ESCUELA POLITÉCNICA NACIONAL

MÉTODOS NUMÉRICOS

JIMÉNEZ JARAMILLO YASID GABRIEL

[Tarea 10] Ejercicios Unidad 04-C Descomposición LU

```
%load_ext autoreload
import numpy as np
from src import multiplicar_matrices, descomposicion_LU, resolver_LU
from src import eliminacion_gaussiana_L,eliminacion_gaussiana_U,
determinante, inversa
```

EJERCICIO UNO

Realice las siguientes multiplicaciones matriz-matriz:

PARTE A

\begin{equation}*} |begin{bmatrix} 2 & -3 | 3 & -1 |end{bmatrix} |begin{bmatrix} 1 & 5 | 2 & 0 | end{bmatrix} |end{equation*}

```
A = np.array([[2,-3],[3,-1]])
B = np.array([[1,5],[2,0]])
C = multiplicar_matrices(A,B)
print("El resultado de la multiplicación es: \n",C)
```

```
El resultado de la multiplicación es:
 [[-4 10]
 [ 1 15]]
```

PARTE B

\begin{equation}*} |begin{bmatrix} 2 & -3 | 3 & -1 |end{bmatrix} |begin{bmatrix} 1 & 5 & -4| -3 & 2 & 0 |end{bmatrix} |end{equation*}

```
A = np.array([[2,-3],[3,-1]])
B = np.array([[1,5,-4],[-3,2,0]])
C = multiplicar_matrices(A,B)
print("El resultado de la multiplicación es: \n",C)
```

```
El resultado de la multiplicación es:
 [[ 11   4  -8]
 [  6  13 -12]]
```

PARTE C

\begin{equation}} |begin{bmatrix} 2 & -3 & 1| 4 & 3 & 0| 5 & 2 & -4 |end{bmatrix} |begin{bmatrix} 0 & 1 & -2| 1 & 0 & -1| 2 & 3 & -2 |end{bmatrix} |end{equation}}

```
A = np.array([[2,-3,1],[4,3,0],[5,2,-4]])
B = np.array([[0,1,-2],[1,0,-1],[2,3,-2]])
C = multiplicar_matrices(A,B)
print("El resultado de la multiplicación es: \n",C)
```

```
El resultado de la multiplicación es:
 [[ -1   5  -3]
 [  3   4 -11]
 [ -6  -7  -4]]
```

PARTE D

\begin{equation}} |begin{bmatrix} 2 & 1 & 2| -2 & 3 & 0| 2 & -1 & 3 |end{bmatrix} |begin{bmatrix} 1 & -2 | -4 & 1 | 0 & 2 |end{bmatrix} |end{equation}}

```
A = np.array([[2,1,2],[-2,3,0],[2,-1,3]])
B = np.array([[1,-2],[-4,1],[0,2]])
C = multiplicar_matrices(A,B)
print("El resultado de la multiplicación es: \n",C)
```

```
El resultado de la multiplicación es:
 [[ -2   1]
 [-14   7]
 [  6   1]]
```

EJERCICIO DOS

Determine cuáles de las siguientes matrices son no singulares y calcule la inversa de esas matrices:

PARTE A

\begin{equation}} |begin{bmatrix} 4 & 2 & 6| 3 & 0 & 7| -2 & -1 & -3 |end{bmatrix} |end{equation}}

```
A = np.array([[4,2,6],[3,0,7],[-2,-1,-3]])
det = determinante(A)
if(det==0):
    print("El determinante es:",det, "\nPor tanto, la matriz es 
singular y no posee inversa")
else:
    inv = inversa(A)
```

```
    print("El determinante es:",det, "\nSu matriz inversa es la siguiente:", inv)
```

```
El determinante es: 0
Por tanto, la matriz es singular y no posee inversa
```

