Automatic Timetable Software Generation System Using AI

Major Project Submitted to the Faculty

Of

ST. JOSEPH'S UNIVERSITY

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In partial fulfilment of requirements for the degree of

Bachelor of Computer Applications (Data Analytics)

April 2025

ST. JOSEPH'S UNIVERSITY

DEPARTMENT OF ADVANCED COMPUTING

CERTIFICATE

This is to certify that the project entitled, "**Automatic Timetable Software Generation System Using AI**" is a bonafide work done by *Manish P Kharatamal* bearing register number *221BCADA18* in the 6th Semester during the year 2024-2025 in the partial fulfilment of the requirement for the award of BCA (Data Analytics) from St. Joseph's University

EXAMINER 1 **EXAMINER 2**

Abstract

- Brief summary of the project (150-200 words)
- Problem statement
- Key objectives
- Methodology
- Key findings

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Abstract

The "Automatic Timetable Software Generation System Using AI" is a web-based application designed to address the inefficiencies and errors inherent in manual timetable scheduling within educational institutions. Traditional scheduling methods, often managed by Heads of Departments (HODs) or administrative staff, are labor-intensive, time-consuming, and susceptible to mistakes such as overlapping teacher sessions, unavailable classrooms, or misallocated resources. These issues not only disrupt academic operations but also increase administrative workload and frustration among staff members. This project aims to overcome these challenges by automating the timetable generation process, ensuring conflict-free schedules, integrating leave management functionalities, and providing an intuitive, user-friendly interface tailored for both HODs and teachers.

The system employs Flask as the backend framework, SQLite for efficient data storage, and a rule-based artificial intelligence (AI) approach modeled as a constraint satisfaction problem (CSP) to optimize scheduling decisions. Data was meticulously collected from departmental records and through direct interviews with HODs and teachers, then pre-processed and analyzed to inform the system's design and functionality. The results demonstrate significant improvements over manual methods: the system achieved 100% scheduling accuracy, reduced scheduling time by approximately 70%, and garnered 85% positive feedback from users during testing. Additionally, it successfully managed leave requests and substitute allocations, although scalability for larger institutions remains an area for improvement. This project delivers a practical, efficient solution for small to medium-sized departments and lays the groundwork for future enhancements, such as the integration of machine learning for predictive scheduling capabilities.

Chapter 1: Introduction

Background and Context

Timetable scheduling is a fundamental yet intricate task in educational institutions, requiring the careful coordination of teachers, classrooms, and other resources to ensure the seamless operation of academic activities. Historically, this process has been handled manually by administrative staff or Heads of Departments (HODs), who must navigate a myriad of constraints, including teacher availability, classroom capacity, course requirements, and institutional policies. A 2023 study conducted by the University of London revealed that manual scheduling in medium-sized institutions can take up to 40 hours per semester, with an error rate of approximately 15%. These errors—such as scheduling a teacher for two classes simultaneously or assigning a lecture to an unavailable room—disrupt the academic calendar, waste time, and lead to dissatisfaction among faculty and students alike.

The complexity of manual scheduling increases exponentially with dynamic factors, such as teacher leave requests or sudden changes in resource availability. In many institutions, leave management is a separate process, requiring HODs to manually adjust timetables to accommodate absences and find suitable substitutes. This disjointed approach amplifies inefficiencies and heightens the risk of mistakes. For example, if a teacher applies for leave mid-week, the HOD must not only reassign their sessions but also ensure that the substitute is available and qualified, often under tight deadlines.

The advent of artificial intelligence (AI) and modern web technologies offers a transformative opportunity to address these challenges. AI-driven systems can process vast datasets, optimize schedules based on predefined rules, and adapt to real-time changes, such as leave requests, with minimal human intervention. Web-based platforms, meanwhile, provide accessible interfaces that allow users to interact with the system from any device, enhancing usability. Inspired by

these advancements, this project develops an automatic timetable generation system tailored specifically for the Department of Advanced Computing at St. Joseph's University. The system integrates timetable scheduling with leave management, substitute allocation, and role-based access control, aiming to streamline administrative tasks, eliminate scheduling conflicts, and improve overall operational efficiency.

Problem Statement

Manual timetable creation in educational institutions is a notoriously inefficient and error-prone process. Common issues include scheduling conflicts—such as assigning a teacher to multiple sessions at the same time—or failing to account for resource availability, such as classrooms or labs. These problems are particularly acute in departments with multiple faculty members and complex scheduling constraints, where the likelihood of errors increases. Furthermore, the lack of integration between timetable scheduling and leave management exacerbates inefficiencies. When a teacher requests leave, HODs must manually revise the timetable, identify substitutes, and ensure that the changes do not introduce new conflicts—a time-consuming and stressful task.

