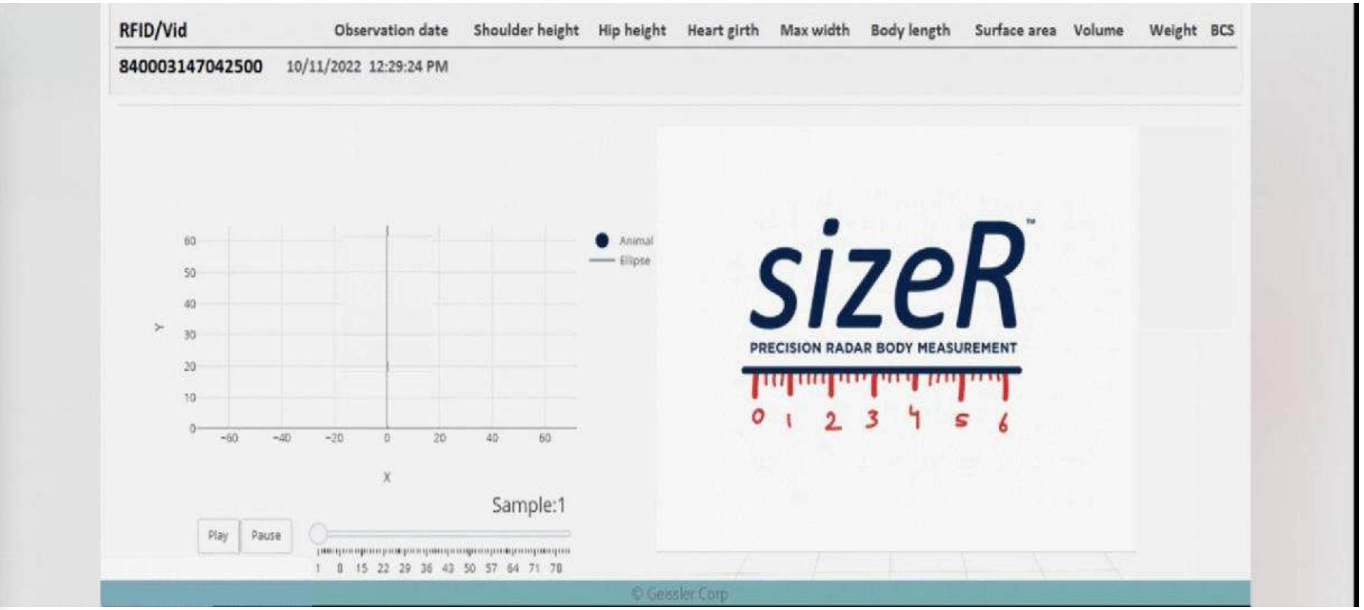


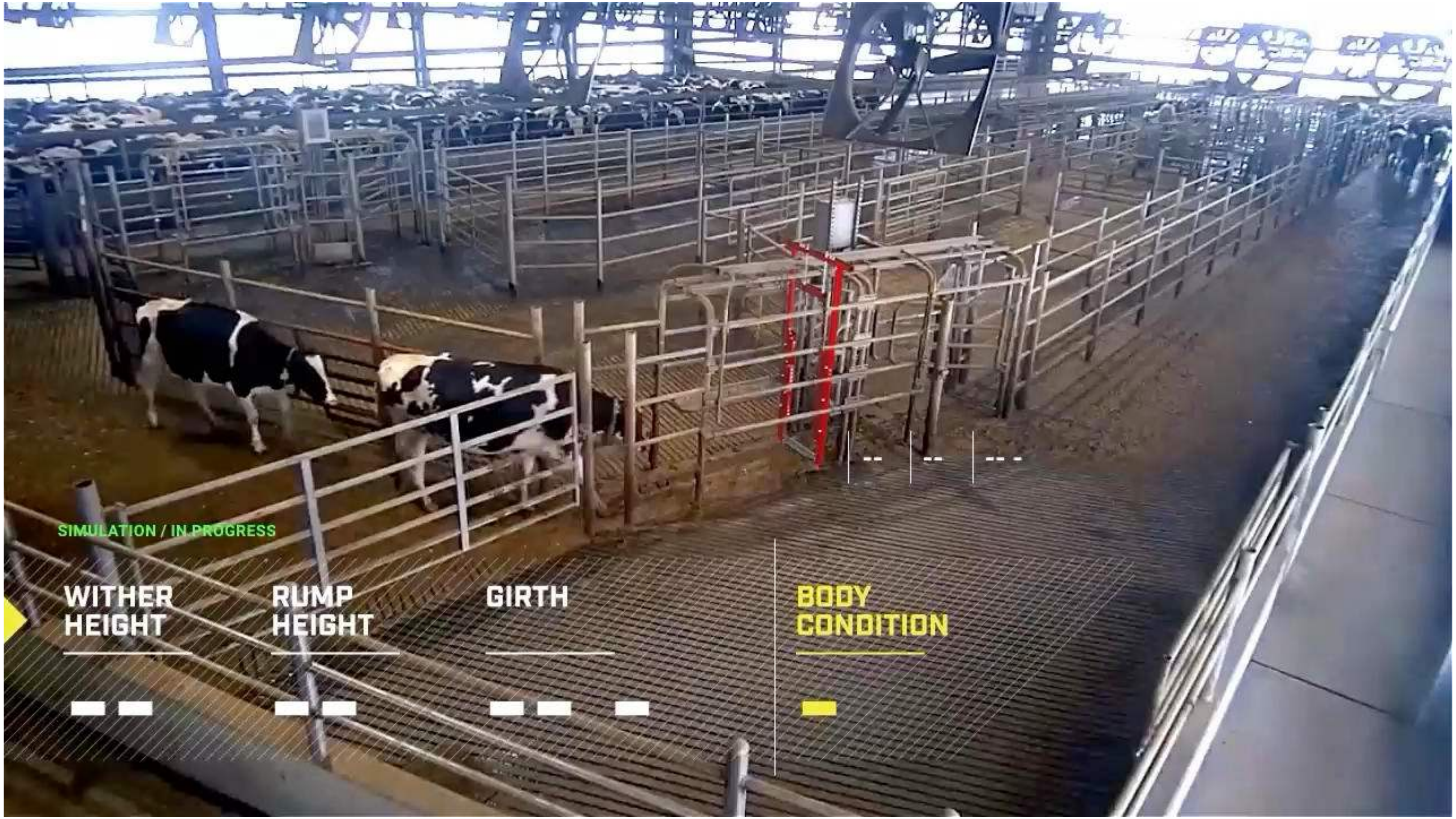


APPLICATIONS FOR PRECISION LIVESTOCK FARMING

PRECISION RADAR BODY MEASUREMENT

- 90 radar sensors operating at 60 MHz
- Produce body-specific vertical slices
    - Static precision level of ±2mm.
- Sensors are sealed
    - Not affected by environmental elements (e.g., heat, cold, humidity, dust, dirt, manure, shades / low light, etc.)





