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Matrix Operations Through Spreadsheets

by

Sami M. Khayat, PhD

Craig N. Refugio, PhD

Negros Oriental State University, Dumaguete City, Philippines

Abstract

Matrix operation is tedious if it is done through manual computations. This paper presents how spreadsheet can do matrix operations such as addition, subtraction, multiplication, determinants, inverse, adjoint and transpose. Applications are also emphasized in this paper like solving systems of equations as well as areas of triangles drawn in a rectangular coordinate plane through spreadsheet.

A group of 19 Bachelor of Secondary Education major in Mathematics students were pre-tested and post-tested about the aforementioned matrix operations through spreadsheet. Results showed that students gained significant skills in performing matrix operations.

Introduction

This study was conducted to a group of 19 Bachelor of Secondary Education students major in Mathematics schoolyear 2011-2012, College of Education, Main Campus 1, Negros Oriental State University, Philippines using a one group pretest-posttest design. The study aimed to use spreadsheets in matrix operations and determine if students would gain significant knowledge in matrix operations upon using spreadsheets.

We conceptualized and developed teaching matrix operations through spreadsheets into 7 parts: addition, subtraction, multiplication, determinants, inverse, adjoint, transpose and applications. In discussing the different parts, the manual computations using the different rules were emphasized first before using spreadsheets so that students would really appreciate the “software” in doing the laborious and often repetitivetasks.

The Study

Matrix is defined as a rectangular array of numbers, these numbers are called the entries of the matrix, enclosed by a pair of brackets, such as:

$$A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix} \text{ and } B = \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$$

and subject to certain rules of operations. Matrix is usually denoted or named by a capital letter such as A, B, C ,... and appear in different sizes. It is defined by the number of rows and columns in the rectangular array. For example, matrix A is a (2X3) and matrix B is a (3X2). If the number of rows is equal to the number of columns, the matrix is called a square matrix. For

example: $A = \begin{bmatrix} 1 & 2 & 3 \\ 0 & 1 & 3 \\ 1 & 2 & 5 \end{bmatrix}$ is a square matrix since the number of columns and the number of rows are equal.

I. Addition and Subtraction of Matrices

Rule: Matrices can be added or subtracted if and only if they have the same sizes, and both matrices must have only real numbers as entries.

Always remember that there is no direct command in MS-Excel to add/subtract two matrices.

Example:

$$\text{Given } A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix} B = \begin{bmatrix} 7 & 8 & 9 \\ 10 & 11 & 12 \end{bmatrix} \text{ Compute the sum of A and B.}$$

To do this operation in MS-Excel, the following procedures are to be followed:

1. Input the entries to Excel. Matrix A will be in cells (A1:C2) and Matrix B cells (A5:C6) as shown below.
2. In cell A9 type =A1+A5 then press Enter.
3. Value 8 will appear as result of sum of 1+7.
4. Click on Cell A9 then Press Ctrl c to copy the cell
5. Highlight cells that range A9:C10.
6. Press Ctrl v to paste the result of adding two matrices as shown below.

You can do the same procedures for subtracting two matrices. You only need to change the command in number 2 by typing =A1-B5.

	A	B	C
1	1	2	3
2	4	5	6
3			
4			
5	7	8	9
6	10	11	12
7			
8			
9	8	10	12
10	14	16	18

II. Multiplication of Matrices.

A. Scalar Multiplication

Scalar multiplication is defined by multiplying each entry of the matrix by a certain constant k.

Example:

$$\text{Given } A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix} \text{ and the constant } k=5. \text{ Compute } kA$$

To do this operation in MS-Excel, the following procedures are to be followed:

1. Input the entries to Excel. Matrix A will be in cells (A1:C2).
2. Click on cell A5, then type =5*A1, press Enter.
3. The value of 5 will appear in Cell A5 as result of product 1 times 5.
4. Copy cell A5 by clicking on cell A5 then press Ctrl c.
5. Highlight the cells that range A5:C6.

- Press Ctrl v to paste the result of multiplying a constant (k) to matrix A as shown below.

