ILVO
Flanders Research Institute for Agriculture, Fisheries and Food

COMBINING ULTRA-WIDEBAND LOCATION AND ACCELEROMETER DATA FOR CATTLE BEHAVIOUR MONITORING
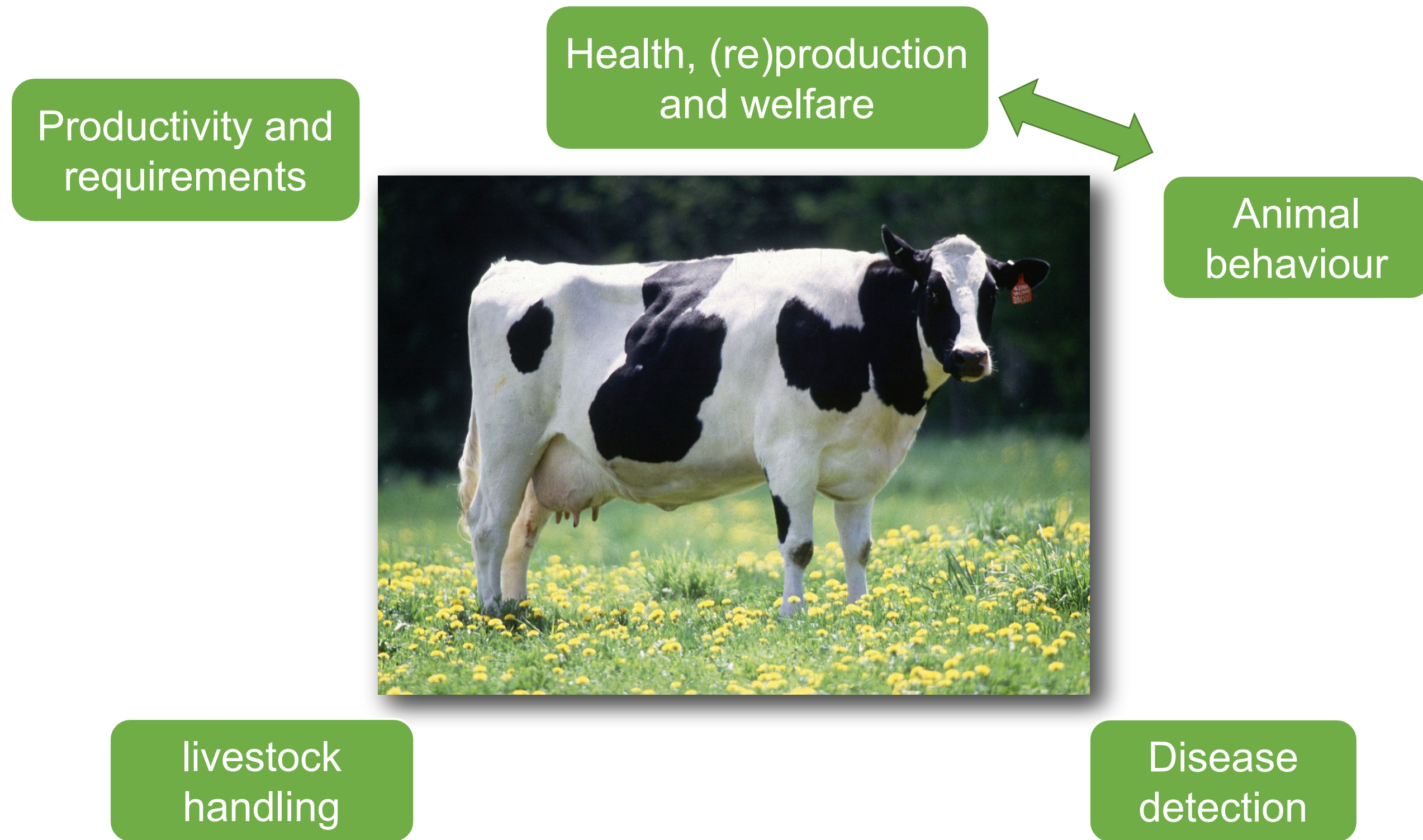
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fwo Research Foundation Flanders Opening new horizons

