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Computer vision technology for automated lameness assessment

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LIVESTOCK RESEARCH WAGENINGEN UR

DeLaval

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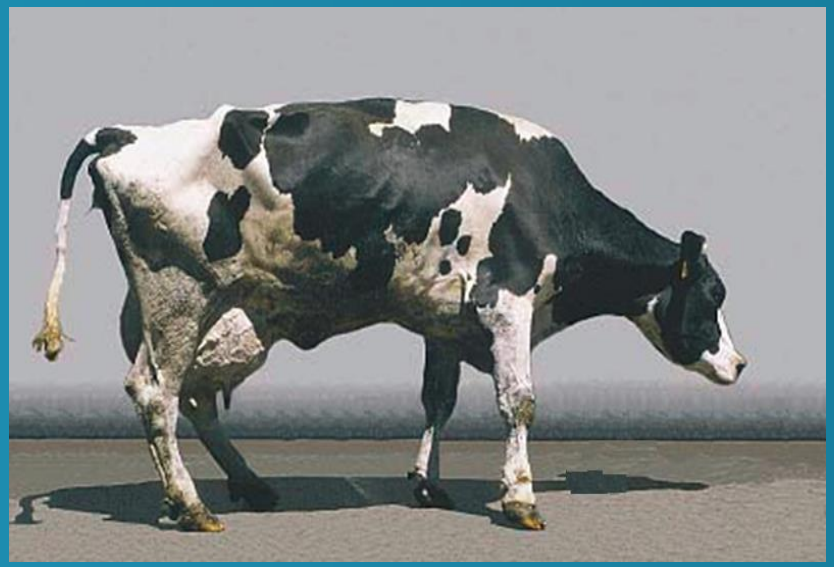
  - Technicians Ludo Happaerts (KUL) & Aharon Antler (ARO)
  - Farmers and staff.

Outline

- Why is lameness detection important?
- Computer vision technology
- Implementation of camera technology
- Behaviour and performance sensing
- Multi-sensor lameness detection
- General conclusions
- EU-PLF project



What is lameness?
Why is lameness important?

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Dairy industry in Flanders

Year	# dairies	#cows/dairy	Kg milk	Kg fat	Kg protein	ejr
2006	3433	45	7942	332	271	1920
2008	3100	49	8014	336	276	1953
2010	2802	55	8175	342	280	1983
2012	2469	59	8317	347	287	2026
2014	2166	67	8392	344	289	2026
	-27%	+49%	+6%	+4%	+7%	+6%

Source: mpr-uitslag 2014 (www.crv4all.be)

➔ Intensification and up-scaling

➔ Less time per animal

Introduction to lameness

- What is lameness?
  - … deviation in gait and posture due to pain or discomfort resulting from hoof and leg injuries and diseases.

Introduction to lameness

- Deviation in gait and posture…

Gait

Asymmetry
Reluctance Bear Weight
Speed
Stride length
Tracking-up
Affected Leg Evident
Abduction-Adduction
Joint Flexion

Posture

Back curvature
Head-Bob
Hip Hick

Others

Difficult turning
Difficult rising
Tenderness
Affected behaviour

Lameness assessment

- Locomotion score
  - Subjective
  - Time consuming
  - Expensive

- Aim: Lameness detection based on PLF
  - ➔ Automated
  - ➔ Objective
  - ➔ Continuous
  - ➔ (Early) warning

Computer vision technology

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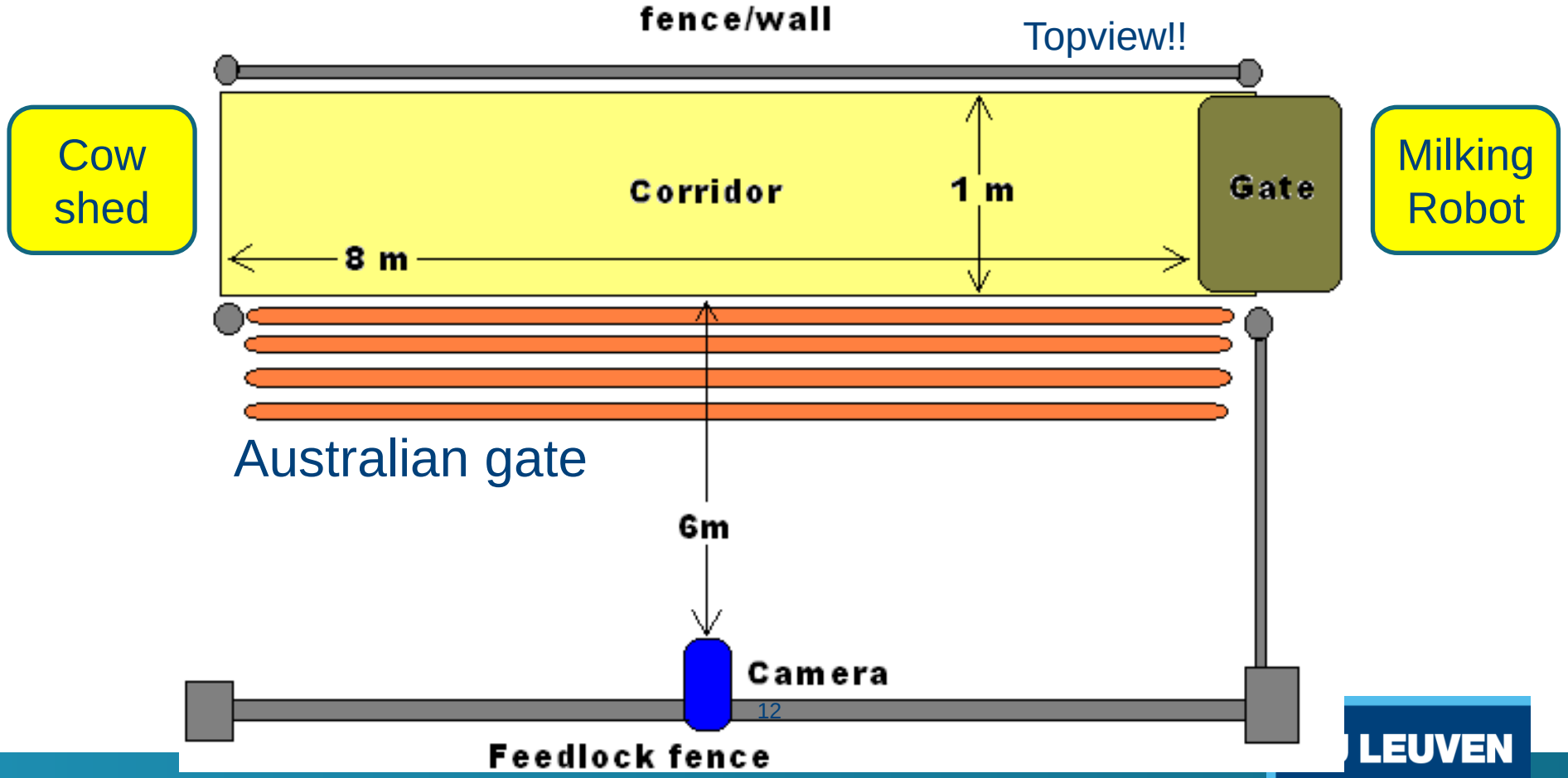
Why computer-vision?

- Replace eyes of farmer
- Biggest effects of lameness:
  - Not on cow behaviour
  - Not on cow performance
  - BUT on cow locomotion
- Non-invasive
- Cheap
- 1 sensor for entire herd

