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Solving the Linear Equation by Using Python Code

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ABSTRACT

In this paper we will introduce the study of solving linear equation. Gauss-elimination and Gauss-Jordan elimination by using python code. This paper aims that students can easily and quickly calculate the linear problems by using python code. Gauss-elimination and Gauss-Jordan elimination are linking the application problem such that electrical networks, traffic flow and commodity marked. By studying this theorem, they know the important characteristics of matrices, concept of vector spaces and properties of special categories of matrices. And also they can know how to use characteristics of matrix to solve a liner system of equations or study properties of a linear transformation.

Keywords: Linear equation, Gauss-Elimination, Gauss-Jordan Elimination, Python code, Electrical network.

I. INTRODUCTION

We now come to one of the most important use of matrices, that is, using matrices to solve system of linear equations. We showed informally, how to represent the information contained in a system of linear equations by a matrix called the augmented matrix. This matrix will then be used in solving the linear system of equations. Our approach to solving linear systems is called the Gauss-elimination method. Since, this method is so fundamental to linear algebra, the student should be alert. A shorter term for system of linear equation is just linear systems model many application in engineering, economics, statistics and many other areas. Electrical networks, traffic flow and commodity markets may serve as specific example of applications.

II. METHODS AND MATERIAL

A. Fundamental Theorem for Linear System

Let's suppose this system of linear equations

$$a_{11}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n = b_1$$
$$a_{21}x_1 + a_{22}x_2 + \cdots + a_{2n}x_n = b_2$$
$$\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots$$
$$a_{n1}x_1 + a_{n2}x_2 + \cdots + a_{nn}x_n = b_n$$

The Matrix Form of the System

$$\boldsymbol{Ax = b}$$

$$A = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ \dots & \dots & \dots & \dots \\ a_{n1} & a_{n2} & \dots & a_{nn} \end{bmatrix}, x = \begin{bmatrix} x_1 \\ x_2 \\ \dots \\ x_n \end{bmatrix}, b = \begin{bmatrix} b_1 \\ b_2 \\ \dots \\ b_n \end{bmatrix}$$

Stage 1: Elimination

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix}$$

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ 0 & a_{22} & a_{23} & a_{24} \\ 0 & a_{32} & a_{33} & a_{34} \\ 0 & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix}$$

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ 0 & a_{22} & a_{23} & a_{24} \\ 0 & 0 & a_{33} & a_{34} \\ 0 & 0 & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix}$$

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ 0 & a_{22} & a_{23} & a_{24} \\ 0 & 0 & a_{33} & a_{34} \\ 0 & 0 & 0 & a_{44} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix}$$

Stage 2: Back Substitutio

$$a_{11}x_1 + a_{12}a_2 + a_{13}x_3 + a_{14}x_4 = b_1$$

$$a_{22}x_2 + a_{23}x_3 + a_{24}x_4 = b_2$$

$$a_{33}x_3 + a_{34}x_4 = b_3$$

$$a_{44}x_4 = b_4$$

$$x_4 = \frac{b_4}{a_{44}}$$

$$x_3 = \frac{(b_4 - a_{34}x_4)}{a_{33}}$$

$$x_2 = \frac{(b_2 - a_{23}x_3 - a_{24}x_4)}{a_{22}}$$

$$x_1 = \frac{(b_1 - a_{12}x_2 - a_{13}x_3 - a_{14}x_4)}{a_{11}}$$

B. Determination of the Inverse by the Gauss-Jordan Method

$$\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \cdots & \cdots & \cdots & \cdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ \cdots \\ x_n \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ \cdots \\ b_n \end{bmatrix}$$

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix}$$

$$\begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} \\ 0 & a_{22} & a_{23} & a_{24} \\ 0 & a_{32} & a_{33} & a_{34} \\ 0 & a_{42} & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix}$$

$$\begin{bmatrix} 1 & 0 & a_{13} & a_{14} \\ 0 & 1 & a_{23} & a_{24} \\ 0 & 0 & a_{33} & a_{34} \\ 0 & 0 & a_{43} & a_{44} \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix}$$

General Formulas

Step 1. Transformation of the pivot row

$$a^*_{k,j} = \frac{a_{k,j}}{a_{k,k}}, b^*_k = \frac{b_k}{a_{k,k}} \quad k = 1,2,\ldots,n, j = k,\ldots,n$$

