" ज्ञान , विज्ञान आणि सुसंस्कार यांसाठी शिक्षण प्रसार"

शिक्षणमहर्षी डॉ. बापूजी साळुंखे.

Shri Swami Vivekanand Shikshan Santha's

कोल्हापूर

Department of mathematics

B.Sc.III

2020 - 2021

Project work on

'APPLICATION OF MATRICES'

By

Miss. Akanksha Dhanaji Patil

Under the guidance of

Prof. Mr. S. P. Patankar **Prof. S.T.Sutar**

ROLL NO - 8138 **SEAT NO.**

" ज्ञान, विज्ञान आणि सुसंस्कार यांसाठी शिक्षण प्रसार"

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Vivekanand college, Kolhapur.

कोल्हापूर

Certificate

Department of Mathematics

This is to certify that, *Miss.* Akanksha Dhanaji Patil Student of Vivekanand college, Kolhapur has successfully completed a project on 'APPLICATION OF MATRICES in B.Sc. III year at Department of mathematics in the year 2020-2021

DATE –

PLACE – Kolhapur.

Teacher in charge **Examiner** **Head of Department**

HEAD
Department of Mathematics
Vivekanand College, Kolhapur

DECLARATION

I, the undersigned hereby declare that the project report entitled **"APPLICATION OF MATRICES"** submitted by me to **"Shivaji University, Kolhapur"** in the partial fulfillment of the requirement for the award of degree of B.Sc. III in Mathematics Department under the guidance of Prof. Patankar S. P. and Prof. Sutar S. T., is our original work. While preparing the report, we have not copied subject matter from any other report. We, understand that any such coping is liable to be punished in a way the institute authority deem fit.

Date:

Place: Kolhapur

ACKNOWLEDGEMENT

It gives me great pleasure while presenting this report on **"APPLICATION OF MATRICES"** and satisfaction and achievement envelopes the whole feelings of completion of the project in the third year 2020-2021 under the guidance of Prof. Patankar S. P. We wish to express our deep sense of gratitude to him for his valuable guidance and keen interest and co-operation without which it would have been impossible to accomplish this success.

We are also thankful to the Principal of our college Dr. R.R.Kumbhar Y.and HOD of Mathematics Department Prof. Patankar S. P. and all teaching and non-teaching staff who helped us during completion of this project.

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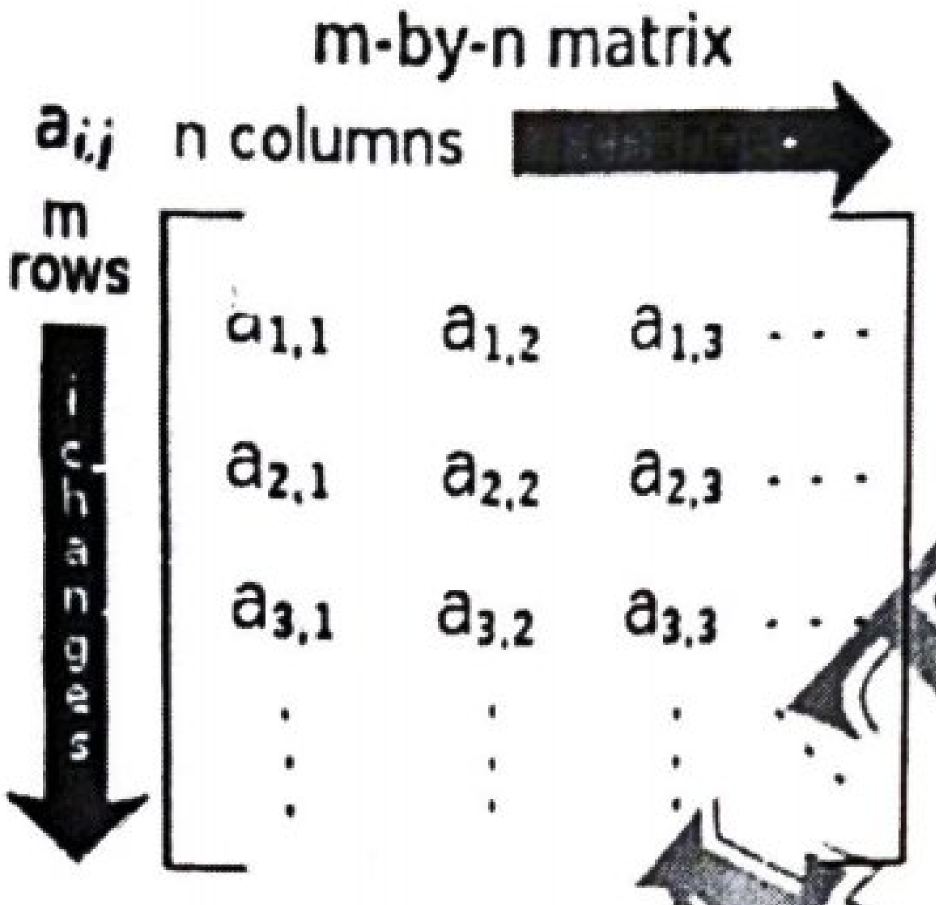
INTRODUCTION

Matrix (mathematics):-



Each element of a matrix is often denoted by a variable with two subscripts. For instance, $a_{2,1}$ represents the element at the second row and first column of a matrix A.

