What sensors work for livestock now and where might we go?

Prof. Mark Rutter
Focus and perspective

• On-farm sensor applications as part of a precision livestock farming (PLF) approach
• Predominantly ruminant livestock, and also predominantly dairy cows
• Precision farming is about measuring and managing the variability in biological resources, ideally at the individual animal level
• Dairy farming is at the forefront in this respect
Electronic identification (EID)

- The full PLF approach requires the automatic identification of individual animals
- EID is the ‘backbone’ of PLF systems
- Predominantly based on passive radio-frequency identification (RFID) tags
- Early systems combined EID with simple motion sensors (pedometers) to detect the increase in activity during oestrus
Accelerometers everywhere!

• The development of cheap triple-axis accelerometers is revolutionizing the capture of animal behaviour data

• Includes human behaviour:
  – Nintendo Wii Remote (games)
  – Smart phones (e.g. VR apps)
  – Smart watches (fitness)
Leg-mounted accelerometers

- Leg-mounted accelerometers are used in several commercial systems.
- Used in on-farm oestrus detection and health monitoring.
- Record activity, steps, lying and standing behaviour.
- E.g. IceRobotics IceQube.
- Based on their earlier IceTag which was a research tool.
Rumination monitoring

- First used to detect oestrus
- Oestrus = ↓eating = ↓ruminating
- ‘Simple’ signal cf. eating
- SCR VocalTag (microphone based neck collar)
- SCR Heatime (accelerometer based, probably using eating time?)
- SmartBow (eartag accelerometer, also gives cow position)
Eating/grazing sensors

• Several accelerometer based systems now on the market:
  • Agis Automatisering SensOor (eating, ruminating, resting and active behaviours are classified based on ear movement)
  • Silent Herdsman ‘health alerts’ (eating and rumination based on a neck mounted accelerometer)
  • Needap Smarttag neck (accelerometer based eating and grazing monitoring and animal position)
Eating sensor validation

- **FeedPhone** (Medria)
  - Collar mounted sensor
  - Eating time and rumination time

Under-estimates eating
Precision 89-90% at ‘day’ level

Delagarde and Lemonnier, 2015. *Proc. EGF Wageningen*
Rumen sensors

• Rumen pH – optimise diet and detect sub-acute acidosis
• Temperature – disease detection and drinking
• **eCow** pH bolus (pH and temperature)
• **smaXtec** bolus (pH, temperature and activity from an accelerometer)
External sensors

- Gait analysis (e.g. StepMatrix)

Video and 3D imaging now being used (e.g. xBox Kinect)
Automatic (robotic) milking

- Robotic milking uses several sensor technologies
- e.g. laser scanners to detect teat position for cluster attachment
- Also incorporate milk analysis, including yield, conductivity etc.
- De Laval **Herd Navigator**:
  - Progesterone (oestrus)
  - Lactase dehydrogenase (mastitis)
  - Beta hydroxybutyrate (ketosis)
Animal position

- Several animal positioning systems now available
- Use animal tags and beacons installed in the building (not GPS)
- GEA CowView collars
- SmartBow ear tag
- Needap smarttag neck
- Mainly used to help farmers find their cows
Where might we go?

• Need to do more with existing sensed data
  – Data integration
  – Using position data to derive social behaviour?
• Bioacoustics: a novel sensing technology?
  – Detect bites, chews and bite mass?
• Use sensors in extensive systems e.g. precision grazing management?

• Working with the new Agri-EPI Centre
Data integration

Oestrus?

Disease?

For that individual animal

Body temp

Lying

Feed intake

'Normal'

'Normal'

'Normal'
Currently, positioning systems are only really being used to help farmers find their cows.

But if we know the position of all of the cows in the herd all of the time we should be able to understand the herd “social network”

Which cows are the “bullies”? How does e.g. disease or oestrus change the social network?
Bioacoustics

Microphone → Radio transmitter → Radio receiver connected to video camera i.e. the sound you will hear in the video is transmitted from the cows head

Noseband → ‘IGER’ Behaviour Recorder
Mainly chew-bites

No. 8 12

Two chews

Chews

Head up
Bioacoustics potential

- Research has shown the energy density of chewing sound is proportional to bite mass, so has the potential to monitor intake.
- Has the potential to detect different plant species and differences in herbage quality.
- The ratio of bites:chews can be used to infer herbage availability i.e. how much grass has been eaten.
- Bioacoustics is already being used on farms (SCR rumination collar).
## Precision Grazing Management

<table>
<thead>
<tr>
<th>Intake per cow</th>
<th>Intake per hectare</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Low</strong></td>
<td><strong>High</strong></td>
</tr>
</tbody>
</table>

- Requires removal of ungrazed herbage
- Optimum residual sward height
- Will reduce daily intake
Precision grazing management

High herbage availability

Few bites · Many chews

Low herbage availability

Many bites · Few chews
• Monitor herbage availability (e.g. bite:chew ratios)
• Automatically open fence at optimum sward depletion level (timed to e.g. not coincide with milking)
• One of the four new BIS-funded AgriTech innovation centres
• A consortium of 76 companies and institutions
• Aims to be a world-leading centre of excellence in engineering for precision agriculture
• I am the academic lead for dairy
Summary

• A wide range of sensors are currently being used on dairy farms
• Need to do more to integrate sensor data
• Position data are currently underutilized
• Bioacoustics could help farmers estimate intake and manage grazing
• PLF approaches can be used in extensive as well as intensive systems
Any questions?