Step 2: Transformation of non-pivot rows

$$a^*_{i,j} = a_{i,j} - a_{i,k}\, a^*_{k,j} \quad , \quad b^*_i = b_i - a_{i,k}\; b^*_k$$

$$where, k = 1,2,\ldots,n, i = 1,\ldots,n,$$

$$i \neq k, j = k,\ldots,n$$

$1. If\ a_{i,k} = 0, skip\ row\ i.$

$2. Apply\ partial\ pivoting\ at\ each\ elimination.$

III. RESULTS AND DISCUSSION

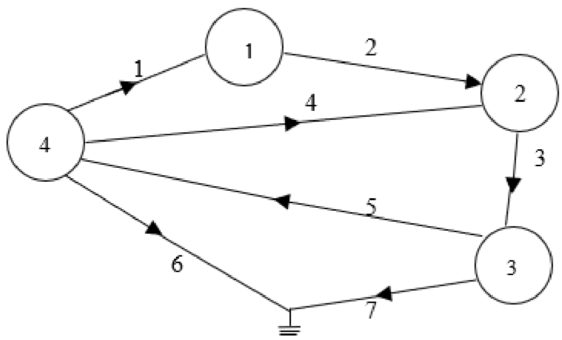

Figure 1. Electric Networks

Figure-1 presents an electrical network having seven branches and four nodes. One of the nodes is reference node. All the nodes are numbered except the reference node. We also numbered except the reference node. We also number and direct the branches.

We can now use 1.1 to form the nodal incidence matrices, we will need a computation table to relate the nodes.

Table 1.

Computation table for Electrical Network in Figure 1

No : of no de	Bra nc h 1	Bra nch 2	Bran ch 3	Bra nch 4	Bra nch 5	Bra nch 6	Bra nc h 7
No de	1	1	0	1	0	0	0

1							
Node 2	0	-1	1	-1	0	0	0
Node 3	0	0	1	0	1	0	1
Node 4	-1	0	0	1	-1	1	0

The nodal incidence matrix is now a 4×7 matrix given by

$$A = \begin{bmatrix} 1 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & -1 & 1 & -1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 & 1 \\ -1 & 0 & 0 & 1 & 1 & 1 & 0 \end{bmatrix}$$

To construct the electrical network in figure 1 from the nodal incidence matrix above, we will follow the reverse operation of the step above,

From the nodal incidence matrix, we will construct table-1 to show us clearly now the nodes and branches are related.

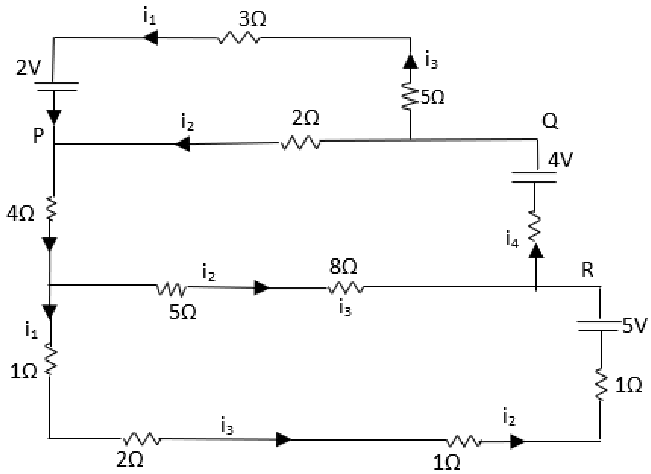

Figure 3. Network and relating the current

$Node\ P$: $3i_1 - 2i_2 + 5i_3 = 2$
$Node\ Q$: $4i_1 + 5i_2 + 8i_3 + i_4 = 4$
$Node\ R$: $4i_1 + 5i_2 + 8i_3 + i_4 = 4$
$Upper\ Loop$: $i_1 + i_2 + 2i_3 + i_4 = 5$
$Lower\ Loop$: $2i_1 + 7i_2 + 6i_3 + 5i_4 = 7$

(A)Solve the following linear system by using Gauss-elimination.

