Libraries and Applications

Outline

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Developing a library involves:

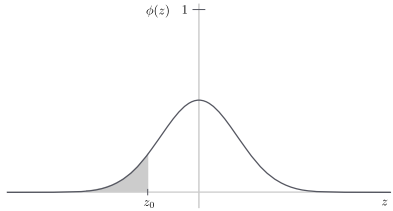
- Designing an API for the library
- Implementing the API

Gaussian Functions

Gaussian Functions

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

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

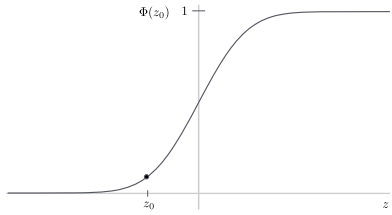


Gaussian pdf with mean μ and standard deviation σ

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

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 Functions

Gaussian Functions

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

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

Gaussian Functions

Program: `gaussiantable.py`

- Command-line input: *mu* (float) and *sigma* (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
```

Gaussian Functions

Program: `gaussiantable.py`

- Command-line input: *mu* (float) and *sigma* (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
$ _
```

Gaussian Functions

Gaussian Functions

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 Functions

Gaussian Functions

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 = float(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 0.5 + total * _pdf(z)

def _main():
    x = float(sys.argv[1])
    mu = float(sys.argv[2])
    sigma = float(sys.argv[3])
    stdio.writeln(cdf(x, mu, sigma))
```

Gaussian Functions

gaussian.py

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

Matrix Functions

Matrix Functions

matrix

`row(a, i)`	returns the *i*th row of matrix *a*
`col(a, j)`	returns the *j*th 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*

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$$P = \begin{bmatrix} p_0 & p_1 & \dots & p_{m-1} \end{bmatrix}, X = \begin{bmatrix} x_{0,0} & x_{0,1} & x_{0,2} \\ x_{1,0} & x_{1,1} & x_{1,2} \\ \vdots & \vdots & \vdots \\ x_{m0} & x_{m-1,1} & x_{m-1,2} \end{bmatrix}, Y = \begin{bmatrix} y_{0,0} & y_{0,1} & y_{0,2} \\ y_{1,0} & y_{1,1} & y_{1,2} \\ \vdots & \vdots & \vdots \\ y_{m0} & y_{m-1,1} & y_{m-1,2} \end{bmatrix}$$

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$$x = X_{r:} \cdot \begin{bmatrix} x & y & 1 \end{bmatrix}, y = Y_{r:} \cdot \begin{bmatrix} x & y & 1 \end{bmatrix}$$

Matrix Functions

Matrix Functions

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

Matrix Functions

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```
$ cat ../data/sierpinski.txt
```

Matrix Functions

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```
$ cat ../data/sierpinski.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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```
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$ cat ../data/sierpinski.txt
3
  .33 .33 .34
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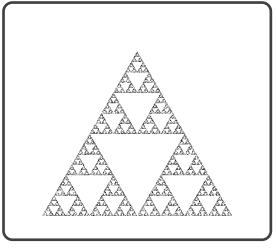
```



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$ cat ../data/barnsley.txt
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Matrix Functions

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$ cat ../data/barnsley.txt
4
   0.01   0.85   0.07   0.07
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
   0.26   0.24  -0.086
$ _
```

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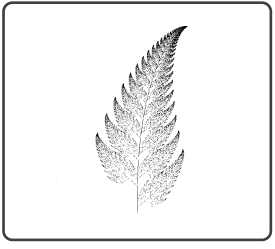

Matrix Functions

Matrix Functions

ifs.py

```
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 Functions

Matrix Functions

matrix.py

```
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 Functions

matrix.py

```
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():
    a = [[1, 2, 3], [4, 5, 6], [7, 8, 9]]
    b = [[1], [2], [3]]
    stdio.writeln('a               = ' + str(a))
    stdio.writeln('b               = ' + str(b))
    stdio.writeln('row(a, 1)       = ' + str(row(a, 1)))
    stdio.writeln('col(a, 1)       = ' + str(col(a, 1)))
    stdio.writeln('add(a, a)       = ' + str(add(a, a)))
    stdio.writeln('subtract(a, a)  = ' + str(subtract(a, a)))
    stdio.writeln('multiply(a, b)  = ' + str(multiply(a, b)))
    stdio.writeln('transpose(b)    = ' + str(transpose(b)))

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