State of the art of automated activity measuring technologies, and how to accelerate technology development

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Outline

- Models in behavioral measurement systems
- Focus on measurements that are feasible on real farms
  - Accelerometers
  - Computer vision
  - Sound

- A few ideas about technology development

How to measure?

- Behavior is predicted from measurement data using a model
- The accuracy of the measurement depends on the accuracy of the sensor, the suitability of the measured parameters, quality of the model and variation between animals
- The models need to be taught using accurate reference data, usually = human observation

How to model

- Methods from machine learning (=data mining = pattern classification =statistical learning)
  - A lot of other applications: speech recognition, autonomous vehicles, targeted advertising on websites, games…
- Data based models are used
  - Purely fitted based on data
  - Expertise based model structure with parameters from data

How to model?

- The models have their limits
  - The choice of the model and the inputs limit the capabilities of the model
  - Some models can adapt, but they need to be told how to do it
  - They are only valid in the scope where they have been developed
  - Introducing data from different environment can produce unexpected results
- **More data leads to better generalization**

Accelerometers and positioning systems

Accelerometers

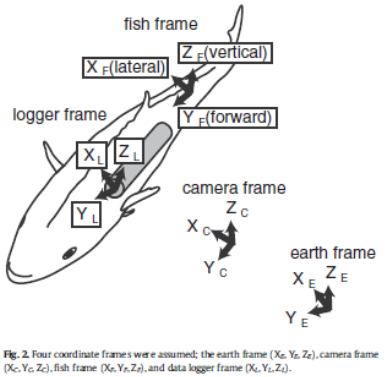
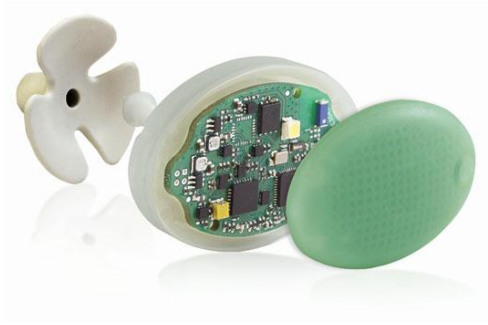


Fig. 2. Four coordinate frames were assumed; the earth frame (X_E, Y_E, Z_E), camera frame (X_C, Y_C, Z_C), fish frame (X_F, Y_F, Z_F), and data logger frame (X_L, Y_L, Z_L).

- Very popular in automated behavioral monitoring
- Well suited for measuring movement and static orientation
- Cheap, reliable, small, works in different conditions
- Commercial and research applications
- Limitations
  - High sampling rate in wireless systems leads to high power consumption
  - The attachment in fixed position/orientation can be important
- On-line algorithms can be used to increase battery life

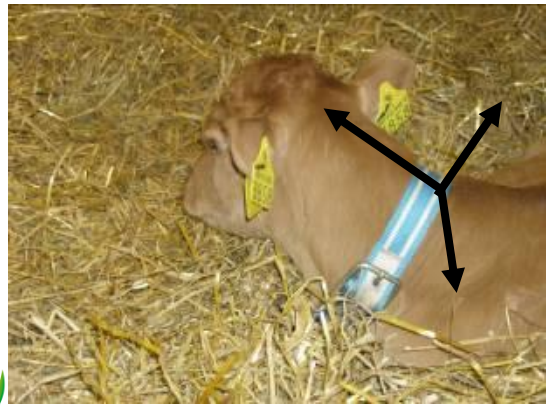
Commercial accelerometer devices

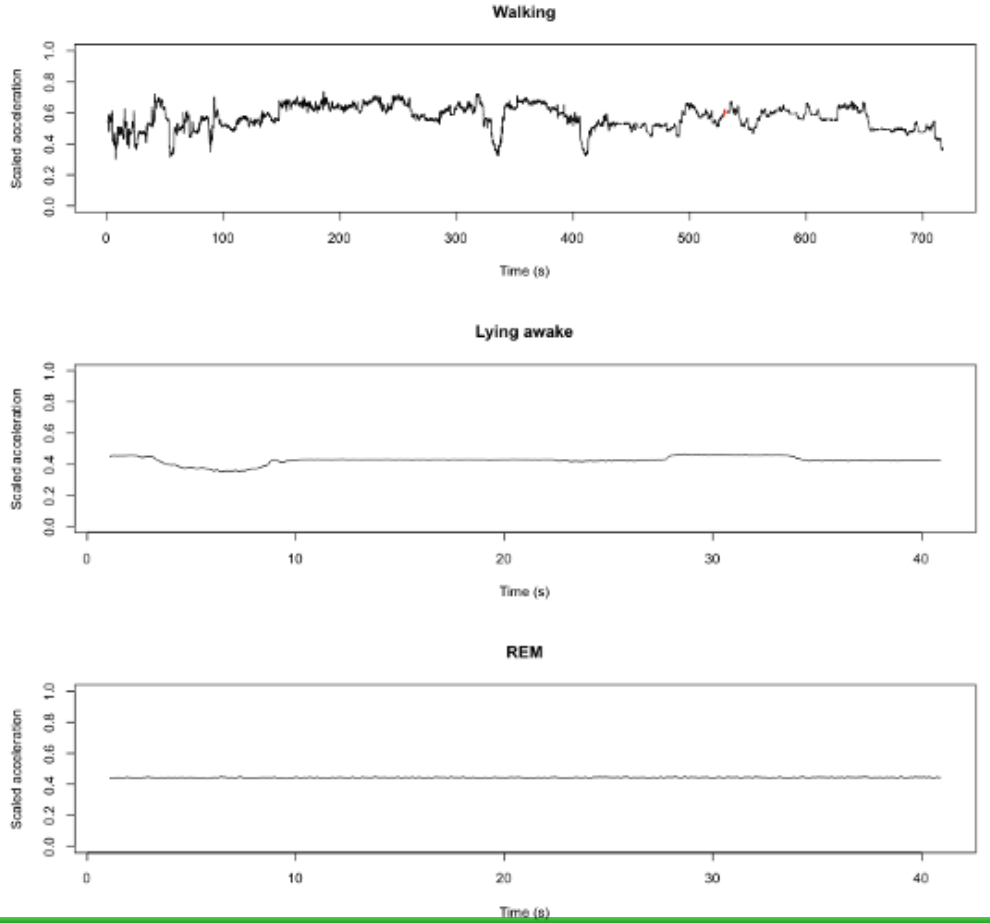
- New generation of pedometers
  - Lying time, standing time, walking, steps, activity index
  - Especially lying time measurement is very accurate and validated in several studies. *(e.g. Munksgaard et al. 2006)*
  - Data generally available in summaries e.g. 1-2 hours.
- Activity from eartag.
- Monitoring feeding behavior
  - Nedap Smarttag Neck
  - Gea CowScout Neck



