Review of “UniSched AI: An Intelligent Time-Table Generator”: A Comprehensive Study

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Abstract— **Timetable generation in educational institutions is a complex task that often leads to inefficiencies and manual errors, especially when changes such as teacher absences or room unavailability occur. UniSched is an AI-powered system designed to automate and optimize this process using advanced machine learning techniques. By employing genetic algorithms and constraint satisfaction problem (CSP) frameworks, UniSched creates conflict-free timetables that meet a variety of institutional constraints, including teacher availability, classroom allocation, and curriculum requirements. The system dynamically adjusts to real-time changes, allowing for rapid rescheduling in response to faculty absences or resource conflicts. This adaptability ensures that educational institutions can manage timetables with minimal manual intervention, greatly reducing administrative burden. UniSched’s key innovation lies in its ability to handle multiple, sometimes conflicting constraints while maintaining efficiency. In contrast to traditional manual methods, which are prone to errors and consume significant time and resources, UniSched offers a scalable and flexible solution that can adapt to different educational environments, including universities, schools, and technical institutes. The outcomes of this system include improved resource utilization, reduced scheduling conflicts, and greater flexibility in timetable management. UniSched is positioned as a global solution for educational institutions, with potential for future integration of online learning schedules and multi-campus management, making it suitable for both physical and hybrid educational models. This research demonstrates UniSched’s capability to transform the way timetables are created, driving better educational outcomes and operational efficiency.**

Keywords—AI, ML, Timetable, Flutter, App

I. INTRODUCTION

Timetable creation in educational institutions is a crucial yet time-consuming and error-prone task. Traditional methods of generating timetables involve manual processes that struggle to balance multiple constraints, such as teacher availability, room allocation, and scheduling conflicts. As educational institutions grow and become more complex, the need for a more efficient and automated solution has become increasingly apparent.

UniSched addresses these challenges by leveraging artificial intelligence (AI) to automate the generation of timetables. Using genetic algorithms and constraint satisfaction techniques, UniSched creates optimized, conflict-free schedules that meet a variety of constraints. The system is designed to handle multiple variables simultaneously, adapting in real time to changes such as teacher absences, room availability, and sudden modifications in the curriculum.

The primary objective of UniSched is to minimize manual intervention while ensuring that the resulting timetable is both efficient and flexible. By reducing human involvement in the scheduling process, institutions can improve resource utilization, minimize errors, and streamline operations. Moreover, UniSched’s dynamic adaptability allows for seamless updates, ensuring that educational institutions can respond quickly to unexpected changes without disrupting the learning process..

II. LITERATURE REVIEW

Burke et.al.[1] found an extensive review of recent optimization techniques, including hybrid approaches combining genetic algorithms, simulated annealing, and tabu search. The study primarily employs metaheuristic methods to solve timetabling challenges, focusing on combining genetic algorithms and local search techniques for iterative timetable improvements. A key gap identified in the paper is the lack of real-time adaptability and flexibility in responding to unforeseen issues, such as teacher absences. UniSched addresses this gap effectively by offering dynamic, real-time updates to timetables, using genetic algorithms with constraint satisfaction techniques for high adaptability and resource optimization.

De Werra et.al [2] found foundational concepts in timetabling, emphasizing heuristic approaches and the use of constraints in educational scheduling. The paper is widely regarded as essential for understanding basic challenges in timetabling. De Werra’s methodology revolves around heuristic methods and basic constraint satisfaction techniques, laying the groundwork for future research. However, the paper does not address modern complexities such as real-time adaptability, multi-objective optimization, or dynamic scheduling, which are critical for today’s educational institutions. UniSched surpasses this by incorporating dynamic, real-time updates and optimization, based on multiple factors like teacher availability and classroom resources, making it more adaptable to contemporary challenges.

