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Research Article

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SeatMatrix: A Cloud-Based Intelligent Examination Management System with Real-Time Seat Mapping

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Abstract
Managing examination seating in academic institutions remains a complex and error-prone process, often relying on manual planning or static digital tools that lack flexibility and real-time accessibility. These traditional approaches frequently result in inefficient seat allocation, student confusion, and increased administrative workload. To address these limitations, this paper proposes SeatMatrix, a hybrid cloud-enabled examination management system designed to automate seat allocation while providing real-time, visually intuitive seating information. The concept of SeatMatrix is inspired by modern movie theatre booking systems, where users can easily identify and select seats through interactive layouts. Adapting this idea to the academic domain, the proposed system introduces an intelligent seat mapping mechanism that generates structured, conflict-free seating arrangements and presents them through graphical representations of examination halls. Unlike existing systems that primarily rely on text-based outputs, SeatMatrix integrates dynamic visualization, enabling students to quickly locate their assigned positions and reducing congestion during examinations. The system leverages a Python-based backend, a Streamlit web interface, and a Firebase Realtime Database to ensure synchronized, multi-user access and instant data updates. A rule-based allocation engine ensures fairness and eliminates duplicate assignments, while the visualization module enhances usability through spatial seat mapping. Experimental evaluations demonstrate that the proposed system significantly improves operational efficiency, reduces manual effort, and enhances the overall student experience. By combining cloud scalability, real-time interaction, and visual intelligence, SeatMatrix presents a modern and practical solution for transforming examination management processes in educational institutions.

***Keywords*:** Automated seat allocation; Cloud-based systems; Examination management, Hybrid cloud computing; Real -Time systems; Seat mapping; Visualization.

1. Introduction

The management of examination processes in academic institutions is a critical administrative task that directly impacts operational efficiency and student experience. Among these processes, the arrangement of seating for examinations remains one of the most challenging and error-prone activities. Traditionally, institutions rely on manual methods or basic spreadsheet-based systems to allocate seats, which often leads to inefficiencies such as duplicate assignments, improper utilization of space, and increased administrative workload. These limitations have been consistently highlighted in existing studies on examination seating systems.[1,2] In recent years, several attempts have been made to automate examination hall allocation and seating arrangements using rule-based or semi-automated approaches. While such systems reduce manual effort to some extent, they largely depend on static data processing and generate text-based outputs, making it difficult for students to interpret their seating positions effectively.[3] Furthermore, many of these solutions do not provide real-time updates or interactive interfaces, which are essential in dynamic academic environments where last-minute changes are common.[4] With the rapid advancement of digital technologies, particularly cloud computing, there is a growing opportunity to modernize examination management systems. Cloud-based systems enable centralized data storage, scalability, and real-time synchronization across multiple users and devices.[5] According to the definition provided by the National Institute of Standards and Technology (NIST), cloud computing allows on-demand network access to shared computing resources, which can be rapidly provisioned with minimal management effort.[6] This paradigm is especially beneficial in educational institutions where multiple stakeholders including administrators, staff, and students require simultaneous access to updated information.

Streamlit, a Python-based web application framework, has emerged as a powerful tool for building interactive and data-driven interfaces with minimal development effort.[7] It allows developers to create responsive dashboards and visualization modules, making it particularly suitable for applications that require dynamic data representation. In the context of examination systems, an intuitive interface can greatly simplify the process of accessing and understanding seating arrangements. Despite these technological advancements, most existing examination management systems still lack effective visualization mechanisms. Many solutions present seating information in the form of lists or tables, which can be difficult for students to interpret, especially in large examination halls. Visualization techniques, on the other hand, provide a spatial representation of seating layouts, enabling users to quickly identify their positions and navigate the environment more efficiently.[8] According to Burke and Petrovic, information visualization have demonstrated that graphical representations significantly improve comprehension and reduce cognitive load compared to textual data.[9] To address these limitations, this research proposes SeatMatrix, a hybrid cloud-enabled examination management system that integrates automated seat allocation with real-time data access and graphical visualization. The concept of SeatMatrix is inspired by modern movie theatre booking systems, where users can view and select seats through interactive layouts. By adapting this approach to examination management, the system introduces a visual seat-mapping module that allows students to easily locate their assigned seats within a classroom layout. Unlike existing systems that focus primarily on automation or scheduling, SeatMatrix combines multiple features into a unified platform. It incorporates a rule-based allocation engine to ensure conflict-free seat assignments, a cloud-based data layer for real-time synchronization, and a visualization module for intuitive seat representation. The system is designed to support multiple user roles, including administrators, staff, and students, each with dedicated functionalities to streamline examination workflows. The primary contribution of this research is the development of a unified examination management platform that combines automated seat allocation, cloud-based data synchronization, and graphical seat visualization. Unlike conventional examination systems that focus only on scheduling or seat assignment, the proposed SeatMatrix framework integrates backend automation with user-centric visualization, thereby improving both administrative efficiency and student accessibility. The proposed approach offers several advantages over traditional and existing digital systems. First, it significantly reduces manual effort by automating the seat allocation process. Second, it enhances transparency and accessibility by providing real-time updates through a cloud-based platform. Third, it improves the overall student experience by introducing graphical seat maps that simplify navigation within examination halls. Finally, the system is scalable and adaptable, making it suitable for institutions of varying sizes and requirements.

