Combining data from multiple sensors to estimate daily time budget of dairy cows

Matti Pastell & Lilli Frondelius

EAAP 2018, Dubrovnik

NATURAL RESOURCES INSTITUTE FINLAND

Why do we measure the time budget of a cow?

- Individual animal
  - Monitor changes in behavior or yield to monitor health, oestrus etc.

- Individual farm
  - Detect deviating individuals, use other animals on same farm as reference
  - Assess the overal farm performance, animal welfare as e.g. number of diseased animals on farm

- Multiple farms
  - Detect deviating individuals, use animals from other farms as reference
  - Real time benchmarking of production process

Measuring daily time budget.
CASE: Luke Maaninka

Measuring daily time budget.
CASE: Luke Maaninka

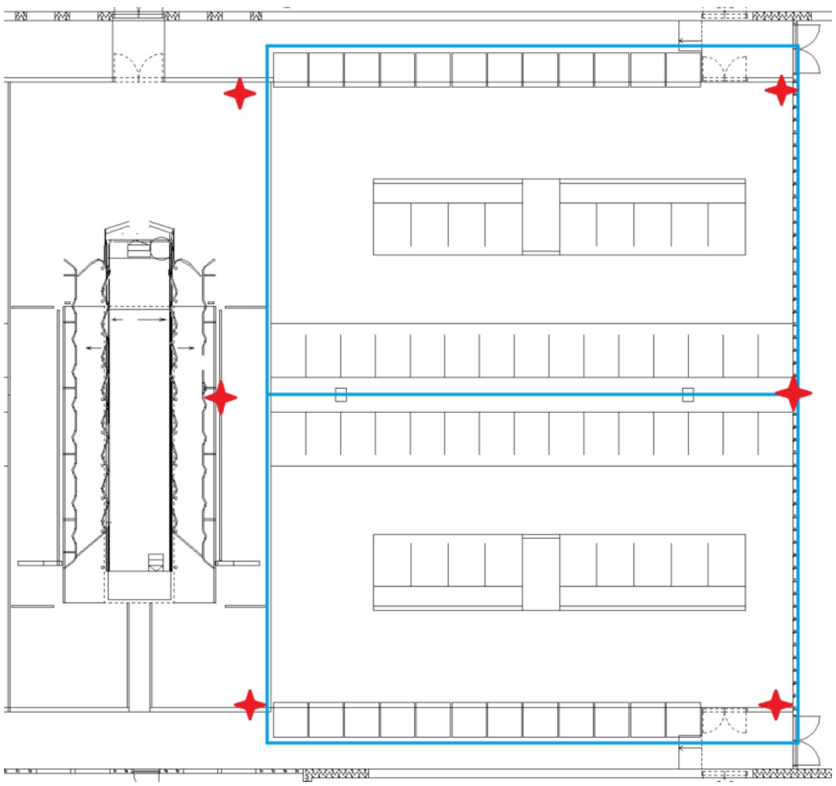
- Research farm equipped with multiple sensor systems:
  - UWB indoor positioning
  - Insentec RIC feeder
  - IceQube pedometer
  - Milking 2 times/day with herringbone parlour

- Calculate daily time budget of 34 dairy cows for 7 days
  - How do we combine sensor data collected with different resolutions?

  - Does combining multiple sensors give more infomation than a single sensor?

Indoor positioning at Luke: Ubisense UWB system

- UWB-based indoor positioning system in freestall barn 22x25 m
- Time difference of arrival and angle of arrival techniques combined
- Accuracy depends on signal path fom tag to the sensors
- Practical issues with noise and data loss