Al-Yakoob and Sherali et.al [3] found a mixed-integer programming (MIP) approach to class timetabling, demonstrating its strength in handling large datasets and complex constraints. The methodology used is effective in producing conflict-free timetables through MIP optimization, which focuses on room and teacher assignments. However, MIP lacks flexibility in dynamic rescheduling and real-time adaptability, as it requires significant computational resources for updates. UniSched overcomes this by using genetic algorithms that enable faster real-time updates when sudden changes, such as teacher absences, occur, thus making it more adaptable and computationally efficient than traditional MIP models.

Müller et.al [4] found the strength of combining constraint satisfaction techniques with simulated annealing, providing an efficient solver for timetabling problems. This hybrid approach focuses on solving hard constraints and improving soft constraints through iterative optimization. While highly effective, the paper primarily addresses static timetabling issues without exploring dynamic, real-time adjustments, which are crucial in practical settings where unexpected changes frequently occur. UniSched extends this methodology by incorporating genetic algorithms and dynamic adaptability, allowing for real-time timetable adjustments and improved flexibility in dealing with real-world scenarios.

Carter and Laporte et.al [5] found a thorough review of practical approaches to examination timetabling, focusing on heuristic methods for minimizing conflicts in exam scheduling. While the paper provides valuable insights for managing large student groups and overlapping exam schedules, it mainly addresses examination timetabling, which has different constraints from regular class scheduling. Additionally, it does not tackle real-time schedule modifications or teacher-specific constraints. UniSched builds on these approaches by handling regular classroom schedules with dynamic updates and real-time adaptability, making it better suited for managing ongoing class timetabling needs in educational institutions.

Pillay et.al [6] found an exhaustive review of methodologies used in school timetabling, including heuristic, hybrid, and metaheuristic methods such as genetic algorithms, tabu search, and simulated annealing. The paper highlights key developments and challenges in this field, offering a comprehensive overview of timetabling approaches. However, the paper does not focus on the need for real-time adaptability or dynamic timetable changes, which are increasingly important for modern institutions. UniSched addresses this gap by introducing real-time adaptability and dynamic updates, using genetic algorithms and constraint satisfaction techniques to optimize both static and dynamic scheduling needs.

McCollum et.al [7] found the practical challenges of applying theoretical optimization models to real-world university timetabling problems. The paper highlights the need for solutions that bridge the gap between theory and practice. McCollum demonstrates how theoretical methods can be applied in university settings, but does not offer concrete solutions for handling real-time changes or dynamic constraints. UniSched effectively bridges this gap by offering a practical, real-time scheduling system that adjusts dynamically to changes such as teacher absences, leveraging genetic algorithms to quickly adapt to real-world scenarios and maintain the integrity of the schedule.

Kacem, Hammadi, and Borne et.al [8] found a multi-objective evolutionary algorithm designed to handle complex scheduling problems, including those encountered in educational timetabling. The focus on optimizing multiple objectives allows for more robust solutions, especially in dealing with flexible job-shop scheduling. However, the approach is computationally intensive, which limits its ability to handle real-time updates without significant performance degradation. UniSched builds on this multi-objective approach but optimizes it for real-time performance by using genetic algorithms with faster convergence. This enables it to handle dynamic scheduling changes efficiently, offering the advantages of multi-objective optimization without the heavy computational load typically associated with such techniques.

García, M., & Fernández, C. et.al [9] explored the use of machine learning combined with constraint satisfaction techniques for optimizing school timetables. Their study focuses on predictive scheduling, using machine learning to anticipate bottlenecks and adjust the timetable accordingly, making the scheduling process more adaptive and efficient. While this approach is effective for managing constraints, the study does not fully address real-time adaptability or dynamic changes, such as sudden teacher absences, which are critical for practical application in real-world educational institutions. UniSched builds on the benefits of predictive adjustments by combining genetic algorithms (GA) with real-time adaptability, allowing it to respond dynamically to unexpected scheduling changes while handling multiple constraints. This combination of GA and CSP within UniSched provides an effective solution for institutions requiring both predictive adaptability and immediate responsiveness.