PARTE B

\begin{equation*} |begin{bmatrix} 1 & 2 & 0| 2 & 1 & -1| 3 & 1 & 1 |end{bmatrix} |end{equation*}

```
A = np.array([[1,2,0],[2,1,-1],[3,1,1]])
det = determinante(A)
if(det==0):
    print("El determinante es:",det, "\nPor tanto, la matriz es singular y no posee inversa")
else:
    inv = inversa(A)
    print("El determinante es:",det, "\nSu matriz inversa es la siguiente:\n", inv)
```

```
El determinante es: -7.999999999999999
Su matriz inversa es la siguiente:
 [[-0.25   0.25   0.25 ]
 [ 0.625 -0.125 -0.125]
 [ 0.125 -0.625  0.375]]
```

PARTE C

\begin{equation*} |begin{bmatrix} 1 & 1 & -1 & 1| 1 & 2 & -4 & -2| 2 & 1 & 1 & 5 | -1 & 0 & -2 & -4 | end{bmatrix} |end{equation*}

```
%autoreload 2
A = np.array([[1,1,-1,1],[1,2,-4,-2],[2,1,1,5],[-1,0,-2,-4]])
det = determinante(A)
if(det==0):
    print("El determinante es:",det, "\nPor tanto, la matriz es singular y no posee inversa")
else:
    inv = inversa(A)
    print("El determinante es:",det, "\nSu matriz inversa es la siguiente:", inv)
```

```
El determinante es: 0
Por tanto, la matriz es singular y no posee inversa
```

PARTE D

\begin{equation*} |begin{bmatrix} 4 & 0 & 0 & 0| 6 & 7 & 0 & 0| 9 & 11 & 1 & 0| 5 & 4 & 1 & 1 | end{bmatrix} |end{equation*}

```
A = np.array([[4,0,0,0],[6,7,0,0],[9,11,1,0],[5,4,1,1]])
det = determinante(A)
if(det==0):
    print("El determinante es:",det, "\nPor tanto, la matriz es 
singular y no posee inversa")
else:
    inv = inversa(A)
    print("El determinante es:",det, "\nSu matriz inversa es la 
siguiente:\n", inv)
```

```
El determinante es: 27.999999999999993
Su matriz inversa es la siguiente:
 [[ 0.25        0.          0.          0.        ]
 [-0.21428571  0.14285714  0.          0.        ]
 [ 0.10714286 -1.57142857  1.          0.        ]
 [-0.5         1.         -1.          1.        ]]
```

EJERCICIO TRES

Resuelva los sistemas lineales 4 x 4 que tienen la misma matriz de coeficientes:

PARTE A

$$\begin{array}{ccc} x_1 - x_2 + 2x_3 - x_4 & ¿6 \quad x_1 - x_2 + 2x_3 - x_4 & ¿1 \\ x_1 - x_3 + x_4 & ¿4 \quad x_1 - x_3 + x_4 & ¿1 \\ 2x_1 + x_2 + 3x_3 - 4x_4 & ¿-2 \, 2x_1 + x_2 + 3x_3 - 4x_4 & ¿2 \\ -x_2 + x_3 - x_4 & ¿5 \quad -x_2 + x_3 - x_4 & ¿-1 \end{array}$$

Como ambos sistemas de ecuaciones poseen la misma matriz de coeficientes, se utilizara la descomposicion LU para resolver, donde:

\begin{equation} *A = |begin{bmatrix} 1 & -1 & 2 & -1| 1 & 0 & -1 & 1| 2 & 1 & 3 &-4| 0 & -1 & 1 & -1 | end{bmatrix} |end{equation*}

```
A = [[1,-1,2,-1],[1,0,-1,1],[2,1,3,-4],[0,-1,1,-1]]
L,U = descomposicion_LU(A)
print("Matriz L:\n",L)
print("Matriz U:\n",U)
```

```
Matriz L:
 [[ 1.    0.    0.    0.  ]
 [ 1.    1.    0.    0.  ]
 [ 2.    3.    1.    0.  ]
 [ 0.   -1.   -0.25  1.  ]]
Matriz U:
 [[ 1. -1.  2. -1.]
 [ 0.  1. -3.  2.]
```

```
 [ 0.   0.   8. -8.]
 [ 0.   0.   0. -1.]]
```

```
%autoreload 2
b_1 = [6,4,-2,5]
sol_1 = resolver_LU(L,U,b_1)
```

```
Calculando y
y
[ 6. -2. -8.  1.]
Verificación Ly=b:
[ 6.  4. -2.  5.]
Calculando x
x
[ 3. -6. -2. -1.]
Verificación Ux=y:
[ 6. -2. -8.  1.]
```

```
%autoreload 2
b_2 = [1,1,2,-1]
sol_2 = resolver_LU(L,U,b_2)
```

```
Calculando y
y
[ 1.  0.  0. -1.]
Verificación Ly=b:
[ 1.  1.  2. -1.]
Calculando x
x
[1. 1. 1. 1.]
Verificación Ux=y:
[ 1.  0.  0. -1.]
```

