Animal Welfare Assessment using PLF

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Structure of the lecture

- **Animal Welfare Indicators**
- Animal behaviour
- Available technologies
- Potential and challenges

Animal Welfare Indicators

Environment

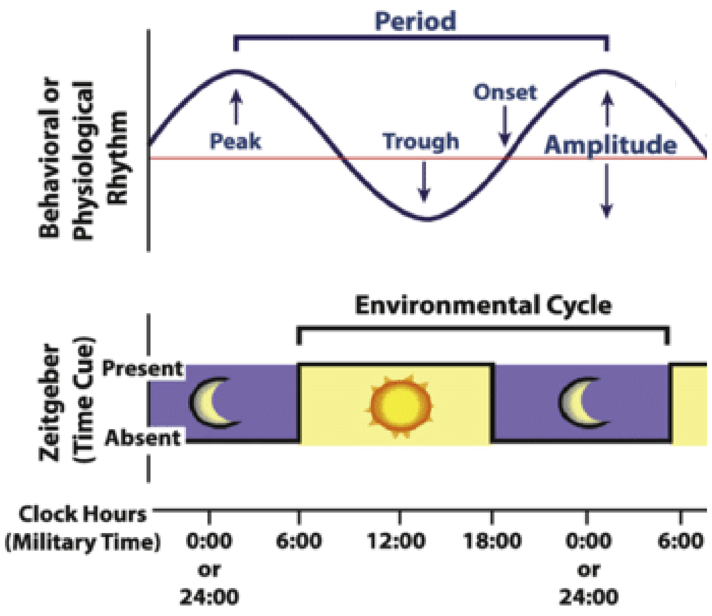
- Risk factors
- Easy to measure
  - Require less time / resources
  - Require less training
- May not reflect the welfare

Phenotype

- Response of the animal
- More time and resources
- Higher specificity and sensitivity

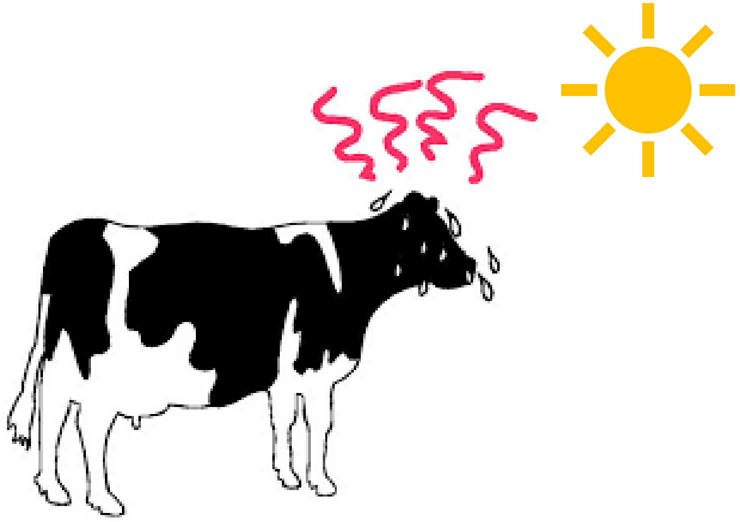
Behavioural indicators

- Patterns of normality(e.g. feeding)
- Abnormal behaviour(e.g. stereotipies)
- Natural Behaviour (foraging in pigs)



The organic response

- The phenotype informs on how an animal adapts to environment
  - Environemntal challenge(body temperature)
  - **Animal Health** (ruminal acidosis)
  - Physiologic and metabolic status

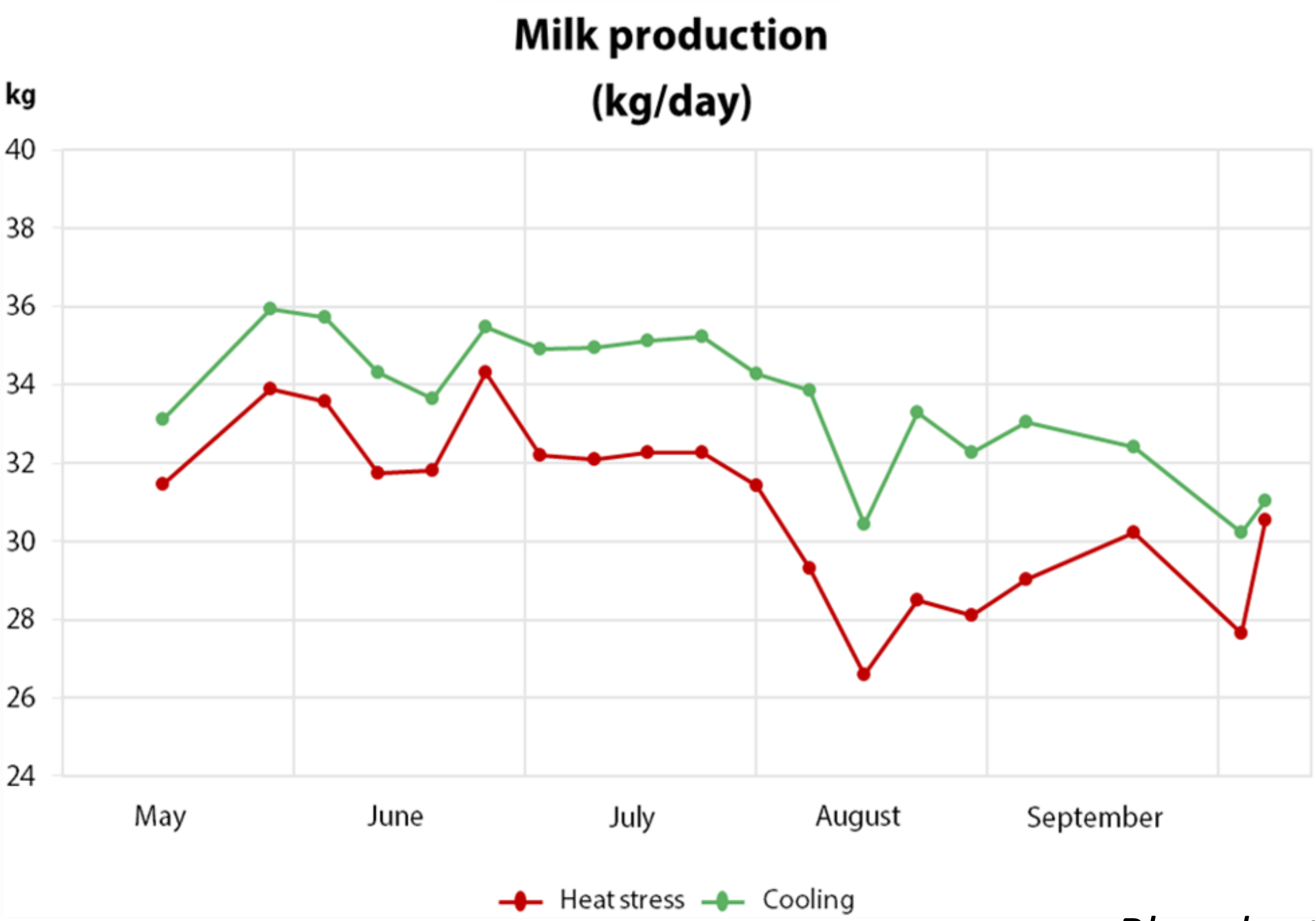


Performance indicators

- Performance is likely the dimension that has been mostly phenotyped in Livestock animals
- It allows inferring the adaptability to the environment, based on the principle that a healthy animal produce more.

- Milk yield (kg/día)
- % protein and fat
- Growth (GMD)

Performance indicators



Rhoads et al., 2009

Structure of the lecture

- Animal Welfare Indicators
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- Potential and challenges

Behaviour as a phenotypical trait

- Behaviour is a very elastic trait
- Very sensitive to changes on the environment
- … but also to intrinsic changes of the animal
  - Health
  - Reproductive status
  - Emotional status

Dimensions of behaviour

Feeding behaviour

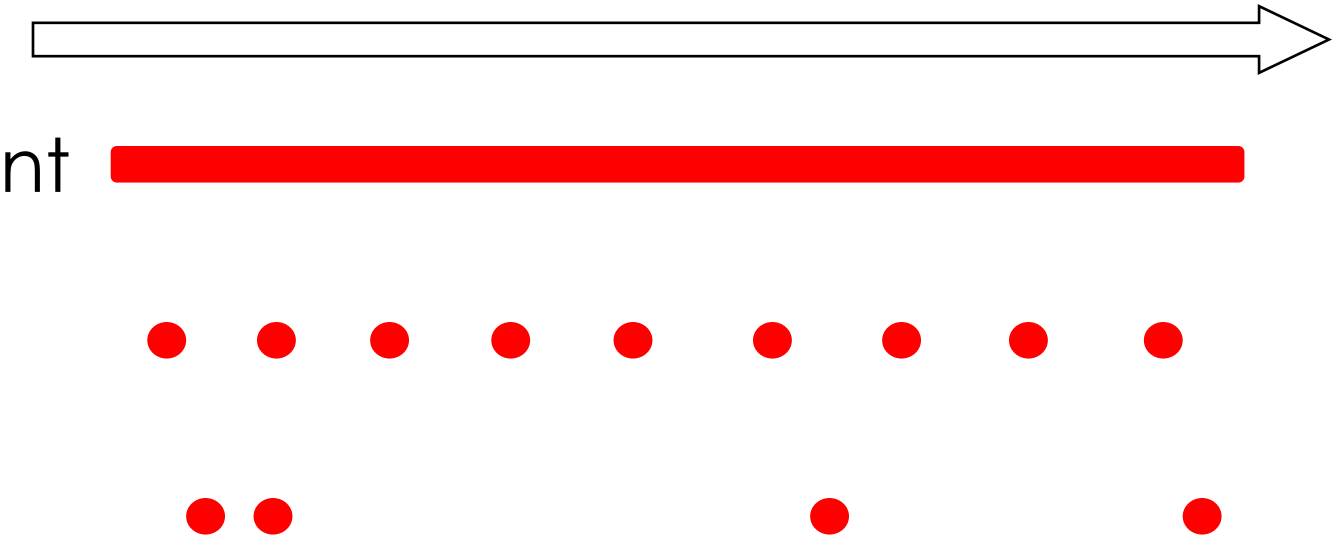
Social behaviour

Activity

Reproductive behaviour

How is Behaviour traditionally measured?

