Performance Evaluation of Cooley Tukey FFT v/s Bluestein's chirp z-transform Algorithm on Audio Signals

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General area

To gain experience performing research in algorithms, measure computational complexities such as running time and frequency resolution to evaluate two variations of FFT for audio signals

Keywords

Analysis of algorithms, time complexity, DFT, FFT, Cooley-Tukey FFT, Chirp Z transform, spectral resolution

Project description

The project aims to evaluate the performance of two variations of FFT algorithm:, Cooley Tukey FFT (Radix 2 implementation) and Chirp-Z Transform FFT on audio signals on computational complexities such as running time, space consumption and spectral resolution for varied-length signals.

Assignment of responsibilities

Nitika would be responsible in understanding the variations of FFT algorithms, collect the audio signal data, and write their implementation in Python.
Srishty would also implement the algorithms in Python as well as visualize their results to evaluate their performance and document the same with Nitika.

Total budget

Proposed budget would include investigators' time and the computing resources(softwares, research papers, processors) that would be needed to implement the algorithms costing around $800.

Deliverables

Project Report, Powerpoint Presentation, Source code, Audio signal data used, Peer review

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In the applications of digital signal processing such as audio or image processing, researchers face challenges while detecting specific tones, frequencies or some other form of signatures of signal which must be either controlled, removed or ignored. Generally, such operations are conducted in frequency domain as it becomes to easier to visualize vital signal properties such as amplitude and phase in frequency spectral form. Fourier Transform is used to convert a signal in time domain into a frequency domain equivalent but due to Discrete Fourier Transform being computationally extensive (O(n^2)) for an n-sized data, researchers prefer to use Fast Fourier Transform with its running time of O(nlogn). Since then, many variations of FFT have been proposed for various applications. The trade-off between processing time and resolution for signals has been a dilemma since ages for different applications. The time spent in performing the conversion to frequency domain and then observing the frequency values to perform spectral analysis like zooming a signal, reconstruction of a signal by removal of noise or identifying the difference in tones of signals is sometimes more crucial than the application itself. Thus, deciding the algorithm based on these factors is crucial to the intent behind the performance analysis.
According to the literature review [1], Cooley Tukey FFT is most commonly used in digital signal processing community. The Radix -2 implementation of Cooley-Tukey algorithm is computationally faster than DFT (Discrete Fourier Transform) by LogN/N times. But, one of the drawbacks of Radix-2 FFT is its limitation on the size of the input data to be of the order of 2^K [where k=1…. Infinity] whereas Chirp-Z transform has no constraints on the data size of input signal. This project, thus, aims to analyze the efficiency of radix-2 implementation of Cooley-Tukey algorithm and Chirp-Z transform when applied to variable-size of audio signal data with or without padding (zeros), calculate their computational complexities such as running time and space and also identify their performance on frequency resolution (on actions, such as zooming effect).
The long term goal of this project would be to analyze and identify the appropriate variation of FFT that should be applied on an audio signal for low running time and high resolution.

Motivation

The need for high-frequency resolution in audio signals to identify variations in tones and voices in voice-recognition devices is growing everyday. It is required to use a fast, efficient algorithm without compromising the resolution quality. Therefore, this project aims to analyze the efficiency of radix-2 implementation of Cooley-Tukey algorithm and Chirp-Z transform when applied to variable-size of audio signal data, calculate their computational complexities such as running time and space and identify their performance on frequency resolution (on actions, such as zooming effect).
This work would be significant in speech recognition and signal matching applications like identification of tones and variations of audio signals for voice-recognition systems, processing of audio signals in

music community, etc. The significant trade-off between two major variations of FFT in audio processing would suggest an appropriate algorithm to be selected and give the investigators a greater understanding of signal processing techniques.