Para finalizar, se obtuvo que $sol_1=[3,-6,-2,-1)$ y $sol_2=[1,1,1,1)$

EJERCICIO CUATRO

Encuentre los valores de A que hacen que la siguiente matriz sea singular

$$A=\begin{bmatrix} 1 & -1 & \alpha \\ 2 & 2 & 1 \\ 0 & \alpha & -\frac{3}{2} \end{bmatrix}$$

Primero se debe encontrar el determinante de la matriz, donde:

$$\left| \begin{matrix} 1 & -1 & a \\ 2 & 2 & 1 \\ 0 & a & -\frac{3}{2} \end{matrix} ¿¿ = 2a^2 - a - 6$$

Para que sea una matriz singular, igualamos al determinante a cero, donde:

Para encontrar los valores de *a* que hacen que el determinante sea cero, resolvemos la ecuación cuadrática:

$$2a^2 - a - 6 = 0$$

Usando la fórmula cuadrática:

$$a = \frac{-B \pm \sqrt{B^2 - 4AC}}{2A}$$

Con *A = 2*, *B = -1* y *C = -6*:

$$a = \frac{1 \pm \sqrt{1+48}}{4} = \frac{1 \pm \sqrt{49}}{4} = \frac{1 \pm 7}{4}$$

Las dos soluciones son:

$$a_1 = \frac{1+7}{4} = 2$$

$$a_2 = \frac{1-7}{4} = -\frac{3}{2}$$

EJERCICIO CINCO

Resuelva los siguientes sistemas lineales:

PARTE A

$$\left[\begin{matrix} 1 & 0 & 0 \\ 2 & 1 & 0 \\ -1 & 0 & 1 \end{matrix} \right) \left[\begin{matrix} 2 & 3 & -1 \\ 0 & -2 & 1 \\ 0 & 0 & 3 \end{matrix} \right) \left[\begin{matrix} x_1 \\ x_2 \\ x_3 \end{matrix} \right) = \left[\begin{matrix} 2 \\ -1 \\ 1 \end{matrix} \right)$$

Usando LU, se tiene:

```
L = np.array([[1,0,0],[2,1,0],[-1,0,1]])
U = np.array([[2,3,-1],[0,-2,1],[0,0,3]])
b = [2,-1,1]
resolver_LU(L,U,b)
```

```
Calculando y
y
[ 2. -5.  3.]
Verificación Ly=b:
[ 2. -1.  1.]
Calculando x
x
[-3.  3.  1.]
Verificación Ux=y:
[ 2. -5.  3.]
```

Su solucion es:

\begin{bmatrix} -3 \ 3 \ 1 \end{bmatrix}

PARTE B

\begin{equation*} |begin{bmatrix} 2 & 0 & 0 | -1 & 1 & 0| 3 & 2 & -1 |end{bmatrix} |begin{bmatrix} 1 & 1 & 1| 0 & 1 & 2| 0 & 0 & 1 |end{bmatrix} |begin{bmatrix} x_1 | x_2 | x_3 |end{bmatrix} = | begin{bmatrix} -1 | 3 | 0 |end{bmatrix} |end{equation*}

```
L = np.array([[2,0,0],[-1,1,0],[3,2,-1]])
U = np.array([[1,1,1],[0,1,2],[0,0,1]])
b = [-1,3,0]
resolver_LU(L,U,b)
```

```
Calculando y
y
[-0.5  2.5  3.5]
Verificación Ly=b:
[-1.  3.  0.]
Calculando x
x
[ 0.5 -4.5  3.5]
Verificación Ux=y:
[-0.5  2.5  3.5]
```

Su solucion es:

\begin{bmatrix} 0.5 \ -4.5 \ 3.5 \end{bmatrix}

EJERCICIO SEIS

Factorice las siguientes matrices en la descomposición LU mediante el algoritmo de factorización LU con lii = 1 para todas las i.

