Jagjit Singh (V00865544)

CSC – 575 (Assignment -1)

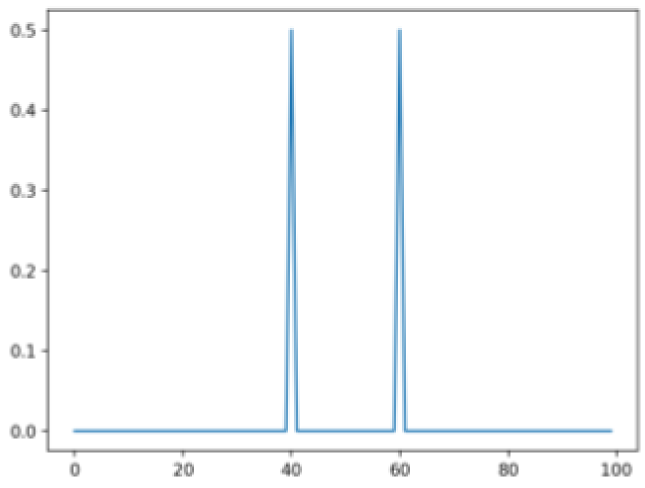
Question1:

Part – 1: Low level DFT Computation method

Code:

```
import numpy as np
import matplotlib.pyplot as plt
import math
import mir
from mir import Sinusoid
#get the sin wave
sin = Sinusoid(Fs=100)
#differentiate real and imaginary components
datar = sin.data.real
datai = sin.data.imag
N = len(datar)
outputr = []
outputi = []
for k in range(N):
    sumr = 0
    sumi = 0
    for n in range(N):
        sumr += datar[n]*math.cos(2*math.pi*k*n/N)+datai[n]*math.sin(2*math.pi*k*n/N)
        sumi += -datar[n]*math.sin(2*math.pi*k*n/N)+datai[n]*math.cos(2*math.pi*k*n/N)
    outputr.append(sumr)
    outputi.append(sumi)
outputp = []
#final output
for a in range(N):
    outputp.append(math.sqrt((outputr[a]*outputr[a])+(outputi[a]*outputi[a])))
#plot output
plt.plot(outputp)
plt.show()
#find the plot dft with built in function
outputk = sin.dft()
plt.plot(abs(outputk))
plt.show()
```

Plot:



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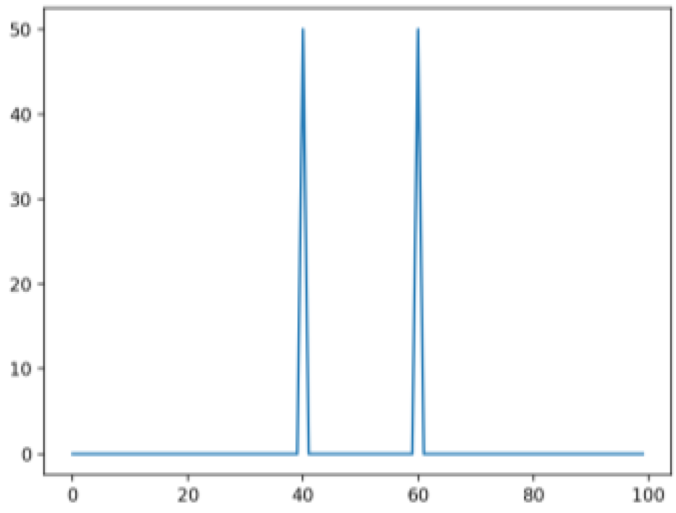
Generated from user written DFT function.



Generated from built in DFT function.

Part – 2: Linear Combination of 3 Sinusoidal

Code:

```
import numpy as np
import matplotlib.pyplot as plt
import math
import mir
from mir import Sinusoid
#fetch the 3 sinusoids
sin1 = Sinusoid(Fs=1000, amp=5, freq=20, phase=5)
sin2 = Sinusoid(Fs=1000, amp=10, freq=40, phase=10)
sin3 = Sinusoid(Fs=1000, amp=15, freq=80, phase=15)
N = len(sin1.data)
signal = []
#Make them one
for a in range(N):
    signal.append(sin1.data[a]+sin2.data[a]+sin3.data[a])
plt.plot(signal)
plt.show()
#calculating for bin 48
bin = 48
k = bin
cosa = []
sina = []
for n in range (N-1):
    theta = 2*math.pi*k*n/N
    cosa.append(math.cos(theta))
    sina.append(math.sin(theta))
plt.plot(abs(np.fft.fft(cosa)))
plt.show()
plt.plot(abs(np.fft.fft(sina)))
plt.show()
#calculating between bins
bin = 48.5
k = bin
cosa = []
sina = []
```

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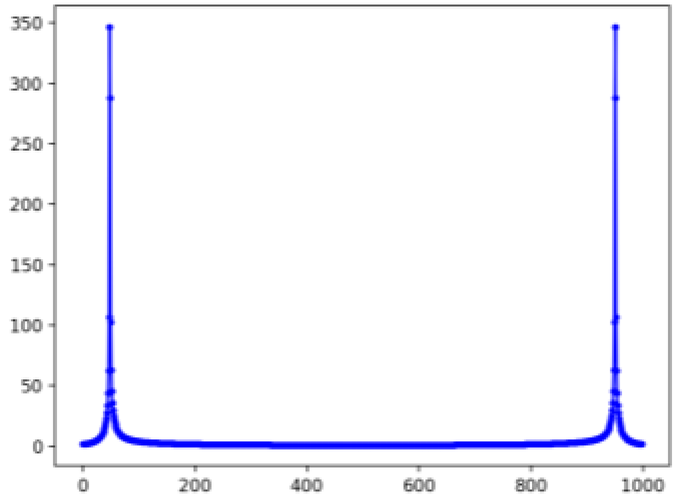
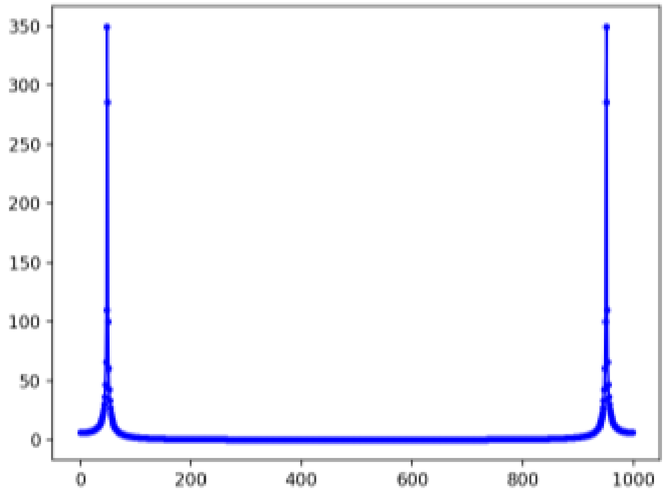
```
for n in range (N-1):
    theta = 2*math.pi*k*n/N
    cosa.append(math.cos(theta))
    sina.append(math.sin(theta))
plt.plot(abs(np.fft.fft(cosa)),'b.-')
plt.show()
plt.plot(abs(np.fft.fft(sina)),'b.-')
plt.show()
```

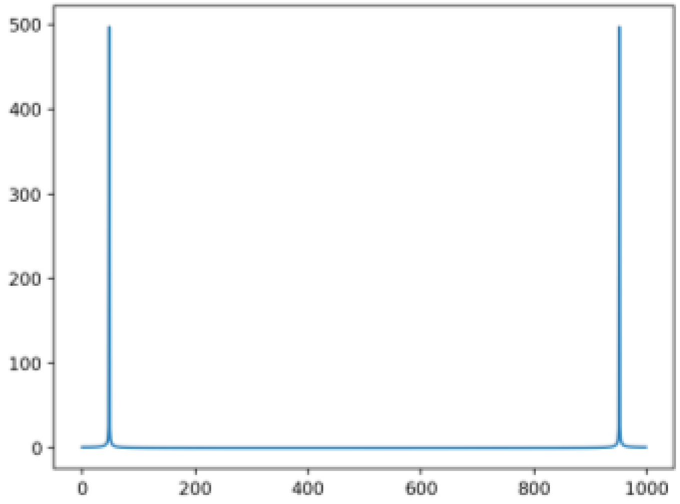
Plots:

