26. Data Visualization

Topics

How to define a useful class for for manipulating sunrise/sunset data.

How to graphically display facts about that data using numpy and pyplot.

The Problem

For various cities around the world, we would like to examine the "Sun Up" time throughout the year.

How does it vary from day to day?

What are the monthly averages?

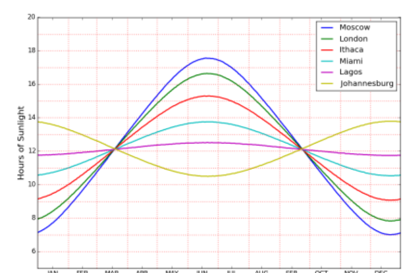
Sun Up Time = Sunset Time – Sunrise Time

How Does Sun-Up Depend on Latitude and Month?

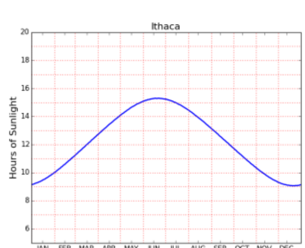
Average Sun-Up (Hours):

City	Latitude	June	September	December	March
London	51.50	16.55	12.64	7.93	11.89
Ithaca	42.43	15.24	12.47	9.13	11.95
NewYork	40.73	15.04	12.45	9.31	11.96
Cairo	30.05	14.05	12.34	10.25	11.99
Miami	25.78	13.72	12.29	10.56	12.02
Lagos	6.58	12.50	12.15	11.75	12.08
Johannesburg	-26.20	10.52	11.94	13.75	12.23
Sydney	-33.88	9.94	11.87	14.36	12.30

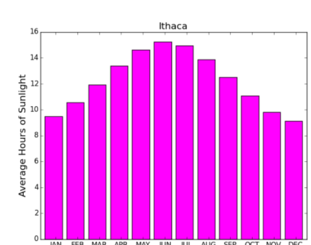
Visualization!



How Does Sun-Up Time Vary Day-to-Day?



How Does Sun-Up Time Vary Month-To-Month?



Recall the Motivating Problem

For various cities around the world, we would like to examine the "Sun Up" time throughout the year.

How does it vary from day to day?

What are the monthly averages?

Let's define a class that makes this easy.

Our Plan

1. We define a class **Daylight** that facilitates data acquisition.
2. We introduce **numpy** arrays and show how to use the **pylab** for plottiing

The Class **Daylight**

5 Attributes

```
Name :    name of the city [str]
Lat:      latitude in degrees  [float]
Long:     longitude in degrees [float]
RiseTime: rise time in hours
               [length-365 numpy array]
SetTime:  set time in hours
                [length-365 numpy array]
```

What the Constructor Does

It will have one argument: the name of a city as a string.

It will then read the .dat file associated with that city and proceed to set up the 5 attributes.

A Folder Called RiseSetData Has **.dat** Files for Each these Cities

Anaheim	Anchorage	Arlington	Athens	Atlanta
Baltimore	Bangkok	Beijing	Berlin	Bogata
Boston	BuenosAires	Cairo	Chicago	Cincinnati
Cleveland	Denver	Detroit	Honolulu	Houston
Ithaca	Johannesburg	KansasCity	Lagos	London
LosAngeles	MexicoCity	Miami	Milwaukee	Minneapolis
Moscow	NewDelhi	NewYork	Oakland	Paris
Philadelphia	Phoenix	Pittsburgh	RiodeJaneiro	Rome
SanFrancisco	Seattle	Seoul	Sydney	Tampa
Teheran	Tokyo	Toronto	Washington	Wellington

For us, **.dat** files are the same as **.txt** files

Downloaded from: `http://www.usno.navy.mil/`

What do the lines in **Ithaca.dat** look like?

