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# Research on Application of Mathematical Modeling Based on Matrix Theory

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**Abstract:** As a simple tool for understanding complex things, matrix has been widely used in various disciplines and mathematical modeling. The development of any discipline is closely related to quantitative analysis and research, and mathematics plays a vital role in quantitative research. Matrix is one of the most basic mathematical concepts, and it is also a simple thinking tool for people to grasp the essence of complex practical things. Matrix is widely used in mathematical modeling. In the process of mathematical modeling, we often encounter some mathematical models that can be handled by graphs and adjacency matrices of graphs. Using adjacency matrix to represent graphs is simple and intuitive, and adjacency matrix can represent some practical information of graphs. In this paper, the application of adjacency matrix in mathematical modeling is analyzed and studied, and on this basis, the application of matrix in mathematical modeling is further studied and popularized.

**Keywords:** Matrix; Mathematical modeling; Thought tool.

## 1. Introduction

It is the mother of mathematical science and the common foundation of many disciplines. With the rapid development of computer and the arrival of information age, people pay more and more attention to quantitative research in most research fields [1]. In the process of mathematical modeling, we often encounter some mathematical models that can be handled by graphs and adjacency matrices of graphs [2]. Using adjacency matrix to represent graphs is simple and intuitive, and adjacency matrix can represent some practical information of graphs [3]. Matrix is one of the most basic mathematical concepts, and it is also a simple thinking tool for people to grasp the essence of complex practical things. In mathematical modeling, matrix is widely used, such as mathematical programming, analytic hierarchy process, Markov chain model, input-output, data fitting, etc., and matrix analysis is mainly used to solve problems [4]. No matter what kind of practical problems are solved by mathematical methods, the establishment of mathematical models is a crucial step, and it is also a very difficult step. By observing and studying the inherent characteristics and laws of practical objects, we should grasp the essence of things, establish a quantitative relationship that reflects practical problems, and then use mathematical theories and methods to analyze and solve problems [5].

It is one of the most important concepts in matrix mathematics and an important mathematical tool. It is widely used in various branches of natural science [6]. Matrix is also widely used in mathematical modeling, such as mathematical programming model, linear algebraic model, differential equation model and data fitting. With the deepening of scientific research, the application of matrix theory is more and more extensive [7]. It plays an irreplaceable role in many disciplines and fields, such as the first-order approximation of multivariate functions in mathematical analysis and the existence theorem of implicit functions are closely related to matrix theory [8]. Matrix is a numerical table, and the data in the table can be operated and transformed by algebraic methods. It can simplify complex and abstract practical problems, so that we can see the essence of practical problems clearly. Therefore, the use of matrix in solving practical problems will often get twice the result with half the effort [9]. There are countless examples of the application of matrix theory in other mathematical disciplines and research fields. Therefore, we should not study it independently, but apply it to other mathematics courses and combine them organically, so as to deepen our understanding of higher algebra. In this paper, the application of adjacency matrix in mathematical modeling is analyzed and studied, and on this basis, the application of matrix in mathematical modeling is further studied and popularized.

## 2. Heterogeneous modal data denoising

With the rapid development of computer and the arrival of information age, people pay more and more attention to quantitative research in most research fields. It can be said that the development of any discipline is closely related to quantitative analysis and research, and mathematics plays a vital role in quantitative research [10]. Matrix theory is the core content of higher algebra, and many ideas and methods in matrix theory greatly enrich the algebraic theory of mathematics. When matrix theory is applied to these mathematical disciplines, such as optimization and graph theory, compared with the conventional methods, it often has unique effects and makes many problems simple and clear.

Assume that the one-dimensional integrated network signal function $f(x)$ is projected onto each step $j$ of the subset $v_j(\ldots \subset V_2 \subset V_1 \subset V_0)$. The projection is set by integrating the scale product $C_{j,k}$ of the network signal function $f(x)$ and the scale function $\varphi_{j,k}(x)$, and the projection setting formula is:

$$C_{j,k} = \left\langle f(x), \varphi_{j,k}(x) \right\rangle \tag{1}$$

$$\varphi_{j,k}(x) = 2^{-k} \varphi\left(2^{-j} x - k\right) \tag{2}$$

Where: $\varphi(x)$ stands for low-pass filter, also called scaling function. Assuming $h(x)$ represents a wavelet function, the scaling function $\varphi(x)$ can be expressed as follows:

$$\frac{1}{2}\varphi\left(\frac{x}{2}\right)=\sum_{x}h(x)\varphi(x-n) \tag{3}$$

$C_{j+1,k}$ can be solved by $C_{j,k}$:

$$C_{j+1,k}=\sum_{n}h(n)C_{j,k} \tag{4}$$

The scale product of wavelet coefficient $w_{j,k}$ can be expressed as:

$$w_{j,k}=\sum_{k}g(n-2k)C_{j,k} \tag{5}$$

$g(n-2k)$ wavelet coefficient set. And so on until the length of the one-dimensional integrated network signal function $f(x)$ becomes 1. Transformations other than down sampling need up sampling before filtering convolution of each scale, so that $C_{j+1,k}$ and discrete wavelet coefficients can be expressed as:

$$C_{j+1,k}=\sum_{l}h(l)C_{j,k+2jl} \tag{6}$$

$$w_{j+1,k}=\sum_{l}g(l)C_{j,k+2jl} \tag{7}$$

Where $l$ represents the maximum step of the subset $V_j(\ldots\subset V_2\subset V_1\subset V_0)$. The redundancy of this wavelet transform is helpful to highlight the characteristics of data signals, especially in noise extraction.