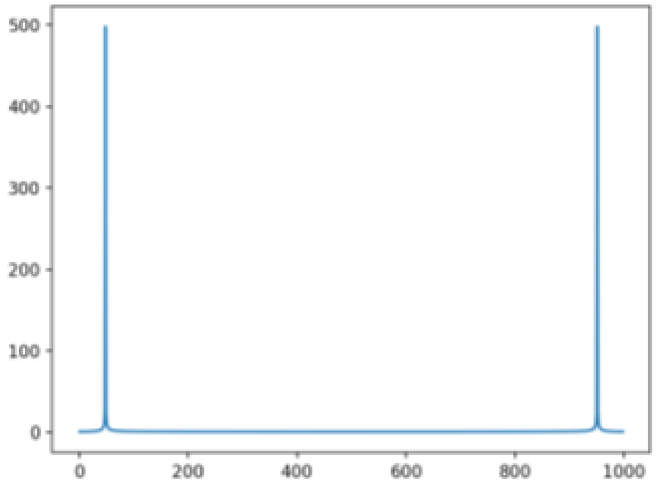
Plots for Cos and Sin with values within Bin





Plots for Cos and Sin with values on Bin





Collective all the 3 Sin additive

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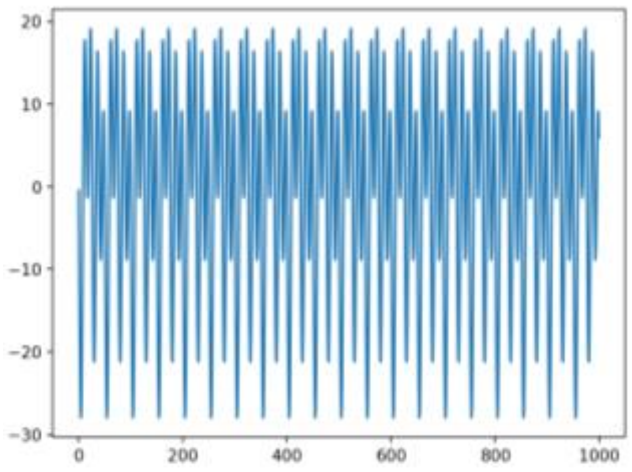

Part 3: Plot the Basis Function

Code:

```
import numpy as np
import matplotlib.pyplot as plt
import scipy.fftpack
import math
import mir
from mir import Sinusoid

sin1 = Sinusoid(Fs=256, amp=5, freq=20, phase=5)

N = len(sin1.data)
print N
signal = []

bin = 4
k = bin

cosa = []
sina = []

for n in range (N-1):
    theta = 2*math.pi*k*n/N
    cosa.append(math.cos(theta))
    sina.append(math.sin(theta))

plt.plot(cosa)
plt.show()
plt.plot(sina)
plt.show()
```

Plot:

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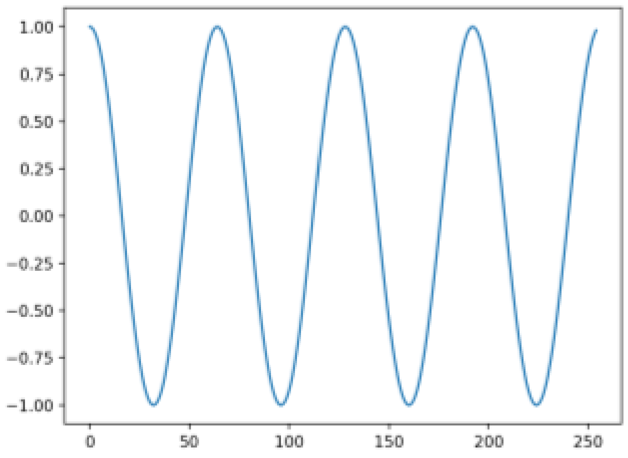

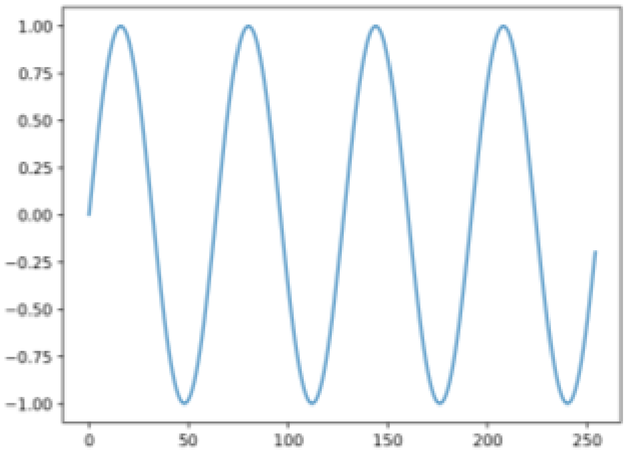

Part 4 : Point Wise Multiplication

Code:

```
import numpy as np
import matplotlib.pyplot as plt
import math
import mir
from mir import Sinusoid

sin1 = Sinusoid(Fs=1000, amp=5, freq=20, phase=5)
sin2 = Sinusoid(Fs=1000, amp=10, freq=40, phase=10)
sin3 = Sinusoid(Fs=1000, amp=15, freq=60, phase=15)
N = len(sin1.data)

signal = []
for a in range(N):
    signal.append(sin1.data[a]+sin2.data[a]+sin3.data[a])
plt.plot(abs(np.fft.fft(signal)))
plt.show()

sin4 = Sinusoid(Fs=1000, amp=5, freq=20, phase=5)

N = len(sin4.data)
#basic function with bin 60
bin = 60
k = bin

cosa = []
sina = []

for n in range (N):
    theta = 2*math.pi*k*n/N
    cosa.append(math.cos(theta))
    sina.append(math.sin(theta))
#point wise multiplication
ppc = []
pps = []
print len(signal)
print len(cosa)
for n in range(N):
    ppc.append(cosa[n] * signal[n])
    pps.append(sina[n] * signal[n])
```

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```
print np.arctan(sum (pps)/sum(ppc))
plt.plot(ppc)
plt.show()
plt.plot(pps)
plt.show()

#basic function with bin 60
bin = 60.5
k = bin

cosa = []
sina = []

for n in range (N):
    theta = 2*math.pi*k*n/N
    cosa.append(math.cos(theta))
    sina.append(math.sin(theta))
#point wise multiplication
ppc = []
pps = []
print len(signal)
print len(cosa)
for n in range(N):
    ppc.append(cosa[n] * signal[n])
    pps.append(sina[n] * signal[n])