There Are 33 Lines

```
 Ithaca
 W07629N4226
 1   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
 2   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
 3   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S

28   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
29   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
30   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
31   R S  R S  R S  R S  R S  R S  R S
```

The Data for a Particular City is Housed in a 33-line .dat file

```
 Ithaca
 W07629N4226
 1   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
 2   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
 3   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S

28   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
29   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
30   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
31   R S  R S  R S  R S  R S  R S  R S
```

Line 2 encodes its longitude and latitude

Helper Function: LongLat

A latlong string has length 11

W08140N4129

```
def LongLat(s):
    Long = float(s[1:4])+float(s[4:6])/60
    if s[0]=='E':
       Long = -Long
    Lat = float(s[7:9])+float(s[9:11])/60
    if s[6]=='S':
        Lat = -Lat
    return (Lat,Long)
```

The Data for a Particular City is Housed in a 33-line .dat file

```
 Ithaca
 W07629N4226
 1   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
 2   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
 3   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S

28   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
29   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
30   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
31   R S  R S  R S  R S  R S  R S  R S
```

The remaining lines house the rise-set data. Each R and S is a length-4 string: '0736'

Helper Function: `ConvertTime`

```
def ConvertTime(s):
    x = float(s[:2])+float(s[2:])/60
    return x
```

In comes a length-4 string and back comes a float that encodes the time in hours

'0736' ----> 7 + 36/60 hours ----> 7.6

The Data for a Particular City is Housed in a 33-line .dat file

Rise/Set data for April 3

```
 Ithaca
 W07629N4226
 1   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
 2   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
 3   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S

28   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
29   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
30   R S  R S  R S  R S  R S  R S  R S  R S  R S  R S  R S
31   R S  R S  R S  R S  R S  R S  R S
```

Day-Number followed by 12 rise-set pairs, one pair for each month

The Class Daylight

```
Attributes:

    City: name of the city [str]
     Lat: latitude in degrees [float]
    Long: longitude in degrees [float]
RiseTime: length-365 numpy array of
             sunrise times
 SetTime: length-365 numpy array of
             sunset times
```

The Constructor

Sample Call

```
C = Daylight('Ithaca')
```

Reads the file **Ithaca.dat** into a list of 33 strings. Each string is deciphered.

Creates the **Daylight** object that house's Ithaca's name, latitude, longitude, the 365 sunrise times and the 365 sunset times.

We Need Some New Tools To Graphically Display the Data

```
from numpy import *
from pylab import *
```

We use **numpy** for arrays and **pylab** for plotting.

A Simple Plot

```
A = Daylight('Ithaca')
D = A.SunUp()
plot(D)
show()
```

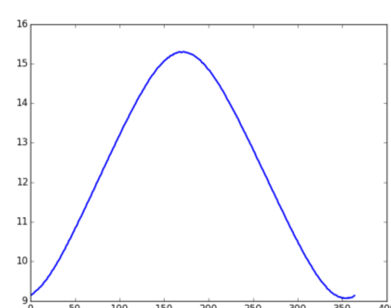
How does this work?

A Simple Plot

```
A = Daylight('Ithaca')
D = A.SunUp()
plot(D)
show()
```

```
def SunUp(self):
   """returns a  length-365 numpy
   array of sun-up times. """
   return self.SetTime - self.RiseTime
```

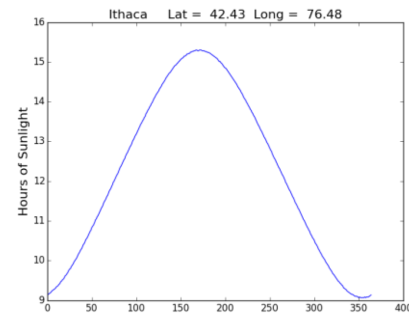
You can subtract one numpy array from another.



How about a title and a labeling of the y-axis?

A Simple Plot

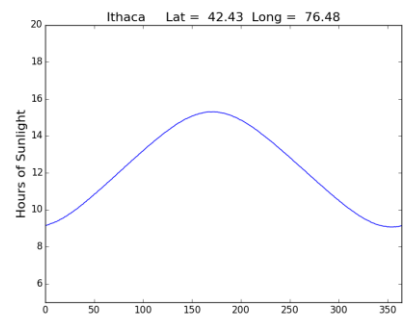
```
A = Daylight('Ithaca')
D = A.SunUp()
plot(D)

titlestr = '%s  Lat = %6.2f  Long = %6.2f' % (A.City,A.Lat,A.Long)
title(titlestr,fontsize=16)
ylabel('Hours of Sunlight',fontsize=16)
show()
```