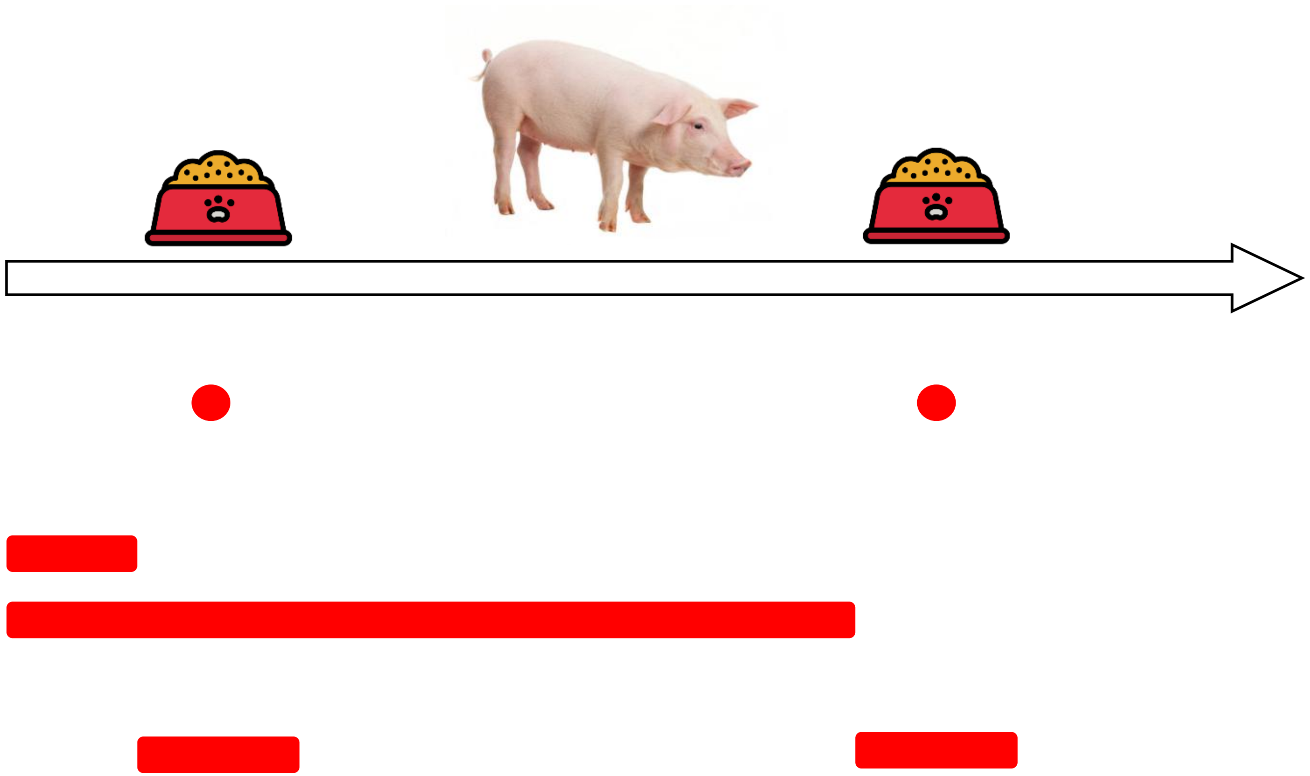
Observation methods



- Continuous assessment
- Focal sampling
- Scan sampling

How is Behaviour traditionally measured?

Variables

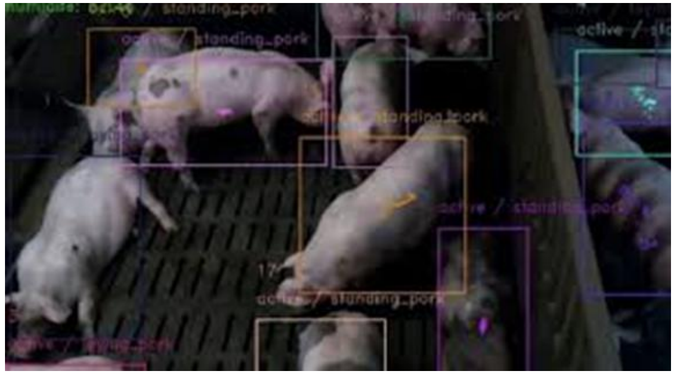


- Frequency
- Latency
- Duration

Limitations of traditional observation

- Limited picture of the behaviour
- Costly (time y resources)
- Some degree of subjectivity
- Anticipation is not possible

Advantages of PLF vs traditional methods



- Continuous information 24/7
- Less time and (human) resources
- Objective evaluation
- Allows anticipation (together with IA)

Structure of the lecture

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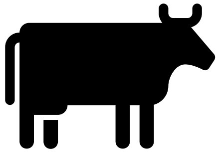
Sensors in cattle

Available sensors on the market

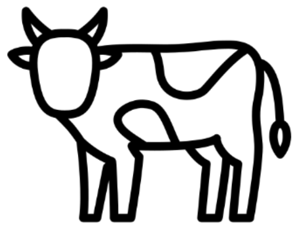


129

Stygar et al., 2021

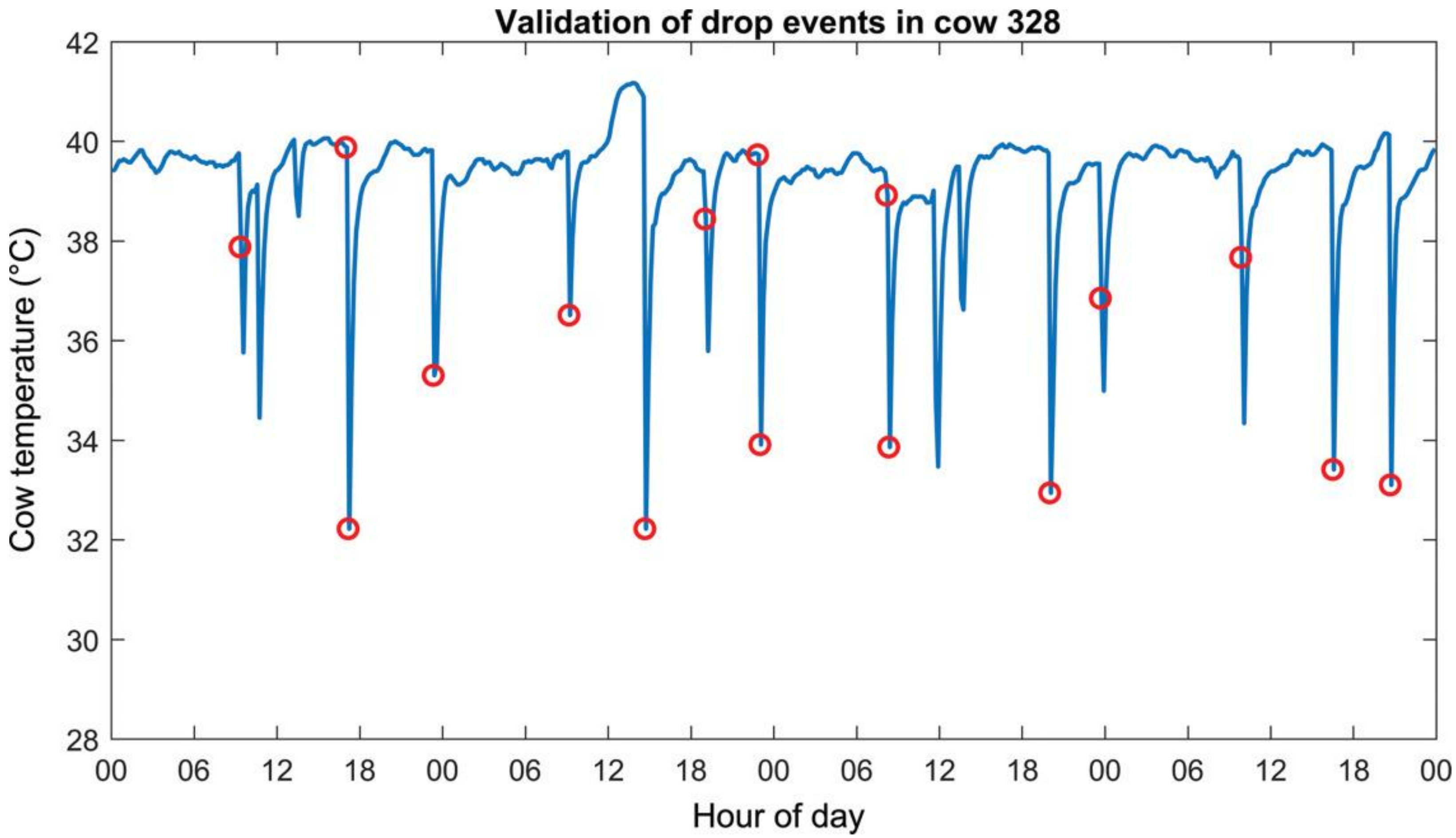
Technology name	Technology provider	No. of validation trials for technology provider	Used sensors and attachment position[a]	Independent validation[b]	Self-validation[c]
AfiAct Pedometer Plus, AfiTagII, Pedometer Plus	Afimilk, Kibbutz Afikim, Israel (S.A.E.Afikim, Israel)	5	Accelerometer, leg	(21–24)	
AfiLab real-time milk analyzer			Spectroscope	(25)	
CowAlert IceQube, IceTag	IceRobotics Ltd., Edinburgh, Scotland	4	Accelerometer, leg	(21, 26–28)	
Track A Cow	ENGS, Rosh Pina, Israel	1	Accelerometer, leg	(21)	
MooMonitor+	Dairymaster, Tralee, Ireland	2	Accelerometer, collar	(18, 29)	
HerdInsights	Alanya Ltd., Cork, Ireland	1	Accelerometer, collar	(30)	
Hi-Tag	SCR Engineers Ltd., Netanya, Israel (currently Allflex)	2	Microphone, collar	(31, 32)	
RumiWatch	Itin+ Hoch GmbH, Liestal, Switzerland	7	Accelerometer and pressure sensor, halter (29, 33–37), halter and leg (38)	(34, 35)	(29, 33, 36–38)
CowScout Leg	GEA Farm Technologies, Bonen, Germany	1	Accelerometer, leg		(27)
CowManager SensOor	Agis, Harmelen, Netherlands	5	Accelerometer, ear	(21, 39–41)	(17)
The Smartbow	Smartbow GmbH, Jutogasse, Austria	1	Accelerometer, ear	(21)	
Lely activity	Lely, Maassluis, the Netherlands	2	Accelerometer, collar	(42)	
Lely- on-line California mastitis test			Viscosity meter	(43)	
GrowSafe	GrowSafe Systems Ltd., Airdrie, AB, Canada	1	RFID (neck collar), load cell	(44)	
Insentec	Insentec, Marknesse, the Netherlands (now Hokofarm group)	1	RFID (ear), load cell	(45)	
Intergado	Intergado Ltd., Contagem, Minas Gerais, Brazil	2	RFID (ear), load cell		(46, 47)
Body Condition Scoring	DeLaval International AB, Tumba, Sweden	2	Camera	(48)	
Combi			Load cell	(49)	
eCow Farmer bolus	eCow, Dekon, UK	2	Bolus (reticulum)	(50, 51)	
KB 3/04 bolus	Kahne Limited, New Zealand	1	Bolus (rumen sac)	(52)	
Bella Ag Cattle	Bella Ag LLC, USA	1	Bolus (reticulum)	(53)	
Stepmetrix	BouMatic, Madison, USA	1	Load cell	(54)	
Optris	Optris, Berlin, Germany	1	Camera	(55)	
Prototypes—locomotion score	ns	2	Camera		(19, 56)
IMAG model—prototype mastitis detection	ns	1	Conductivity meter, thermometer (milk temperature)		(57)
Prototype-mastitis detection	detection model (prototype) and online cell counter, DeLaval International AB, Tumba, Sweden	1	Viscosity meter		(58)
Prototype-activity	ns	1	Accelerometer		(59)

