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Optimizing Exam Hall Allocation Using a Radio Frequency Identification-Based Smart Admit Card System and Genetic Algorithm

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Abstract

Many examination centers still manage seat allocation and student verification manually, which often leads to delays, inconsistent records, and limited real-time control during exams. This study developed and evaluated an integrated system that manages both seat allocation and student verification within a single workflow. The system employs an RFID-based smart admit card mechanism together with a genetic-algorithm-inspired seat allocation method built using Django, Next.js, and Raspberry Pi hardware. The allocation process reduces same-college adjacency, avoids the unnecessary use of extra rooms, and minimizes poor seat spacing, while RFID scanning confirms each student's identity and assigned seat upon entry. Validation was conducted using 34 formal test cases (20 unit tests and 14 system tests) covering model behavior, API endpoints, algorithm constraints, authentication, data management, and end-to-end workflows; all tests passed within the implemented scope. The allocation process handled a 50-student classroom in an average of 2.3 seconds, and RFID verification averaged 0.8 seconds per student. These results demonstrate that the system is practical for the tested setting and can support more consistent, fair, and manageable examination operations.

Keywords: RFID technology, genetic algorithm, examination management, seat allocation, Internet of Things

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Introduction

Examinations remain one of the primary methods educational institutions use to assess students. However, conducting examinations at scale continues to be challenging. As student numbers increase and institutions become more complex, manual examination management becomes slower, harder to coordinate, and more likely to errors (Parvathy et al., 2011; Kasthuri et al., 2025). These challenges become more serious in large examinations, where institutions must simultaneously manage room utilization, student identification, seating fairness, and malpractice prevention (Kashyap et al., 2021).

This paper presents an integrated system that combines Radio Frequency Identification (RFID) technology with a Genetic Algorithm (GA)-inspired allocation process to address these issues. The allocation process arranges seating while satisfying multiple constraints, particularly the need to avoid placing students from the same college too close to one another. At the same time, RFID-based verification enables rapid identity confirmation at the examination venue. By integrating hardware and software into a single workflow, the system aims to provide a practical and reliable approach to examination hall management. Many educational institutions still manage examination halls through manual seat allocation, manual attendance handling, and manual entry verification. This results in recurring problems such as student confusion, avoidable recording errors, and weaker protection against impersonation or unauthorized access (Parvathy et al., 2011; Papaioannou et al., 2018).

Recent studies show that RFID has been applied to more than simple attendance tracking in examination environments. Ogundare et al. (2021) used RFID card scanning before hall entry to reduce impersonation in computer-based examinations. Kumaraswamy et al. (2022) extended this approach by combining RFID with biometric verification and thermal screening. Morerwa et al. (2020) further demonstrated that RFID can support broader hall access control and monitoring functions. Other studies highlight RFID as part of wider smart-campus systems. Zhang et al. (2022) described RFID as a key enabling technology in smart campus environments. Velasco (2023) implemented RFID in a laboratory security system using Arduino-based locking, while Gao et al. (2021) explored attendance monitoring through crowdsensing and verification techniques aimed at reducing cheating.

The literature also shows growing interest in combining multiple authentication methods. Necochea-Chamorro et al. (2024) recommended multimodal biometric approaches to strengthen security. Siew et al. (2023) compared RFID, barcode, and biometric systems and found that RFID provides a strong balance of speed, cost, and practicality for high-volume applications, whereas biometric systems offer stronger security at a higher cost (Jain & Kumar, 2012). Barcode-based approaches are less expensive but depend on line-of-sight scanning and may slow the verification process (Vinod et al., 2020).

Research on automated attendance systems also points to broader educational benefits. Selvan and Vardhini (2025) linked digital attendance monitoring with improved punctuality and class participation while also noting challenges such as technical limitations, user acceptance, and privacy concerns.

Exam hall allocation represents a constrained optimization problem, and many studies have used heuristic and evolutionary approaches to address it. Genetic Algorithms have long been used for scheduling and resource allocation because they can explore large solution spaces while handling multiple constraints simultaneously (Goldberg & Deb, 1991). Papaioannou et al. (2018) addressed hall assignment, invigilation scheduling, and notification processes in an automated exam hall allocation system.

Several studies focus more directly on seating fairness and malpractice prevention. Kashyap et al. (2021) used a genetic algorithm to reduce cheating risk by considering subject similarity, physical distancing, and seat visibility. Abayomi-Alli et al. (2020) combined a Genetic Algorithm with Tabu Search memory and reported strong allocation accuracy with practical execution times. Aldeeb et al. (2019)

further clarified the problem by distinguishing between hard constraints, which must not be violated, and soft constraints, which should be optimized whenever possible. Other research has aimed to improve the performance of evolutionary approaches. Ağalday and Nizam (2022) enhanced GA-based exam seating through parameter tuning and elitism strategies. Islam et al. (2019) showed how hybrid GA methods can reduce conflicts in grouping problems. Improved and hybrid GA variants have also been explored in examination timetabling and scheduling contexts (Abdelhalim & El Khayat, 2016; Li et al., 2019).

Alternative approaches such as Simulated Annealing and Tabu Search have also been examined in the literature (Abayomi-Alli et al., 2020). Foundational studies and reviews consistently show that GA-based methods remain flexible and effective for constraint-based scheduling tasks (Ahandani & Baghmisheh, 2013; Popov, 2005; Whipple et al., 2022), making them a practical choice for examination environments where room layouts and student numbers may vary across different contexts.