EAAP + WAAP + Interbull Congress 2023

CONTENTS

- Introduction
  - Context, motivation, objectives
- Experiment 1: Static validation of the location system
- Experiment 2: Behaviour monitoring
- Applications
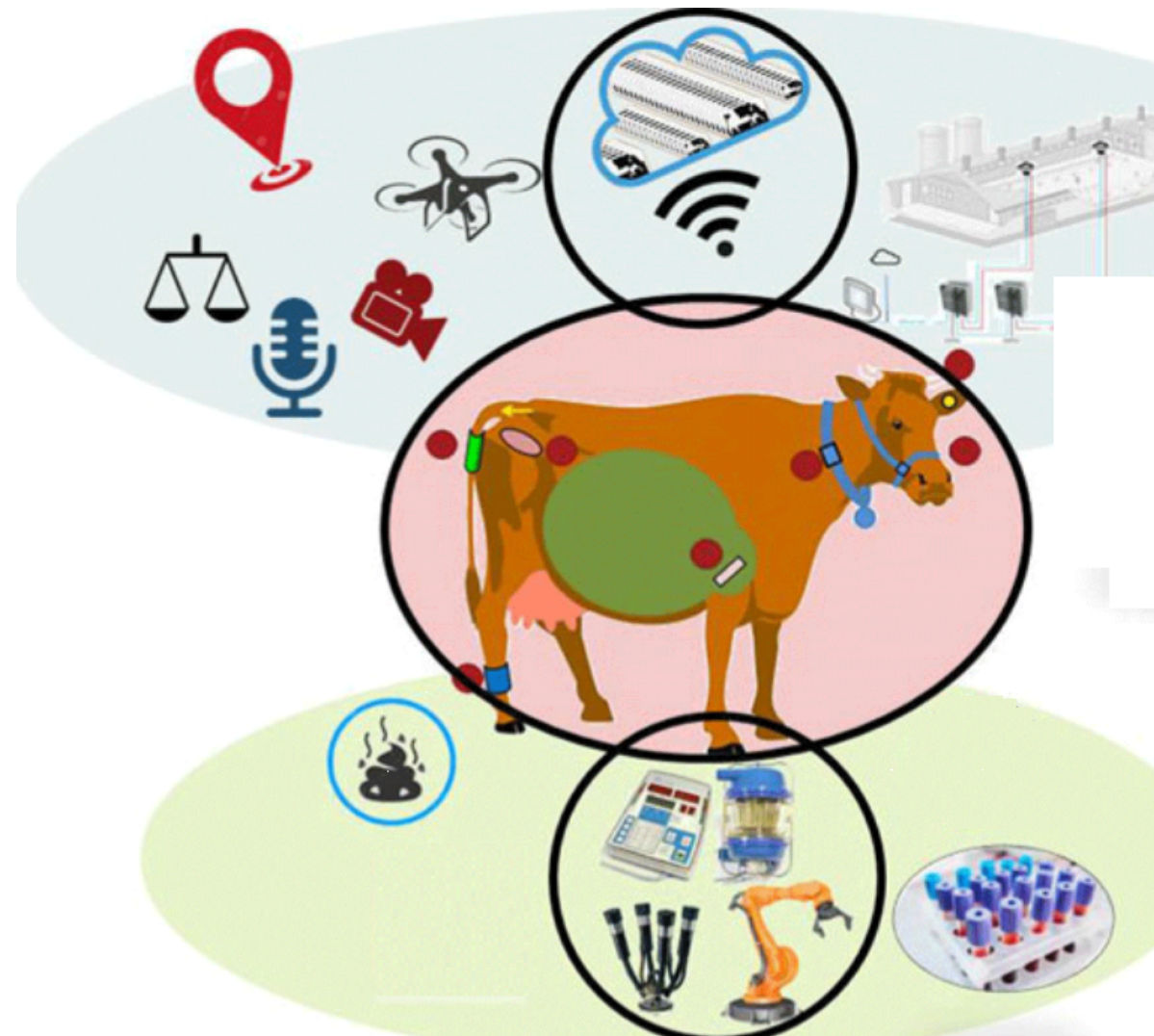- Conclusions and future work

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CONTEXT AND MOTIVATIONS

Health, (re)production and welfare

Productivity and requirements

Animal behaviour

livestock handling

Disease detection

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CONTEXT AND MOTIVATIONS

Commercial PLF systems

Accelerometer data alone

Average accuracy

Limited number of behaviours

Limited applications

Less frequently expressed behaviours

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OBJECTIVES

Location + **Accelerometer** = **Improved cattle behaviour monitoring systems**

Determine the functional area in which the animal is located

Considered a limited number of behaviours

- Higher classification accuracy
- Classify less frequently expressed behaviours (drinking, eating concentrate...)
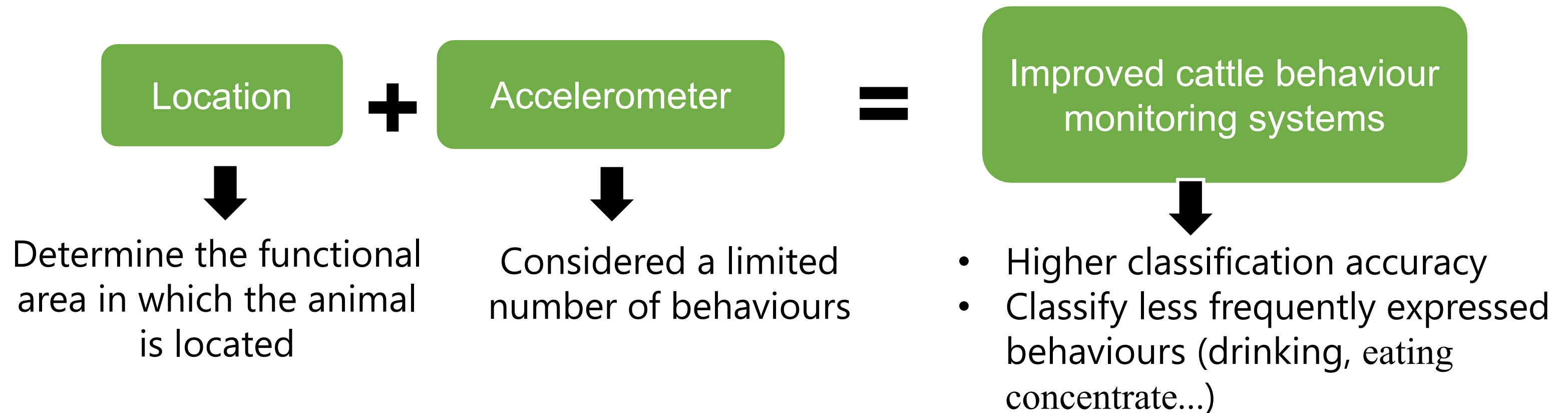
# HOUSING CONDITIONS AND TRACKING SYSTEM

