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Evaluation of an automated cattle lameness detection system

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Introduction

- **Lameness: major welfare and health issue**
- **High herd prevalence**
- **Underestimated by farmers**

- **Detection**
 - *ad hoc* - problematic
 - manual mobility scoring
 - ✓ reduces lameness prevalence & higher cure rates
 - ✗ labour-intensive
 - ✗ hard to maintain consistency
 - ✗ subjectivity – intra- & inter-scorer disagreement

Introduction

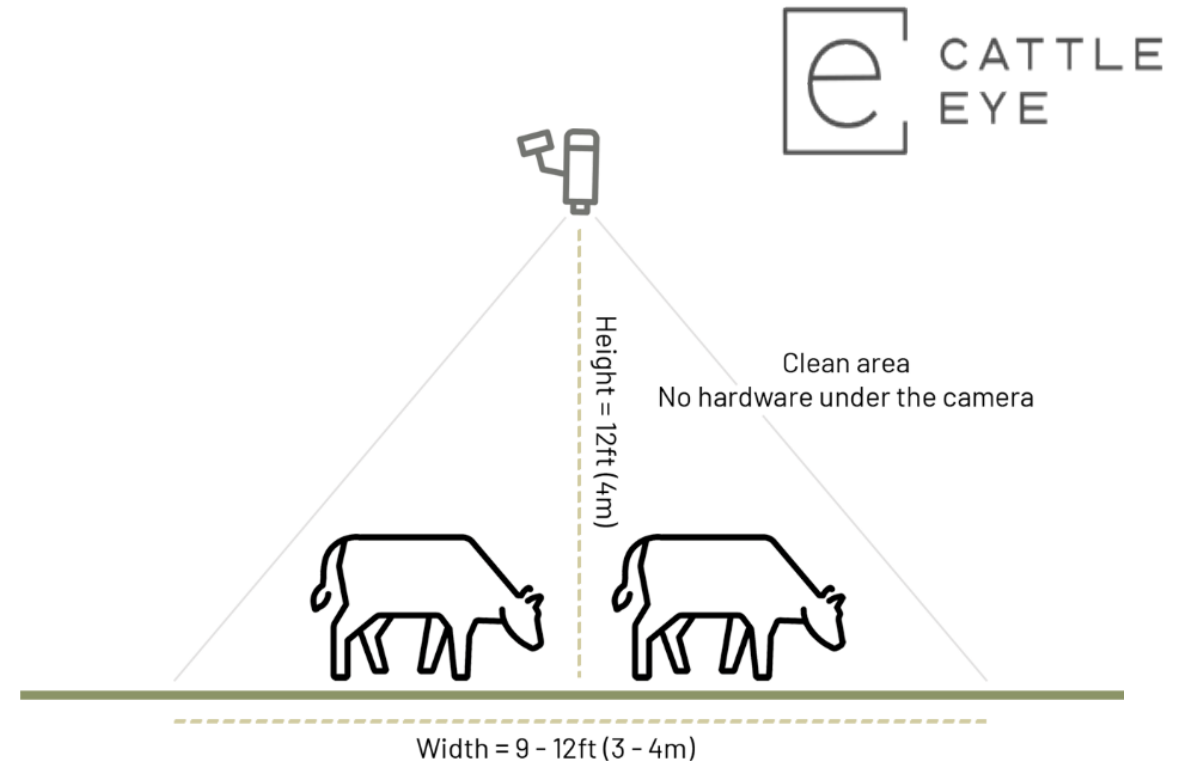
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 - ✗ subjectivity – intra- & inter-scorer disagreement
 - Automated systems
 - ✓ overcome these issues