2. Literature survey

The automation of examination management systems has been an active area of research, particularly focusing on seating arrangement, hall allocation, and scheduling optimization. Early studies primarily addressed the challenge of manual seat planning by introducing basic computerized solutions. For instance, systems proposed in focused on automating seat allocation using predefined rules and structured datasets, significantly reducing manual workload.[1,2] However, these systems

were largely limited to generating static seating lists without incorporating user-friendly interfaces or visualization capabilities. Subsequent research introduced web-based solutions to improve accessibility and usability. The work presented in Subhashini *et al.*, developed an online examination seating system that allowed administrators to manage seating data digitally.[3] Although this approach improved efficiency, it still relied heavily on textual outputs, making it difficult for students to interpret their seating positions within large examination halls. Similarly, the system in integrated SMS notifications to inform students about their seating details, enhancing communication but lacking real-time interaction and graphical representation.[4]

To address optimization challenges, researchers explored algorithmic approaches such as genetic algorithms and heuristic techniques. Dener *et al*., study demonstrated the effectiveness of genetic algorithms in solving large-scale exam scheduling problems by optimizing seat distribution and minimizing conflicts.[5] While these methods improved allocation efficiency, they were primarily focused on backend computation and did not consider user experience or visualization aspects. With the emergence of cloud computing technologies, more scalable and distributed solutions were developed. The system proposed in Savakar *et al.,* study utilized cloud infrastructure to manage examination seating data, enabling centralized storage and improved accessibility.[6] Similarly, works in Sangeetha *et al.,* and Onyedeke *et al.,* introduced automated hall allocation systems that leveraged digital platforms to streamline administrative processes.[7,10] Despite these advancements, most of these systems lacked real-time synchronization and interactive interfaces, limiting their practical usability in dynamic environments. Further developments in examination management systems emphasized integrated platforms that combine multiple functionalities. The Online Hall Allocation System (OHAS) presented in improved scheduling efficiency by optimizing resource utilization across examination centers.[6] Additionally, earlier automation efforts in Burke *et al.,* study laid the foundation for digitizing examination processes but did not incorporate modern technologies such as cloud-based synchronization or visualization modules.[9] Beyond domain-specific systems, broader research in timetabling and scheduling has contributed valuable insights. Babaei *et al.,* and George *et al.,* studies explored various optimization techniques for academic scheduling, including integer programming and heuristic methods.[11,12] Another important dimension is data visualization. Research in Shneiderman *et al.*, Ware *et al.,* Heer *et al.,* studies demonstrates that graphical representations significantly enhance user comprehension compared to traditional text-based outputs.[13-15] Despite this, most existing examination systems fail to integrate effective visualization techniques, resulting in poor user experience, especially for students navigating large examination halls.

Over time, examination management systems have evolved across several key parameters, as illustrated below:

- Manual → Automated Systems: Early systems focused on replacing manual processes with basic automation. [1,2]
- Static → Web-Based Platforms: Introduction of online systems improved accessibility but remained largely static.[3,4]
- Basic Logic → Optimization Algorithms: Advanced techniques such as genetic algorithms improved allocation efficiency.[5,11]
- Standalone → Cloud-Based Systems: Cloud integration enabled scalability and centralized data management. [6]
- Text-Based → Visual Interfaces: Recent trends emphasize graphical visualization for better usability.[13,14]
- Offline → Real-Time Systems: Modern systems require real-time synchronization for dynamic updates.[16]

Despite significant progress in automating examination systems, several critical gaps remain:

1. Lack of Visualization: Most existing systems rely on textual seating lists, which are difficult to interpret and do not provide spatial context.[3,4]
2. Limited Real-Time Capabilities: Many solutions do not support real-time updates, leading to inconsistencies when changes occur during examination preparation.[6,16]
3. Fragmented System Design: Existing approaches often focus on isolated functionalities such as scheduling or allocation without integrating them into a unified platform.[5,8]
4. Poor User Experience: Minimal emphasis on user interface design results in systems that are not intuitive for students or staff.
5. Lack of Inspiration from Modern Systems: Current solutions do not leverage proven interaction models (e.g., movie theatre seat visualization), which could significantly improve usability.

To address the limitations identified in existing examination management solutions, the proposed SeatMatrix framework integrates automated seat allocation, cloud-based data management, real-time synchronization, and graphical visualization within a unified platform. By combining these capabilities, the system aims to improve administrative efficiency while providing an enhanced user experience for students and examination staff. Inspired by modern seat-booking applications, SeatMatrix introduces an intuitive graphical seat-mapping mechanism that simplifies seat identification and navigation. Recent studies have highlighted the growing importance of cloud-based

Table 1: Comparison of existing systems.

Ref.	System	Automated Allocation	Cloud Support	Real-Time Updates	Visualization	Multi-User Support	Scalability	Major Limitation
[1]	Basic Seating System	Yes	No	No	No	No	Low	Static output
[3]	Online Seating System	Yes	Partial	No	Limited	Partial	Medium	Text-based interface
[4]	SMS-Based System	Yes	No	No	No	Limited	Medium	No graphical view
[5]	Genetic Algorithm Based	Yes	No	No	No	No	High	Backend-focused
[6]	Cloud-Based Seating System	Yes	Yes	Limited	No	Partial	High	Limited user interaction
[7]	Automated Hall Allocation	Yes	Partial	No	No	Partial	Medium	No visualization
Proposed	SeatMatrix	Yes	Yes	Yes	Yes	Yes	High	None

technologies in educational management systems. Sikarwar *et al.* conducted a comprehensive review of cloud-based learning management systems and reported that cloud infrastructures significantly improve scalability, accessibility, collaboration, and centralized data management in educational environments.[17] Their findings emphasize the role of cloud computing in supporting large-scale academic operations while reducing infrastructure constraints. However, the study primarily focused on learning management environments and did not address examination-specific allocation and visualization challenges. The adoption of cloud technologies has also influenced the development of digital examination platforms. Singh and Mansotra proposed a cloud-based architecture for online examination management and demonstrated how cloud infrastructures can reduce operational costs, improve accessibility, and support dynamic resource allocation.[18] Their work established the feasibility of cloud-enabled examination services but concentrated mainly on examination delivery rather than seat allocation and classroom visualization.