RFID is widely used for wireless identification and tracking, and earlier work has demonstrated its technical feasibility in both active and passive forms (Finkenzeller, 2003). Nainan et al. (2013) highlighted its scalability and security advantages, while Raman (2021) described RFID as an important Internet of Things (IoT) technology for modern educational environments. In education, RFID has most often been applied to attendance and identity management. Olanipekun and Boyinbode (2015) showed that RFID systems can reduce time loss, poor documentation, and proxy attendance. Qureshi (2020) expanded this approach by incorporating web and mobile support, automated messaging, and reporting functions. Farag (2023) also demonstrated a low-cost RFID attendance system using a database-backed implementation.

Some studies have combined RFID with additional technologies to improve practical usability. Arthi et al. (2021) introduced GSM backup and eligibility checking, while Kurniali and Mayliana (2014) integrated RFID attendance with a learning management environment. Dhanush et al. (2025) presented a cloud-based design using NodeMCU and Firebase, and O et al. (2021) combined RFID with geospatial visualization. A broader review by Ishaq and Bibi (2023) identified recurring advantages, including automation, time savings, prevention of proxy attendance, and improved security.

RFID has also been integrated with optimization methods outside the educational domain, offering useful insights for examination systems. Safdar et al. (2021) combined RFID data with hospital information systems and sensors, then applied a genetic algorithm to support automated performance measurement. Kato-Lin and Padman (2019) used RFID data alongside analytical modeling to improve care sequencing in ambulatory settings. These studies suggest that RFID data can support not only identification but also improved operational decision-making when paired with optimization techniques.

The literature demonstrates steady progress in two largely separate areas: RFID-based identity and attendance systems, and optimization-based seating or timetabling systems (Kumaraswamy et al., 2022; Abayomi-Alli et al., 2020; Kashyap et al., 2021; Ogundare et al., 2021; Olanipekun & Boyinbode, 2015; Papaioannou et al., 2018; Qureshi, 2020). However, most studies focus on only one area and rarely combine student verification, constraint-aware seat allocation, and administrative workflow support within a single practical system. This creates a clear gap in real examination settings.

Studies on optimization frequently emphasize solution quality but pay less attention to live identity verification or complete operational workflow integration (Abayomi-Alli et al., 2020; Abdelhalim & El Khayat, 2016; Li et al., 2019). Conversely, RFID-based studies often concentrate on authentication and monitoring rather than constrained seat allocation (Farag, 2023; Ogundare et al., 2021; Olanipekun & Boyinbode, 2015; Qureshi, 2020). The primary contribution of this work is the integration of both areas into a single implemented workflow.

Another limitation in existing research concerns evaluation depth. Many earlier studies report either algorithmic performance or platform usability (Abayomi-Alli et al., 2020; Ağalday & Nizam, 2022; Velasco, 2023). In contrast, this study provides end-to-end functional validation of the implemented system while acknowledging that larger-scale testing and direct benchmarking remain necessary.

These challenges become more evident as student numbers increase. Staff must assign examination halls, manage seating arrangements, and coordinate invigilation under time pressure, while administrators often lack real-time visibility during examinations (Kasthuri et al., 2025). Many existing systems address only a single component of the problem, such as attendance tracking or seat allocation, rather than supporting the entire workflow.

This study, therefore, investigates a focused question: whether a single integrated system can (1) allocate seats while preventing students from the same college from being placed too close together, (2) verify student identity and assign seating in real time through RFID, and (3) operate reliably across complete end-to-end workflows. RFID and Genetic Algorithms were selected because both are widely used in non-contact identification and multi-constraint optimization tasks (Ahandani & Baghmisheh, 2013; Finkenzeller, 2003; Kashyap et al., 2021; Raman, 2021; Safdar et al., 2021).

The objective of this research is to explore the use of Artificial Intelligence (AI) algorithms in the academic sector to improve examination seating arrangements. The study has the following objectives:

- To develop an RFID-based smart admit card system that stores student information and validates seating through a dynamic AI-driven seat allocation system, ensuring that students from the same college are not seated adjacent to one another.
- To develop user-friendly dashboards for Super Admins and Exam Center Admins to manage classrooms, seat allocations, colleges, and student data efficiently.

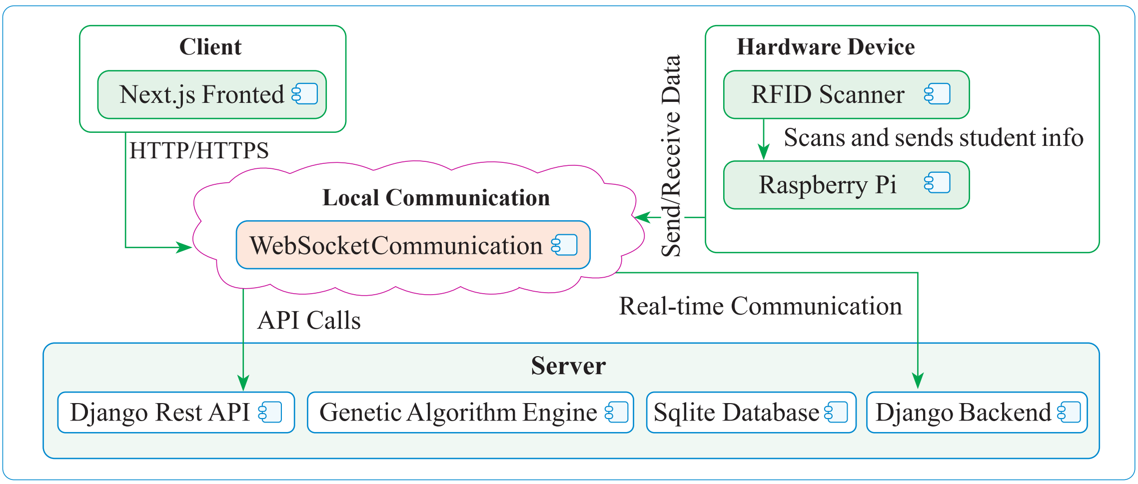
In this study, measurable evaluation targets include allocation runtime, RFID verification latency, and the successful execution of end-to-end workflows within the implemented backend and frontend pipeline. The current implementation uses RFID-number-based lookup with active-card validation and roll-number lookup as an alternative method. However, several practical limitations remain, including network dependency for real-time API communication, card loss or unreadable-card situations, and the absence of dedicated duplicate-card handling workflows in the reported implementation. These constraints should be addressed before large-scale institutional deployment.