Research Example:
Sleep actigraph for calves *(Hokkanen. et al 2011)*

- Collected behavioral data: accelerometer data from collar and video observations of 10 calves.





The Accelerometer

- Selectable sample rate up to 250Hz and sensitivity of 1.5, 2, 4 and 6 g (MMA7260Q, Freescale)
- 869 MHz radio (nRF9E5 Nordic Semiconductor) guarantees good signal transmission
- Battery life of 20 days with ½ AA battery and sample rate of 25 Hz
- Motion trigger for battery saving

Sleep actigraph for calves

- Relevant features were extracted from accelerometer data in 20s epochs
  - Wavelet variance
  - Orientation

- A Support Vector Machine classifier was taught and validated using 10-fold cross-validation

- 90% accuracy achieved for predicting total sleeping time

Sleep actigraph results

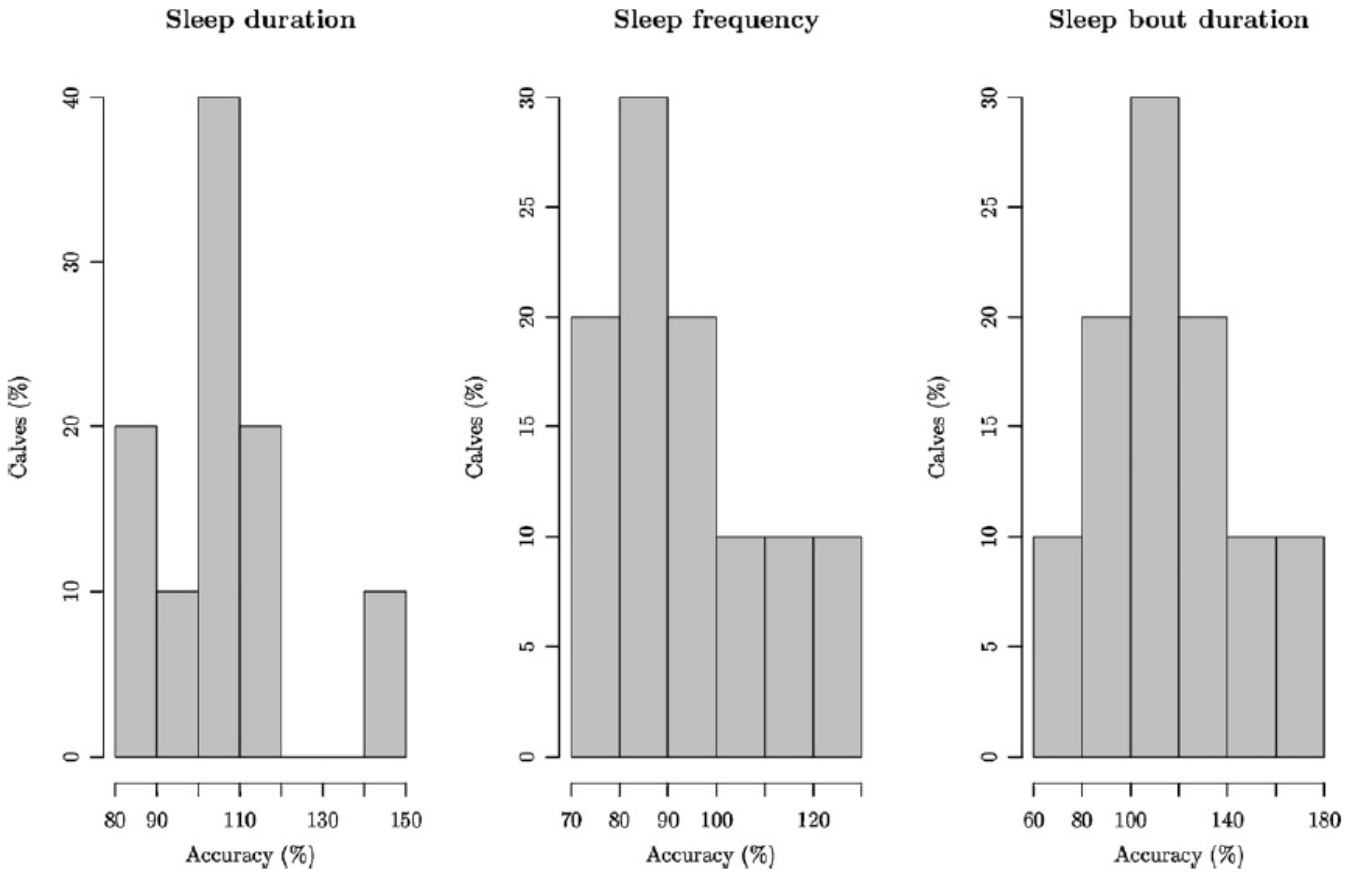