Introduction

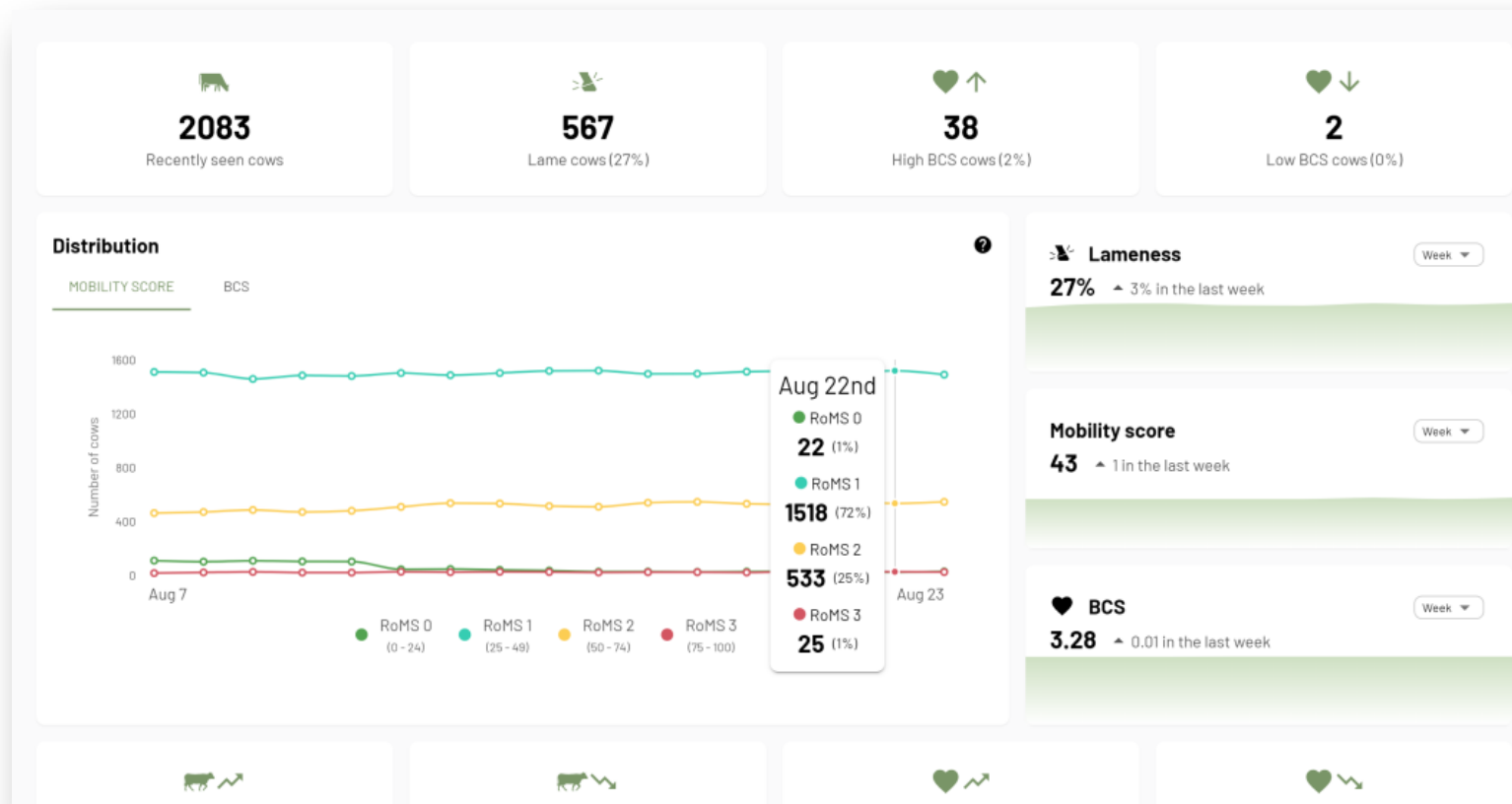
➤ Autonomous monitoring system (CattleEye Ltd., Belfast, UK)

- 2D surveillance camera – overhead view
- Artificial Intelligence
 - Object tracking-algorithm
 - Convolutional neural network
- Mobility score from 0 to 100
 - each 25-points → 0-3 AHDB system



