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Abstract—This manual shows how to construct geometric figures using Python.

1 TRIANGLE

1.1 Consider $\triangle ABC$ with $BC = a$, $CA = b$ and $AB = c$. Find the coordinates of **A**, **B** and **C**.

Solution: Let

$$\mathbf{A} = \begin{pmatrix} p \\ q \end{pmatrix} \quad (1)$$

$$\mathbf{B} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \quad (2)$$

$$\mathbf{C} = \begin{pmatrix} a \\ 0 \end{pmatrix} \quad (3)$$

1.2 Let

$$\mathbf{A} = \begin{pmatrix} 1 & 1 \\ 3 & -1 \end{pmatrix} \quad (4)$$

Find $\det(\mathbf{A})$.

Solution: The *determinant* is obtained as

$$\det(\mathbf{A}) = 1 \times -1 - 3 \times 1 = -4. \quad (5)$$

1.3 Write a program for finding $\det(\mathbf{A})$.

Solution: The following program finds the determinant.

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```
#Code by GVV Sharma
#March 14, 2019
#released under GNU GPL
import numpy as np
```

```
a1 = 1
a2 = 1
b1 = 3
b2 = -1
c1 = 8
c2 = 12
```

```
A = np.array([[a1,a2],[b1,b2]])
x = np.linalg.det(A)
print(x)
```

1.4 Write your own function for calculating $\det \mathbf{A}$
Solution: The following routine finds the determinant.

```
#Code by GVV Sharma
#March 14, 2019
#released under GNU GPL
import numpy as np
```

```
def det(A):
    a1 = A[0][0]
    a2 = A[0][1]
    b1 = A[1][0]
    b2 = A[1][1]
    y = a1*b2 - a2*b1
    return y
```

```
a1 = 1
a2 = 1
b1 = 3
b2 = -1
```

```
A = np.array([[a1,a2],[b1,b2]])
```

```
x = det(A)
print(x)
```

1.5 Write a program to check if two lines intersect.

Solution: Two lines intersect if $\det(\mathbf{A}) \neq 0$.
The following code checks for this condition.

```
#Code by GVV Sharma
#March 16, 2019
#released under GNU GPL
import numpy as np

a1 = 1
a2 = 1
b1 = 3
b2 = -1

A = np.array([[a1,a2],[b1,b2]])
x = np.linalg.det(A)
if x != 0:
    print('The lines intersect')
else:
    print('The lines do not intersect')
```

1.6 Let

$$\mathbf{A}_1 = \begin{pmatrix} 8 & 1 \\ 12 & -1 \end{pmatrix} \quad (6)$$

$$\mathbf{A}_2 = \begin{pmatrix} 1 & 8 \\ 3 & 12 \end{pmatrix} \quad (7)$$

Verify that

$$x_1 = \frac{\det \mathbf{A}_1}{\det \mathbf{A}} \text{ and } x_2 = \frac{\det \mathbf{A}_2}{\det \mathbf{A}} \quad (8)$$

satisfy (??).

Solution:

$$\frac{\det \mathbf{A}_1}{\det \mathbf{A}} = \frac{-20}{-4} = 5 \quad (9)$$

Similarly,

$$\frac{\det \mathbf{A}_2}{\det \mathbf{A}} = \frac{-12}{-4} = 3 \quad (10)$$

2 GRAPHICAL SOLUTION

2.1 Find a graphical solution for (??).

Solution: The following code plots Fig. 2.1. It is obvious that the two equations in (??) represent the lines y_1 and y_2 in Fig. 2.1 and intersect at $\begin{pmatrix} 5 \\ 3 \end{pmatrix}$

```
#Code by GVV Sharma
#March 14, 2019
#released under GNU GPL
import numpy as np
import matplotlib.pyplot as plt

#if using termux
import subprocess
import shlex
#end if

x = np.linspace(-2,8,20)
y1 = 8-x
y2 = 3*x-12

fig = plt.figure()
ax = fig.add_subplot(1, 1, 1)