- **Animals and housing**
  - 30 cows
  - Free-stall barn (ILVO, Belgium)
  - Automatic Milking Robot (VMS300, Delaval)
- **Tracking system**
  - Pozyx system (Pozyx, Belgium)
  - Location 2 Hz
  - Accelerometer 12.5 Hz
  - Accuracy of 10-30 cm (Pozyx)

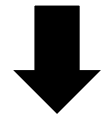Dimensions (mm) 50x42x15
Weight 21 g

EXPERIMENT 1

- ## Static validation of location system
  - Without cows, tag at fixed locations
  - Different areas of the barn
  - 2 min per location (120 samples)
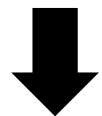 - Compared to barn ground plan (reference)
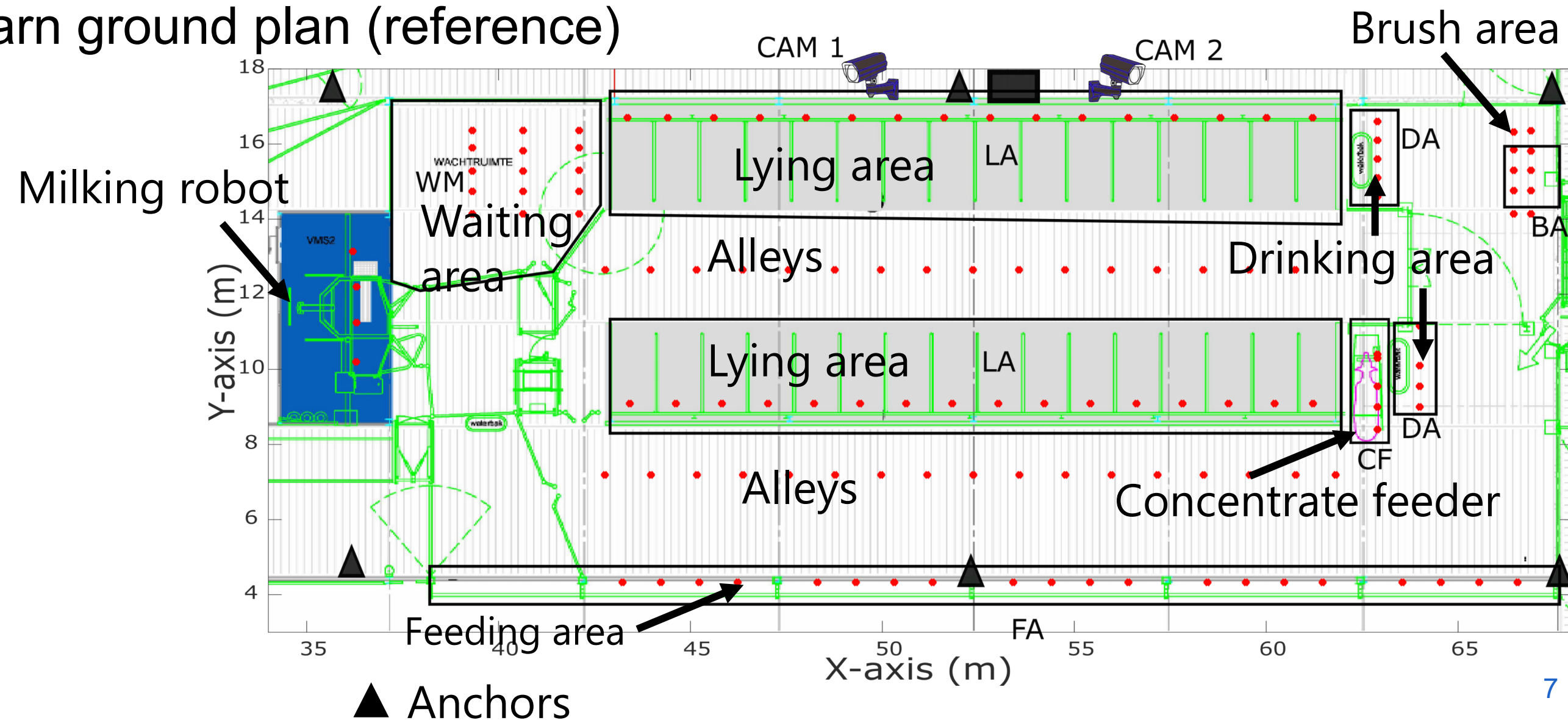
EXPERIMENT 1