PARTE A

\begin{equation*} |begin{bmatrix} 2 & -1 & 1| 3 & 3 & 9| 3 & 3 & 5 |end{bmatrix} |end{equation*}

```
A = [[2,-1,1],[3,3,9],[3,3,5]]
L,U = descomposicion_LU(A)
print("Matriz L:\n",L)
print("Matriz U:\n",U)
```

```
Matriz L:
 [[1.  0.  0. ]
 [1.5 1.  0. ]
 [1.5 1.  1. ]]
Matriz U:
 [[ 2.  -1.   1. ]
 [ 0.   4.5  7.5]
 [ 0.   0.  -4. ]]
```

PARTE B

\begin{equation*} |begin{bmatrix} 1.012 & -2.132 & 3.104| -2.132 & 4.096 & -7.013| 3.104 & -7.013 & 0.014 |end{bmatrix} |end{equation*}

```
B = [[1.012,-2.132,3.104],[-2.132,4.096,-7.013],[3.104,-7.013,0.014]]
L,U = descomposicion_LU(B)
print("Matriz L:\n",L)
print("Matriz U:\n",U)
```

```
Matriz L:
 [[ 1.          0.          0.        ]
 [-2.10671937  1.          0.        ]
 [ 3.06719368  1.19775553  1.        ]]
Matriz U:
 [[ 1.012      -2.132       3.104     ]
 [ 0.         -0.39552569 -0.47374308]
 [ 0.          0.         -8.93914077]]
```

PARTE C

\begin{equation*} |begin{bmatrix} 2 & 0 & 0 & 0| 1 & 1.5 & 0 & 0| 0 & -3 & 0.5 & 0| 2 & -2 & 1 & 1 | end{bmatrix} |end{equation*}

```
C = [[2,0,0,0],[1,1.5,0,0],[0,-3,0.5,0],[2,-2,1,1]]
L,U = descomposicion_LU(C)
print("Matriz L:\n",L)
print("Matriz U:\n",U)
```

```
Matriz L:
 [[ 1.          0.          0.          0.        ]
```

```
 [ 0.5         1.          0.          0.        ]
 [ 0.         -2.          1.          0.        ]
 [ 1.         -1.33333333  2.          1.        ]]
Matriz U:
 [[2.  0.  0.  0. ]
 [0.  1.5 0.  0. ]
 [0.  0.  0.5 0. ]
 [0.  0.  0.  1. ]]
```

PARTE D

\begin{equation*} |begin{bmatrix}* 2.1756 & 4.0231 & -2.1732 & 5.1967| -4.0231 & 6.0000 & 0 & 1.1973| -1.0000 & -5.2107 & 1.1111 & 0| 6.0235 & 7.0000 & 0 & -4.1561 |end{bmatrix} | end{equation*}

```python
D = [[2.1756,4.0231,-2.1732,5.1967],[-4.0231,6.0000,0,1.1973],
     [-1.0000,-5.2107,1.1111,0],[6.0235,7.0000,0,-4.1561]]
L,U = descomposicion_LU(D)
print("Matriz L:\n",L)
print("Matriz U:\n",U)
```

```
Matriz L:
 [[ 1.          0.          0.          0.        ]
 [-1.84919103  1.          0.          0.        ]
 [-0.45964332 -0.25012194  1.          0.        ]
 [ 2.76866152 -0.30794361 -5.35228302  1.        ]]
Matriz U:
 [[ 2.17560000e+00  4.02310000e+00 -2.17320000e+00  5.19670000e+00]
 [ 0.00000000e+00  1.34394804e+01 -4.01866194e+00  1.08069910e+01]
 [ 0.00000000e+00  4.44089210e-16 -8.92952394e-01  5.09169403e+00]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.20361280e+01]]
```

EJERCICIO SIETE

Modifique el algoritmo de eliminación gaussiana de tal forma que se pueda utilizar para resolver un sistema lineal usando la descomposición LU y, a continuación, resuelva los siguientes sistemas lineales.