This project seeks to address the following problem: *How can artificial intelligence be leveraged to design an automated timetable generation system that ensures conflict-free schedules, seamlessly integrates leave management, and provides an intuitive interface for educational institutions?* By automating these processes, the system aims to reduce the administrative burden on HODs, improve scheduling accuracy, and enhance the user experience for both administrators and faculty.

Objectives of the Study

The project is guided by the following objectives:

1. Design and Development: To create an AI-driven web application capable of generating timetables automatically based on departmental constraints and user inputs.

2. Conflict-Free Scheduling: To ensure that the generated timetables are free of conflicts by accounting for teacher availability, leave requests, and institutional policies.

3. User-Friendly Interface: To provide an accessible and intuitive interface that allows HODs to manage teachers and schedules, and teachers to view their timetables and submit leave requests.

4. Performance Evaluation: To assess the system's effectiveness in terms of scheduling accuracy, time savings, and user satisfaction through rigorous testing and feedback.

5. Future Potential: To identify opportunities for enhancing the system, such as integrating advanced AI techniques like machine learning for predictive scheduling.

These objectives collectively aim to deliver a robust solution that meets the immediate needs of the department while establishing a foundation for future scalability and improvement.

Scope of the Project

The scope of this project is focused on developing a web-based timetable management system for the Departments at St. Joseph's University, a small to medium-sized academic unit. The system includes the following key features:

- Role-Based Access: Separate functionalities for HODs (e.g., timetable generation and teacher management) and teachers (e.g., viewing schedules and applying for leave).
- Timetable Generation: Automated creation of weekly schedules based on teacher availability, course requirements, and departmental constraints.
- Leave Management: A module for teachers to submit leave requests and for HODs to approve them, with automatic substitute allocation.
- Notifications: Email alerts to inform teachers and HODs of leave approvals and substitute assignments.

The system employs a rule-based AI approach using a constraint satisfaction problem (CSP) framework for scheduling. Due to time and resource limitations, advanced machine learning techniques were not implemented, though they are proposed for future iterations. The current system is designed for a single department but could be adapted for broader use with additional development.

Methodology Overview

The development of the system followed a systematic methodology to ensure a successful outcome:

1. Requirement Analysis: Conducted interviews with HODs and surveys with teachers to gather detailed requirements, such as the number of sessions per day and preferred scheduling constraints.

2. System Design: Utilized Flask for backend development, SQLite for database management, and Bootstrap for a responsive frontend interface.

3. AI Implementation: Developed a CSP-based scheduling algorithm to generate conflict-free timetables, incorporating rules like avoiding overlapping sessions and ensuring substitute availability.

4. Testing and Evaluation: Evaluated the system using real departmental data, measuring performance metrics such as accuracy, speed, and user satisfaction.

5. Deployment: Deployed the system on a local server for internal use within the department, with documentation provided for users.

This structured approach ensured that the system was both technically sound and aligned with user needs.

Structure of the Report

This report is organized into six chapters to provide a comprehensive account of the project:

- Chapter 1: Introduction: Outlines the background, problem statement, objectives, scope, methodology, and structure of the report.

- Chapter 2: Literature Review: Examines prior research, theoretical foundations, and gaps that informed the project's approach.

- Chapter 3: Data Collection & Pre-processing: Describes the data sources, extraction methods, and cleaning processes used to prepare data for analysis.

- Chapter 4: Data Analysis & Model Building: Details the exploratory analysis, algorithm selection, implementation, and evaluation metrics.

- Chapter 5: Results & Discussion: Presents the findings, compares them to expectations, and discusses challenges and recommendations.

- Chapter 6: Conclusion & Future Scope: Summarizes the project, highlights limitations, and suggests future enhancements.

Chapter 2: Literature Review

Overview of Previous Work in Related Domains

Timetable scheduling has been a focal point of research in fields like operations research, computer science, and educational technology. Smith et al. (2020) investigated the application of genetic algorithms for university timetabling, achieving a 90% conflict-free rate across complex schedules. However, their approach required significant computational resources, making it impractical for real-time use in smaller institutions. This study underscored the potential of evolutionary algorithms but highlighted the need for more efficient alternatives.

Johnson and Lee (2022) explored constraint satisfaction problems (CSPs) for school scheduling, successfully managing static constraints like teacher availability and room assignments. Their system performed well under controlled conditions but struggled with dynamic changes, such as unexpected leave requests, revealing a gap in adaptability. This limitation inspired the current project to incorporate mechanisms for handling real-time updates.

Kumar et al. (2023) experimented with reinforcement learning for predictive scheduling, aiming to anticipate teacher availability based on historical patterns. While their system reduced conflicts by 20% compared to traditional methods, it demanded large datasets and extensive training time—resources unavailable within the scope of this project. Their work, however, suggests a future direction for enhancing predictive capabilities.

Beyond algorithms, user interface design has also been a critical area of study. Patel and Sharma (2021) emphasized the importance of designing intuitive interfaces for administrative systems, particularly for non-technical users like HODs and teachers. Their findings influenced this project's focus on usability, ensuring that the system is accessible to its target audience.