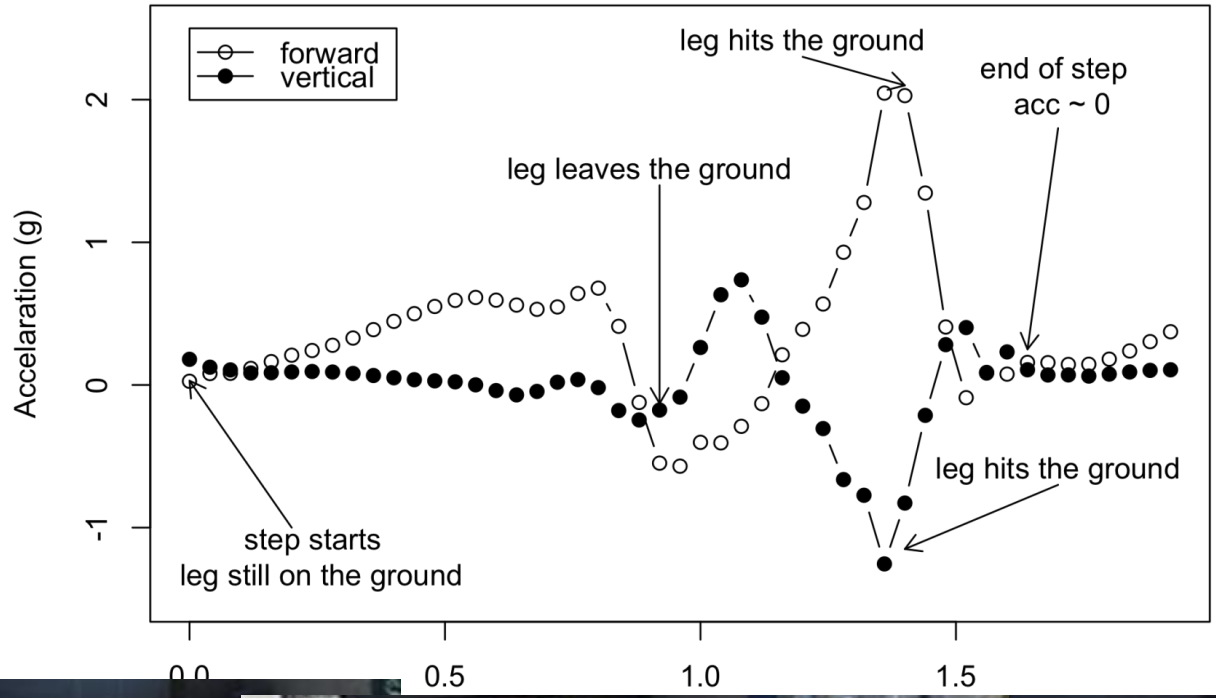


Fig. 4. The distribution of the prediction accuracy (predicted/observed × 100%) of the total duration, frequency and bout duration of total sleep during 24 h (n = 10 calves).

(Hokkanen et al. 2011)

Measuring gait *(Pastell et al. 2009)*

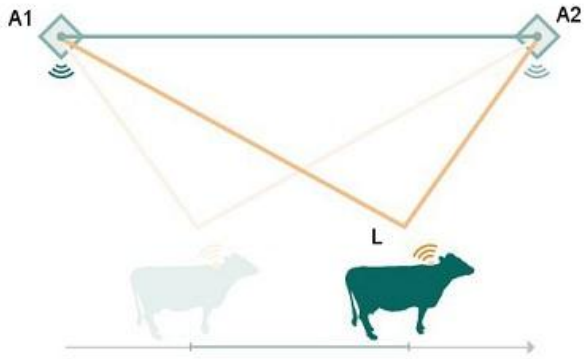


Animal positioning

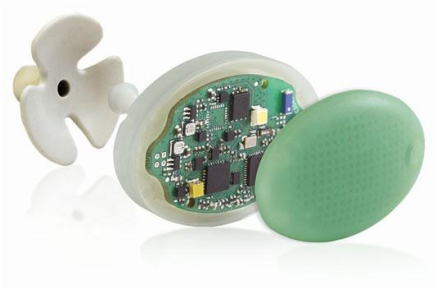
- GPS based systems with accelerometers and tilt sensors
- UWB and WiFi systems for indoors
  - New systems have good accuracy

- Has a lot of potential based on ethological studies, but no the data is not yet utilized very well

Indoor positioning



- Several commercial systems
  - Gea CowView (UWB)
  - Ubisense (Tracklab) (30-60 cm, UWB)
  - Smartbow (~1 m, 2.4 GHz)
  - Nedap (30-60 cm, ~50KHz)
- Active research in several institutes