PARTE A

$$\begin{aligned} 2x_1 - x_2 + x_3 &\text{¿} -1 \\ 3x_1 + 3x_2 + 9x_3 &\text{¿} 0 \\ 3x_1 + 3x_2 + 5x_3 &\text{¿} 4 \end{aligned}$$

```python
A = [[2,-1,1],[3,3,9],[3,3,5]]
b = [1,0,4]
L,U = descomposicion_LU(A)
print("\nMatriz L:\n",L)
print("\nMatriz U:\n",U)
y = eliminacion_gaussiana_L(L,b)
print("\nValor de y:", y,"\n")
x = eliminacion_gaussiana_U(U,y)
print("\nValor de la solución x:", x)
```

```
Matriz L:
 [[1.  0.  0. ]
 [1.5 1.  0. ]
 [1.5 1.  1. ]]

Matriz U:
 [[ 2.  -1.   1. ]
 [ 0.   4.5  7.5]
 [ 0.   0.  -4. ]]

[[ 1.   0.   0.   1. ]
 [ 0.   1.   0.  -1.5]
 [ 1.5  1.   1.   4. ]]

[[ 1.   0.   0.   1. ]
 [ 0.   1.   0.  -1.5]
 [ 0.   1.   1.   2.5]]

[[ 1.   0.   0.   1. ]
 [ 0.   1.   0.  -1.5]
 [ 0.   0.   1.   4. ]]

Valor de y: [ 1.  -1.5  4. ]

[[ 2.  -1.   1.   1. ]
 [ 0.   4.5  7.5 -1.5]
 [ 0.   0.  -4.   4. ]]

[[ 2.  -1.   1.   1. ]
 [ 0.   4.5  0.   6. ]
 [ 0.   0.  -4.   4. ]]

[[ 2.  -1.   0.   2. ]
 [ 0.   4.5  0.   6. ]
 [ 0.   0.  -4.   4. ]]

[[ 2.          0.          0.          3.33333333]
 [ 0.          4.5         0.          6.        ]
 [ 0.          0.         -4.          4.        ]]
```

```
Valor de la solución x: [ 1.6666666  1.3333334 -1.        ]
```

PARTE B

$$1.012\,x_1 - 2.132\,x_2 + 3.104\,x_3 \quad ¿1.984$$
$$-2.132\,x_1 + 4.096\,x_2 - 7.013\,x_3 \quad ¿-5.049$$
$$3.104\,x_1 - 7.013\,x_2 + 0.014\,x_3 \quad ¿-3.895$$

```
A = [[1.012,-2.132,3.104],[-2.132,4.096,-7.013],[3.104,-7.013,0.014]]
b = [1.984,-5.049,-3.895]
L,U = descomposicion_LU(A)
print("\nMatriz L:\n",L)
print("\nMatriz U:\n",U)
y = eliminacion_gaussiana_L(L,b)
print("\nValor de y:", y,"\n")
x = eliminacion_gaussiana_U(U,y)
print("\nValor de la solución x:", x)
```

```
Matriz L:
 [[ 1.          0.          0.        ]
 [-2.10671937  1.          0.        ]
 [ 3.06719368  1.19775553  1.        ]]

Matriz U:
 [[ 1.012      -2.132       3.104     ]
 [ 0.         -0.39552569 -0.47374308]
 [ 0.          0.         -8.93914077]]

[[ 1.          0.          0.          1.984     ]
 [ 0.          1.          0.         -0.86926877]
 [ 3.06719368  1.19775553  1.         -3.895     ]]

[[ 1.          0.          0.          1.984     ]
 [ 0.          1.          0.         -0.86926877]
 [ 0.          1.19775553  1.         -9.98031225]]

[[ 1.          0.          0.          1.984     ]
 [ 0.          1.          0.         -0.86926877]
 [ 0.          0.          1.         -8.93914077]]

Valor de y: [ 1.984     -0.8692688 -8.93914  ]

[[ 1.012      -2.132       3.104       1.98399997]
 [ 0.         -0.39552569 -0.47374308 -0.86926877]
 [ 0.          0.         -8.93914077 -8.93914032]]

[[ 1.012      -2.132       3.104       1.98399997]
```

```
 [ 0.         -0.39552569  0.         -0.39552572]
 [ 0.          0.         -8.93914077 -8.93914032]]

[[ 1.012      -2.132       0.         -1.11999987]
 [ 0.         -0.39552569  0.         -0.39552572]
 [ 0.          0.         -8.93914077 -8.93914032]]

[[ 1.012       0.          0.          1.01200026]
 [ 0.         -0.39552569  0.         -0.39552572]
 [ 0.          0.         -8.93914077 -8.93914032]]

Valor de la solución x: [1.0000002  1.0000001  0.99999994]
```