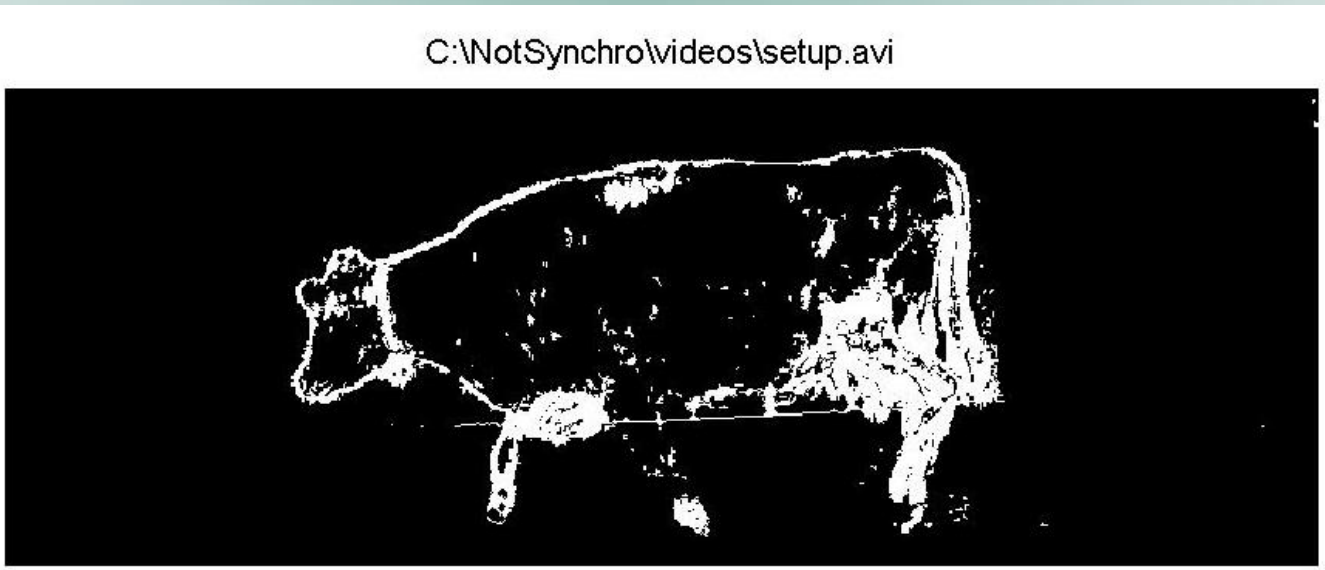
2D RGB computer vision

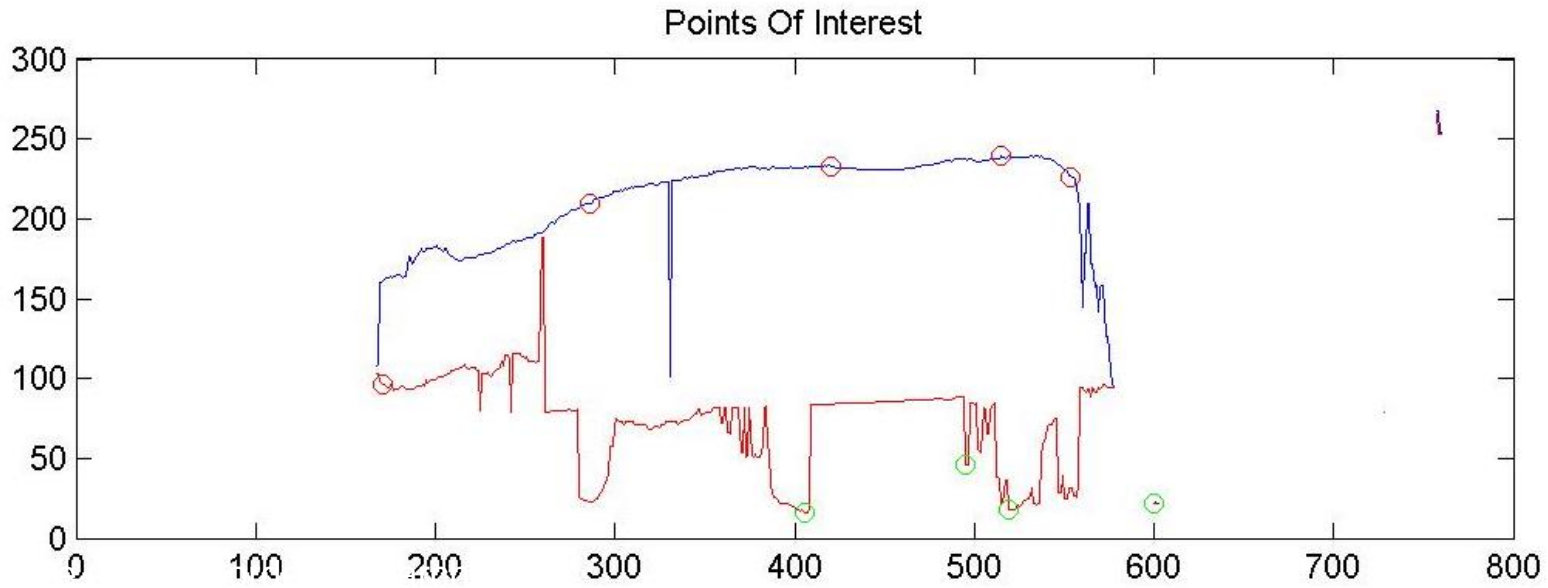
- Replace eyes of farmer
- Lameness ➔ Recording of cow gait ➔ after milking




Cow shed
Milking Robot

2D Video preprocessing





2D side view computer vision

- Manual labeling of POI → lameness classification model

Limitations:

- Robustness of segmentation
  - Foreground (cow) <-> background
  - Need for static background
  - Computational power vs. real-time
- Side view
  - Interfered management practices
  - → limit commercialization

De

Microsoft Kinect

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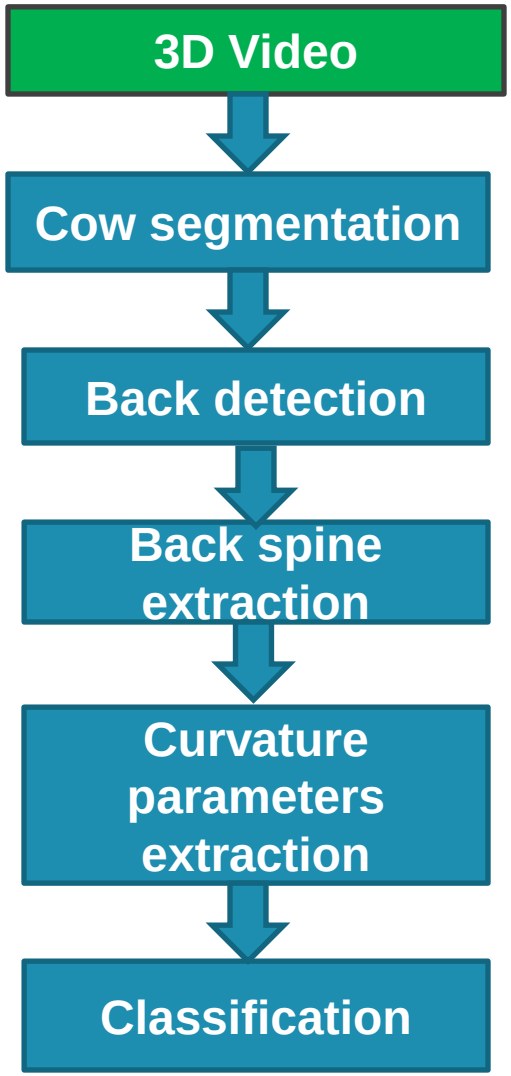
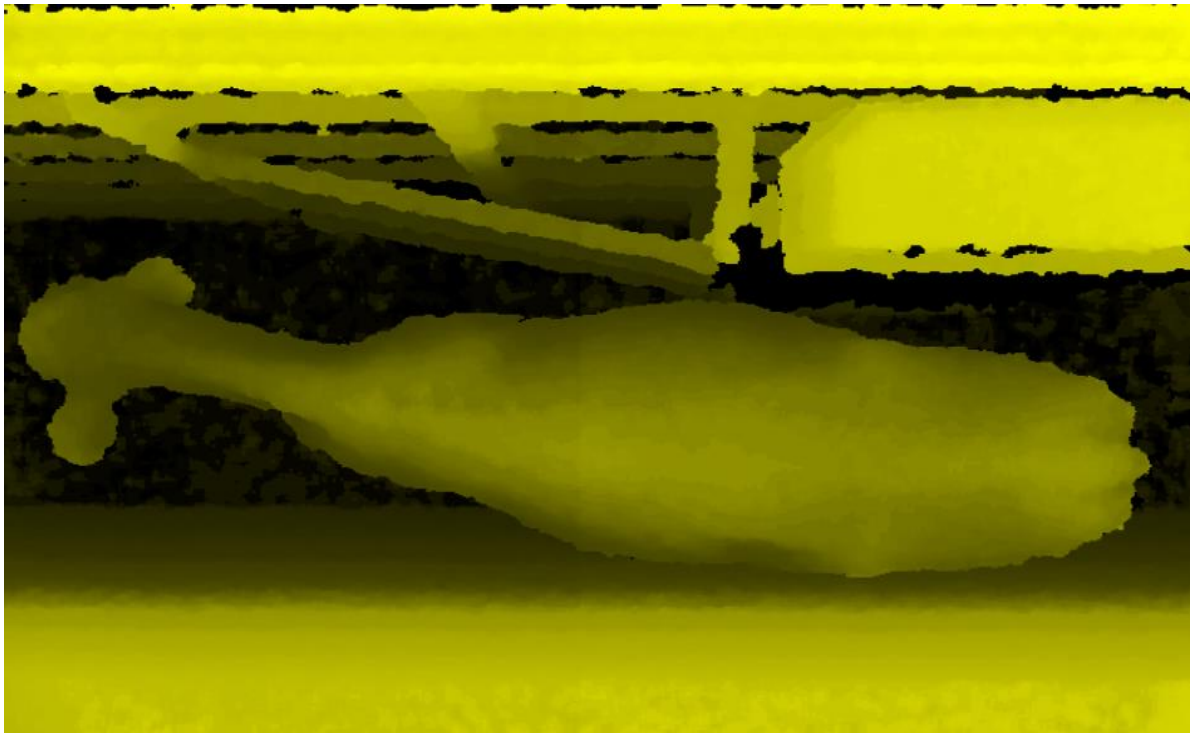
Algorithm flowchart





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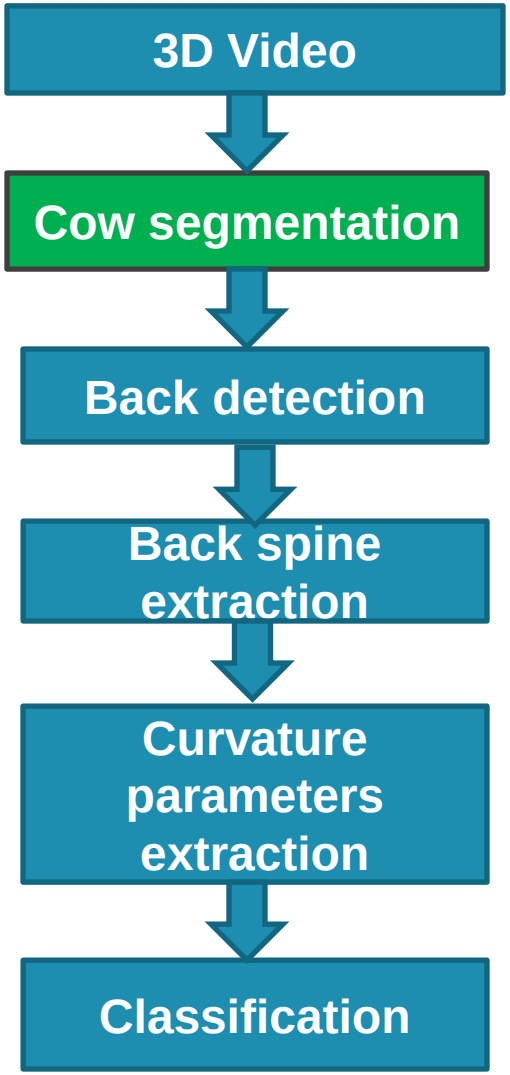