print np.arctan(sum (pps)/sum(ppc))
plt.plot(ppc)
plt.show()
plt.plot(pps)
plt.show()
```

Plot:

Plot of absolute magnitude of 3 sin waves

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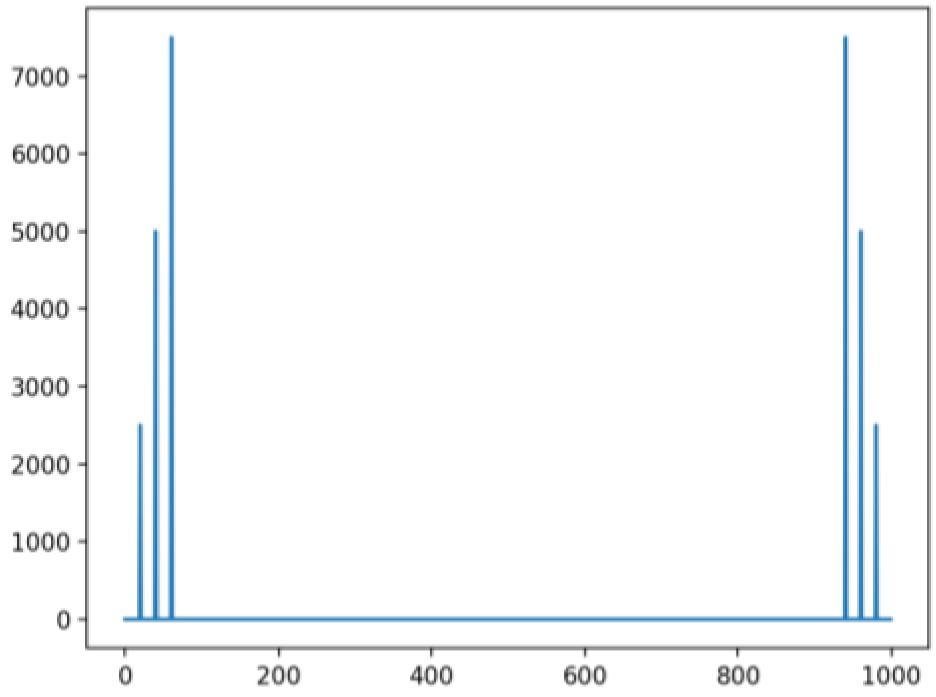
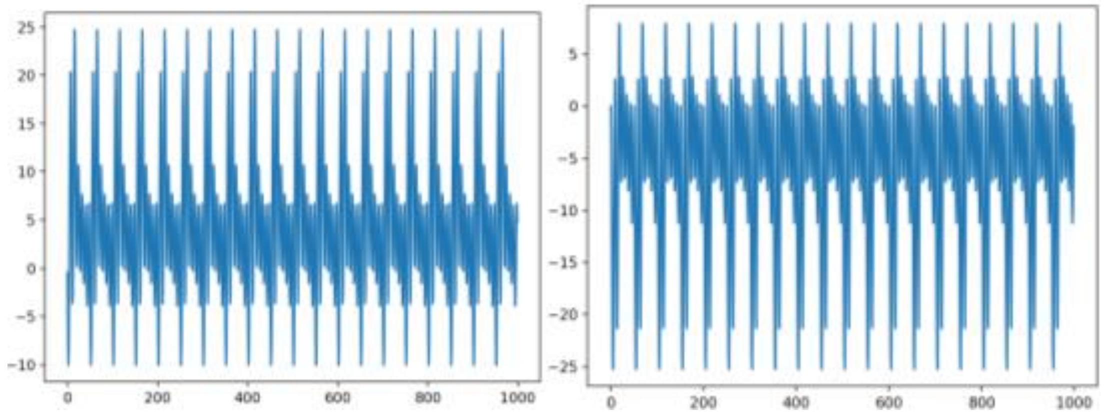
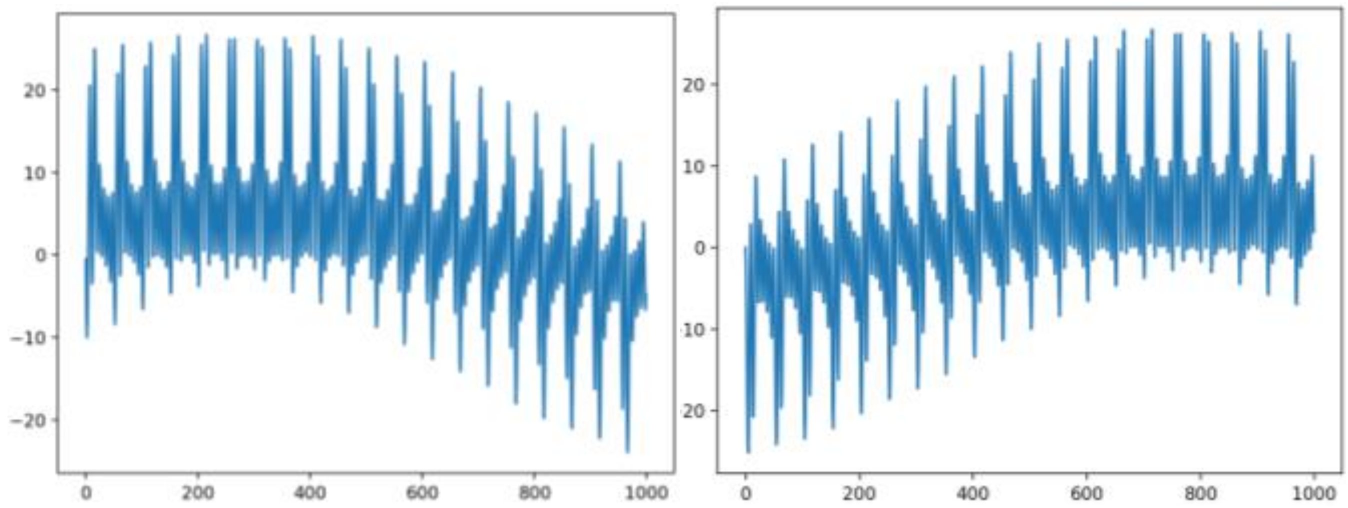




Plot of Sin and Cos with Closest DFT Bin



Plot of Sin and Cos with unrelated DFT Bin

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Part5:Finding Time

Code:

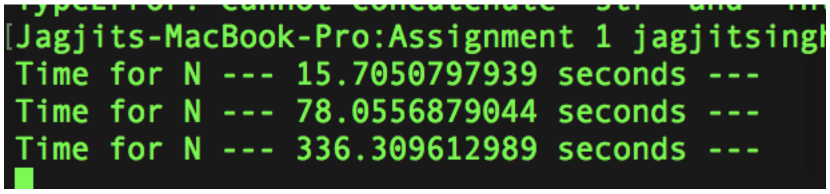
```
import numpy as np
import matplotlib.pyplot as plt
import math
import mir
from mir import Sinusoid
import time
start_time = time.time()
size = [256,512,1024,2048]

for n1 in range(4):
    for n2 in range(100):
        #get the sin wave
        sin = Sinusoid(Fs=size[n1])
        #differentiate real and imaginary components
        datar = sin.data.real
        datai = sin.data.imag
        N = len(datar)
        outputr = []
        outputi = []
        for k in range(N):
            sumr = 0
            sumi = 0
            for n in range(N):
                sumr += datar[n]*math.cos(2*math.pi*k*n/N)+datai[n]*math.sin(2*math.pi*k*n/N)
                sumi += -datar[n]*math.sin(2*math.pi*k*n/N)+datai[n]*math.cos(2*math.pi*k*n/N)
            outputr.append(sumr)
            outputi.append(sumi)
        outputp = []
        #final output
        for a in range(N):
            outputp.append(math.sqrt((outputr[a]*outputr[a])+(outputi[a]*outputi[a])))
        #plot output
    print("Time for N --- %s seconds ---" % (time.time() - start_time))

start_time = time.time()
size = [256,512,1024,2048]
output = []
for n1 in range(4):
    for n2 in range(100):
        #get the sin wave
        sin = Sinusoid(Fs=size[n1])
        output = sin.dft()
    print("Time for N --- %s seconds ---" % (time.time() - start_time))
```

Results:

Time for 256, 512 and 1024 size with 100 iterations. (Still running for rest of the two)



```
[Jagjits-MacBook-Pro:Assignment 1 jagjitsingh
 Time for N --- 15.7050797939 seconds ---
 Time for N --- 78.0556879044 seconds ---
 Time for N --- 336.309612989 seconds ---
```

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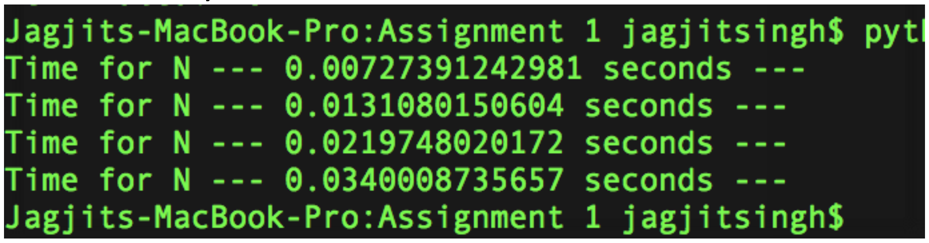
Time taken by the Built in function