PARTE C

$$
\begin{array}{rl}
2x_1 & ¿3 \\
x_1+1.5x_2 & ¿4.5 \\
-3x_2+0.5x_3 & ¿-6.6 \\
2x_1-2x_2+x_3+x_4 & ¿0.8
\end{array}
$$

```
A = [[2,0,0,0],[1,1.5,0,0],[0,-3,0.5,0],[2,-2,1,1]]
b = [3,4.5,-6.6,0.8]
L,U = descomposicion_LU(A)
print("\nMatriz L:\n",L)
print("\nMatriz U:\n",U)
y = eliminacion_gaussiana_L(L,b)
print("\nValor de y:", y,"\n")
x = eliminacion_gaussiana_U(U,y)
print("\nValor de la solución x:", x)
```

```
Matriz L:
 [[ 1.          0.          0.          0.        ]
 [ 0.5         1.          0.          0.        ]
 [ 0.         -2.          1.          0.        ]
 [ 1.         -1.33333333  2.          1.        ]]

Matriz U:
 [[2.  0.  0.  0. ]
 [0.  1.5 0.  0. ]
 [0.  0.  0.5 0. ]
 [0.  0.  0.  1. ]]

[[ 1.          0.          0.          0.          3.        ]
 [ 0.          1.          0.          0.          3.        ]
 [ 0.         -2.          1.          0.         -6.6       ]
 [ 1.         -1.33333333  2.          1.          0.8       ]]

[[ 1.          0.          0.          0.          3.        ]
```

```
 [ 0.          1.          0.          0.          3.        ]
 [ 0.         -2.          1.          0.         -6.6       ]
 [ 1.         -1.33333333  2.          1.          0.8       ]]

[[ 1.          0.          0.          0.          3.        ]
 [ 0.          1.          0.          0.          3.        ]
 [ 0.         -2.          1.          0.         -6.6       ]
 [ 0.         -1.33333333  2.          1.         -2.2       ]]

[[ 1.          0.          0.          0.          3.        ]
 [ 0.          1.          0.          0.          3.        ]
 [ 0.          0.          1.          0.         -0.6       ]
 [ 0.         -1.33333333  2.          1.         -2.2       ]]

[[ 1.   0.   0.   0.   3. ]
 [ 0.   1.   0.   0.   3. ]
 [ 0.   0.   1.   0.  -0.6]
 [ 0.   0.   2.   1.   1.8]]

[[ 1.   0.   0.   0.   3. ]
 [ 0.   1.   0.   0.   3. ]
 [ 0.   0.   1.   0.  -0.6]
 [ 0.   0.   0.   1.   3. ]]

Valor de y: [ 3.   3.  -0.6  3. ]

[[ 2.          0.          0.          0.          3.        ]
 [ 0.          1.5         0.          0.          3.        ]
 [ 0.          0.          0.5         0.         -0.60000002]
 [ 0.          0.          0.          1.          3.        ]]

[[ 2.          0.          0.          0.          3.        ]
 [ 0.          1.5         0.          0.          3.        ]
 [ 0.          0.          0.5         0.         -0.60000002]
 [ 0.          0.          0.          1.          3.        ]]

[[ 2.          0.          0.          0.          3.        ]
 [ 0.          1.5         0.          0.          3.        ]
 [ 0.          0.          0.5         0.         -0.60000002]
 [ 0.          0.          0.          1.          3.        ]]

[[ 2.          0.          0.          0.          3.        ]
 [ 0.          1.5         0.          0.          3.        ]
 [ 0.          0.          0.5         0.         -0.60000002]
 [ 0.          0.          0.          1.          3.        ]]

[[ 2.          0.          0.          0.          3.        ]
 [ 0.          1.5         0.          0.          3.        ]
 [ 0.          0.          0.5         0.         -0.60000002]
 [ 0.          0.          0.          1.          3.        ]]
```

```
[[ 2.          0.          0.          0.          3.        ]
 [ 0.          1.5         0.          0.          3.        ]
 [ 0.          0.          0.5         0.         -0.60000002]
 [ 0.          0.          0.          1.          3.        ]]

[[ 2.          0.          0.          0.          3.        ]
 [ 0.          1.5         0.          0.          3.        ]
 [ 0.          0.          0.5         0.         -0.60000002]
 [ 0.          0.          0.          1.          3.        ]]

Valor de la solución x: [ 1.5  2.  -1.2  3. ]
```