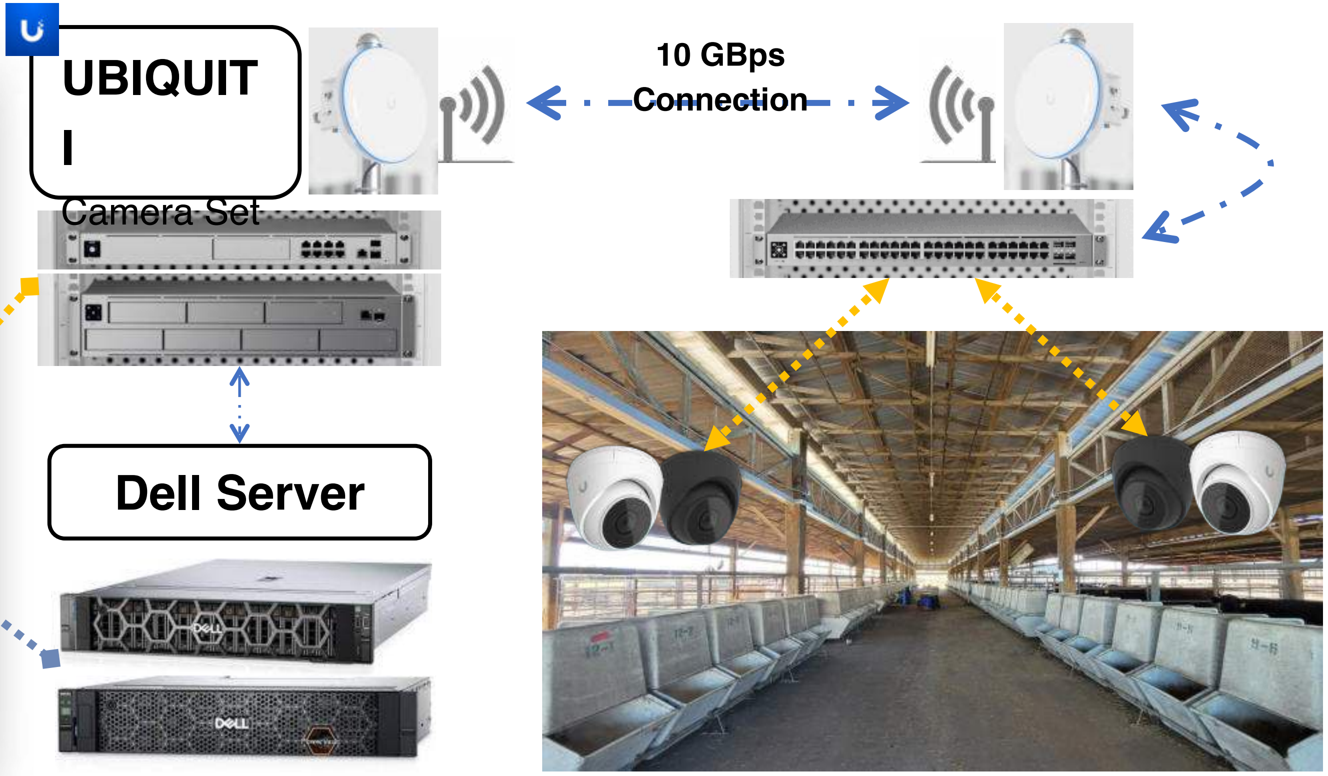
sizeR™
PRECISION RADAR BODY MEASUREMENT

Harnessing Precision Livestock Farming to Support Agriculture Smart Sustainable Beef Cattle

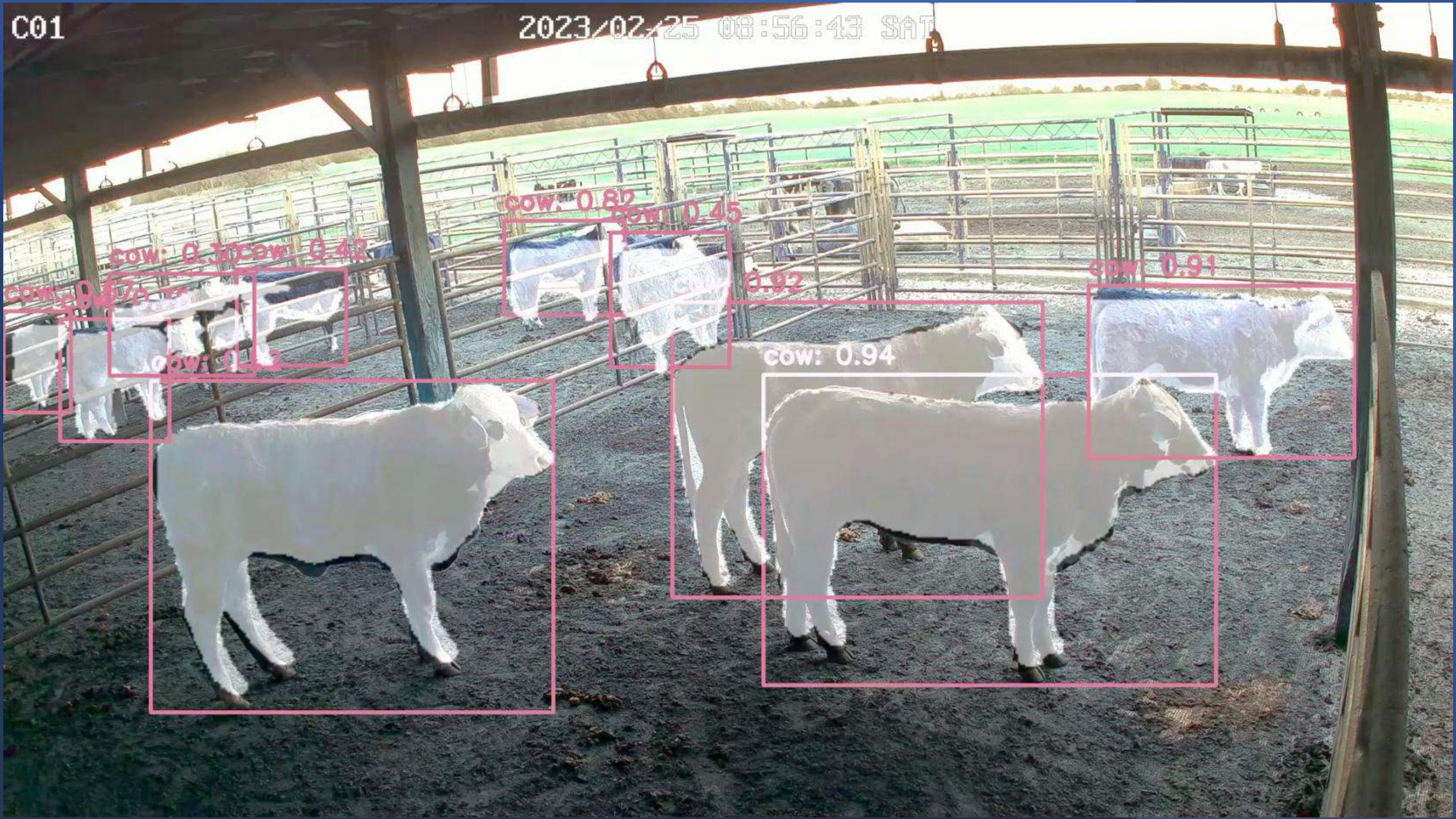
ANIMAL SCIENCE
TEXAS A&M UNIVERSITY

Dell PowerEdge R760 Server
Dell PowerVault ME5012 Storage Array

80 cameras (Ubiquiti-Unifi)