# Major ticks every 2, minor ticks every 1
major_ticks = np.arange(-10, 10, 2)
minor_ticks = np.arange(-10, 10, 1)

ax.set_xticks(major_ticks)
ax.set_xticks(minor_ticks, minor=True)
ax.set_yticks(major_ticks)
ax.set_yticks(minor_ticks, minor=True)

# If you want different settings for the grids:
ax.grid(which='minor', alpha=0.2)
ax.grid(which='major', alpha=0.5)

#Plotting all lines
ax.plot(x,y1,label='$y_1$')
ax.plot(x,y2,label='$y_2$')

plt.xlabel('$x$')
plt.ylabel('$y$')
ax.legend(loc='best')

#if using termux
plt.savefig('../figs/draw_line.pdf')
plt.savefig('../figs/draw_line.eps')
subprocess.run(shlex.split("termux-open ../figs/draw_line.pdf"))
#else
plt.show()
```

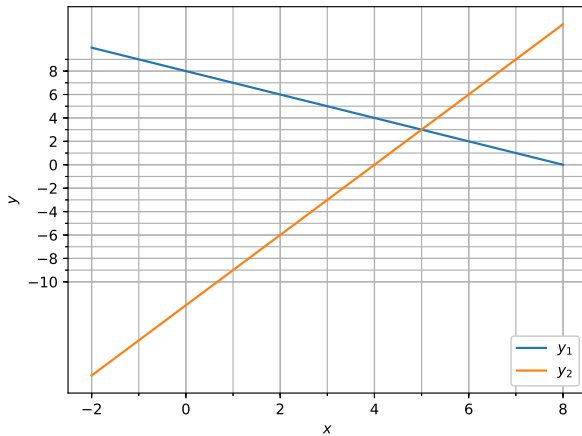


Fig. 2.1

2.2 The **np.linspace** function above generates an arithmetic sequence with first term -2, last term 8 and number of terms 20. Write your own linspace function and verify.

Solution: The code is available below.

```
#Code by GVV Sharma
#March 14, 2019
#released under GNU GPL
import numpy as np

def linspace(first,last,k):
    t= np.zeros((k,1))
    t[0]=first
    d = (last-first)/(k-1)
    for n in range(2,k):
        t[n-1] = t[0]+(n-1)*d
    return t

x = np.linspace(-2,8,20)
print(x)
```

3 C PROGRAMMING

3.1 Write a C program to generate an arithmetic sequence with $t_0 = -2, t_{n-1} = 8, n = 20$ and print it to the file **ap.dat**.

Solution:

```
#include <stdio.h>

int main(void)
{
    FILE *fp;
```

```
float t_0 = -2.0, t_k = 8.0, d,t_n;
int k = 20, n;
```

```
//Common difference
d = (t_k-t_0)/(k-1);
fp = fopen("ap.dat","w");
for(n = 0; n < k; n++)
{
    t_n = t_0+n*d;
    printf("%f\n",t_n);
    fprintf(fp,"%f\n",t_n);
}
fclose(fp);
return 0;
}
```

3.2 Now execute the following code.

```
#Code by GVV Sharma
#March 15, 2019
#released under GNU GPL
import numpy as np
import matplotlib.pyplot as plt

#if using termux
import subprocess
import shlex
#end if

x = np.loadtxt('ap.dat',dtype='float')
y1 = 8-x
y2 = 3*x-12

fig = plt.figure()
ax = fig.add_subplot(1, 1, 1)

# Major ticks every 2, minor ticks every 1
major_ticks = np.arange(-10, 10, 2)
minor_ticks = np.arange(-10, 10, 1)

ax.set_xticks(major_ticks)
ax.set_xticks(minor_ticks, minor=True)
ax.set_yticks(major_ticks)
ax.set_yticks(minor_ticks, minor=True)

# If you want different settings for the grids:
ax.grid(which='minor', alpha=0.2)
ax.grid(which='major', alpha=0.5)

#Plotting all lines
```

```

ax.plot(x,y1,label='$y_1$')
ax.plot(x,y2,label='$y_2$')

plt.xlabel('$x$')
plt.ylabel('$y$')
ax.legend(loc='best')