In mathematics, a matrix (plural matrices) is a rectangular array of numbers, symbols, or expressions arranged in rows and columns. The individual items in a matrix are called its *elements* or *entries*. An example of a matrix with 2 rows and 3 columns is

$$\begin{bmatrix} 1 & 9 & -13 \\ 20 & 5 & -6 \end{bmatrix}.$$

Matrices of the same size can be added or subtracted element by element. The rule for matrix multiplication, however, is that two matrices can be multiplied only when the number of columns in the first equals the number of rows in the second. A major application of matrices is to represent linear transformations, that is, generalizations of linear functions such as $f(x) = 4x$. For example, the rotation of vectors in three dimensional space is a linear transformation which can be represented by a rotation matrix R. If v is a column vector (a matrix with only one column) describing the position of a point in space, the product Rv is a column vector describing the position of that point after a rotation. The product of two matrices is a matrix that represents the composition of two linear transformations. Another application of matrices is in the solution of a system of linear equations. If the matrix is square, it is possible to deduce some of its properties by computing its determinant. For example, a square matrix has an inverse if and only if its determinant is not zero. Eigen values and eigen vectors provide insight into the geometry of linear transformations.

Applications of matrices are found in most scientific fields. In every branch of physics, including classical mechanics, optics, electromagnetism, quantum mechanics, and quantum electrodynamics, they are used to study physical phenomena, such as the motion of rigid bodies. In computer graphics, they are used to project a 3-dimensional image onto a 2-dimensional screen. In probability theory and statistics, stochastic matrices are used to describe sets of probabilities; for instance, they are used within the Page Rank algorithm that ranks the pages in a Google search. Matrix calculus generalizes classical analytical notions such as derivatives and exponentials to higher dimensions.

A major branch of numerical analysis is devoted to the development of efficient algorithms for matrix computations, a subject that is centuries old and is today an expanding area of research. Matrix decomposition methods simplify computations, both theoretically and practically. Algorithms that are tailored to particular matrix structures, such as sparse matrices and near-diagonal matrices, expedite computations in finite element method and other computations. Infinite matrices occur in planetary theory and in atomic theory. A simple example of an infinite matrix is the matrix representing the derivative operator, which acts on the Taylor series of a function.

Matrix

Definition:-

A matrix is a rectangular array of numbers or other mathematical objects, for which operations such as addition and multiplication are defined. Most commonly, a matrix over a field F is a rectangular array of scalars from F. Most of this article focuses on real and complex matrices, i.e., matrices whose elements are real numbers or complex numbers respectively. More general types of entries are discussed below. For instance, this is a real matrix:

$$\mathbf{A} = \begin{bmatrix} -1.3 & 0.6 \\ 20.4 & 5.5 \\ 9.7 & -6.2 \end{bmatrix}.$$

The numbers, symbols or expressions in the matrix are called its entries or its elements. The horizontal and vertical lines of entries in a matrix are called rows and columns, respectively.

Size:-

The size of a matrix is defined by the number of rows and columns that it contains. A matrix with m rows and n columns is called an m × n matrix or m-by-n matrix, while m and n are called its dimensions. For example, the matrix A above is a 3 × 2 matrix.

Matrices which have a single row are called row vectors, and those which have a single column are called column vectors. A matrix which has the same number of rows and columns is called a square matrix. A matrix with an infinite number of rows or columns (or both) is called an infinite matrix. In some contexts, such as computer algebra programs, it is useful to consider a matrix with no rows or no columns, called an empty matrix.

Name	Size	Example	Description
Row vector	$1 \times n$	$\begin{bmatrix} 3 & 7 & 2 \end{bmatrix}$	A matrix with one row, sometimes used to represent a vector
Column vector	$n \times 1$	$\begin{bmatrix} 4 \\ 1 \\ 8 \end{bmatrix}$	A matrix with one column, sometimes used to represent a vector
Square matrix	$n \times n$	$\begin{bmatrix} 9 & 13 & 5 \\ 1 & 11 & 7 \\ 2 & 6 & 3 \end{bmatrix}$	A matrix with the same number of rows and columns, sometimes used to represent a linear transformation from a vector space to itself, such as reflection, rotation, or shearing.

Notation:-

Matrices are commonly written in box brackets:

$$A = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{bmatrix}.$$

An alternative notation uses large parentheses instead of box brackets:

$$A = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{m1} & a_{m2} & \cdots & a_{mn} \end{pmatrix}.$$

The specifics of symbolic matrix notation varies widely, with some prevailing trends. Matrices are usually symbolized using upper-case letters (such as **A** in the examples above), while the corresponding lower-case letters, with two subscript indices (e.g., a_{11}, or $a_{1,1}$), represent the entries. In addition to using upper-case letters to symbolize matrices, many authors use a special typographical style, commonly boldface upright (non-italic), to further distinguish matrices from other mathematical objects. An alternative notation involves the use of a double-underline with the variable name, with or without boldface style, (e.g., $\underline{\underline{A}}$).