$$3x_1 - 2x_2 + 5x_3 = 2$$
$$4x_1 + 5x_2 + 8x_3 + x_4 = 4$$
$$x_1 + x_2 + 2x_3 + x_4 = 5$$
$$2x_1 + 7x_2 + 6x_3 + 5x_4 = 7$$

$$\begin{bmatrix} 3 & -2 & 5 & 0 \\ 4 & 5 & 8 & 1 \\ 1 & 1 & 2 & 1 \\ 2 & 7 & 6 & 5 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \end{bmatrix}$$

$$\begin{matrix} 0 \\ 1 \\ 2 \\ 3 \end{matrix} \left[\begin{array}{cccc|c} 0 & 1 & 2 & 3 & b \\ 3 & -2 & 5 & 0 & 2 \\ 4 & 5 & 8 & 1 & 4 \\ 1 & 1 & 2 & 1 & 5 \\ 2 & 7 & 6 & 5 & 7 \end{array}\right]$$

$$\frac{a[0,0]}{a[1,0]} = \frac{3}{4} = 0.75 \quad \times row[1]$$

$$\frac{a[0,0]}{a[2,0]} = \frac{3}{1} = 3 \quad \times row[2]$$

$$\frac{a[0,0]}{a[3,0]} = \frac{3}{2} = 1.5 \quad \times row[3]$$

$$\begin{matrix} 0 \\ 1 \\ 2 \\ 3 \end{matrix} \left|\begin{array}{cccc|c} 0 & 1 & 2 & 3 & b \\ 3 & -2 & 5 & 0 & 2 \\ 3 & 3.75 & 6 & 0.75 & 3 \\ 3 & 3 & 6 & 3 & 15 \\ 3 & 10.5 & 9 & 7.5 & 10.5 \end{array}\right.$$

$$\frac{a[1,1]}{a[2,1]} = \frac{-5.75}{-5} = 1.15 \quad \times row[2]$$

$$\frac{a[1,1]}{a[3,1]} = \frac{-5.75}{-12.5} = 0.46 \quad \times row[3]$$

$$\begin{matrix} 0 \\ 1 \\ 2 \\ 3 \end{matrix} \left|\begin{array}{cccc|c} 0 & 1 & 2 & 3 & b \\ 3 & -2 & 5 & 0 & 2 \\ 0 & -5.75 & -1 & -0.75 & -1 \\ 0 & -5 & -1 & -3 & -13 \\ 0 & -12.5 & -4 & -7.5 & -8.5 \end{array}\right.$$

$$\frac{a[1,1]}{a[2,1]} = \frac{-5.75}{-5} = 1.15 \quad \times row[2]$$

$$\frac{a[1,1]}{a[3,1]} = \frac{-5.75}{-12.5} = 0.46 \quad \times row[3]$$

$$\begin{array}{c|cccc|c} & 0 & 1 & 2 & 3 & b \\ 0 & 3 & -2 & 5 & 0 & 2 \\ 1 & 0 & -5.75 & -1 & -0.75 & -1 \\ 2 & 0 & -5.75 & -1.15 & -3.45 & -14.95 \\ 3 & 0 & -5.7.5 & -1.84 & -3.45 & -3.91 \end{array}$$

$$\begin{array}{c|cccc|c} & 0 & 1 & 2 & 3 & b \\ 0 & 3 & -2 & 5 & 0 & 2 \\ 1 & 0 & -5.75 & -1 & -0.75 & -1 \\ 2 & 0 & 0 & 0.15 & 2.7 & 13.95 \\ 3 & 0 & 0 & 0.84 & 2.7 & 2.91 \end{array}$$

$$\frac{a[2,2]}{a[3,2]} = \frac{0.15}{0.84} = 0.178571 \quad \times row[3]$$

$$\begin{array}{c|cccc|c} & 0 & 1 & 2 & 3 & b \\ 0 & 3 & -2 & 5 & 0 & 2 \\ 1 & 0 & -5.75 & -1 & -0.75 & -1 \\ 2 & 0 & 0 & 0.15 & 2.7 & 13.95 \\ 3 & 0 & 0 & 0.15 & 0.482143 & 0.519643 \end{array}$$

$$\begin{array}{c|cccc|c} & 0 & 1 & 2 & 3 & b \\ 0 & 3 & -2 & 5 & 0 & 2 \\ 1 & 0 & -5.75 & -1 & -0.75 & -1 \\ 2 & 0 & 0 & 0.15 & 2.7 & 13.95 \\ 3 & 0 & 0 & 0 & 2.217857 & 13.430357 \end{array}$$