Sensors in cattle



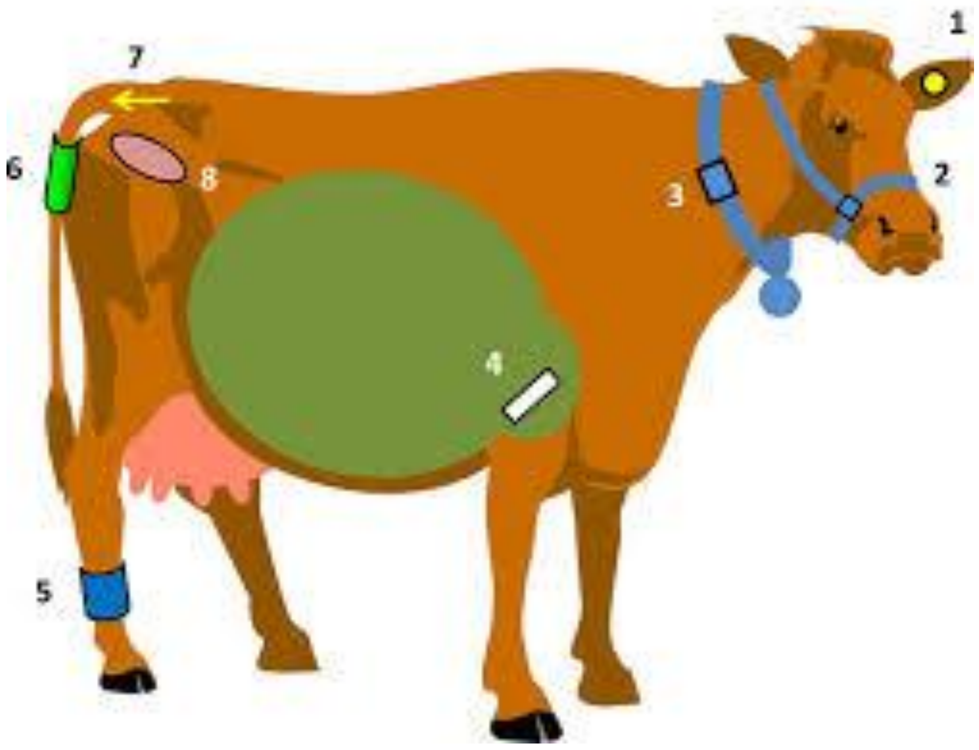
Accelerometer	Camera	GPS	Scale	Thermometer	Microphone
37	10	8	5	4	2

Sensors in cattle



Vázquez-Disodado et al., 2019

Sensors in cattle

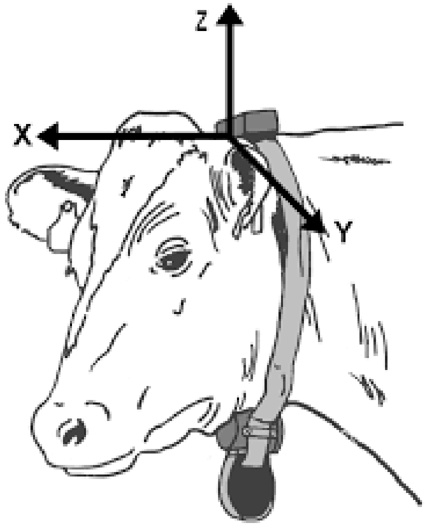


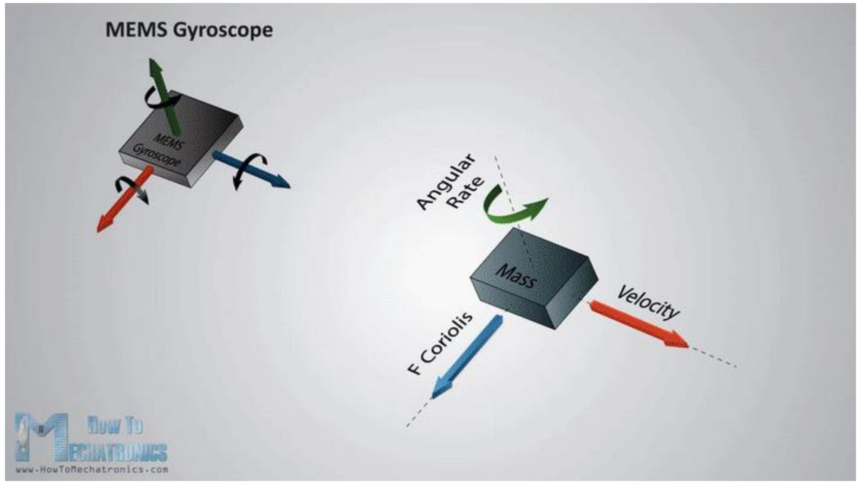
1. Electronic eartag

2. Collar
3. Ruminal bolus
4. Podometer

5. Rectal bolus

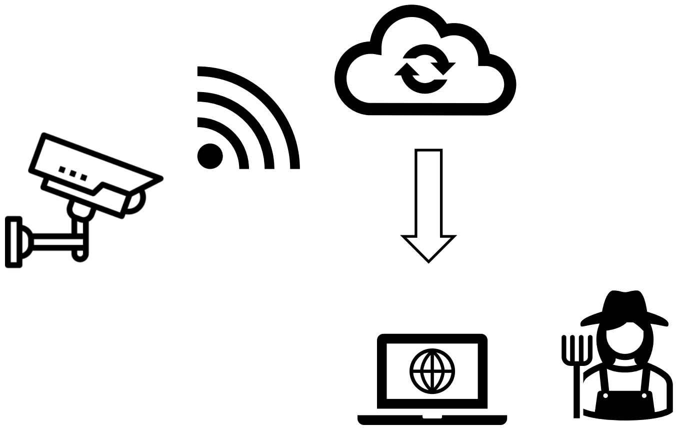
Sensors in cattle: accelerometer





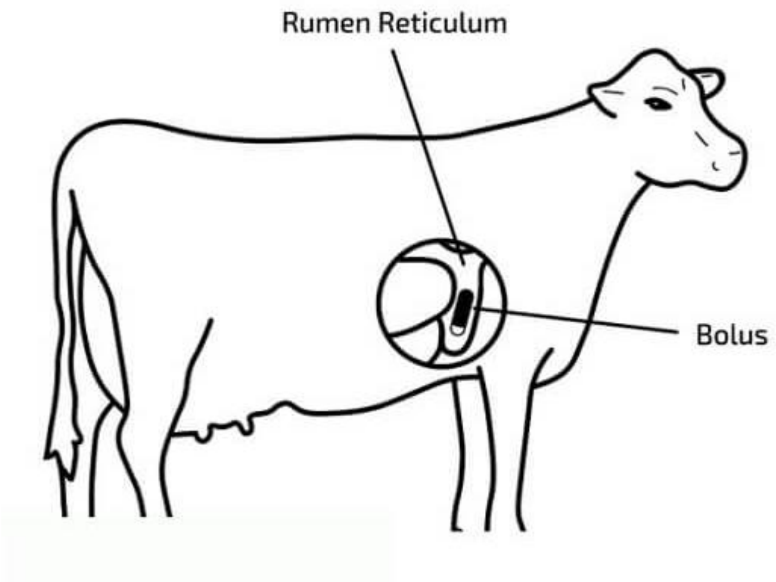
- Number of steps
- Laying and standing time
- Estimate other behaviours
  - Feeding
  - Ruminating

Sensors in cattle: computer vision



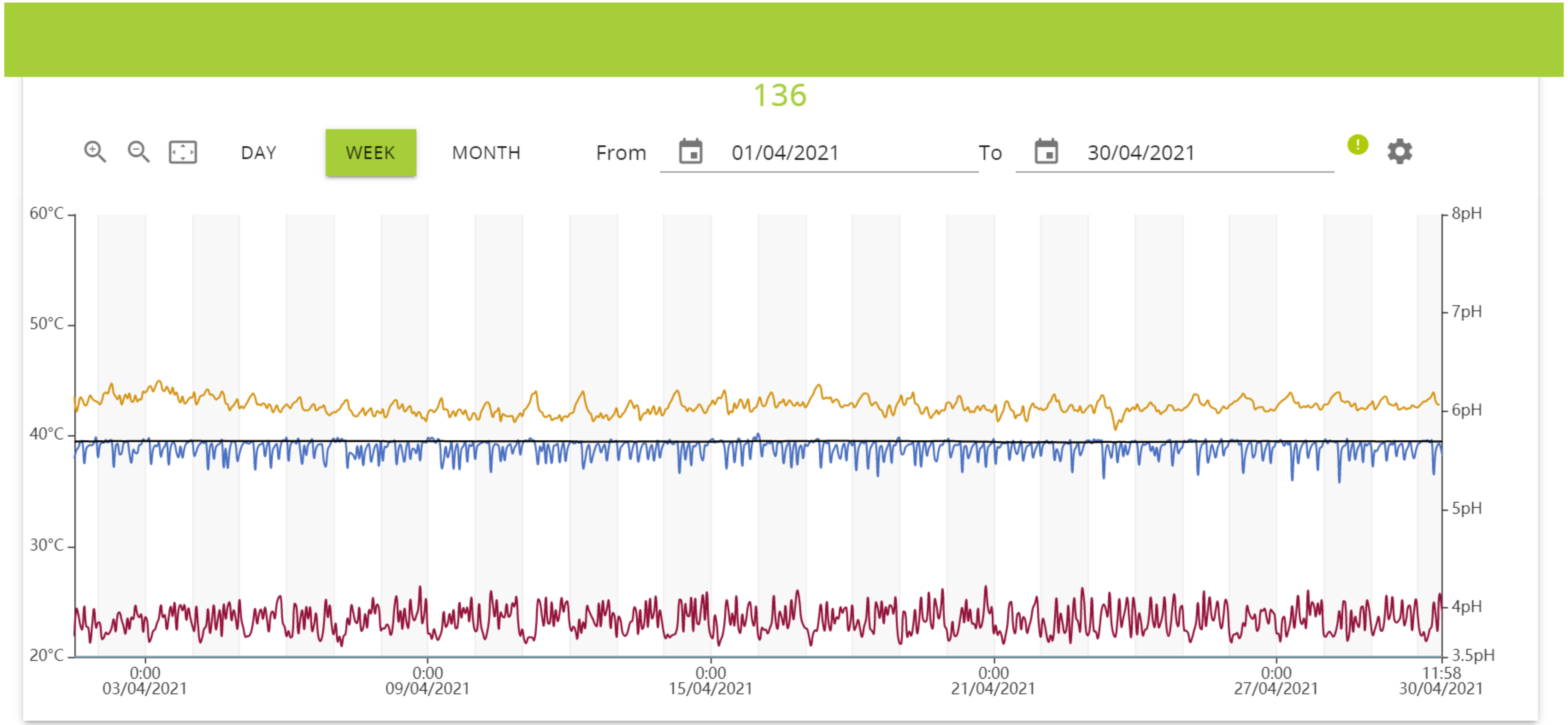
- Activity and behaviour
- Posture
- Localisation in the pen