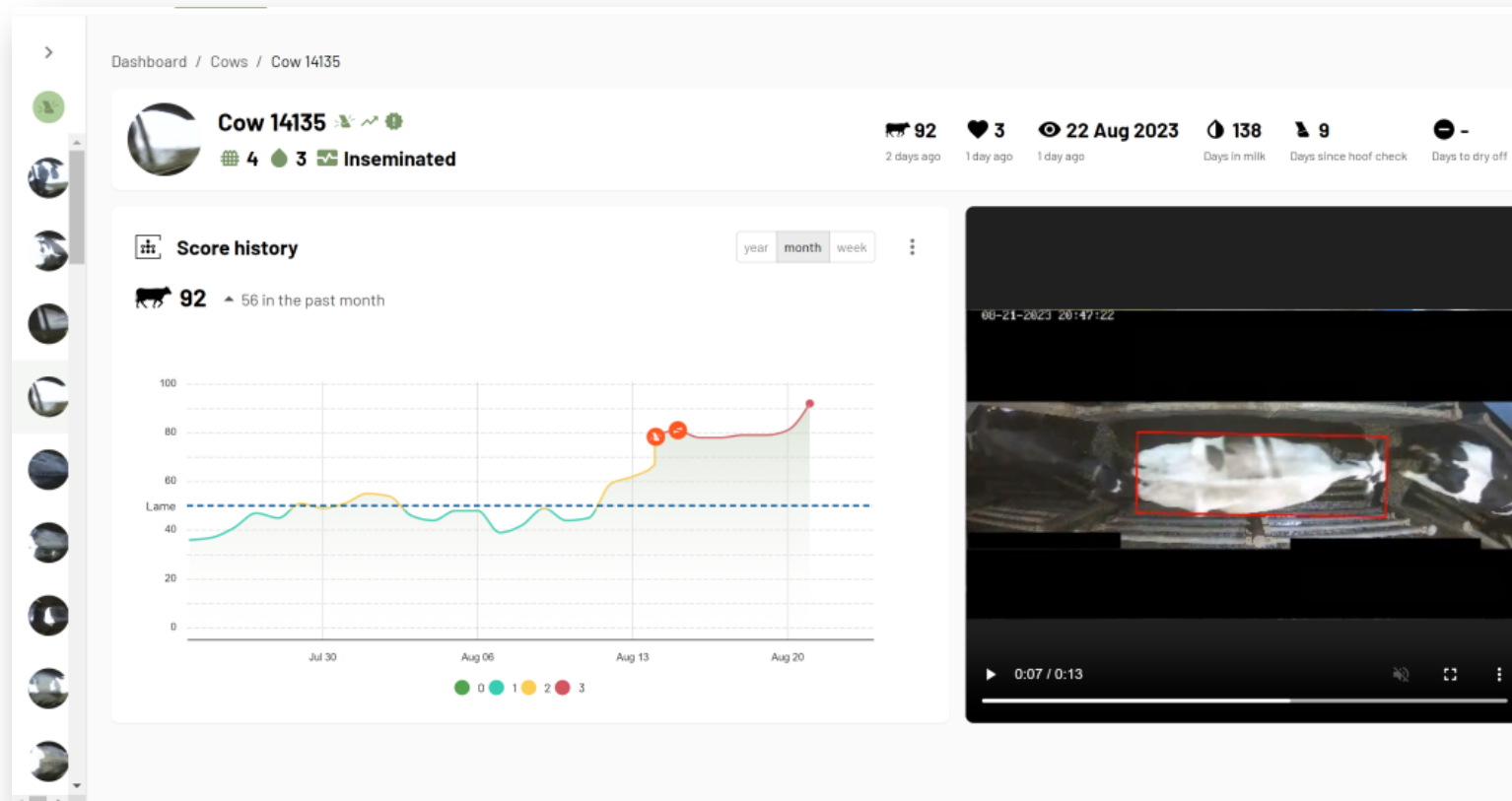
Introduction

➤ Autonomous monitoring system (CattleEye Ltd., Belfast, UK)



Introduction

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Objective

**To evaluate the performance
of an automated lameness detection system,
using manual mobility scores
& foot lesion records as the gold standard**

Materials and Methods

➤ Farms

- 8 dairy farms
- Wales and West England
- Herd size: 600 – 2,300 milking Holsteins
- Equipped with 2D camera

Materials and Methods





➤ Manual mobility scores (MAN_MOB)