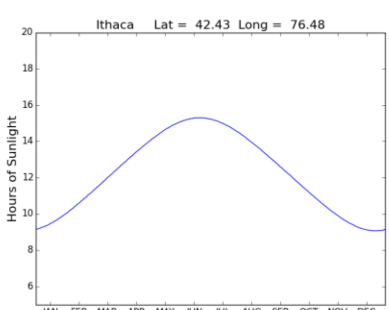
Modify the x range and the y range

A Simple Plot

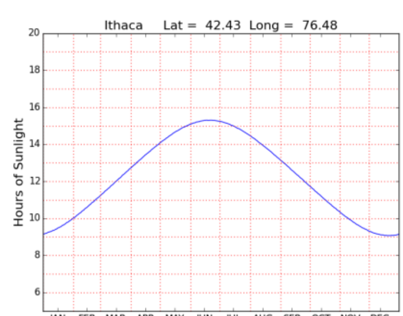
```
A = Daylight('Ithaca')
D = A.SunUp()
plot(D)

titlestr = '%s  Lat = %6.2f  Long = %6.2f' % (A.City,A.Lat,A.Long)
title(titlestr,fontsize=16)
ylabel('Hours of Sunlight',fontsize=16)

xlim(0,364)
ylim(5,20)

show()
```



Label the x-axis with month names



Add a Grid

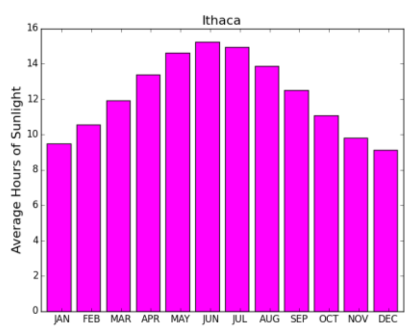


Monthly Averages

```
def MonthAves(self):
    x = zeros((12,1))
    D = self.SunUp()
    start  = [0, 31, 59, 90, 120, 151, 181, 212, 243, 273, 304, 334]
    finish = [30, 58, 89, 119, 150, 180, 211, 242, 272, 303, 333,364]
    for k in range(12):
        z = D[start[k]:finish[k]]
        x[k] = sum(z)/len(z)
    return x
```

A Bar Plot

```
A = Daylight('Ithaca')
M = A.MonthAves()

bar(range(12),M,facecolor='magenta')
xlim(-.2,12)
ylabel('Average Hours of Sunlight')
title(A.City,fontsize=16)
show()
```



More on Numpy Arrays

1-dimensional Array Basics

```
>>> from numpy import *
>>> x = array([1,2,3])
>>> x
array([1, 2, 3])
>>> x[2]
3
```

X is a 1d array. (2d arrays soon!)

It has 3 entries

The entries are floats.

1-dimensional Array Basics

```
>>> y = array([1,2,3],dtype='int')
>>> z = y[2]/y[1]
>>> z
1
```

This is how you create an array of ints.

1-dimensional Array Basics

```
>>> a = array([10,20,30])
>>> b = array([5,4,15])
>>> a+b
array([15, 24, 45])
>>> a-b
array([ 5, 16, 15])
>>> a/b
array([2, 5, 2])
>>> a*b
array([ 50,  80, 450])
```

You can add, subtract, divide, and multiply arrays.

1-dimensional Array Basics

```
>>> f = array([10,20])
>>> g = array([1,2,3])
>>> f+g
Traceback (most recent call last):
  File "<stdin>", line 1, in <module>
ValueError: operands could not be
broadcast together with shapes (2,) (3,)
```

But they better be the same size!.

1-dimensional Array Basics

```
>>> u = [1,2,3]
>>> type(u)
<type 'list'>
>>> v = array([10,20,30])
>>> type(v)
<type 'numpy.ndarray'>
>>> z = u+v
>>> z
array([11, 22, 33])
>>> type(z)
<type 'numpy.ndarray'>
```

You can mix "regular" lists of numbers with numpy arrays

1-dimensional Array Basics

```
>>> x = array([-10.3,12.6,-89.7])
>>> y = abs(x)
>>> y
array([ 10.3,  12.6,  89.7])
```

You can apply a function to an array if it is ok to apply the function to each entry in the array.

The numpy `linspace` function

```
x = linspace(1,3,5)
```

x : | 1.0 | 1.5 | 2.0 | 2.5 | 3.0 |

`linspace(a,b,n)` is a length-n list of values that are equally spaced from x = a to x = b.

