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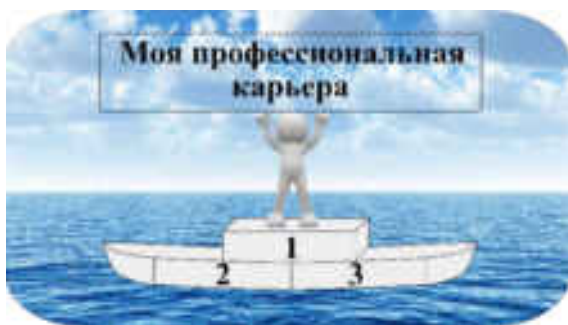


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**Международный научно-образовательный электронный журнал
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Журнал объединяет авторов на территории стран СНГ и помогает обмениваться передовыми научно-образовательными исследованиями.

Содержит научные работы отечественных и зарубежных авторов по экономическим, техническим, философским, юридическим и другим наукам.

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Atalyyeva Yazgul, Hemrayeva Musurgul INVERSION IN ENGLISH	279
Kakamyradova Aygul, Mekan Toylyyew 3D CITY MODELING AND VISUALIZATION USING GEOSPATIAL TECHNOLOGIE	284
Kurbanow Yusif, Mekan Toylyyew MAPPING AND MONITORING OF SOIL DEGRADATION IN TURKMENISTAN USING REMOTE SENSING AND GIS	289
Kurbanova Guljan, Malikgulyyewa Dursun MULTICRITERIA SPATIAL EVALUATION OF SITE SUITABILITY IN GIS-BASED DECISION SUPPORT SYSTEMS	294
Magtymow Guwanc, Mekan Toylyyew GEOSPATIAL DATABASE DESIGN AND MANAGEMENT FOR SUSTAINABLE AGRICULTURE	299
Gulshat Charyyeva, Merjen Esenova, Annajemal Annadurdyyeva THE ROLE OF BIOCHEMICAL REACTIONS IN DAILY LIFE	304
Yklym Amanberdiyev, Meredov Aymyrat THE CONNECTION BETWEEN DISCRETE OBSERVATIONS AND CONTINUOUS STATISTICAL MODELS	307
Gurbanova Maral, Jumayeva Bagul, Shyhyyeva Bilbil METHODS OF DEVELOPING WRITING SKILLS	311
Igdyrova Patma, Altyyev Atamyrat, Muhammedova Leyli OBSERVING THE ANTIBACTERIAL POWER OF MANDRAGORA TURKOMANICA ETHANOL EXTRACTS AGAINST PATHOGENIC STRAINS (E. COLI, S. AUREUS)	315
Muhammedow Rowsen, Malikgulyyewa Dursun THE ROLE OF GIS SYSTEMS IN URBAN MANAGEMENT	319
Kakageldi Bashimov, Muhammetberdiyev Nurmuhamet ITERATIVE METHODS FOR LARGE SYSTEMS: JACOBI AND GAUSS-SEIDE	324
Lale Orazgulyyeva, Murriyeva Aynagozel POMEGRANATE SEED OIL EXTRACTION METHODS	329
Myradow Azym, Malikgulyyewa Dursun THE ROLE OF GIS TECHNOLOGIES IN LAND USE PLANNING	335
Nilufar Botirova ARAB AL-ANDALUS MUSIQA MEROSIDA NŪBA JANRI	340
Nazarova Cemen, Malikgulyyewa Dursun CARTOGRAPHIC GENERALIZATION USING GIS	351
Oraznepesova Kumus, Mekan Toylyyew SPATIAL DATA ANALYSIS FOR CLIMATE CHANGE IMPACT ASSESSMENT IN CENTRAL ASIA	356
Orazova Selbi, Mekan Toylyyew DEVELOPING DIGITAL TOPOGRAPHIC MAPS USING OPEN- SOURCE GIS TOOLS	361

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Название публикации: «ITERATIVE METHODS FOR LARGE SYSTEMS:
JACOBI AND GAUSS-SEIDE»

Abstract

The efficient solution of large-scale linear systems is a central problem in numerical analysis and scientific computing. Direct methods, while accurate, often become computationally prohibitive for high-dimensional systems. Iterative methods, such as the Jacobi and Gauss–Seidel approaches, provide practical alternatives by generating successive approximations to the solution. This paper presents a detailed conceptual analysis of these methods, focusing on their theoretical foundations, convergence properties, computational efficiency, and applicability to large sparse systems.

