Development of alert systems: CUSUM control charts to identify unusual bovine TB outbreaks in Scottish cattle herds

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Aim

To develop a flexible framework with minimal data requirements for early detection of unusual disease outbreaks and general veterinary syndromic surveillance. This system should be simple enough to be used effectively by veterinarians and policy-makers with little or no formal statistical training.

Data

Bovine tuberculosis (bTB) is used as an exemplar to illustrate the utility of our proposed alert system. Although bTB is a well-studied disease with considerable covariate and denominator data available in the UK, the analysis was limited to the incidence count data that might be available in more general surveillance applications. Monthly number of bTB SICCT reactors and number of confirmed bTB herd breakdowns in Scotland, for the period January 2003 to December 2012, were extracted from the VetNet database (APHA). Only reactors detected in routine herd tests as listed in AHVLA (2013) were included.

Methods

Singular spectrum analysis (SSA)

SSA is a nonparametric method to extract the principal frequencies from a time series sequence (Golyandina and Zhigljavsky, 2013). It does not depend on any distributional assumptions about the population from which the data originated. A model of the form

$$\text{Time series} = \text{Signal} + \text{Noise}$$

is assumed, where the first small number (q) of singular spectra account for the signal in the time series. A window length of $L = 12$ months was used.

CUSUM control chart

The cumulative sum (CUSUM) control chart value at time t, C_t, was calculated as

$$C_t = \max\left(0, x_t - \tilde{x}_t + C_{t-1}\right),$$

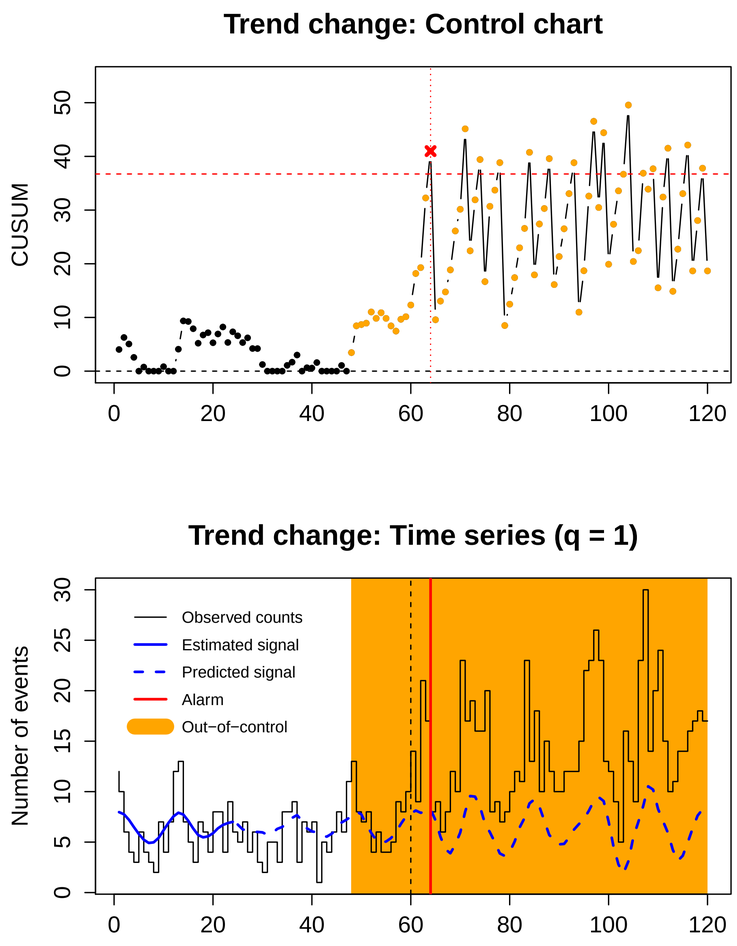
where x_t is the observed value of the time series at time t, and $\tilde{x}_t$ is the expected value estimated with the SSA procedure. An alarm to signal an out-of-control situation is triggered if the CUSUM exceeds a threshold, h, calculated by simulation to allow for an average in-control run length of 200 months.