Prof. Mark Rutter
smrutter@harper-adams.ac.uk
Precision farming

Manual data → Data integration/analysis → Semi-automated decision making → Improved manual control → Integrate/monitor/document outcomes

Sensed data → Data integration/analysis → Semi-automated decision making → Automated control → Integrate/monitor/document outcomes

External data → External input to decision making → External control → Integrate/monitor/document outcomes

Control diagram adapted from Banhazi, 2011
A bioacoustic problem

• The microphone can pick up the sound of conspecifics grazing alongside the subject...
• ...so may need to be combined with other sensors e.g. accelerometers
Some words of caution

• Precision farming is **not** intended to replace the expert stockperson or vet
• It should be a **tool** to help them manage their animals
• The systems will need to incorporate robust **fail-safe** mechanisms to ensure system failures do not compromise animal welfare
In the 1990’s, development of a carbon-filled noseband sensor allowed the opening and closing of the jaws to be recorded.

- This formed the basis of the ‘IGER Behaviour Recorder’ and Graze analysis software.
Cattle grazing jaw movements

Jaw movement amplitude

Time

Chews

Bites and “chew-bites”

15 seconds
Rumination jaw movements

Swallows then regurgitates bolus

1 minute
Importance of oestrus

• Why are the main on-farm ‘foraging’ sensors using rumination to detect oestrus?
• Oestrus is economically important:
  – Inseminate → Pregnant → Calf → Milk
  – Cost of wasted semen from ‘good’ bulls
• Although disease is important, sick cows produce some milk...
• So what happens during oestrus?
During oestrus

• The cow’s biological imperative changes from finding food...
During oestrus

• The cow’s biological imperative changes from finding food...
• ... to finding a mate
• But there are usually only other cows...
Oestrus and behaviour

- Activity levels increase on the day of oestrus:
  - 2.3 times higher (Schofield *et al.*., 1991)
  - 4 times higher in cows in free stalls (Kiddy, 1977)
  - Detect using pedometers and/or accelerometers

- On the day of oestrus i.e. the day of successful insemination, Halli *et al.* (2015) found:
  - Number of visits to feeder declined 9.1%
  - Fresh matter intake declined 10.3%
  - Time spent feeding declined 20.8% 
    \[\text{Intake rate increased}\]
Using an oil-filled sensor
Rumination ‘pattern’

“The short intervals without ... jaw movements and the uniformity of the waveform are characteristic of rumination.” Braun et al. 2013

IGER Behaviour Recorder
Regular blocks of chews

Smartbow “ear-wagging”

SCR Heatime?
Rumination activity

• Cows are generally stationary when ruminating (lying down or standing still), and they only perform one type of jaw movement (chewing)

• In contrast, foraging animals are engaged bites, chews, chew-bites and body movements:
  – Head movements at a feed face
  – Head and body movement when grazing

• Consequently, accelerometer signals from animals that are eating are very complex
Why rumination & oestrus?

• In contrast to eating, rumination is comparatively easy to detect.
• Dairy tech companies have gone for the “low hanging fruit” when looking to use a ‘foraging’ measure to detect the reduction in feed intake during oestrus.
Rumination and DMI

• Rumination time (RT) is linked to recent intake:
  – RT increases 4h after a period of high DMI (Schirmann et al., 2012)
  – RT made a significant but small contribution in a DMI prediction model (Clement et al., 2014)
  – After controlling for between-cow variability, RT can predict both DMI (Johnston and DeVries, 2015)
• Halli et al. (2015) found on the day of oestrus:
  – intake declined 10% but feeding time declined 21%
• Given these issues, wouldn't we be better using direct measures of eating to predict intake?
Recent developments (1)

- **SensOor** (Agis Automatisering)
  - Behaviours classified based on ear movement

<table>
<thead>
<tr>
<th>Behaviour</th>
<th>Kappa</th>
<th>Concordance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ruminating</td>
<td>0.85</td>
<td>0.93</td>
</tr>
<tr>
<td>Eating</td>
<td>0.77</td>
<td>0.75</td>
</tr>
<tr>
<td>Resting</td>
<td>0.86</td>
<td>0.97</td>
</tr>
<tr>
<td>Active</td>
<td>0.47</td>
<td>0.35</td>
</tr>
</tbody>
</table>

Opportunities not problems!

• Although this complexity makes intake difficult to estimate, it could provide useful on-farm information

• Does sorting a total mixed ration indicate:
  – That it is not properly mixed?
  – It fails to meet the cow’s nutritional needs?

• Bite:chew ratios could be of use in monitoring herbage availability in grazing animals

• What other types of sensors might we use?
Rumination and dietary fibre

- RT is linked to the fibre in the diet:
  - Total dietary neutral detergent fibre (NDF) is consistently linked to RT (de Vries, 2016)
  - Cows have an RT between 25 and 80 min kg$^{-1}$ of roughage consumed (Sjaastad et al., 2003)
  - An increase from 25 to 35% NDF increased R from 380 to 500 min day$^{-1}$ (Dado and Allen, 1995)