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Univariate and multivariate surveillance of outbreaks

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AKADEMISK AVHANDLING

som för avläggande av filosofie doktorsexamen i statistik, med tillstånd av Handelshögskolans fakultetsnämnd vid Göteborgs Universitet, framlägges till offentlig granskning torsdagen den 25 november 2010, klockan 13.00 i sal F43, Hus F, 4:e våningen, Handelshögskolan, Vasagatan 1, Göteborg.

Fakultetsopponent är professor Sven Knoth, Institute of Mathematics and Statistics, Department of Economics and Social Sciences, Helmut Schmidt University Hamburg, Tyskland.

Abstract

In many areas there is a need to monitor observations in order to detect changes in the underlying processes as quickly as possible. The theory of statistical surveillance provides the possibility of making optimal decisions about whether a change has occurred or not based on the data available at the time of the decision. Surveillance can be used in many different situations. It is important that the relevant characteristics of the change are identified and that the relevant optimality criterion is used. There is a need to further develop the theory of statistical surveillance.

One area where surveillance is of special interest is the detection of outbreaks of epidemic diseases. New strains of influenza virus like avian flu and swine flu have drawn much attention, but it is also important to detect the varying onset of the seasonal influenza. Outbreaks are characterized by a change from a constant incidence to an increasing one. A quick and reliable detection of epidemic outbreaks can be beneficial to society as it has the potential to prevent loss of lives and severe economic consequences. The detection of a change from a constant level to a monotonically increasing (or decreasing) regression is of interest also in other areas, for example in finance. This thesis considers outbreak detection in a wide meaning. It deals with topics of statistical surveillance in general and with applications to warning systems for influenza in particular.

When information on several variables is available it should be efficiently used in the surveillance system. The construction and evaluation of multivariate surveillance methods need to be developed, and one aim of the thesis is to contribute to this development.

In Paper I, a nonparametric univariate method for surveillance was applied to Swedish data on seasonal influenza and tularemia. An experiment to compare the statistical method to subjective judgment was performed. A user-friendly program implementing the method is presented.

As Swedish influenza data are collected from several different regions, a multivariate surveillance system could be superior to a univariate one. However, the evaluation of multivariate surveillance demands special care. Paper II deals with these problems. The suggested evaluation measures were subsequently used in Paper III and V.

In Paper III it was demonstrated that in some cases there exists a sufficient statistic that can be used to reduce a multivariate surveillance problem to a univariate one.

In Paper IV it was examined how the spreading pattern of influenza in Sweden could be characterized. In Paper V, the information from the other papers was used to construct a method for multivariate outbreak detection. Motivated by the findings on the spreading pattern of influenza in Paper IV, the univariate outbreak detection method of Paper I was generalized to a multivariate method for outbreak detection by the results on multivariate techniques found in Paper II and Paper III.

Key words: change-points, expected delay, exponential family, false alarms, generalised likelihood, inference principles, influenza, MEWMA, monitoring, multivariate, ordered regression, performance metrics, outbreak, predictive value, subjective judgment, spatial, statistical models, surveillance, tularemia

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