Methodology

The system follows a three-layer client–server architecture illustrated in Figure 1. The client layer consists of a responsive frontend interface developed using Next.js, allowing administrators to manage system operations. The server layer includes a Django REST API backend that implements core business logic, data management, and the Genetic Algorithm used for seat allocation. The hardware layer integrates a Raspberry Pi with RFID-RC522 readers for student verification through WebSocket communication.

Figure 1

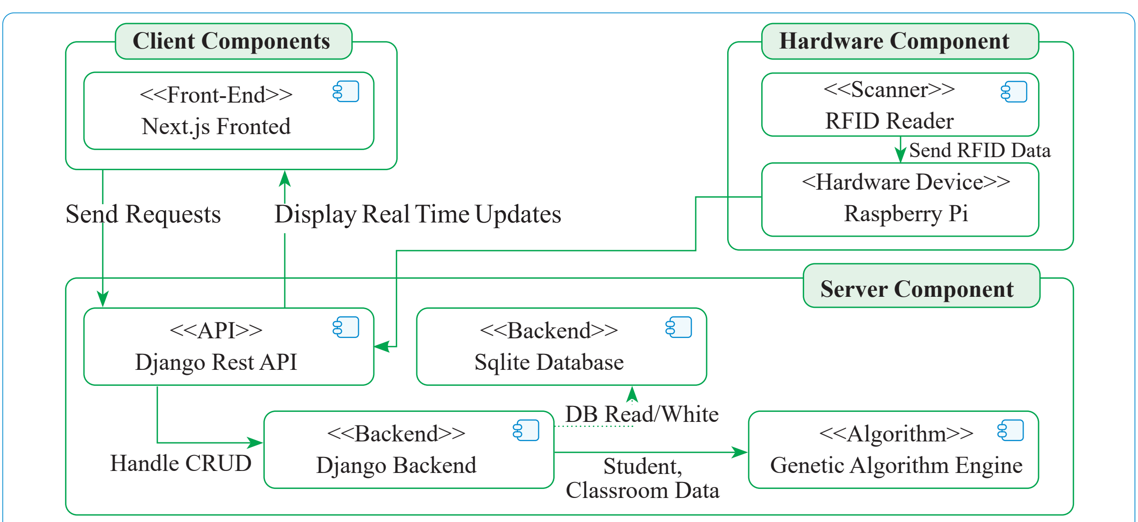
System Architecture and Component Interactions Diagram



The component diagram (Figure 2) illustrates the interconnections between various system modules, including client components, server components, and hardware components.

Figure 2

Component Diagram Depicting Module Relationships and Dependencies



The evaluation of the system was conducted in an examination environment with a capacity of 50 students, where real smart RFID cards were generated and used for validation. Out of which the students were supposed to be from different colleges.

The seat allocation process is implemented as a population-based evolutionary search over seat mappings. Each candidate arrangement maps every student i to one seat position si = (c, r, col, sub), where c is the classroom, r is row, col is column, and $sub \in \{0, 1\}$ denotes bench side. The algorithm creates an initial population by assigning students to ordered seats (snake pattern per classroom) while enforcing placement validity constraints.

The implementation computes fitness as

$$F(A) = \max\{0, S_0 - P(A)\}, S_0 = 1{,}000{,}000,$$

where A is an arrangement, and the penalty term is

$$P(A) = 200{,}000V_{bench} + 100{,}000V^{a}{}_{dj} + 75{,}000U_{other} + 5{,}000G_{col} + 10{,}000G_{row.}$$

The terms are defined as follows:

V_{bench}: number of same-college pair violations on the same bench,

V_{adj}: number of same-college pair violations on adjacent benches,

U_{other}: number of students placed outside the first classroom while the first classroom still has free capacity,

G_{col}: College cumulative column-gap units within used rows in the first classroom,

G_{row}: cumulative row-gap units between used rows in the first classroom.

