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Multivariate syndromic surveillance system for cattle diseases in Switzerland: Epidemic simulation and algorithm performance evaluation

C Faverjon[1]*, LP Carmo[1], J Berezowski[1]

[1] Veterinary Public Health Institute, Vetsuisse Faculty, University of Bern, Liebefeld, Switzerland

BACKGROUND

Syndromic surveillance systems (SyS) should be multivariate, because multiple data sources contain more information about a population. Numerous methods have been proposed for multivariate SyS but the number of such systems that are operational in veterinary medicine is still very limited, partially because of the gap between research and surveillance practice.

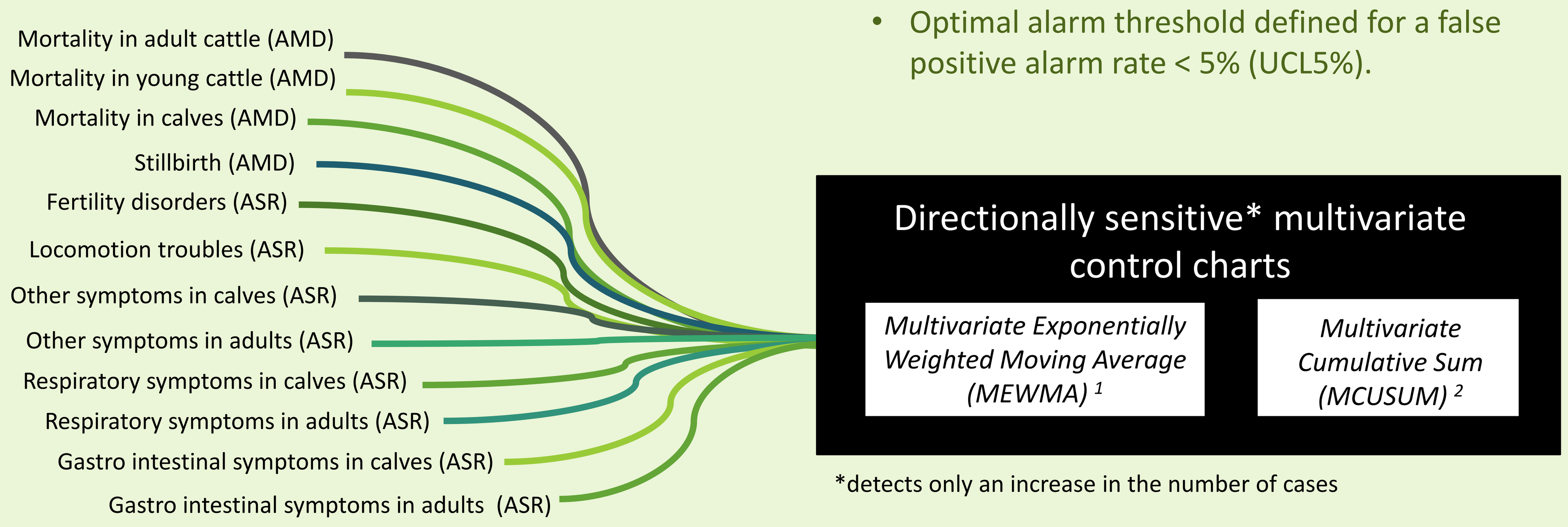
Objective

Evaluate a multivariate SyS system for cattle diseases in Switzerland using realistic simulated multivariate epidemics of 4 cattle diseases.

MATERIAL & METHODS

12 weekly syndrome time series extracted from 2 national databases

- Swiss Animal Movement Databases (AMD).
- Database owned by the Association of Swiss Cattle Breeders (ASR).



*detects only an increase in the number of cases

2 aberration detection algorithms implemented and compared

- Training dataset: for years 2014-2015.
- Test multiple algorithm parameters. Optimal parameter = parameter maximizing sensitivity and specificity.
- Optimal alarm threshold defined for a false positive alarm rate < 5% (UCL5%).

