A hidden Markov model for overlapping of seismic waves

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Hidden Markov models (HMM) have been used for finite-state mixture data and has a variety of applications. HMM consists of an unobserved state process and an observed process. A hidden state process is characterized by a transition probability matrix representing the probabilities of the change from one state to another state at a time point. This process is not observed so needs to be estimated. This talk focuses on the use of HMM in the analysis of the running spectra. Running spectrum (spectrogram) is the time series representing the change of spectrum of frequencies. By fitting HMM to running spectra, we separate the time series into a couple of states, and each state has different feature about frequency. As a result, we obtain the estimated parameters of frequency characteristic at each state, say, "wave A is mostly made from the 3 Hz component" or "wave B consists of high frequency components." However, a naive application of classical HMM often leads to some modeling bias because observed data are usually a "mixture" of important signals and noises. In the seismology, an earthquake arrives time and time again such as body waves, reflected waves, and converted waves. An earthquake swarm contains multiple seismic phenomena that have different features.
To avoid such modeling bias of classical HMM, we propose a method that can accommodate the "overlapping" of states. Our approach builds upon a state space model which is an extension of classical HMMs. Moreover, it can remove an assumption that "there is only one state at each time point." To this end, we introduce a latent variable that indicates "dominating rate" of each state. Our method provides three kinds of estimates simultaneously: parameter estimates for observed process, the transition probabilities of hidden states, and the dominance rate of each hidden state. Additionally, we examine the performance of our method by using both synthetic and real seismic data.

Keywords: Seismology, Statistics, Hidden Markov model, State space model