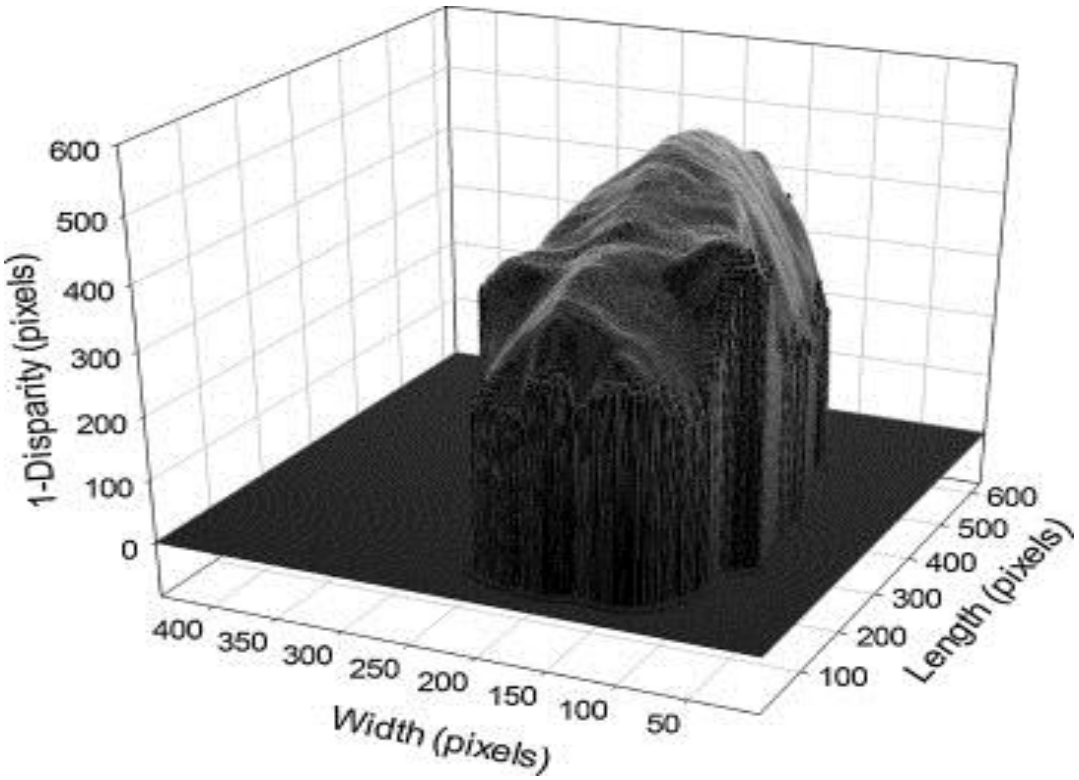

Threshold on depth image

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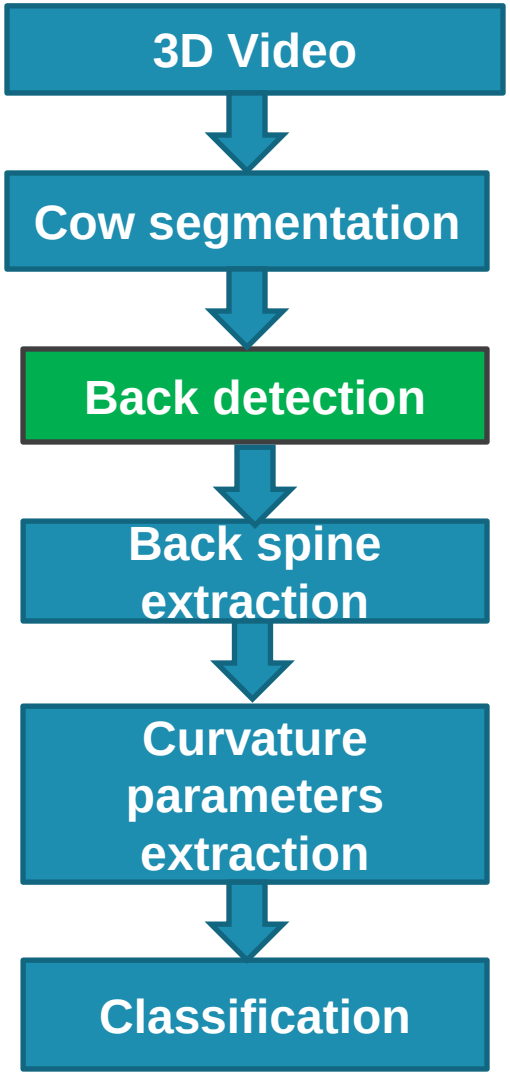
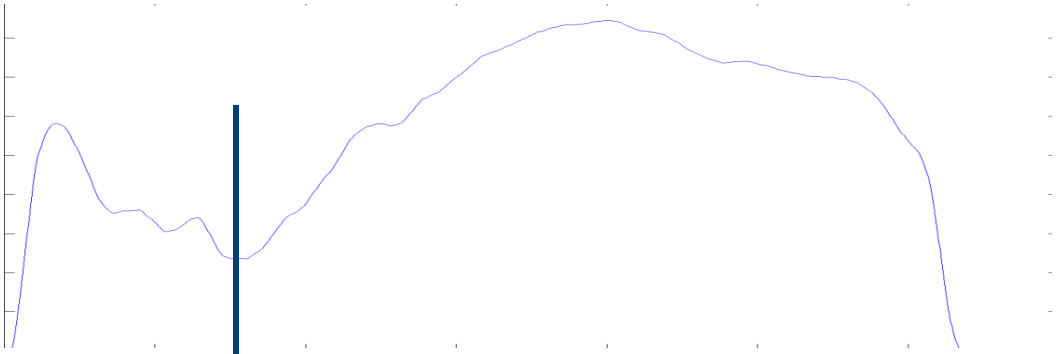
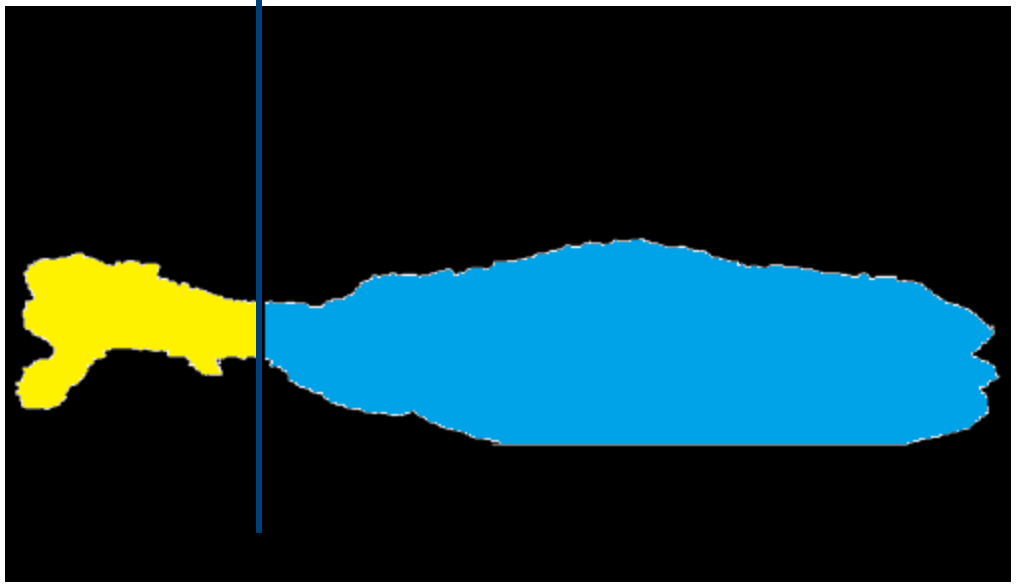
Algorithm flowchart





Pixel histogram along x-axis



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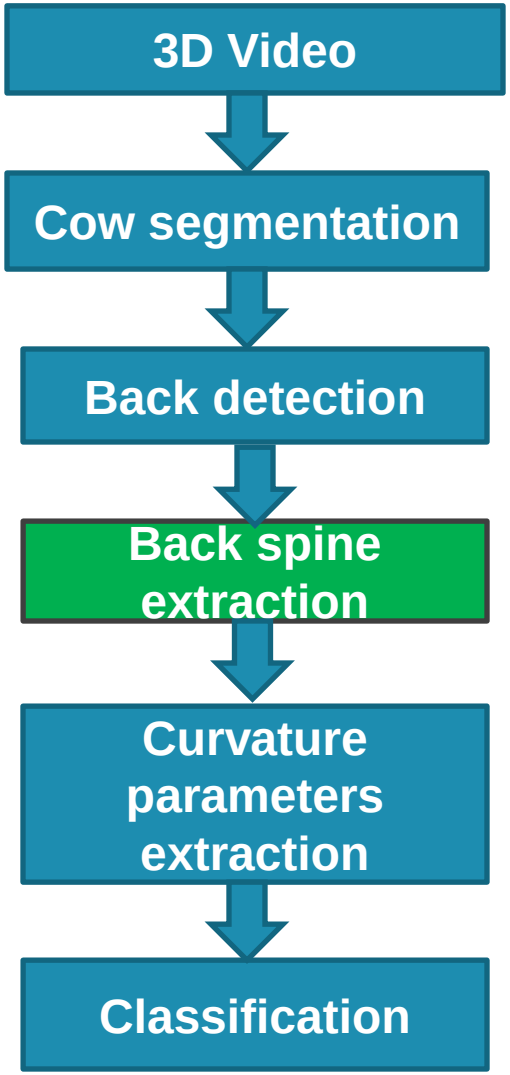
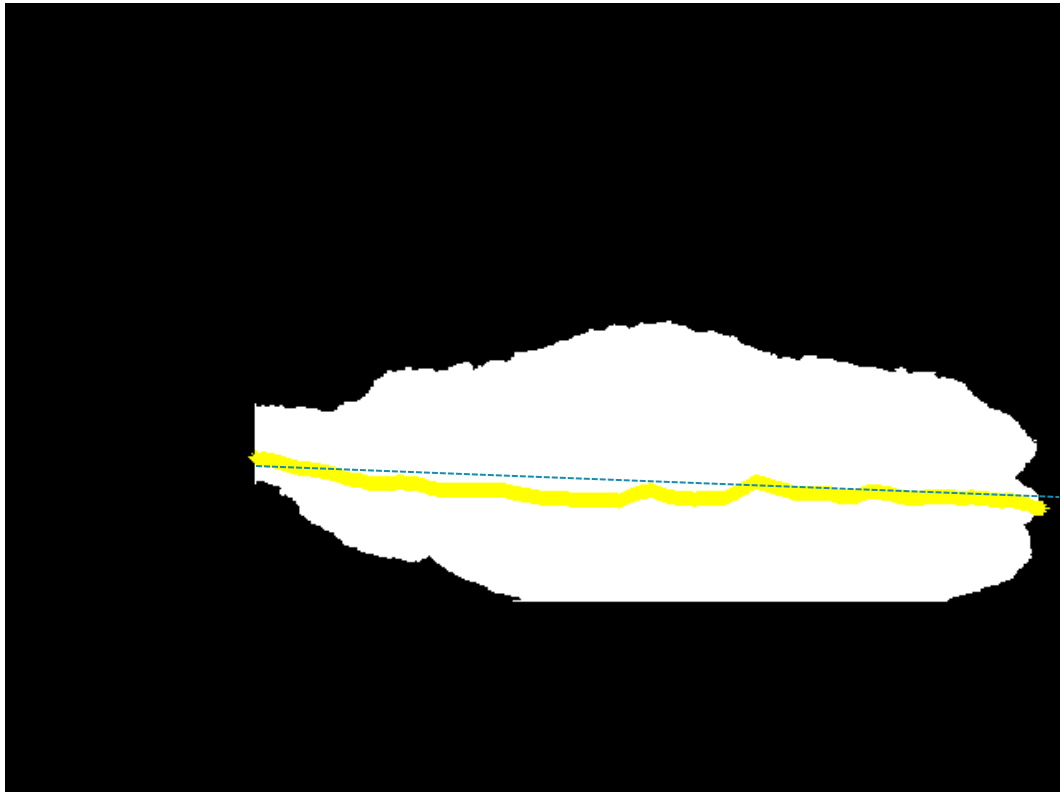
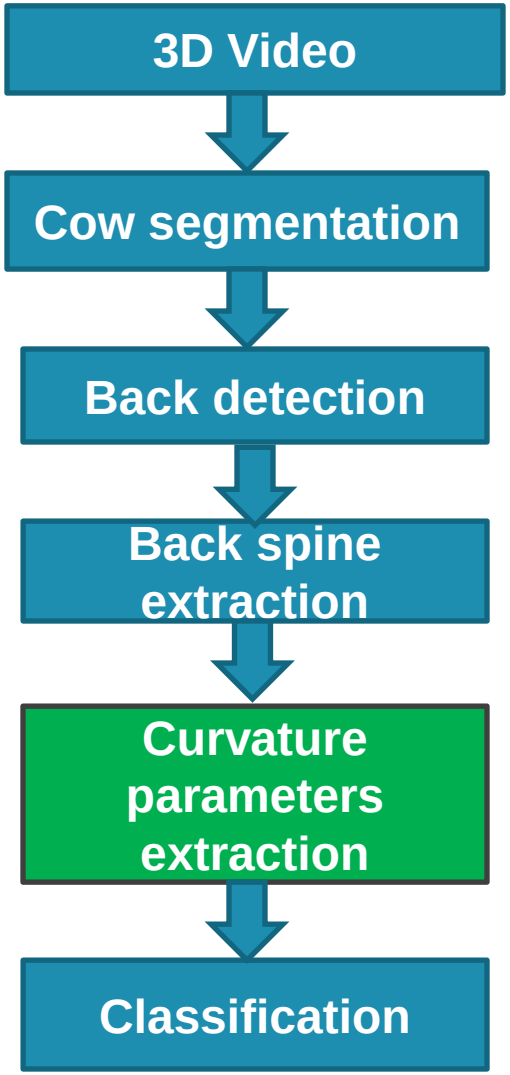
Algorithm flowchart