Detection performance assessed using sensitivity, specificity and timeliness

✓ **Test dataset 1 = simulated data**

- **300 epidemic-free baselines** were simulated for each syndrome using model predictions obtained from Holt–Winters generalized exponential smoothing on the training dataset.
- **300 multivariate epidemics** were simulated for 4 cattle diseases: Bovine Virus Diarrhea (BVD), Infectious Bovine Rhinotracheitis (IBR), Bluetongue virus (BTV), Schmallenberg virus (SV). Simulations were based on expert opinion:

Step 1. Estimate the total number of new infections for each disease at each time step in the Swiss cattle population

Step 2. Estimate the expected proportion of new calf and adult cattle infections at each time step

Step 3. Estimate the proportion of infected adult cattle and calves that are expected to show clinical signs

Step 4. Estimate the proportion of adult cattle and calves that are expected to be recorded in the data.

Simulated epidemics were randomly inserted in the simulated epidemic-free baselines.

✓ **Test dataset 2 = real data from 2016 and 2017**

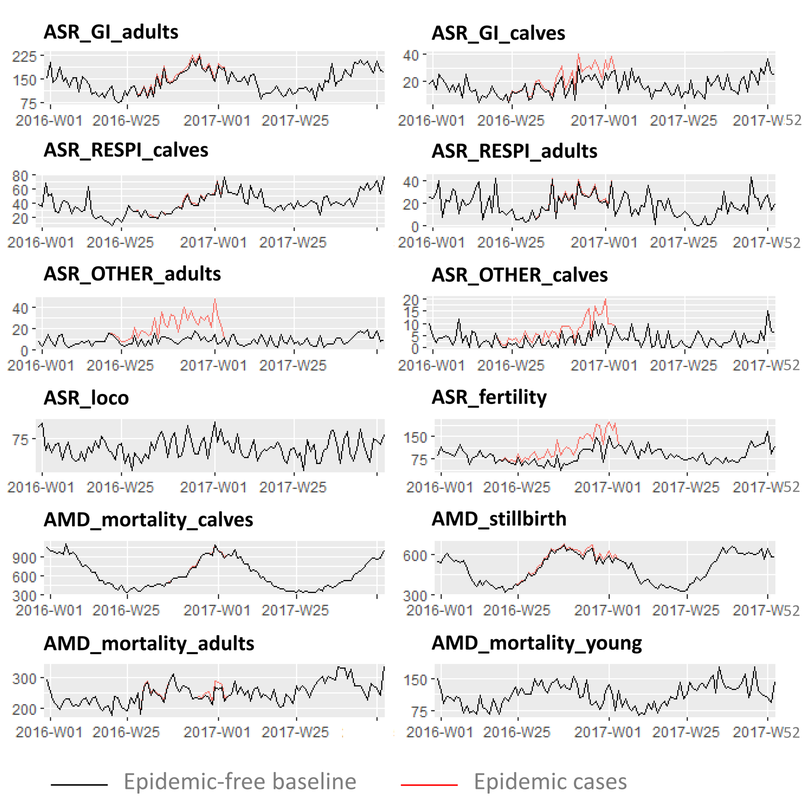
RESULTS - Simulated Data

Optimum algorithms parameters and alarm thresholds

- **MEWMA** $\lambda = 0.3$, UCL5% = 29.5
- **MCUSUM** k = 0.5, UCL5% = 6.5

Algorithm comparison

- More than 97% of the simulated epidemic were detected.
- Positive predictive value range: 87 – 95%.
- Time to detection: 8.6 weeks for MEWMA, 14.6 weeks for MCUSUM.



Disease comparison

- IBR epidemics easier to detect: shorter timeliness, higher weekly sensitivity.
- SV epidemics detected 1 to 3 weeks later than IBR.
- BTV and BVD epidemics were the most difficult to detect: longer time to detection, lower weekly sensitivity.