Pi et al. (2023; 10.20944/preprints202307.0705.v1)



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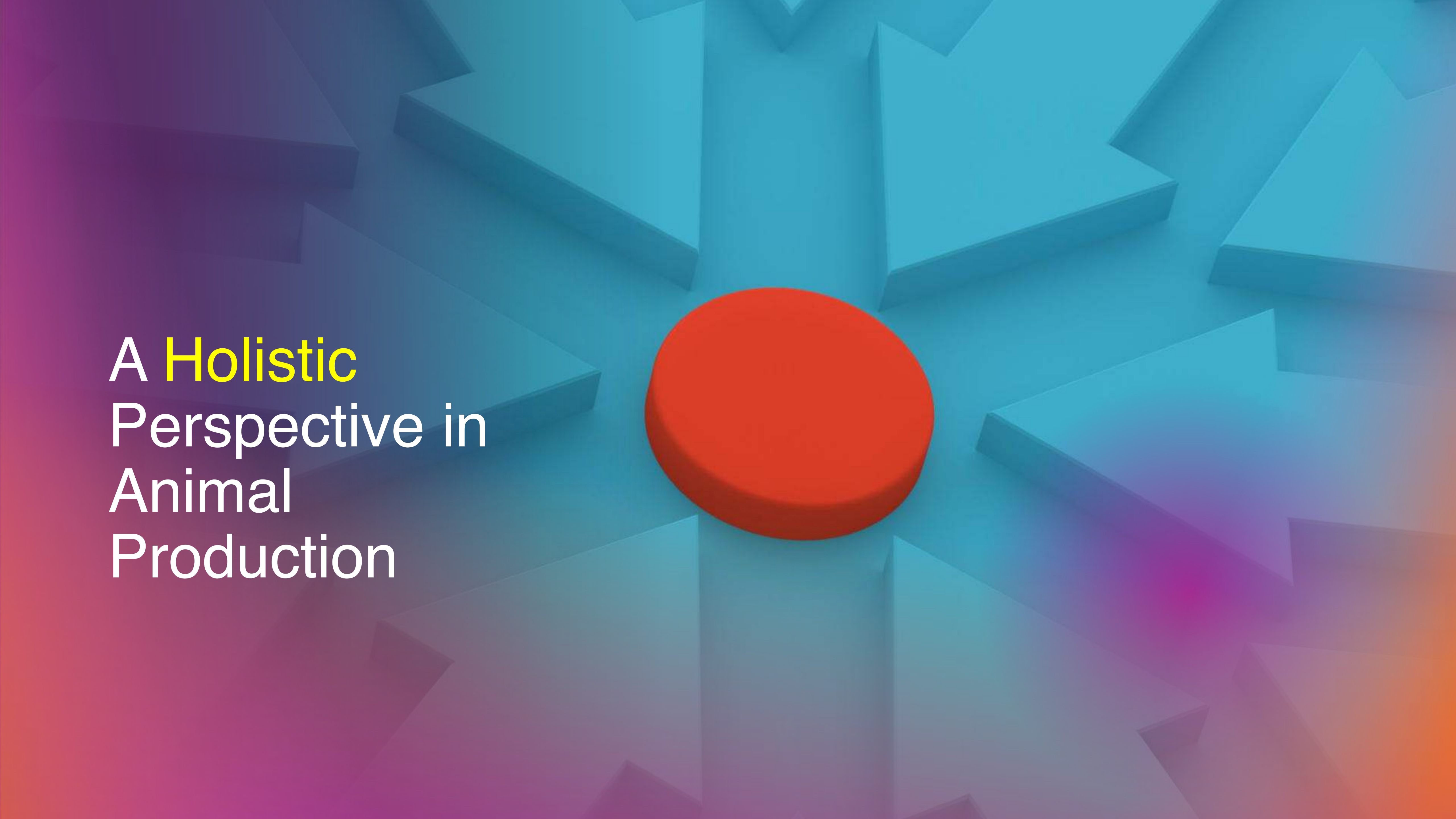

A Holistic
Perspective in
Animal
Production

The Integrated Data Ecosystem

The true power of PLF is unlocked when all systems are connected.

DAIRY CATTLE EXAMPLE

DATA INTEGRATION

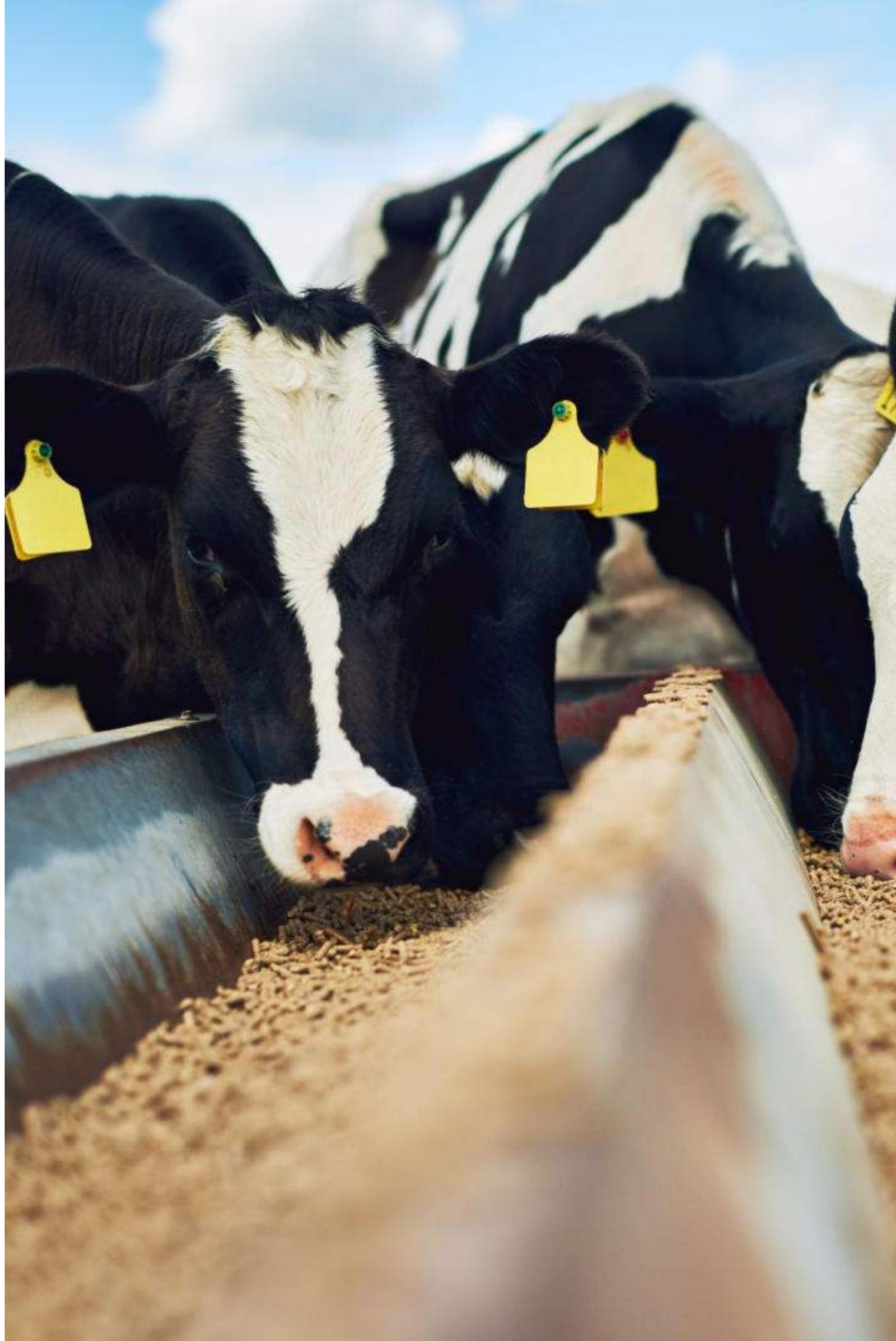
- Information from automatic milking systems (milk yield, components), health sensors (rumination, pH), and feeding robotics (intake) are merged