```
Jagjits-MacBook-Pro:Assignment 1 jagjitsingh$ pyt
Time for N --- 0.00727391242981 seconds ---
Time for N --- 0.0131080150604 seconds ---
Time for N --- 0.0219748020172 seconds ---
Time for N --- 0.0340008735657 seconds ---
Jagjits-MacBook-Pro:Assignment 1 jagjitsingh$
```

Question2:

Part 1: Hanning Windows

Code:

```
import numpy as np
import matplotlib.pyplot as plt
import scipy.fftpack
import math
import mir
from mir import Sinusoid

N = 2048

bin = 525
k = bin

sina = []

for n in range (N):
    theta = 2*math.pi*k*n/N
    sina.append(math.sin(theta))

N = 2048

bin = 600.5
k = bin

sinaa = []

for n in range (N):
    theta = 2*math.pi*k*n/N
    sinaa.append(math.sin(theta))

N = 2048

bin = 525.5
k = bin

sinaaa = []

for n in range (N):
    theta = 2*math.pi*k*n/N
    sinaaa.append(math.sin(theta))

hann = np.hanning(2048)
wave =[]
for n in range (N):
```

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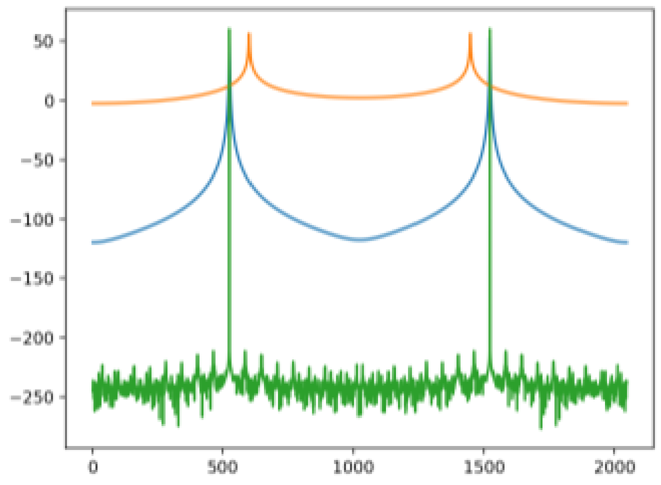
```
    wave.append(hann[n]*sinaaa[n])

dft3 = np.fft.fft(wave)
dft2 = np.fft.fft(sinaa)
dft = np.fft.fft(sina)
dft3t= abs(dft3)
dft2t= abs(dft2)
dftt= abs(dft)
plt.plot(20*np.log10(dft3t))
plt.plot(20*np.log10(dft2t))
plt.plot(20*np.log10(dftt))
plt.show()
```

Plot:



Two plots coincide that are within the bin and the other on the bin is different in Orange color.

Part2: Single Note Sound Analysis

Code:

```
import numpy as np
import matplotlib.pyplot as plt
import scipy.fftpack
import math
import mir
from mir import Sinusoid
from mir import Signal

sin = Signal()
sin.wav_read('2.wav')
wave = sin.data
wave = wave[0:2048]

hann = np.hanning(2048)
wave1 =[]
N = 2048
for n in range (N):
    wave1.append(hann[n]*wave[n])
```

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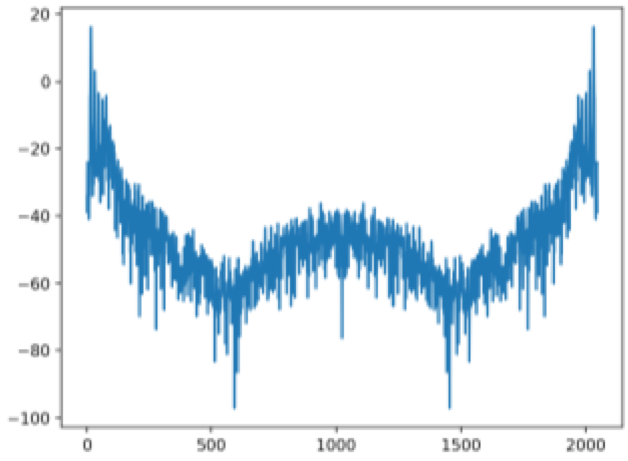
```
dft = np.fft.fft(wave1)
dftt= abs(dft)
plt.plot(20*np.log10(dftt))
plt.show()
```

Plot



The resultant plot after the windowing will have reduced spectral leakage.

Part 3: Zero Padding Array

Code:

```
import numpy as np
import matplotlib.pyplot as plt
import scipy.fftpack
import math
import mir
from mir import Sinusoid
from mir import Signal

sin = Signal()
sin.wav_read('2.wav')
wave = sin.data
wave = wave[0:2048]

hann = np.hanning(2048)
wave1 =[]
N = 2048
for n in range (N):
    wave1.append(hann[n]*wave[n])

dft = np.fft.fft(wave1)
dftt= abs(dft)
plt.plot(dftt)
plt.show()

dft1 = np.fft.fft(wave)
dft1t= abs(dft1)
plt.plot(dft1t)
plt.show()

wave = wave[0:256]
```

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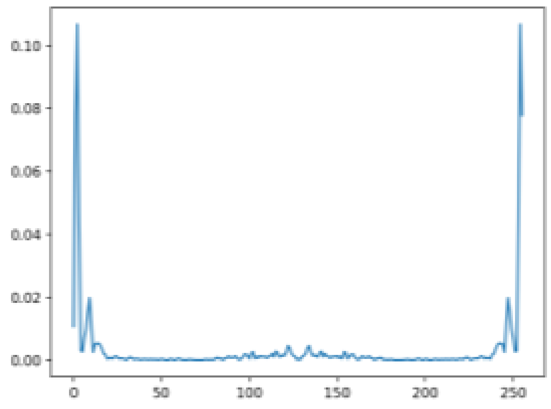
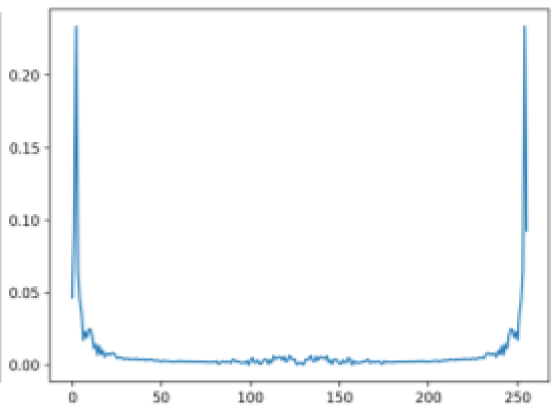
```
hann = np.hanning(256)
wave1 =[]
N = 256
for n in range (N):
    wave1.append(hann[n]*wave[n])

dft = np.fft.fft(wave1)
dftt= abs(dft)
plt.plot(dftt)
plt.show()

dft1 = np.fft.fft(wave)
dft1t= abs(dft1)
plt.plot(dft1t)
plt.show()

list = []
N = 2048
for n in range (N):
    if n < 255:
        list.append(wave[n])
    else:
        list.append('0')

dft1 = np.fft.fft(list)
dft1t= abs(dft1)
plt.plot(dft1t)
plt.show()

hann = np.hanning(2048)
wave1 = [x*y for x,y in zip([hann],list)]



