

Blind-source recovery of composite signals and time series

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Abstract: The inverse problem of resolving the “cocktail party problem” is the topic of discussion in this lecture. As an example, consider listening to a beautiful piece of classical music either from playing a CD or enjoying a symphony orchestra. The sound of the music being played is considered a blind source. The blind-source recovery problem is the inverse problem of identifying which musical instruments are being played, the number of all such instruments, as well as finding the amplitudes, musical tone, and time-varying (or instantaneous) frequencies, produced by each individual musical instrument. Being able to identify the music produced by every individual instrument requires determining the times of “arrival (signal onset) and departure (signal offset)” of the sound produced by this particular instrument and calculating its sound volumes (amplitudes) and instantaneous frequencies (IFs).

We will first introduce a general mathematical model of composite signals and time series, and explain why the existing decomposition methods fail to resolving the inverse problem. We will then recall two existing and somewhat successful approaches, namely: “synchro-squeezing transform (SST)” proposed by Ingrid Daubechies, and “signal separation operation (SSO)” introduced by Hrushikesh Mhaskar and myself, while pointing out that they are completely different but sharing the same requirement of positive IFs in the entire time interval and the necessity of adjusting two (free) parameters for extracting the IFs, from which the composite signal or time series components are to be resolved.

A new theory, along with effective computational schemes and algorithms, based on spline approximation and continuous wavelet transform (CWT), will be presented in this lecture. As a departure from the SST and SSO approaches, extracting the IFs is not necessary for resolving the inverse problem of separating and recovering the components of the composite signal or time series from the blind source. Instead, the scale of the CWT is the only parameter to be determined, for which wavelet thresholding is instrumental to separating this wavelet scale into clusters, with cardinality to match the number of (active) components that constitute the composite signal or time series, and that extrema estimation for each cluster gives rise to the optimal scales, from which the components as well as their corresponding IFs are recovered independently.