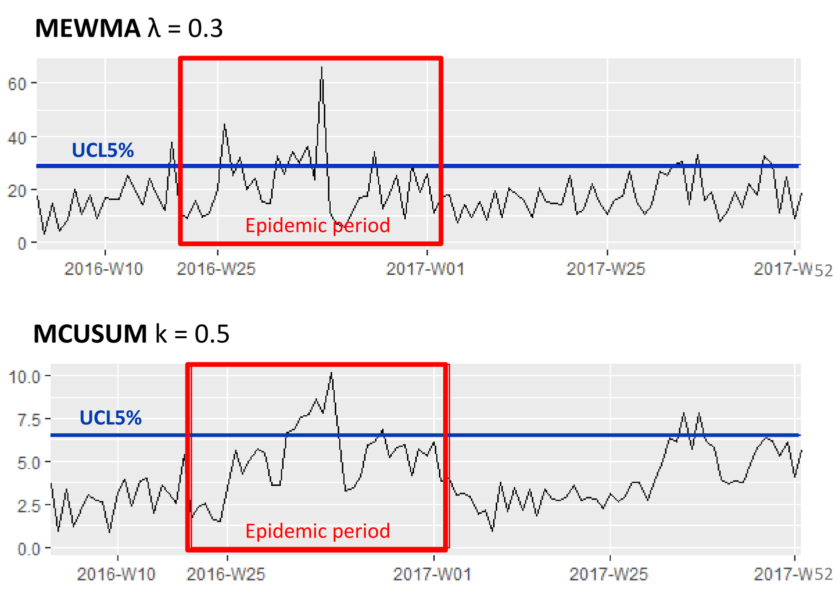
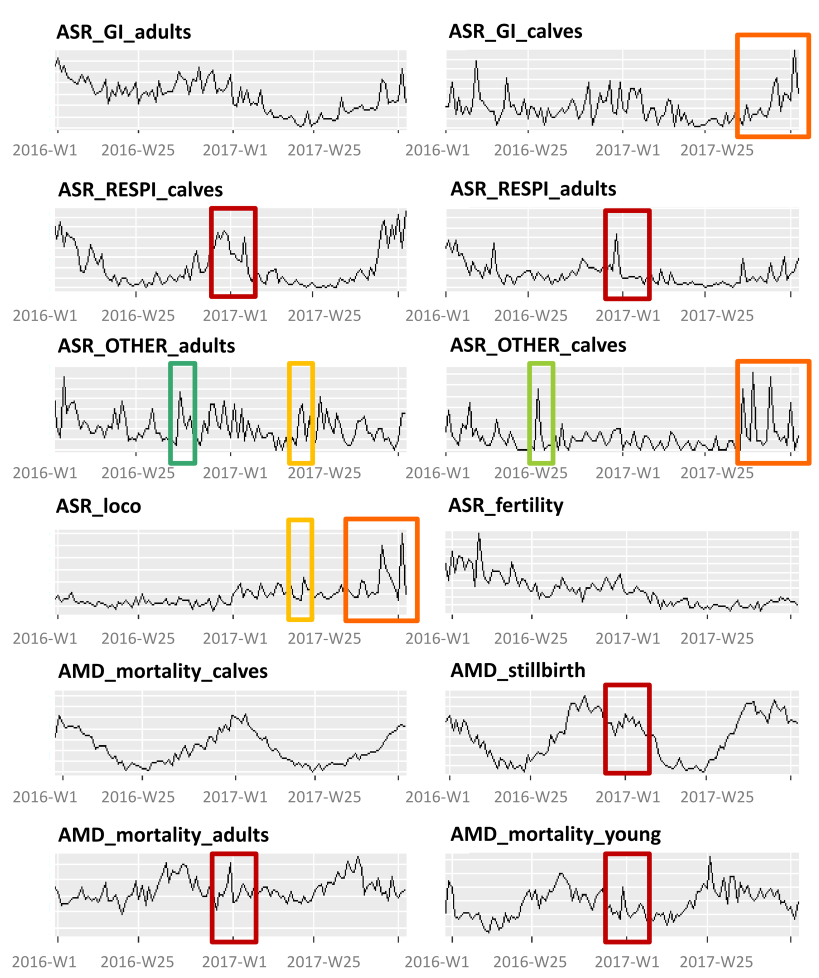


Fig1: Exemple of one simulated multivariate epidemic of BVD (left graph), and corresponding outome of the two directional multivariate control charts (right graph).