Although, collection of significant audio data would be a major concern. If the data is too noisy or too less, the results would be inappropriate and hence, the investigators plan to use signification data for reference. Also, determination of spectral resolution would be challenging since the algorithms might exhibit similar overall performance but huge variations in running times and resolutions. So, deciding the best-fit would be difficult.

Previous Work

In **K. Marcolini et. al** [1], various Fast Fourier Transform algorithms have been described and running time of FFT algorithms on the audio signal data-set have been compared. But, it failed to measure and analyze the effect of applying FFT algorithms on audio-signal properties such as frequency resolutions. Secondly, it did not consider the concept of padding of data i.e, in order to implement radix-2 transform, dataset size should be of order 2^k [where k=1,.....n], so if dataset is not of size 2^k, then the data set should be padded with zeros in order to make it as O(2^k) size. This concept of padding had not been evaluated in the literature review [2]. This project handles the test cases of dataset padded with zeros and measures the efficiency of algorithms (Cooley-Tukey radix-2 and Chirp-Z Transform) in terms of audio-signal properties.

Specific Aims

The project aims to analyze two variations of FFT algorithms i.e Cooley-Tukey Radix 2 and Chirp-Z transform, on the following test cases: 1) Analyse computational complexities of FFT algorithms on variable size data-set with or without padding; 2) Measure and study the effect on audio- signal properties such as frequency resolution (e.g. Zooming effect); 3) Identify the best-fit algorithm

Plan

1) Collect audio signals in discretized format, generate inputs of varied data sizes; 2) Experiment and analyze the trend of performance of algorithms with different input size audio signals; 3) Use data visualization tools like Matplotlib or highcharts to analyze the effect on frequency resolution of signals

Deliverables

Evaluation report with results obtained for FFT algorithms; source code of their Python implementations.; Collected audio signal data ; graphical running-time vs resolution evaluation; Powerpoint presentation; Project Report

Issues

Collection of significant audio data would be a major concern. If the data is too noisy or too less, the results would be inappropriate and hence, the investigators plan to use signification data for reference. Also, determination of spectral resolution would be difficult for investigators not having significant signal processing knowledge and thereby, plan to read as many research papers as required to understand the concepts.

Bibliography

[1] K. Marcolini et. al , Various Fast Fourier Transform algorithms
[2] K.R.Rao et. al, Fast Fourier Transform - Algorithms and Applications, Springer
[3] Cooley et. al "The Fast Fourier Transform and Its Applications," IEEE Transaction Education
[4] Bluestein et. al , "A linear filtering approach to the computation of discrete Fourier transform," Audio and Electroacoustics, IEEE

Biographical sketches of the investigator(s)

Nitika Khurana is pursuing her Masters in Computer Science at UMBC. She has worked as a software engineer for three years and is currently pursuing her research in cyber security and cloud computing.
Srishty Saha is a Masters in Computer Science student at UMBC. Her research interests is in Machine Learning and Text Analytics.

Schedule

Oct-10 Oct 20	Oct 21-Nov 15	Nov15- Nov 25	Nov 25 - Dec 5
Collect audio signals	Implement algos & analyze	Find best fit FFT	Report & slides

Budget

Proposed budget would include :
1) investigators' time
2) computing resources (softwares, research papers, processors) that would be needed to implement the algorithms

Investor's time (Nitika)	6 hours every week @$20/hour	$120
Investor's time (Srishty)	6 hours every week @$20/hour	$120
Computing resources (Laptops)	Windows 10 64-bit	$1000
Computing resources (Softwares)	NVIDIA Graphic card, pyCharm	$100
Total		$1340

Appendix A:

[1] Cooley et. al "The Fast Fourier Transform and Its Applications," IEEE Transaction Education,1969
[2] Bluestein et. al , "A linear filtering approach to the computation of discrete Fourier transform," Audio and Electroacoustics, IEEE, 1980
[3] K. Marcolini et. al , Various Fast Fourier Transform algorithms
[4] Hong Zhang et. al Design and implementation of mixed light effect based on the audio spectral analysis.