The entry in the i-th row and j-th column of a matrix **A** is sometimes referred to as the i,j, (i,j), or $(i,j)^{\text{th}}$ entry of the matrix, and most commonly denoted as $a_{i,j}$, or a_{ij}. Alternative notations for that entry are $A[i,j]$ or $A_{i,j}$. For example, the (1,3) entry of the following matrix **A** is 5 (also denoted a_{13}, $a_{1,3}$, $A[1,3]$ or $A_{1,3}$):

$$\mathbf{A} = \begin{bmatrix} 4 & -7 & 5 & 0 \\ -2 & 0 & 11 & 8 \\ 19 & 1 & -3 & 12 \end{bmatrix}$$

Sometimes, the entries of a matrix can be defined by a formula such as $a_{i,j} = f(i, j)$. For example, each of the entries of the following matrix **A** is determined by $a_{ij} = i - j$.

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

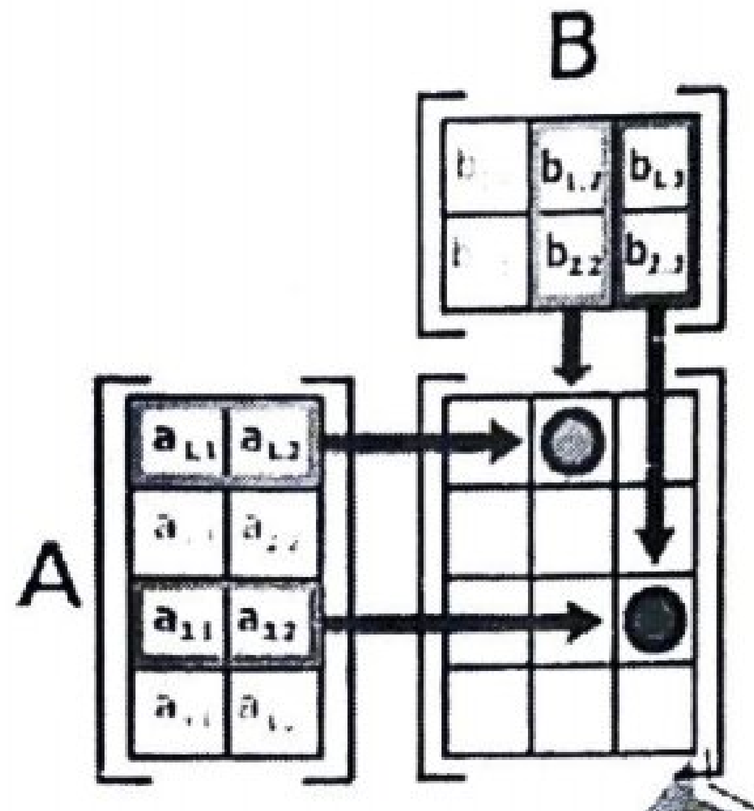
In this case, the matrix itself is sometimes defined by that formula, within square brackets or double parenthesis. For example, the matrix above is defined as $A = [i\text{-}j]$, or $A = ((i\text{-}j))$. If matrix size is $m \times n$, the above-mentioned formula $f(i, j)$ is valid for any $i = 1, ..., m$ and any $j = 1, ..., n$. This can be either specified separately, or using $m \times n$ as a subscript. For instance, the matrix A above is 3×4 and can be defined as $A = [i - j]$ $(i = 1, 2, 3; j = 1, ..., 4)$, or $A = [i - j]_{3\times4}$.

Some programming languages utilize doubly subscripted arrays (or arrays of arrays) to represent an m-×-n matrix. Some programming languages start the numbering of array indexes at zero, in which case the entries of an m-by-n matrix are indexed by $0 \le i \le m - 1$ and $0 \le j \le n - 1$. This article follows the more common convention in mathematical writing where enumeration starts from 1. The set of all m-by-n matrices is denoted (m, n).

Basic Operations

There are a number of basic operations that can be applied to modify matrices, called matrix addition, scalar multiplication, transposition, matrix multiplication, row operations, and submatrix.

Matrix multiplication:-



Schematic depiction of the matrix product **AB** of two matrices **A** and **B**.

Multiplication of two matrices is defined if and only if the number of columns of the left matrix is the same as the number of rows of the right matrix. If **A** is an m-by-n matrix and **B** is an n-by-p matrix, then their matrix product **AB** is the m-by-p matrix whose entries are given by dot product of the corresponding row of **A** and the corresponding column of **B**:

$$[\mathbf{AB}]_{i,j} = A_{i,1}B_{1,j} + A_{i,2}B_{2,j} + \cdots + A_{i,n}B_{n,j} = \sum_{r=1}^{n} A_{i,r}B_{r,j},$$

where $1 \le i \le m$ and $1 \le j \le p$. For example, the underlined entry 2340 in the product is calculated as $(2 \times 1000) + (3 \times 100) + (4 \times 10) = 2340$:

$$\begin{bmatrix} \underline{2} & \underline{3} & \underline{4} \\ 1 & 0 & 0 \end{bmatrix} \begin{bmatrix} 0 & \underline{1000} \\ 1 & \underline{100} \\ 0 & \underline{10} \end{bmatrix} = \begin{bmatrix} 3 & \underline{2340} \\ 0 & 1000 \end{bmatrix}.$$

Matrix multiplication satisfies the rules **(AB)C** = **A(BC)** (associativity), and **(A+B)C** = **AC+BC** as well as **C(A+B)** = **CA+CB** (left and right distributivity), whenever the size of the matrices is such that the various products are defined. The product **AB** may be defined without **BA** being defined, namely if A and B are m-by-n and n-by-k matrices, respectively, and $m \neq k$. Even if both products are defined, they need not be equal, i.e., generally

$$AB \neq BA,$$

i.e., matrix multiplication is not commutative, in marked contrast to (rational, real, or complex) numbers whose product is independent of the order of the factors. An example of two matrices not commuting with each other is:

$$\begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} \begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ 0 & 3 \end{bmatrix},$$

whereas

$$\begin{bmatrix} 0 & 1 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} 1 & 2 \\ 3 & 4 \end{bmatrix} = \begin{bmatrix} 3 & 4 \\ 0 & 0 \end{bmatrix}.$$

Besides the ordinary matrix multiplication just described, there exist other less frequently used operations on matrices that can be considered forms of multiplication, such as the Hadamard product and the Kronecker product. They arise in solving matrix equations such as the Sylvester equation.