Computer vision

Computer vision / Image analysis

- Usually used to monitor fixed areas indoors
  - Usually group of animals of individually kept animals
  - Possibility to obtain ID from RFID or recognize animals from image
- 3D cameras are becoming more popular
  - Stereo vision, projected light, time of flight
  - Depth information makes it easier to separate animals from background and provides additional information about posture.
- Strategies:
  - Animals are recognized from image and the behavior is predicted based on posture movement
  - Animal precense at a certain are e.g. feeding trough is measured
  - Overall movement in the image is used to quantify activity

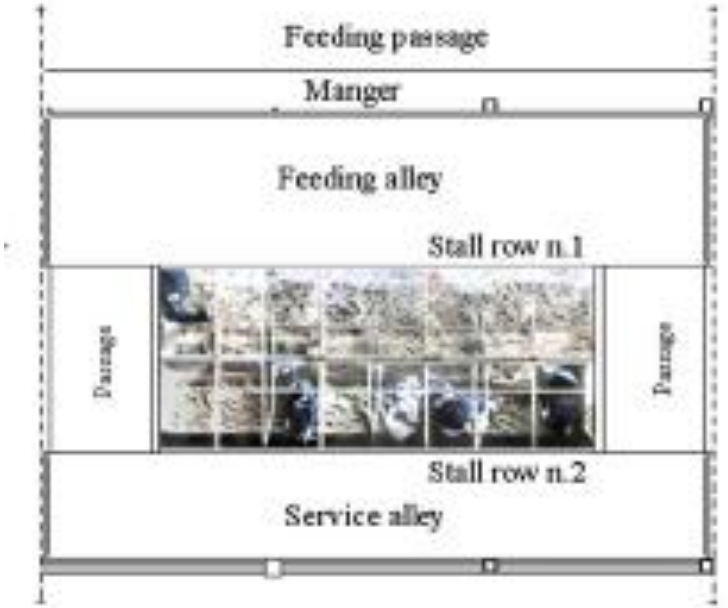
Computer vision / Image analysis

- Advantages
  - Can used fixed power supply
  - No need to attach sensors to animals

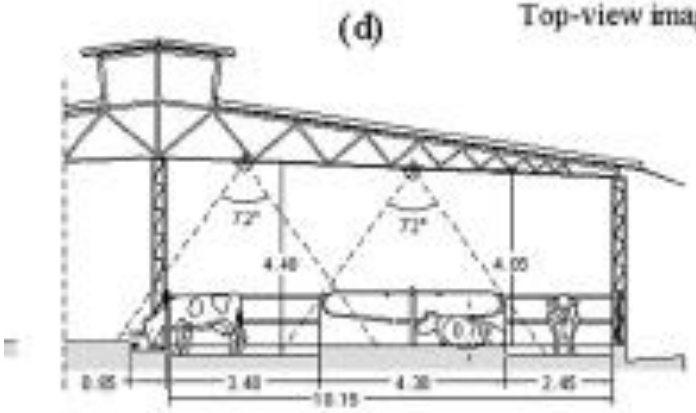
- Challenges
  - Robustness of the algorithms in different conditions. Lighting changes, color of animals, extra movement in images etc.
  - Identification of individuals
  - Computational power in complex algorithms.

Lying time of dairy cows *(Porto et al. 2013)*

- Monitoring lying dairy cows in a freestall
- Lying cows were detected with the accuracy of 92%
- No identification for individuals
- Only works during daytime