- 4 experienced human assessors (HAs)
- 29 whole-herd mobility scoring sessions
- 4-grade (0-3) AHDB scoring method
 - Binary transformed non-Lame (scores 0 & 1) vs. Lame (scores 2 & 3)

HEALTHYFEET

AHDB

Mobility score

Category of score	Score	Description of cow behaviour	Suggested actions
Good mobility			
	0	<ul style="list-style-type: none">• Walks with even weight-bearing and rhythm on all four feet, with a flat back• Long, fluid strides possible	<ul style="list-style-type: none">• No action needed• Routine (preventative) foot trimming when/if required• Record mobility at next scoring session
Imperfect mobility			
	1	<ul style="list-style-type: none">• Steps uneven (rhythm or weight-bearing) or strides shortened; affected limb or limbs not immediately identifiable	<ul style="list-style-type: none">• Could benefit from routine (preventative) foot trimming when/if required• Further observation recommended
Impaired mobility			
	2	<ul style="list-style-type: none">• Uneven weight-bearing on a limb that is immediately identifiable and/or obviously shortened strides (usually with an arch to the centre of the back)	<ul style="list-style-type: none">• Lame and likely to benefit from treatment• Foot should be lifted to establish the cause of lameness before treatment• Should be attended to as soon as practically possible
Severely impaired mobility			
	3	<ul style="list-style-type: none">• Unable to walk as fast as a brisk human pace (cannot keep up with the healthy herd)• Lame leg easy to identify – limping; may barely stand on lame leg/s; back arched when standing and walking• Very lame	<ul style="list-style-type: none">• This cow is very lame and requires urgent attention, nursing and further professional advice• Examine as soon as possible• Cow will benefit from treatment• Cow should not be made to walk far and kept on a straw yard or at grass• In the most severe cases, culling may be the only possible solution

Materials and Methods

- **Automatically generated mobility scores (AI_MOB)**
 - Individual AI_MOB records stored
 - Weekly average score calculated at end of study
 - Binary transformed
 - Lame (AI_MOB \geq 50) vs. non-Lame (AI_MOB $<$ 50)

Materials and Methods

➤ Foot lesions data

- Same HA
- 17 trimming sessions in 3 farms
- Both routine & therapeutic trims
- HA blind to which cows were presented

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All cases in all 4 feet

- ✓ *Sole hemorrhage*
- ✓ *Sole ulcer*
- ✓ *White line*
- ✓ *Toe ulcer*
- ✓ *Digital dermatitis*
- ✓ *Interdigital hyperplasia*
- ✓ *Interdigital phlegmon*



Grading severity



*Classification of lesions
as potentially painful*

ICAR CLAW HEALTH ATLAS



Materials and Methods

➤ Foot lesions data

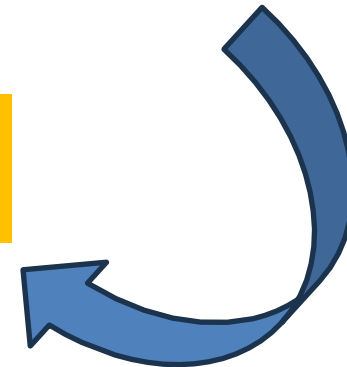
- Same HA
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- HA blind to which cows were presented

All cases in all 4 feet

- ✓ *Sole hemorrhage*
- ✓ *Sole ulcer grade ≥ 2*
- ✓ *White line grade 3*
- ✓ *Toe ulcer grade ≥ 1*
- ✓ *Digital dermatitis active M.2*
- ✓ *Interdigital hyperplasia*
- ✓ *Interdigital phlegmon grade 2*



“HIGH” severity status
binary classification



Materials and Methods

➤ Statistical analysis

- **Inter-rater agreement between binary AI_MOB and MAN_MOB**
 - Percentage agreement (PA) – Cohen’s kappa (κ) – Gwet’s coefficient (AC)

- **Confusion matrix – Presence of “HIGH” severity lesions as gold standard**
 - Measures of accuracy for both AI_MOB & MAN_MOB
Accuracy (ACC) – Sensitivity (SE) – Specificity (SP)