Linear Equations

Matrices can be used to compactly write and work with multiple linear equations, i.e., systems of linear equations. For example, if **A** is an *m*-by-*n* matrix, **x** designates a column vector (i.e., $n \times 1$-matrix)of n variables x_1, x_2, ...,x_n, and **b** is an $m \times 1$-column vector, then the matrix equation

$$\mathbf{Ax} = \mathbf{b}$$

is equivalent to the system of linear equations

$$A_{1,1}x_1 + A_{1,2}x_2 + \ldots + A_{1,n}x_n = b_1$$

$$\ldots$$

$$A_{m,1}x_1 + A_{m,2}x_2 + \ldots + A_{m,n}x_n = b_m \, .$$

Square matrices:-

A square matrix is a matrix with the same number of rows and columns. An *n*-by-*n* matrix is known as a square matrix of order *n*. Any two square matrices of the same order can be added and multiplied. The entries a_{ii} form the main diagonal of a square matrix. They lie on the imaginary line which runs from the top left corner to the bottom right corner of the matrix.

Types of Matrices

i. Diagonal matrix
ii. Lower triangular matrix
iii. Upper triangular matrix
iv. Symmetric or skew-symmetric matrix
v. Orthogonal matrix

Invertible matrix and its inverse:-

A square matrix **A** is called *invertible* or *non-singular* if there exists a matrix **B** such that

$$\mathbf{AB} = \mathbf{BA} = \mathbf{I}_n.$$

If **B** exists, it is unique and is called the *inverse matrix* of **A**, denoted $\mathbf{A}^{-1}$.

Applications

Matrices find many applications in scientificfields and apply to practical real life problems as well, thus making an indispensable concept for solving many practical problems. . Some of them merely take advantage of the compact representation of a set of numbers in a matrix. For example, in game theory and economics, the payoff matrix encodes the payoff for two players, depending on which out of a given (finite) set of alternatives the players choose

Some of the main applications of matrices are briefed below:-

- **Physics:-**

In physics related applications, matrices are applied in the study of electrical circuits, quantum mechanics and optics. In the calculation of battery power outputs, resistor conversion of electrical energy into another useful energy, these matrices play a major role in calculations. Especially in solving the problems using Kirchoff's laws of voltage and current, the matrices are essential.•

- **In computer:-**

In computer based applications, matrices play a vital role in the projection of three dimensional image into a two dimensional screen, creating the realistic seeming motions. Stochastic matrices and Eigen vector solvers are used in the page rank algorithms which are used in the ranking of web pages in Google search. The matrix calculus is used in the generalization of analytical notions like exponentials and derivatives to their higher dimensions. One of the most important usages of matrices in computer side applications are encryption of message codes. Matrices and their inverse matrices are used for a programmer for coding or encrypting a message. A message is made as a sequence of numbers in a binary format for communication and it follows code theory for solving. Hence with the help of matrices, those equations are solved. With these encryptions only, internet functions are working and even banks could work with transmission of sensitive and private data's. Computer graphics uses matrices both to represent objects and to calculate transformations of objects using affine rotation matrices to accomplish tasks such as projecting a three-dimensional object onto a two-dimensional screen, corresponding to a theoretical camera observation. Matrices over a polynomial ring are important in the study of control theory.

- **Chemistry:-**

Chemistry makes use of matrices in various ways, particularly since the use of quantum theory to discuss molecular bonding and spectroscopy. Examples are the overlap matrix and the Fock matrix used in solving the Roothaan equations to obtain the molecular orbitals of the Hartree–Fock method.

- **Electronics:-**

Traditional mesh analysis in electronics leads to a system of linear equations that can be described with a matrix.The behaviour of many electronic components can be described using matrices. Let A be a 2-dimensional vector with the component's input voltage v_1 and input current i_1 as its elements, and let B be a 2-dimensional vector with the component's output voltage v_2 and output current i_2 as its elements. Then the behaviour of the electronic component can be described by $B = H \cdot A$, where H is a 2 x 2 matrix containing one impedance element (h_{12}), one admittance element (h_{21}) and two dimensionless elements (h_{11} and h_{22}). Calculating a circuit now reduces to multiplying matrices.

- **Geometrical optics:-**

Geometrical optics provides further matrix applications. In this approximative theory, the wave nature of light is neglected. The result is a model in which light rays are indeed geometrical rays. If the deflection of light rays by optical elements is small, the action of a lens or reflective element on a given light ray can be expressed as multiplication of a two-component vector with a two-by-two matrix called ray transfer matrix: the vector's components are the light ray's slope and its distance from the optical axis, while the matrix encodes the properties of the optical element. Actually, there are two kinds of matrices, viz. a *refraction matrix* describing the refraction at a lens surface, and a *translation matrix*, describing the translation of the plane of reference to the next refracting surface, where another refraction matrix applies. The optical system, consisting of a combination of lenses and/or reflective elements, is simply described by the matrix resulting from the product of the components' matrices.