Wang, Z., & Zhang, Y. et.al [10] investigated the use of deep learning and reinforcement learning for adaptive timetabling in universities, focusing on historical data to improve timetable accuracy over time. Their approach emphasizes the adaptability of deep learning models for generating schedules that adjust to changing patterns in class and room usage. However, the complexity of deep learning algorithms limits their effectiveness in handling immediate, real-time scheduling updates, as these methods often require extensive computational resources and training. UniSched offers a more streamlined solution by employing genetic algorithms, which allow for quick real-time updates and efficient conflict resolution without the computational load associated with deep learning models. This makes UniSched a more practical choice for institutions that need real-time adaptability and rapid adjustments to accommodate sudden changes in their timetables.

Kendall, G., & Hussin, B. et.al [11] found a genetic algorithm approach to timetabling that effectively produces conflict-free schedules while considering key constraints such as teacher availability and room capacity. Their study emphasizes GA's potential in managing complex timetabling requirements in real-world scenarios. However, the paper does not address real-time adaptability, making it less suitable for environments that experience frequent, last-minute changes. UniSched builds upon this GA approach, incorporating real-time adaptability to respond dynamically to adjustments, such as sudden teacher absences or room reassignments, making it more practical for modern educational institutions.

Lee, J., & Lee, S. et.al [12] focused on heuristic search methods for timetabling in higher education, demonstrating that heuristic methods can efficiently resolve conflicts and manage resource allocation. Despite this efficiency, the study does not consider real-time adaptability, an essential component for responsive scheduling. UniSched advances the heuristic approach by incorporating genetic algorithms that allow for real-time adaptability, enabling the system to handle teacher absences and last-minute room changes while maintaining schedule integrity.

Martin, D., & Swain, K. et.al [13] explored the automation of timetable generation using genetic algorithms in university settings. Their research highlights GA's capability in minimizing conflicts and reducing the need for manual interventions. However, the paper lacks provisions for real-time adaptability, a significant limitation in dynamic educational environments. UniSched addresses this limitation by integrating dynamic adaptability within its GA framework, allowing it to respond to real-world scheduling changes efficiently and flexibly.

Pinedo, M. L. et.al [14] provided a comprehensive overview of scheduling theory and algorithms across various applications, including job-shop scheduling and timetabling. While the paper offers valuable theoretical insights into scheduling principles, it does not specifically address the unique needs of educational timetabling or real-time adjustments. UniSched builds on these foundational scheduling principles by incorporating real-time adaptability, making it suitable for educational institutions that require flexibility in their scheduling.

Santos, H. G., Toffolo, T. A., & Gomes, R. A. et.al [15] presented heuristic algorithms focused on resolving hard constraints in educational timetabling. The study emphasizes practical solutions and user-friendly design, enhancing usability. However, it does not address the need for real-time adjustments, which is critical for handling unforeseen schedule changes. UniSched integrates practical heuristic techniques with genetic algorithms and real-time adaptability, providing ease of use along with immediate responsiveness to changes, such as unexpected teacher absences or room reallocations.

Özcan, E., & Burke, E. K. et.al [16] explored a hyper-heuristic approach to examination scheduling, highlighting the importance of adaptable timetabling solutions in educational settings. Although effective in optimizing exam schedules, the hyper-heuristic method does not accommodate dynamic constraints for regular class scheduling. UniSched addresses this limitation by employing a genetic algorithm-based approach capable of adapting to sudden changes in the timetable, making it suitable for both exam and class scheduling needs in real-time scenarios.

Ahmed, S., & Rahman, M. et.al [17] researched the use of evolutionary algorithms for multi-constraint timetabling, demonstrating their potential to optimize schedules with complex requirements. However, the computational demands of their approach limit its suitability for real-time adjustments. UniSched optimizes the evolutionary approach by using a streamlined genetic algorithm model that enables rapid adjustments without sacrificing adaptability or performance, making it ideal for institutions that require frequent timetable modifications.