$$x[3] = \frac{b[3]}{a[3,3]} = \frac{13.430357}{2.217857} = 6.055556$$

$$x[2] = \frac{(b[2] - a[2,3] * x[3])}{a[2,2]}$$

$$= \frac{[13.95 - 2.7 \times 6.055556]}{0.15} = -16$$

$$x[1] = \frac{(b[1] - a[1,3] * x[3] - a[1,2] * x[2])}{a[1,1]}$$

$$= \frac{[-1 - (-0.75) \times 6.055556 - (-1) \times (-16)]}{(-5.75)}$$

$$= 2.166667$$

$$x[0] = \frac{(b[0] - a[0,3] * x[3] - a[0,2] * x[2] - a[0,1] * x[1])}{a[001]} = \frac{[2 - 0 \times 6.055556 - 5 \times (-16) - (-2) \times 2.166667]}{3} = 28.777778$$

The solution is $\begin{bmatrix} x_0 \\ x_1 \\ x_2 \\ x_3 \end{bmatrix} = \begin{bmatrix} 28.77778 \\ 2.166667 \\ -16 \\ 6.055556 \end{bmatrix}$

(B) Solving the linear equation of Gauss-elimination by using Python Code

Code

```
            [2,7,6,5]]),float)
b=array([2,4,5,7],float)
n=len(b)
x=zeros(n,float)
#Elimination
for k in range(n-1):
    for i in range(k+1,n):
        If a[i,k]==0 : continue
        factor=a[k,k]/a[i,k]
        for j in range (k,n):
            a[i.j]=a[k,j]-a[i.j]*factor
        b[i]=b[k]-b[i]*factor
print(a)
print(b)
#Back-substitution
X[n-1]=b[n-1]/a[n-1,n-1]
for i in range(n-2,-1,-1):
```

The solution of the system is [28.777777778, .1666668, -16, 6.0555556]

(C) Solve the following linear system by using Gauss-Jordan elimination.

$$a = \begin{bmatrix} 0 & 2 & 0 & 1 \\ 2 & 2 & 3 & 2 \\ 4 & -3 & 0 & 1 \\ 6 & 1 & -6 & -5 \end{bmatrix}, b = \begin{bmatrix} 0 \\ -2 \\ -7 \\ 6 \end{bmatrix}$$

$$\begin{array}{c|cccc|c} & 0 & 1 & 2 & 3 & b \\ 0 & 0 & 2 & 0 & 1 & 0 \\ 1 & 2 & 2 & 3 & 2 & -2 \\ 2 & 4 & -3 & 0 & 1 & -7 \\ 3 & 6 & 1 & -6 & -5 & 6 \end{array}$$

$$\begin{array}{c|cccc|c} & 0 & 1 & 2 & 3 & b \\ 0 & 2 & 2 & 3 & 2 & -2 \\ 1 & 0 & 2 & 0 & 1 & 0 \\ 2 & 4 & -3 & 0 & 1 & -7 \\ 3 & 6 & 1 & -6 & -5 & 6 \end{array}$$

$$Row[0] = Row[0]/2$$

$$\begin{array}{c|cccc|c} & 0 & 1 & 2 & 3 & b \\ 0 & 1 & 1 & 1.5 & 1 & -1 \\ 1 & 0 & 2 & 0 & 1 & 0 \\ 2 & 4 & -3 & 0 & 1 & -7 \\ 3 & 6 & 1 & -6 & -5 & 6 \end{array}$$

$$Row[2] = Row[2] - 4 * Row[0]$$

$$Row[3] = Row[3] - 6 * Row[0]$$

$$\begin{array}{c|cccc|c} & 0 & 1 & 2 & 3 & b \\ 0 & 1 & 1 & 1.5 & 1 & -1 \\ 1 & 0 & 2 & 0 & 1 & 0 \\ 2 & 0 & -7 & -6 & -3 & -3 \\ 3 & 0 & -5 & -15 & -11 & 12 \end{array}$$