- Static validation of location system
  - Accuracy and precision

$$\text{Accuracy} = \frac{1}{N} \sum_{k=1}^{k=N} \sqrt{\left(\widehat{X_k} - X\right)^2 + \left(\widehat{Y_k} - Y\right)^2}$$
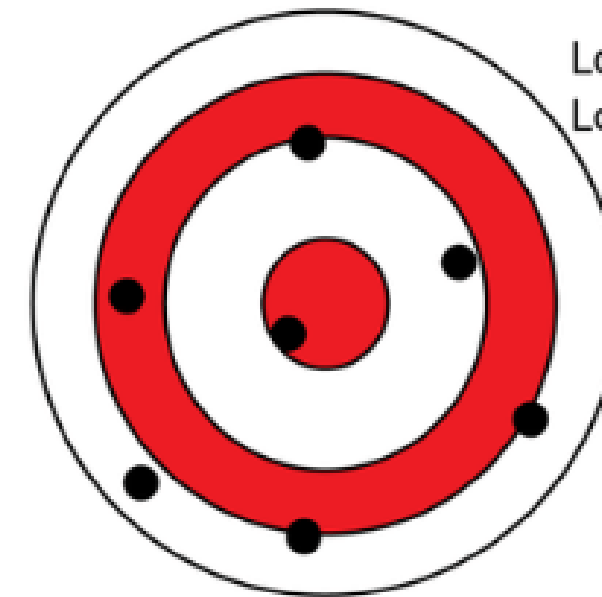
⬇

How much the samples are close to the target

$$\text{Precision} = \sqrt{\frac{1}{N} \sum_{k=1}^{k=N} \left(\widehat{X_k} - \bar{X}\right)^2 + \left(\widehat{Y_k} - \bar{Y}\right)^2}$$
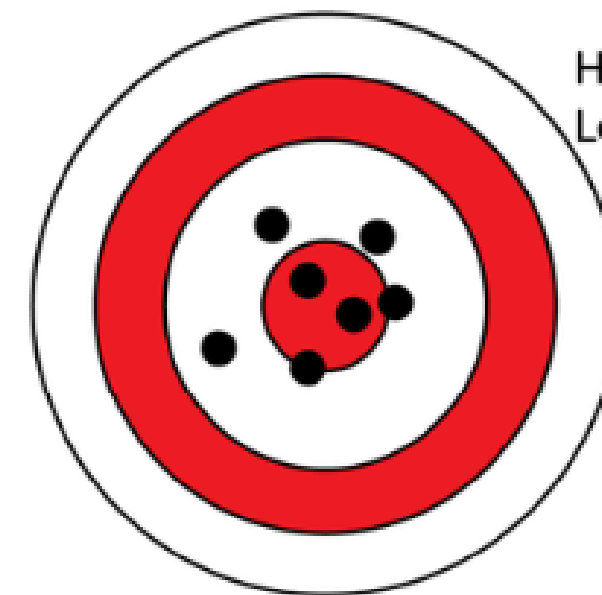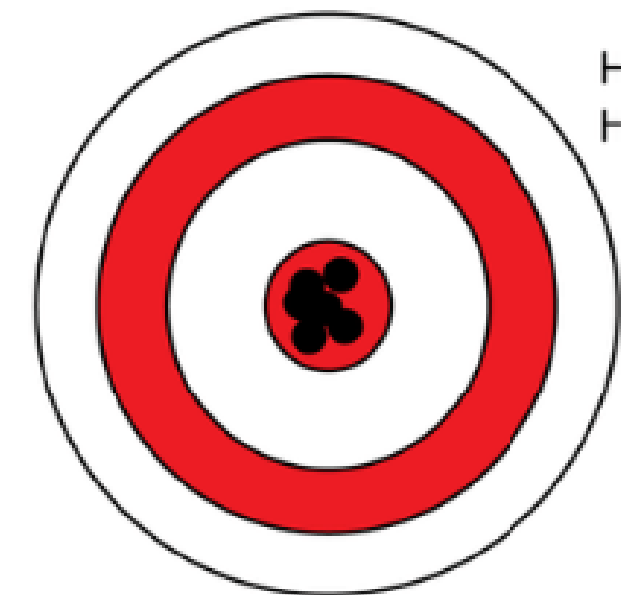
⬇