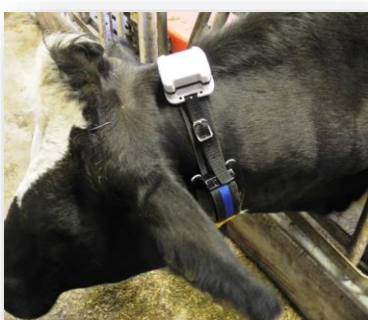


Luke NATURAL RESOURCES INSTITUTE FINLAND

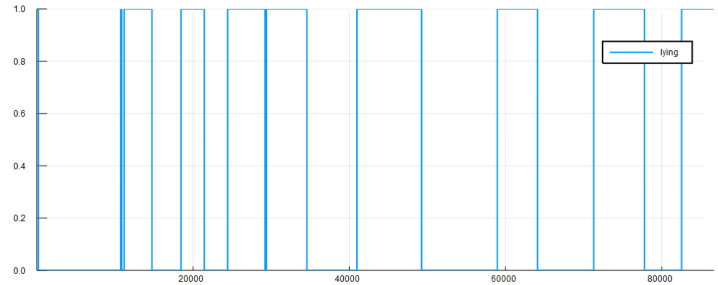
What can we do with the data?

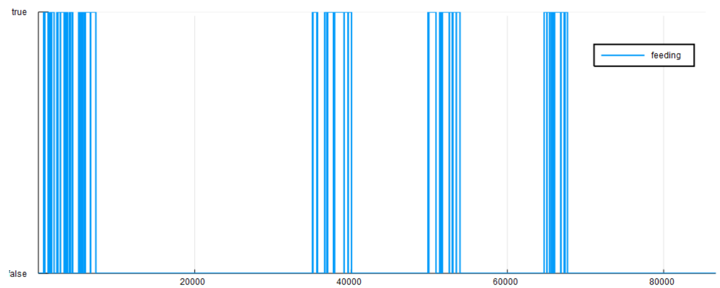
- Missing data and reflection errors are the biggest problem with our Ubisense set up
- We are able to solve most of the errors with filtering and interpolation
- We can get: robust estimates of time spent in different in different functional areas (*Feeding time, Pastell & Frondelius 2018*)
- More work is needed for reliable movement analysis for e.g. lameness -> combination with movement sensors?
- **See:** *Pastell et al. 2018. Filtering methods to improve the accuracy of indoor positioning data for dairy cows. Biosystems Engineering.*

