Topics for Today

- Plotting/Graphing Software
  - MatPlotLib
  - VPython
- Digital Audio – questions?

References

- MatPlotLib Tutorial: http://matplotlib.sourceforge.net/users/pyplot_tutorial.html
- VPython plotting http://www.vpython.org/webdoc/visual/graph.html

Reminder!

EXAM 1

- Thursday, February 19, 6:30-7:30pm
- Location: LWSN 1106 (class room)
- Review on Wednesday 2/18
- Material
  - Know how statements are used and what they produce
  - Numbers, strings, lists/arrays, loops, conditions, functions
  - Understand short programs
- pdf of Appendix A of Zelle posted on Blackboard

Clicker Question

```
L1 = ['r', 'l', 'up', 'down']
L2 = L1

k = 15
n = k

L1[0] = 5
k = 0

print k, n
print L1, L2
```

What is printed?

A
0 15
[5, 'l', 'up', 'down'] ['r', 'l', 'up', 'down']

B
0 15
[5, 'l', 'up', 'down'] [5, 'l', 'up', 'down']

C
0 0
[5, 'l', 'up', 'down'] [5, 'l', 'up', 'down']

D
None of the above

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Clicker question

```
from numpy import zeros, int16
def what(A):
    N = len(A)
    B = zeros(2*N, dtype=int16)
    for k in xrange(N):
        B[k] = A[k]
        B[N+k] = A[k]
    return B
```

What is returned for
A = [0, 1, 2, 3, 4]

A. [0 0 0 0 0 0 0 0 0 0]

B. [0, 1, 2, 3, 4, 0, 1, 2, 3, 4]

C. [0 1 2 3 4 0 1 2 3 4]

D. [0, 0, 1, 1, 2, 2, 3, 3, 4, 4]

E. [0 0 1 1 2 2 3 3 4 4]

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```
def main():
    data = read_wav_file('wav/preamble.wav')
    slow = half_speed(data)
    dur = len(data)/float(SAMPLE_FREQUENCY)
    sine_data1 = sin_sample(440, .05, dur)
    sine_data2 = sin_sample(550, .05, dur)
    sine_data = combine_interleave([sine_data1, sine_data2])
    data = append(data, silence(dur))
    normalize(slow)
    data = combine_mean([sine_data, data, slow])
    data = echo(data, .3, .25)
     normalize(data)
    scale_volume(data, 1.2)
    play(data)
```

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Matplotlib (MPL)

- http://matplotlib.sourceforge.net/
- **from pylab import ***
- matplotlib is a powerful Python 2D plotting library generating plots, histograms, power spectra, bar charts, errorcharts, scatterplots, etc.
- Plots can be saved in many file formats
  - useful in other courses and projects
- Plot is drawn using show()
  - this is generally the last statement of your program
  - Interactive mode exists

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Matplotlib versus VPython

- Matplottlib is a more complete plotting library than VPython
- VPython has3D features and interactive features missing in MPL

Matplotlib versus Matlab

- Plotting in MPL is very similar to Matlab
- MPL integrates with Python which can be an advantage
- Matlab is not a free software

MPL use in course

- Simple plots
- Bar graphs
- Histograms

- Most control of visuals is optional
- Add basic text and labels
- Computed data will generally be in an array

Future value program (Zelle p 44)

```
# futval.py
#    A program to compute the value of an investment
#    carried 10 years into the future

def main():
   print "This program calculates the future value"
   print "of a 10 year investment."

   principal = input("Enter the initial principal: ")
   apr = input("Enter the annualized interest rate: ")

   for i in range(10):
      principal = principal * (1 + apr)

   print "The value in 10 years is:", principal

main()
```

Graphing the yearly value

- Show as plot
  - X-axis: value
  - Y-axis years
- Show as bar graph
  - One year as one bar (assuming not too many years)

MPL_interest_plot.py

```
from pylab import *
from numpy import *

principal = 10000
apr = 5
years = 10
values = zeros(years)
apr = (100+apr)/100.

for i in range(years):
    values[i] = principal
    principal = apr*principal

# show a MPL plot; use default values
plot(range(years),values)
show()
```

Graphing future values

- Bar graph
  - replace **plot(range(years),values)** with **bar(range(years),values)**
  - file **MPL_interest_plot_bar.py**
- More customization
  - file **MPL_interest_bar2.py**
  - Give graph a name
  - Label x and y coorinate, make a title

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Another MPL plotting example

MPL_1_plots.py

```
from pylab import *

def plot_three():
    t = arange (0.0, 20.1, 0.1)
    s = range(21)
    # plot three functions
    plot (s,s, t,2*t,"rs", t,t*t, 'go')

    xlabel("input size")
    ylabel("time")
    ti = title("Plotting three functions")
    ti.set_color("r")
    ti.set_fontsize(14)
    ti.set_fontweight("bold")

if __name__ == "__main__":
    plot_three()
     show()
```

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Making subplots in MPL

MPL_2_subplots.py

```
def mysubplots():
    t = arange (0.0, 20.1, .1)
    s = range(21)

    # define first figure
    subplot(211)  # final figure has 2 rows, 1 column
                  # use 121 for two colums and one row
    plot (s,s, t,2*t,"r+", t,t*t, 'go')
    xlabel("input size")
    ylabel("time")
    title("Plotting three runtime functions")

    # define second figure
    subplot(212)
    plot (t, sin(2*pi*t))
```


Histograms

hist(x, bins=10, …)

- computes the histogram of x
- bins is either an integer number or a sequence givi ng the bins
- Returns the histogram of *x* with *bins* equally sized bins. Return value is a tuple (*n*, *x*, *patches*) where *n* is the count for each bin in *x*.

http://matplotlib.sourceforge.net/api/pyplot_api.html#matplotlib.pyplot.hist

MPL Histogram example

MPL_3_histogram1.py

```
v=[1,1,1,2,3,4,4,5,7,7,7,7,10,12,12,12,12,13,13,15,22,22,25]

# the histogram of the data in v
n, bins, patches = hist(v, 10, facecolor = 'g')
        # n is an array with the frequencies

xlabel('v')
ylabel('Counts')
title('Data set v')
```

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MPL: multiple plots, interactive plots

- **Multiple plots:**
  - name each figure
  - one show command for all
  - MPL_4_multiple.py
- **Interactive plots:**
  - MPL_5_interactive.py
  - pylab.ion() turns interactive mode on
  - Partial results are shown as soon as they are generated

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Plotting in VPython

VPplot1.py

```
from numpy import *
from visual.graph import * # import graphing features

funct1 = gcurve(color=color.cyan)

for x in arange(0., 8.1, 0.1): # x goes from 0 to 8
    funct1.plot(pos=(x, 5.*cos(2.*x)*exp(-0.2*x)))  # plot
```

pos=(x,y) adds points to the plot shown in the display