How much the samples are close to each other

Low accuracy
Low precision
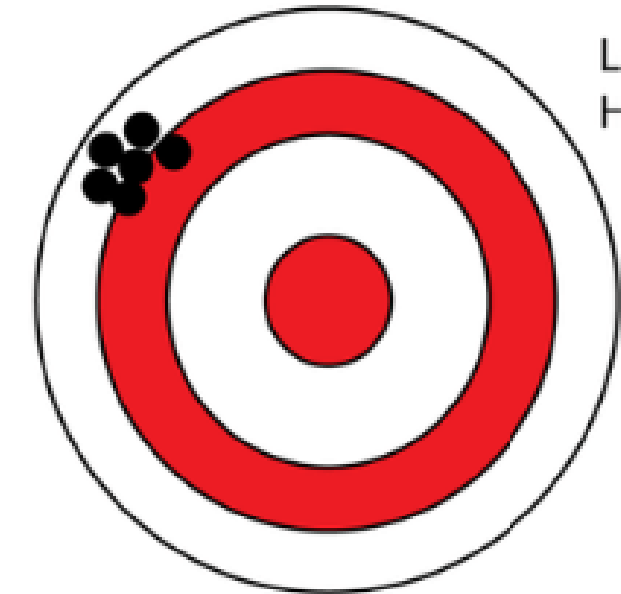
Low accuracy
High precision

High accuracy
Low precision

High accuracy
High precision

- Experiment 1: Static validation of location system

Areas	Accuracy (mean ± SE, cm)			Precision (mean ± SE, cm)		
	X-axis	Y-axis	2D (XY)	X-axis	Y-axis	2D (XY)
Feeding	8.3 ± 1.4	17.3 ± 3.8	21.0 ± 3.6	5.0 ± 0.6	7.6 ± 1.1	9.1 ± 1.2
Lying cubicles	7.6 ± 1.2	15.3 ± 2.2	18.6 ± 2.1	4.8 ± 0.4	6.5 ± 0.7	8.2 ± 0.8
Alleys	6.0 ± 1.1	9.6 ± 1.3	12.6 ± 1.3	4.8 ± 0.7	6.0 ± 0.9	8.9 ± 1.1
Drinking area	15.5 ± 3.6	21.3 ± 6.0	29.6 ± 5.3	10.4 ± 1.8	11.0 ± 2.0	15.2 ± 2.6
Concentrate feed	14.3 ± 4.5	22.0 ± 9.0	28.8 ± 8.1	9.6 ± 1.3	12.6 ± 1.6	15.9 ± 2.0
Brushing area	4.0 ± 1.1	17.4 ± 2.8	18.2 ± 2.7	6.3 ± 0.5	6.1 ± 0.5	6.8 ± 0.7
Wait for milking	11.4 ± 2.2	8.37 ± 2.5	15.5 ± 2.8	7.4 ± 1.3	7.0 ± 1.5	10.3 ± 2.0
Milking robot	74.9 ± 19.7	34.9 ± 12.9	86.8 ± 17.8	34.9 ± 9.8	18.3 ± 3.0	39.6 ± 10.0
Average (Barn)	10.4 ± 1.3	16.0 ± 1.3	21.2 ± 1.6	6.8 ± 0.6	7.5 ± 0.5	10.4 ± 0.8

- The location system presented high accuracy 21 cm
- The accuracy was **highest** for the **alleys** and **lowest** for the **milking robot**

=>Covered with a concrete ceiling (signal attenuation)

EXPERIMENT 2: BEHAVIOUR MONITORING

Tracking tag

- **Data collection**
  - Tags attached to collars, 30 cows, 5 days
  - Video recording for validation (golden standard)

- **Data processing**
  - Step 1: area detection (location data)
 - Step 2: behaviour classification (accelerometer data, Decision tree algorithm)
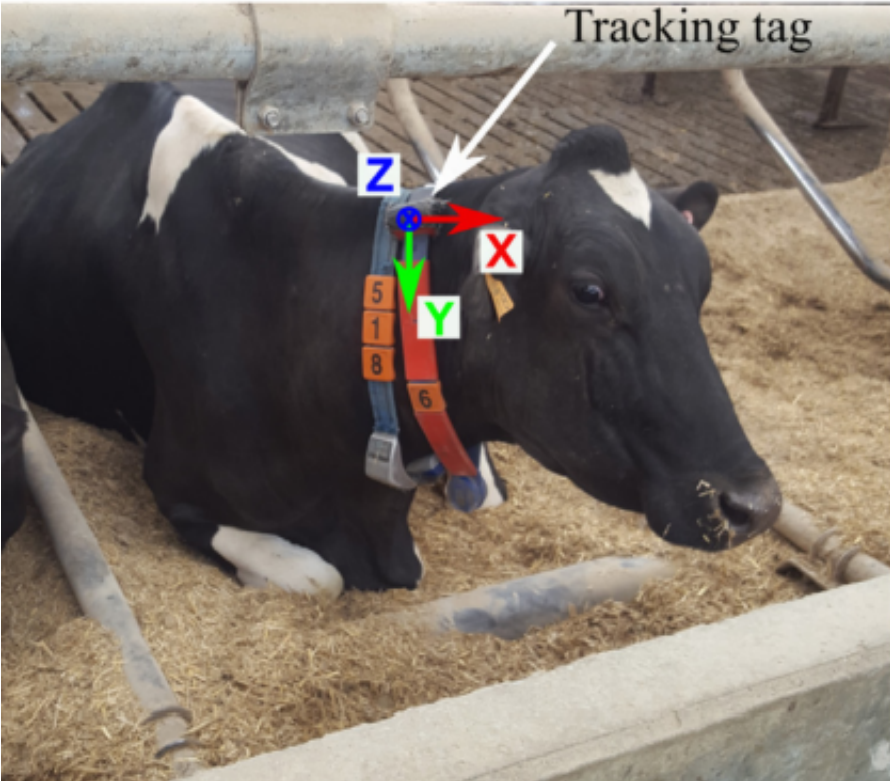
Areas (location)	Behaviours (accelerometer)
Alleys	Ruminating, resting, other activity
Drinking area	Drinking, resting, other activity
Wait for milking area	Ruminating, resting, other activity
Milking robot	Eating concentrate, other activity
Lying area	Ruminating, resting, other activity
Concentrate feeder	Eating concentrate, other activity
Feeding area	Feeding, resting, other activity

