Bayesian Robustness
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ROBUST TREATMENT OF IMPULSIVE NOISE IN SPEECH AND AUDIO SIGNALS*

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Markov chain Monte Carlo methods are presented for treatment of localized, impulsive noise (outliers) in digitized waveforms, within a Bayesian hierarchical framework. Outliers in audio signals occur as 'clicks' and 'crackles' in degraded sound recordings and impulsive noise in communications channels. Sampling-based methods for detection and correction of such artefacts are presented, in which individual noise sources are modelled as Gaussian with unknown scale, allowing for robustness to heavy-tailed noise distributions. Results are presented for speech and audio signals obtained from digitized sound recordings.

1. Introduction. This paper is concerned with the reconstruction of acoustically recorded signals, such as speech and music, which are degraded by impulsive noise sources ('outliers'). In the case of gramophone recordings there are several mechanisms for such defects in the physical storage medium, including natural irregularities, scratches, cracks and dust particles. These all give rise to localized noise artefacts in the recorded sound which are perceived as the 'click' and 'crackle' noise associated with old recordings. In analogue communications channels impulsive noise occurs as a result of electromagnetic interference, switching noise and atmospheric noise, all of which exhibit impulsive properties.

Godsill, Rayner and Cappé (1996) give a thorough review coverage of methods currently available for correction of impulsive and other types of degradation found in audio material. One approach which has been very successful involves modelling the audio signal as an autoregressive (AR) process (Vaseghi and Rayner, 1990). Identification (detection) of outliers is achieved by thresholding the estimated AR innovation sequence, while reconstruction is performed by least-squares interpolation of the corrupted data values. Disadvantages of the method include the inability to detect small impulses in the presence of much larger disturbances as well as the introduction of distortion in the presence of certain signal characteristics. Godsill and Rayner (1992, 1995) have developed recursive Bayesian methods which improve performance by allowing very accurate detection of audio outliers occurring in arbitrary configurations and bursts.

The rapid increases in available computational power which have occurred over the last few years have led to a revival of interest in Markov

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