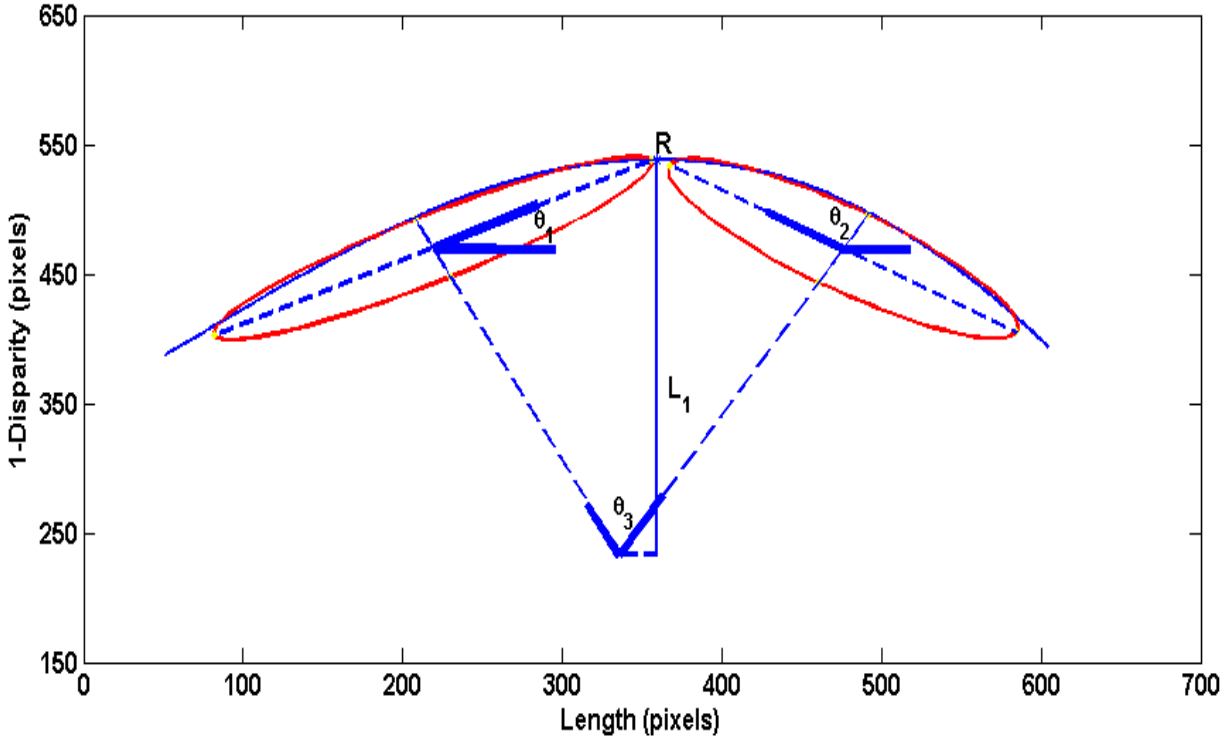




Back spine extraction

Algorithm flowchart





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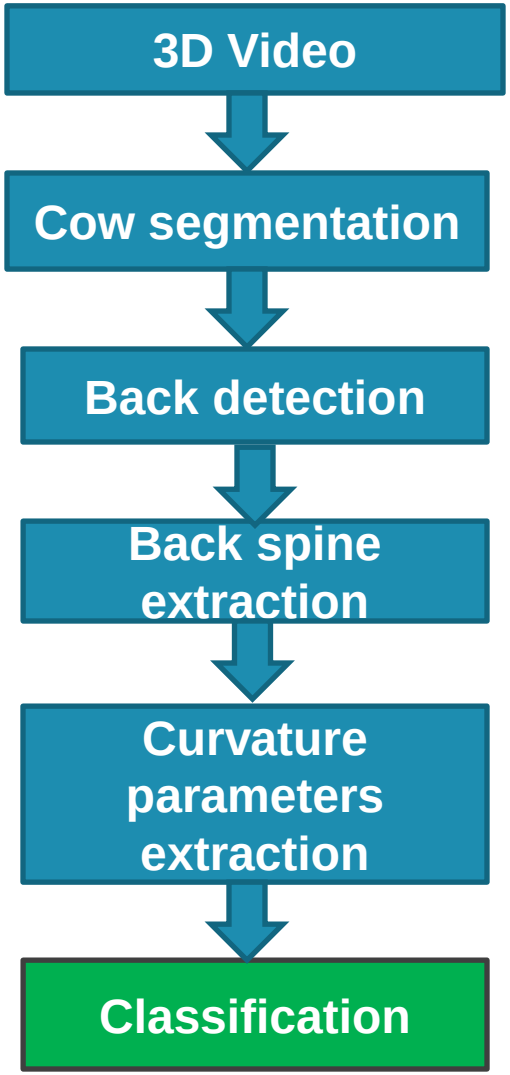
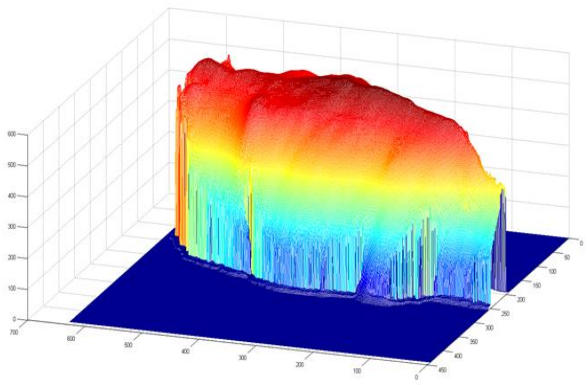
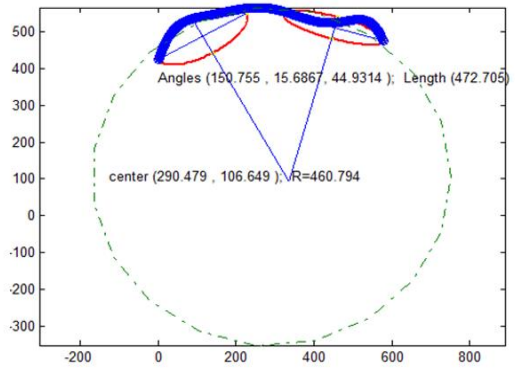
Algorithm flowchart

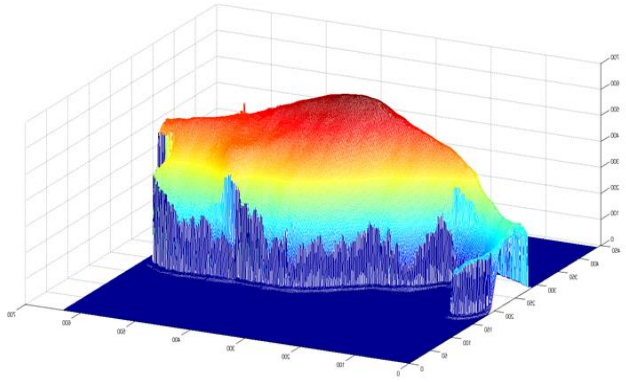


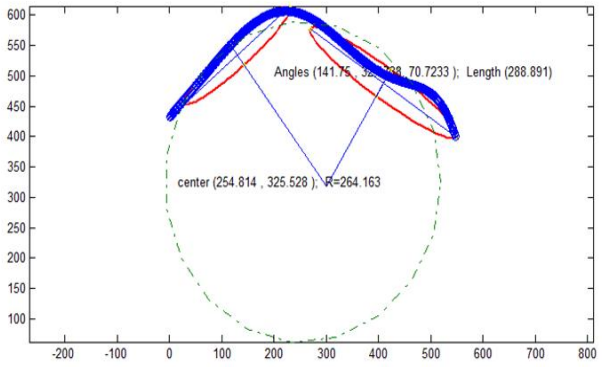
Not Lame





Lame





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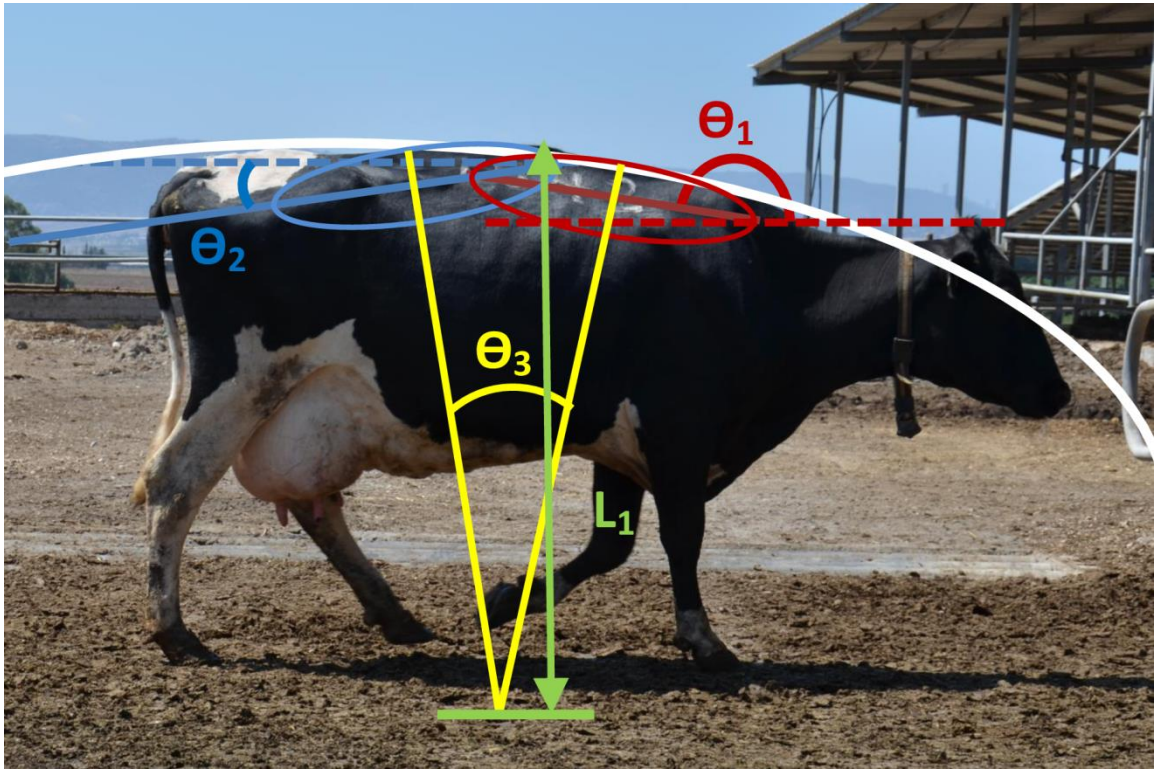
Algorithm output

- Back Posture Measurement
  BPM



Variables θ1, θ2, θ3 and L1 extracted from the reconstructed back curvature of the cow.