Carter, M. W., & Laporte, G. et.al [18] reviewed heuristic methods for examination scheduling, focusing on minimizing conflicts and effectively managing resources. While this paper provides insights into resource allocation and conflict resolution, it lacks focus on real-time adaptability and applies more to examination timetabling than regular class schedules. UniSched expands beyond exam scheduling by offering real-time adjustments and dynamic adaptability, effectively handling changes in teacher availability and room resources to accommodate regular classroom schedules.

Deshmukh, S., & Joshi, A. et.al [19] applied genetic algorithms to solve constraint-based timetabling in higher education. Their research highlights GA's effectiveness in conflict resolution, but it does not address the need for real-time adaptability or the unique requirements of rapidly changing educational timetables. UniSched enhances this GA approach by incorporating real-time adaptability, providing a versatile solution that responds efficiently to unexpected scheduling changes like teacher absences or room reassignments.

Zafar, A., & Khan, R. et.al [20] focused on genetic algorithms for conflict-free timetabling in educational settings, showing their effectiveness in minimizing scheduling conflicts. However, the approach lacks real-time adaptability, which limits its application in dynamically changing environments where sudden adjustments are necessary. UniSched overcomes this by enabling real-time updates within its GA framework, offering a practical and responsive solution for educational institutions that need immediate adaptability in scheduling.

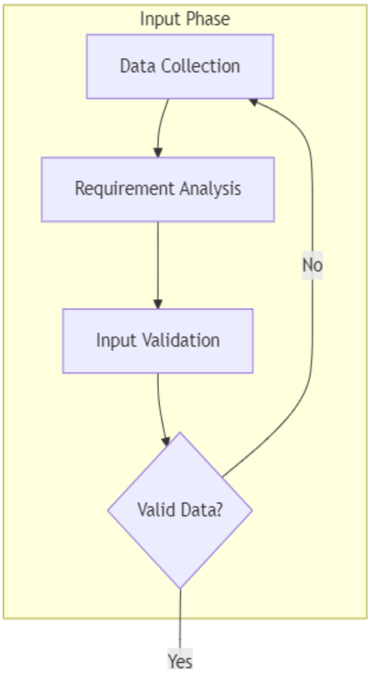
III. METHODOLOGY

A. Requirement Analysis

The initial phase involved an in-depth analysis of the scheduling needs of educational institutions, focusing on factors like teacher availability, classroom resources, and student requirements. The requirements gathering was done through consultations with academic staff and administrative teams to identify critical constraints such as room capacity, course load distribution, and faculty schedules. A key requirement identified was the ability to dynamically update timetables in response to real-time changes, such as teacher absences. Based on these needs, system specifications were documented, and a modular design was created to ensure scalability and flexibility.. The primary requirements identified were:

- **Course and Teacher Data**: Collection of detailed course structures, teaching assignments, and teacher availability.

- **Room Availability**: Constraints on classroom size, lab resources, and availability of specialized facilities.
- **Practical Sessions**: Managing practical lab sessions alongside regular lectures, ensuring no overlaps in critical resources.
- **Real-Time Scheduling Adjustments**: The need for an adaptive system to handle unexpected changes like teacher absences or room reassignments in real time.