Modern educational management systems increasingly emphasize centralized information management and real-time data accessibility. UNESCO's work on next-generation educational management information systems highlighted the importance of integrated digital platforms capable of supporting data sharing, administrative coordination, and informed decision-making across educational institutions.[19] These systems improve organizational efficiency but generally focus on institutional data management rather than examination seating operations. Recent research has further demonstrated the value of intelligent educational platforms that combine data analytics and user-centered interfaces. Zhang *et al.* proposed an advanced learning management system capable of extracting meaningful insights from student data while improving system usability and decision support.[20] Their findings reinforce the importance of integrating analytics and interactive interfaces into educational applications. Nevertheless, the proposed framework does not address examination hall management, seat allocation, or graphical classroom visualization. In addition, studies in information visualization consistently demonstrate that graphical interfaces improve user comprehension, reduce cognitive effort, and support faster decision-making when compared with purely text-based information presentation. Visual representations are particularly beneficial in environments involving spatial information, where users must quickly identify locations and interpret complex layouts. These findings provide strong support for incorporating graphical seat-mapping mechanisms into examination management systems. The review of recent literature indicates that existing solutions have achieved considerable progress in cloud-based deployment, educational information management, and digital examination services. However, automated seat allocation, real-time synchronization, and graphical seat visualization are often implemented as separate functionalities. Very limited research has addressed the integration of these components within a single examination management platform. This research gap motivates the development of SeatMatrix, which combines automated seat allocation, cloud-based synchronization, and graphical seat visualization to enhance both operational efficiency and user experience. A comparative analysis of existing examination management systems and the proposed SeatMatrix framework is presented in Table 1, highlighting the key differences in automation, cloud integration, visualization, scalability, and real-time functionality.

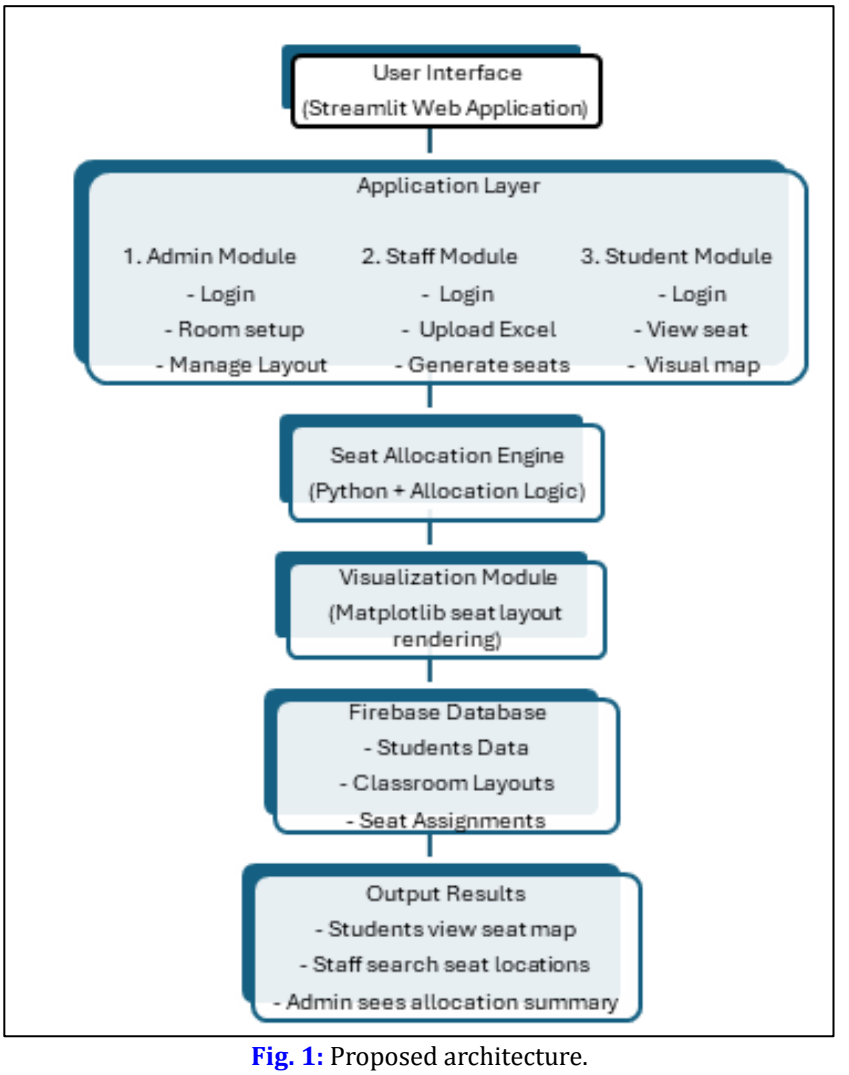

Fig. 1: Proposed architecture.