1. Introduction

Large systems of linear equations arise naturally in numerous scientific and engineering applications, including fluid dynamics, structural analysis, machine learning, and network modeling. As the size of these systems increases, traditional direct solution techniques become inefficient due to high memory requirements and computational complexity.

Iterative methods address this challenge by starting from an initial guess and progressively refining the solution through repeated calculations. Among the most fundamental iterative techniques are the Jacobi and Gauss–Seidel methods, which remain widely used due to their simplicity and effectiveness in certain classes of problems.

2. General Concept of Iterative Methods

Iterative methods transform the problem of solving a linear system into a process of successive approximations. At each step, the current estimate of the solution is updated based on the structure of the system.

Unlike direct methods, which attempt to compute the exact solution in a finite number of operations, iterative methods aim to approach the true solution gradually. This makes them particularly suitable for large systems, especially when the coefficient matrix is sparse.

3. The Jacobi Method

3.1 Conceptual Description

The Jacobi method is one of the simplest iterative techniques. It computes each component of the solution vector independently using values from the previous iteration. In other words, all updates are performed simultaneously based on outdated information.

This parallel structure makes the Jacobi method well-suited for implementation on distributed computing systems.

3.2 Convergence Behavior

The convergence of the Jacobi method depends strongly on the properties of the coefficient matrix. In particular, it performs well when the matrix exhibits a dominant diagonal structure, meaning that each equation is strongly influenced by its corresponding variable.

However, convergence may be slow, and in some cases, the method may fail to converge altogether if the system does not satisfy certain conditions.

3.3 Advantages and Limitations

The Jacobi method is easy to implement and highly parallelizable. However, its main drawback is relatively slow convergence, especially for large or poorly conditioned systems.

4. The Gauss–Seidel Method

4.1 Conceptual Description

The Gauss–Seidel method improves upon the Jacobi approach by using updated values as soon as they become available within the same iteration. Instead of waiting for the next iteration, each newly computed component is immediately used in subsequent calculations.

This sequential update mechanism allows the method to incorporate more current information, leading to faster convergence in many cases.

4.2 Convergence Properties

Like the Jacobi method, Gauss–Seidel convergence depends on the structure of the system. It typically converges more rapidly when the matrix is diagonally dominant or symmetric and positive definite.

In practice, Gauss–Seidel often requires fewer iterations than Jacobi to achieve the same level of accuracy.

4.3 Advantages and Limitations

The primary advantage of the Gauss–Seidel method is its improved convergence speed compared to Jacobi. However, its sequential nature makes it less suitable for parallel computing environments.

Additionally, convergence is not guaranteed for all systems, and careful analysis is required before application.

5. Comparative Analysis

5.1 Convergence Speed

Gauss–Seidel generally converges faster than Jacobi because it uses updated information during each iteration. Jacobi, by contrast, relies entirely on previous iteration values.

5.2 Computational Efficiency

Both methods are computationally inexpensive per iteration. However, the total computational cost depends on the number of iterations required for convergence, which is typically lower for Gauss–Seidel.

5.3 Parallelization

Jacobi is naturally parallelizable because each component update is independent. Gauss–Seidel, due to its sequential updates, is more difficult to parallelize efficiently.

6. Applications

Iterative methods are widely used in applications involving large and sparse systems:

- **Engineering:** Finite element and finite difference methods
 - **Physics:** Simulation of physical systems and field equations
 - **Computer Science:** Graph algorithms and machine learning
 - **Economics:** Large-scale optimization models
-

7. Conclusion

The Jacobi and Gauss–Seidel methods represent foundational approaches to solving large systems of linear equations iteratively. While both methods share a common conceptual basis, their differences in update strategies lead to distinct performance characteristics.

The Jacobi method offers simplicity and parallel efficiency, whereas the Gauss–Seidel method provides faster convergence in many practical scenarios. The choice between these methods depends on the problem structure, computational resources, and desired accuracy.

Understanding their theoretical properties and practical limitations is essential for effective application in large-scale numerical problems.

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