Results

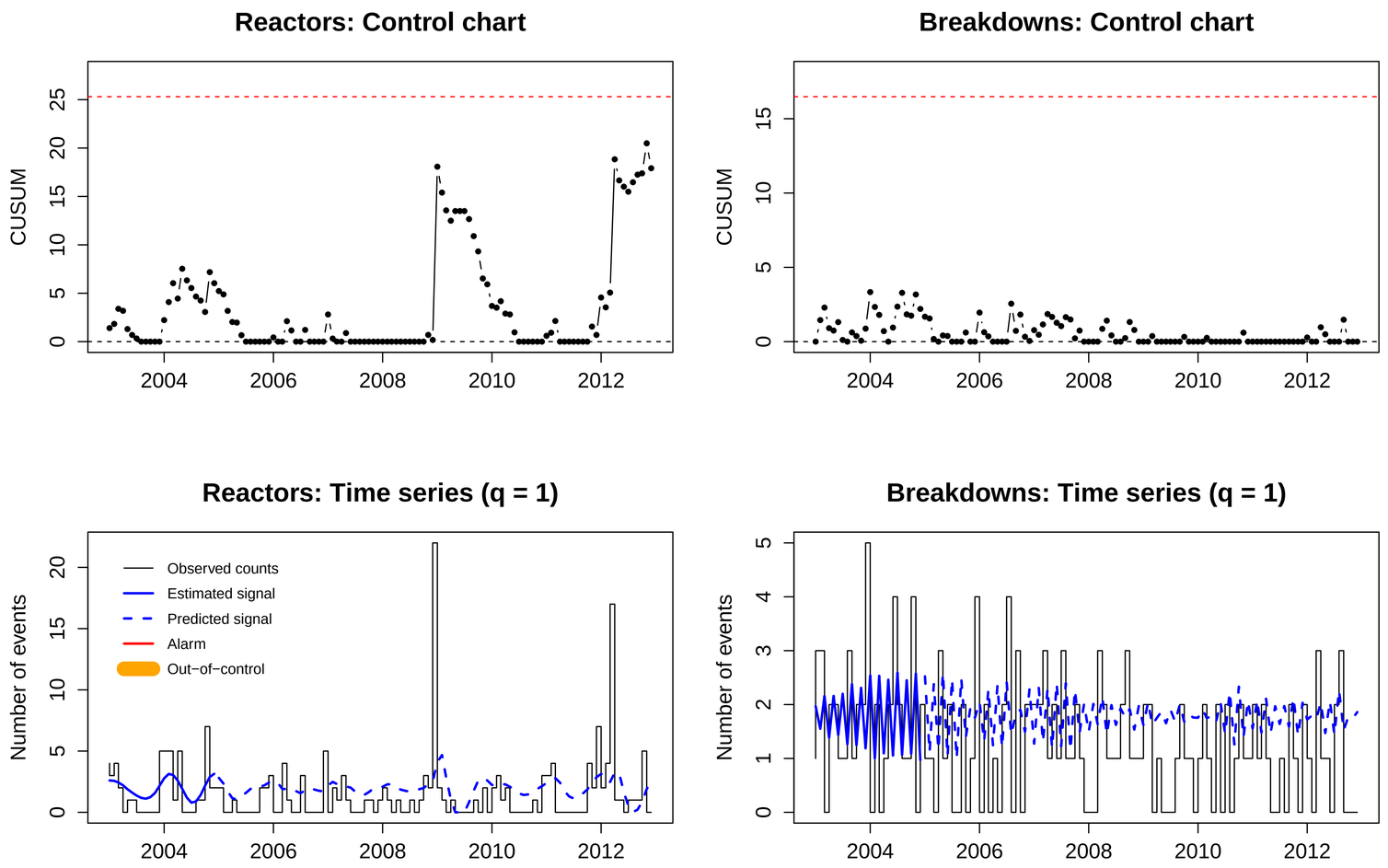
The SSA-CUSUM was tested on simulated count data with a gradual trend change ($\tilde{x}_t + \frac{11(t-60)}{10}$, $t = 61, \ldots, 120$) or abrupt jump change ($\tilde{x}_t + 2\sqrt{\tilde{x}_t}$) starting at time point 61. The shifts to out-of-control situations were quickly detected in both cases.

No alarms were triggered by the SSA-CUSUM charts for either reactors or herd breakdowns in Scotland. The first singular spectrum models seasonal variation in the number of bTB reactors, but there is no clear seasonal component in the number of breakdowns.

Simulated data



Scotland



Conclusions

The proposed SSA-CUSUM is a flexible method for the early detection of unusual disease outbreaks after accounting for seasonal variation. No unusual bTB outbreaks were detected in Scotland for the period 2003-2012, which is consistent with the current officially TB-free (OTF) status of Scotland.

References

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