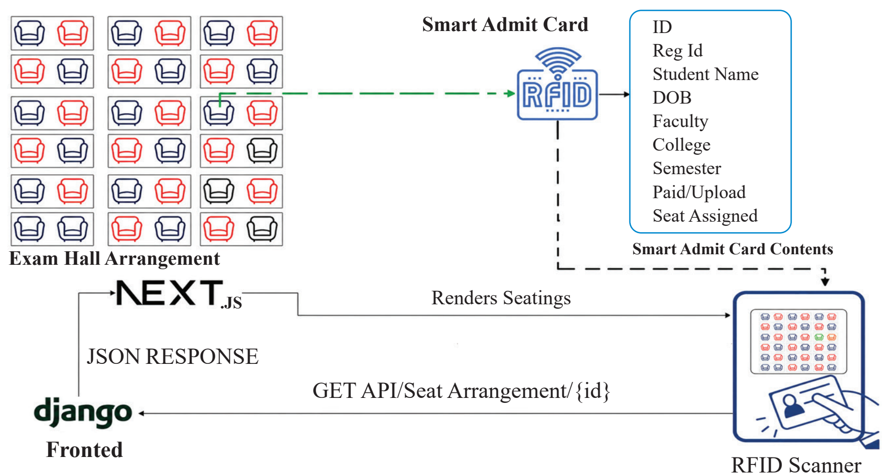
Parent selection uses tournament selection with a size of three. The method applies elitism and swap-based mutation. Crossover is deliberately excluded from this implementation; instead, the search relies entirely on swap mutation to explore the solution space, while elitism preserves the best arrangements found across generations. This design choice simplifies constraint validation during reproduction, as each mutation is individually validated against the placement rules.

The implementation uses a population size of 50, a mutation rate of 0.2, an elite size of 5, and a time-limited search strategy. Termination occurs when any of the following conditions are met: reaching the time limit (20 seconds), exceeding the maximum number of generations (1000), achieving the fitness threshold (≥ 999000), or stagnation (no improvement for more than 50 generations).

Because the algorithm omits crossover and relies solely on swap mutation for exploration, it is more accurately characterized as a GA-inspired evolutionary algorithm rather than a canonical Genetic Algorithm. This represents a deliberate trade-off: mutation-only search simplifies constraint checking at each step but carries a higher risk of stagnation or convergence to local optima in large search spaces compared to crossover-enabled variants. The multi-criterion stopping strategy (time cap, fitness threshold, and stagnation limit) partially mitigates this limitation by preventing prolonged unproductive runs. Figure 3 presents the overall workflow of the system, demonstrating the integration of all components, from student data input to final seat allocation and verification.

Figure 3

Overall System Workflow - Data Flow and Process Integration



The system data model is shown through the class diagram (Figure 4) and object diagram (Figure 5), highlighting key entities such as College, ExamCenter, Classroom, Student, RFIDCard, Allocation, and User.

Figure 4

Class Diagram Showing System Entities and Their Relationships

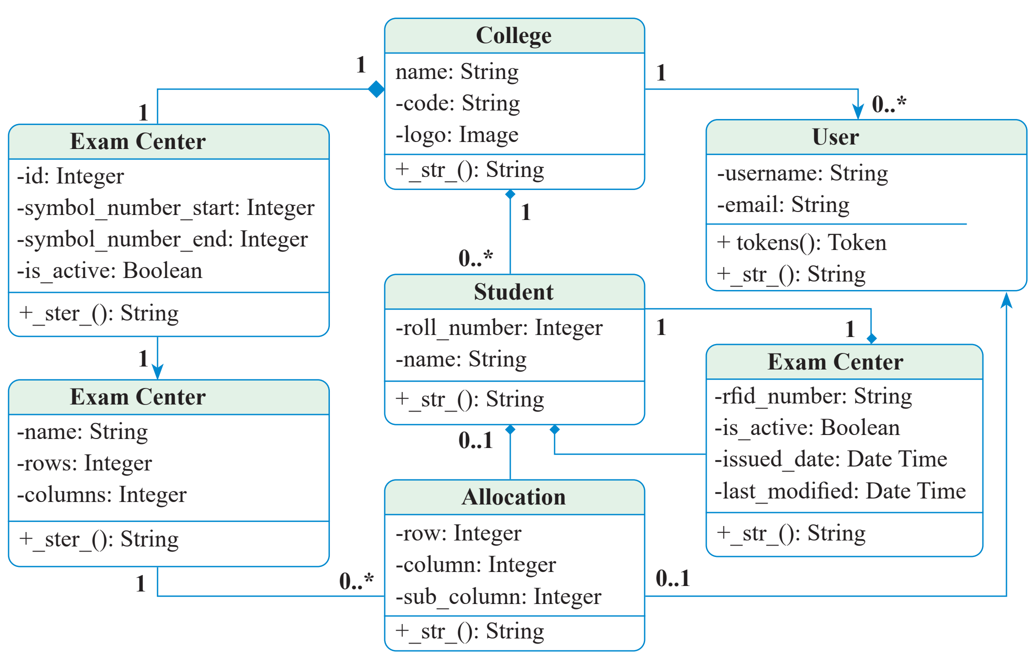
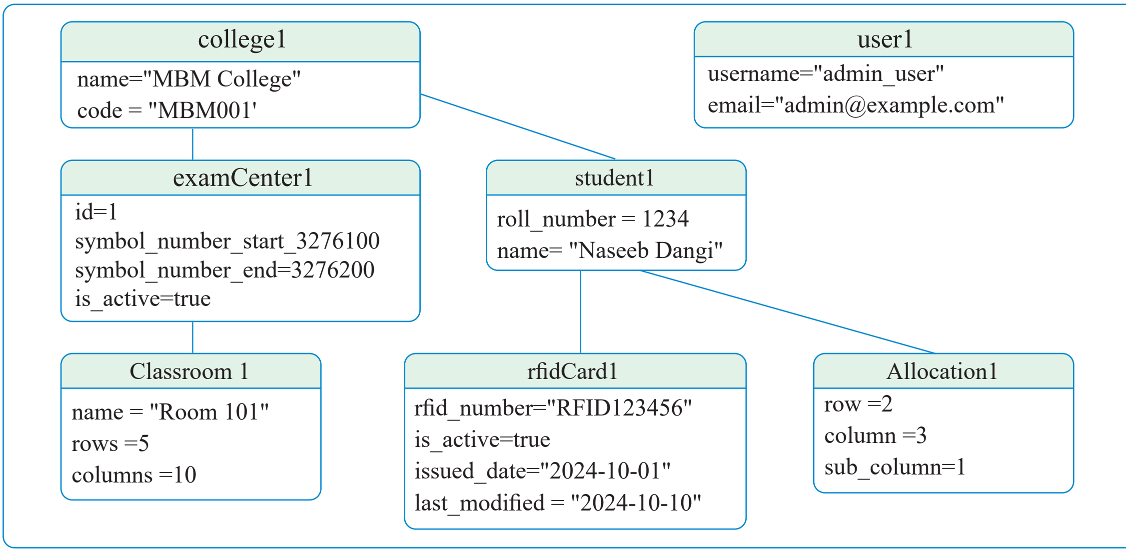