$$Row[1] = Row[1]/2$$

$$\begin{array}{c|cccc|c} & 0 & 1 & 2 & 3 & b \\ 0 & 1 & 1 & 1.5 & 1 & -1 \\ 1 & 0 & 1 & 0 & 0.5 & 0 \\ 2 & 0 & -7 & -6 & -3 & -3 \\ 3 & 0 & -5 & -15 & -11 & 12 \end{array}$$

$$Row[0] = Row[0] - 1 * Row[1]$$
$$Row[2] = Row[2] - (-7) * Row[1]$$
$$Row[3] = Row[3] - (-5) * Row[1]$$

$$\begin{array}{c|cccc|c} & 0 & 1 & 2 & 3 & b \\ 0 & 1 & 0 & 1.5 & 0.5 & -1 \\ 1 & 0 & 1 & 0 & 0.5 & 0 \\ 2 & 0 & 0 & 1 & -0.0833 & 0.5 \\ 3 & 0 & 0 & -15 & -8.5 & 12 \end{array}$$

$$Row[0] = Row[0] - 1.5 * Row[2]$$
$$Row[3] = Row[3] - (-1.5) * Row[2]$$

$$\begin{array}{c|cccc|c} & 0 & 1 & 2 & 3 & b \\ 0 & 1 & 0 & 0 & 0.625 & -1.75 \\ 1 & 0 & 1 & 0 & 0.5 & 0 \\ 2 & 0 & 0 & 1 & -0.0833 & 0.5 \\ 3 & 0 & 0 & 0 & -9.75 & 19.5 \end{array}$$

$$Row[3] = Row[3]/(-9.75)$$

$$\begin{array}{c|cccc|c} & 0 & 1 & 2 & 3 & b \\ 0 & 1 & 0 & 0 & 0.625 & -1.75 \\ 1 & 0 & 1 & 0 & 0.5 & 0 \\ 2 & 0 & 0 & 1 & -0.0833 & 0.5 \\ 3 & 0 & 0 & 0 & 1 & -2 \end{array}$$

$$Row[0] = Row[0] - (0.625) * Row[3]$$
$$Row[1] = Row[1] - (0.5) * Row[3]$$
$$Row[2] = Row[2] - (-0.0833) * Row[3]$$

$$\begin{array}{c|cccc|c} & 0 & 1 & 2 & 3 & b \\ 0 & 1 & 0 & 0 & 0 & -0.5 \\ 1 & 0 & 1 & 0 & 0 & 1 \\ 2 & 0 & 0 & 1 & 0 & 0.3333 \\ 3 & 0 & 0 & 0 & 1 & -2 \end{array}$$

The solution of the system $\begin{bmatrix} -0.5 \\ 1 \\ 0.3333 \\ -2 \end{bmatrix}$

(D) Solving the linear equation of Gauss-Jordan elimination by using Python Code

```
#main loop
for k in range (n):
   #Partial Pivotin g
    If np.fabs (a[k, k] )<1.0e-12: import numpy as np
def gassjrdn(a,b):
    a=np.array (a, float)
    b=np.array (b, float)
   n=len (b)
      For i in range (k+1,n):
          If np . fabs (a [i , k]) > np . fabs (a[k , k]) :
             for j in range (k , n) :
                 a [k, j] , a [i , j ] = a [i, j] , a [i,j ], a [k, j]
                b[k] ,b [i] =b [i] , b [k]
                break
#Division of the pivot row
pivot = a[k , k]
for j in range (k , n):
    a [k, j] / = pivot
b [k] /= pivot
#Elimination loop
for i in range (n) :
    if I == k or a [i, k] == 0: continue
    factor = a [ i , k]
 a = [ [0,2,0,1] , [2,2,3,2] , [4,-3,0,1], [6,1,--6,-5] ]
 b = [0,-2,-7,6]
 x, A = g s s j r d n (a, b)


 print ("The solution:")
 print (X)
 print ("The transformed [a]: ")
 print(A)
```

The solution of the system is [-0.5, 1, 0.333333333, -2

IV. CONCLUSION

In this paper, firstly we have considered how to derive nodal incidence matrices from electrical networks, conversely how to sketch electrical networks from nodal incidence matrices. Secondly, we calculate the linear equation by using python code with two methods. The paper aims to show that linear equation is calculated. The advantage of this paper is that it would be desirable to continuous the study of method engineering networks, networking in the computer studies and any other scientific field.

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