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METHOD FOR CALCULATING MATRIX RANK USING MODERN PROGRAMMING LANGUAGES

Jumaboyeva Zevarjon Rustamboyevna
jumaboyevazevarjon9@gmail.com
Trainee Lecturer at the Department of Physics and Mathematics, UrDPI

Keywords: Matrix rank, linear algebra, NumPy library, Python programming, Flask web framework, matrix computation algorithm, interactive interface, programming in education, SVD (Singular Value Decomposition), system of linear equations.
Annotation: This article focuses on an interactive application developed using Python and the Flask web framework for calculating the rank of a matrix. Matrix rank, a fundamental concept in linear algebra, represents the degree of linear independence of a matrix's rows or columns and is widely applied in areas such as linear systems, data compression, machine learning, and scientific research. The application enables users to input the dimensions and elements of a matrix, computes its rank using the NumPy library, and displays the result in a user-friendly interface. This tool is particularly beneficial in educational contexts for demonstrating linear algebra principles, as well as in research and practical applications that require efficient mathematical analysis. The article thoroughly explores the application's functionalities, technical structure, mathematical foundation, and practical significance, showcasing its role as a reliable and interactive computational resource for modern technological advancements.
In modern mathematics and technology, matrices occupy an important position, and their analytical and computational properties have become one of the main topics of fundamental research. Matrix color (rank) computation is important in various interdisciplinary studies, including linear algebra, differential equations, artificial intelligence algorithms, and data compression processes.

Importance of Matrix Rank:
Determining whether a matrix has full or zero rank defines its deterministic properties.
Rank helps identify linear dependence, which is useful in modeling physical problems, optimization, and data analysis.

- Definition of Matrix Rank
- The rank of a matrix indicates the degree of linear independence of its row or column vectors. This concept plays a key role in linear algebra.

Definition of Matrix Rank
The rank of a matrix indicates the degree of linear independence of its row or column vectors. This concept plays a key role in linear algebra.
Main Methods for Calculating Matrix Rank:
1. **Gaussian Elimination Method** – The matrix is transformed into row echelon form, and the number of nonzero rows is counted.
2. **Singular Value Decomposition (SVD)** – The rank is determined through the matrix's singular values.

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3. **Minors Determinant Method-** The rank is the largest order k for which the determinant of a times k×k minor is nonzero.

Formula for Matrix Rank Calculation:

$$\text{rank}(A) = \max\{k : \det(M_k) \quad 0\}$$

where M_k represents the $k \quad k$ minors of the matrix.

Matrix Rank and Solutions to Systems of Linear Equations

Matrix rank plays a crucial role in analyzing the solutions of linear systems. For example:

- If the rank of a matrix is equal to the number of unknowns, the system has a unique solution.
- If the rank is lower, the system has either infinitely many solutions or no solution at all.

Example:

$$A = \begin{matrix} 1 & 2 & 3 \\ 4 & 5 & 6 \\ 7 & 8 & 9 \end{matrix}, \quad b = \begin{matrix} 1 \\ 2 \\ 3 \end{matrix}, \quad Ax = b.$$

$\text{rank}(A) = 2,$ meaning there is no unique solution.

Using Modern Programming Languages

The NumPy library is widely used for matrix operations in Python. The following code demonstrates how to compute matrix rank:

```
import numpy as np

# Matritsani aniqlash
A = np.array([
    [1, 2, 3],
    [4, 5, 6],
    [7, 8, 9]
])

# Matritsa rangini hisoblash
rank = np.linalg.matrix_rank(A)
print(f"Matritsa rangi: {rank}")
```

Result: this program returns that the matrix color is equal to 222.

Using MATLAB

In the MATLAB application, the matrix color can be calculated using the following code:

```
A = [1 2 3; 4 5 6; 7 8 9];
r = rank(A);
```

```
disp(['Matritsa rangi: ', num2str(r)]);
```

With the help of Julia

In Julia, a **LinearAlgebra** module is used to calculate the color of the Matrix:

```
using LinearAlgebra

A = [1 2 3; 4 5 6; 7 8 9]
rank = rank(A)
println("Matritsa rangi: $rank")
```

Singular Value Decomposition (SVD) Method

SVD is a modern and precise approach for calculating matrix rank. The decomposition is expressed as:

$$A = U\Sigma V^T$$

where:

- **U** and **V** are orthogonal matrices,
- is a diagonal matrix containing the singular values of A

```
U, S, Vt = np.linalg.svd(A)

rank = np.sum(S > 1e-10)  #

print(f"Matritsa rangi (SVD usuli): {rank}")
```

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Visual Interface of the Matrix Rank Calculation Application

The figure above illustrates the main interface of an interactive web application for calculating matrix rank. This interface allows users to input matrix dimensions and elements to compute its rank.

Interface Structure

1. **Matrix Dimension Input** – Users specify the matrix size (e.g, 3×3) in a dedicated input field.
2. **Matrix Element Input** – Users enter matrix elements row-wise, separated by spaces (e.g, "1 2 3").
3. **"Calculate Rank" Button** – Submits user input to the server for processing and returns the computed rank.
4. Displaying the Result – The matrix rank is displayed in green below the input fields. The example above shows "Matrix Rank: 2" as the result.

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