dft = np.fft.fft(wave1)
dftt= abs(dft)
plt.plot(dftt)
plt.show()
```

Plot:





With and without window 256

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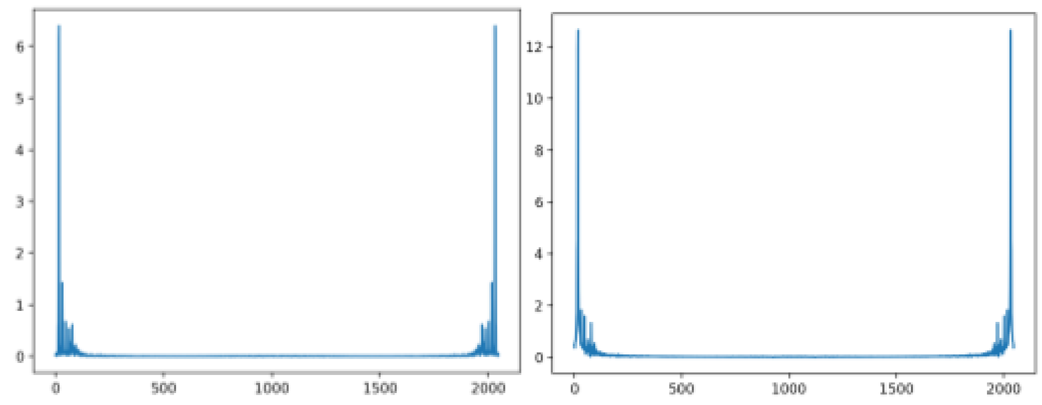
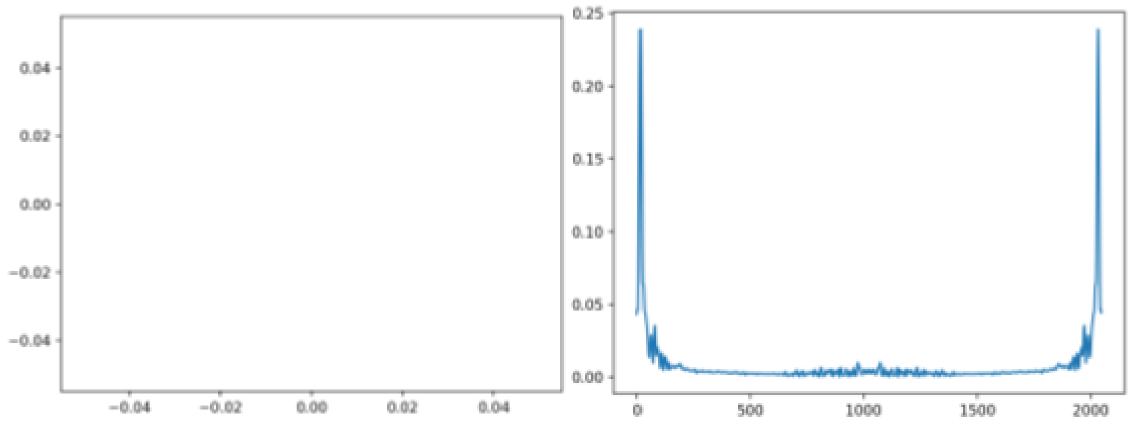


With and without Window 2048



With and without window Zero Padded

Effects – Initially the plots with higher sample size are dense and the plots with lower Sample size are widely places, with hanning we avoided the spectral leakage in both the cases and the sound was soften by the hanning window effect. When we made an 256 sample signal with Zero padding the windowing showed a straight wave, that means the window size may be higher than 256 so it didn't came in.

Question3:

For purpose of answering the question, I have selected the GTA San Andreas (Theme Song) - https://www.youtube.com/watch?v=W4VTq0sa9yg

Part -1
Time Scales – Short, Middle and Long Term
Dimensions – Timber, Orchestration, Acoustics, Rhythm, Melody, Harmony and Structure.

The opening of the music starts with Chimes followed by repetitive drum beats and piano.

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Rhythm – The music has a time scale – Middle Term, where a sound is being repeating multiple times. The entire Sequence is coming back again.
Melody – The music after the initial opening has a middle term melody repetition, that is high and low drum beats.
Timber – There is a lot of classification in Timber (Short term) when the opening comes from the Chimes.
Structure – When seen for the long term the music has a lot of time scale differences.

Part – 2
Casual Users – Since casual users like listening and collecting music their request will be like (Finding the song that sounds like this) (I like this one, what other songs I may admire)(I have to organize my collection)
Professional Users – They may be using music in advertisement and production, they need music for an application, their request information will be like (Given a rhythm give me the music that matches it) (I need this kind of soundtrack with this instrument)
Music Scholars – These kinds of people and interested in studying music, developing music (analysis of music tools)(I don't want the music but the pitch it was sung in)

Part – 3
Query By humming – Humming is a way where in a casual user will use a combination of whistling and singing to produce a melody. Then that melody will be used to search/query the sound/music database to find the full version of the song/music corresponding to the melody.
Query by Example – When a part of the music/example of the music is used to query the database to retrieve the full music it is termed as query by example. This will avoid mismatching of the retrieved music.

Part- 4
Music XML- This is a type of music representation which used XML as portable format for exchange of information. The best part is the industry wide support including the open-source and commercial projects. Since we can write XML in Latex so we can represent this using the latex.
MIDI- it stands for Musical Instrument Digital Interface. This is format where we do the data exchange within digital instruments. This requires sequential information transfers. SMF-Standard Midi File will be used for the future information transfer.

Part-5
Since this entire document deals with MIR and we are doing MIR for the end users, for me that's the best part of explaining various users that uses MIR. There are three levels of users starting from the most basic going to the most complex ones. The casual users are the one who need music for fun and hobbits. The second level is for the professional student that may

need music for their professional purposes, they are commercial users of music. The music scholars are most advanced users; they are one who study music and its composition. It also includes musicians.

Part-6
Paper – 1: Indexing Music Databases Using Automatic Extraction of Frequent Phrases
In the field of MIR the extraction of music for the database is a crucial and complex task, if we wish to have the offline database then storing the entire indexing file structure take a lot of memory, The best possible way to improve this is using the phrases instead of full content. Repetition is an important property of music, if we utilize that property and only store the most occurring phrase instead of entire file we can save a lot of space. We already have efficient text mining methods that can be applied with minor modifications.
The paper is based of Irish folk music, and concludes with a text-mining based indexing algorithm for music which extracts repeating patterns from the music.

Paper -2: A Multimodal Framework for Music Inputs
Music waves have one excellent property of being multimodal, since the previous research in this field have done a lot of work with the indexing and fetching of data but the technique outlined in this paper is essentially for the query. Since when users interact with computer they want the ease of use, that means that it should be possible for them to query the music database in any form they wish to, example – sing, play or sent symbols.
Since this idea is a new step in terms of the Human Computer Interaction (HCI), which is one of the most emerging topic and further it gives the user a flexibility to interact with the music system.

Paper - 3: Query By Humming -- Musical Information Retrieval in an Audio Database
If we have all the text in the database, we need to query it using a text, but what if we have a database full of music and audio files, it would be great if we could just hum the melody and fetch the music of our choice. Efficient pattern matching is an important aspect of this paper. It may be possible not to return just one but multiple matching music files.
It is equally essential to have an optimized version of query in the system. Since taking extra time will result in the user losing interest in the system. The authors use pith as the medium of detection between the hummed melody and original sound wave in the database.

Question4:
Part - 1
Additive Synthesis Instrument: The actual concept is to have n number of sin wave generator using the defined frequency and helper function – Mixture ()

Code:

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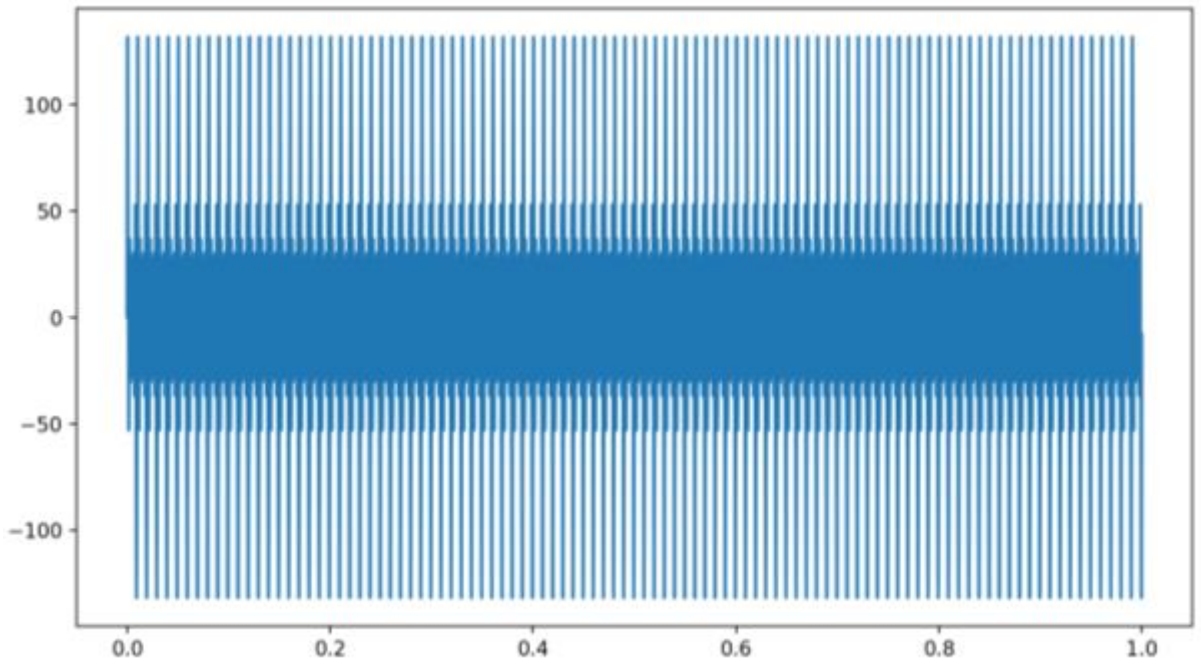
```
import numpy as np
import matplotlib.pyplot as plt
import math
import mir
from mir import Sinusoid
from mir import Signal
from mir import Mixture