HOLISTIC VIEW

- The AI agent analyzes the complete dataset for a single animal.
    - **Example:** A drop in milk fat % from the milking robot, combined with low rumination from a collar and reduced feed intake, generates a high-confidence alert for acidosis

AUTOMATED FARM MANAGEMENT

- The AI agent can help run the farm by flagging animals for inspection, suggesting ration changes, or even sorting animals automatically



AI-POWERED PASTURE & GRAZING MANAGEM

Optimizing grazing for rumen health using remote sensing, from collars or tags, and using virtual fencing solutions

- **SATELLITE & DRONE IMAGERY**
  - AI analyzes NDVI (Normalized Difference Vegetation Index) data to map pasture quality, identifying areas with excessively rich or poor forage
- **Virtual Fencing (e.g., Halter, Nofence, eShepherd, Vence, etc.)**
  - GPS collars are used to confine the herd to specific grazing zones without physical fences
- **Integrated Management**
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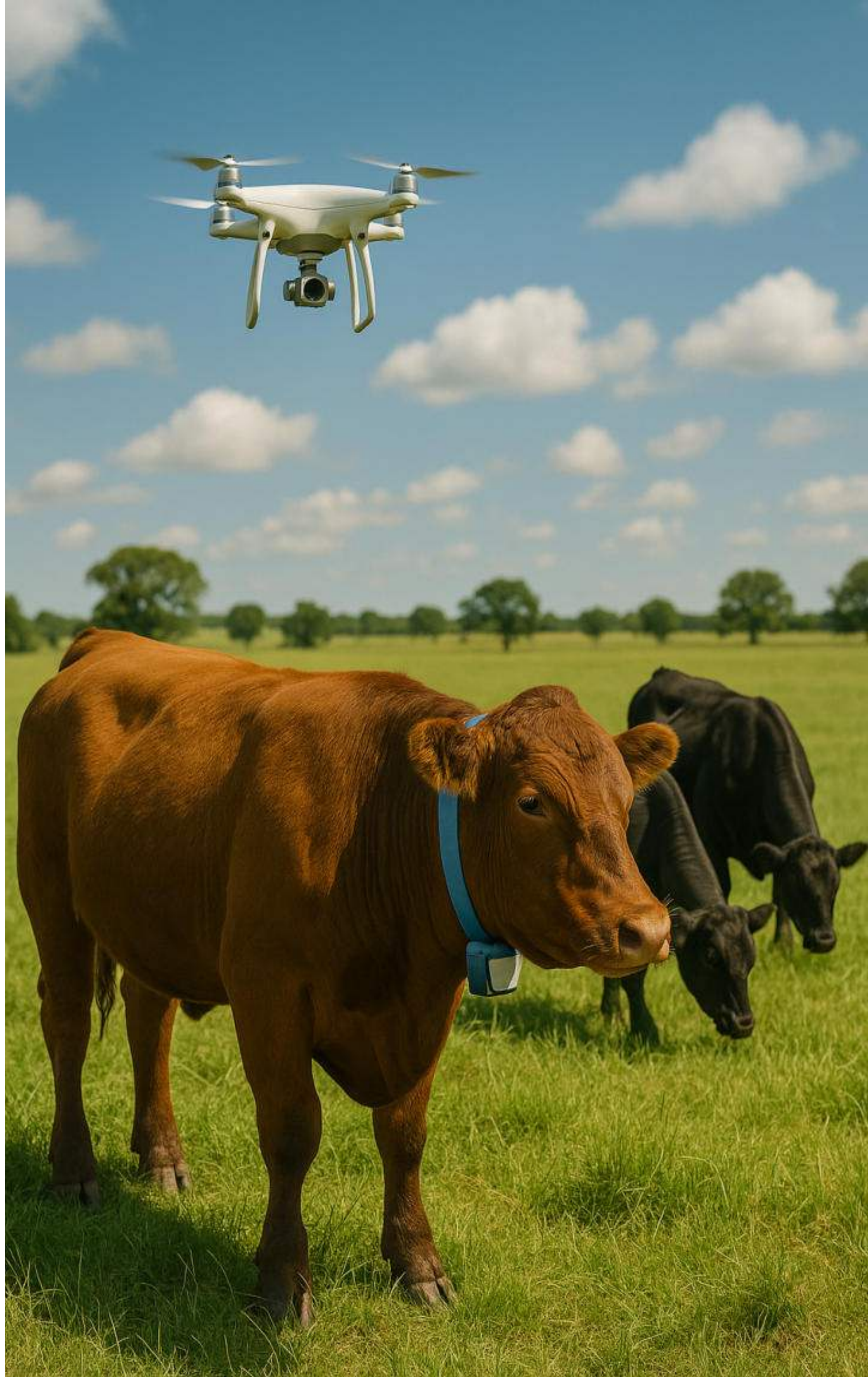
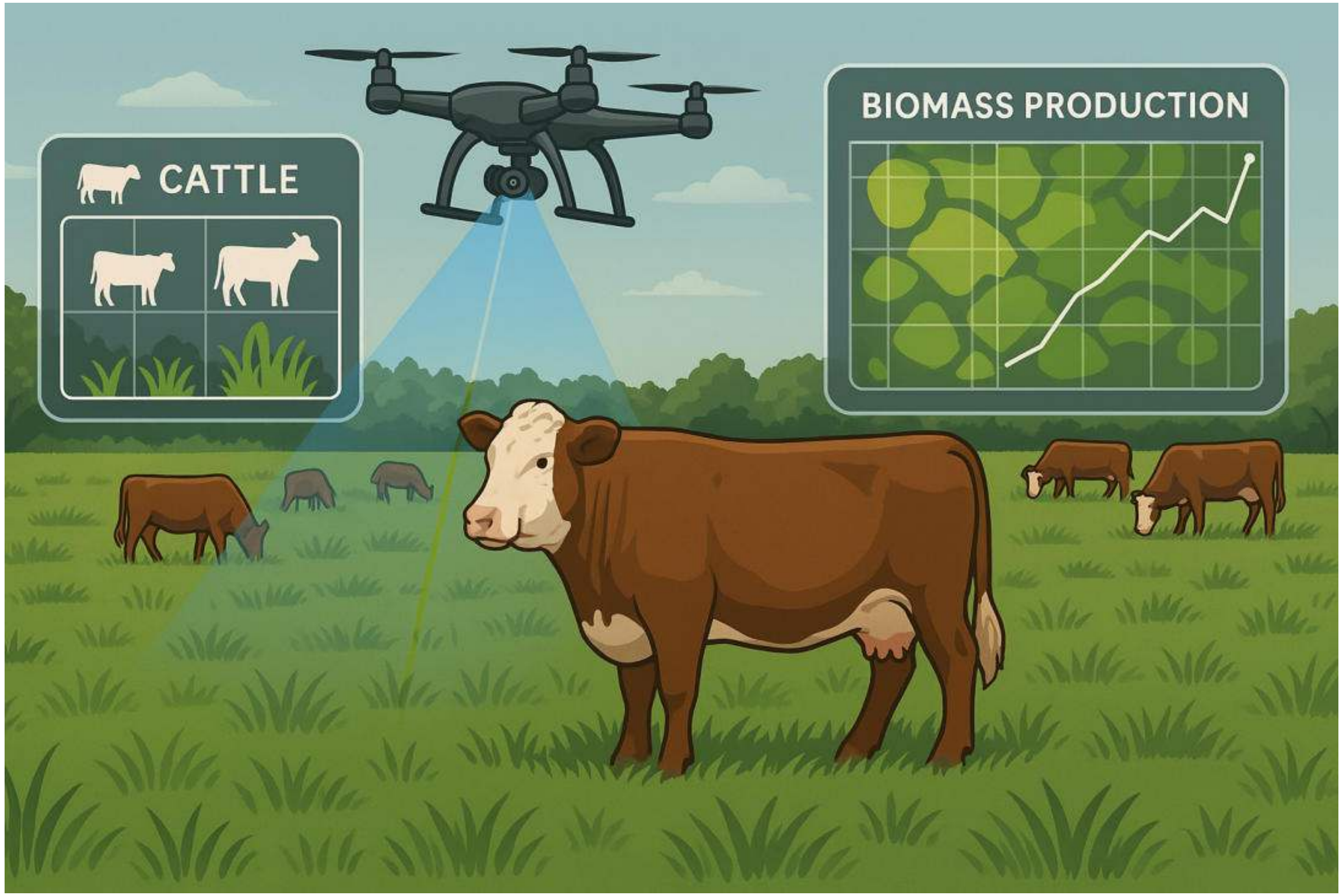
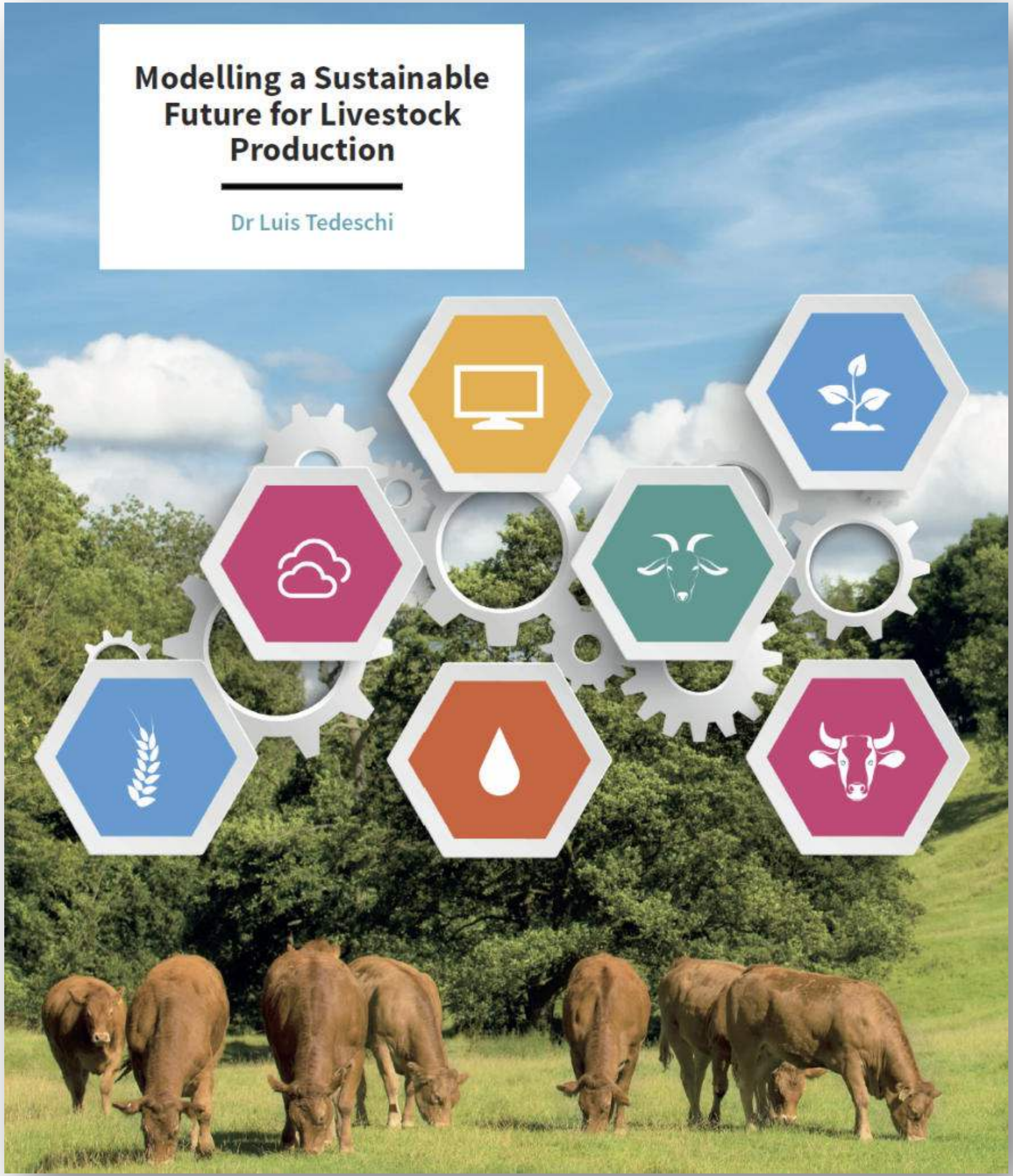