- **Normal modes:-**

A general application of matrices in physics is to the description of linearly coupled harmonic systems. The equations of motion of such systems can be described in matrix form, with a mass matrix multiplying a generalized velocity to give the kinetic term, and a force matrix multiplying a displacement vector to characterize the interactions. The best way to obtain solutions is to determine the system's eigenvectors, its normal modes, by diagonalizing the matrix equation. Techniques like this are crucial when it comes to the internal dynamics of molecules: the internal vibrations of systems consisting of mutually bound component atoms.[96] They are also needed for describing mechanical vibrations, and oscillations in electrical circuits.

- **In geology:-**

In geology, matrices are used for taking seismic surveys. They are used for plotting graphs, statistics and also to do scientific studies in almost different fields.

- **In GDP:-**

Matrices are used in calculating the gross domestic products in economics which eventually helps in calculating the goods production efficiently. Matrix is nothing but measurements. There are **three types of matrix.**

1. QAM--Quality Assurence Measurement that means how much quality required in the project

2. PCM--Process compatability mesurement that means to estimate testing process for upcoming project depending on current project experienced.

3. TMM-- Test Manager Measurement that means to estimate how much work is completed and how much work yet to complete.

- **In robotics and automation:-**

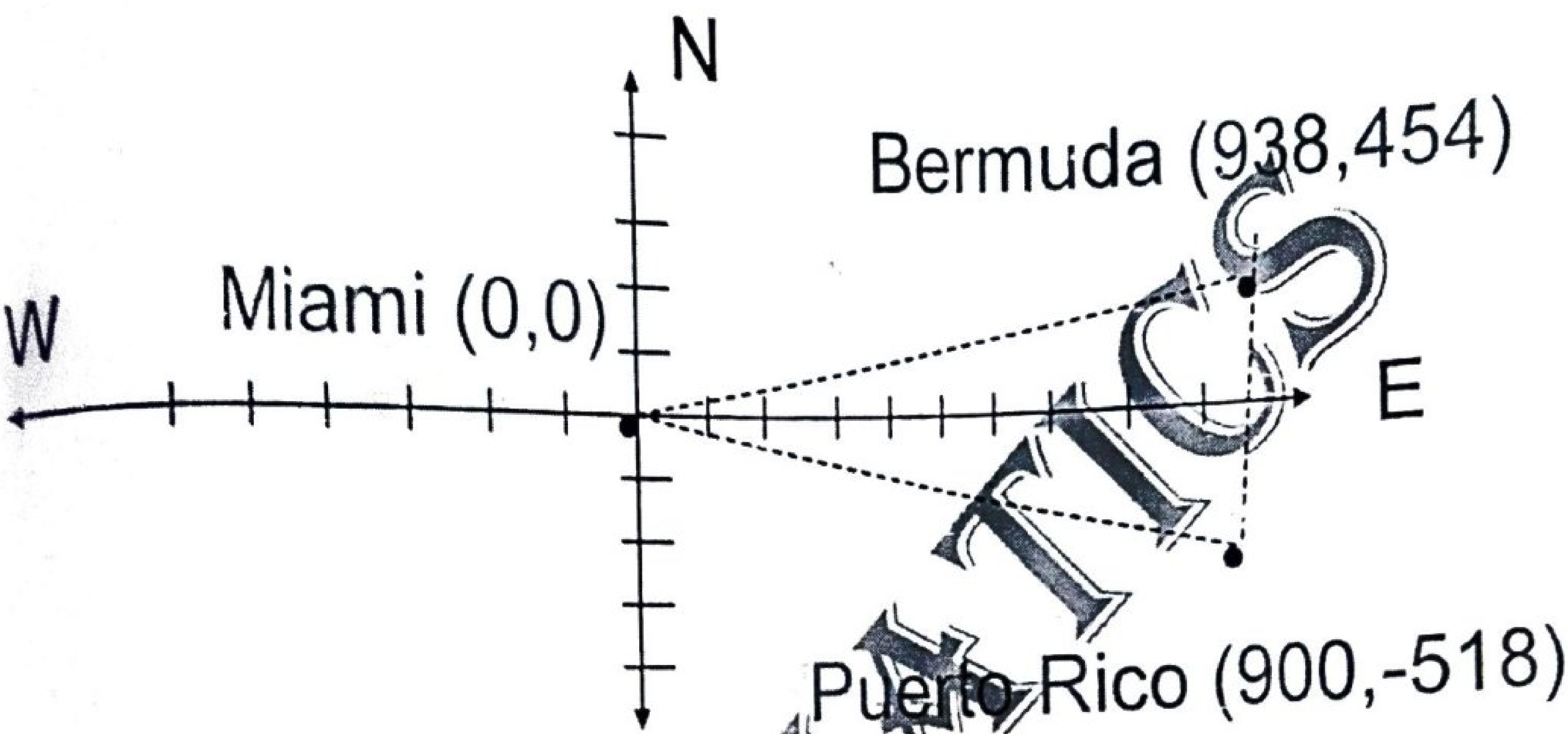
In robotics and automation, matrices are the base elements for the robot movements. The movements of the robots are programmed with the calculation of matrices' rows and columns. The inputs for controlling robots are given based on the calculations from matrices.