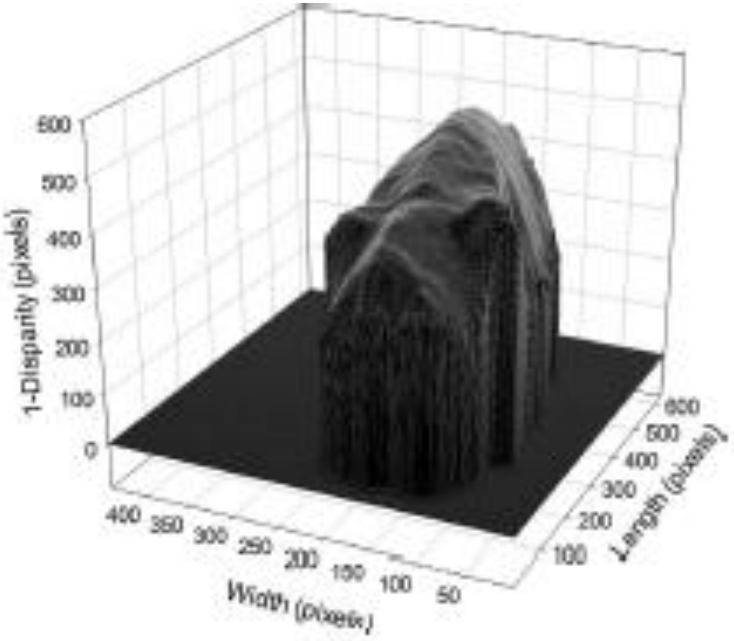


Top-view image

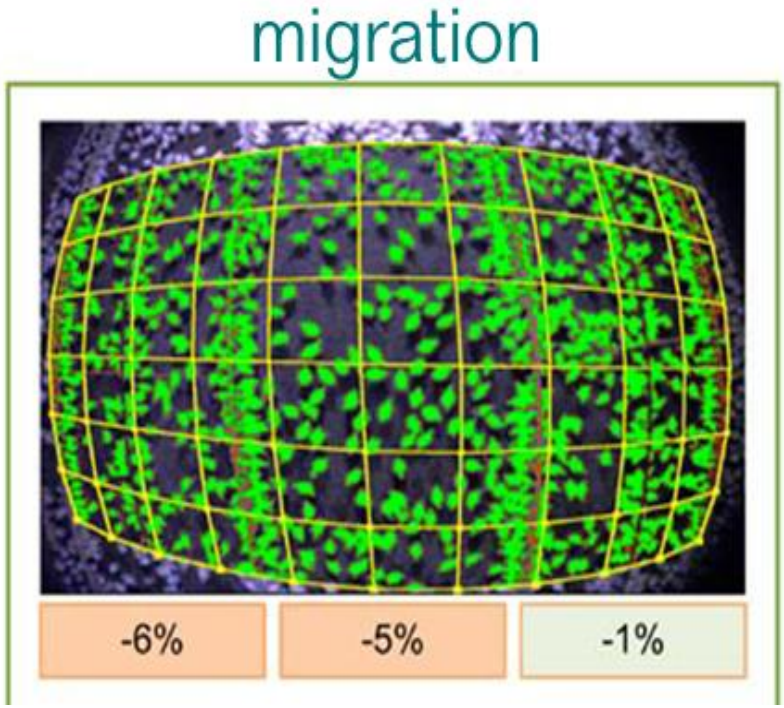


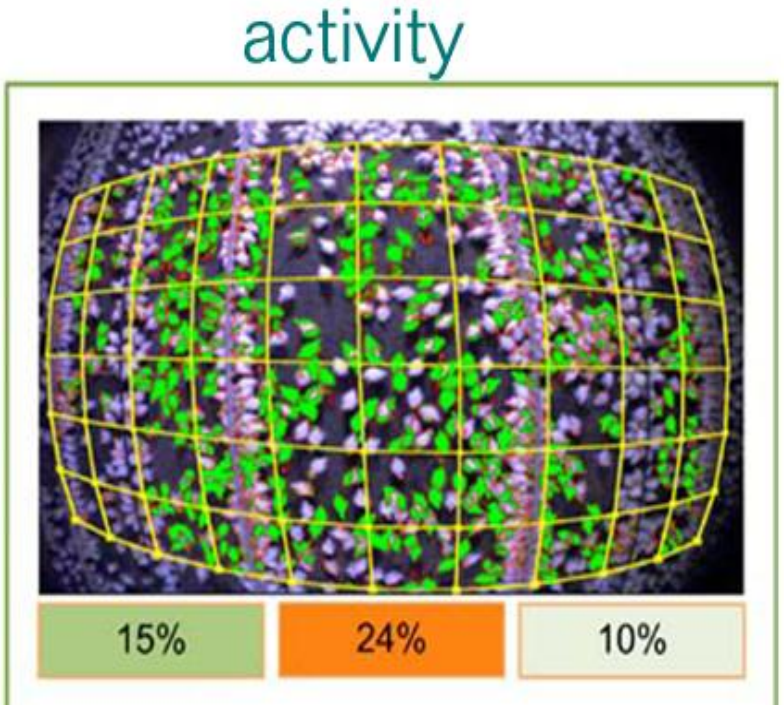
2D vs 3D in measuring back arch of a cow *(Viazzi et al. 2013)*

- Easier segmentation of cow from background -> more robust method
- Kinect camera (3D) used doesn't work in sunlight



Activity of Broilers





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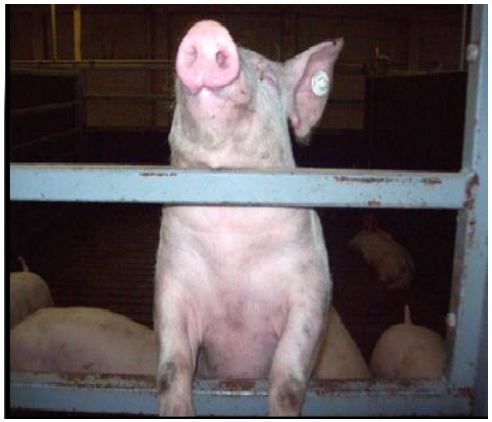
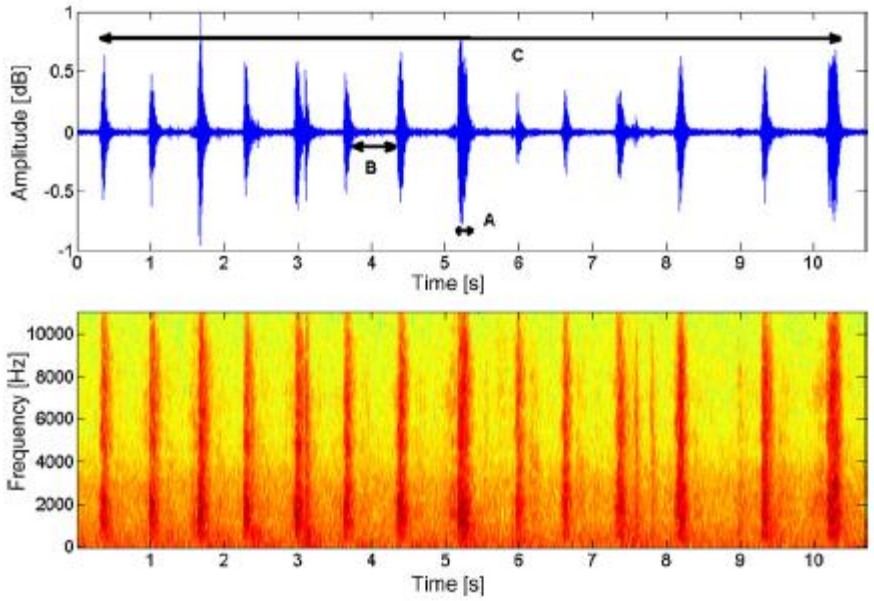
Sound