The considered cows' behaviours for each barn's area

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EXPERIMENT 2

- ## Performance analysis

  - 123 hours were annotated using ELAN software
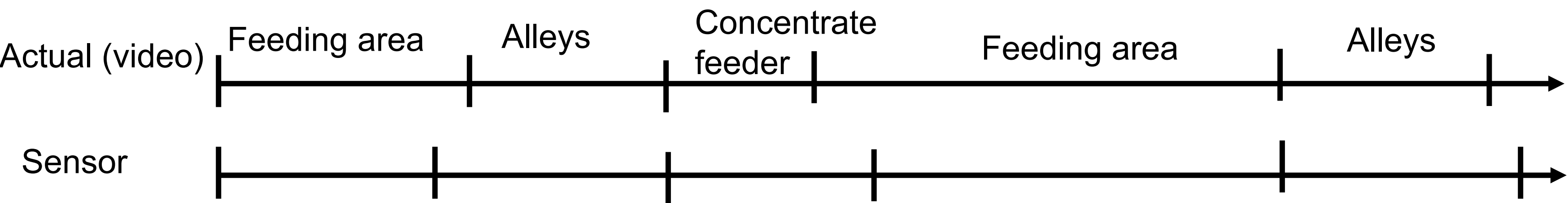
	Video	Sensor
Feeding area sample 1	20 min	18 min
Alleys sample 1	7 min	9 min
Concentrate feeder sample 1	3 min	5 min
Feeding area sample 2	25 min	22 min
Alleys sample 2	11 min	13 min

=>Bland-Altman plot (correlation and difference plot): R^2, RMSE, CV (Coefficient of variation)

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RESULTS AND DISCUSSION

All sample

- Locating the animals into the correct functional areas:

  - Overall (all samples) RMSE = 1.4 min

  - Best: lying area (large area, cows not moving)