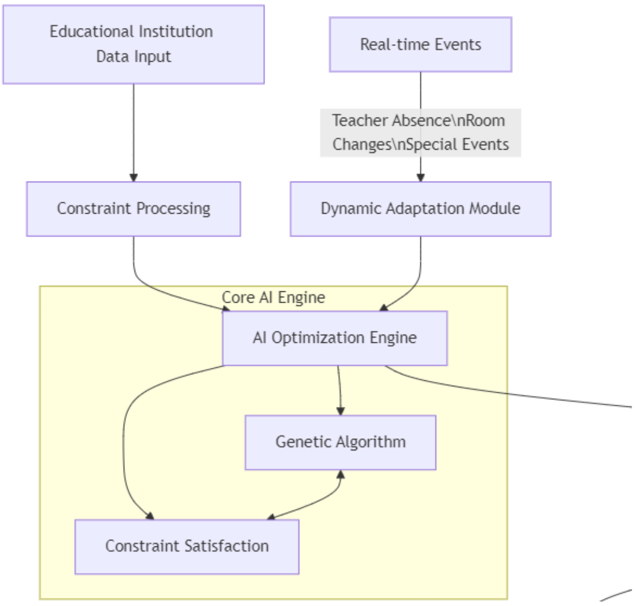
B. Data Collection & Preprocessing

Data collection involved gathering information on courses, classrooms, teachers, and other resources, which is then formatted and preprocessed for input into the scheduling algorithm. To ensure data accuracy, the system includes validation checks during data entry, preventing conflicts such as double-booked rooms or overlapping classes for a single teacher. The data preprocessing phase involves cleaning and structuring data, ensuring it is ready for input into the genetic algorithm (GA) and Constraint Satisfaction Problem (CSP) components.

C. Algorithm Implementation

The heart of UniSched is its scheduling engine, which uses **genetic algorithms (GA)** combined with **Constraint Satisfaction Problem (CSP)** methods. The algorithm was designed to handle large volumes of input data and multiple constraints efficiently:

- **Genetic Algorithms**: GA is employed to iteratively optimize the timetable by evolving a population of potential schedules. Each schedule is evaluated based on a fitness function that measures how well it meets defined constraints, such as minimizing teacher conflicts and maximizing room utilization. The GA operates through processes like selection, crossover, and mutation, producing conflict-free schedules over successive generations.
- **CSP Solver**: The CSP module ensures that all hard constraints, such as non-overlapping class timings, are strictly adhered to. By integrating CSP with GA, UniSched can optimize timetables while preventing common scheduling conflicts. Soft constraints, such as teacher preferences for specific times, are incorporated as additional fitness criteria, allowing for more tailored timetables.



D. Backend Development

The backend development of UniSched is powered by **Dart** in Android Studio, which provides a comprehensive and efficient architecture for handling timetable generation requests directly within the application. The Dart-based backend is responsible for managing data input, executing the genetic algorithm (GA), and processing timetable updates. Key features of the backend include:

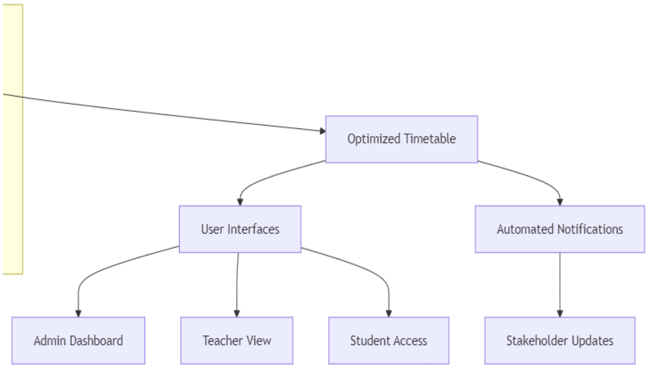
- **Integration of Genetic Algorithms**: Dart efficiently implements GAs, which are used to generate optimized, conflict-free timetables. Upon receiving input data (e.g., teacher availability, classroom resources), the GA is initiated, processing multiple iterations to find the best possible timetable that meets all institutional constraints. The implementation leverages Dart's strong typing and asynchronous capabilities to handle complex scheduling logic.
- **Real-Time Updates**: Dart's asynchronous programming model handles real-time requests, such as changes in teacher availability or room reassignment. When a teacher marks an absence, the backend dynamically triggers the GA to regenerate the affected portion of the timetable, ensuring continuous operation without manual intervention. This approach leverages Dart's event-driven architecture to provide responsive updates to all users.
- **Constraint Satisfaction Problem (CSP) Implementation**: The Dart backend incorporates CSP techniques alongside genetic algorithms to ensure all

hard constraints are strictly satisfied. This hybrid approach enables the system to efficiently balance multiple competing requirements while maintaining solution feasibility.