Sound analysis

- Several interesting applications
  - Rumination, eating, pig cough
  - Stress
- Background noise can make the analysis difficult
- Possibility to localize the sounds
- Methods similar to those in speech recognition can be used

Pig cough recognition





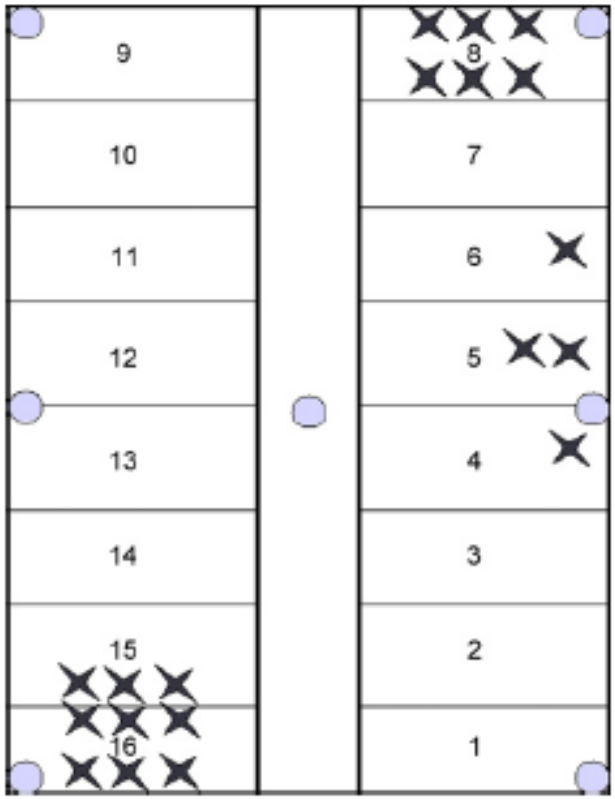


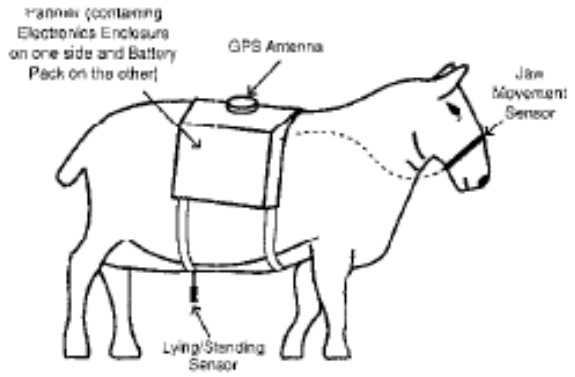
Fig. 4 – mapped cough attacks during experiment 1 (the number of stars indicates the number of cough attacks recorded in that pen, the circles indicate the position of the microphones).

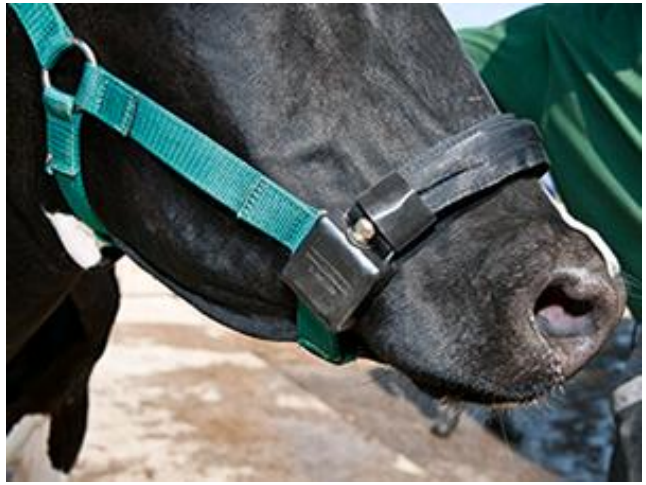
(Ferrari et al. 2008)

Feeding behavior

Measuring jaw movement

- Jaw movement can be used to measure eating time and rumination *(e.g. Matsui 1994)*
- Rumiwatch: rumination with a noseband measuring jaw movement
- Good accuracy