PARTE D

$$
\begin{array}{rl}
2.1756\,x_1 + 4.0231\,x_2 - 2.1732\,x_3 + 5.1967\,x_4 & ¿17.102 \\
-4.0231\,x_1 + 6.0000\,x_2 + 0\,x_3 + 1.1973\,x_4 & ¿-6.1593 \\
-1.0000\,x_1 - 5.2107\,x_2 + 1.1111\,x_3 + 0\,x_4 & ¿3.0004 \\
6.0235\,x_1 + 7.0000\,x_2 + 0\,x_3 - 4.1561\,x_4 & ¿0.0000
\end{array}
$$

```
A = [[2.1756,4.0231,-2.1732,5.1967],[-4.0231,6.0000,0,1.1973],[-1,-
5.2107,1.1111,0],[6.0235,7.0000,0,-4.1561]]
b = [17.102,-6.1593,3.0004,0.0000]
L,U = descomposicion_LU(A)
print("\nMatriz L:\n",L)
print("\nMatriz U:\n",U)
y = eliminacion_gaussiana_L(L,b)
print("\nValor de y:", y,"\n")
x = eliminacion_gaussiana_U(U,y)
print("\nValor de la solución x:", x)
```

```
Matriz L:
 [[ 1.          0.          0.          0.        ]
 [-1.84919103  1.          0.          0.        ]
 [-0.45964332 -0.25012194  1.          0.        ]
 [ 2.76866152 -0.30794361 -5.35228302  1.        ]]

Matriz U:
 [[ 2.17560000e+00  4.02310000e+00 -2.17320000e+00  5.19670000e+00]
 [ 0.00000000e+00  1.34394804e+01 -4.01866194e+00  1.08069910e+01]
 [ 0.00000000e+00  4.44089210e-16 -8.92952394e-01  5.09169403e+00]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.20361280e+01]]

[[ 1.          0.          0.          0.         17.102     ]
 [ 0.          1.          0.          0.         25.46556496]
 [-0.45964332 -0.25012194  1.          0.          3.0004    ]
 [ 2.76866152 -0.30794361 -5.35228302  1.          0.        ]]
```

```
[[ 1.          0.          0.          0.         17.102     ]
 [ 0.          1.          0.          0.         25.46556496]
 [ 0.         -0.25012194  1.          0.         10.86122   ]
 [ 2.76866152 -0.30794361 -5.35228302  1.          0.        ]]

[[  1.           0.           0.           0.          17.102     ]
 [  0.           1.           0.           0.          25.46556496]
 [  0.          -0.25012194   1.           0.          10.86122   ]
 [  0.          -0.30794361  -5.35228302   1.         -47.34964929]]

[[  1.           0.           0.           0.          17.102     ]
 [  0.           1.           0.           0.          25.46556496]
 [  0.           0.           1.           0.          17.23071662]
 [  0.          -0.30794361  -5.35228302   1.         -47.34964929]]

[[  1.           0.           0.           0.          17.102     ]
 [  0.           1.           0.           0.          25.46556496]
 [  0.           0.           1.           0.          17.23071662]
 [  0.           0.          -5.35228302   1.         -39.50769122]]

[[ 1.          0.          0.          0.         17.102     ]
 [ 0.          1.          0.          0.         25.46556496]
 [ 0.          0.          1.          0.         17.23071662]
 [ 0.          0.          0.          1.         52.71598078]]

Valor de y: [17.102    25.465565 17.230717 52.71598 ]

