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Bayesian Source Modelling for Single-Channel Audio Separation

Abstract

In many audio processing tasks, such as source separation, denoising or compression, it is crucial to construct realistic and flexible models to capture the physical properties of audio signals. This can be accomplished in the Bayesian framework through the use of appropriate prior distributions. In this thesis, we describe two prior models, Gamma Markov chains (GMCs) and Gamma Markov random fields (GMRFs) to model the sparsity and the local dependency of the energies, i.e. variances, of time-frequency expansion coefficients. These models are not limited to audio source modelling, but can be used in other problems where there is dependency between variables, such as the Poisson observation models.

A GMC model defines a prior distribution for the variance variables such that they are correlated along the time or frequency axis, while a GMRF model describes a non-normalised joint distribution in which each variance variable is dependent on all the adjoining variance variables. In our audio models, the actual source coefficients are independent conditional on the variances and distributed as zero-mean Gaussians. Our construction ensures a positive coupling between the variance variables, so that signal energy changes smoothly over both axes to capture the temporal and/or spectral continuity. The coupling strength is controlled by a set of hyperparameters.

Inference on the overall model is convenient because of the conditional conjugacy of all of the variables in the model, but automatic optimisation of hyperparameters is crucial to obtain better fits. In GMCs, hyperparameter optimisation can be carried out using the EM algorithm, with the E-step approximated with the posterior distribution estimated by the inference algorithm. In this optimisation, it is important for the inference algorithm to estimate the covariances between the variables inferred, because the hyperparameters depend on them.

The marginal likelihood of the GMRF model is not available because of the intractable normalising constant. Maximum likelihood estimation methods are not applicable for hyperparameter optimisation. There are methods to estimate the optimal hyperparameters in these cases, such as pseudolikelihood, contrastive divergence and score matching. However, only contrastive divergence is applicable to models with latent variables. We optimised the hyperparameters of our GMRF-based audio model using contrastive divergence. We tested our audio models that are based on GMC and GMRF models in denoising and single-channel source separation problems where all the hyperparameters are jointly estimated given only audio data.

PUBLICATIONS

Journals

1. **O. Dikmen** and A. T. Cemgil, "Gamma Markov Random Fields for Audio Source Modelling," IEEE Transactions on Audio, Speech, and Language Processing, vol. 18 (3) , pp. 589-601, 2010.

Conferences

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2. **O. Dikmen**, A. T. Cemgil and L. Akarun, "Gamma Markov Random Fields for Audio Source Modelling," in Proc. of IEEE 17th Signal Processing and Communications Applications

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