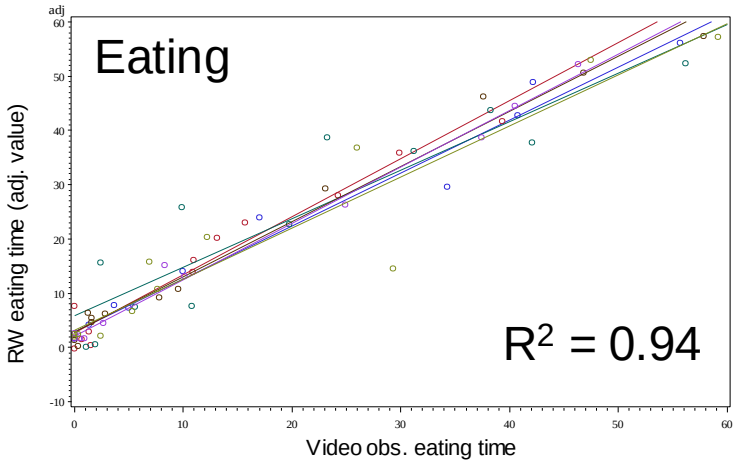


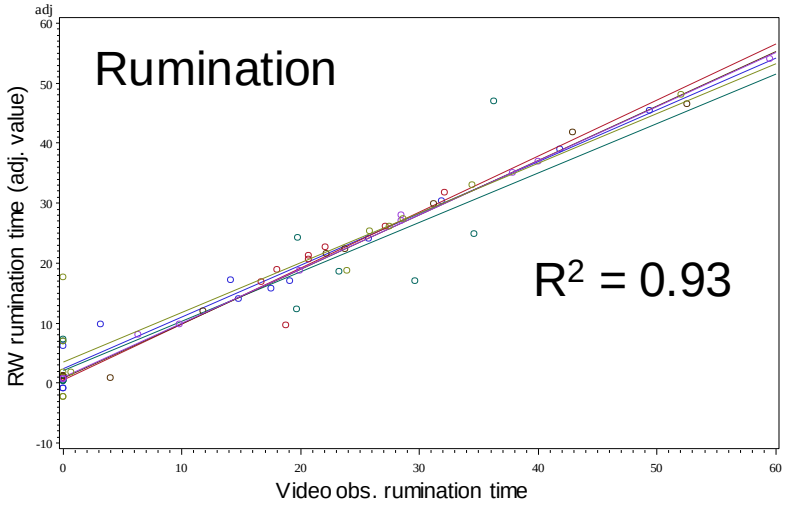


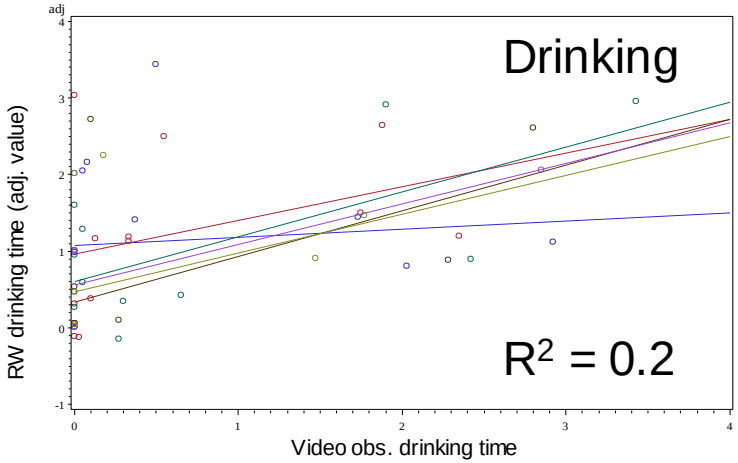
RumiWatch Noseband sensor *(Kajava et al. 2013)*

measurements compared with the continuous behaviour recording in tie stalls

- N = 6
- 72 observation hours
- RWS data processed as min/h for each behaviour class