- **In real-life:-**

We can have application for matrices of any dimension in real-life. Most things when changed have an impact on others, or change as a result of many factors. Take something simple - price of bread. Price can be determined by supply against demand - however can also be made very complicated. Price will be affected by price of grain, economic conditions, location. This can then be taken further - price of grain is affected by weather, demand for other products, and even price of oil to fill the tractor on the farm. If you want to see how something changes in a what-if situation then you need a dimension for each factor.

1. The Bermuda Triangle is a large trianglular region in the Atlantic ocean. Many ships and airplanes have been lost in this region.

The triangle is formed by imaginary lines connecting Bermuda, Puerto Rico, and Miami, Florida. Use a determinant to estimate the area of the Bermuda Triangle



The approximate coordinates of the Bermuda Triangle's three vertices are: (938,454), (900,-518), and (0,0). So the area of the region is as follows:

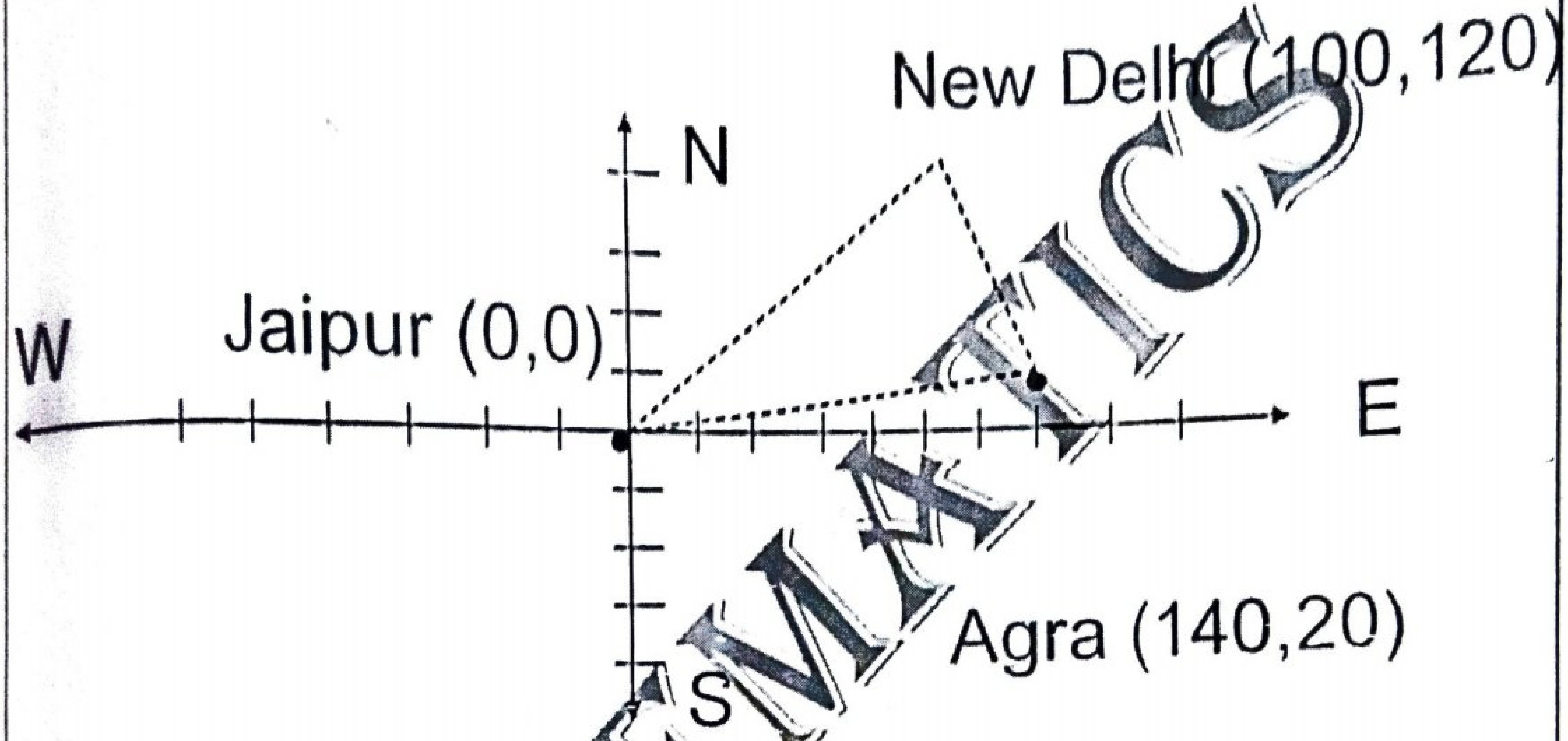
$$Area=\pm\frac{1}{2}\begin{vmatrix} 938 & 454 & 1 \\ 900 & -518 & 1 \\ 0 & 0 & 1 \end{vmatrix}$$

$$Area=\pm\frac{1}{2}[(-458,884+0+0)-(0+0+408,600)]$$

$$Area=447,242$$

Hence, area of the Bermuda Triangle is about 447,000 square miles.