Results

➤ 27,082 mobility scores

- After merging AI_MOB & MAN_MOB using cow ID

➤ 991 cows with foot lesions records

- All of them with AI_MOB
- 340 cows with AI_MOB & MAN_MOB (previous 1 – 3 days)

Results

➤ Inter-rater agreement between AI_MOB & MAN_MOB

AI_MOB vs.	<i>n</i>	PA (%)	K	AC
HA1	15,191	85.4	0.41	0.81
HA2	7,225	81.5	0.23	0.76
HA3	3,466	82.1	0.32	0.76
HA4	1,200	86.3	0.34	0.83

“substantial” & “almost perfect”
agreement

Results

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Within “fair” and “moderate”
agreement range

Results

Low κ despite high PA & AC

“kappa paradox”

κ affected by prevalence & rater’s bias and accuracy

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Results

➤ Measures of accuracy – predicting presence of “HIGH” severity lesions

AI_MOB	Prevalence	SE	SP	ACC
n = 991	9.6%	0.40	0.88	83.3

MAN_MOB	Prevalence	SE	SP	ACC
n = 340	9.4%	0.53	0.83	80.3

Results

➤ Measures of accuracy – predicting presence of “HIGH” severity lesions

AI_MOB	Prevalence	SE	SP	ACC
n = 991	9.6%	0.40	0.88	83.3
Range between farms:		<i>0.11 – 0.50</i>	<i>0.83 – 0.92</i>	<i>78.3 – 86.3</i>

MAN_MOB	Prevalence	SE	SP	ACC
n = 340	9.4%	0.53	0.83	80.3
Range between farms:		<i>0.26 – 0.92</i>	<i>0.67 – 0.88</i>	<i>71.1 – 83.3</i>

Accuracy varies between farms

Conclusions

➤ CattleEye performed like experienced human scorers

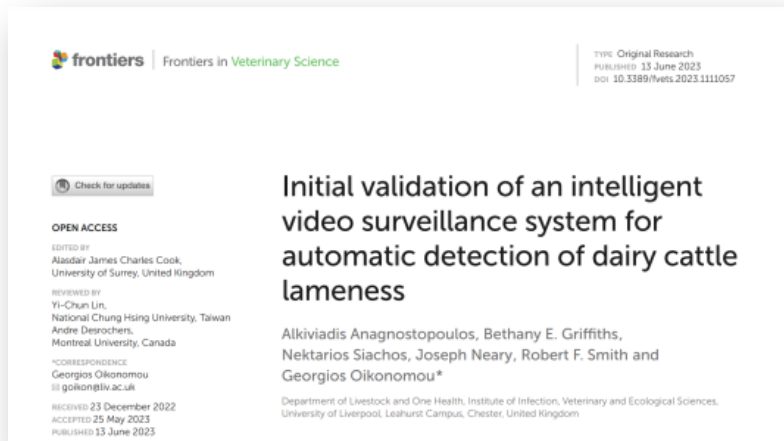


<i>n</i>	PA (%)	κ	AC
903	88.2	0.41	0.85

- **Thomsen et al., 2008, *J Dairy Sci* 91, 119–126.** → $\kappa = 0.24 - 0.68$
- **Linardopoulou et al., 2022, *Proceedings of 31st WBC, Madrid, p. 297.*** → $\kappa = 0.004 - 0.565$

Conclusions

- CattleEye performed like experienced human scorers
- Both AI_MOB & MAN_MOB had moderate SE & high SP



	<i>n</i>	SE	SP	ACC
AI_MOB	84	0.52	0.81	73.8
MAN_MOB		0.29	0.89	73.8

Conclusions

- **CattleEye performed like experienced human scorers**
- **Both AI_MOB & MAN_MOB had moderate SE & high SP**
 - **Farm – prevalence of pathologies**
 - **Parity**
 - **Chronicity – Severity**
 - **Consensus on which lesions impair mobility**

Ongoing research

- **Patterns in historical daily mobility scores in cows with foot lesion records**
 - Effects of Farm, Parity, DIM classes
 - Focus on “moderate” foot pathologies
- **RCT – intervention study using CattleEye as lameness management tool**
 - Long-term effects of using AI_MOB on lameness, productivity, profitability

Funding

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Thank you