Sensors in cattle: ruminal bolus



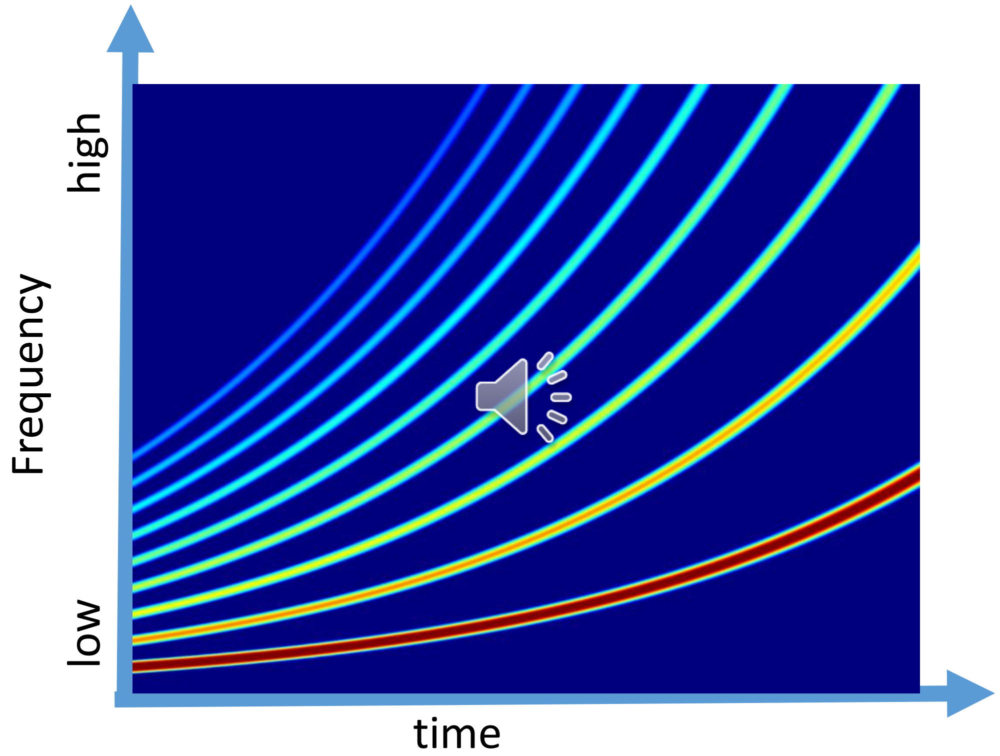
- Ruminal thermometer
- Accelerometer
- pH meter

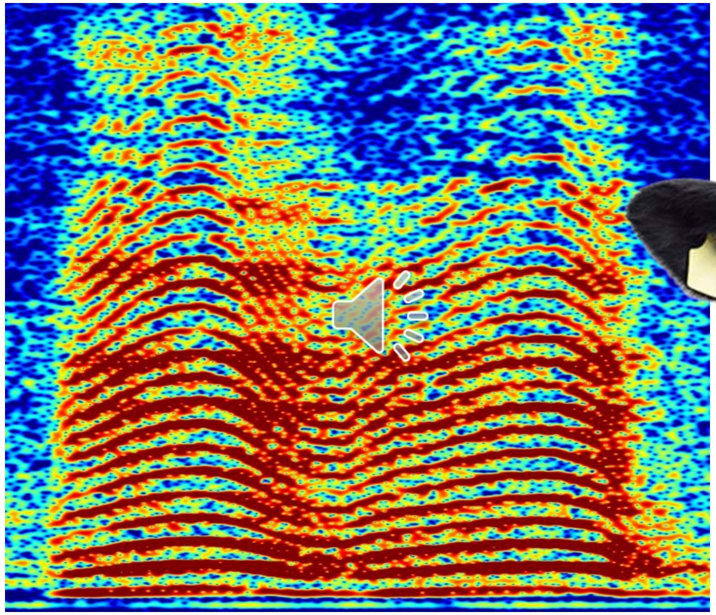
Sensors in cattle: ruminal bolus

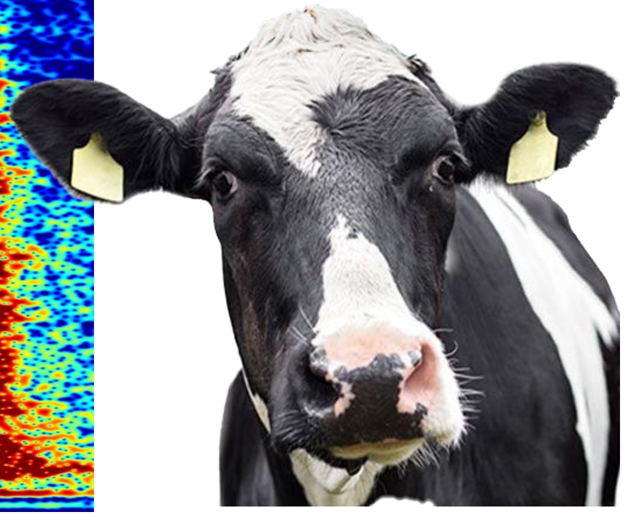


Microphone: predicting emotional status

- Early detection of negative emotions (pain, hunger)
- Advantages: Non-invasive, group análisis (low cost)
- Disadvantages: Individual assessment not possible

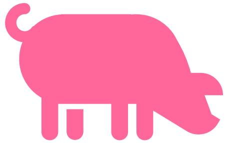






Sensors in pigs

Commercially available sensors

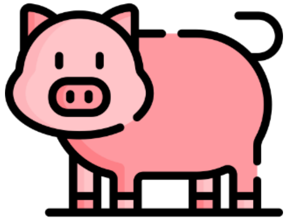


83

Gomez et al., 2021

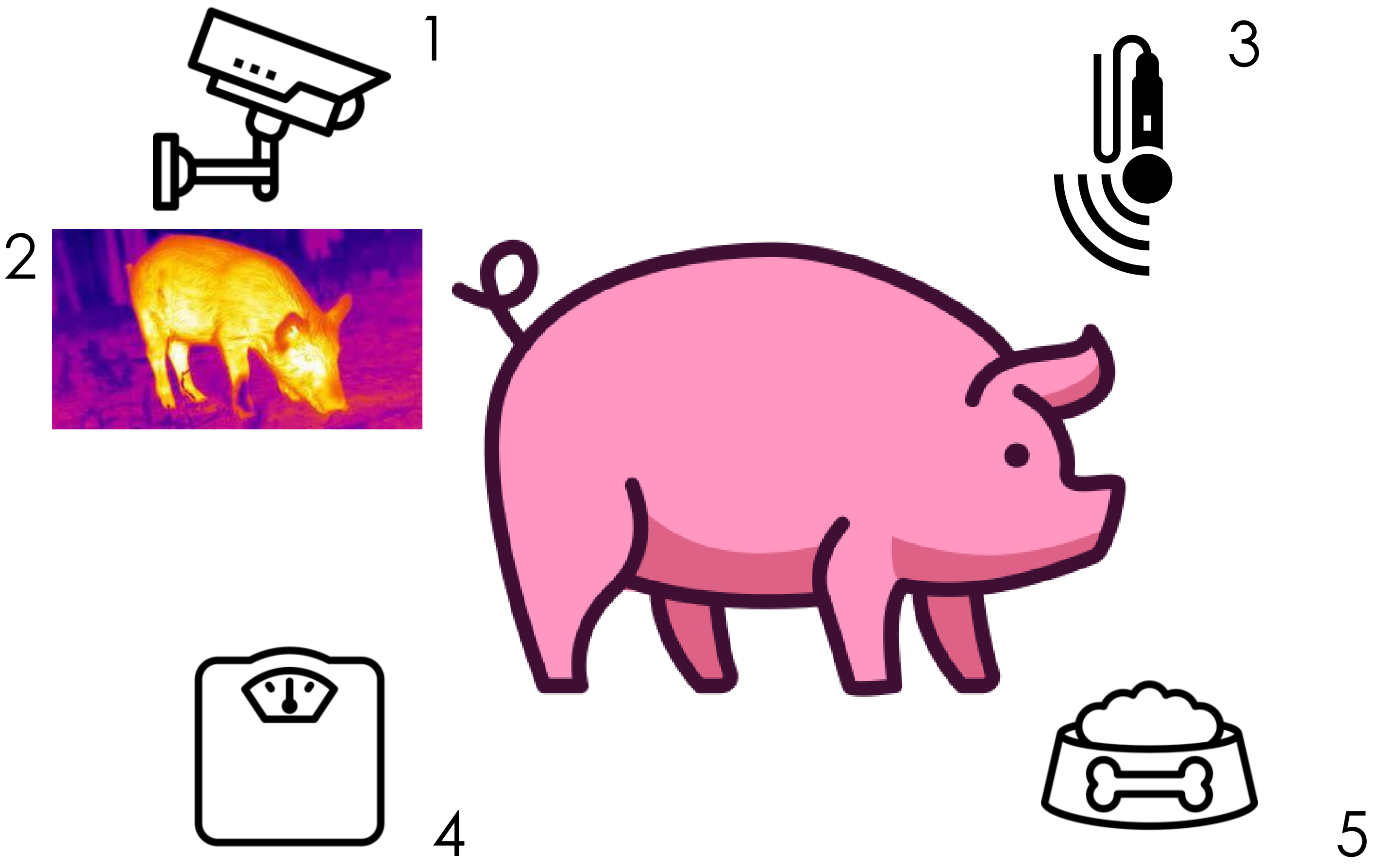
Indicator	Reason of use (monitored trait)	Technologies tested
Activity and posture-related behavior	Active and/or passive (without distinguishing on activity type)	Accelerometer (60–65) Photoelectric sensor (56)[a], (66–68) Camera (30, 69–71)
	Lying	Camera (72–76) Accelerometer (43, 60–62, 77, 78)
	Standing	Camera (72–74, 79) Accelerometer (43, 62, 77)
	Sitting	Camera (72–74) Accelerometer (43, 77)
	Kneeling	Camera (73, 74)
	Posture state and transitions between states (e.g., between lying and standing)	Photoelectric sensor (59)[a] Accelerometer (78) Camera (74)
	General motion activity and tracking (related to thermal comfort)	Camera (34, 76, 80) Accelerometer (78) Thermal camera (81)
	Walking (number of steps)	Accelerometer (61)
	Tracking (identifying location or number of animals)	Camera (32, 82–84) RFID (41)
Feeding and drinking behavior	Feed intake (kg)	Load cells with RFID (52)[a], (49, 85)
	Feeding time and/or frequency	RFID (42, 58, 86)[a], (87, 88) RFID and environment temperature and humidity sensors (46) Camera (37, 73, 74) Accelerometer (61, 64)
	Hunger stress identification	Thermal camera (89) Microphone (90–92)
	Nursing, suckling	Camera (37)
	Drinking time and/or frequency	RFID (93) Accelerometer (64) Camera (37, 73, 74, 94–97)
	Thirst stress identification	Thermal camera (89) Microphone (90, 92)
Other behavior	Nest- building behavior	Accelerometer (98)
	Aggressive behavior	Camera (99–104) Accelerometer (64)
	Cascade defense (freezing and startle duration)	Camera (105)
	Rooting	Accelerometer (61)
	Mounting behavior	Camera (97, 106)
	Tail biting	Camera (50, 107) Water flow meter and environment temperature sensor (108)
	Exploratory behavior	Accelerometer (64)
	Playing behavior	Camera (96)[b] Accelerometer (64)[c]
Physical condition	Gait attributes	Load cells [force plates, (35, 40, 109–111)] Camera and accelerometer (112), Camera (113)
	Cough detection	Microphone (45, 51, 114, 115)
	Body weight	Camera (29, 33, 36, 116–122) Load cells (scales) with RFID (52)[a] Load cells (scales) (39, 123)
	Muscle score	Camera (124)
	Body temperature	Thermal camera (48, 53)[a], (54)[a], (125, 126) Pyrometer (55)[a]
	Stress (e.g., due to heat or cold, pain, fear)	Microphone (57, 90)[a], (91, 92, 127–130) Thermal camera (89)
Health-related traits	Lameness and claw lesions detection	Accelerometer (131) Camera (35) Thermal camera (132)
	African Swine Fever (sign: changes in activity level)	Camera (31) Accelerometer and microchip for body temperature (44)
	Influenza A virus (signs: fever) and changes in activity level	IR thermometer (133)
	Respiratory disease	Thermal camera (47, 134) Microphone (135, 136)
	General health problems	RFID (137)
	Diarrhea	Water flow meter (38)