3. Proposed architecture

The overall architecture of the proposed SeatMatrix system is illustrated in Fig. 1. The architecture demonstrates the interaction between the user interface, application modules, seat allocation engine, visualization layer, and cloud database components. The system has been developed using a combination of modern programming and database technologies:

- Python 3.11 - Implementation & Backend Logic
- Streamlit to build the web-driven user interface
- Firebase Realtime Database: For data synchronization and storing on the cloud.
- Pandas for handling Excel input
- Matplotlib for generating seat visualization maps
- JSON files that store metadata of classroom layouts

The operational workflow of SeatMatrix is shown in Fig. 2, illustrating the interaction among administrators, staff members, students, and the automated seat allocation process. Key source files include:

- Seating_dashboard.py – handles login, seat assignment, and student information display
- Seat_visualizer.py – generates graphical layouts of classroom seating
- Classrooms.json - defines seating structures like rows and columns.
- Firebase_admin.py – handles the communication and authentication with Firebase

4. System overview

The platform consists of five major components that work together to support end-to-end examination management:

4.1 Administrator interface

This module provides facilities to upload student lists, arrange classroom layouts, and generate seating plans. It simplifies administrative work by reducing manual tasks and introduces order into managing examination logistics.

4.2 Allocation engine

Deterministic seat assignment logic inside the engine will avoid duplicate placements in ensuring an optimized manner of distribution, orderly assignment inside, and conflict-resolution techniques for consistency and fair play while allocating the seats.

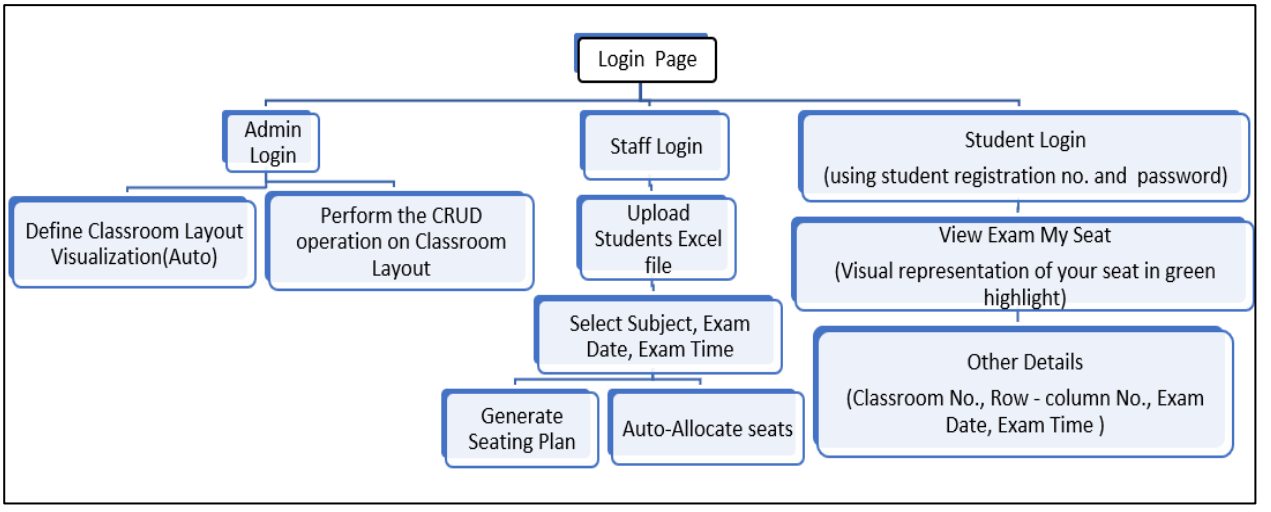

Fig. 2: System workflow.

4.3 Firebase data management layer

This module keeps all user dashboards and the database in real-time sync. This ensures that whenever an admin or staff makes some modifications, it reflects instantly on all dashboards to manage exams smoothly and in sync.

4.4 Student portal

Students can log in securely to get their seating information such as seat number, hall name, and details about the examination. The seating arrangement diagram is also provided within the portal for easy familiarization by the students.

4.5 Visualization module

The visualization component uses Matplotlib to create classroom seat maps. It emphasizes the student's assigned seat and shows the surrounding seating context for a clear, user-friendly visual representation of the room.

5. Methodology

The proposed system, SeatMatrix, follows a structured and modular methodology to automate examination seat allocation while ensuring fairness, efficiency, and real-time accessibility. The methodology integrates data preprocessing, constraint-based allocation, and visualization into a unified workflow.

The overall workflow consists of four sequential stages:

1. Data Acquisition and Preprocessing
2. Classroom Configuration
3. Intelligent Seat Allocation
4. Visualization and Data Retrieval

Each stage is designed to operate independently while maintaining seamless integration through a centralized cloud database.

5.1 Data acquisition and preprocessing

The process begins with the collection of student data, which includes attributes such as student ID, subject, examination date, and session. This data is uploaded in structured formats (e.g., Excel files) and processed using data-handling libraries.

Let the student dataset be defined as:

$$S=\{s_1,s_2,s_3,\ldots,s_n\} \quad (1)$$

where each s_i represents an individual student record.

Preprocessing ensures:

- Removal of duplicate entries
- Validation of required fields
- Grouping of students based on examination parameters

5.2 Classroom configuration model

Each examination hall is modeled as a grid-based structure defined by rows and columns.

Let a classroom be represented as:

C = (R,K)

where:

R = number of rows

K = number of columns

Total seating capacity is given by:

Cap = R x K

The system stores classroom configurations in structured JSON format, enabling flexibility in modifying layouts dynamically.

5.3 Seat allocation algorithm

The core of the system is a deterministic allocation algorithm designed to assign seats without duplication while maintaining an ordered distribution.

