Conventional Statistical Modeling of Linear-frequency Spectrograms
Probabilistic models of parts-based representation and spectral envelope estimation have been proposed

**Nonnegative Matrix Factorization (NMF)**
Each local spectrum is approximated by a weighted sum of basis spectra

\[
x_n \approx \sum_{k=1}^{K} w_k h_{kn} = y_n
\]

**Composite Autoregressive Modeling (CAR)**
Each local spectrum is approximated by combinations of sources and filters

**Linear Predictive Coding (LPC) and Discrete All-pole Modeling (DAP)**
Input: \( N \); Observed power spectrum \( F_m \); Spectral envelope \( \sigma^2 \); Gain

\[
\text{LPC aims to maximize the likelihood function given by}
\end{align*}

\[
X_n \sim \text{Exponential} \left( \frac{\sigma^2}{F_m} \right),
\]

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\]

**Source-filter Decomposition of Log-frequency Spectrograms**
We propose a new variant of source-filter NMF by complementing CAR with DAP in the log-frequency domain

**Evaluation of Multipitch Estimation on MAPS Database**
The proposed model was tested for multipitch analysis of piano recordings (mono-instrument music signals)

Since the proposed model can deal with only harmonic sounds, HPSS was used as preprocessing.

To improve the performance, HMM smoothing was used instead of naive thresholding.

The proposed model attained the promising results even if the model was used in a completely unsupervised setting.