Real Data



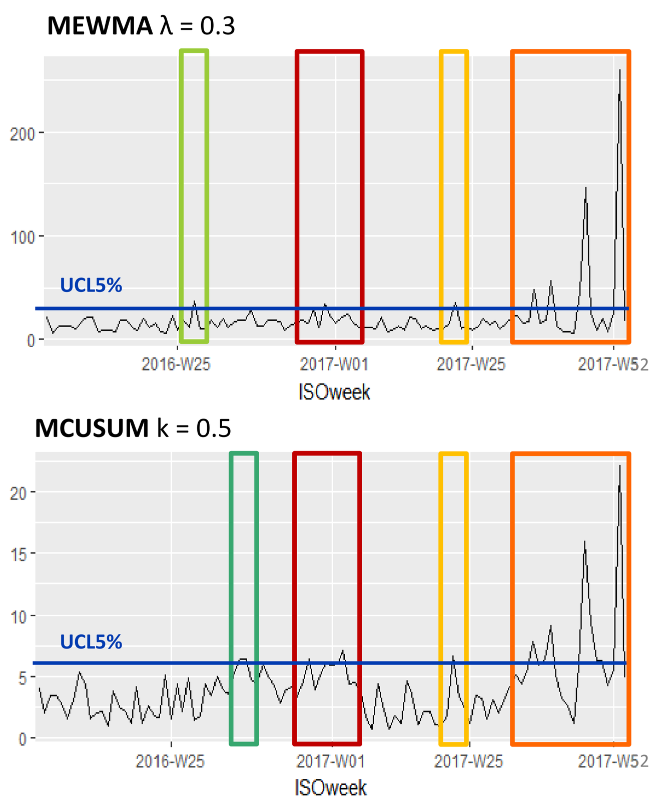


Fig2: real data from 2016 to 2017 (left graph) and ouctomes of the two directional multivariate control charts (right graph). The color of the alarms raised by the two algorithms correspond to the peaks identified in the real data at the same time period.

True positive alarms

- The two algorithms raised alarms that were linked with peaks observed in the raw data (see alarms and peaks , and) and with modifications of the ASR and AMD databases.

False alarms?

- Some peaks observed in the data only lead to an alarm in one of the two algorithms (see and).

CONCLUSION

First report of directionally sensitive multivariate control charts being evaluated for animal health surveillance!

- Advantages: method is easy to implement, and results are easy to interpret
- Disadvantage: not possible to identify which TS contributed the most to the alarms

Comparison to the current Swiss early detection system is complicated…

- Little information available about epidemics of these diseases in the country
- Based on expert opinion, we estimated 9 months to be the maximum time needed, on average, to identify an epidemic of IBR, BVD, BTV or SV in Switzerland with the current Swiss active surveillance systems

MEWMA outperformed MCUSUM in terms of detection timeliness

- Other authors[1] have suggested that the MEWMA should be selected over the MCUSUM because it is easier to develop an intuitive appreciation for how to choose λ than k
- Our results suggest that MEWMA is more robust than MCUSUM to the so-called inertia problem found in all control charts

Simulating multivariate epidemics using expert opinion; is this the way to go?

- Expert opinion is a cost-effective approach for simulating realistic multivariate epidemics but it has some limitations (e.g., results are not generalizable to epidemics in other countries)
- Epidemiological models could be used, but they are costly in terms of resources and data, which limit their use. For example, there was no information available to develop compartmental models for the 4 diseases considered in this study for Switzerland

References:

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2. Joner M.D., Woodall W.H., Reynolds M.R., F.R.D., 2008. A One-sided MEWMA Chart for Health Surveillance. Qual. Reliab. Eng. Int. 24, 503–518

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Céline Faverjon
Postdoc
celine.faverjon@vetsuisse.unibe.ch

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