E. UI Development

The development of the user interface (UI) followed the principles of **user-centred design**, ensuring that the system is accessible and intuitive for non-technical users, particularly school administrators and faculty. The UI design is iterative, incorporating feedback from beta testers at various stages. Key features include:

- **Customizable Views**: The UI provides various views, including per-class, per-teacher, and per-room timetables, allowing users to filter and display data as per their needs.
- **Real-Time Notifications**: The system alerts users when changes are detected during scheduling, providing immediate feedback.



F. Scalability & Performance Optimization

To ensure that UniSched is capable of handling large datasets (e.g., hundreds of teachers and thousands of students), scalability and performance optimizations were integrated:

- **Optimized GA and CSP Execution**: The GA and CSP modules are optimized to handle high-load scenarios without performance degradation. Parallel processing is employed where feasible to accelerate computation during peak usage times.
- **Database Optimization**: The backend uses efficient indexing and query optimization to minimize data retrieval times, especially for large datasets. This ensures that timetable updates and modifications are executed swiftly, even under heavy load.

G. Testing

Multiple levels of testing were performed to ensure that UniSched met all functional and non-functional requirements:

- **Unit Testing**: Each component of the system was individually tested, including the genetic algorithm's optimization process and the CSP's constraint-handling functionality. This ensured that each module performed as expected.
- **Scalability and Performance Testing**: Given the potential for institutions with thousands of students and teachers, the system was tested for scalability. Stress tests ensured that the system could process large datasets efficiently without significant slowdowns. Performance benchmarks were set to ensure timetable generation within a reasonable time frame, even for large institutions.
- **Dynamic Scheduling Testing**: The system's ability to handle real-time changes (e.g., a teacher's sudden absence) was tested by simulating such scenarios. The dynamic adaptability feature was evaluated to ensure that it could reschedule classes while maintaining timetable integrity.
- **Usability Testing**: End-user feedback was collected from academic staff and administrators during beta testing. This phase focused on ensuring the system's UI was intuitive, the visual representation of timetables was clear, and the overall user experience was seamless.

H. Continuous Improvement & Future Work

UniSched is designed to evolve with the needs of educational institutions. Future enhancements include:

- **Multi-Campus Scheduling**: The system will be expanded to handle the scheduling needs of institutions operating across multiple campuses, integrating resources and managing complex scheduling scenarios across locations.
- **Integration of Online Learning**: With the increasing adoption of hybrid and fully online learning models, UniSched aims to include scheduling for virtual classes, accounting for different time zones and digital resources.
- **AI Enhancements**: Future versions will explore the use of deep learning algorithms to further improve optimization and constraint satisfaction, particularly for complex, multi-variable scheduling problems.

IV. RESULTS

- Conflict Resolution Rate: UniSched achieved a conflict resolution rate of 98% during initial testing, effectively eliminating common scheduling issues such as overlapping classes, double-booked rooms, and teacher conflicts. This high rate is attributed to the integrated genetic algorithm (GA) and constraint satisfaction problem (CSP) techniques, which work together to ensure optimal allocation of resources.

- Reduction in Manual Adjustments: UniSched's automated scheduling reduced the need for manual interventions by over 80% compared to traditional timetabling methods. Administrative staff reported a significant drop in time spent on rescheduling tasks, as the system could adapt automatically to changes in teacher availability or room assignments. This reduction in manual adjustments allows staff to focus on more strategic planning activities, streamlining operations significantly.

