

# Assignment

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**Abstract**—This manual provides solutions to the Assignment of Random Numbers

### I. UNIFORM RANDOM NUMBERS

Let  $U$  be a uniform random variable between 0 and 1.

I.1 Generate  $10^6$  samples of  $U$  using a C program and save into a file called uni.dat .

**Solution:** Download the following files and execute the C program.

```
wget https://github.com/GovindaRohith/
Assignments/blob/main/Randomnum/
codes/1.1.c
wget https://github.com/GovindaRohith/
Assignments/blob/main/Randomnum/
codes/source.h
```

Download the above files and execute the following commands

```
$ gcc 1.1.c
$ ./a.out
```

I.2 Load the uni.dat file into python and plot the empirical CDF of  $U$  using the samples in uni.dat. The CDF is defined as

$$F_U(x) = \Pr(U \leq x) \quad (1)$$

**Solution:** The following code plots Fig. I.2

```
wget https://github.com/GovindaRohith/
Assignments/blob/main/Randomnum/
codes/1.2.py
```

Download the above files and execute the following commands to produce Fig.I.2

```
$ python3 1.2.py
```

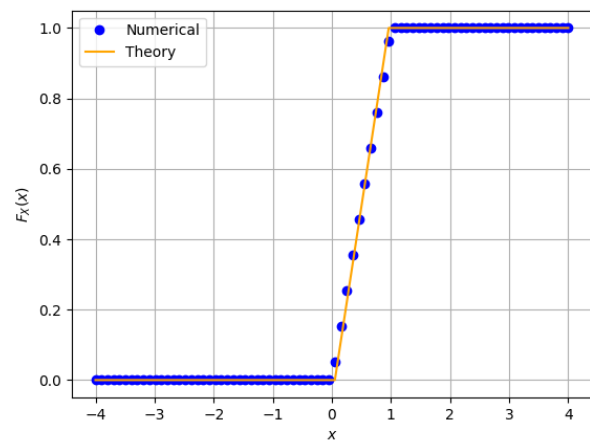


Fig. I.2. The CDF of  $U$

I.3 Find a theoretical expression for  $F_U(x)$ .

**Solution:** Given  $U$  is a uniform Random Variable

$$p_U(x) = 1 \text{ for } 0 < x < 1 \quad (2)$$

$$F_U(x) = \int_{-\infty}^{\infty} p_U(x) dx \quad (3)$$

$$\Rightarrow F_U(x) = \begin{cases} 0 & x \leq 0 \\ x & 0 < x < 1 \\ 1 & x \geq 1 \end{cases} \quad (4)$$

I.4 The mean of  $U$  is defined as

$$E[U] = \frac{1}{N} \sum_{i=1}^N U_i \quad (5)$$

and its variance as

$$\text{var}[U] = E[U - E[U]]^2 \quad (6)$$

Write a C program to find the mean and variance of  $U$ .

**Solution:** Download the following files and execute the C program.

```
wget https://github.com/GovindaRohith/
  Assignments/blob/main/Randomnum/
  codes/1.4.c
wget https://github.com/GovindaRohith/
  Assignments/blob/main/Randomnum/
  codes/source.h
```

Download the above files and execute the following commands

```
$ gcc 1.4.c
$ ./a.out
```