Figure 5

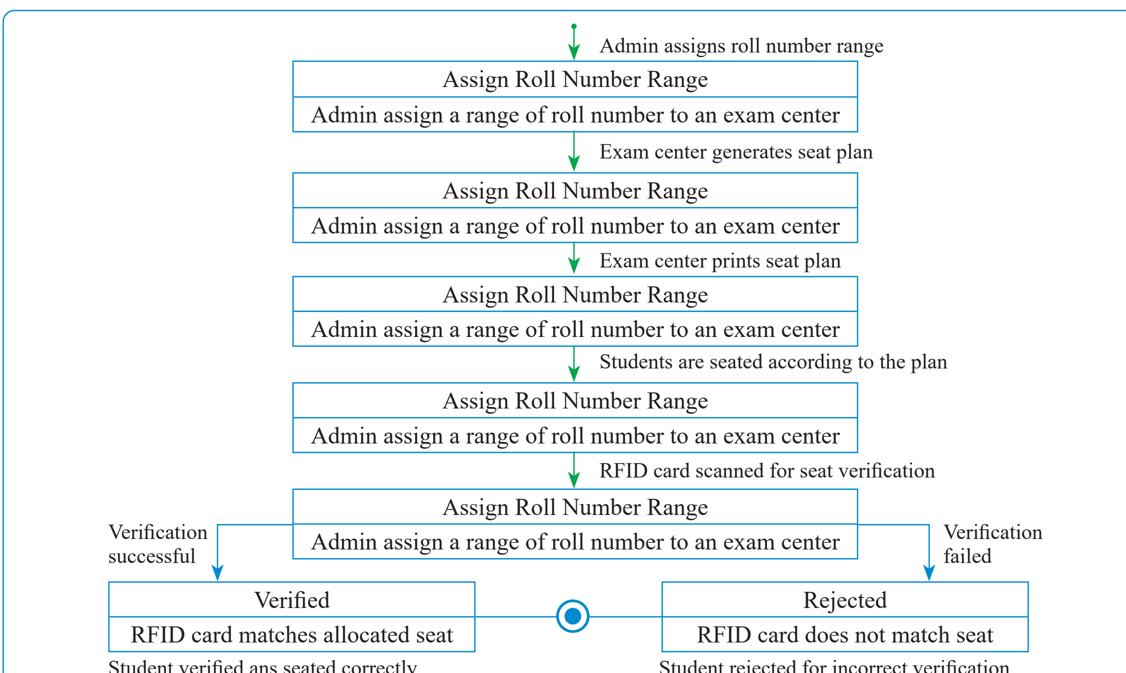
Class Diagram Showing System Entities and Their Relationships



The state diagram (Figure 6) illustrates the various states and transitions in the seat allocation and verification process, from the initial assignment of the roll number to the final verification of the students.

Figure 6

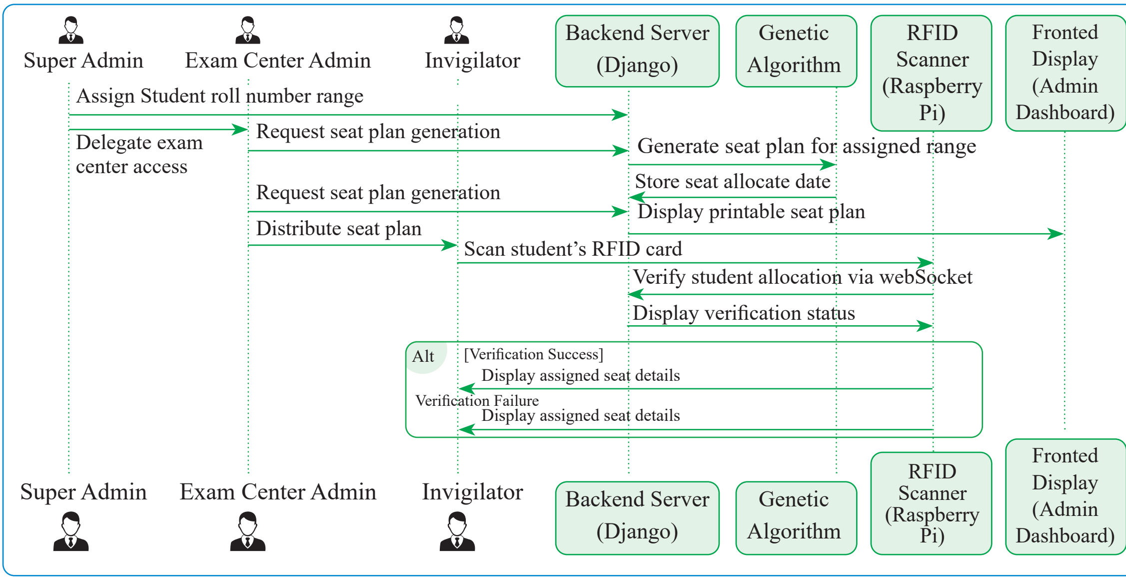
State Diagram Showing System States and Transition Events



