Introduction to Programming in Python

Procedural Programming: Libraries and Applications

Outline

Libraries Versus Applications

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We distinguish between two types of Python programs

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2. Applications

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Applications are standalone programs that are executed directly

Example: `quadratic.py`, `sample.py`, `gambler.py`

Libraries Versus Applications

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Developing a library involves

- Designing an API for the library
- Implementing the API
- Testing the library

`matrix`

`row(a, i)`	returns the ith row of matrix a
`col(a, j)`	returns the jth column of matrix a
`add(a, b)`	returns the sum of matrices a and b
`subtract(a, b)`	returns the difference of matrices a and b
`multiply(a, b)`	returns the product of matrices a and b
`transpose(a)`	returns the tranpose of matrix a
`dot(a, b)`	returns the dot-product of 1-by-n matrices a and b

`ifs.py`

Command-line input	n (int)
Standard input	a $1 \times m$ vector of probabilities and two $m \times 3$ matrices of x, y coefficients
Standard draw output	a set of n points

```
>_ ~/workspace/ipp/programs

$ _
```

```
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$ cat data/sierpinksi.txt
```

```
>_ ~/workspace/ipp/programs

$ cat data/sierpinksi.txt
3
  .33 .33 .34
3 3
  .50 .00 .00
  .50 .00 .50
  .50 .00 .25
3 3
  .00 .50 .00
  .00 .50 .00
  .00 .50 .433
$ _
```

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$ python3 ifs.py 100000 < data/sierpinski.txt
```

Library of Matrix Functions · Using the Library

```
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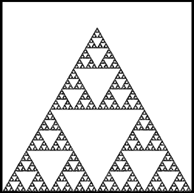

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$ cat data/barnsley.txt
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4 3
   0.00  0.00  0.500
   0.85  0.04  0.075
   0.20 -0.26  0.400
  -0.15  0.28  0.575
4 3
   0.00  0.16  0.000
  -0.04  0.85  0.180
   0.23  0.22  0.045
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   0.26  0.24 -0.086
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$ _
```

</> ifs.py

```python
import matrix
import stdarray
import stddraw
import stdrandom
import sys

def main():
    n = int(sys.argv[1])
    dist = stdarray.readFloat1D()
    cx = stdarray.readFloat2D()
    cy = stdarray.readFloat2D()
    x, y = 0.0, 0.0
    stddraw.setPenRadius(0.0)
    for i in range(n):
        r = stdrandom.discrete(dist)
        col = [x, y, 1]
        x0 = matrix.dot(matrix.row(cx, r), col)
        y0 = matrix.dot(matrix.row(cy, r), col)
        x = x0
        y = y0
        stddraw.point(x, y)
    stddraw.show()

if __name__ == "__main__":
    main()
```

matrix.py 1/2

```
import stdarray
import stdio

def row(a, i):
    return a[i]

def col(a, j):
    c = []
    for row in a:
        c += [row[j]]
    return c

def add(a, b):
    m, n = len(a), len(a[0])
    c = stdarray.create2D(m, n, 0.0)
    for i in range(m):
        for j in range(n):
            c[i][j] = a[i][j] + b[i][j]
    return c

def subtract(a, b):
    m, n = len(a), len(a[0])
    c = stdarray.create2D(m, n, 0.0)
    for i in range(m):
        for j in range(n):
            c[i][j] = a[i][j] - b[i][j]
    return c

def multiply(a, b):
    m, n = len(a), len(b[0])
    c = stdarray.create2D(m, n, 0.0)
    for i in range(m):
        for j in range(n):
            c[i][j] = dot(row(a, i), col(b, j))
    return c
```

matrix.py 2/2

```
def transpose(a):
    m, n = len(a), len(a[0])
    c = stdarray.create2D(n, m, 0.0)
    for i in range(m):
        for j in range(n):
            c[j][i] = a[i][j]
    return c

def dot(a, b):
    total = 0.0
    for x, y in zip(a, b):
        total += x * y
    return total

def _main():
    # Unit tests the library.