I.5 Verify your result theoretically given that

$$E[U^k] = \int_{-\infty}^{\infty} x^k dF_U(x) \quad (7)$$

**Solution:**

$$\text{var}[U] = E[U - E[U]]^2 \quad (8)$$

$$\Rightarrow \text{var}[U] = E[U^2] - E[U]^2 \quad (9)$$

$$E[U] = \int_{-\infty}^{\infty} x dF_U(x) \quad (10)$$

$$E[U] = \int_0^1 x \quad (11)$$

$$\Rightarrow E[U] = \frac{1}{2} \quad (12)$$

$$E[U^2] = \int_{-\infty}^{\infty} x^2 dF_U(x) \quad (13)$$

$$E[U^2] = \int_0^1 x^2 dF_U(x) \quad (14)$$

$$\Rightarrow E[U^2] = \frac{1}{3} \quad (15)$$

$$\Rightarrow \text{var}[U] = \frac{1}{12} = 0.0833 \quad (16)$$

## II. CENTRAL LIMIT THEOREM

II.1 Generate  $10^6$  samples of the random variable

$$X = \sum_{i=1}^{12} U_i - 6 \quad (17)$$

using a C program, where  $U_i, i = 1, 2, \dots, 12$  are a set of independent uniform random variables between 0 and 1 and save in a file called gau.dat

**Solution:** Download the following files and execute the C program.

```
wget https://github.com/GovindaRohith/
  Assignments/blob/main/Randomnum/
  codes/2.1.c
wget https://github.com/GovindaRohith/
  Assignments/blob/main/Randomnum/
  codes/source.h
```

Download the above files and execute the following commands

```
$ gcc 2.1.c
$ ./a.out
```

II.2 Load gau.dat in python and plot the empirical CDF of  $X$  using the samples in gau.dat. What properties does a CDF have?

**Solution:** The CDF of  $X$  is plotted in Fig. II.2 using the code below

```
wget https://github.com/GovindaRohith/
  Assignments/blob/main/Randomnum/
  codes/2.2.py
```

Download the above files and execute the following commands to produce Fig.II.2

```
$ python3 2.2.py
```

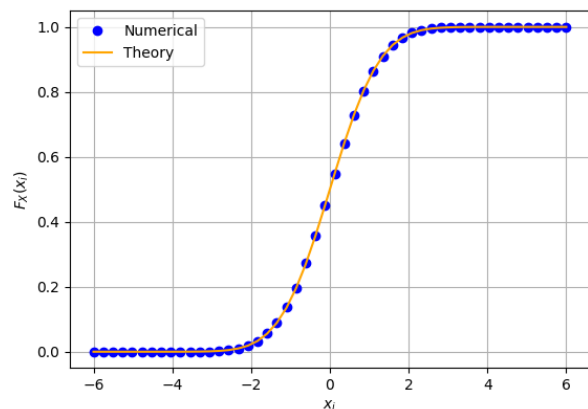


Fig. II.2. The CDF of  $X$

Some of the properties of CDF

a)  $F_X(x)$  is non decreasing function.

b) Symmetric about one point.

II.3 Load gau.dat in python and plot the empirical PDF of  $X$  using the samples in gau.dat. The PDF of  $X$  is defined as

$$p_X(x) = \frac{d}{dx} F_X(x) \quad (18)$$

What properties does the PDF have?

**Solution:** The PDF of  $X$  is plotted in Fig. II.3 using the code below

```
wget https://github.com/GovindaRohith/
Assignments/blob/main/Randomnum/
codes/2.3.py
```

Download the above files and execute the following commands to produce Fig.II.3

```
$ python3 2.3.py
```

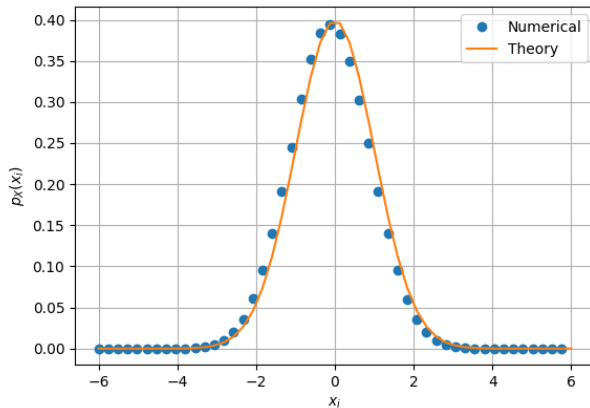


Fig. II.3. The PDF of  $X$

Some of the properties of the PDF:

- Symmetric about  $x = \mu$
- decreasing function for  $x > \mu$  and increasing for  $x < \mu$  and attains maximum at  $x = \mu$
- Area under the curve is unity.