	A	B	C
1	1	2	3
2	4	5	6
3			
4			
5	5	10	15
6	20	25	30

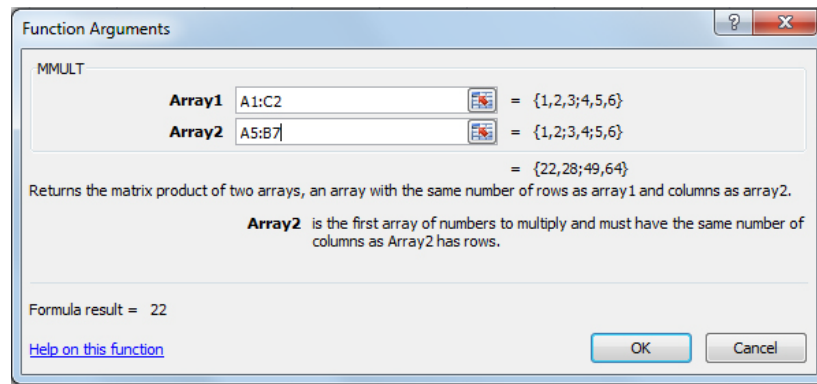
B. Multiplication of two Matrices

Rule: Matrix multiplication is possible only when the number of columns in the first matrix are equal to the number of rows in the second matrix, and both matrices must have only real numbers as entries.

Example: Given $A = \begin{bmatrix} 1 & 2 & 3 \\ 4 & 5 & 6 \end{bmatrix}$ and $B = \begin{bmatrix} 1 & 2 \\ 3 & 4 \\ 5 & 6 \end{bmatrix}$ Compute AB.

To do this operation in MS-Excel, the following procedures are to be followed:

- Input the entries to Excel. Matrix A will be in cells (A1:C2) and Matrix B cells (A5:B7)
- Select cell A9
- Click on “Formulas” in the menu bar, then select “MMULT” from “Math & Trig” Menu, or simply click on f_x and select the two matrices as shown below. Then press OK.



- Copy cell A9 by clicking on cell A5 then press Ctrl c.
- Highlight the cells that range A9:B10.
- Press F2.
- Press Ctrl + Shift + Enter, the result of multiplying two matrices will appear as shown below.

	A	B	C
1	1	2	3
2	4	5	6
3			
4			
5	1	2	
6	3	4	
7	5	6	
8			
9	22	28	
10	49	64	

III. Determinants and Singular Matrices

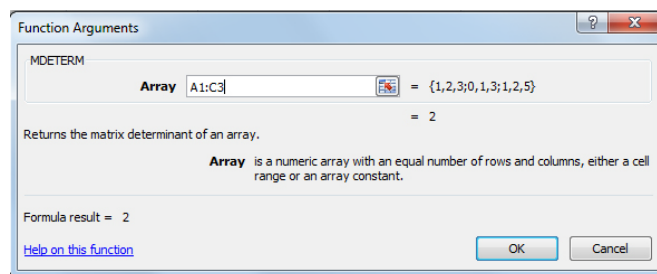
Example:

Given $A = \begin{bmatrix} 1 & 2 & 3 \\ 0 & 1 & 3 \\ 1 & 2 & 5 \end{bmatrix}$ Compute the determinant of matrix A which is usually denoted by

$\det(A)$ or $|A|$.

To do this operation in MS-Excel, the following procedures are to be followed:

1. Input the entries to Excel. Matrix A will be in cells (A1:C3).
2. Click on cell A5
3. Click on “Formulas” in the menu bar, then select “MDETERM” from “Math & Trig” Menu, or simply click on f_x , and select the Matrix A (Range From A1 to C3) as shown below. Then press OK.



4. The value 2 will appear as a result as shown below.

	A	B	C
1	1	2	3
2	0	1	3
3	1	2	5
4			
5	2		

IV. The Inverse of a Matrix

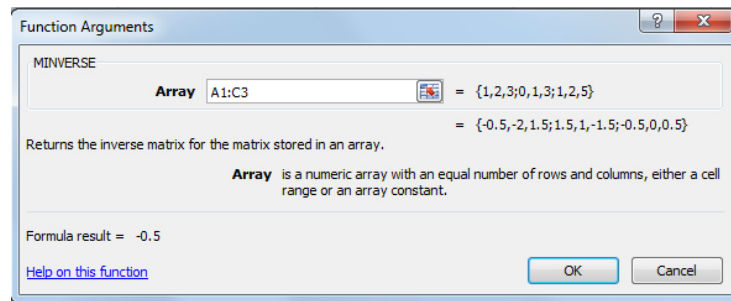
Rule: The matrix should be square a matrix and the $\det(A)$ should be non-zero. If $\det(A)=0$, the inverse matrix does not exist and A is said to be singular or noninvertible.