Sensors in pigs



Cameras	Scales	Accelerom.	Microphone	Thermal camera	Activity sensor
45	28	14	14	10	5

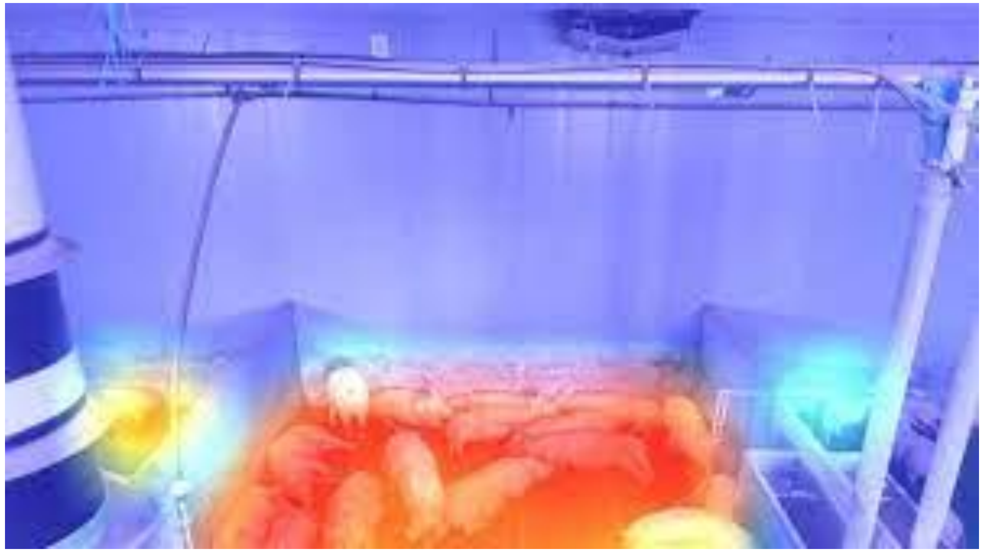
Sensors in pigs



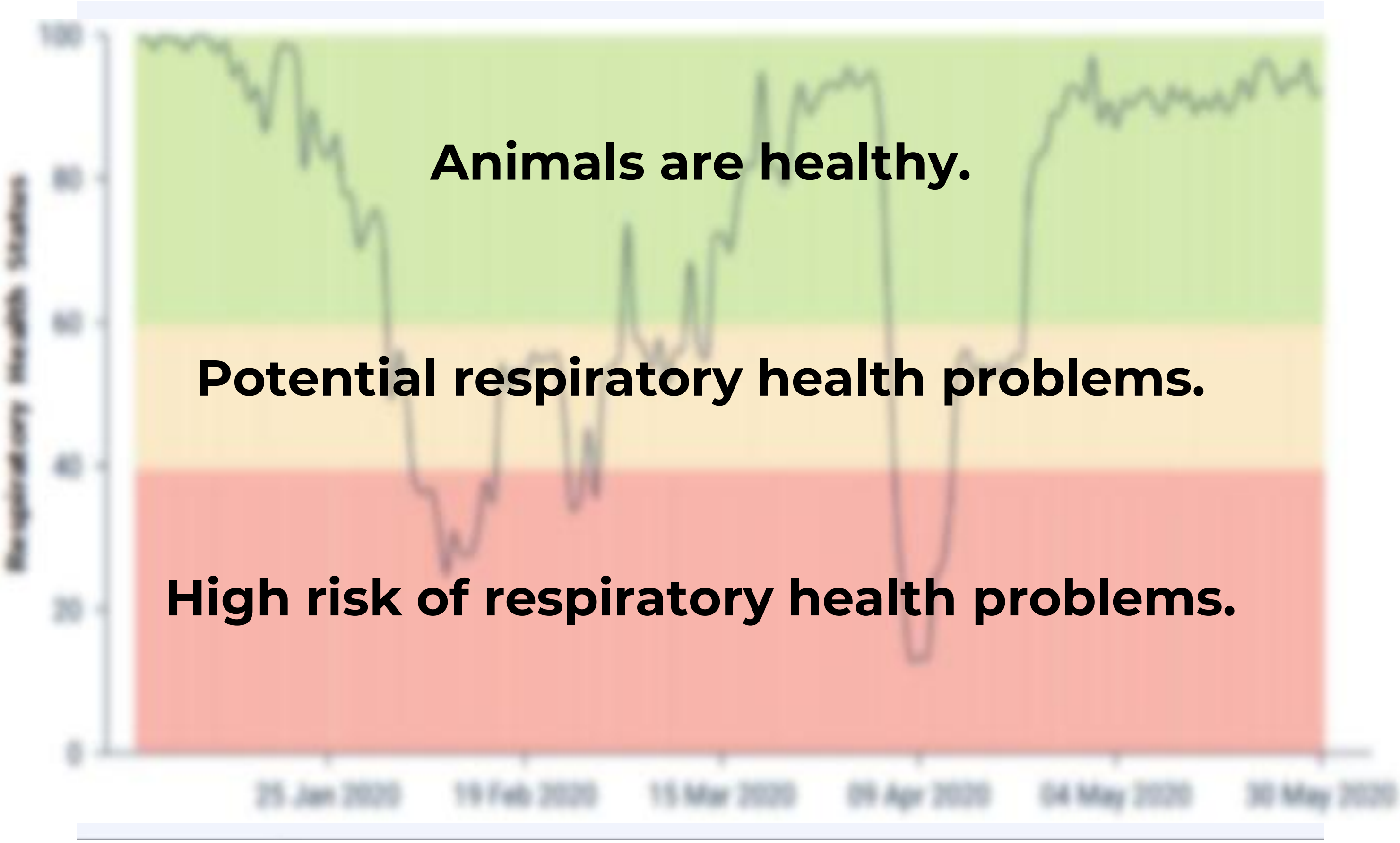
1. Computer vision
2. Thermal camera
3. Microphone
4. Scale
5. Feed inatke
6. Water intake

Sensors in pigs: computer vision

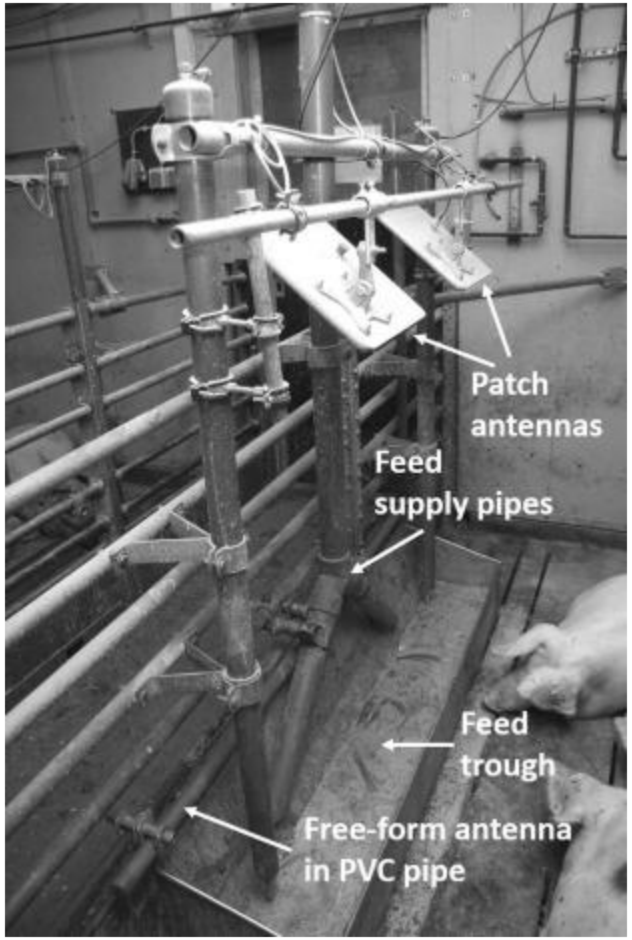
- Activity (total distance)
- Animal posture
- Position inside the pen



Sensors in pigs: microphone



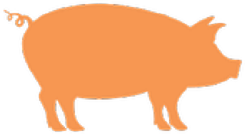
Sensors in pigs: electronic feeders



- To identify feeding patterns, feeding time, frequency, duration, etc.
- Feeding patterns allow identifying changes in the Health status and productivity

Sensors at the slaughterhouse

aWISH
ANIMAL WELFARE INDICATORS AT THE SLAUGHTERHOUSE



- Nutrition
- Health
- Behaviour
- Environment
- Mental

- Stunning effectiveness
- Killing effectiveness

Sensors at the slaughterhouse

Stunning effectiveness

Description

This is a monitoring process to ensure that animals are properly stunned, focusing on the stage of animal consciousness. Loss of consciousness occurs when the pig experiences temporary or permanent brain damage blocking the perception of external stimuli. This can be assessed by monitoring the brain stem reflexes, such as the corneal reflex, rhythmic breathing, attempt to regain posture, etc.

