MODE DECOMPOSITION OF SIGNALS USING WAVELET FILTER BANKS

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ABSTRACT

An algorithm to decompose a signal in various components, or modes, is introduced. This is done using a wavelet packet filter bank. Furthermore the possibility of postprocessing the modes with hilbert transform, resulting in a „hilbert spectrum“ is discussed.

1 INTRODUCTION

There are several well known methods to estimate a time frequency distribution of a given signal. The most popular methods are: Short Time Fourier Transform (STFT), Wavelet Analysis, Wigner-Ville Distributions (WVD). All of them have drawbacks: STFT and Wavelet Analysis are restricted by heisenbergs uncertainty principle [3]. WVD without smoothing kernels is of virtually no practical use, since it works perfectly only with linearly frequency swept sine signals. A great deal of research time is invested by the signal processing community to find smoothing kernels to extend it‘s area of applicability.

Other than these integral transform signal analysis methods, one can decompose a signal using a filter bank and then draw the desired information out of the output signals of the filter bank, which can be thought of as components of the original signal. Then one way to draw information of these components is to calculate the instantaneous frequency and instantaneous amplitude of each component over time. This can be done for a fairly general class of signals, namely amplitude and phase modulated sine signals, using hilbert transform [1,2]. If one draws the curves of the instantaneous frequency vs. time with the extension of modulating the pen color with the according instantaneous amplitude, one gets a spectrogram-like plot, called the „hilbert spectrum“ [1,2]. One example of a hilbert spectrum is also depicted in the results section of this article.

The presented algorithm represents one of these filter bank approaches and uses a dyadic wavelet filter bank [3,4,5].

2 IMPLEMENTATION

For all experiments National Instruments Labview with the Labview signal processing toolset was used, especially the „wavelet and filter bank designer“.

The wavelet filter bank was implemented according to a dyadic tree structure (see fig. 1):

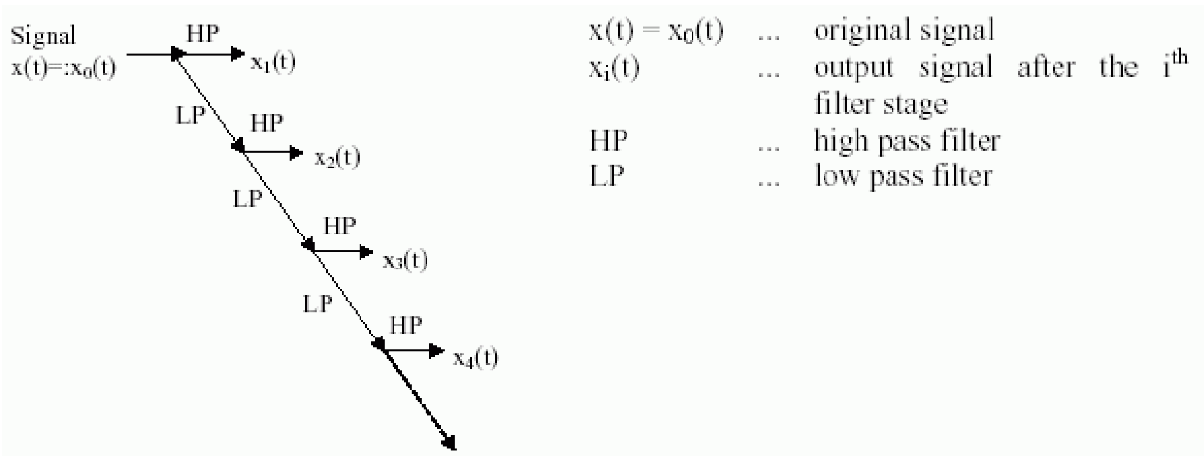


Fig. 1: *Implementation schematic of a dyadic filter bank*

Also, a 22 tap daubechies wavelet filter was used. This rather high filter order results in less problems with aliasing. But we got good results with orders of about 10, too.

Some of these outputs contain modes of the signal, while others don't. Those who contain modes are resynthesized by setting all other outputs to zero and using a synthesis filter bank.

3 RESULTS

We tested our algorithm with a vibration signal of a gear box, rotating at 1200rpm. This signal and two of its modes can be seen in the following figures:

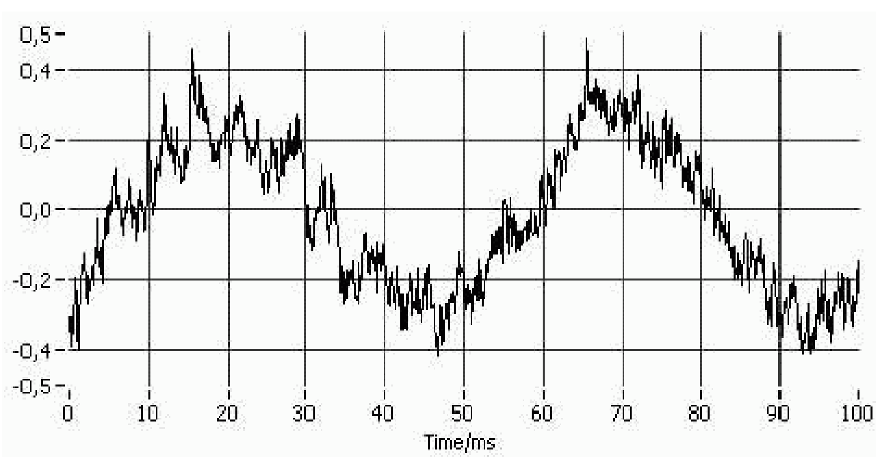
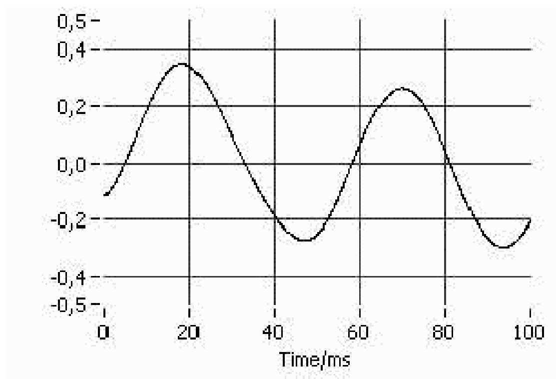