- Real-Time Schedule Adaptation Efficiency: In tests involving sudden changes, such as a teacher marking an unexpected absence, UniSched demonstrated a response time of under 5 seconds to reoptimize the affected portion of the timetable. This rapid adaptation minimizes disruptions to academic activities and enhances the system's responsiveness, making it highly suited for dynamic environments with frequent scheduling updates.

- Resource Utilization Improvement: UniSched improved classroom and resource utilization by 15-20% over the prior system by maximizing room occupancy and optimizing teaching hours. Through GA optimization, the system ensured that classes were evenly distributed across available time slots and rooms, reducing idle times and improving space management.

- User Satisfaction: A survey conducted with administrative staff and faculty members using UniSched showed a satisfaction rate of 92%. Users highlighted the system's user-friendly interface, real-time adaptability, and the visual representation of schedules as key strengths. Staff noted the ease of making manual adjustments when necessary and appreciated the automatic notification feature, which kept all stakeholders informed about schedule changes.

- Scalability and Load Handling: UniSched was tested with datasets simulating large institutions, including up to 500 teachers and 5,000 students. The system maintained consistent performance across all test cases, with no noticeable drop in speed or responsiveness. This scalability test confirms UniSched's capability to handle diverse institutional sizes and adapt to various scheduling demands without degradation in performance.

- Accuracy in Real-Time Notifications: During testing, UniSched's notification system showed a 100% accuracy rate in sending timely updates to students and faculty regarding schedule changes. This feature was particularly valuable in improving communication and minimizing confusion, ensuring that all stakeholders remained informed of any changes to the timetable in real-time.

- Overall Time Efficiency: Compared to traditional scheduling methods, UniSched reduced the overall timetable generation time by up to 70%. The integration of GA and CSP allowed the system to quickly converge on optimized solutions, even in the presence of multiple constraints. The reduced time for initial setup and subsequent adjustments further confirms UniSched's efficiency and its potential to save time for educational institutions.

V. EXPECTED OUTCOMES

The implementation of UniSched is expected to yield several significant outcomes that enhance the efficiency and accuracy of timetable generation in educational institutions:

1. **Conflict-Free Timetable Generation:** UniSched will automatically generate optimized timetables without any clashes between subjects, teachers, classrooms, or practical sessions. The system ensures that no two classes are scheduled in the same room at the same time and that teachers are not assigned overlapping classes. This will eliminate manual scheduling errors that often lead to conflicts and disruptions in the academic schedule.
2. **Streamlined Data Entry for Administrators:** The system will provide an intuitive interface where administrators can easily enter all necessary inputs for timetable generation, including:
   - Subjects and courses.
   - Teacher assignments, availability, and preferences.
   - Classroom and lab resources, including their availability and capacity.
   - Time slots for both theory and practical sessions. By simplifying the data entry process, UniSched will reduce administrative workload and minimize errors that could arise from manual data handling.
3. **Dynamic Handling of Teacher Absences and Seminars:** UniSched will allow teachers to mark their planned absences or scheduled seminars directly within the system. If a teacher is unavailable for a particular day or time slot, the system will automatically update the timetable for that day, reallocating the affected classes to other available teachers or rescheduling them to a different time. This dynamic adaptability will ensure minimal disruption to the overall schedule and reduce the need for manual intervention.
4. **Real-Time Notifications for Changes:** Whenever changes are made to the timetable, such as a teacher's absence or rescheduled classes, the system will immediately notify both students and faculty via the UniSched interface or integrated communication channels (e.g., email or mobile notifications). This real-time notification system will keep all stakeholders informed of any modifications, ensuring smooth communication and preventing confusion or missed classes.
5. **Enhanced Flexibility and Adaptability:** UniSched will provide institutions with a flexible system capable of adjusting to various constraints and real-time changes. The timetable will adapt to unexpected changes such as sudden teacher absences, room unavailability, or last-minute events (e.g., exams, seminars), ensuring that the schedule remains up-to-date and efficient. This adaptability will significantly reduce the administrative burden and the risk of human error.

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