Comparison of a three-dimensional and two-dimensional camera system for automated measurement of back posture in dairy cows

Computers and Electronics in Agriculture Volume 100 2014 139 - 147

Algorithm Verification I

- Verification matrix

	Sensitivity	Specificity	Accuracy	n
Calibration	0.76	0.93	0.90	293
Verification	0.54	0.90	0.83	1100

Sensitivity = ability to detect lame animals
Specificity = ability to detect not-lame animals
Accuracy = ability to detect lame and not-lame animals (correct classification rate)

Algorithm Verification II

N =	744 (4x186)	Reference Live Score				
		1	2	3	4	5
Model Score	1	46	14	5	1	0
	2	16	50	15	5	1
	3	1	6	9	3	2
	4	0	2	2	4	0
	5	0	0	0	0	4

90.9%

60.8%

Intermediate conclusions

- Strong relation between BPM and locomotion score
- Classification more robust when considering multiple recordings
- Difficulty in identifying mildly lame cows

➔ need for continuous measurements

On-farm implementation of camera technology

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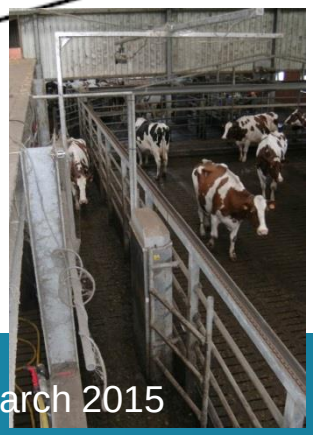
Commercial farm layout



Waiting area

Alley

Pen Group 1

Pen Group 2

Treatment

Human observer position

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Process automation

- Fully automatic video recording & processing
  - Automatic trigger → photocell + RFID
  - Automatic identification
    - RFID-antenna
    - Overlap window for timestamp correlation
      - Recording time stamp [recording pc]
      - RFID time stamp [farm pc]
      - Time delay (every session re-estimated!)
      - 100% accuracy!
  - Automatic analysis (**BPM**-measurement)
    - Offline
    - After the milking + recording session
    - Filter to select good videos

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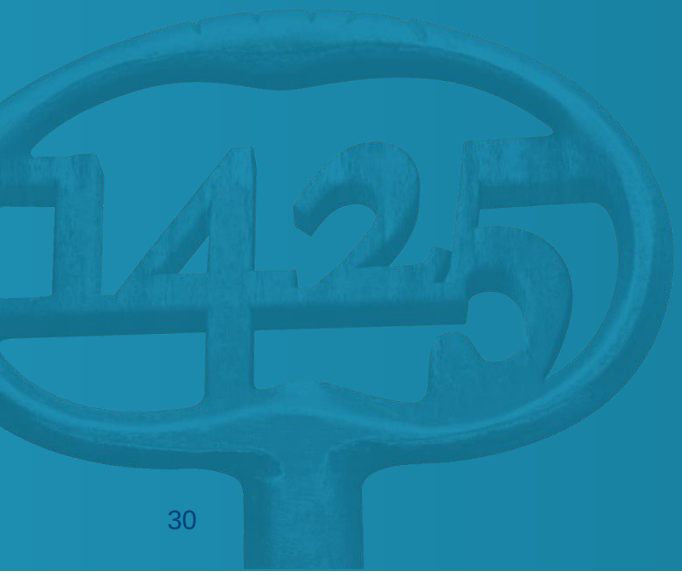
Video recording performance

On recording session level



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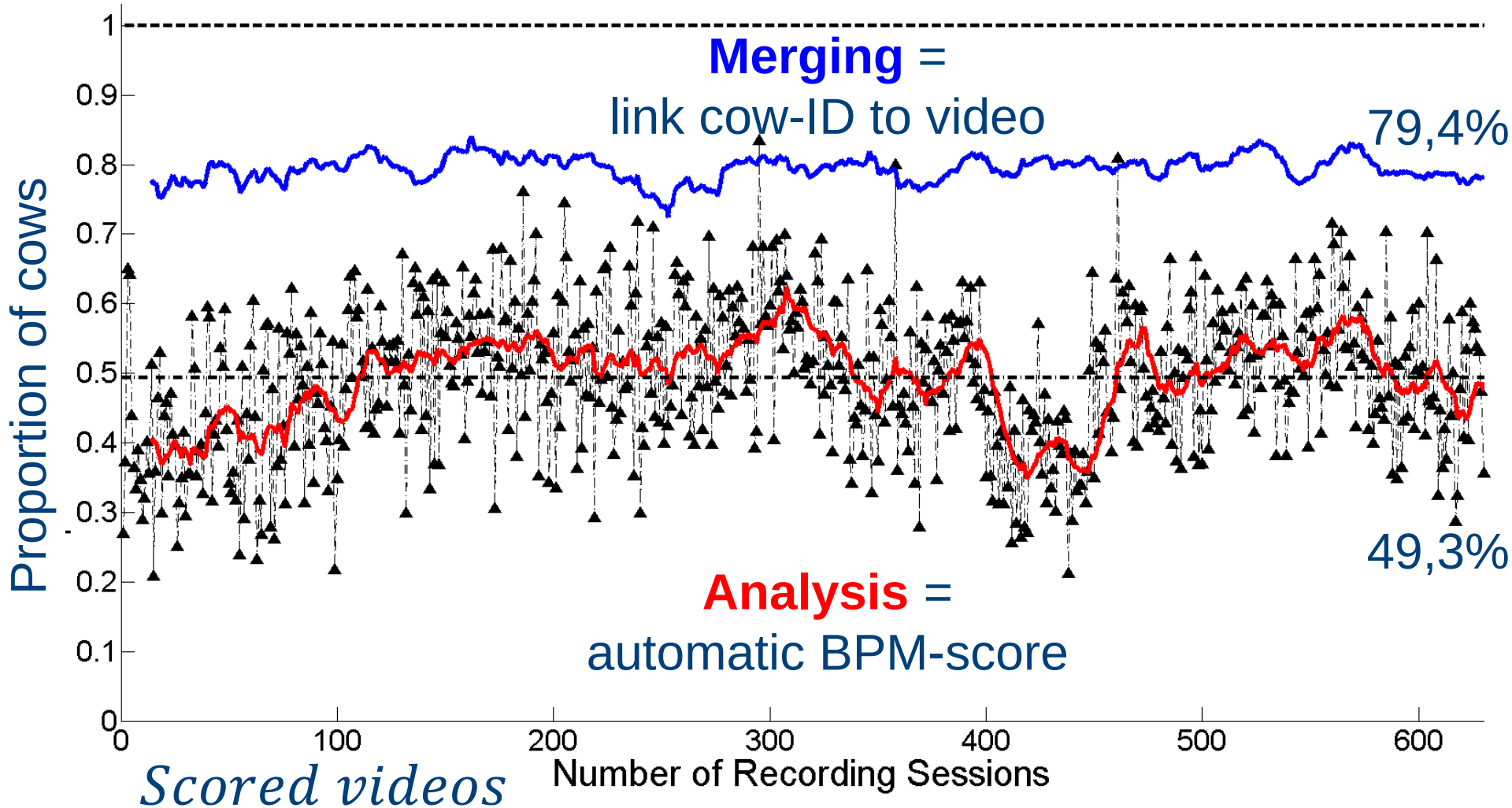
Performance

- Collection period: 20/09/2013 – 19/08/2014
- 630+ recording sessions
- 111900+ BPM-scores

Step in Process	Absolute number	Relative Number [%]
Number of cows milked	226 ± 9	100
Number of cows RFID	224 ± 10	99,1 ± 1,3
Number of recorded videos	197 ± 16	88,1 ± 6,6
Number of video-cowID links	178 ± 14	**79,4** ± 5,5
Number of analysed videos	110 ± 24	**49,3** ± 10,8

Performance per session: analysis



$$\frac{Scored\ videos}{cowID\ linked\ videos} = 61{,}8\%$$

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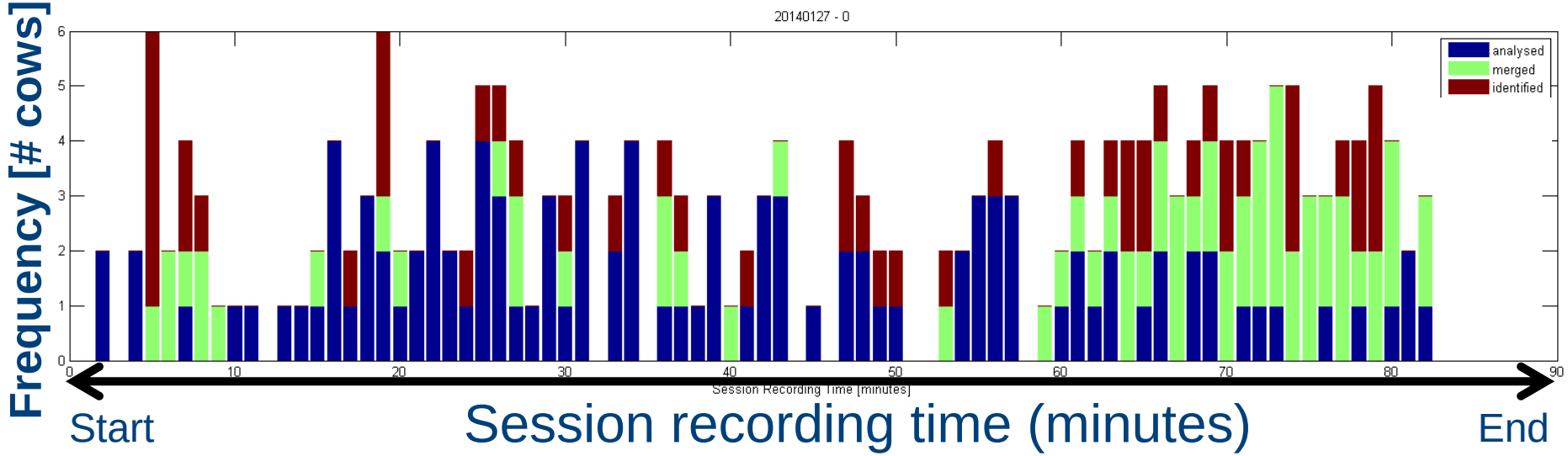
Recording/Milking session performance