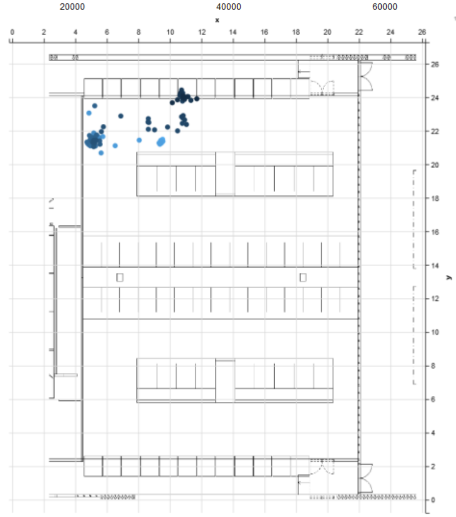
Combining sensor data



Expand and interpolate data to 1s sampling rate







Behaviors

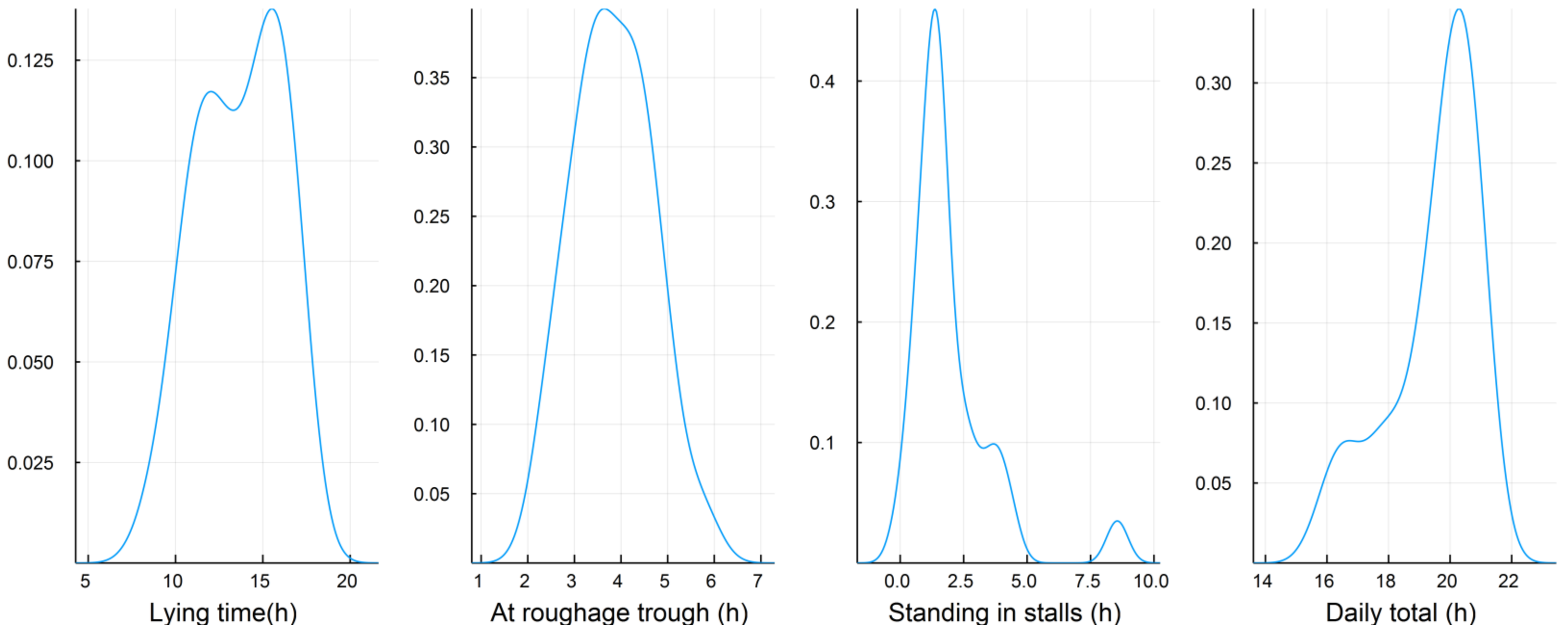
- Lying time
- Feeding time
- Standing in stalls

Other benefits

- Quality control of data
- Easy to calculate behavioral synchrony

Results from time budget experiment

- Cows spent 13.6 ± 2.4h lying, 3.8 ± 0.84h feeding and 2.0 ± 0.46h standing in stalls. In total these behaviors accounted for 19.5 ± 1.5h of daily cow behavior.
- The rest of the time was either spent walking or standing, additional processing of positioning data is needed to differentiate between these behaviors.



Does combining multiple sensors give more information than a single sensor?

