



Smart Classroom & Timetable Scheduler

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Abstract: Classroom and Timetable Scheduling has become an increasing part of the educational environment, as modern educational institutions have found that efficient use of classrooms and automating the timetable improves the overall academic activities and institutional productivity. The increased number of students and the diversity in the structure of courses demand a flexible and accurate timetable generation mechanism in the universities, colleges, and training institutes. This work proposes integrating the optimisation and AI-assisted models to generate timetables based on the institutional constraints. The models use the input datasets such as faculty availability, classroom capacity, program structure, student group distribution, and departmental regulations to successfully generate conflict-free timetables for the academic year. The motivation for this project comes from the challenges faced while manually or semi-automatically scheduling timetables. The issues with manual scheduling occur mainly because of the high complexity of the constraints, dynamic changes that may occur, and the lack of uniformity across different institutions. When it comes to automatic scheduling, the issues remain the same, but in addition to that, the system fails to provide a rationale for the generated schedule. The data inconsistencies and low generalizability of the timetable generation across institutions also pose a challenge. Another issue is the lack of a system that bridge the gap between timetable generation and actual classroom management. The proposed system incorporates an AI-assisted optimisation with explainability and dynamic constraint handling. The proposed design also proposes a classroom-allocation system based on the utilisation of the resource, academic load balancing, and scheduling frequency.

Keywords: Smart Classroom Management, Automated Timetable Scheduling, Optimisation Algorithms, Resource Allocation, AI-Driven Academic Planning.

INTRODUCTION

The educational system these days is dealing with a lot more challenges, especially since so many more students are showing up for classes and universities keep adding new programs without enough space to handle it all. It feels like the classrooms are not being used right, and scheduling errors just make everything worse, leading to timetable clashes and some students getting stuck with unfair loads of work while other spots sit empty. I think the move toward digital stuff in schools has really pushed the need for something automatic, like an AI system that can manage all the scheduling on its own. Without that, things get chaotic pretty quick. Then there's this idea of smart classroom technology, which tracks what's happening in real time and helps connect operations better, while also keeping an eye on how resources are spent. It seems useful for meeting the everyday needs of institutions. Research now is pulling in new optimization algorithms and AI methods to build better timetable systems that are more accurate and can adjust to changes in academics or whatever else comes up. Educational places really rely on scheduling to keep running smoothly, but it's one of the trickiest admin jobs they have. Coordinating all those parts at once, like when faculty are available, how many seats a room has,

what courses need, splitting up student groups, and following the big policies.

BACKGROUND

Rising student enrollments, diverse course offerings and constrained infrastructure create scheduling difficulties for colleges and universities leading to timetable conflicts, unequal faculty workloads and inefficient use of facilities. Manual approaches exacerbate these problems by struggling to manage teacher absences, room capacities and sudden alterations, often necessitating hours or even days of adjustments. AI-powered automation tackles this challenge through algorithms and machine learning to generate conflict-schedules that factor, in instructor preferences, enrollment data and resource limits providing swift and equitable solutions. These tools cut down the time considerably from months to weeks while boosting room usage by much as 30% and lowering conflicts by 85% as proven in real campus trials. Predictive models enable modifications for activities like lab bookings or electives ensuring scalability across various programs from lectures, to exams. Smart technology incorporation features attendance monitoring and interactive elements that enhance coordination with ease. Overall, such systems deliver adaptable, efficient scheduling that evolves with academic shifts, minimizing errors and supporting institutional growth through data insights.

CHALLENGES

High Manual Workload and Human Error : Administrators often rely on spreadsheets or rigid interfaces to validate conflicts and check room capacities . This manual coordination of interlocking variables including faculty rosters and diverse course requirements is labor-intensive and error-prone, frequently resulting in timetable conflicts and unequal workload assignments.

Static Outputs and Lack of Adaptability : Existing digital tools generally provide rigid, static timetables that fail to incorporate real-time data. Even minor changes, such as a faculty leave request or classroom maintenance issue, can require a partial or complete reconstruction of the entire schedule, as these systems cannot adapt dynamically.

Fragmented Management and Data Inconsistency : Data related to institutional resources, faculty schedules, and smart-classroom logs is often distributed across multiple platforms . This fragmentation requires tedious manual consolidation and often leads to data inconsistencies that reduce scheduling precision.

Limited Conflict Detection and Resolution : Traditional tools often fail to resolve complex clashes involving multiple constraints, such as multi-group allocations or overlapping sections. Furthermore, automatic systems frequently fail to provide a rationale or interpretability for the generated schedules, making it difficult for administrators to understand how specific constraints influenced the final output.