[[ 2.17560000e+00  4.02310000e+00 -2.17320000e+00  5.19670000e+00
   1.71019993e+01]
 [ 0.00000000e+00  1.34394804e+01 -4.01866194e+00  1.08069910e+01
   2.54655647e+01]
 [ 0.00000000e+00  4.44089210e-16 -8.92952394e-01  5.09169403e+00
   1.72307167e+01]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.20361280e+01
   5.27159805e+01]]

[[ 2.17560000e+00  4.02310000e+00 -2.17320000e+00  5.19670000e+00
   1.71019993e+01]
 [ 0.00000000e+00  1.34394804e+01 -4.01866194e+00  1.08069910e+01
   2.54655647e+01]
 [ 0.00000000e+00  4.44089210e-16 -8.92952394e-01  0.00000000e+00
  -5.06994697e+00]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.20361280e+01
   5.27159805e+01]]

[[ 2.17560000e+00  4.02310000e+00 -2.17320000e+00  5.19670000e+00
   1.71019993e+01]
 [ 0.00000000e+00  1.34394804e+01 -4.01866194e+00  0.00000000e+00
  -2.18670265e+01]
 [ 0.00000000e+00  4.44089210e-16 -8.92952394e-01  0.00000000e+00
```

```
  -5.06994697e+00]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.20361280e+01
   5.27159805e+01]]

[[ 2.17560000e+00  4.02310000e+00 -2.17320000e+00  0.00000000e+00
  -5.65857084e+00]
 [ 0.00000000e+00  1.34394804e+01 -4.01866194e+00  0.00000000e+00
  -2.18670265e+01]
 [ 0.00000000e+00  4.44089210e-16 -8.92952394e-01  0.00000000e+00
  -5.06994697e+00]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.20361280e+01
   5.27159805e+01]]

[[ 2.17560000e+00  4.02310000e+00 -2.17320000e+00  0.00000000e+00
  -5.65857084e+00]
 [ 0.00000000e+00  1.34394804e+01  0.00000000e+00  0.00000000e+00
   9.49870688e-01]
 [ 0.00000000e+00  4.44089210e-16 -8.92952394e-01  0.00000000e+00
  -5.06994697e+00]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.20361280e+01
   5.27159805e+01]]

[[ 2.17560000e+00  4.02310000e+00  0.00000000e+00  0.00000000e+00
   6.68028266e+00]
 [ 0.00000000e+00  1.34394804e+01  0.00000000e+00  0.00000000e+00
   9.49870688e-01]
 [ 0.00000000e+00  4.44089210e-16 -8.92952394e-01  0.00000000e+00
  -5.06994697e+00]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.20361280e+01
   5.27159805e+01]]

[[ 2.17560000e+00  0.00000000e+00  0.00000000e+00  0.00000000e+00
   6.39593946e+00]
 [ 0.00000000e+00  1.34394804e+01  0.00000000e+00  0.00000000e+00
   9.49870688e-01]
 [ 0.00000000e+00  4.44089210e-16 -8.92952394e-01  0.00000000e+00
  -5.06994697e+00]
 [ 0.00000000e+00  0.00000000e+00  0.00000000e+00  1.20361280e+01
   5.27159805e+01]]

Valor de la solución x: [2.9398508  0.07067764 5.677735   4.3798122 ]
```

REPOSITORIO:

https://github.com/ImYasid/METODOS_NUMERICOS.git

REFERENCIAS BIBLIOGRÁFICAS:

[1] Richard L. Burden, 2017. Análisis Numérico. Lugar de publicación: 10ma edición. Editorial Cengage Learning.

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Se utilizo IA para la optimización de código adicional al mejoramiento de la gramática del texto para un mejor entendimiento.