#if using termux
plt.savefig('../figs/draw_line.pdf')
plt.savefig('../figs/draw_line.eps')
subprocess.run(shlex.split("termux-open ../figs/draw_line.pdf"))
#else
plt.show()

```

- 3.3 Do all computations in Problem 2.1 using C and store the data into files. Import this data so that Python is used only for plotting.
- 3.4 Write a function for computing the common difference d given t_0, t_{n-1} and n .

Solution:

```

#include <stdio.h>

float comm_diff(float,float,int);
int main(void)
{
    FILE *fp;
    float t_0 = -2.0, t_k = 8.0, d,t_n;
    int k = 20, n;

    //Common difference
    d = comm_diff(t_0,t_k,k);
    fp = fopen("ap.dat","w");
    for(n = 0; n < k; n++)
    {
        t_n = t_0+n*d;
        printf("%f\n",t_n);
        fprintf(fp,"%f\n",t_n);
    }
    fclose(fp);
    return 0;
}

float comm_diff(float first,float last,int n)
{
    float d;
    d = (last-first)/(n-1);
    return d;
}

```

4 PYTHON PROGRAMMING EXERCISES

- 4.1 Find \mathbf{A}^{-1} .

Solution: The *inverse* of \mathbf{A} is obtained as

$$\mathbf{A}^{-1} = \frac{1}{\det \mathbf{A}} \begin{pmatrix} -1 & -1 \\ -3 & 1 \end{pmatrix} \quad (11)$$

$$= \frac{1}{-4} \begin{pmatrix} -1 & -1 \\ -3 & 1 \end{pmatrix} = \frac{1}{4} \begin{pmatrix} 1 & 1 \\ 3 & -1 \end{pmatrix} \quad (12)$$

- 4.2 Write your own function for calculating \mathbf{A}^{-1}

- 4.3 Let

$$\mathbf{c} = \begin{pmatrix} 8 \\ 12 \end{pmatrix} \quad (13)$$

Find $\mathbf{A}^{-1}\mathbf{b}$

Solution: From (11) and (13),

$$\mathbf{A}^{-1}\mathbf{b} = \frac{1}{4} \begin{pmatrix} 1 & 1 \\ 3 & -1 \end{pmatrix} \begin{pmatrix} 8 \\ 12 \end{pmatrix} \quad (14)$$

$$= \frac{1}{4} \begin{pmatrix} 1 \times 8 + 1 \times 12 \\ 3 \times 8 - 1 \times 12 \end{pmatrix} = \frac{1}{4} \begin{pmatrix} 20 \\ 12 \end{pmatrix} = \begin{pmatrix} 5 \\ 3 \end{pmatrix} \quad (15)$$

- 4.4 Verify that (15) is a solution of (??).

- 4.5 Write a program to find the solution of (??).

Solution: The following program finds the solution

```

#Code by GVV Sharma
#March 14, 2019
#released under GNU GPL
import numpy as np

a1 = 1
a2 = 1
b1 = 3
b2 = -1
c1 = 8
c2 = 12

A = np.array([[a1,a2],[b1,b2]])
c = np.array([c1,c2])
Ainv = np.linalg.inv(A)
x = np.matmul(Ainv,c)

print(x)

```

- 4.6 Write your own program for **np.matmul**.

5 C PROGRAMMING EXERCISES

5.1 A geometric sequence is defined as

$$t_{n-1} = t_0 r^{n-1} \quad (16)$$

Write a function for generating the n th term of a geometric sequence from t_0 , r and n .

Solution:

```
#include <stdio.h>
#include <math.h>
//nth term of a GP
//t_0 = first term
//t_n = nth term
//r = common ratio
//k = number of terms

int main(void)
{
    float t_0 = 1, r = 2, t_n;
    int n = 3;

    t_n = t_0*pow(r,n);
    printf("%f\n",t_n);
    return 0;
}
```

5.2 Write a function to calculate simple interest and amount.

5.3 Write a function to calculate compound interest and amount.

5.4 Write a function to calculate the circumference of a circle.

Solution:

```
#include <stdio.h>
#include <math.h>

float circumference(float);
int main(void)
{
    printf("%f\n",circumference(0.5));
    return 0;
}

float circumference(float r)
{
    return 2*M_PI*r;
}
```

5.5 Write a function to calculate the area of a circle.

5.6 Write a program to find the sum of the first n terms of an arithmetic sequence. Verify by finding the sum of the numbers 1, ..., 10.

Solution:

```
#include <stdio.h>
//sum to n terms of an AP
//t_0 = first term
//t_n = nth term
//d = common difference
//k = number of terms

int main(void)
{
    float t_0 = 1, d = 1, s_n, t_n;
    int k = 10, n;

    s_n = 0;
    //For Loop
    for(n = 0; n < k; n++)
    {
        t_n = t_0 + n*d;
        s_n = s_n+t_n;
    }
    printf("%f\n",s_n);
    return 0;
}
```

5.7 Write a program to find the sum of the first n terms of a geometric sequence.

5.8 Write a program to check if given lengths can form the sides of a triangle.

Solution:

```
#include <stdio.h>
#include <math.h>
//verify if given lengths
//are sides of a triangle.
int main(void)
{
    float a,b,c;

    printf("Enter the sides of the triangle\n");
    scanf("%f%f%f", &a,&b,&c);

    if(a+b < c)
    {
        printf("No triangle\n");
    }
    else if(b+c < a)
    {

```

```

printf("No\_triangle\n");
}
else if(c+a < b)
{
printf("No\_triangle\n");
}
else
{
printf("Yes\_Triangle\n");
}
return 0;
}

```

5.9 Write a program to find A^{-1} and print it.
Solution:

```

#include <stdio.h>
#include <stdlib.h>

//This program shows how to use pointers as
//2-D arrays

//Function declaration
double **createMat(int m,int n);
void readMat(int m,int n,double **p);
void print(int m,int n,double **p);
double detMat(double **p);
double **invMat(double **p);

//End function declaration

int main() //main function begins
{

//Defining the variables
int m,n;//integers
double **A,**A_inv,det;

m = 2;
n = 2;
printf("Enter\_the\_values\_of\_the\_matrix\n");
A = createMat(m,n);//creating the matrix
det = detMat(A);
readMat(m,n,A);//reading values into the
//matrix a
A_inv = invMat(A);
print(m,n,A_inv);//printing the matrix a

return 0;
}

```

```

double **invMat(double **p)
{
double **q, det;
det = detMat(p);
q = createMat(2,2);
q[0][0] = p[1][1]/det;
q[0][1] = -p[0][1]/det;
q[1][0] = -p[1][0]/det;
q[1][1] = p[0][0]/det;
return q;
}

```

```

double detMat(double **A)
{
double det;
det = A[0][0]*A[1][1]-A[0][1]*A[1][0];
return det;
}

```

```

//Defining the function for matrix creation
double **createMat(int m,int n)
{
int i;
double **a;

//Allocate memory to the pointer
a = (double **)malloc(m * sizeof( *a));
for (i=0; i<m; i++)
a[i] = (double *)malloc(n * sizeof(
*a[i]));

return a;
}

```

//End function for matrix creation

```

//Defining the function for reading matrix
void readMat(int m,int n,double **p)
{
int i,j;
for(i=0;i<m;i++)
{
for(j=0;j<n;j++)
{
scanf("%lf",&p[i][j]);
}
}
}
//End function for reading matrix

```

```

//Defining the function for printing
void print(int m,int n,double **p)
{
    int i,j;

    for(i=0;i<m;i++)
    {
        for(j=0;j<n;j++)
            printf("%lf\t",p[i][j]);
        printf("\n");
    }
}

```

- 5.10 Write a program to find the intersection of two lines using Cramer's rule.
- 5.11 Write a program to verify if two lines intersect.
- 5.12 Write a program to find $\mathbf{A}^{-1}\mathbf{c}$.