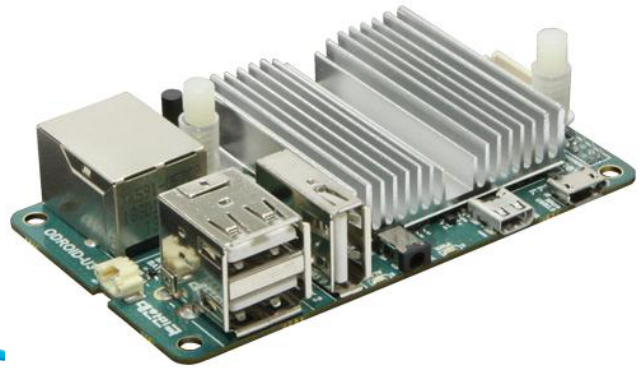


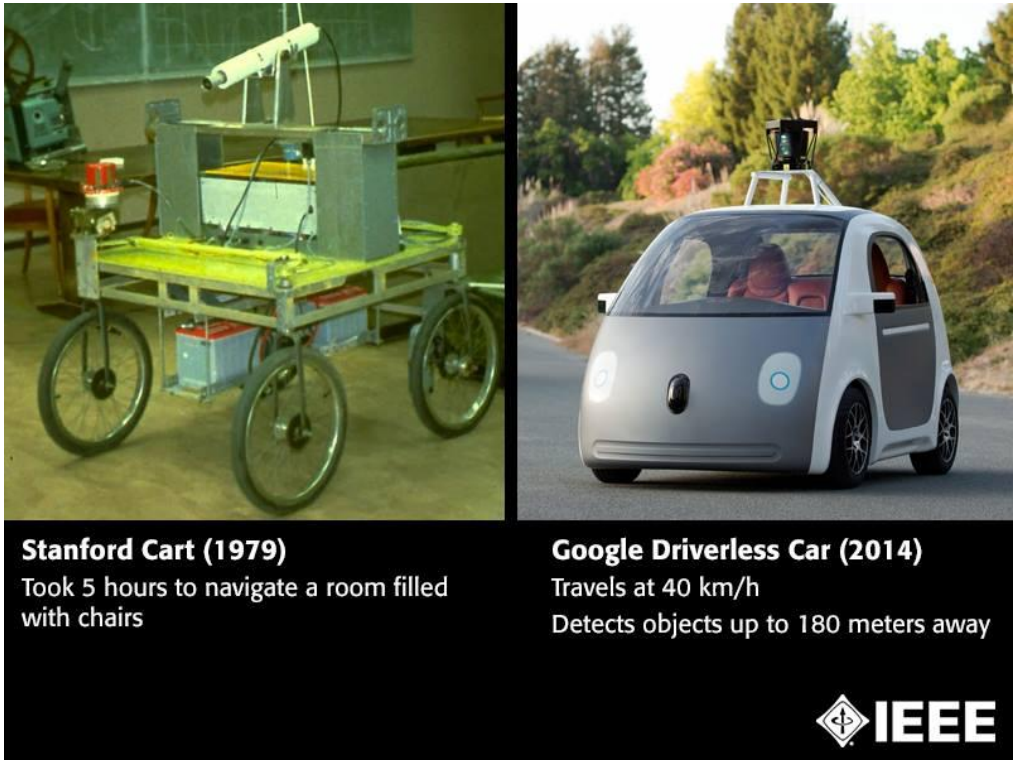
Feed intake with measurement troughs

- Measuring feed intake is expensive
- However feeding time measurement is relatively cheap
- In some cases measuring feeding time is good enough *(Gonzalez et al. 2008)*

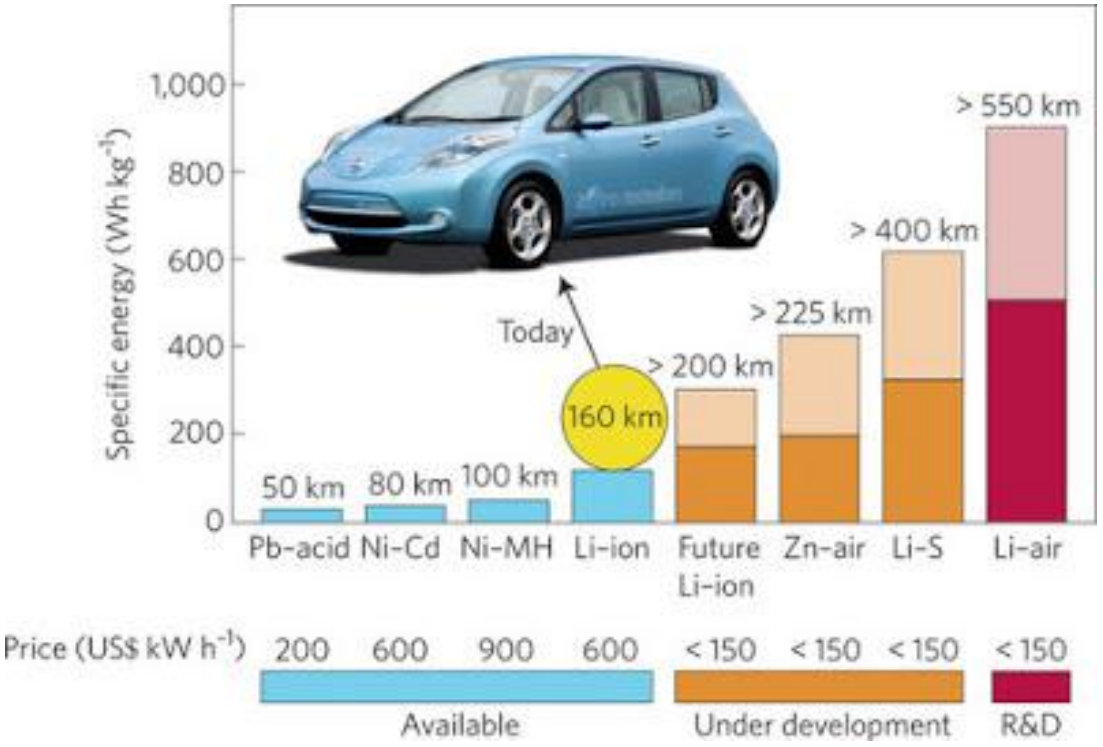
Accelerating technology development?

4x1.7Ghz @5W, 65$

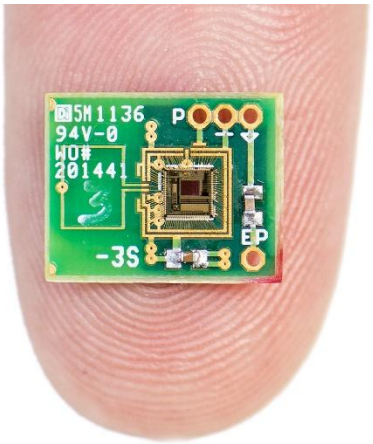




Battery life is a challenge



IEA forecasts 5x increase in energy density in 2030



The situation in dairy technology today

Farmers

- Farmers get too much raw data and not enough information
- Systems don't always provide added value
- Incompatible systems
- New systems come to market at increasing rate, but are adopted quite slowly

Scientists

- Don't always get enough (raw) data from commericial systems
- Getting data from some systems is laborous and not standardized
- Research has had more focus on sensors and models from quite small datasets
- Battery life is still a big issue in moving some systems forward

Accelerating adoption important for development

- Research needs and possibilities:
  - Better understanding of animal behavior and collected measures
  - Provide clear added value with decision support
  - More focus to on-farm data collection and more robust models

- Combining measures:
  - Sensor fusion for more accurate behavioral measurements
  - Multivariate methods for health/welfare evaluation

- I see Increasing on-farm adoption as the most important development need

Conclusions

- We already have many good methods to automatically measure animal behavior
- We aren't making very good use of the data yet
- We will benefit from research in other areas in terms of energy efficiency, sensor price and computational power
- Easier access to data and databases and standardization is needed