#Declare the frequency and amplitude array
freq = [100,200,300,400,500]
amp = [10,20,30,40,50]
#Declare the empty list
list = []
#Making a list of all 5 sinusoids
for n in range (5):
    sin = Sinusoid(amp=amp[n], freq=freq[n])
    list.append(sin)
#Making a mixture using the helper function in mir.py
mix = Mixture(*list)
#Plot the mixture of all 5 waves
mix.plot()
```

Plot:



Part - 2

Different Sounds of Same Pitch – passing them to additive Instrument.

Sound 1 = Flute D Tone

Sound 2 = Violin D Tone

Spectrum Analysis Sound 1

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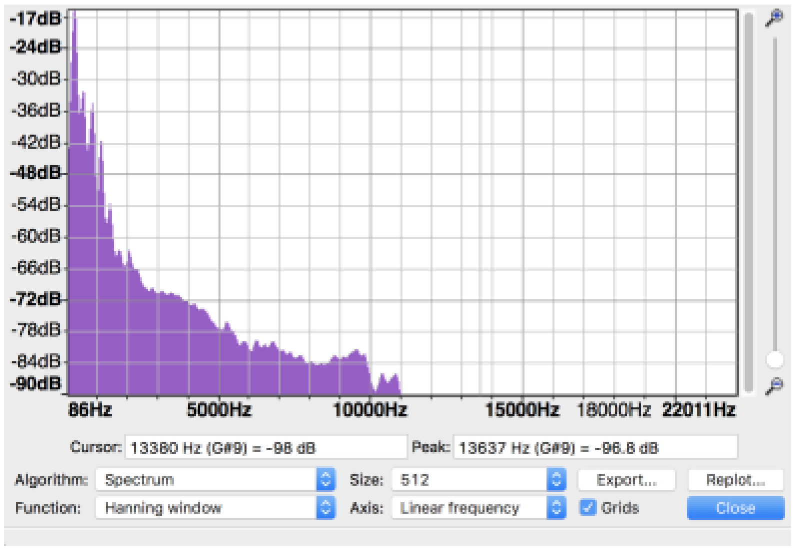
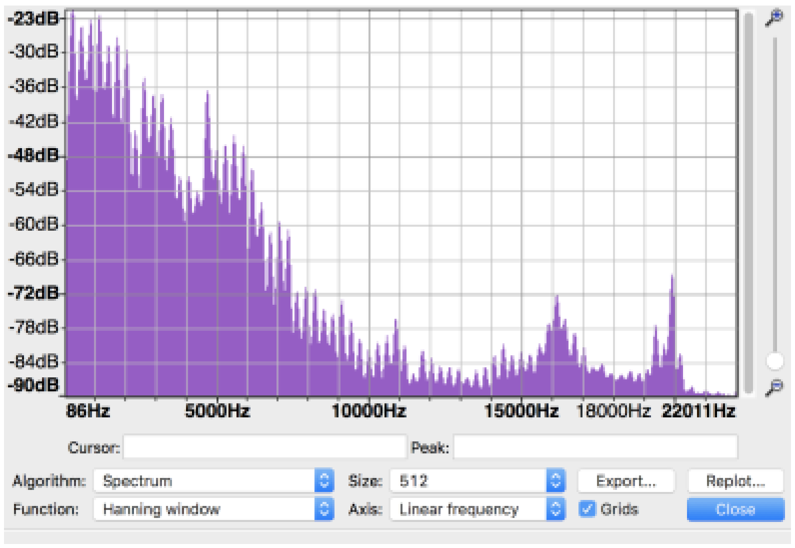


Cursor: 13380 Hz (G#9) = -98 dB Peak: 13637 Hz (G#9) = -96.8 dB
Algorithm: Spectrum Size: 512
Function: Hanning window Axis: Linear frequency ✓ Grids

freq = [292,563,869,1160,1439,1767,2064,2828,3159,3447]
amp =
[0.15488166189124816,0.03162277660168379,0.019275249131909367,0.008511380382023767,0.0023173946499684774,0.0007328245331389037,0.0007673614893618193,0.0003388441561392024,0.00031988951096913973,0.00030549211132155157]

Spectrum Analysis Sound 2



Cursor: Peak:
Algorithm: Spectrum Size: 512
Function: Hanning window Axis: Linear frequency ✓ Grids

freq = [295,572,882,1165,1460,1764,2052,2343,2633,2931]
amp =
[0.0812830516164099,0.06165950018614822,0.06095368972401691,0.07852356346100718,0.03890451449942807,0.042169650342858224,0.033884415613920256,0.006760829753919818,0.022130947096056376,0.01428893958511103]

Code:

```
import numpy as np
import matplotlib.pyplot as plt
import math
import mir
from mir import Sinusoid
from mir import Signal
```

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```
from mir import Mixture

#Frequency and Amplitude for Sound 1
freq = [292,563,869,1160,1439,1767,2064,2828,3159,3447]
amp =
[0.15488166189124816,0.03162277660168379,0.019275249131909367,0.008511380382023767,0.0023173946499684774,0.000732
8245331389037,0.0007673614893618193,0.0003388441561392024,0.00031988951096913973,0.00030549211132155157]

list = []
for n in range (10):
    sin = Sinusoid(amp=amp[n], freq=freq[n])
    list.append(sin)
#make signal mixture
mix1 = Mixture(*list)

sig1 = Signal(data=mix1.data)
#output new audio file
sig1.wav_write('flu_new.wav',normalize=False)

mix1.plot()
#Frequency and Amplitude for Sound 2
freq = [295,572,882,1165,1460,1764,2052,2343,2633,2931]
amp =
[0.0812830516164099,0.06165950018614822,0.06095368972401691,0.07852356346100718,0.03890451449942807,0.04216965034
2858224
    ,0.033884415613920256,0.006760829753919818,0.022130947096056376,0.01428893958511103]

list1 = []
for n in range (10):
    sin = Sinusoid(amp=amp[n], freq=freq[n])
    list1.append(sin)
#make signal mixture
mix2 = Mixture(*list1)

sig2 = Signal(data=mix2.data)
#output new audio file
sig2.wav_write('voi_new.wav',normalize=False)

mix2.plot()
```