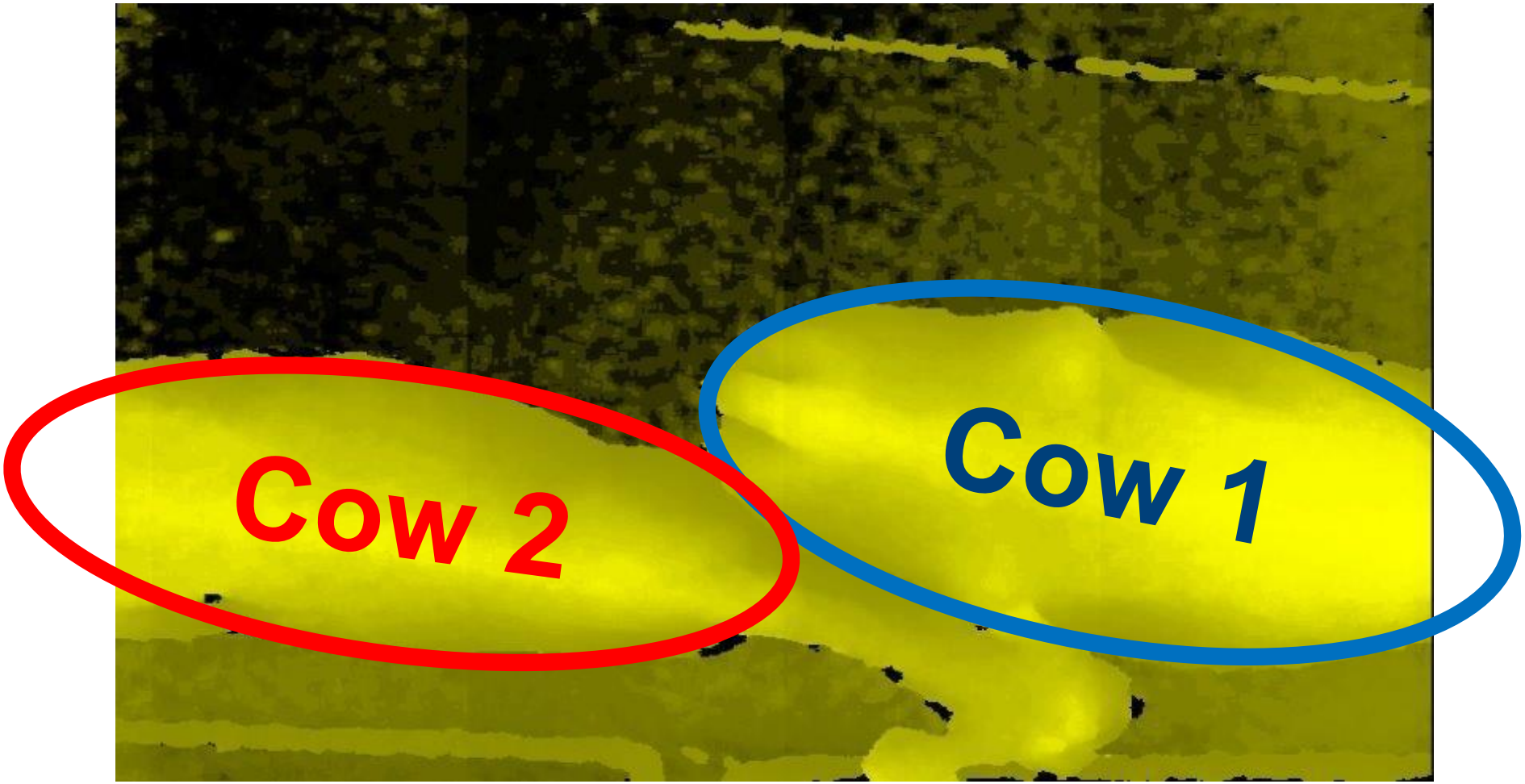


Video ID = 77,7%
BPM-score = 48,2%

MISSED
IDENTIFIED
SCORED

- Impact of cow traffic
- Impact of selection gate (setup)
- Hardware failure
  - Photocell
  - RFID

Cow traffic: crowding in alley



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Video recording performance

On cow individual level

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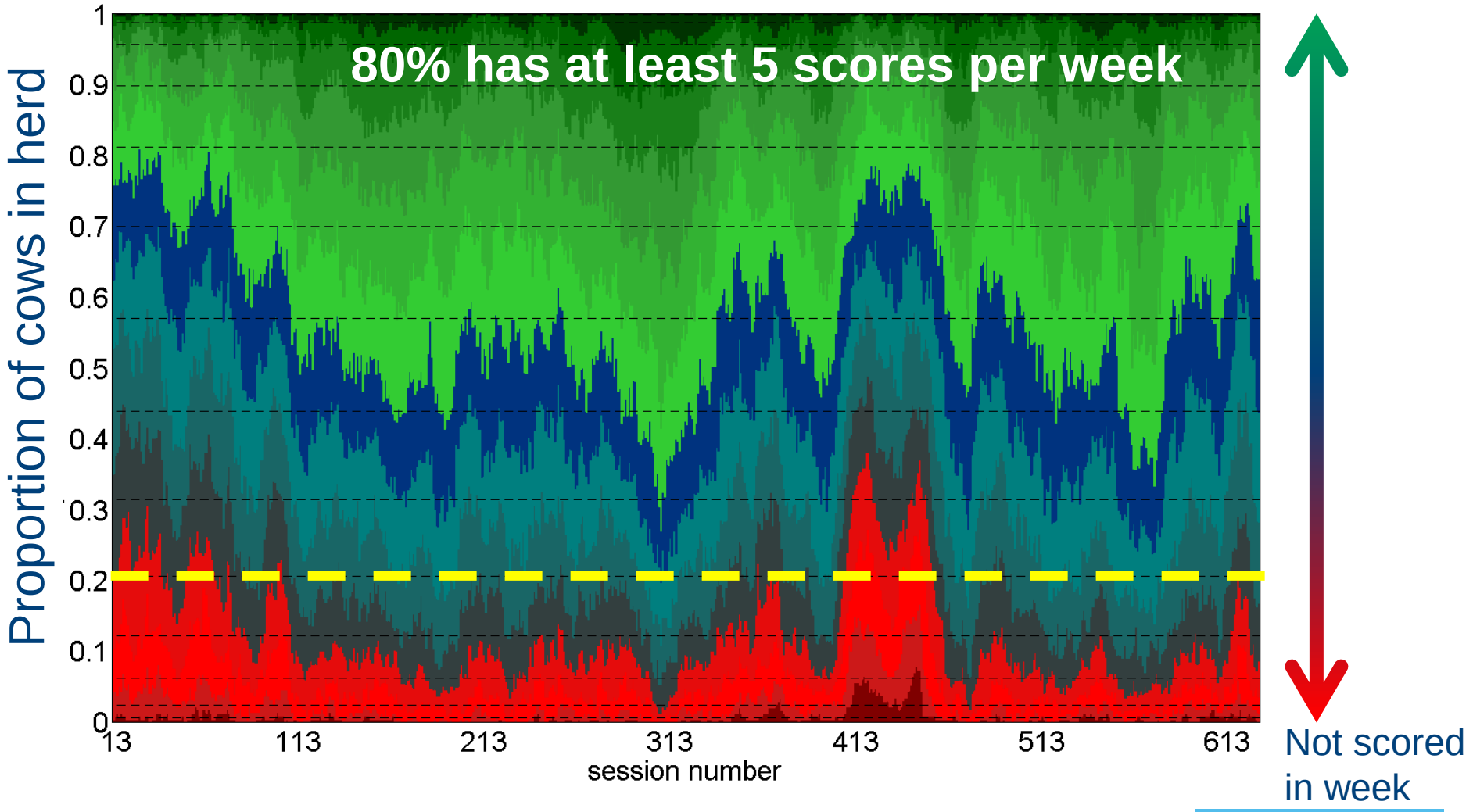
Performance per cow



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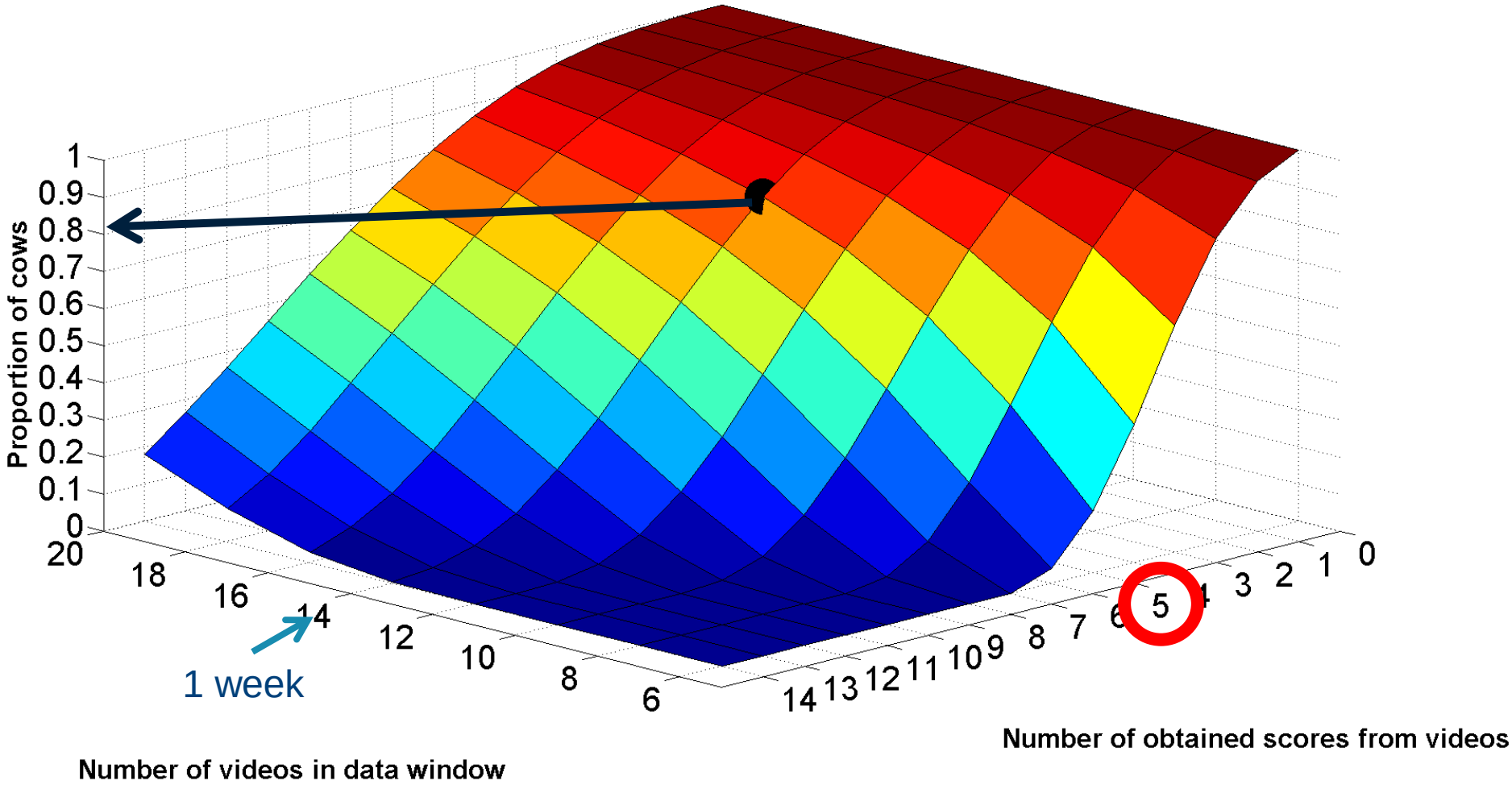
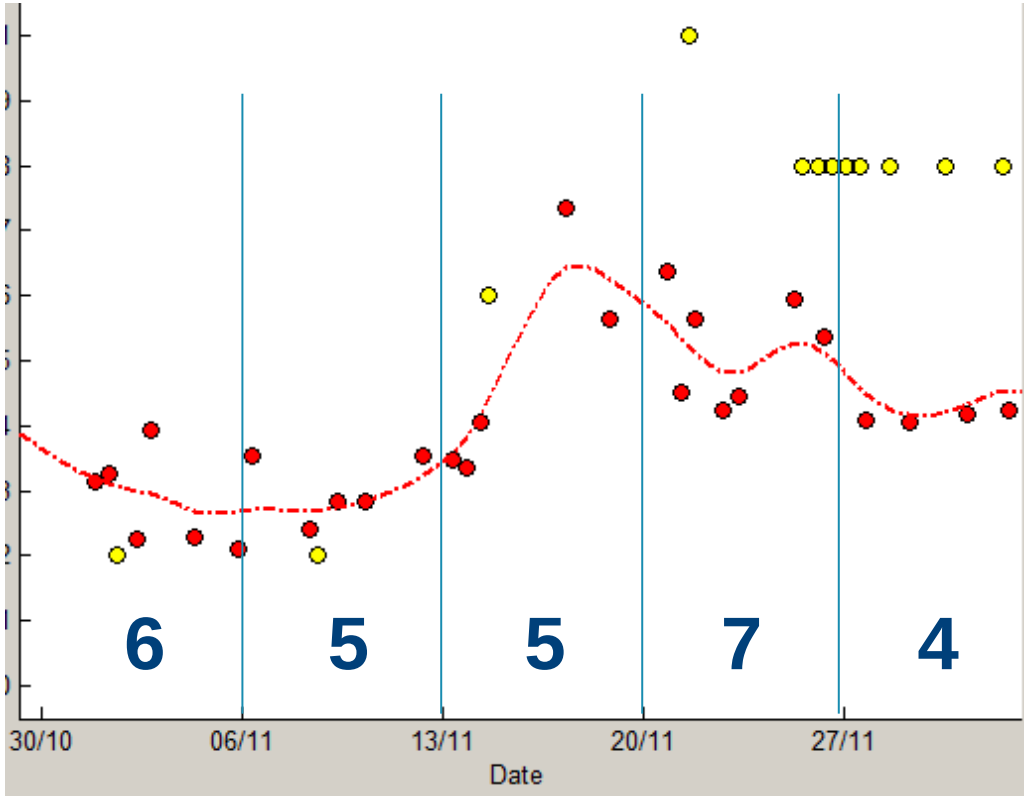
Trade-off for selected window size