1) Problem definition

Given:

- A set of students S
- A set of classrooms $C_1, C_2, \ldots, C_m$

Objective:

- Assign each student a unique seat such that:
- No seat is assigned to more than one student
- Classroom capacity constraints are satisfied

2) Allocation function

The seat allocation can be defined as a mapping function:

$$f: S \rightarrow (C, r, k) \quad (2)$$

where,

C= classroom

r= row index

k= column index

Seat allocation can be formally represented as a one-to-one mapping function:

A : S → P

where S represents the set of students and P represents the set of available seats.

The allocation must satisfy the following constraints:

1. Uniqueness Constraint

A(si) ≠ A(sj), ∀ i ≠ j

ensuring that no two students are assigned the same seat.

2. Capacity Constraint

|S| ≤ Σ Capk

where Capk denotes the capacity of classroom k.

3. Validity Constraint

A(si) ∈ P

ensuring that every assigned seat belongs to a valid classroom layout.

The optimization objective is to maximize seat utilization while maintaining conflict-free allocation:

Maximize U = Assigned Seats / Total Available Seats

3) Algorithm steps

Step 1: Sort students based on predefined criteria (e.g., subject or registration number).

Step 2: Iterate through classrooms sequentially.

Step 3: For each classroom, assign students in row-major order:

$$Seat(i) = \left(\left\lfloor \frac{i}{K} \right\rfloor, \ i \bmod K\right) \quad (3)$$

where $i$is the index of the student in the ordered list.

Step 4: Ensure constraint satisfaction: If capacity is exceeded, move to the next classroom. Avoid duplicate assignments by maintaining a tracking structure

Step 5: Store allocation results in the cloud database

4) Conflict avoidance

To prevent allocation conflicts, a constraint function is applied:

$$g(s_i, seat_j) = \begin{cases} 1, & \text{if seat is available} \\ 0, & \text{otherwise} \end{cases} \quad (4)$$

Only seats satisfying $g(s_i, seat_j) = 1$are assigned.

5) Real-Time data synchronization

The system employs a cloud-based NoSQL database to maintain synchronization across all users. Any update in seating allocation is immediately propagated to connected clients.

Let the system state be represented as:

$$D(t) \quad (5)$$

where $t$denotes time. Updates follow:

$$D(t+1) = D(t) + \Delta D \quad (6)$$

ensuring consistency across all interfaces.

6) Visualization model

The visualization module converts allocation data into a graphical representation of classroom layouts. Each seat is mapped to a coordinate:

$$V = \{(x, y)\} \quad (7)$$

where:

x corresponds to row position

y corresponds to column position

The assigned student seat is highlighted distinctly, enabling easy identification. This approach improves usability and reduces confusion during examinations.

7) Complexity analysis

The time complexity of the allocation algorithm is:

$$O(n) \quad (8)$$

where n is the number of students, since each student is assigned a seat exactly once. Space complexity is also linear due to storage of allocation mappings.

The linear time complexity O(n) demonstrates that the proposed allocation algorithm scales efficiently with increasing numbers of students, making it suitable for deployment in large academic institutions conducting examinations for thousands of candidates simultaneously. The detailed time and space complexity analysis of the proposed allocation algorithm is summarized in Table 2.

Table 2: Time and space complexity analysis of SeatMatrix.

Operation	Complexity
Student Sorting	O(n log n)
Seat Allocation	O(n)
Database Storage	O(n)
Overall Time Complexity	O(n log n)
Space Complexity	O(n)

Time Complexity:-

Step 1: Sort students → O(n log n)

Step 2: Seat assignment → O(n)

Step 3: Store allocations → O(n)

Overall:

$T(n) = O(n \log n) + O(n) + O(n)$
$T(n) = O(n \log n)$
Space Complexity:
Student records = $O(n)$
Seat mapping = $O(n)$
Tracking structure = $O(n)$
Space Complexity = $O(n)$

8) Summary of methodology

The proposed methodology combines:

- Structured data processing
- Constraint-based seat allocation
- Real-time cloud synchronization
- Graphical visualization

This integrated approach ensures that the system is scalable, efficient, and user-friendly. A comparison between the capabilities of existing systems and the proposed SeatMatrix framework is provided in Table 3, demonstrating the advantages of the proposed solution.

6. Results

To evaluate system performance, A test case was executed:

6.1 Login page

The login interface of SeatMatrix is shown in Fig. 3. The system supports secure authentication for administrators, staff members, and students through a unified access portal.

Table 3: Comparison between existing system and SeatMatrix.

Feature	Existing Systems	SeatMatrix
Seat Allocation	Semi/Rule-based	Fully automated & optimized
Real-Time Updates	Not supported	Fully supported
Visualization	Text-based output	Graphical seat mapping
User Interaction	Minimal	Interactive dashboards
Multi-User Access	Restricted	Admin, Staff, Students
Scalability	Limited	Highly scalable

6.2 Admin classroom management page

Fig. 4 presents the classroom management dashboard used by administrators to create examination halls, define seating layouts, and manage classroom configurations.

6.3 Staff panel (Upload excel / Generate seating)

The staff dashboard shown in Fig. 5 enables examination personnel to upload student records, configure examination details, and automatically generate seating arrangements.

Student Dashboard: (Visual Seat Map), Fig. 6 illustrates the student dashboard, where users can view their examination details and identify their assigned seat through an interactive graphical seat map.

The characteristics of the dataset and experimental environment used for system evaluation are summarized in Table 4.