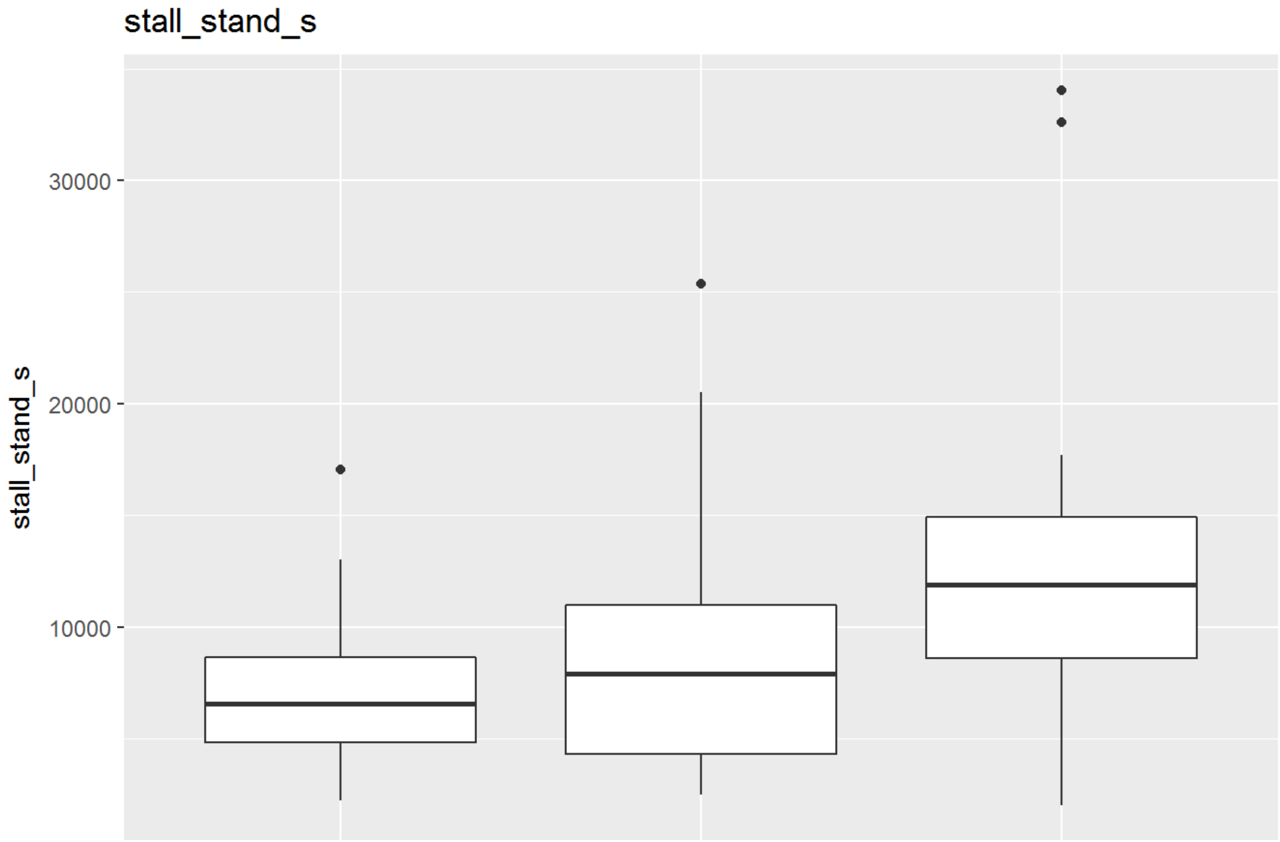
- Do actually need combined information, can’t we just use positioning?
  - Cow at feeder is most likely eating, cow at stall is most likely lying down etc.
  - Very accurate results can be obtained via e.g. probabilistic models

- Yes we do!
  - Indirect approaches can break down with abnormal behavior and we are interested in detecting abnormality!
  - Always trust direct measurement over location,activity etc. prediction
  - Example follows…

Effect of hoof lesions on daily stall usage (unpublished data)

Example: combined information

Effect of lameness on time spent standing in stalls. Combined IceQube and UWB data



Mild lesions + Healthy n = 29

White line disease n = 15

Sole ulcers n = 15

What is next?

- Combining different sensors gives us a lot of oppoturnities for accurate monitoring of time budgets

- Noisy data limits our ability to do movement analysis from positioning -> need additional sensors

- We’ve only scratched the surface in terms of analysing the data
  - Understanding behavior: what is an expected time budget in different circumstances?
  - Interactions between animals

How should we model time budget data when we want to act in realtime?

How should we model time budgets?

- Challenge is to calculate the expected state for an **individual animal** based on current state and biological knowledge i.e. the average animal

- Time series data, ordering of the data matters

- Need to consider:
  - Physiology and production
  - External environment e.g. climate
  - Correlation with other behaviors (allocation of time budget)
  - Behaviors of other animals in a group

- Total duration as well as occurrence of behaviors, bout duration, frequency etc.

Can’t we just learn the right model from the data?

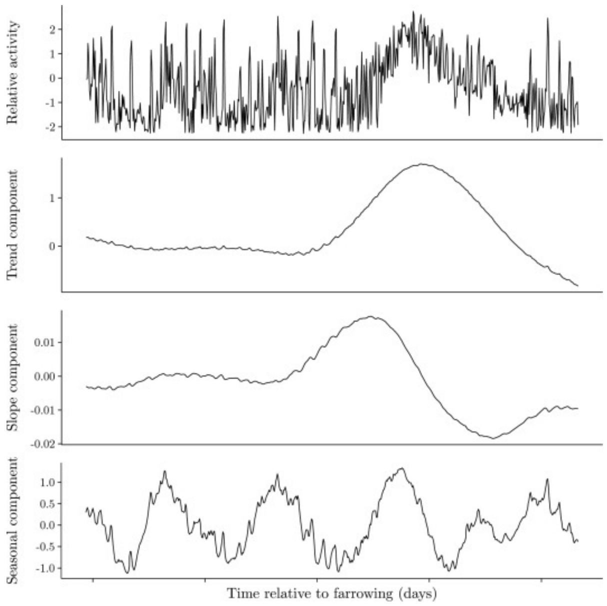
- **Yes, but:**
  - You need a lot of data, samples become sparse in high dimensions (curse of dimensionality)
  - Hard to avoid learning dataset specific features
  - The model learns more than we do -> not very useful for taking action
- **Methods:**
  - Traditional machine learning approaches, logistic regression, SVMs
  - Deep learning: Variational autoencoders (able to learn sequences)