II.4 Find the mean and variance of  $X$  by writing a C program.

**Solution:** Download the following files and execute the C program.

```
wget https://github.com/GovindaRohith/
Assignments/blob/main/Randomnum/
codes/2.4.c
wget https://github.com/GovindaRohith/
Assignments/blob/main/Randomnum/
codes/source.h
```

Download the above files and execute the following commands

```
$ gcc 2.4.c
$ ./a.out
```

II.5 Given that

$$p_X(x) = \frac{1}{\sqrt{2\pi}} \exp\left(-\frac{x^2}{2}\right), -\infty < x < \infty, \quad (19)$$

repeat the above exercise theoretically.

**Solution:**

1) CDF is given by

$$F_X(x) = \int_{-\infty}^{\infty} p_X(x) dx \quad (20)$$

$$F_X(x) = 1 \quad (21)$$

2) Mean is given by

$$E(x) = \int_{-\infty}^{\infty} x p_X(x) dx \quad (22)$$

$$\Rightarrow E(x) = 0 \quad (23)$$

3) Variance is given by

$$\text{var}[U] = E(U^2) - (E(U))^2 \quad (24)$$

$$\Rightarrow \text{var}[U] = \sqrt{2} \quad (25)$$

### III. FROM UNIFORM TO OTHER

III.1 Generate samples of

$$V = -2 \ln(1 - U) \quad (26)$$

and plot its CDF.

**Solution:** Download the following files and execute the C program.

```
wget https://github.com/GovindaRohith/
Assignments/blob/main/Randomnum/
codes/3.1.c
wget https://github.com/GovindaRohith/
Assignments/blob/main/Randomnum/
codes/source.h
```

Download the above files and execute the following commands

```
$ gcc 3.1.c -lm
$ ./a.out
```

The CDF of  $V$  is plotted in Fig. III.1 using the code below

```
wget https://github.com/GovindaRohith/
Assignments/blob/main/Randomnum/
codes/3.1pyth.py
```

Download the above files and execute the following commands to produce Fig.III.1

```
$ python3 3.1pyth.py
```

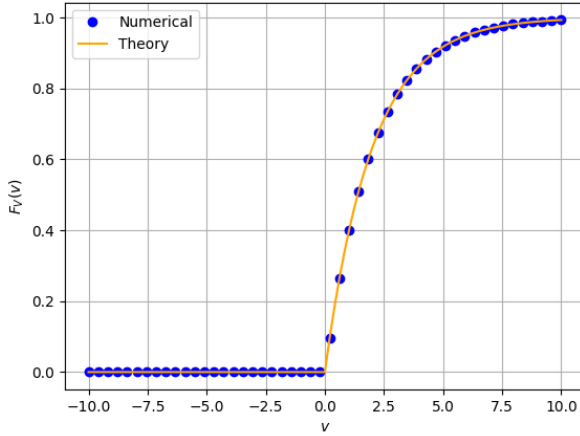


Fig. III.1. The PDF of  $X$

III.2 Find a theoretical expression for  $F_V(x)$ .

**Solution:** If  $Y = g(X)$ , we know that  $F_Y(y) = F_X(g^{-1}(y))$ , here

$$V = -2 \ln(1 - U) \quad (27)$$

$$1 - U = e^{\frac{-V}{2}} \quad (28)$$

$$U = 1 - e^{\frac{-V}{2}} \quad (29)$$

$$F_V(x) = F_U(1 - e^{\frac{-x}{2}}) \quad (30)$$

$$\Rightarrow F_V(x) = \begin{cases} 0 & x < 0 \\ 1 - e^{\frac{-x}{2}} & x \geq 0 \end{cases} \quad (31)$$