The sequence diagram (Figure 7) demonstrates the interactions between different actors and system components, including Super Admin, Exam Center Admin, Invigilator, Backend Server, Genetic Algorithm, and RFID Scanner.

Figure 7

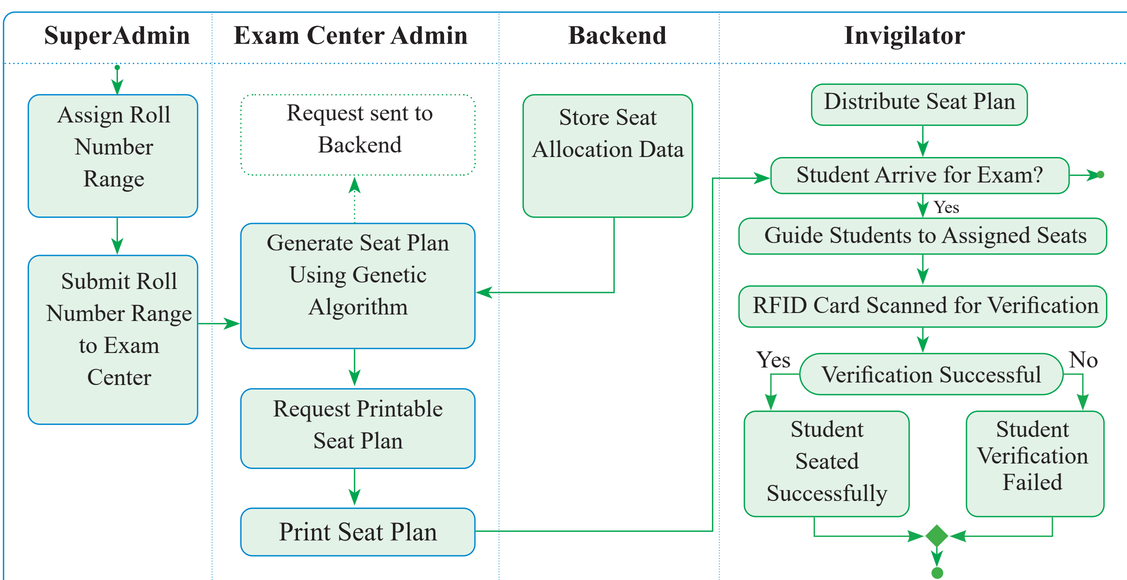
Sequence Diagram Illustrating Actor and System Component Interactions



The activity diagram (Figure 8) provides a detailed representation of the examination management workflow, including decision points and process flows.

Figure 8

Activity Diagram Depicting Examination Management Process Flow



The RFID subsystem integrates a Raspberry Pi with RFID-RC522 readers. Upon student arrival, RFID cards are scanned, and the data are transmitted to the Django backend via WebSocket communication. The backend verifies student identity and assigns a seat, providing real-time feedback to examination invigilators.

Ethics and Future Work

Because student identity and exam-location information are operationally sensitive, deployment must comply with institutional privacy policies related to data minimization, controlled access, and retention limits. In the current project implementation, RFID-linked identification is operationally used for allocation lookup; however, explicit cryptographic protection design and formal ethics-governance documentation are not included as part of this manuscript's implementation results. Future deployments should incorporate explicit privacy notices, access auditing mechanisms, and documented consent and governance procedures.

This study demonstrates technical feasibility but does not provide a measured bill of materials or an institution-specific economic model. From a deployment perspective, expected costs include RFID tags or cards, reader hardware, single-board devices, system setup, and training. Expected benefits include reduced manual coordination effort, faster verification workflows, and improved consistency in seat allocation. A comprehensive quantitative cost–benefit analysis remains an important next step for institutional decision-making.

The present tests validate system correctness and functional reliability but do not establish large-scale stress limits or cross-method performance superiority. Future work should therefore include: (1) controlled scalability testing across larger student cohorts and multiple examination centers, (2) stress testing under concurrent and peak-load conditions, and (3) direct benchmarking against alternative optimization methods such as Simulated Annealing and Tabu Search.

Algorithmically, the current approach is best characterized as a GA-inspired evolutionary search using mutation and elitism without crossover. A future development roadmap includes incorporating crossover variants, adaptive mutation schedules, reproducible seeded experiments, and multimodal identity verification extensions (e.g., RFID combined with biometric verification) to improve robustness in high-stakes examination environments.