2. The Golden Triangle is a large triangular region in the India. The Taj Mahal is one of the many wonders that lie within the boundaries of this triangle. The triangle is formed by the imaginary lines that connect the cities of New Delhi, Jaipur, and Agra. Use a determinant to estimate the area of the Golden Triangle. The coordinates given are measured in miles.



The approximate coordinates of the Golden Triangle's three vertices are: (100,120), (140,20), and (0,0). So the area of the region is as follows:

$$Area = \pm\frac{1}{2}\begin{vmatrix} 100 & 120 & 1 \\ 140 & 20 & 1 \\ 0 & 0 & 1 \end{vmatrix}$$

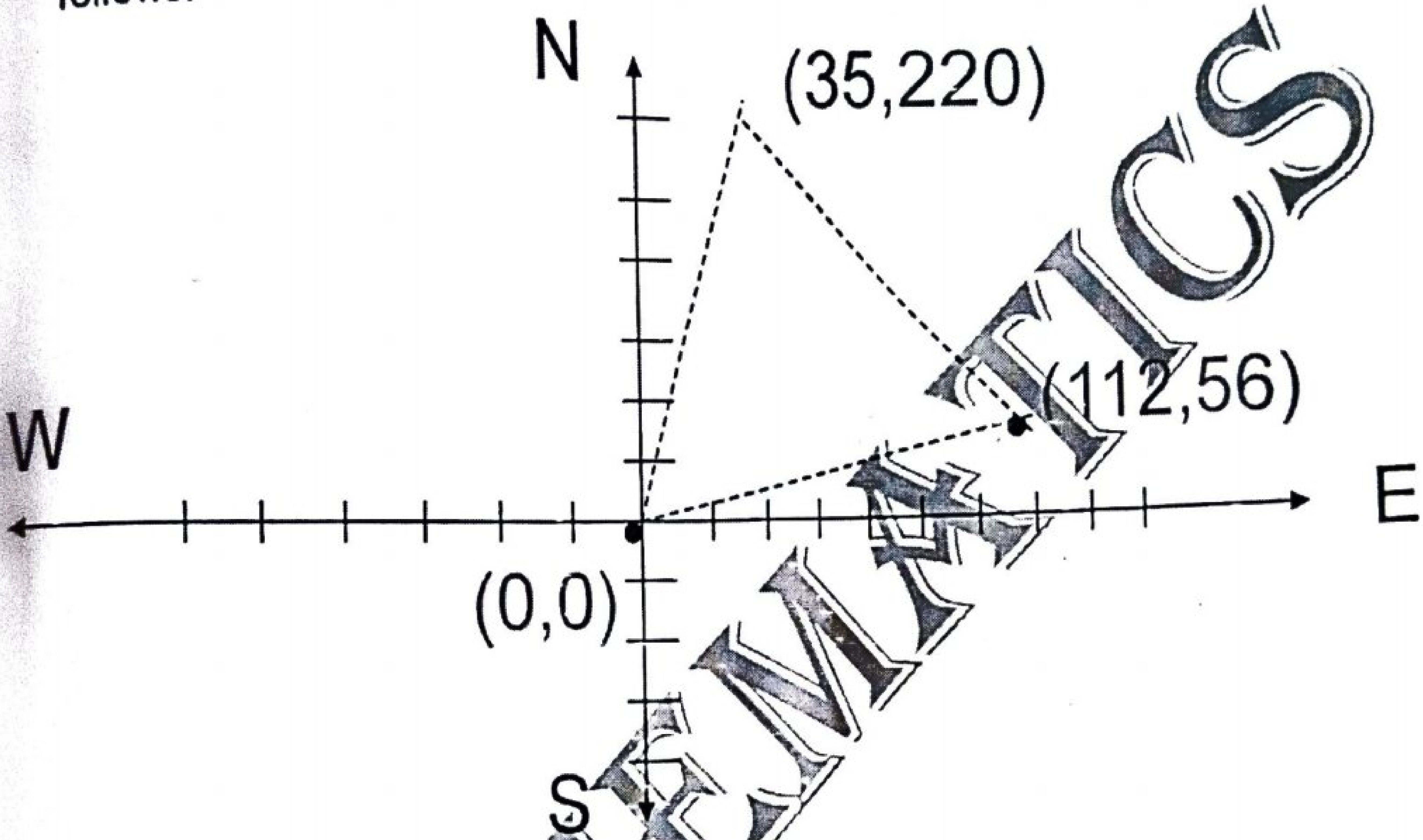
$$Area = \pm\frac{1}{2}[(2000+0+0)-(0+0+16800)]$$

$$Area = 7400$$

Hence, area of the Golden Triangle is about 7400 square miles.

3. Black neck stilts are birds that live throughout Florida and surrounding areas but breed mostly in the triangular region shown on the map. Use a determinant to estimate the area of this region. The coordinates given are measured in miles.

The approximate coordinates of the Golden Triangle's three vertices are: (35,220), (112,56), and (0,0). So the area of the region is as follows:



$$Area = \pm\frac{1}{2}\begin{vmatrix} 35 & 220 & 1 \\ 112 & 56 & 1 \\ 0 & 0 & 1 \end{vmatrix}$$

$$Area = \pm\frac{1}{2}[(1960+0+0)-(0+0+24640)]$$

$$Area = 11340$$

Hence, area of the region is about 11340 square miles.