  - Worst: concentrate feeder
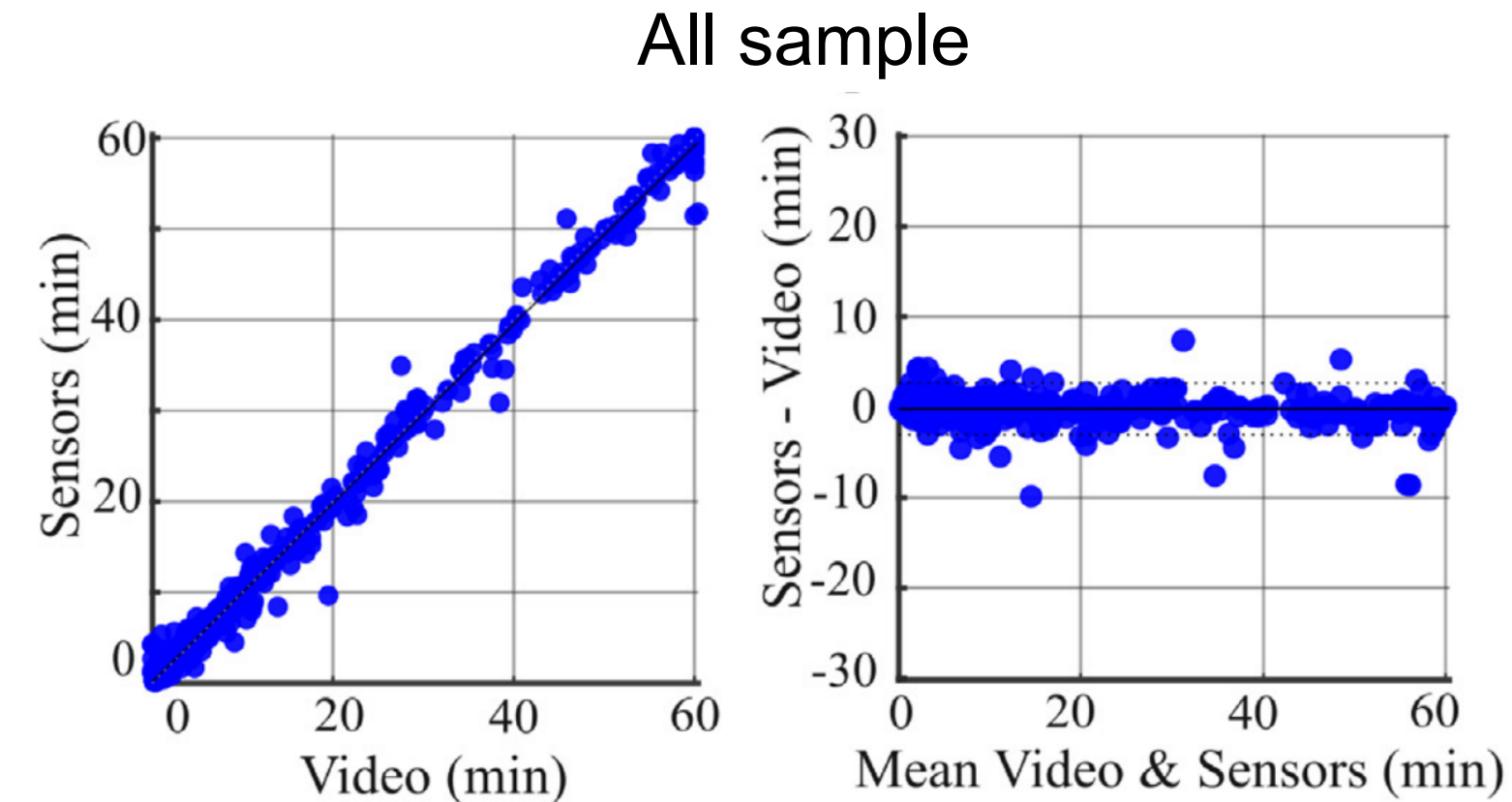
Area/behaviour	Samples N	R² (-)	RMSE (min)	CV (%)
Feeding area	97	0.99***	1.5	5.3
Lying area	98	0.99***	1.5	**3.5**
Wait for milking	59	0.98**	2.0	8.6
Milking robot (VMS)	48	0.95*	0.5	9.0
Drinking area	67	0.93**	0.7	24.0
Concentrate feeder	43	0.85*	0.7	**33.0**
Alleys	98	0.96*	1.5	19.0
All samples (Barn)	510	0.99***	**1.4**	7.5

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, no asterisks mean $P > 0.05$
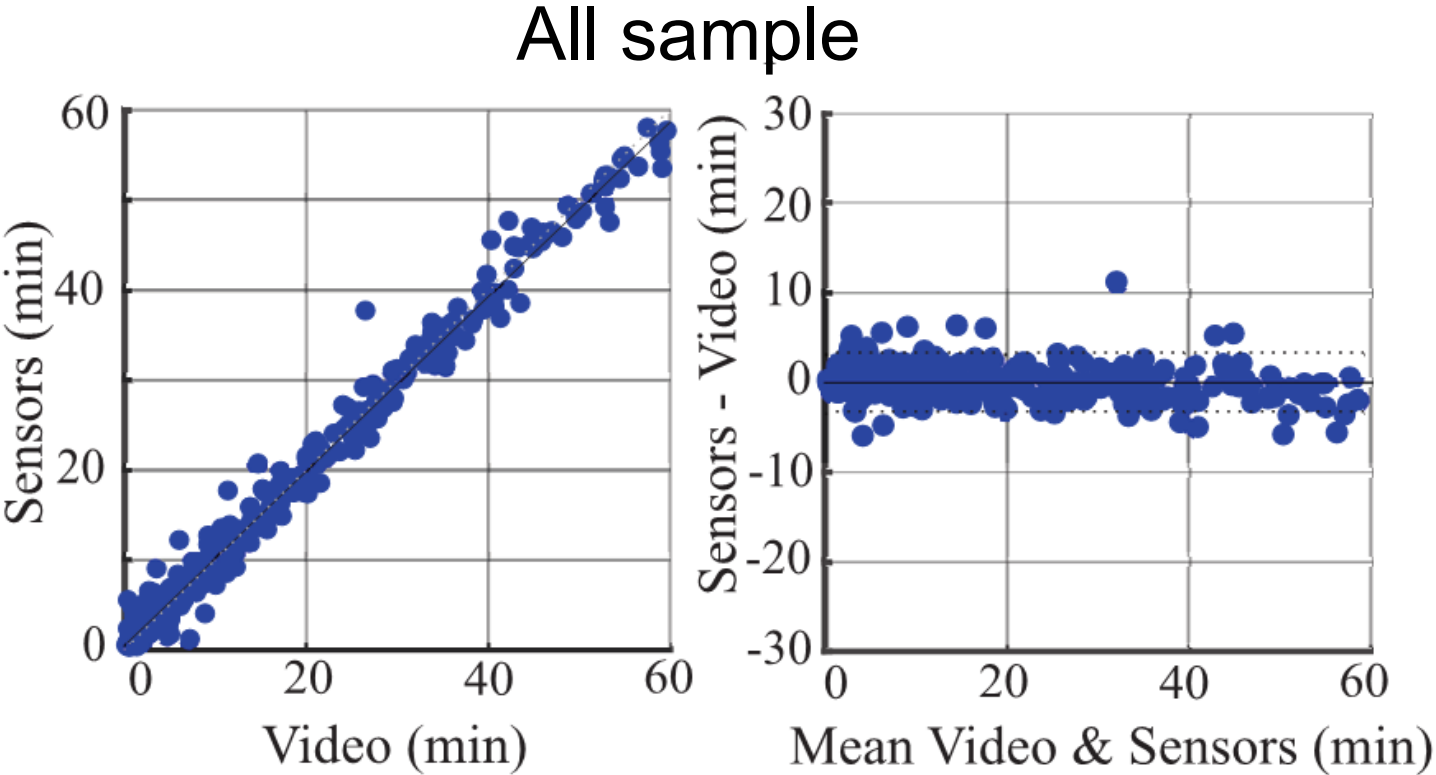
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RESULTS AND DISCUSSION

