Sequential Change-Point Analysis of Markov Chains with Application in Early Detection of Epidemics

Abstract

In epidemiology, an epidemic is usually declared when mortality rate exceeds an epidemic threshold. However, it is often possible to detect an epidemic earlier. We focus on the development of efficient sequential change-point detection tools for Markov processes, which finds a number of important and useful applications in epidemiology and other fields where the standard assumptions of independent and identically distributed observations are impractical.

An extension of cumulative sum (CUSUM) based on conditional log-likelihood ratio for Markov chains is proposed. It is shown to be suboptimal under the considered Markov model. A new adaptive threshold for the CUSUM process is developed for fast detection of change-points in sequences of dependent random variables, and large sample approximations are derived. The properties of the new method are explored both theoretically and by simulation.

The proposed sequential algorithms are applied to detect the epidemics and pre-epidemic trends in the 2001-2008 seasonal influenza data and the 2009 inuenza A (H1N1) pandemic data(CDC). The proposed procedures are sufficiently sensitive to detect trends leading to epidemics before the in uenza mortality achieves the epidemic threshold and epidemics are officially declared.