Example output of 1 cow



Visual locomotion score

Automatic BPM-score

Herd specific factors affecting analysis rate

- Parity
  - Parity 1: r = -0,51
  - Parity 4: r = 0,38
- Lactation stage
  - Late (271-305 days after calving): r = -0,49
  - Early (0 – 20 days after calving): r = 0,25
- Milking duration: r = 0,43
- Autumn & Spring < Winter & Summer

r = correlation coefficient with analysis rate

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Discussion

- System performance ~ time of farmer
- Optimal traffic intervals for free cow traffic?
- How many scores do we need for lameness detection?
- Type of milking parlour ~ location of recording system
- Can other sensor data help?

Behaviour and performance sensing in dairy cows

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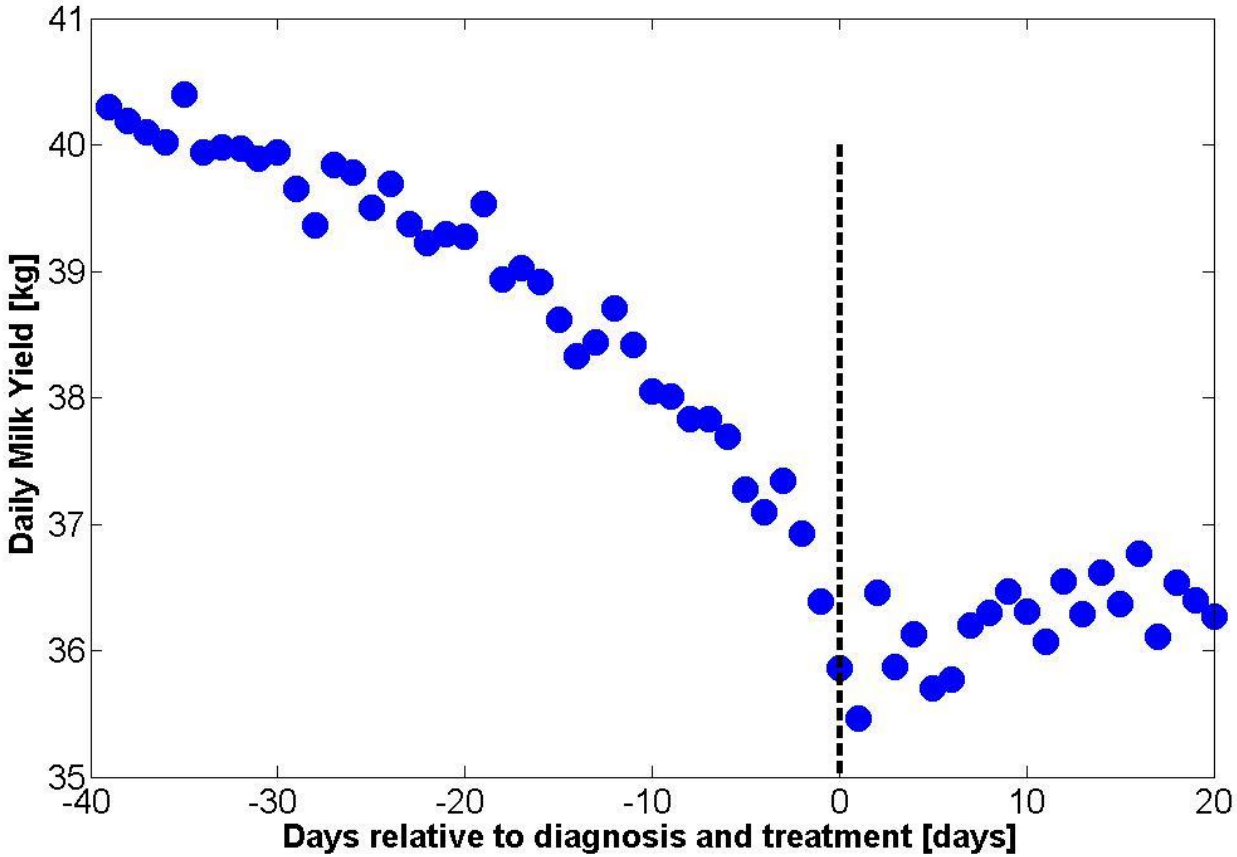
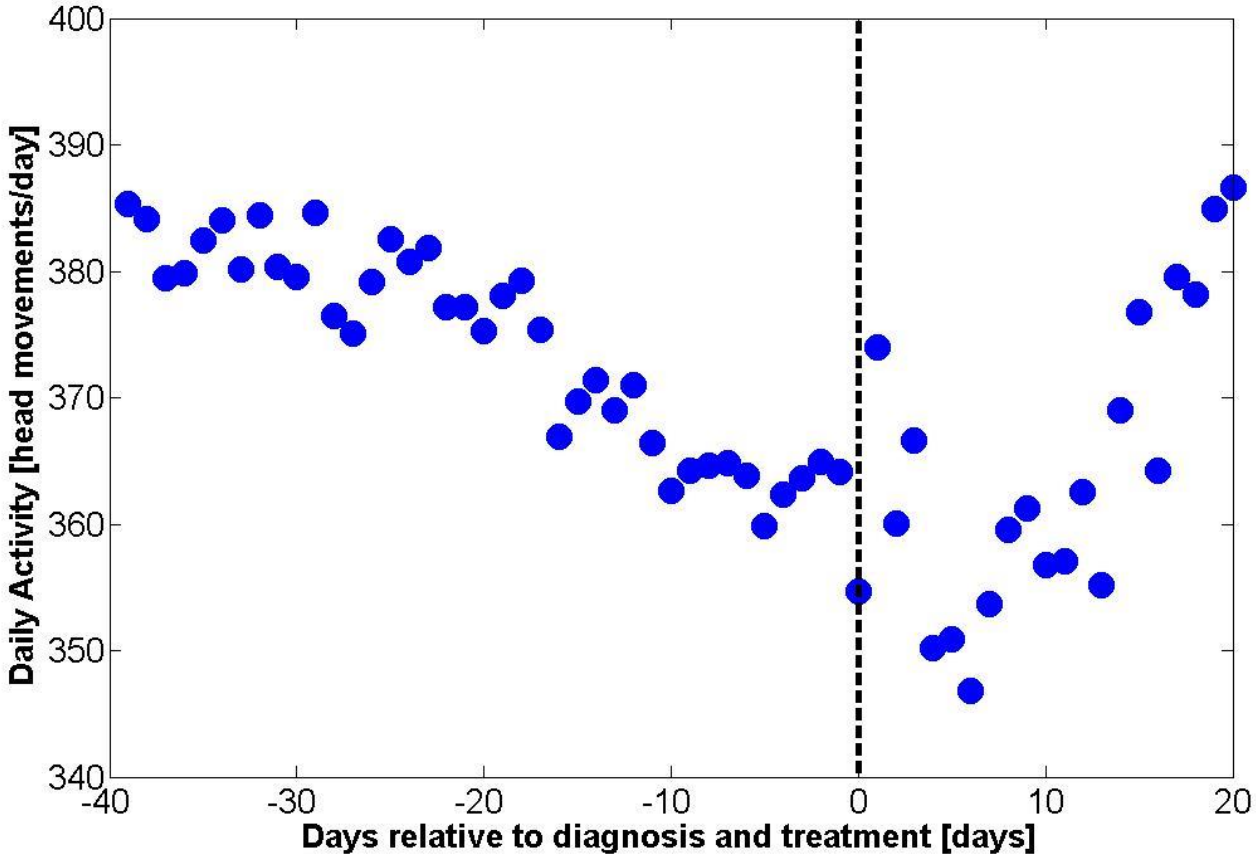
Milk yield in relation to lameness treatment



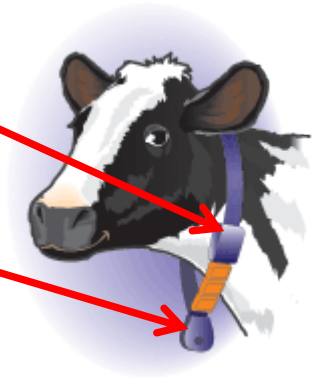
Activity in relation to lameness treatment



Behaviour and performance sensors

- Milk meter MM27BC (DeLaval)
  - Milk yield
  - Milk conductivity
  - Milk flow rate

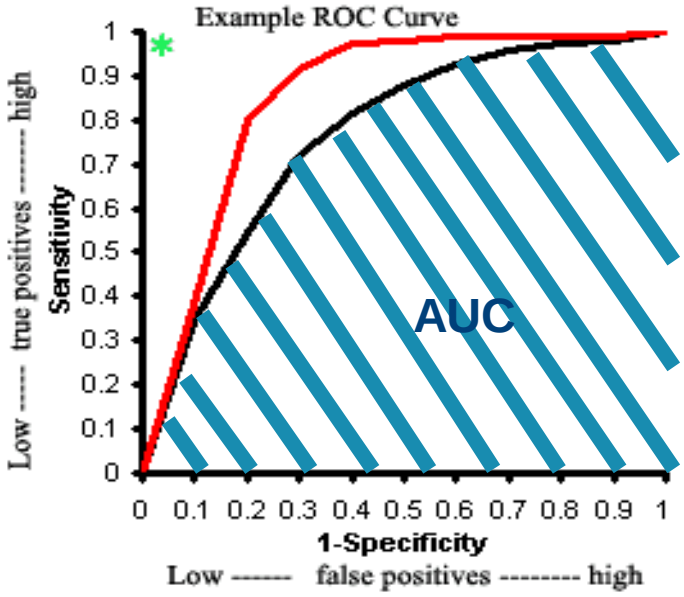
- Activity meter system (DeLaval)
  - Activity [bits/hour]
- Cow recognition
  - Milking time/order