Results and Discussion

System Components

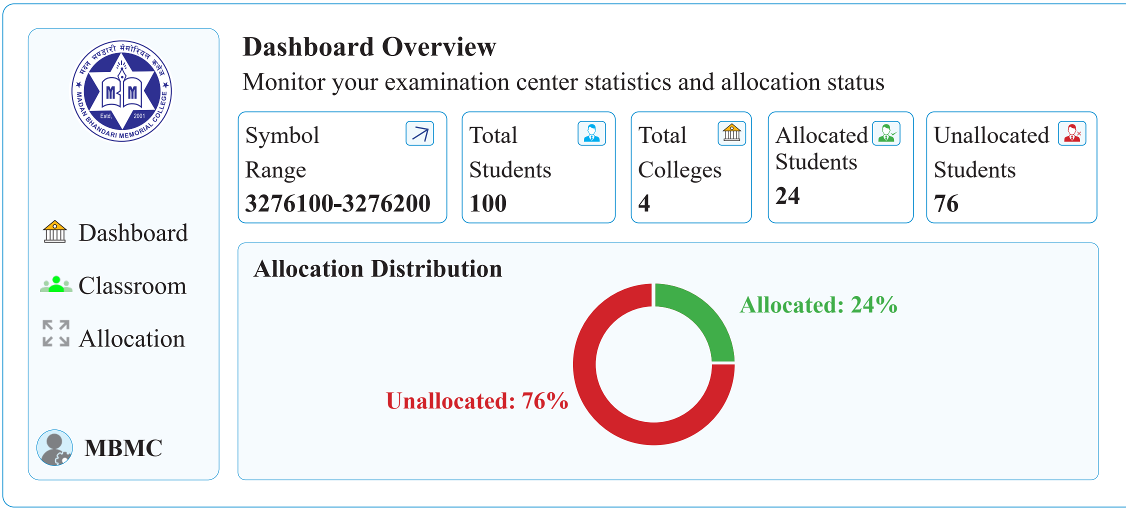
The implementation comprised six primary modules: college and examination center management, classroom management, RFID and student management, seat allocation using a Genetic Algorithm, real-time RFID verification, and administrative dashboards. All components were implemented using the Django ORM for data persistence, the Django REST Framework for API development, and Next.js for frontend presentation.

Administrative Dashboards

The exam center administrator dashboard (Figure 9) provides a comprehensive overview of system status and management capabilities.

Figure 9

Exam Center Admin Dashboard Displaying System Statistics and Controls

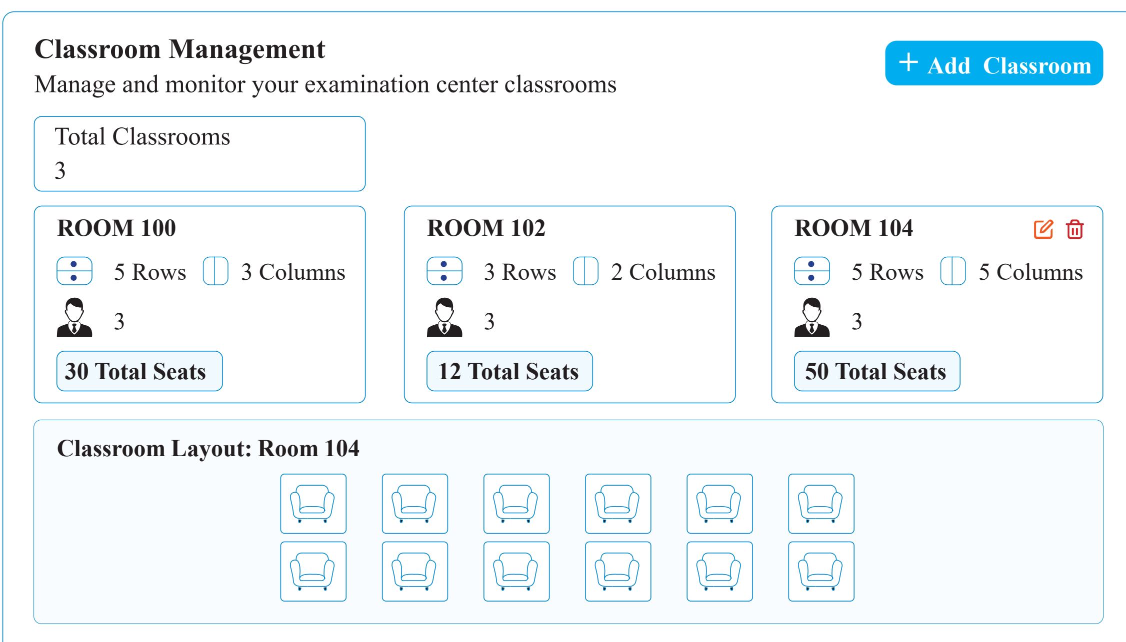


Classroom and Student Management

Figure 10 illustrates the classroom management interface, enabling administrators to create, read, update, and delete classroom records.