4. The atomic weights of three compounds are shown. Use a linear system and Cramer's rule to find the atomic weights of carbon(C), hydrogen(H), and oxygen(O).

Compound	Formula	Atomic weight
Methane	CH_4	16
Glycerol	$C_3H_8O_3$	92
Water	H_2O	18

Write a linear system using the formula for each compound

$$C + 4H = 16$$

$$3C + 8H + 3O = 92$$

$$2H + O = 18$$

Evaluate the determinant of the coefficient matrix

$$\begin{vmatrix} 1 & 4 & 0 \\ 3 & 8 & 3 \\ 0 & 2 & 1 \end{vmatrix} = (8+0+0)-(0+6+12) = -10$$

Apply cramer's rule since determinant is not zero.

$$C=\frac{\begin{vmatrix}16 & 4 & 0\\ 92 & 8 & 3\\ 18 & 2 & 1\end{vmatrix}}{-10}=\frac{-120}{-10}=12$$

$$H=\frac{\begin{vmatrix}1 & 16 & 0\\ 3 & 92 & 3\\ 0 & 18 & 1\end{vmatrix}}{-10}=\frac{-10}{-10}=1$$

$$O=\frac{\begin{vmatrix}1 & 4 & 16\\ 3 & 8 & 92\\ 0 & 2 & 18\end{vmatrix}}{-10}=\frac{-160}{-10}=16$$

Atomic weight of carbon = 12

Atomic weight of hydrogen = 1

Atomic weight of oxygen = 16

- **Cryptography:-**

When a programmer encrypts or codes a message, he can use matrices and their inverse. The internet function could not function without encryption, and neither could banks since they now use these same means to transmit private and sensitive data.

Cryptography is concerned with keeping communications private. Today governments use sophisticated methods of coding and decoding messages. One type of code, which is extremely difficult to break, makes use of a large matrix to encode a message.

The receiver of the message decodes it using the inverse of the matrix. This first matrix is called the encoding matrix and its inverse is called the decoding matrix.

MATHEMATICS

Matrices are also used in following

- Matrices are also used in graphs and statistics for doing scientific studies in many other different fields. Matrices are used to calculate gross domestic product in economics, and thereby help in calculation for producing goods more efficiently.

- Matrices are also sometimes used in computer animation. They can also be used as labels for students to stay organized. They could label things like "School," "Sports," "Home work," and "Recreation." Along the side, list yourself and 3 friends. Poll your friends and fill out the table, rounding the time to whole numbers. Compare this matrix to the matrices you have been doing. Like, in the example shown previously, matrices are useful for polls.

- Matrices are very useful for organization, like for scientists who have to record the data from their experiments if it includes numbers. In engineering, math reports are recorded using matrices.

- And in architecture, matrices are used with computing. If needed, it will be very easy to add the data together, like we do with matrices in mathematics. Like in some problems of our homework, matrices could be useful to figuring out things like price and quantity, like with the foods and prices in our homework. As you can see, there are many and very useful ways matrices could be applied in our everyday lives and even in the future.

- Most things when changed have an impact on others, or change as a result of many factors. Take something simple - price of bread. Price can be determined by supply against demand -however can also be made very complicated. Price will be affected by price of grain, economic conditions, location. This can then be taken further - price of grain is affected by weather, demand for other products, and even price of oil to fill the tractor on the farm. If you want to see how something changes in a what-if situation then you need a dimension for each factor.

- Matrices are used in representing the real world data's like the traits of people's population, habits, etc. They are best representation methods for plotting the common survey things.

- Matrices are used in many organizations such as for scientists for recording the data for their experiments.

Reference

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2.Basic Matrix Book Operation-OriginLab

❖ **Website:-**

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STUDY TOUR REPORT

We are the students of B.Sc.-III Mathematics of Vivekanand College, Kolhapur. Accompanied by our teachers Prof.Mr.S.P.Patankar & Prof. Mr.S.T.Sutar visited to Mathematics department in Shivaji University,Kolhapur dated on 5th January 2018.

We gathered there at 10:00 a.m. near the main building of the University. Our college teacher Prof.Mr.S.P.Patankar & Mr.S.T.Sutar had informed the University, we got familiar to the University premises , architectural layout of all department was worth appreciating & then we moved to the Mathematics department.

Initially, there was short introductory speech held in RAMANUJAN HALL .Later it started with the lectures by Prof.S.B.Bhalekar, who taught us Dynamical Systems. Then the lecture was held by Prof. K.D. Kucche who made us familiar to basic concepts of Calculus.

We all really had a great experience to learn various concepts related to Algebra & Calculus. Later on we had the discussion on our difficulties for preparation of the subject. There we met to the M.Sc. students. We had a short talk with them. After all the discussion we came to a conclusion that habit of reading books is very essential. As well as self study & hard work are key to success.

This short study tour was really helpful to clear up our basic concepts of Mathematics which gave us the great pleasure & satisfaction. We all came back to our college; this short STUDY TOUR merged to be very successful.

NAME : Akanksha Dhanaji Patil

ROLL .No : 8138

EXAM SEAT No :

G.B.Kolhe

Teacher in charge
Prof. Mr. S.T. Sutar

Examiner

Head of Department
Prof.Mr.S.P.Patankar

HEAD
Department of Mathematics
Vivekanand College, Kolhapur