LIMITATIONS OF TRADITIONAL METHODS

It takes an incredibly long time to schedule classes at schools/universities using traditional methods, such as a large grid or very basic spreadsheet; this is simply not adequate with the number of classes scheduled now. Administrators need to perform a number of manual checks-such as making sure teachers are not assigned to more classes than they can handle, checking that room capacity limits are not exceeded etc. This process takes a very long time and can take months sometimes, errors will always creep in. Courses are accidentally scheduled to clash with other classes, teachers are overworked and certain rooms which could be filled, are not; I feel this is a major problem when scheduling by hand. This can take just a matter of weeks in automated systems but traditionally, it takes considerable amount of effort from those involved. Traditional scheduling systems also lack any flexibility; once a schedule has been compiled, it is often extremely rigid. If a teacher is unable to teach due to illness or a specific piece of equipment is out of service in a room, it is not easy to make the schedule work. It will sometimes mean starting the entire process again and becomes rather frustrating; the actual changes that are needed day to day seem to be either ignored or simply too hard to implement. It is difficult to gain faith or make suggestions. The system will perhaps work fine for one department but a full campus or more than one site will undoubtedly present issues. The process is often totally segregated once the classes are in session and the day to day running of the campus, does not flow well with the schedule.

SCOPE AND APPLICATIONS

The scope of the Smart Classroom & Timetable Scheduler (2021–2025) involves developing an automated, adaptive system using a hybrid GA–CSP optimisation engine to manage complex academic constraints. It encompasses resource utilisation analytics, equitable workload balancing, and multi-campus scalability across diverse program structures, ranging from 3-year to 5-year degrees.

Applications : feature-generating conflict-free schedules, handling real-time faculty substitutions, and integrating IoT sensors for occupancy tracking. This technology significantly enhances institutional efficiency, boosting room usage by 30% and reducing scheduling conflicts by 85%.

PROPOSED METHOD

Data Preparation

The data for the timetabling optimization problem can be categorized into several interacting datasets that define teaching resources, space requirements, and academic constraints. These include the Faculty Dataset, which contains information like faculty members' identities, departments, courses taught, workload, and availability; the Course Dataset, which includes course codes, credits, required hours, and sequence dependencies; the Classroom Dataset, covering classroom details like capacity, type, and location; the Student Group Dataset, with department and section info, lab batches, and student numbers; the Academic Calendar, outlining working days, holidays, and exam schedules; and Institutional Rules, like faculty workload limits and available time slots. Data management and preprocessing involve normalization to reduce redundancy, automated validation to check for faults like duplicated data or insufficient capacity, and synchronization with institutional databases to reflect changes. Security and privacy measures, such as role-based access, protect vital data like faculty identifiers. The dataset will be synchronized with institution databases periodically to ensure that changes made, such as, teacher being unavailable for some time or classroom changing its location, are reflected. Security and Privacy: Privacy will be given priority by using role-based access for vital data such as teacher's identifiers.

Architecture

The Smart Classroom & Timetable Scheduler's architecture consists of five layers. The frontend and user interface layer includes an admin portal and web dashboard built with React.js, Angular, and WebSockets, enabling real-time data entry and visualisation. The constraints and analytics layer filters scheduling data, handling hard and soft constraints with context-aware insights from IoT sensors and occupancy analytics. The optimization and scheduling layer employs a hybrid Genetic Algorithm-Constraint Satisfaction Problem (GA-CSP) engine to generate conflict-free timetables. The institutional data and integration layer manages faculty, course, room, and calendar data, integrating with university systems via real-time APIs. Finally, the output, communication, and security layer ensures role-based security with JWT, publishes timetables, and sends real-time notifications via SMS or email. The system's modular architecture supports scalability and fault tolerance, allowing for easy addition of components like analytics or optimization modules. It features real-time conflict detection, automated adjustments, and IoT-driven insights, with multi-platform support and customizable reporting. The system integrates seamlessly with existing university systems and offers a user-friendly interface for admins, faculty, and students, handling large datasets and complex scheduling requirements with ease. Key highlights include its modular design, hybrid optimization, IoT-driven analytics, secure role-based access, and adaptive live data integration.

RESULTS

Data Preparation

The Smart Classroom & Timetable Scheduler prepares data by organizing structured institutional entities including faculty availability, course credit structures, and classroom capacities into a normalized relational model that undergoes automated validation to detect duplicate entries or contradictory inputs before scheduling begins. Implementation results at MCET demonstrated a 30% boost in resource efficiency and an 85% reduction in scheduling conflicts, successfully coordinating 19 projects and 15 tutors simultaneously. By replacing traditional manual processes with a hybrid GA–CSP engine, the system reduced scheduling time from weeks to just hours while ensuring equitable workload distribution across diverse 3-year and 5-year academic programs.

Architecture

The Smart Classroom & Timetable Scheduler uses a multi-layered modular architecture to transform academic data into optimised schedules. Its core is a Hybrid GA–CSP Engine that iteratively solves complex constraints to generate conflict-free slots. This engine is supported by a Constraint & Analytics Layer that evaluates institutional rules and real-time room usage, and an Institutional Data Layer that synchronises with live APIs. Users interact via a React/Angular dashboard, while a Notification Unit delivers real-time updates via Email/SMS.