Plot :

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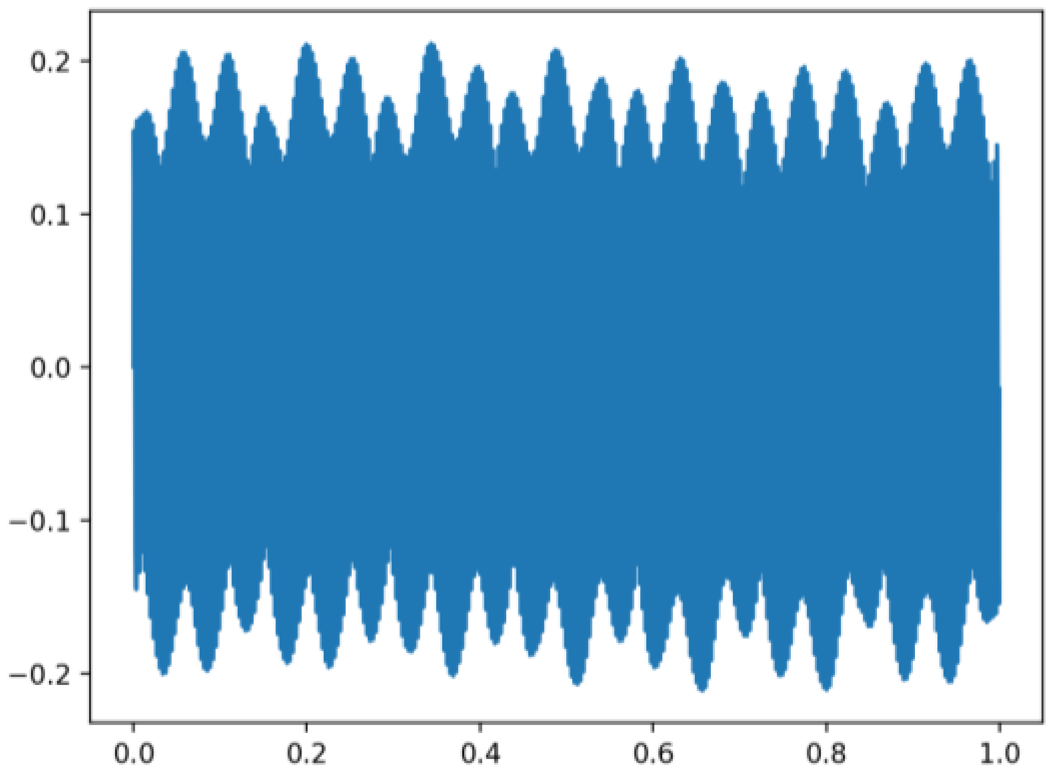

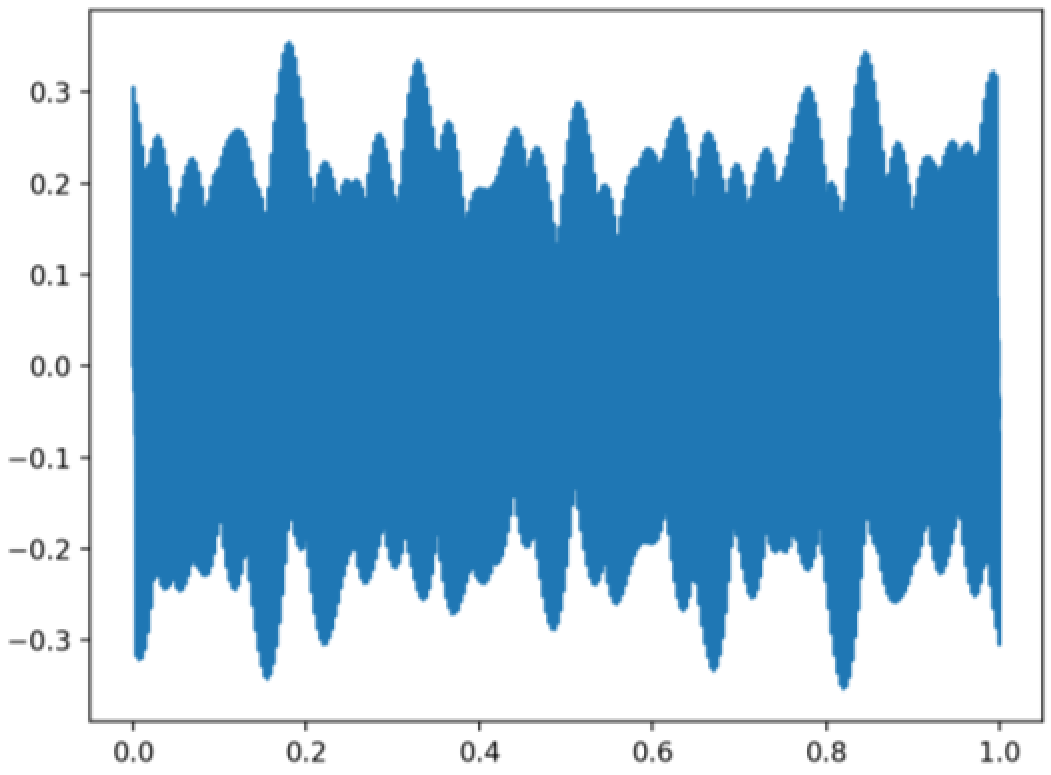

Effect – Its hard to tell which sound is which, we cannot make out the sound because its like an artificial sound without the musical instrument properties. No wood, metal noise.
Its just like a plain artificial note.

Jagjit Singh (V00865544)

Part 3

MIDI note Numbers to Frequency Conversion – Used 4 MIDI numbers converted them to corresponding waves and then used the mixture to make a melody out of them.

Code:

```
import numpy as np
import matplotlib.pyplot as plt
import math
import mir
from mir import Sinusoid
from mir import Signal
from mir import Mixture

#midi notes from 0-119
note = [7,8,9,10]
freq = []
list = []
for n in range (4):
    freq.append(440*pow((note[n]-57)/12,2))
    sin = Sinusoid(freq=freq[n])
    list.append(sin)

#make signal mixture
mix1 = Mixture(*list)

sig1 = Signal(data=mix1.data)
#output new audio file
sig1.wav_write('melody.wav',normalize=False)

mix1.plot()
```

Melody File - https://github.com/JagjitUvic/MIR/blob/master/Assignment%201/melody.wav
Recorded Audio File-
https://github.com/JagjitUvic/MIR/blob/master/Assignment%201/Question4audio.wav