Example:

$$\text{Given } A = \begin{bmatrix} 1 & 2 & 3 \\ 0 & 1 & 3 \\ 1 & 2 & 5 \end{bmatrix} \text{ Compute inverse matrix } (A^{-1})$$

To do this operation in MS-Excel, the following procedures are to be followed:

1. Input the entries to Excel. Matrix A will be in cells (A1:C3).
2. Click on cell A5
3. Click on “Formulas” in the menu bar, then select “MINVERSE” from “Math & Trig” Menu, or simply click on f_x , and select the Matrix A (Range From A1 to C3) as shown below. Then press OK.



a.

4. Copy cell A5 by clicking on cell A5 then press Ctrl c.
5. Highlight the cells that range A5:C7.
6. Press F2.
7. Press Ctrl + Shift + Enter, the result of multiplying two matrices will appear as shown below.

	A	B	C
1	1	2	3
2	0	1	3
3	1	2	5
4			
5	-0.5	-2	1.5
6	1.5	1	-1.5
7	-0.5	0	0.5

8. If you want an output in fraction form, do the following:
 - a. Select the output cells ranged from A5 to C7.
 - b. Press Ctrl 1 to open Format Cell.
 - c. Select Number then click on Fraction
 - d. Select the appropriate type for your output. Then press ok.

-	1/2	-2	1	1/2
1	1/2	1	-1	1/2
-	1/2	0		1/2

V. Adjoint of Matrix $Adj(A)$.

Rule: If A a square matrix and $\det(A) \neq 0$, then $A^{-1} = \frac{1}{\det(A)} Adj(A)$

Example:

Given $A = \begin{bmatrix} 1 & 2 & 3 \\ 0 & 1 & 3 \\ 1 & 2 & 5 \end{bmatrix}$ Compute $Adj(A)$.

To do this operation in MS-Excel, the following procedures are to be followed:

1. Input the entries to Excel. Matrix A will be in cells (A1:C3).
2. As described above, do the following:
 - a. Compute $\det(A)$.
 - b. Compute A^{-1} .
 - c. Multiply A^{-1} by the $\det(A)$.

	A	B	C
1	1	2	3
2	0	1	3
3	1	2	5
4			
5	-1	-4	3
6	3	2	-3
7	-1	0	1

VI. Transpose of Matrix A^T

Rule: Transpose means to change column of the matrix to rows and vice versa.

Example:

Given $A = \begin{bmatrix} 1 & 2 & 3 \\ 0 & 1 & 3 \\ 1 & 2 & 5 \end{bmatrix}$ Find the transpose of A which is usually denoted by matrix (A^T) .

To do this operation in MS-Excel, the following procedures are to be followed:

1. Input the entries to Excel. Matrix A will be in cells (A1:C3).
2. Select cells that range from A1 to C3. Then press Ctrl c to copy them.
3. Click on Cell A5

4. Click on the small arrow at Paste icon and select Transpose.

	A	B	C
1	1	2	3
2	0	1	3
3	1	2	5
4			
5	1	0	1
6	2	1	2
7	3	3	5

VII. Application

A. Solve Systems Using Matrix Equations

Rule: The determinant of A should be non-zero.

Example:

Given the system bellow:

$$X + 2Y + 3Z = 6 \quad \text{-----1}$$

$$2X - Y + Z = 2 \quad \text{-----2}$$

$$5X + 2Y = 7 \quad \text{-----3}$$

Find the value of X,Y and Z.

To solve this problem:

1. Form the matrices $AB=C$

$$\begin{bmatrix} 1 & 2 & 3 \\ 2 & -1 & 1 \\ 5 & 2 & 0 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 6 \\ 2 \\ 7 \end{bmatrix}$$

2. Find the $\det(A)$. since the $\det(A) = 35$, proceed to step 3
3. Find A^{-1} .
4. Multiply A^{-1} by C. the result is the answer for X,Y and Z.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

	A	B	C	D	E
1	1	2	3		6
2	2	-1	1		2
3	5	2	0		7
4					
5	35				
6					
7	- 2/35	6/35	1/7		
8	1/7	- 3/7	1/7		
9	9/35	8/35	- 1/7		
10					
11	1				
12	1				
13	1				