# 3. Estimation of matrix eigenvalue

The traditional error bound estimation of matrix eigenvalues is described as the distance between the eigenvalues of the original matrix and the eigenvalues of the disturbance matrix. The characteristic coefficient of polynomial plays a key role in the application of quantum physics, especially it provides such information. If the matrix $A$ is a normal matrix, the binomial value becomes smaller. At this time, the elementary symmetric function is aimed at all singular values instead of the maximum value, which can get better coefficient constraints. For the lower bound of the minimum eigenvalue $q(A\circ A^{-1})$ of the Had-amard product of matrix $A$ and its inverse $A^{-1}$, it is obtained that:

$$q(A\circ A^{-1})\geq\frac{1}{n} \tag{8}$$

And guess:

$$q(A\circ A^{-1})\geq\frac{2}{n} \tag{9}$$

When the order of $A$ matrix is very large, the result of this estimation formula is not good. Improved results:

$$q(A\circ A^{-1})\geq\max\left\{1-\rho(J)^2,\frac{1+\rho(J)^{\frac{1}{n+2}}}{1+(n-1)\rho(J)^{\frac{1}{n+2}}}\right\} \tag{10}$$

Due to the complexity of $\rho(J)$ calculation, it is concluded from the elements of the matrix that:

$$q(A\circ A^{-1})\geq\min_{i\in N}\left\{\frac{a_{ii}-s_iR_i}{1+\sum_{j\neq i}s_{ji}}\right\} \tag{11}$$

Including:

$$R_i=\sum_{j\neq i}|a_{ij}|,d_k=\frac{R_k}{|a_{kk}|}$$
$$j\neq i,s_i=\max_{j\neq i}\{s_{ij}\},i\in N \tag{12}$$

# 4. Feature extraction of heterogeneous modal data in integrated networks

When the number of columns in the matrix is the same as the number of elements in a certain column vector, multiplying the matrix by the vector will get another vector, which is the linear transformation of the vector. When the matrix is square, the linear transformation can continue. That is, a new vector is obtained by multiplying a matrix by a vector, and another new vector is obtained by multiplying the same matrix by the new vector. The essence of this operation is to multiply the initial vector by the power of the matrix. Let the heterogeneous modal data matrix of the basic network after denoising and classification be as follows:

$$X^{'}=[x^{''},\ldots,x_N^{''}]\in R^{M\times N} \tag{13}$$

Each column vector represents the original data points with $M$ spectral bands, and $NMF$ aims to find two non-negative matrices $U=[u_{ir}]=R^{M\times R}$ and $V=[v_{jr}]=R^{N\times R}$. Multiply these two non-negative matrices, the product can represent $X^{'}$, and take $R\leq M$. At this time, $v_i$ represents the low-dimensional representation of hyperspectral data $x_i^{''}$ on the basis vector set $\{u_r\|r=1,\ldots,R\}$, and the spectral feature extraction is completed by matrix reconstruction.

In order to solve this problem, when most of the high-dimensional data are distributed in a highly nonlinear way, the concept decomposition is regarded as an improved $NMF$, a non-negative linear combination of the high-dimensional data and the data set represented as basis vectors $x_{j^{'}}^{''}$ and $u_r$ respectively:

$$x_{j^{'}}^{''}\cong\sum_{r=1}^{R}u_rv_{j^{'}r} \tag{14}$$

$$u_{j^{'}}^{''}\cong\sum_{j=1}^{N}x_{j^{'}}^{''}s_{j^{'}r} \tag{15}$$

When using Euclidean distance to measure the reconstruction error, it is necessary to obtain the optimization result according to the minimization objective function:

$$\begin{aligned}\phi_{CF} &= \left\| X^{'} - XSV^{T} \right\|^{2} \\ &= Tr\left(X^{'} X^{'T}\right) - Tr\left(Z^{2}\right)\end{aligned} \tag{16}$$

Where $Tr$ is matrix trace, $Z$ is auxiliary matrix, $T$ is transposed symbol, and $XSV^T$ represents reconstruction error set. The calculation formula for obtaining the optimal solution of the objective function by the iterative updating method is as follows:

$$s_{j^{'}r} \leftarrow s_{j^{'}r} \frac{x_{j^{'}}^{n}}{XSV^{T}} \tag{17}$$

$$v_{j^{'}r} \leftarrow \phi_{CF} v_{j^{'}r} \frac{xj_{j^{'}}^{n}}{XSV^{T}} \tag{18}$$

To solve this optimization problem, the kernel method is introduced to calculate the inner product, and the category information of labeled samples is regarded as a hard constraint to ensure that labeled data with the same category attributes are projected to the same area in the low-dimensional space.

# 5. Conclusions

The application of analytic matrix operation must consider not only the need of constructing matrix theory, but also the actual need of teaching. The basic purpose of studying matrix operations and their operation laws is to make full use of these operations to introduce new matrix concepts, and at the same time to grasp the relationship between matrices, so as to gradually construct the whole matrix theory system. Therefore, the application of matrix operation in the construction of matrix theory is very common, and it has become a basic tool to study matrix problems. Usually, in the structural information of network data, the attribute information of each node is different, which will also affect the matching accuracy of network nodes. How to design a more effective node matching algorithm by combining the attribute of nodes with the topology of the network will be a meaningful thing. Macroscopically, matrix operation is a great tool to discuss matrix problems, but it is not the only one. In fact, elementary transformation of matrix is not only the application basis of matrix theory in the whole higher algebra, but also a powerful tool to analyze matrix theory itself. With the development of science and technology, there will be more and more intersections among various disciplines and fields, and the penetration of matrix application will be deeper and deeper. Therefore, the research and popularization of matrix application is helpful to tap the potential of matrix, and has positive significance for the increasingly complex and interdisciplinary mathematical modeling in the future.

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