Audacity Spectrum –

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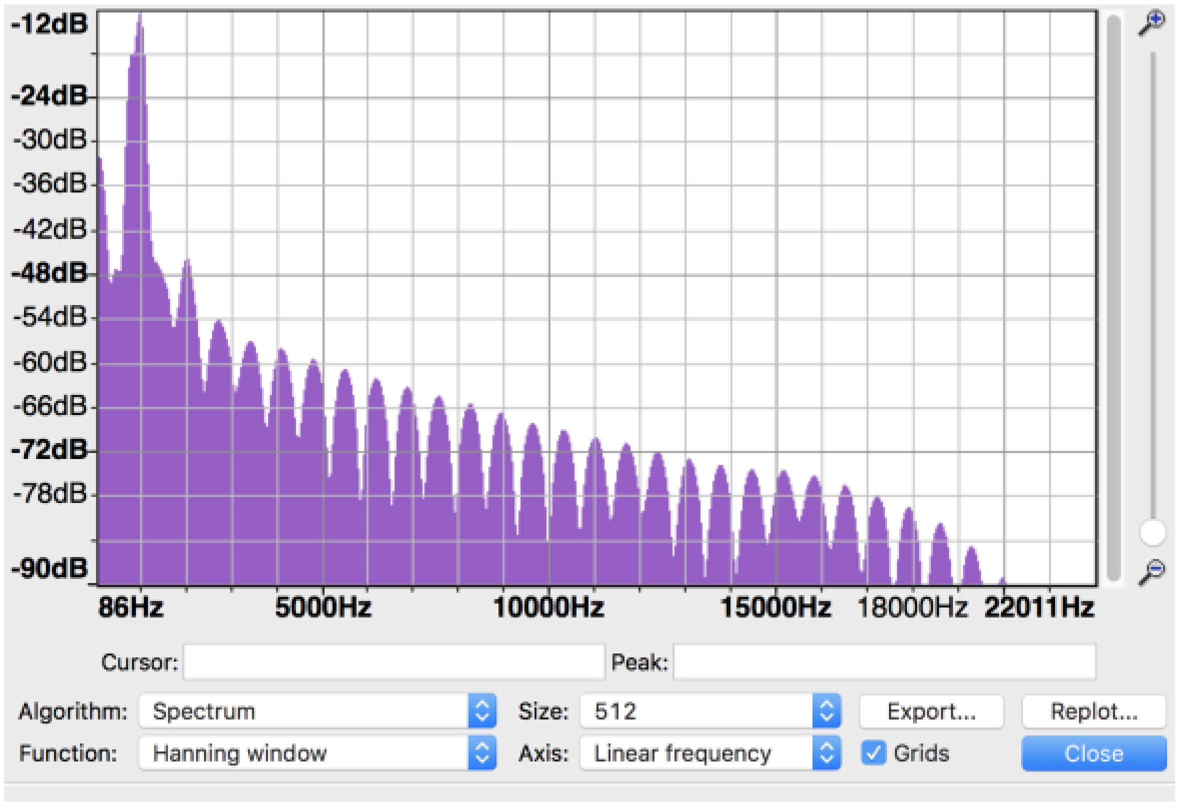

Cursor:

Peak:

Algorithm: Spectrum

Size: 512

Function: Hanning window

Axis: Linear frequency

✓ Grids

Question5:

Part – 1

Use the helping function provided in the file to read and write the audio file.

Code:

```
import numpy as np
import matplotlib.pyplot as plt
import scipy.fftpack
import math
import mir
from mir import Sinusoid
from mir import Signal

sig = Signal()
#Read audio File
sig.wav_read('Ques5Input.wav')
wave = sig.data
wavefft = np.fft.fft(wave)
waveifft = np.fft.ifft(wavefft)
#Writing the audio file
sig = Signal(data=waveifft)
sig.wav_write('Ques5Output.wav')
```

Result: Both the audio files are identical.

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Input Audio –
https://github.com/JagjitUvic/MIR/blob/master/Assignment%201/Ques5Input.wav
Output Audio -
https://github.com/JagjitUvic/MIR/blob/master/Assignment%201/Ques5Output.wav

Part – 2

Code:

```
import numpy as np
import matplotlib.pyplot as plt
import scipy.fftpack
import math
import mir
from mir import Sinusoid
from mir import Signal

sig = Signal()
#Read audio File
sig.wav_read('Ques5Input.wav')
wave = sig.data
wavefft = np.fft.fft(wave)
length = len(wavefft)
magnitude = []
phase = []
for n in range (length):
    magnitude.append(np.absolute(wavefft[n]))
    phase.append(np.angle(wavefft[n]))
#phase goes random
phase = np.random.randn(length)
sigC = []
for n in range (length):
    val1 = magnitude[n]*math.cos(phase[n])
    val2 = magnitude[n]*math.sin(phase[n])
    sigC.append(np.complex(val1,val2))
#find inverse transform
waveifft = np.fft.ifft(sigC)
#write back the signal object
sig = Signal(data=waveifft)
sig.wav_write('Ques5_2Output.wav')
```

Output File -
https://github.com/JagjitUvic/MIR/blob/master/Assignment%201/Ques5_2Output.wav

Effects – the sound lost its original voice and Timber, it’s now just a rough ended music. After applying different window size we can hear distortion at the window size ends.

Part – 3

Code:

```
import numpy as np
import matplotlib.pyplot as plt
import scipy.fftpack
import math
```

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```
import mir
from mir import Sinusoid
from mir import Signal

sig = Signal()
#Read audio File
sig.wav_read('Ques5Input.wav')
wave = sig.data
wavefft = np.fft.fft(wave)
length = len(wavefft)
magnitude = []
phase = []
for n in range (length):
    magnitude.append(np.absolute(wavefft[n]))
    phase.append(np.angle(wavefft[n]))
#fetching 4 high values of magnitude
index = []
value = []
for n in range (4):
    index.append(np.argmax(magnitude))
    value.append(np.amax(magnitude))
    magnitude[np.argmax(magnitude)] = 0
#setting 4 high values rest all 0
for n in range (length):
    if n == index[0]:
        magnitude[n] = value[0]
    elif n == index[1]:
        magnitude[n] = value[1]
    elif n == index[2]:
        magnitude[n] = value[2]
    elif n == index[3]:
        magnitude[n] = value[3]
    else:
        magnitude[n] = 0
sigC = []
for n in range (length):
    val1 = magnitude[n]*math.cos(phase[n])
    val2 = magnitude[n]*math.sin(phase[n])
    sigC.append(np.complex(val1,val2))
#find inverse transform
waveifft = np.fft.ifft(sigC)
#write back the signal object
sig = Signal(data=waveifft)
sig.wav_write('Ques5_3Output.wav')
```

Effects - The output audio has 4 places where it gave different sound than the usual straight sound in the previous cases. There were high nodes at the corresponding high magnitudes that were available in the magnitude spectrum.

Output File -
https://github.com/JagjitUvic/MIR/blob/master/Assignment%201/Ques5_3Output.wav

Part 4: Overlap-add – using window Size – 32768

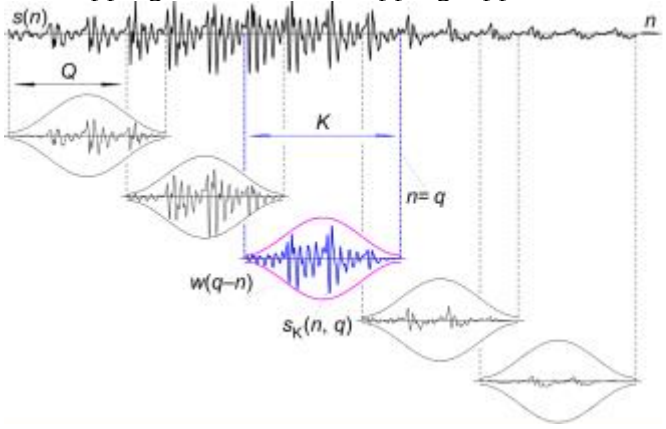
```
import numpy as np
import matplotlib.pyplot as plt
```

Jagjit Singh (V00865544)

```
import scipy.fftpack
import math
import mir
from mir import Sinusoid
from mir import Signal

sin = Signal()
#Read audio File
sin.wav_read('Ques5Input.wav')
wave = sin.data
wavefft = np.fft.fft(wave)
length = len(wavefft)
print length
window =  length/32768
list = []
print window
#overlapping window
list.append(wavefft[0:32769])
list.append(wavefft[32768:65537])
list.append(wavefft[65536:131073])
list.append(wavefft[131072:262145])
#inverse and save back
waveifft = np.fft.ifft(list)
#write back the signal object
sig = Signal(data=waveifft)
sig.wav_write('Ques5_4Output.wav')
```

Overlapping and Non-Overlapping Approach



(https://i.stack.imgur.com/Jg5EG.png)

The overlapping approach is producing the better audio which is without the distortions at the window edges. In this technique, I have used WindowIndex+1, I have the window size = 32768 but I am always taking 32769 to have that overlap.

If you wish to reconstruct the wave after reducing spectral leakage make sure you use windowing but to avoid artifacts use Overlap-Add.