Methodology

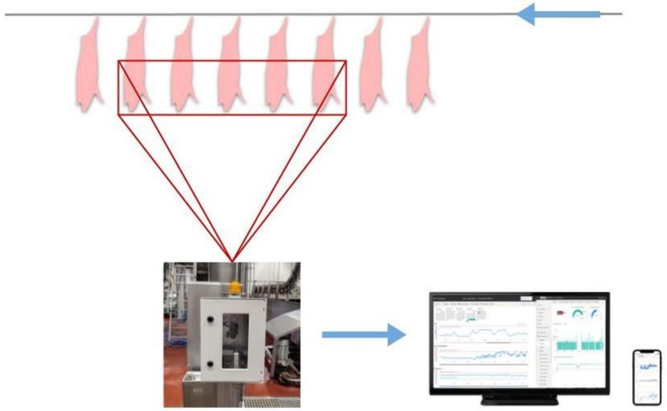
- Computer vision

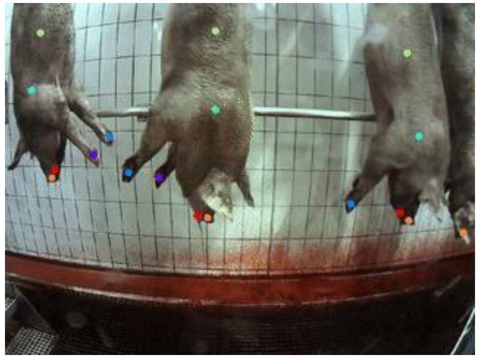
- Pig Automatique'
- Monitoring of the CO_2 Stunning

Sensors at the slaughterhouse

Monitoring of the CO_2 Stunning

Automated visual assessment of stunning quality, detecting signs such as mouth opening and carcass movements to verify if the animal is

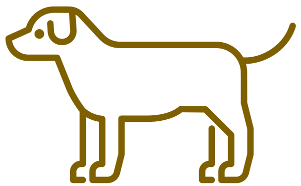




Provider	Genba Solutions
Specifications:	Real-time alerts
	Data is recorded to track the stunning accuracy historically
	Monitoring of up to five pigs per system
	A visual and acoustic alarm emerges when movement is detected, and short video is recorded
Website link	

Source: Genba Solutions website

Sensors in companion animals



In development…

GPS

Accelerometer

EEG

Cameras

microphone

Activity

Feeding

Drinking

Sleep

Kumpulainen et al. 2021;
I den Uijl et al., 2017;
Cleghern et al., 2021

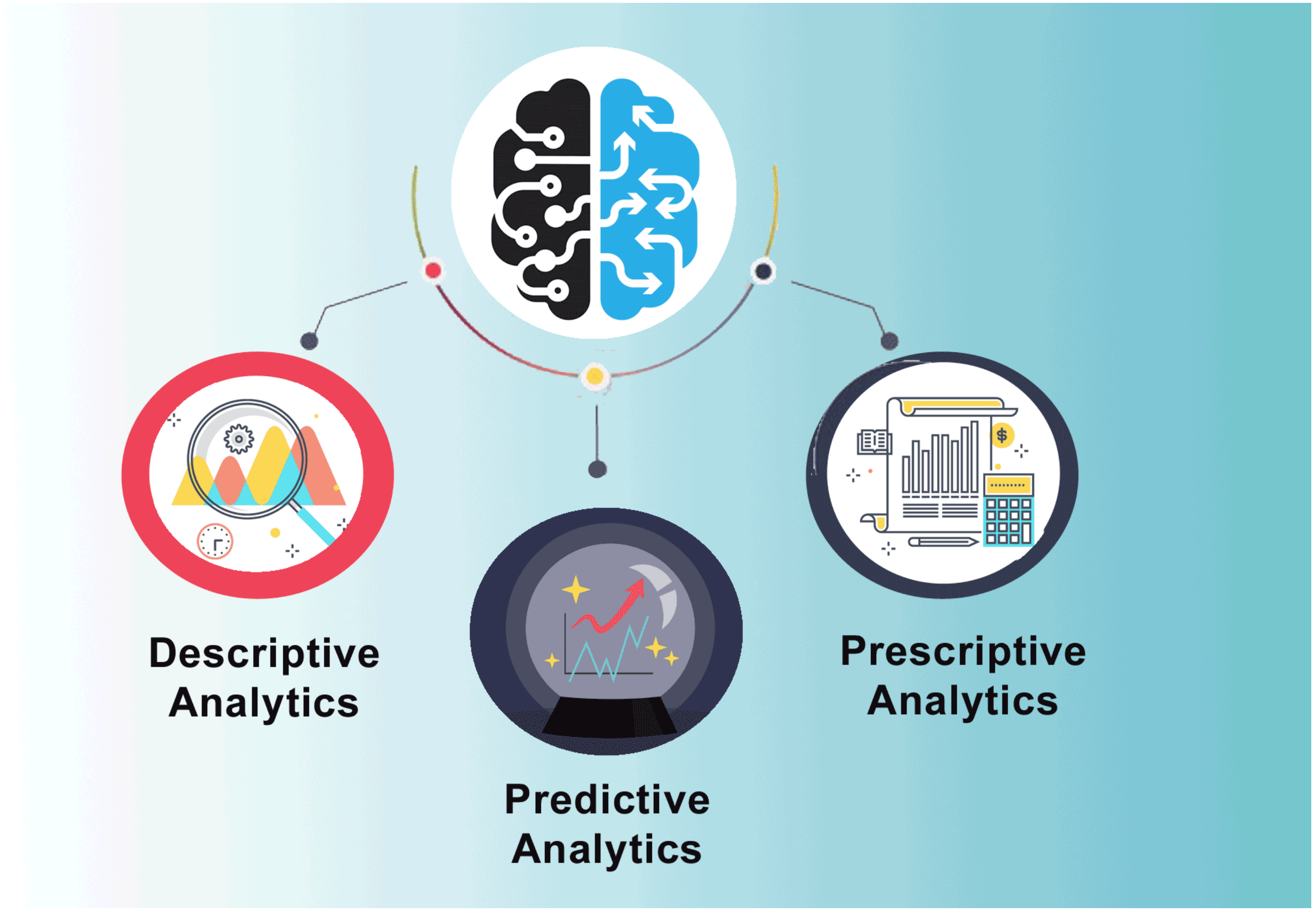
Structure of the lecture

- Animal Welfare Indicators
- Animal behaviour
- Available technologies
- **Potential and challenges**

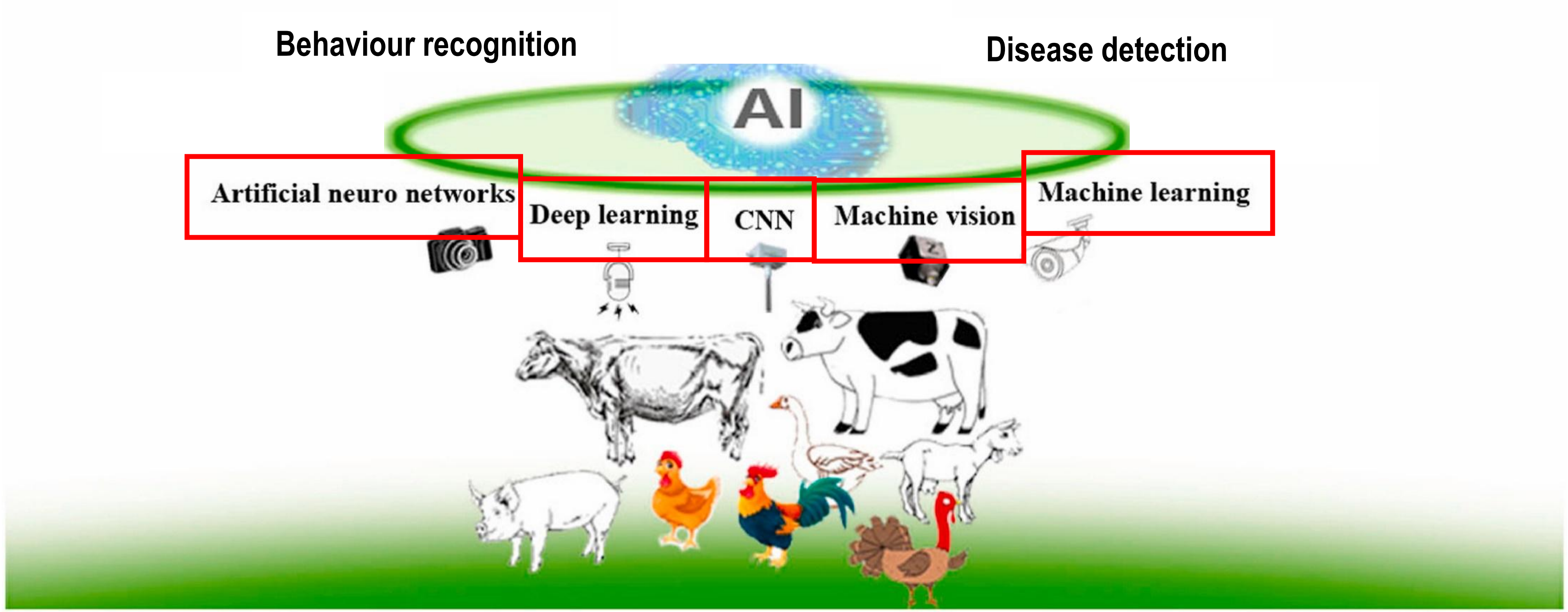
Potential of PLF

- Data coming from PLF sensors gives a lot of data with a LOT of potential
- They must be analyzed with appropriate mathematical tools, especially based on artificial intelligence algorithms.
- They allow not only to know how the animals are at all times, but also have predictive power about what may happen in the future, based on changes in the present.