Luke NATURAL RESOURCES INSTITUTE FINLAND

Simple time series models

- *“A time series model is essentially a confession of ignorance, generally describing situations statistically without relating them to explanatory variables.” West & Harrison 1997*

- Modeling only based on historical data and detect changes
- Good at detecting short term changes

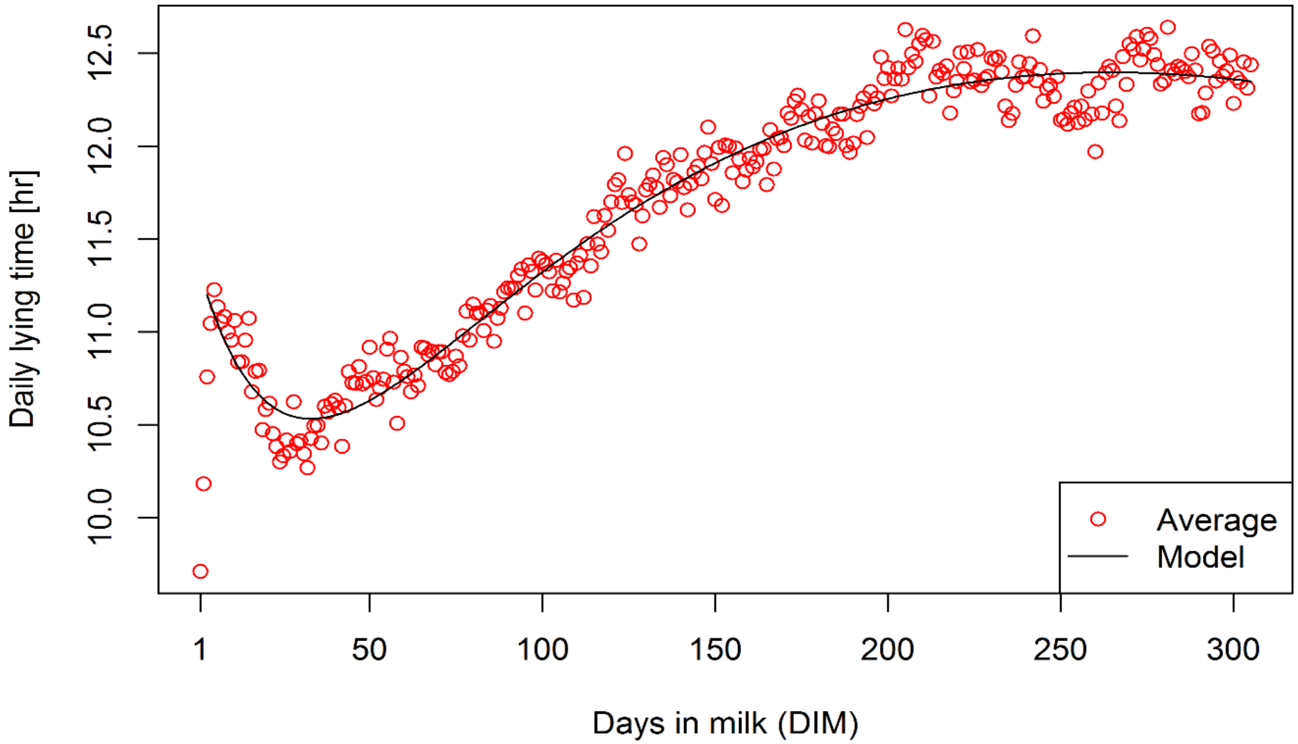


- Example: Detecting changes in activity related to farrowing: *Pastell et al. 2016*