if __name__ == "__main__":
    _main()
```

Library of Gaussian Functions

Library of Gaussian Functions

Gaussian probability density function (pdf) with mean 0 and standard deviation 1

$$\phi(z) = \frac{e^{-\frac{z^2}{2}}}{\sqrt{2\pi}}$$

Gaussian pdf with mean μ and standard deviation σ

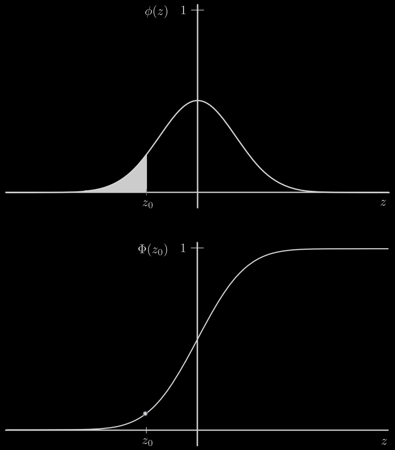
$$\phi(x, \mu, \sigma) = \frac{\phi\left(\frac{x-\mu}{\sigma}\right)}{\sigma}$$

Gaussian cumulative distribution function (cdf) with mean 0 and standard deviation 1

$$\Phi(z) = \frac{1}{2} + \phi(z)\left(z + \frac{z^3}{3} + \frac{z^5}{3 \cdot 5} + \frac{z^7}{3 \cdot 5 \cdot 7} + \cdots\right)$$

Gaussian cdf with mean μ and standard deviation σ

$$\Phi(x, \mu, \sigma) = \Phi\left(\frac{x-\mu}{\sigma}\right)$$



gaussian	
`pdf(x, mu=0.0, sigma=1.0)`	returns the value of the Gaussian pdf with mean *mu* and standard deviation *sigma* at the given x value
`cdf(x, mu=0.0, sigma=1.0)`	returns the value of the Gaussian cdf with mean *mu* and standard deviation *sigma* at the given x value

gaussiantable.py

Command-line input	μ (float) and σ (float)
Standard output	a table of the percentage of students scoring below certain scores on the SAT

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Command-line input	μ (float) and σ (float)
Standard output	a table of the percentage of students scoring below certain scores on the SAT

~/workspace/ipp/programs

```
$ python3 gaussiantable.py 1019 209
```

gaussiantable.py

Command-line input	μ (float) and σ (float)
Standard output	a table of the percentage of students scoring below certain scores on the SAT

~/workspace/ipp/programs

```
$ python3 gaussiantable.py 1019 209
 400  0.0015
 500  0.0065
 600  0.0225
 700  0.0635
 800  0.1474
 900  0.2845
1000  0.4638
1100  0.6508
1200  0.8068
1300  0.9106
1400  0.9658
1500  0.9893
1600  0.9973
$ _
```

gaussiantable.py

```
import gaussian
import stdio
import sys

def main():
    mu = float(sys.argv[1])
    sigma = float(sys.argv[2])
    for score in range(400, 1600 + 1, 100):
        percentile = gaussian.cdf(score, mu, sigma)
        stdio.writef("%4d  %.4f\n", score, percentile)

if __name__ == "__main__":
    main()
```

gaussian.py

```
import math
import stdio
import sys

def pdf(x, mu=0.0, sigma=1.0):
    z = (x - mu) / sigma
    return _pdf(z) / sigma

def cdf(x, mu=0.0, sigma=1.0):
    z = (x - mu) / sigma
    return _cdf(z)

def _pdf(z):
    return math.exp(-z * z / 2) / math.sqrt(2 * math.pi)

def _cdf(z):
    if z < -8.0:
        return 0.0
    if z > +8.0:
        return 1.0
    total = 0.0
    term = z
    i = 3
    while total != total + term:
        total += term
        term *= z * z / i
        i += 2
    return 1 / 2 + total * _pdf(z)

def _main():
    # Unit tests the library.

if __name__ == "__main__":
    _main()
```