DYNAMICS OF FREQUENCY ESTIMATION IN THE FREQUENCY DOMAIN

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Abstract

We try to show how much error we can reduce in frequency estimation by using multipoint interpolated DFT for different window functions and a tradeoff between the reduction in systematic error of the frequency estimation.

Applications or importance of the task

1) Frequency estimation
2) useful where the natural frequency of the signal does not coincide with the basis set of the periodic components of the DFT
3) Preserves the relevance of DFT by partially neutralizing the effect of spectral leakage.

Challenges or motivation of work

The FFT interpolation has a greater edge over the older methods being :

- ***a fast method***
- ***non-parametric***

Using the interpolated DFT we have an option of getting a close approximate of the frequency provided we choose a proper window to calculate without changing the interval – (so that the main tone frequency becomes an integral multiple of frequency interval).

This also serves as a way to study properties of Windows like induction of systematic errors and Noise sensitivity.

References

[1] https://ieeexplore.ieee.org/document/1351218
[2] http://www.robots.ox.ac.uk/~sjrob/Teaching/SP/l7.pdf
[3] https://web.eecs.umich.edu/~fessler/course/451/l/pdf/c5.pdf
[4] https://www.researchgate.net/publication/220792939_Identification_and_Error_Analysis_in_Frequency_Domain

Important concepts

- ***If we try to find main tone frequency without interpolation, we will get***
  $$f_0 = k_m(\Delta f)$$

here k_m = bin of a local DFT maximum and $\Delta f = fs/N$.

- ***The accuracy of this solution for frequency depends in the accuracy of location of DFT peak. If the main tone is not an integral multiple of the frequency interval, then we have to interpolate the fft.***

- ***The different interpolating methods get their name on the basis of number of bins used for calculation.***

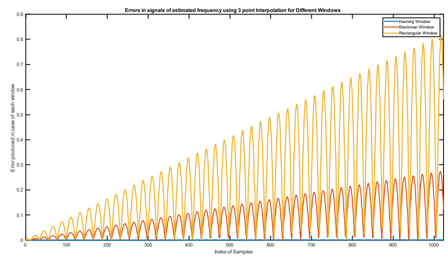
Any relevant discussion

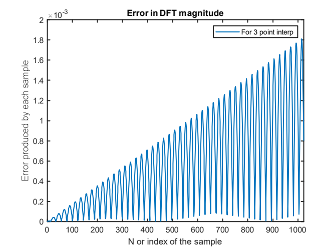
- ***In the simulation we've implemented 2 point and 3 point interp. and observed that as we increase the number of bins we get a more accurate estimate of the main tone frequency i.e., the more bins considered for interpolation, the more the accuracy.***

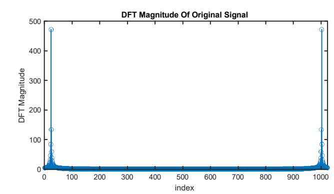
- ***We can calculate multipoint interpolation of FFTs using the same logic. This may seem a more "accurate" and desirable method, but it may not be true always as this non-parametric method is quite noise sensitive.***

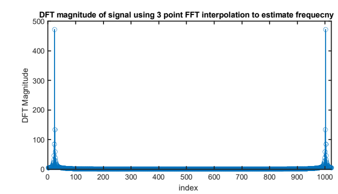
- ***Another way to decrease the systematic errors is to reduce the sampling frequency while keeping the no. Of samples a constant. However, this can result in aliasing.***
- ***The selection of window also plays a vital role for accuracy: Hanning > Blackman> Rectangular.***
- ***However, for noise sensitivity:***
  Rectangular> Blackman> Hanning

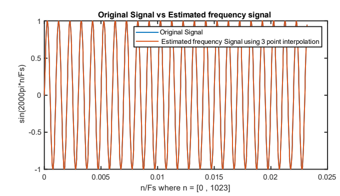
Results











Conclusion

Interpolations with a larger number of DFT coefficients decreased the systematic errors and increased the noise distortion in the results and with smaller numbers of coefficients, there is an inverse result.