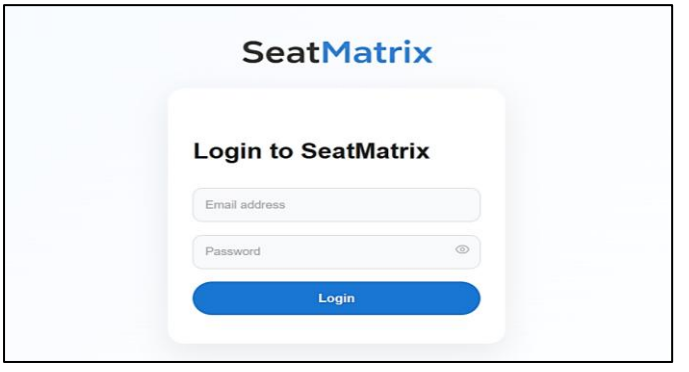

Fig. 3: Login interface supporting admin, staff, and student authentication.

Table 4: Experimental dataset description.

Parameter	Value
Total students	100
Number of classrooms	7
Seats per classroom	28
Total capacity	196
Number of experimental runs	5
Database platform	Firebase Realtime Database
Interface framework	Streamlit

7. Statistical performance analysis

To quantitatively evaluate the effectiveness of SeatMatrix, the proposed system was compared with conventional examination seating management approaches across six performance criteria. Scores were assigned on a ten-point scale based on functional capability, responsiveness, automation level, and usability characteristics. The comparative evaluation results are presented in Table 5.

The average score achieved by existing systems was 4.67, whereas SeatMatrix achieved an average score of 9.00. This represents an overall improvement of 92.7%. The highest performance gain was observed in visualization capability, where the proposed graphical seat-mapping approach improved effectiveness by 200% compared with traditional text-based seating systems. Real-time synchronization also showed substantial improvement due to the integration of Firebase Realtime Database, enabling instant propagation of seating updates across all connected users. The standard deviation of SeatMatrix scores was found to be considerably lower than that of existing systems, indicating consistent performance across multiple

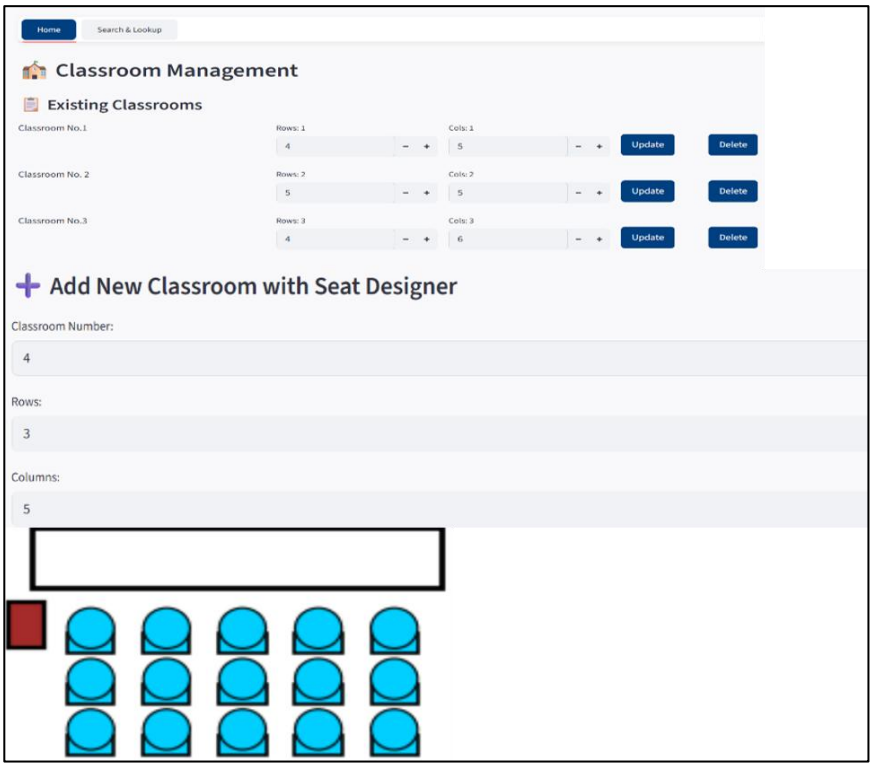

Fig. 4: Classroom management dashboard for creating and managing examination halls.

