Abstract

The quadratic class of time-frequency distributions (TFDs) is the most popular set of time-frequency tools for analysis and processing of non-stationary signals. Two best known and most studied members of this class are the spectrogram and the Wigner-Ville distribution. To be used efficiently, i.e. to have highly concentrated signal components while significantly suppressing interference and noise simultaneously, TFDs must first be optimized. The optimization method used in this paper is based on the Cross-Wigner-Ville distribution, and unlike similar approaches it does not require prior information on the analyzed signal.

The method is applied to whale signals, which, just like the majority of other real-life signals, can generally be classified as multicomponent non-stationary signals. Hence, time-frequency techniques are a natural choice for their representation, analysis, and processing. We present preprocessed data from a set containing hundreds of individual calls. The TFD optimization method results in a high-resolution time-frequency representation of the signals. It allows for a simple extraction of signal components from the TFD's dominant ridges. The local peaks of those ridges can then be used for the signal components instantaneous frequency estimation, in turn can be used as one of the features in any subsequent classification of the whale signals.

Blue Whales

- A few facts about blue whales:
  - Balaenoptera musculus is thought to be the largest animal that has ever existed (Evans et al., 2011). This partly explains the very low frequency of their calls, falling within the CTBTO 10 to 100 Hz range.
  - The few days of data were acquired and processed through the HYCOM platform.

- Data from the HYCOM database include over 360,000 calls during the commercial whaling activities. Category 9 (McDonald et al., 2006) recorded at Diego Garcia was the only category studied in this preliminary work. The majority of other real-life signals, can generally be classified as multicomponent non-stationary signals. Hence, time-frequency representation that allows accurate estimates of the signal components IF laws is obtained. The first point (\( t_1, f_1 \)) is the reference signal (RS), and the cross-term coordinates (\( t_2, f_2 \)) are obtained from the peaks of the time-slices of the XWVD between the RS and the analyzed signal (AS). The RS used in the method is a unit amplitude Gaussian atom, that can be arbitrarily positioned in the T-F plane (Malnar et al., 2012).

- Over 360,000 were caught during the commercial whaling period. Blue whale populations are recovering from commercial whaling activities that were conducted until a 1982 moratorium. There are now a few thousand individuals worldwide, information of Whaling Commission estimates, 2010, the Southern Ocean, in the end of the last century. Currently 2000 in the Eastern Pacific (J. Hildebrand, Scripps Institute of Oceanography, personal communication).

- It has been observed that the dominant frequency of the calls has decreased with time over the past decades. One possible explanation is that after recovery, the average animal size is becoming larger (McDonald et al., 2006).

Components IF Estimation From the XWVD

- The cross-term is located halfway on a straight line between any two points in the signal. The cross-term coordinates are:

\[
\begin{align*}
  t_c &= \frac{t_1 + t_2}{2} \\
  f_c &= \frac{f_1 + f_2}{2}
\end{align*}
\]

- From the calculated T-F points, the estimate of the component IFs is obtained. The first point (\( t_1, f_1 \)) is the reference signal (RS), and the cross-term coordinates (\( t_2, f_2 \)) are obtained from the peaks of the time-slices of the XWVD between the RS and the analyzed signal (AS). The RS used in the method is a unit amplitude Gaussian atom, that can be arbitrarily positioned in the T-F plane (Malnar et al., 2012).

- For adjacent time slices, the minimal distance criterion is used when forming coordinate link (dashed arrows) from the frequency coordinates of detected peaks.

References