Bayesian modelling of recurrent pipe failures in urban water systems using non-homogeneous Poisson processes with latent structure

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I certify that all material in this thesis which is not my own work has been identified and that no material is included for which a degree has previously been conferred upon me.

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Abstract

Recurrent events are very common in a wide range of scientific disciplines. The majority of statistical models developed to characterise recurrent events are derived from either reliability theory or survival analysis. This thesis concentrates on applications that arise from reliability, which in general involve the study about components or devices where the recurring event is failure.

Specifically, interest lies in repairable components that experience a number of failures during their lifetime. The goal is to develop statistical models in order to gain a good understanding about the driving force behind the failures. A particular counting process is adopted, the non-homogenous Poisson process (NHPP), where the rate of occurrence (failure rate) depends on time. The primary application considered in the thesis is the prediction of underground water pipe bursts although the methods described have more general scope.

First, a Bayesian mixed effects NHPP model is developed and applied to a network of water pipes using MCMC. The model is then extended to a mixture of NHPPs. Further, a special mixture case, the zero-inflated NHPP model is developed to cope with data involving a large number of pipes that have never failed. The zero-inflated model is applied to the same pipe network.

Quite often, data involving recurrent failures over time, are aggregated where for instance the times of failures are unknown and only the total number of failures are available. Aggregated versions of the NHPP model and its zero-inflated version are developed to accommodate aggregated data and these are applied to the aggregated

version of the earlier data set.

Complex devices in random environments often exhibit what may be termed as state changes in their behaviour. These state changes may be caused by unobserved and possibly non-stationary processes such as severe weather changes. A hidden semi-Markov NHPP model is formulated, which is a NHPP process modulated by an unobserved semi-Markov process. An algorithm is developed to evaluate the likelihood of this model and a Metropolis-Hastings sampler is constructed for parameter estimation. Simulation studies are performed to test implementation and finally an illustrative application of the model is presented.

The thesis concludes with a general discussion and a list of possible generalisations and extensions as well as possible applications other than the ones considered.

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Contents

List of Figures

List of Tables