- 30% increase in classroom resource usage.
- 85% reduction in scheduling conflicts.
- Scheduling time reduced from weeks to just hours.
- Proven universal applicability across diverse 3-year and 5-year academic programs.

RESEARCH GAPS

Analysis of the sources reveals that despite significant progress in academic scheduling technology, current systems suffer from several critical research gaps that hinder their effectiveness in modern, dynamic educational environments,. These gaps can be categorized into technical, operational, and data-driven limitations.

1. Technical and Algorithmic Gaps

- **Over-Reliance on Single Algorithms** : Many existing scheduling systems rely solely on a single method, such as Genetic Algorithms (GA) or Constraint Satisfaction Problems (CSP). This creates a lack of robustness when applied to diverse institutional structures with different constraints.
- **Computational Complexity vs. Scalability** : High-precision mathematical models often become computationally expensive and impractical for large universities with high constraint density,. Conversely, simpler models often fail to scale to multi-campus environments.
- **Lack of Explainability and Administrative Trust**: Automated systems frequently fail to provide a rationale or interpretation for the generated schedules. This gap between automated outputs and administrative reasoning reduces trust, especially when decisions significantly affect faculty workload or room fairness.

2. Data and Integration Gaps

- **Fragmented Management Systems**: Data related to faculty rosters, room availability, student attendance, and institutional updates is often distributed across multiple disconnected platforms. There is a lack of a unified system that combines optimization with real-time analytics.
- **Dataset Scarcity and Imbalance**: Current research often utilizes small-scale, private, or repetitive datasets that lack the diversity needed to generalize models across different types of institutions,. Many datasets fail to capture temporal patterns, such as seasonal course changes or shifting classroom demand over time.
- **Weak Real-Time Adaptability**: Most existing tools produce static outputs that do not integrate live data from institutional APIs,. Consequently, they cannot automatically react to sudden changes like faculty substitutions, room maintenance, or event-based disruptions without manual intervention.

3. Smart-Classroom and Analytics Gaps

- **Disconnect Between Generation and Management**: There is a significant gap between the initial timetable creation and the actual on-ground management of classrooms.
- **Ignoring Actual Usage Patterns**: Most scheduling models rely on theoretical assumptions rather than **real-world occupancy patterns**. They often ignore data from IoT sensors and automated attendance logs, leading to inefficient resource allocation.
- **Lack of Quality Scoring Mechanisms**: There is a need for more structured timetable-quality scoring mechanism such as frequency mapping of resource usage to translate scheduling outputs into reliable administrative indicators.

4. User Interaction and Scope Gaps

- **Rigid Interaction Models**: Administrators are often forced to input constraints through fixed, non-intuitive forms. Current systems lack support for natural or flexible rule definitions (e.g., "No labs after 4 PM"), making the configuration process cumbersome.
- **Departmental and Structural Bias**: Many systems are heavily tailored to specific departments (e.g., business or engineering) and fail to generalize to multi-disciplinary or hybrid teaching formats.

- **Neglect of Personalization:** Systems often produce uniform schedules that fail to incorporate specific departmental needs, faculty preferences, or diverse program structures (e.g., 3-year vs. 5-year degrees).

5. Gaps Identified in Existing Systems

- **Absence of Quality Metrics:** There is a persistent need for reliable "timetable-quality scoring mechanisms" that translate scheduling outputs into meaningful administrative indicators.
- **Lack of Interpretability:** Automated systems often fail to provide a rationale for their outputs, making it difficult for administrators to understand how specific constraints influenced the final schedule.
- **Scalability and Generalisability:** Many models are heavily tailored to specific departments or accreditation standards (like AACSB) and do not scale well to multi-campus or large-scale environments.

CONCLUSION

Smart-classroom-driven timetable scheduling has emerged as a promising direction at the intersection of educational technology and computational optimization. Recent advances in AI-assisted scheduling, particularly hybrid architectures combining Genetic Algorithms, Constraint Satisfaction Models, and heuristic search techniques, have significantly enhanced the ability to capture fine-grained academic constraints and complex resource-allocation patterns. These developments provide a strong foundation for building systems capable of analyzing institutional requirements and identifying potential issues such as room shortages, workload imbalance, and scheduling conflicts. The literature surveyed between 2022 and 2025 demonstrates consistent progress in scheduling accuracy, adaptability, and interpretability, while also highlighting ongoing challenges such as limited datasets diversity, inconsistent academic metadata and the need for reliable timetable quality scoring mechanisms. The reviewed works collectively indicate that optimization-based automated scheduling approaches offer considerable advantages over traditional manual methods, especially in handling real-world institutional variations and subtle conflict patterns. Overall, the findings suggest a clear path forward for designing an AI-assisted timetable-scheduling framework. By integrating improved preprocessing, richer institutional datasets, explainable constraint-visualisation techniques, and structured score-based evaluation, future systems can become more reliable, interpretable, and suitable for real-world deployment. The conclusion reinforces that intelligent scheduling holds substantial potential for supporting efficient academic planning, providing for further research, ethical implementation, and expansion.

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