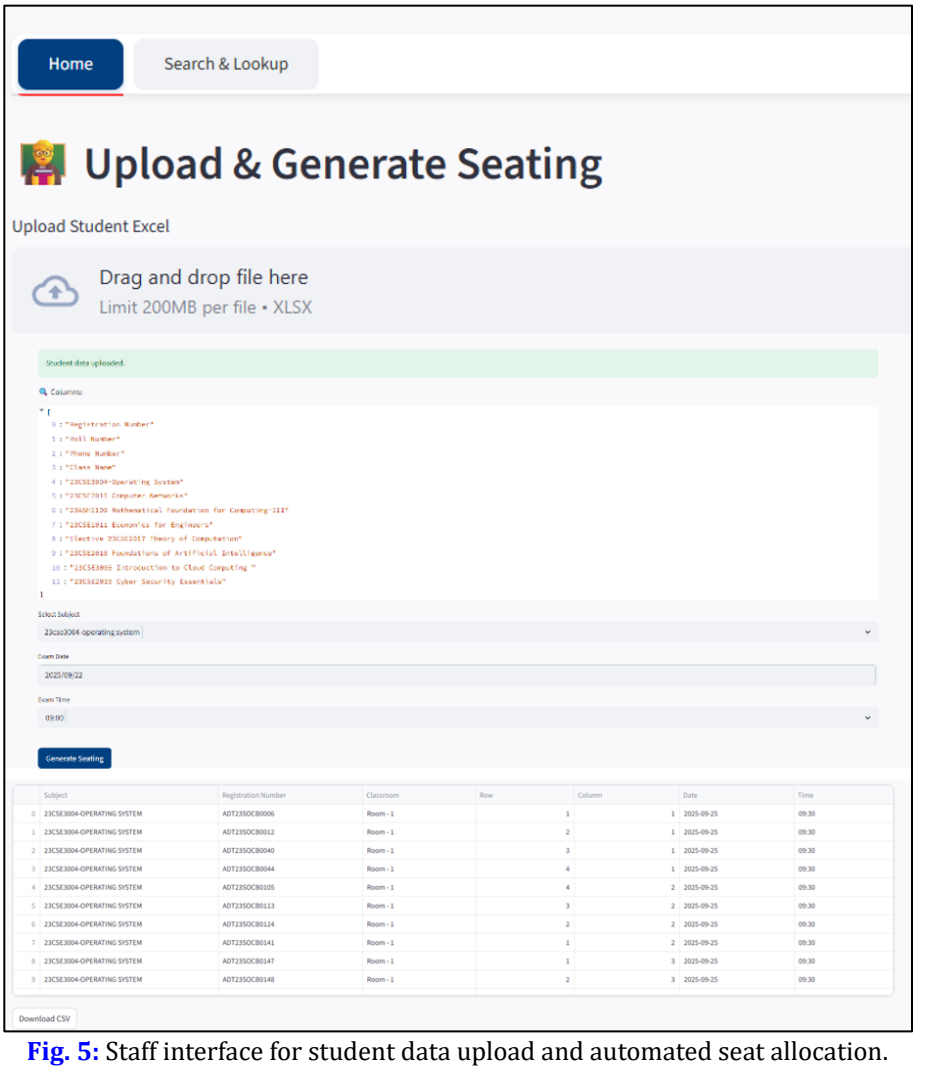

Fig. 5: Staff interface for student data upload and automated seat allocation.

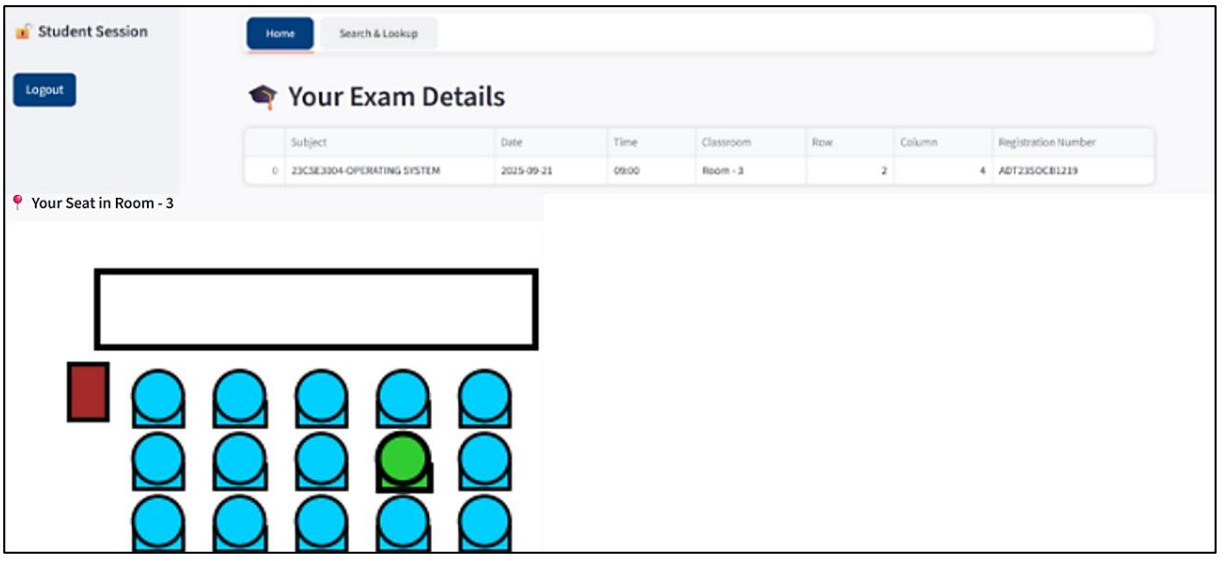

Fig. 6: Student dashboard displaying assigned seat through graphical visualization.

evaluation parameters. The results demonstrate that the proposed framework not only enhances automation but also provides a balanced improvement in usability, scalability, and user interaction. These findings validate the effectiveness of combining cloud computing, automated seat allocation, and graphical visualization within a unified examination management platform.

Table 5: Statistical comparison of existing examination management systems and SeatMatrix.

Parameter	Existing Systems	SeatMatrix	Improvement (%)
Automation	6	9	50.0
Cloud Support	5	9	80.0
Real-Time Synchronization	4	9	125.0
Visualization	3	9	200.0
Scalability	5	9	80.0
Usability	5	9	80.0

8. Experimental validation

To validate the effectiveness of SeatMatrix, experiments were conducted using examination datasets of varying sizes. The evaluation focused on seat allocation accuracy, processing time, and system scalability. Three datasets containing 100, 500, and 1000 student records were used. Each dataset was processed five times under identical conditions, and the average execution time was recorded. The experimental performance results are summarized in Table 6.

The results indicate that processing time increases gradually with the number of students, while allocation accuracy remains at 100%. No duplicate seat assignments or capacity violations were observed during testing. These findings demonstrated that the proposed system maintains high reliability and scalability even when handling large examination datasets.

To assess the consistency of the proposed system, multiple experimental runs were conducted for each dataset size. The statistical results obtained from these repeated executions are summarized in Table 7. The observed standard deviation values were low across all test cases, indicating stable and repeatable allocation performance. The results demonstrate that the proposed allocation mechanism produces consistent execution times while maintaining 100% seat allocation accuracy without conflicts or duplicate assignments.