Data analysis

- Univariate lameness classifiers
  - Receiver Operating Characteristic (ROC)-curve
  - Area Under Curve (AUC)

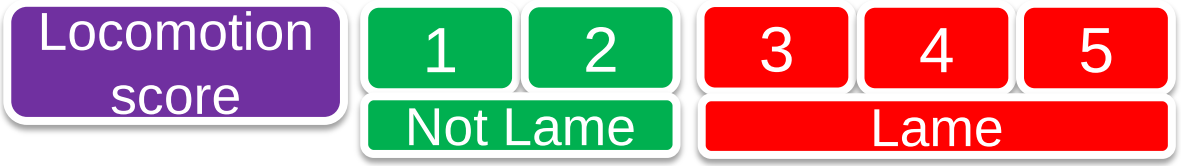
AUC	Test performance
[0,9 – 1]	Excellent
[0,8 – 0,9[	Good
[0,7 – 0,8[	Fair
[0,6 – 0,7[	Poor
[0,5 – 0,6[	Fail



- Multivariate models
  - Forward stepwise binary logistic regression

Data analysis

- Gold standard
  - Human visual locomotion scoring (LS)
    - Discrete numerical 5-point score
- Binary reference
  - LAME



  - SEVLAME

- Dataset: n = 3439 cow-observations

Univariate analysis

Variable	Variable class	LAME - AUC	Rank
Theta2	Video	0.7199	1
Back Posture Measure	Video	0.7021	2
Theta3	Video	0.6745	3
Inverse radius	Video	0.6724	4
L-distance	Video	0.6715	5
Number of Frames	Video	0.5963	7
Walking Speed	Video	0.5722	11
Theta1	Video	0.5452	13
Daytime activity	Activity	0.6155	6
Daily activity	Activity	0.5898	8
Night-time activity	Activity	0.5397	15
Milk peak conductivity	Milk	0.5846	9
Milk conductivity	Milk	0.5789	10
Milking order	Milk	0.5560	12
Milk peak flow rate	Milk	0.5444	14
Daily milk yield	Milk	0.5372	16
Lactation stage	Milk	0.5359	17

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Multi-sensor lameness detection

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Multivariate binary logistic regression model

- Reference = LAME (12)(345)
- Resulting model AUC = 0,76

Variable	Coefficient	Standard error	Step
Constant term	-15.8804	1.5034	0
BPM	15.1437	0.8320	1
Daytime activity	0.0014	0.0003	2
Theta1	0.0658	0.0078	3
Walking Speed	-3.4867	0.6163	4
Daily activity	-0.0021	0.0002	5
Milk conductivity	0.2346	0.0835	6
Daily milk yield	-0.0664	0.0142	7
Milk peak flow rate	0.0996	0.0259	8
Milking order	0.4257	0.1399	9
Lactation stage	-0.0009	0.0005	10

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Does multivariate sensing improve lameness detection?

Model	Included variables[1]	AUC		Sensitivity (%)		Specificity (%)		Accuracy (%)	
		Mean	std	Mean	std	Mean	std	Mean	std
Single sensor systems									
Video	BPM, T1, T2, T3, L1, IR, WS, nFr	0.732	0.011	48.4	3.3	83.6	2.8	69.3	1.8
Activity	dACT, nACT	0.633	0.018	29.9	3.7	83.9	1.9	61.9	1.3
Milking	MY, MO, MCo, MPFR, DIM	0.604	0.026	19.2	2.7	87.2	4.6	59.5	2.1
Milk	MY, MO	0.562	0.037	7.0	2.1	96.3	1.5	60.0	0.7

[1] The included variables in the models are milk yield (MY), milking order (MO), lactation stage (DIM), milk conductivity (MCo), milk peak flow rate (MPFR), daytime activity (dACT), night-time activity (nACT), number of frames (nFr), walking speed (WS), back posture measure (BPM), Theta1 (T1), Theta2 (T2), Theta3 (T3), L-distance (L1) and inverse radius (IR).

Does multivariate sensing improve lameness detection?

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Milk	MY, MO	0.562	0.037	7.0	2.1	96.3	1.5	60.0	0.7
Double sensor systems									
Milking & Video	MY, MO, DIM, MCo, MPFR, BPM, T1, T2, T3, L1, IR, WS, nFr	0.755	0.033	52.0	5.8	83.2	2.0	70.5	3.1
Activity & Video	dACT, nACT, BPM, T1, T2, T3, L1, IR, WS, nFr	0.750	0.031	51.4	4.0	83.1	2.3	70.2	2.1
Milking & Activity	MY, MO, DIM, MCo, MPFR, dACT, nACT	0.669	0.028	38.0	2.5	80.7	2.1	63.3	1.6
Milk & Activity	MY, MO, dACT, nACT	0.649	0.028	34.8	4.0	82.7	2.2	63.2	2.1
Multi-sensor system									
Milking, Activity & Video	MY, MO, DIM, MCo, MPFR, dACT, nACT, WS, nFr, BPM, T1, T2, T3, L1, IR	**0.757**	0.029	**52.1**	4.7	**83.2**	2.3	**70.5**	2.7

[1] The included variables in the models are milk yield (MY), milking order (MO), lactation stage (DIM), milk conductivity (MCo), milk peak flow rate (MPFR), daytime activity (dACT), night-time activity (nACT), number of frames (nFr), walking speed (WS), back posture measure (BPM), Theta1 (T1), Theta2 (T2), Theta3 (T3), L-distance (L1) and inverse radius (IR).

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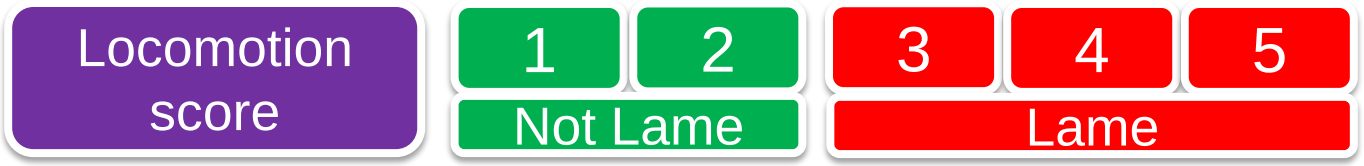
Discussion points

- Correct variable vs. Multivariate analysis
- How good is our gold standard method?
  - 5-point numerical score to quantify changes in *n* indicators



Gait
Asymmetry
Reluctance to Bear
Speed
Stride length

Posture
Arched-Back
Head-Bob

Others
Behaviour
Difficult rising

General Conclusions

- Lameness affects cow locomotion, behaviour and performance
- Sensor technology can help us identify the changes
- Key feature variables for dairy cow locomotion assessment can be extracted from captured video recordings
- An automatic computer vision prototype-system was successfully installed in a commercial farm
- A multi-sensor system is not outperforming a single sensor system

- Questions?

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Future research

- Impact of cow traffic on system implementation
- Changes from individual behaviour
  - Cow specific threshold
  - Large pool of historical data
- Warning list to farmer

  → value creation

EU-PLF project

Bright Farm by Precision Livestock Farming

www.eu-plf.eu

- **Title: Bright Farm by Precision Livestock Farming (EU-PLF)**
  Animal and farm-centric approach to Precision Livestock Farming in Europe

- **Objective:** The objective is to deliver a validated Blueprint for an animal and farm-centric approach to innovative livestock farming in Europe proven through extensive field studies.

- **Project funding:** EU – Collaborative project

- **Budget:** 5.900 000 Euro

- **Time line:** 4 years

- **Project Partners:** 20

KULeuven, SLU, Bristol, INRA, Teagasc, ARO, UMIL, WU, DLO, RVC, FANCOM, SoundTalks, PLF AgritechEurope, Xenon, ABROX, M&M, Syntesa, VITAMEX, EAAP, GEA

Objectives of the EU-PLF project
Validated Blueprint

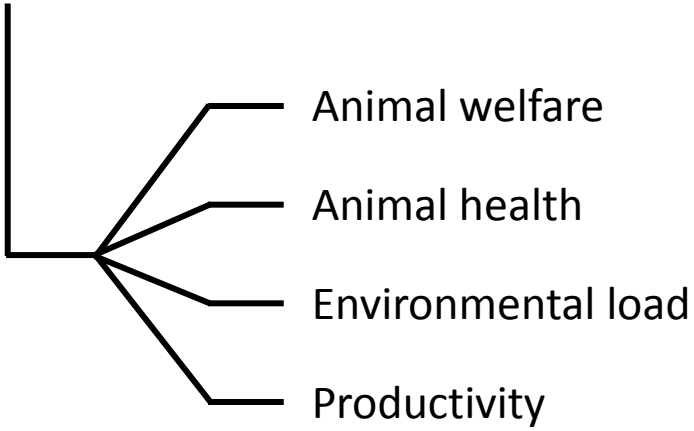
- **Core deliverable: Validated Blueprint**

  - "manual" for farmers, industry and stakeholders
  - website support

PLF ⟶ Operational system at **farm level**

Objectives of the EU-PLF project
Key Indicators and Gold Standards

- Core deliverable: **Validated Blueprint**
- Define **Key Indicators** + **Gold Standards**



Objectives of the EU-PLF project
Value Creation

- Core deliverable: **Validated Blueprint**
- Define **Key Indicators** + **Gold Standards**
- Relate KIs on farm to Social and Economic value measures for **Value Creation**

Objectives of the EU-PLF project
SME Drive

- Core deliverable: **Validated Blueprint**
- Define **Key Indicators** + **Gold Standards**
- Relate KIs on farm to Social and Economic value measures for **Value Creation**
- SME drive

High-tech SMEs ⟷ Market players

Objectives of the EU-PLF project
Farm level

- Core deliverable: **Validated Blueprint**
- Define **Key Indicators** + **Gold Standards**
- Relate KIs on farm to Social and Economic value measures for **Value Creation**
- SME drive
- Realise all these in different farms
  - 10 Pig farms
  - 5 Broiler farms
  - 5 Cow farms

What is a Blueprint

A design plan, descriptions of concepts, schemes, technical drawings, plans, protocols, detailed working methods and descriptions

that act as a model on how to realise the implementation of PLF-technologies in farms

and how to create value with it




Creation of the Blueprint

- Description of the different steps in the logic line
- Choices at the different steps and how they are made
- Link to value creation for the Farmer
- Validation via the SME drive

Validation of the Blueprint

- Info- and training- sessions for young entrepreneurs and potential spin-out activities
- Competition for a new PLF system
- Four winning teams will get funding to realise a prototype at farm level
  - They will use the Blueprint
    - **They will validate the Blueprint**

Thank you for your attention

www.eu-plf.eu

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Foot Note