Possibilities of CV bringing together animal and agriculture science

- **Drone Flight Over Pastures**
  - Captures high-resolution RGB, multispectral, or NDVI images
- **Computer Vision & AI Models**
  - Analyze grass coverage, growth stage, and biomass production
  - Predict areas of high forage potential
- **Animal Science Integration**
  - Data feeds into livestock management software
  - Guides cattle movement, stocking rates, and supplemental feeding
- **Synchronized Management**
  - Supports **smart grazing** based on both animal behavior and pasture growth
  - Enables precision matching of **supply (grass)** and **demand (nutritional needs)**





The NEXT Scientific Breakthrough: Sensors + IoT + Machine Learning

Tedeschi, L. O. 2020. Modelling a sustainable future for livestock production. Scientia. (134):88-91. doi: 10.33548/SCIENTIA523

COMPUTER VISION APPLICATIONS FOR LIVESTOCK

CattleQuants

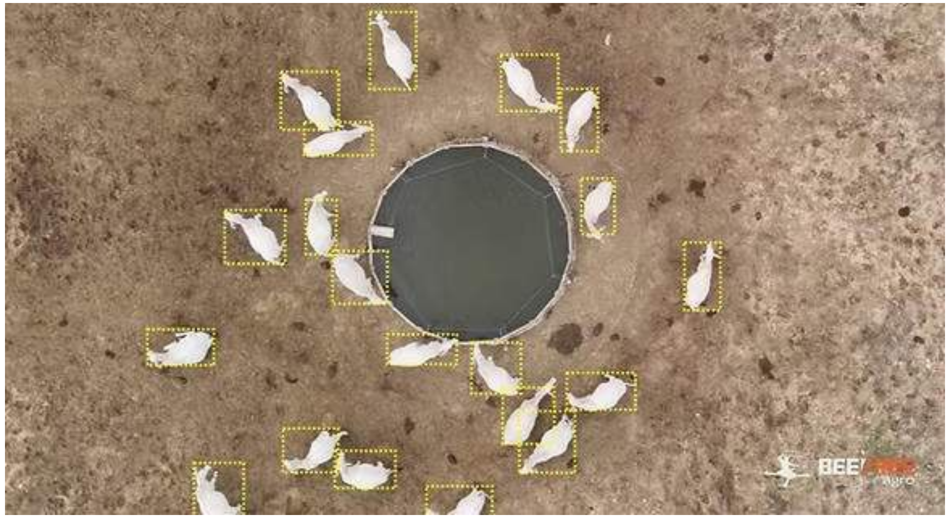
Automated Drone-Based Cattle Counting

cattlequants.com

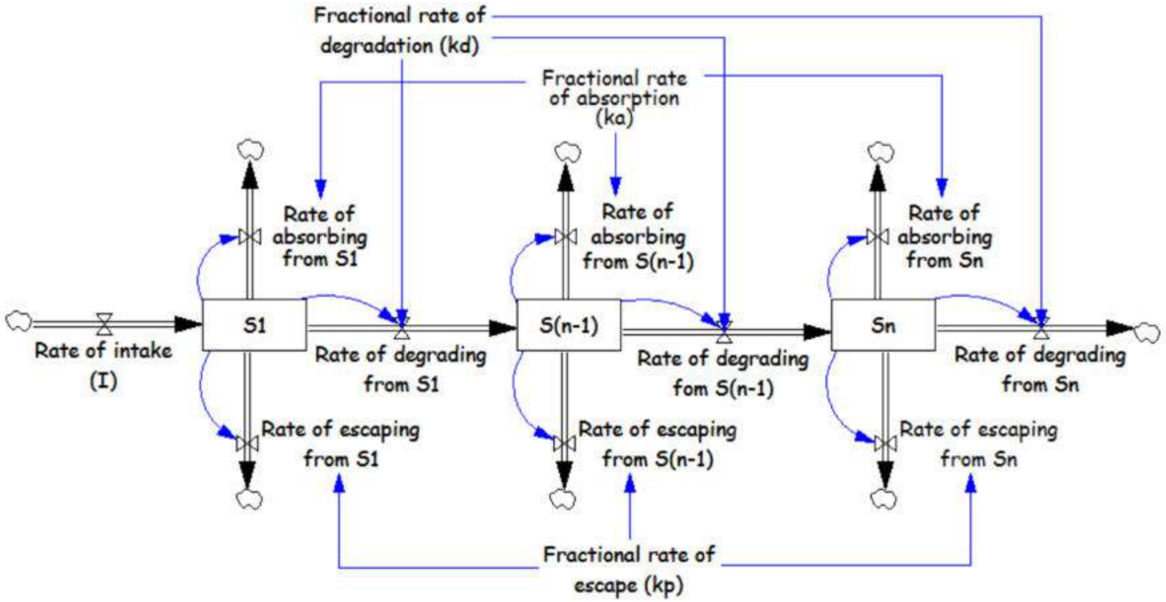
BeeFree Agro

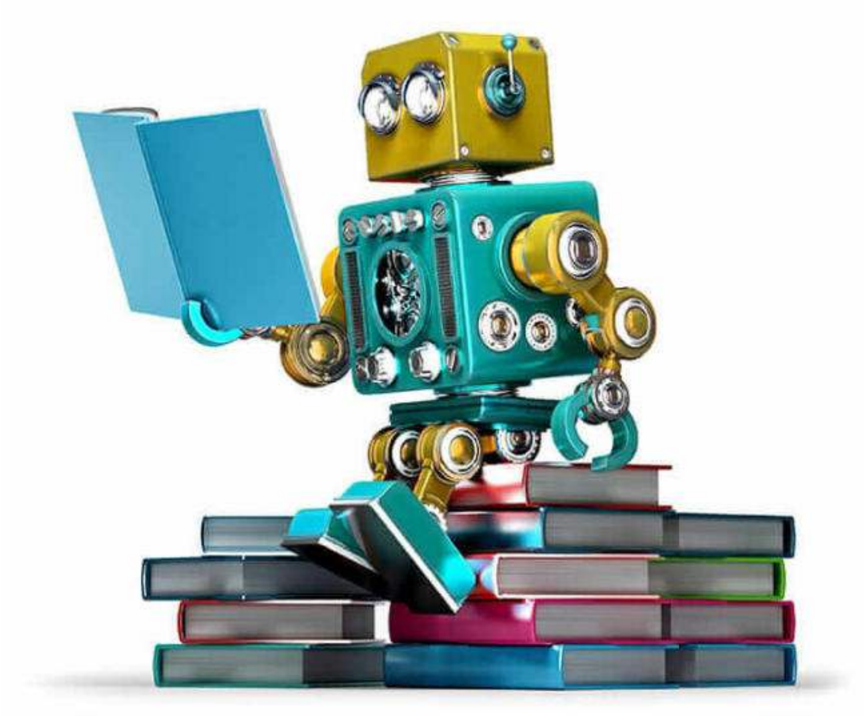
Drone-based precision livestock technology