Potential of PLF: data analysis

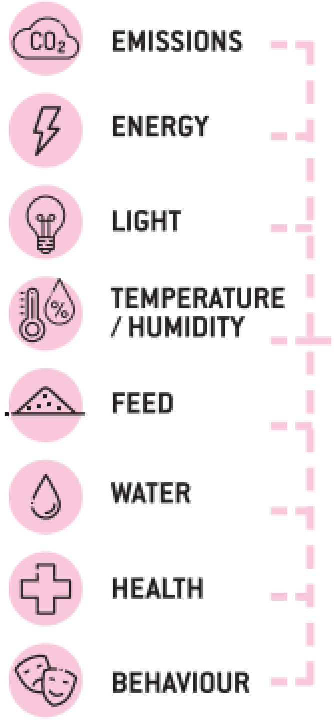


Potential of PLF: data analysis



Bao & Xie et al., 2022

Descriptive analytics



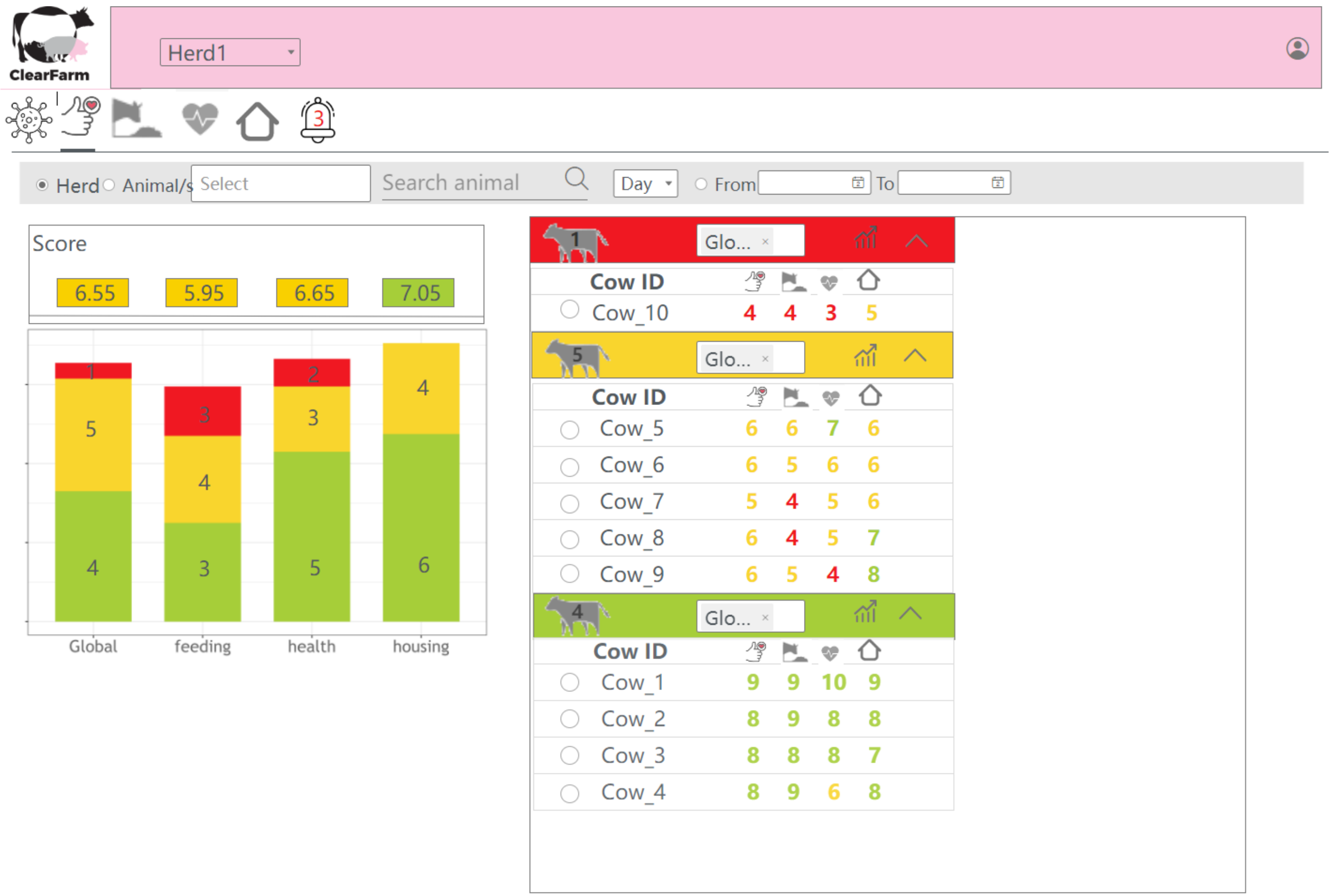

```
cow_data_day(43582, '2021-02-01')
```

```
==============================
Feeding Score: 7.5
Housing Score: 7.5
Health Score: 8.89
------------------------------
Total Score: 7.96
==============================
eating: 7834.69
ruminating: 14133.38 - Smaller than 15720
temperature: 38.74243
drinking.times: 6.0
lying: 17988.46
standing: 20738.99
walking: 7523.18
pH: 5.93153
SCC: nan - No data
```

```
cow_data_day(101371, '2022-08-29')
```

```
==============================
Feeding Score: 10.0
Housing Score: 10.0
Health Score: 10.0
------------------------------
Total Score: 10.0
==============================
eating: 17582.69
ruminating: 29606.23
temperature: nan - No data
drinking.times: nan - No data
lying: 20849.72
standing: 56180.38
walking: 9316.55
pH: nan - No data
SCC: nan - No data
```

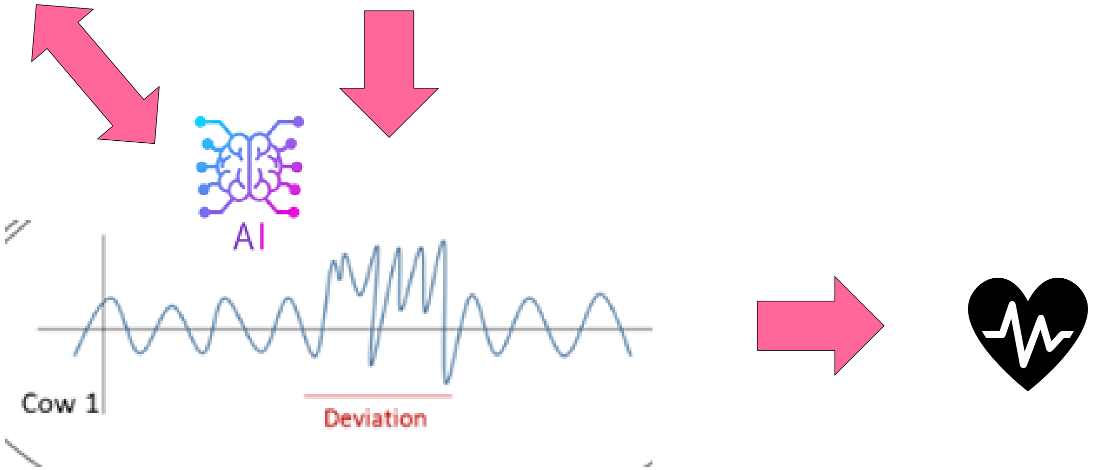
Descriptive analytics



Predictive analytics

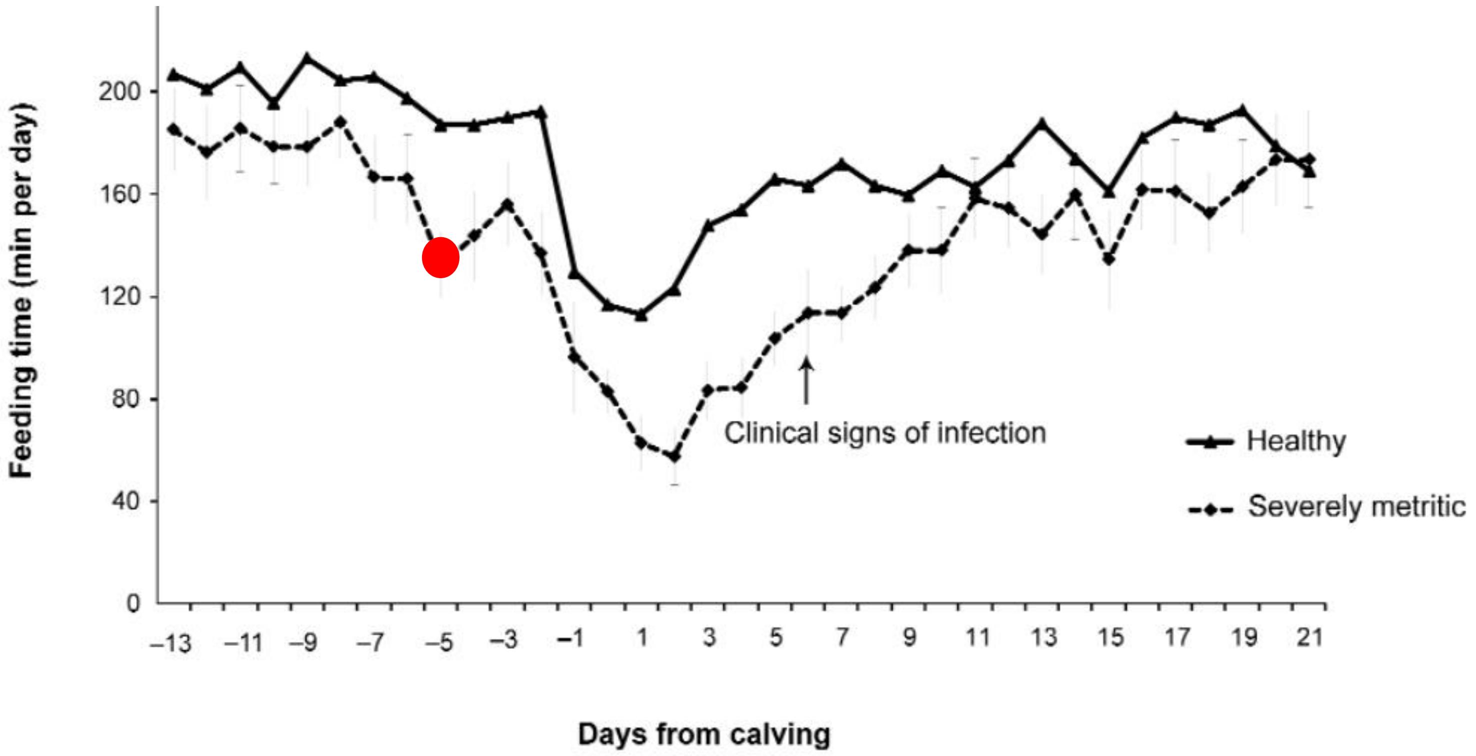
Disease

Reference



Predictive analytics

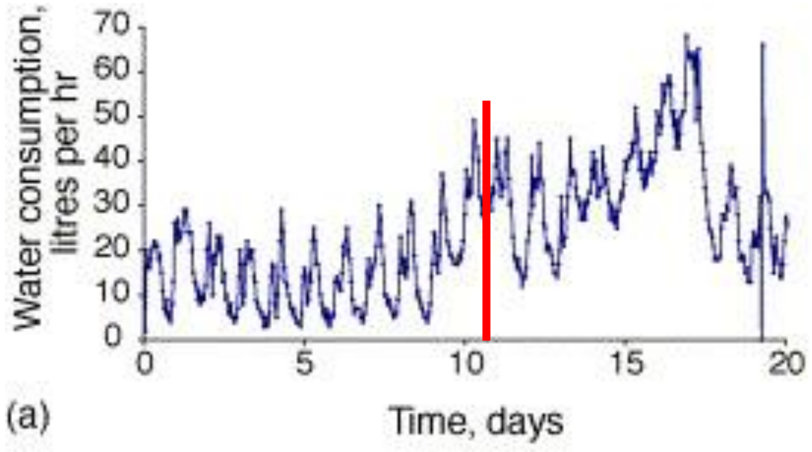
Comparing the eating time of metritic *vs.* Healthy cows, days before its clinical detection