B. Compute the Area of Triangle by using the Determinants

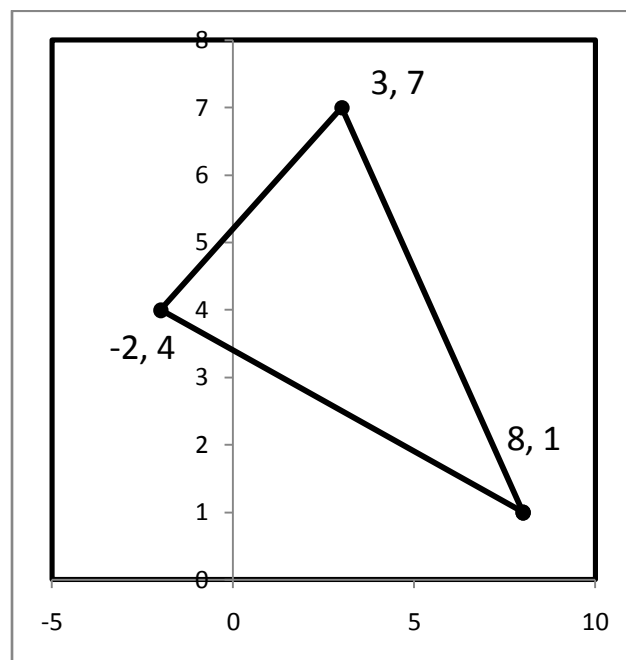
If the vertices of a triangle has vertices (a_1, b_1) , (a_2, b_2) , and (a_3, b_3) , then the area of the triangle can be calculated by using determinant as shown below:

$$Area = \mp \frac{1}{2} \begin{vmatrix} a_1 & b_1 & 1 \\ a_2 & b_2 & 1 \\ a_3 & b_3 & 1 \end{vmatrix}$$

The sign $\pm$ is chosen to make the area positive. However, the result of the determinant is always positive if you arrange the vertices of the triangle in a counter clockwise direction.

Example:

Find the area of the triangle shown below



The area can be computed as follows:

$$Area = \mp \frac{1}{2} \begin{vmatrix} 8 & 1 & 1 \\ -2 & 4 & 1 \\ 3 & 7 & 1 \end{vmatrix} = \pm \frac{1}{2} (-45) = 22.5 \text{ square units}$$

8	1	1
-2	4	1
3	7	1
-45		

Results

Before starting the formal instruction of the course, a Likert-type (0-Has No Knowledge, 1-Has Basic Knowledge, and 3-Has Advanced Knowledge) pretest that contains 14 items was conducted to find out if the students had prior knowledge of the seven aforementioned parts of the designed course. At the end of the course, a post-test (items were the same to pretest but randomly reordered) was then administered.

The pretest and posttest were designed in such a way that students answered them in written form and their respective answers were counter checked during the hands on activities for the pretest and posttest. We matched their written ratings and the ratings that we gave during the pretest and posttest hands on activities. Results indicated perfect matching between the two types of ratings.

Table 1.0 shows the knowledge levels of the 19 subjects of this study.

Table 1.0 Pretest and Posttest Knowledge Levels
in Matrix Operations through Spreadsheets
n=19

Type of Test	Mean	Standard Deviation	Description
Pretest	0.63	0.50	Has No Knowledge
Posttest	1.84	0.37	Has Advanced knowledge

Legend:

0.00-0.66	Has No Knowledge
0.67-1.33	Has Basic Knowledge
1.34-2.00	Has Advanced knowledge

As reflected in table 1.0, the pretest mean score (0.63) disclosed that the 19 subjects of the study had no knowledge of the seven different parts of the course from addition of matrices to its applications. This is being substantiated when we let the students browse and operate matrices using spreadsheets in accordance with the seven parts of the course. Twelve out of 19 manifested/demonstrated basic knowledge and the remaining 7 had no knowledge at all.

However, the post test mean score (1.84) revealed that at the end of the course, students' had gained advanced knowledge. This is further substantiated when we let the students perform tasks according to the seven parts of the course. Sixteen out of 19 manifested/demonstrated advanced knowledge while the remaining three showed basic knowledge.

The standard deviations showed that pretest scores were more variable than the posttest scores. To determine the significance of the mean difference between the pretest and posttest mean scores, a dependent t-test was performed and the results are shown in table 2.0.

Table 2.0 Test of Difference Between the Pretest and Posttest Knowledge
in Matrix Operations through Spreadsheets
n=19

Type of Test	n	Mean	Mean Difference	Standard Deviation	Computed t	Degrees of Freedom	p-value at $\alpha=0.05$	Interpretation
Pretest	19	0.63	-1.21	0.50	-12.60	18	0.000	Significant
Posttest	19	1.84		0.37				

A dependent t-test comparing the mean scores of the pretest and posttest found a significant difference between the means of the two groups ($t(18) = -12.60$, $p < 0.05$). The mean of the pretest was significantly lower ($m=0.63$, $sd=0.50$) than the mean of the posttest ($m=1.84$, $sd=0.37$). This means that the post-test disclosed that the 19 subjects gained significant knowledge in matrix operation through spreadsheets at 5% level of significance from basic to advanced knowledge level.

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