- 96.7% of farrowing related activity detected in 2 different environments: farrowing crates and pens

Time series model with structure

- If you have knowledge about process structure you should use it



Short Communication

Daily lying time, motion index and step frequency in dairy cows change throughout lactation

Jarissa Maselyne [a], Matti Pastell [b], Peter T. Thomsen [c], Vivi M. Thorup [d], Laura Hänninen [e], Jürgen Vangeyte [a], Annelies Van Nuffel [a], Lene Munksgaard [c,*]

Time series model with structure

- State Space Models allow
  - Time series models with known structure e.g. lactation curve
  - Exogenous variables
  - Multivariate series
    - Model covariance of several variables jointly
    - Combine individual time series models
  - Detect process change points

- Kalman filter algorithm for linear gaussian models

- Particle filters for non-linear and non-gaussian models

Fitting more complex time series models using Particle filters

$$Yield = \beta_0 + \beta_1 t + \beta_0 + e^{kt}$$

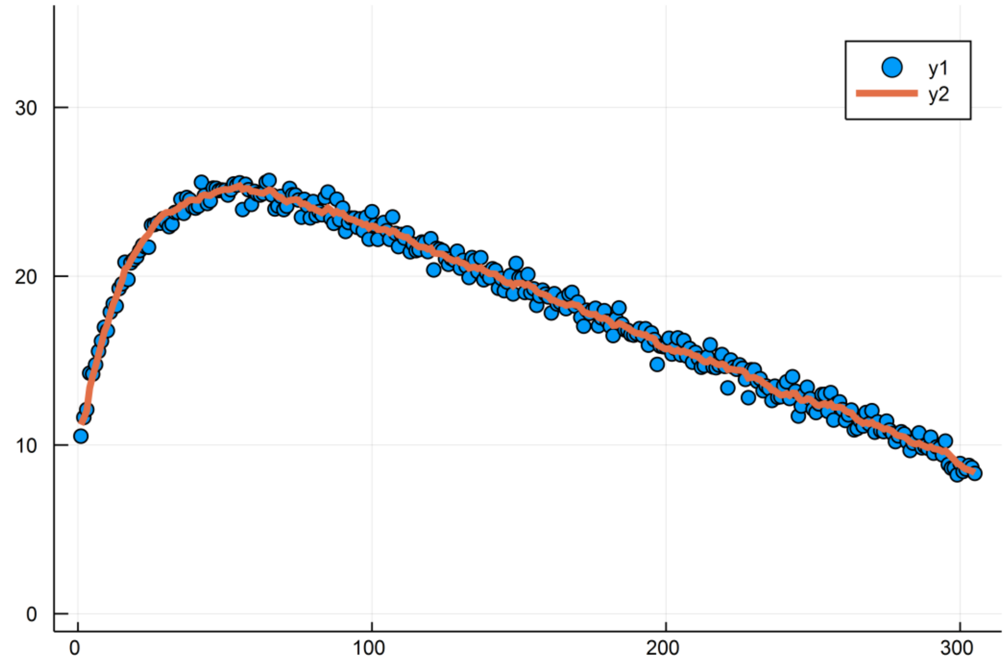
↓

$$Y_t = Y_{t-1} + \beta_1 \Delta t + \beta_2 e^{kt} \Delta t$$

- sequential Monte Carlo method for fitting state space models (Gordon et al.1993)

- Estimation, filtering and smoothing of non-linear and non-gaussian models
- Distributions

- Parameter estimation using PMMH algorithm (Andrieu & Roberts 2009)



Conclusions

- Better models will bring improved understanding
  - Allows us to test theories
  - Improved welfare assesment
  - Allows improving systems -> decision support systems *(Kristensen 2015. From biological models to economic optimization)*

- When we know what is normal we have a better change of detecting the abnormal

- Models and our understanding will improve with more data -> open data and sharing is important

Thank you!

“THINK, and do not sacrifice yourself to mathematical magic.” - West & Harrison 1997

NATURAL RESOURCES INSTITUTE FINLAND

Luke

NATURAL RESOURCES
INSTITUTE FINLAND