All sample

- ## Behaviour (location+ accelerometer)

  - Overall RMSE 1.6 min

  - Improved RMSE feeding time and ruminating time compared to the accelerometer data alone (2.6 min [1] to 1.4 min).

 - Detection of eating concentrates and drinking

Area/behaviour	Samples N	R^2 (-)	RMSE (min)	CV (%)
Feeding time	83	0.99***	1.4	5.6
Drinking time	50	0.85**	0.7	25.0
Ruminating time	86	0.99***	1.8	7.7
Resting time	90	0.98**	1.8	13.0
Eating concentrates	59	0.90*	0.7	18.0
Other activity	83	0.83**	1.4	30.0
All samples	454	0.99***	**1.6**	12.0

*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$, no asterisks mean $P > 0.05$

[1] Benaissa, S., Tuyttens, F.A.M., Plets, D., Cattrysse, H., Martens, L., Vandaele, L., Joseph, W., Sonck, B., 2019a. Classification of ingestive-related cow behaviours using RumiWatch halter and neck-mounted accelerometers. Applied Animal Behaviour Science 211, 9–16.

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APPLICATIONS

- Time in feeding area while not eating ➡ prolonged hunger

- Time in drinking area while not drinking ➡ prolonged thirst

- Resting/ruminating outside lying area

    ➡ Alert the farmer about the animals that require attention

- Social behaviour analysis
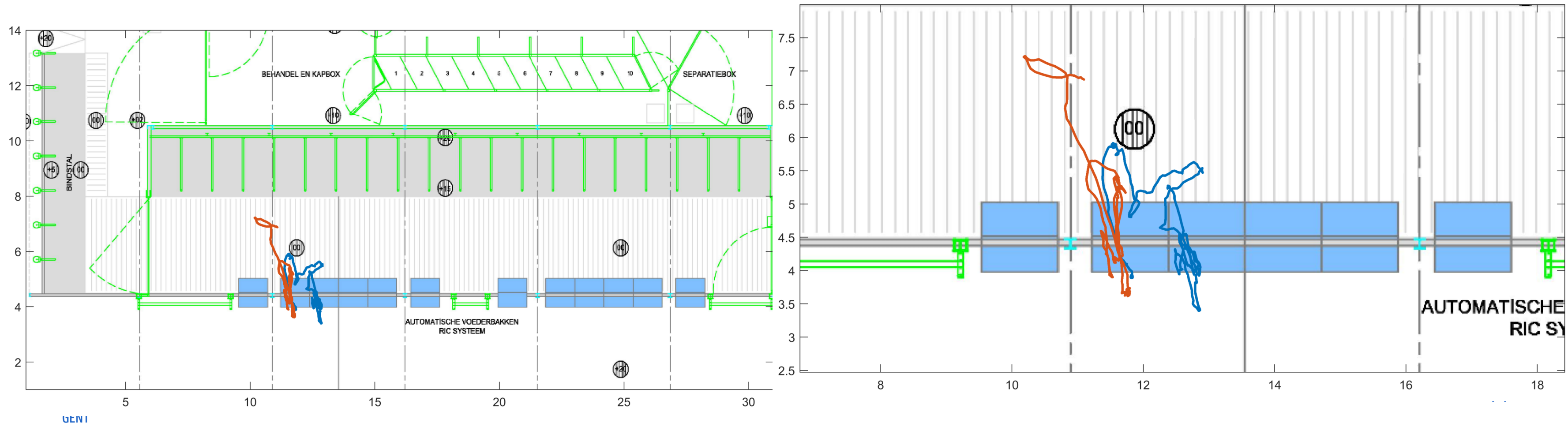
CONCLUSION AND FUTURE WORK

- Potential of combining accelerometer and UWB location data

  ➡ Robust behaviour monitoring system for dairy cattle

- Future work will include the tracking of the social interactions

  ➡ Still a challenge for current PLF systems

- Important step towards data integration from multiple data sources

- Improved production efficiency

- Animal welfare and sustainability

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