Fig. 2: *Vibration signal of a gear box*



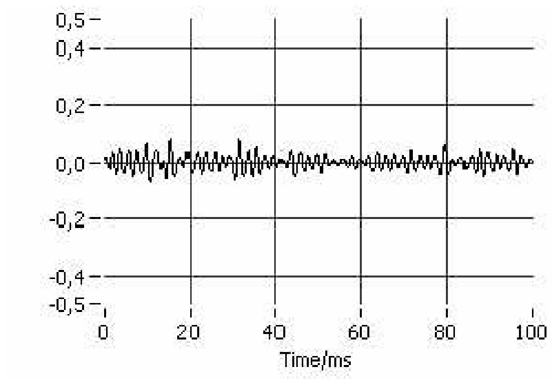


Fig. 3: *Low frequency mode of the previous signal*

Fig. 4: *Higher frequency mode of the previous signal*

As said before, one way to postprocess these modes is to calculate the instantaneous amplitude and frequency of each mode over time. These data can be depicted in a „hilbert spectrum" [1,2]. The following figure shows the hilbert spectrum of the previously shown low frequency mode:

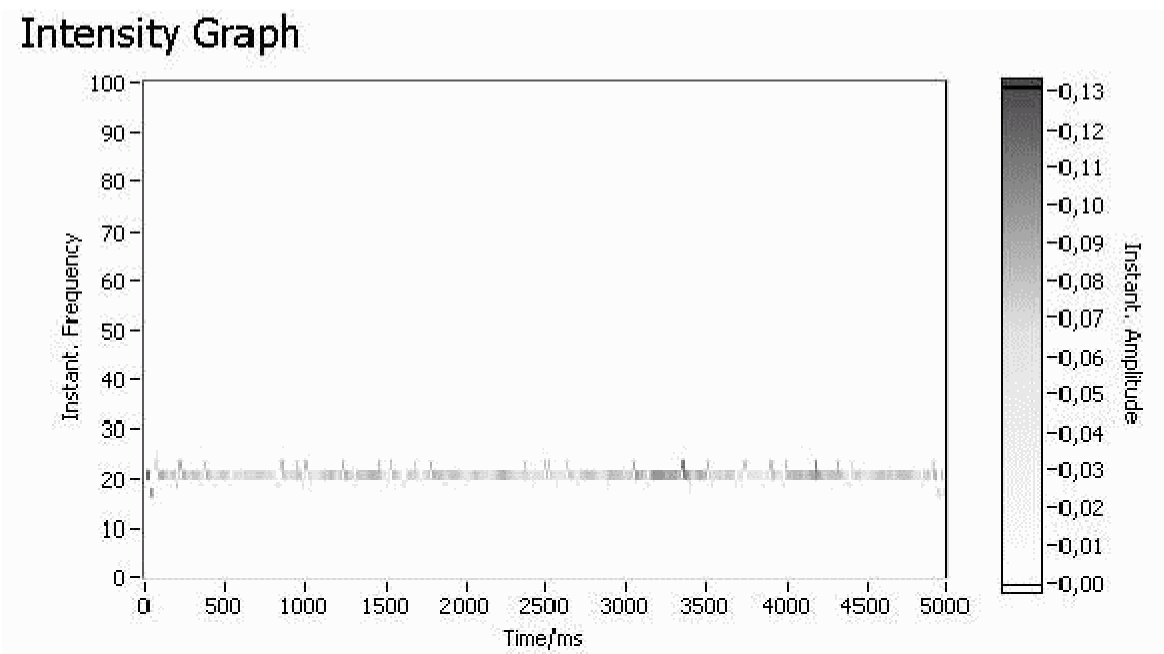


Fig. 5: *Hilbert spectrum of the low frequency mode of the signal*

The Hilbert spectrum can be interpreted like a spectrogram [1,2], i.e. as a time-varying spectral density. The most prominent difference to the spectrogram is that the hilbert spectrum consists of one or several lines in the time-frequency plane, where (instantaneous) amplitude is represented by the color of the line at a specific time.

4 CONCLUSION

Due to the nature of the dyadic wavelet transform, modes can only be separated if they differ by more than on octave. If this is the case, the algorithm works sufficiently good. The applicability of hilbert transform to the modes depends of course on the signal source. In our case of a rotating gear box, hilbert transform gave good results, as the hilbert spectrum shows.

Test with wavelet packets were less promising, which is unfortunate, since wavelet packets allow for a more versatile frequency range subdivision. The problems are caused by aliasing products.

Maybe the use of other types of filter banks will give better results. This still has to be investigated. And finally, there are also other ways to perform a mode decomposition [1,2] which work in the time domain, rather than the spectral domain, as is the case with filter banks.

REFERENCES

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