Plotting a With Pylab

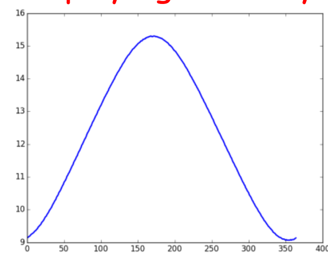
```
Assume:
    from numpy import *
    from pylab import *
```

Displaying an Array

Assume:

```
from numpy import *
from pylab import *
```

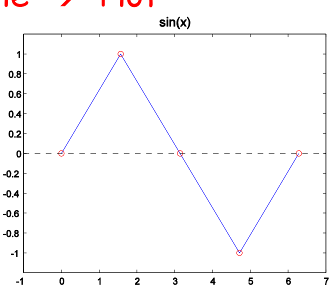
Displaying an Array



```
U = Daylight('Ithaca')
D = U.SunUP()
plot(D)
```

Table → Plot

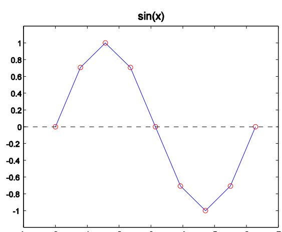
x	sin(x)
0.00	0.0
1.57	1.0
3.14	0.0
4.71	-1.0
6.28	0.0



Plot based on 5 points

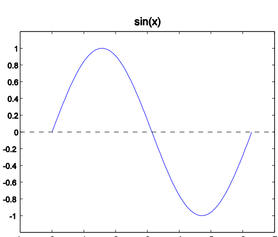
Table → Plot

x	sin(x)
0.000	0.000
0.784	0.707
1.571	1.000
2.357	0.707
3.142	0.000
3.927	-0.707
4.712	-1.000
5.498	-0.707
6.283	0.000



Plot based on 9 points

Table → Plot

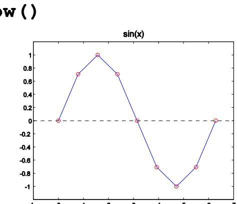


Plot based on 200 points—looks smooth

Generating Tables and Plots

x	sin(x)
0.000	0.000
0.784	0.707
1.571	1.000
2.357	0.707
3.142	0.000
3.927	-0.707
4.712	-1.000
5.498	-0.707
6.283	0.000

```
x = linspace(0,2*pi,9)
y = sin(x)
plot(x,y)
show()
```



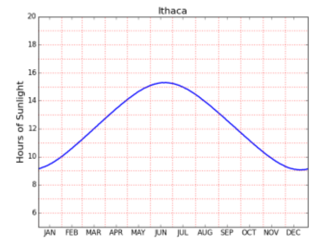
plot(x,y)

`x,y` 1-dim arrays of numbers
That have the same length

`plot(x,y)` "connects the dots":

`(x[0],y[0]) ,..., (x[n-1],y[n-1])`

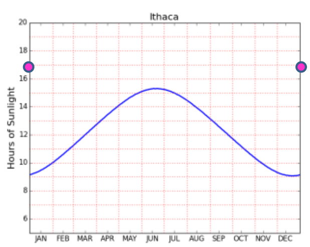
Drawing Lines




```
for k in range(6,20):
    # Draw horizontal line from (0,k) to (365,k)
    plot(array([0,365]),array([k,k]),
                        color='red',linestyle=':')
```

Drawing Lines

Connect
two dots

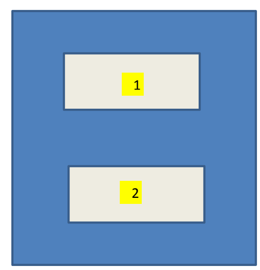



```
for k in range(6,20):
    # Draw horizontal line from (0,k) to (365,k)
    plot(array([0,365]),array([k,k]),
                        color='red',linestyle=':')
```

A Note on subplot

```
subplot(2,1,1)
   <code>
subplot(2,1,2)
   <code>

Show()
```

When you want
more than one
plot in the window.



A Note on subplot

```
subplot(2,2,1)
   <code>
subplot(2,2,2)
   <code>
subplot(2,2,3)
   <code>
subplot(2,2,4)
   <code>

Show()
```