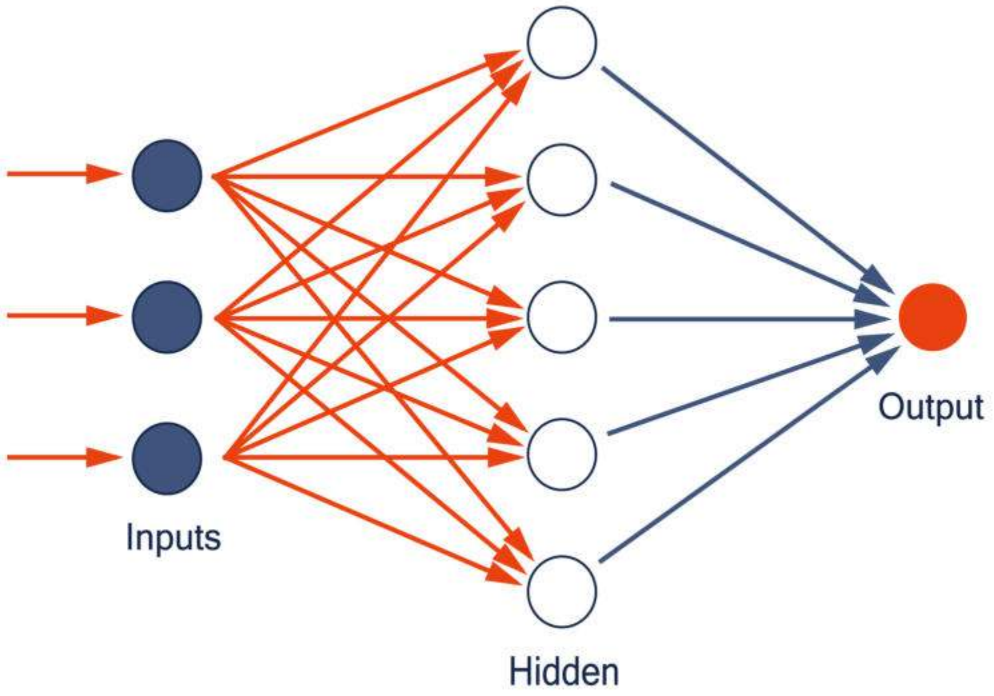
beefreeagro.com



From Mechanistic Modeling to Machine Learning

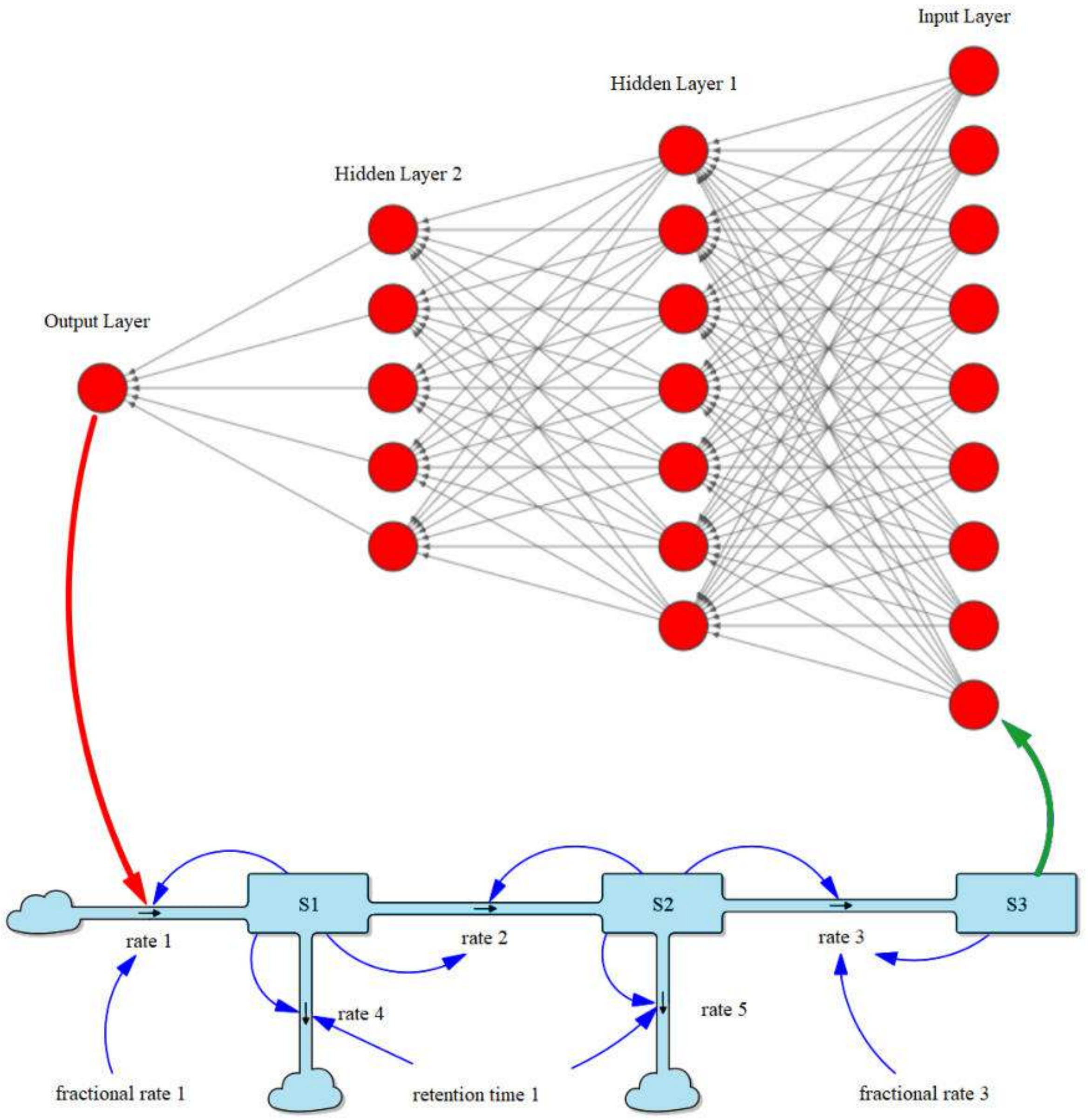






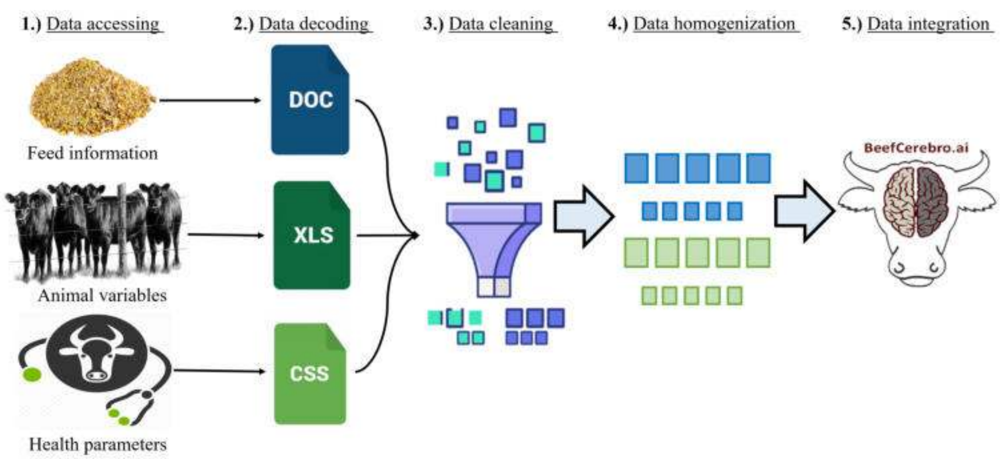
Hybrid Intelligent Mechanistic Models

1. AI is embedded in the MM, and its primary purpose is to predict variables needed by the MM. AI is assisting the user to obtain variables that might be affected by multiple factors, and one can hardly guess its value without causing the type II error, i.e., accepting an incorrect value for the variable (Dean and Voss, 1999; Tedeschi, 2006), which has often been extrapolated to the type III error, i.e., using an irrelevant model (in our case variable value) and believe the outcome is true when, in fact, the model (or the variable) answers the wrong question or has the wrong value (Kimball, 1957; Kuhn and Johnson, 2013; Sokolowski and Banks, 2009)