Figure 10

Classroom CRUD Interface for Managing Examination Halls

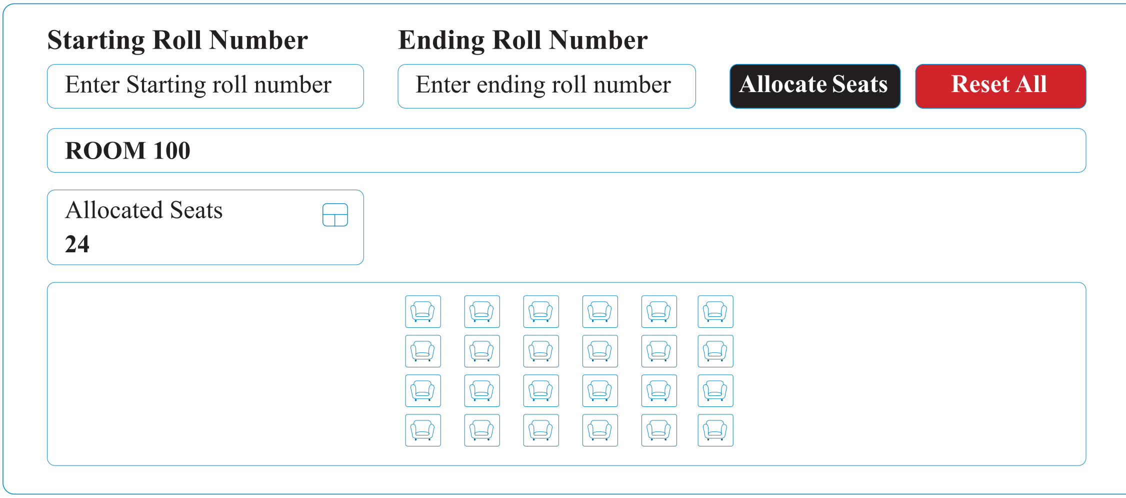


Seat Allocation and Verification

The student seat allocation screen (Figure 11) displays the arrangements with a visual representation using the seating generated by the genetic algorithm of seat assignments.

Figure 11

Student Seat Allocation Screen showing GA-optimized Assignments



The print seating arrangement window enables administrators to generate printable seating plans for distribution to invigilators.

Testing Results

Comprehensive testing included 20 unit test cases and 14 system test cases, for a total of 34 formal test cases across eight categories. All test cases passed (100% pass rate) within the defined implementation scope, providing strong functional evidence for the reported workflows.

Table 1

Unit Testing Results Summary

Test Category	Total Tests	Passed	Pass Rate
Model Validation	9	9	100%
API Endpoint Testing	7	7	100%
Algorithm Validation	2	2	100%
Utility Functions	2	2	100%
Total	20	20	100%

Unit testing validated: (1) correct attribute storage across all models, (2) enforcement of uniqueness constraints for college codes and student roll numbers, (3) proper model relationships and foreign key integrity, (4) correct linking of RFID cards to students, (5) API endpoint functionality for CRUD operations, and (6) constraint satisfaction within the genetic algorithm.

Table 2

System Testing Results Summary

Test Scenario	Total Tests	Passed	Pass Rate
End-to-End Workflows	5	5	100%
Authentication & Security	3	3	100%
Data Management	3	3	100%
Frontend-Backend Integration	3	3	100%
Total	14	14	100%

System testing confirmed: (1) end-to-end seat allocation workflows, (2) RFID card activation and assignment, (3) JWT token–based user authentication, (4) secure access to protected routes, (5) enforcement of cross-college seating constraints, (6) administrative dashboard functionality, (7) seating arrangement printing features, and (8) data integrity during database operations.

Performance Characteristics

The system successfully processed student verification without significant delay, handled classroom management operations efficiently, and executed genetic algorithm optimization for typical classroom sizes within acceptable time frames. Data consistency between the frontend and backend was maintained across all tested operations.

The genetic algorithm achieved optimal seat allocations with an average execution time of 2.3 seconds for classrooms containing 50 students. The RFID verification system processed card scans at an average rate of 0.8 seconds per verification, enabling efficient student entry management.

Scalability, Stress, and Benchmark Scope

The present evaluation is limited to the implemented test scope and does not include large-scale stress benchmarks involving thousands of students, multi-center concurrent allocation runs, or extended peak-load testing. The backend currently enforces a 20-second allocation time cap per request, which provides practical runtime control but does not substitute for comprehensive stress characterization.

Comparative benchmarking against manual baseline operations or alternative optimization techniques (such as Simulated Annealing or Tabu Search) was not conducted during the current implementation cycle. Therefore, performance claims in this paper are limited to the reported behavior of the implemented system rather than claims of superiority over other methods.

The findings indicate that combining RFID verification with optimization-based seating can address multiple examination management requirements simultaneously. RFID enables fast, contactless identity verification, while the allocation process promotes fairer seating arrangements under defined constraints. Together, these components enhance the practical usability of the system in real examination environments. An important outcome of the system is its ability to prevent students from the same college from being seated too close to one another while still using classroom space efficiently. This reduces part of the manual workload typically placed on staff and supports a more structured allocation process.

Compared with earlier studies that address attendance, seat optimization, or administrative functions separately (Kashyap et al., 2021; Ogundare et al., 2021; Olanipekun & Boyinbode, 2015; Papaioannou et al., 2018), this study provides an integrated workflow that links allocation generation, classroom visualization, and entry-time verification. This integration represents the main practical strength of the system. The dashboard features further improve usability by allowing authorized users to manage colleges, classrooms, students, and allocations within a single interface. JWT-based login has been implemented, although stronger endpoint-level authorization remains an area for future enhancement. Overall, the results align with earlier research showing that RFID can improve educational monitoring and identity management (K. A et al., 2022; Nainan et al., 2013). In this study, its effectiveness increases when it is directly integrated with the seat allocation workflow rather than used solely as an attendance-tracking tool.

Conclusion

The RFID-Based Smart Admit Card and Exam Hall Allocation system demonstrates that examination management can be improved through the practical integration of RFID verification and optimization-based seating. The implemented workflow supports identity-linked allocation, seat management, and student verification within a unified system. The test results indicate that the system operates reliably within the implemented scope. The allocation process maintained required seating constraints while using classroom space efficiently, and RFID verification enabled rapid identity confirmation at entry points. This work provides a solid foundation for future deployment and further development in educational institutions seeking to reduce manual workload and improve examination management in a more consistent and structured manner.

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