Table 6: Performance evaluation results of the proposed SeatMatrix system.

Number of Students	Allocation Time (s)	Allocation Accuracy (%)
40	0.12	100
70	0.46	100
100	0.91	100

9. Discussion

The system identifies remarkable advancements in three The system identifies remarkable advancements in three distinct operational areas:

A. Operational Efficiency – Automation takes manual seat planning out of the separate planning process thus, weekly seat plans can be provided quickly and with a reduction in administrative burden.
B. Student Experience – Visual seat maps help to clarify seat assignments and reduce interactions with staff, especially during the busy exam period students must be told quickly where to sit on an exam day.
C. Scalability – Being cloud-driven is advantageous to expansion truly and adopting meta-data room configuration principals for travel makes the

Table 7: Statistical analysis of seat allocation performance.

Students	Run 1	Run 2	Run 3	Run 4	Run 5	Mean Time (s)	Standard Deviation
70	0.11	0.12	0.13	0.12	0.12	0.12	0.007
100	0.44	0.46	0.47	0.45	0.48	0.46	0.015

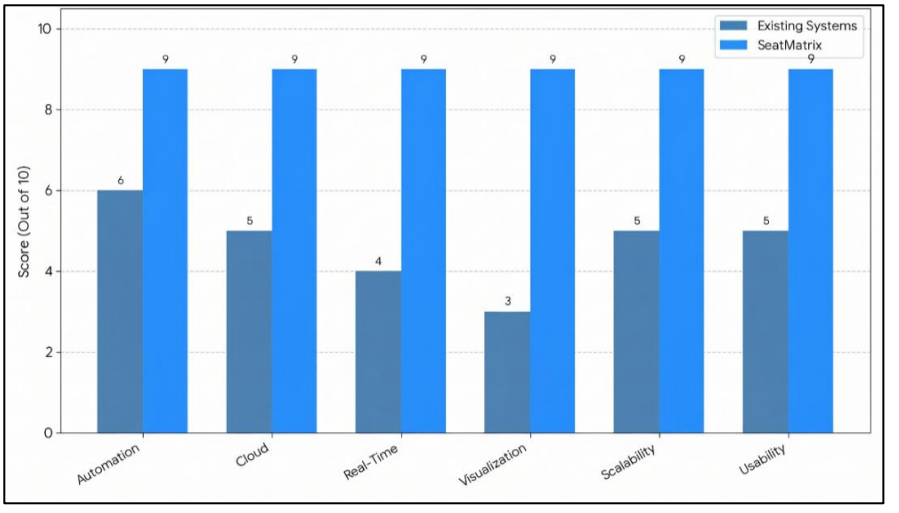

Fig. 7: Comparison of existing examination systems and the proposed SeatMatrix.

operation of the system easy to expand across multiple departments, buildings, or wrestling with large populations of students.

Fig. 7 visually compares the performance of SeatMatrix with conventional examination management systems across key evaluation parameters, demonstrating the improvements achieved by the proposed framework.

10. Conclusion

This paper presented SeatMatrix, a cloud-based intelligent examination management system designed to automate seat allocation, provide real-time synchronization, and offer graphical seat visualization for students and administrators. The proposed framework integrates a rule-based allocation engine, Firebase Realtime Database, Streamlit-based interfaces, and visualization modules into a unified platform for examination management. The experimental evaluation demonstrated that the system successfully generated conflict-free seating arrangements with 100% allocation accuracy across different dataset sizes. Statistical analysis further indicated significant improvements in automation, usability, visualization, scalability, and real-time accessibility when compared with traditional examination seating approaches. In addition, the computational complexity analysis showed that the proposed allocation mechanism operates efficiently with linear space requirements and O(n log n) time complexity, making it suitable for large-scale academic environments. By combining cloud computing, automated allocation, and interactive visualization, SeatMatrix addresses several limitations of existing examination management systems, including manual effort, lack of real-time updates, and poor user interaction. The proposed solution enhances operational efficiency while improving the overall examination experience for students and staff. Future work may focus on integrating QR-code-based examination entry verification, advanced security mechanisms, subject-wise separation constraints, predictive classroom utilization analytics, and dedicated mobile applications to further improve accessibility and functionality.

CRediT Author Contribution Statement

Kashish Reshamwala: Conceptualization, Data Curation, Experimental Evaluation, Formal Analysis, Investigation, Methodology, Software, Validation, Visualization, Writing – Original draft, Writing – Review & editing. **Savitri Chougule:** Methodology, Supervision, Writing – Review & editing. **Mohd. Shafi Pathan:** Supervision, Validation, Writing – Review & editing. All authors have read and agreed to the published version of the manuscript.

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Data Availability Statement

The data used to support the findings of this study consist of examination seating datasets, classroom configuration records, and experimental evaluation data generated during the development and testing of the proposed SeatMatrix system. The datasets are not publicly available

as they contain institution-specific information used for research validation. However, anonymized data and additional implementation details can be made available by the corresponding author upon reasonable request for academic and research purposes. The source code, classroom layout configurations, and system implementation details described in this paper are available from the authors upon request, subject to institutional policies and research usage guidelines.

Conflict of Interest

There is no conflict of interest.

Artificial Intelligence (AI) Use Disclosure

The authors declare that artificial intelligence (AI)-assisted tools were used only for language refinement, grammar improvement, and manuscript structuring purposes during the preparation of this work. All technical content, experimental implementation, results, and interpretations were independently developed and verified by the authors.

Supporting Information

No Applicable.

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