2. MM embedded in the neural structure of the AI model. MM is used to estimate an input to the AI model, but multiple MM variables could be linked into different parts of the AI structure. It is based on the fact that MM are developed based on



Tedeschi (2022; J. Anim. Sci. 100:1-11. doi: 10.1093/jas/skac111)

AI is the Glue of Big Data: The **BeefCerebro.ai**



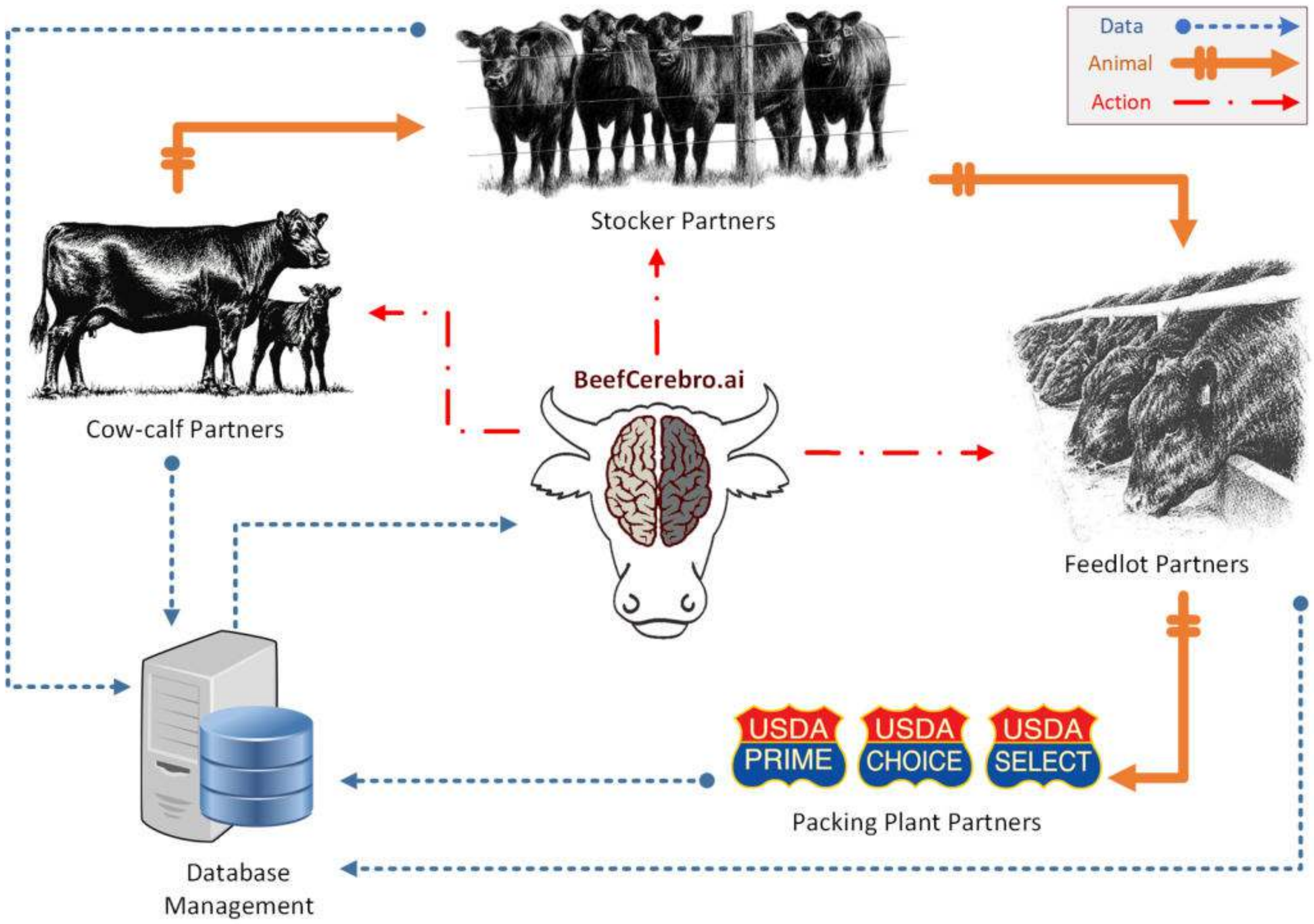
•**Animal-Level Data:** Health, behavior, rumination, weight, reproductive status

•**Feeding & Intake Data:** Feed consumption, ration efficiency, feeding behavior

•**Movement & Location:** GPS tracking, activity levels, pasture occupancy

•**Environmental Parameters:** Temperature, humidity, gas levels, ventilation status

•**Forage & Field Data:** Biomass maps, NDVI, pasture quality and regrowth estimates



Thank You!

TEXAS A&M AGRILIFE RESEARCH

TEXAS A&M UNIVERSITY