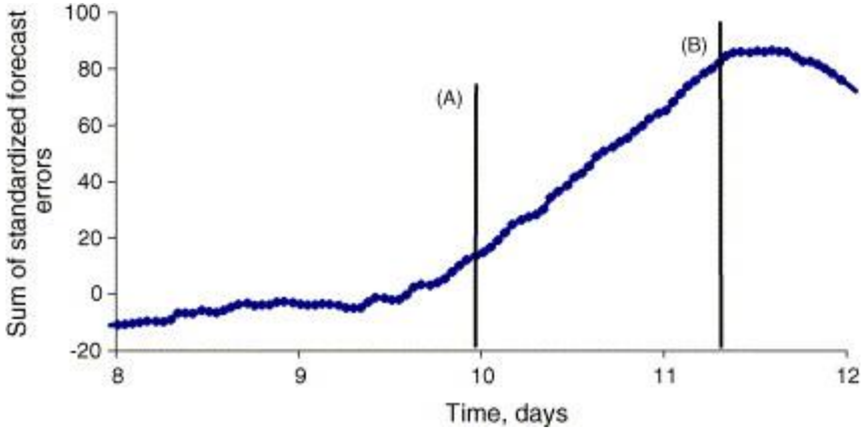


Rushen et al., 2012

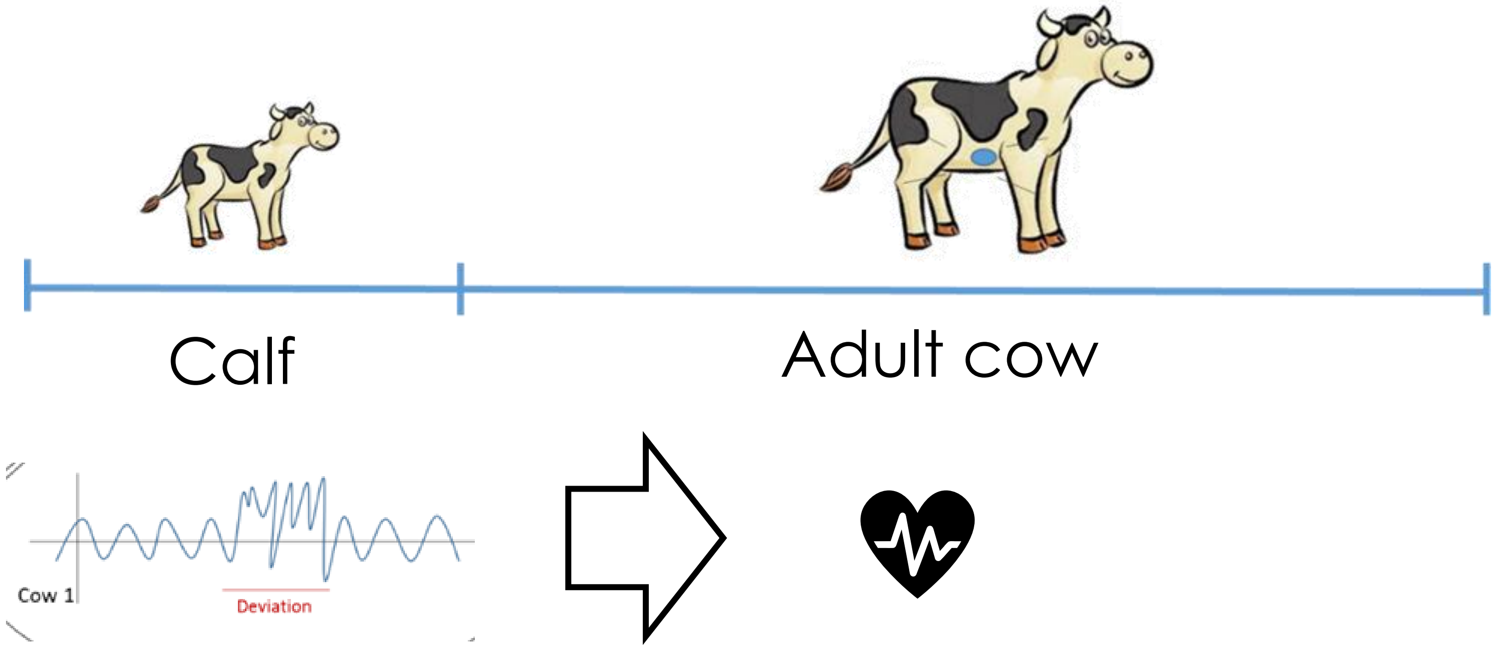
Predictive analytics

- Water intake
- Estimating gastrointestinal disease(e.g. diarrhoea)



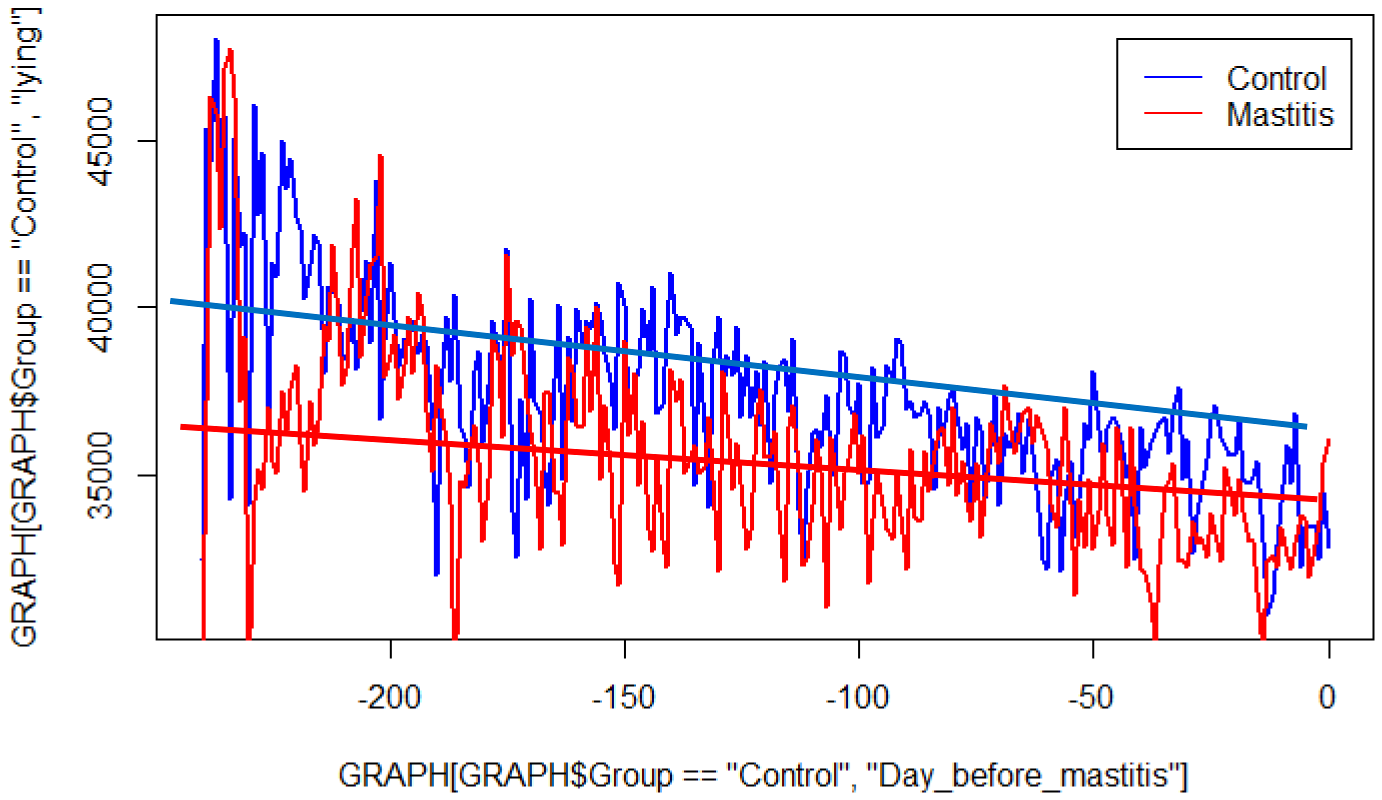


Prescriptive analytics



Prescriptive analytics

Lying time of cows with mastitis (red) vs healthy (blue) before its clinical detection

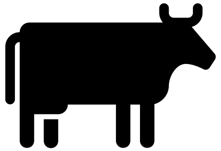


Hervé et al., 2023

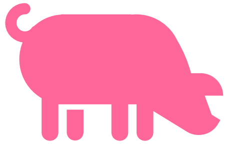
Limitations of PLF

Available sensors in the market

Stygar et al., 2021



129



83

Gomez et al., 2021

Externally validated sensors

18

8

Limitations of PLF

frontiers | Frontiers in Veterinary Science

REVIEW
published: 27 May 2022
doi: 10.3389/fvets.2022.889623

Twelve Threats of Precision Livestock Farming (PLF) for Animal Welfare

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Research and development of Precision Livestock Farming (PLF) is booming, partly due to hopes and claims regarding the benefits of PLF for animal welfare. These claims remain largely unproven, however, as only few PLF technologies focusing on animal welfare have been commercialized and adopted in practice. The prevailing enthusiasm and optimism about PLF innovations may be clouding the perception of possible threats that PLF may pose to farm animal welfare. Without claiming to be exhaustive, this paper lists 12 potential threats grouped into four categories: direct harm, indirect harm via the end-user, via changes to housing and management, and via ethical stagnation or degradation. PLF can directly harm the animals because of (1) technical failures, (2) harmful effects of exposure, adaptation or wearing of hardware components, (3) inaccurate predictions and decisions due to poor external validation, and (4) lack of uptake of the most meaningful indicators for animal welfare. PLF may create indirect effects on animal welfare if the farmer or stockperson (5) becomes under- or over-reliant on PLF technology, (6) spends less (quality) time with the animals, and (7) loses animal-oriented husbandry skills. PLF may also compromise the interests of the animals by creating transformations in animal farming so that the housing and management are (8) adapted to optimize PLF performance or (9) become more industrialized. Finally, PLF may affect the moral status of farm animals in society by leading to (10) increased speciesism, (11) further animal instrumentalization, and (12) increased animal consumption and harm. For the direct threats, possibilities for prevention and remedies are suggested. As the direction and magnitude of the more indirect threats are harder to predict or prevent, they are more difficult to address. In order to maximize the potential of PLF for improving animal welfare, the potential threats as well as the opportunities should be acknowledged, monitored and addressed.

Keywords: animal well-being, automation, digital agriculture, ethics, internet of things, sensors, smart farming, technology

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Limitations of PLF

- PLF can **directly harm the animals** because of
  - technical failures
  - harmful effects of exposure, adaptation or wearing of hardware components
  - inaccurate predictions and decisions due to poor external validation, and
  - lack of uptake of the most meaningful indicators for animal welfare

- PLF may create **indirect effects on animal welfare** if the farmer or stockperson
- (5) becomes under- or over-reliant on PLF technology
- (6) spends less (quality) time with the animals, and
- (7) loses animal-oriented husbandry skills

- PLF may also **compromise the interests of the animals** by creating transformations in
- animal farming so that the housing and management are
- (8) adapted to optimize PLF performance or
- (9) become more industrialized

- Finally, PLF may **affect the moral status of farm animals** in society by leading to
- (10) increased speciesism
- (11) further animal instrumentalization, and
- (12) increased animal consumption and harm

In summary...

- PLF sensors open a new paradigm for animal control
- Animal sensors(livestock and companion) presents upward growth prospects in the coming years
- This will increase the demand for personnel specialized in data analysis and management
- There is great potential for research and innovation in the development of new sensors
- ... but still many challenges