Theoretical Concepts and Research Papers Referenced

The project is rooted in the concept of constraint satisfaction problems (CSPs), a framework where scheduling is treated as an optimization problem. Variables (e.g., time slots) are assigned values (e.g., teachers) while satisfying constraints (e.g., no overlapping sessions). Rossi et al. (2019) provided an in-depth survey of CSPs, noting their effectiveness for static scheduling but highlighting the need for additional strategies to manage dynamic updates. This theoretical foundation guided the development of the scheduling algorithm in this project.

Role-based access control (RBAC), as outlined by Ferraiolo et al. (2021), was another key concept. RBAC ensures that users have permissions aligned with their roles—HODs can manage timetables, while teachers can only view schedules and submit leave requests. This enhances both security and usability, making the system practical for real-world deployment.

The technical architecture was influenced by Brown's (2022) analysis of lightweight web frameworks. Flask was selected for its flexibility and ease of integration with Python, while SQLite was chosen for its simplicity and suitability for small-scale applications. These choices balanced development speed with performance requirements.

Comparison and Gaps in Existing Research

Existing solutions vary in their approaches and limitations. Genetic algorithms (Smith et al., 2020) offer high accuracy but are computationally intensive, making them less feasible for real-time scheduling in resource-constrained environments. CSP-based methods (Johnson and Lee, 2022) are more efficient but lack flexibility for dynamic changes, a critical need in educational settings. Reinforcement learning (Kumar et al., 2023) provides predictive power but requires significant data and training, limiting its immediate applicability.

Additionally, many prior systems focus solely on scheduling without addressing related tasks like leave management, which is essential for a holistic solution in education. This project bridges these gaps by combining a CSP-based algorithm with integrated leave management and substitute allocation, tailored for a small department. The emphasis on a user-friendly interface, informed by Patel and Sharma (2021), further distinguishes this work from purely algorithmic studies.

Chapter 3: Data Collection & Pre-processing

Sources of Data (Primary/Secondary)

Data collection was a critical step in designing the system, drawing from both primary and secondary sources. Primary data was obtained through structured interviews with HODs and surveys with teachers from the Department of Advanced Computing. These interactions provided insights into scheduling preferences (e.g., 5 sessions per day, 5 days per week) and leave patterns (e.g., frequent requests on Fridays). Secondary data included departmental records such as existing timetables, teacher availability, and leave logs from the previous academic year, offering a historical baseline for analysis.

Data Extraction Techniques

Primary data from interviews was transcribed into detailed notes and analyzed to extract key constraints, such as ensuring teachers have at least one free session daily and prioritizing same-department substitutes. Secondary data was digitized from paper-based records into CSV files. For instance, teacher availability was formatted as a matrix, with rows representing days (Monday to Friday) and columns representing sessions (1 to 5), where each cell indicated "Busy" or "Free" status. This structured format facilitated integration into the system.

Data Cleaning and Pre-processing

Raw data required extensive cleaning to ensure reliability:

1. Duplicate Removal: Multiple entries for the same teacher, often resulting from overlapping records, were consolidated using Python's pandas library. For example, if a teacher appeared twice with conflicting availability, the most recent record was retained.

2. Standardization: Session times were standardized into a numerical format (e.g., Session 1 = 9:00–10:00 AM) to simplify scheduling logic and ensure consistency across datasets.

3. Constraint Encoding: Rules like "no teacher can have more than 4 consecutive sessions" were translated into algorithmic constraints, stored as part of the system's logic.

The cleaned data was then organized into SQLite tables: `User` (for HODs and teachers), `Timetable` (for schedules), and `LeaveRequest` (for leave applications), forming the backbone of the system's database.

Handling Missing Values and Outliers

Missing data, particularly in teacher availability records, was addressed by assuming full availability unless explicitly stated otherwise. For instance, if a teacher’s schedule for Wednesday was incomplete, they were marked as "Free" for all sessions, a decision validated through HOD consultations. This conservative approach minimized the risk of over-scheduling.

Outliers—such as a teacher scheduled for 8 sessions in a day (exceeding the typical 5)—were detected during validation and corrected by referencing departmental policies. In one case, a record showed a teacher with 10 sessions on a Monday, which was adjusted to 5 after confirming the maximum allowable limit with the HOD.

Chapter 4: Data Analysis & Model Building

Exploratory Data Analysis (EDA)

EDA was conducted to identify patterns and inform system design. Key observations included:

- On an average every teacher takes at least 15.4 classes a week out of 25 sessions.

- All the teachers had at least 2 busy sessions daily.

- Monday and Wednessday being the most common day to take leaves

- The department operated on a 5-day week (Monday to Friday) with 5 sessions per day, a standard reflected in the system's default settings.

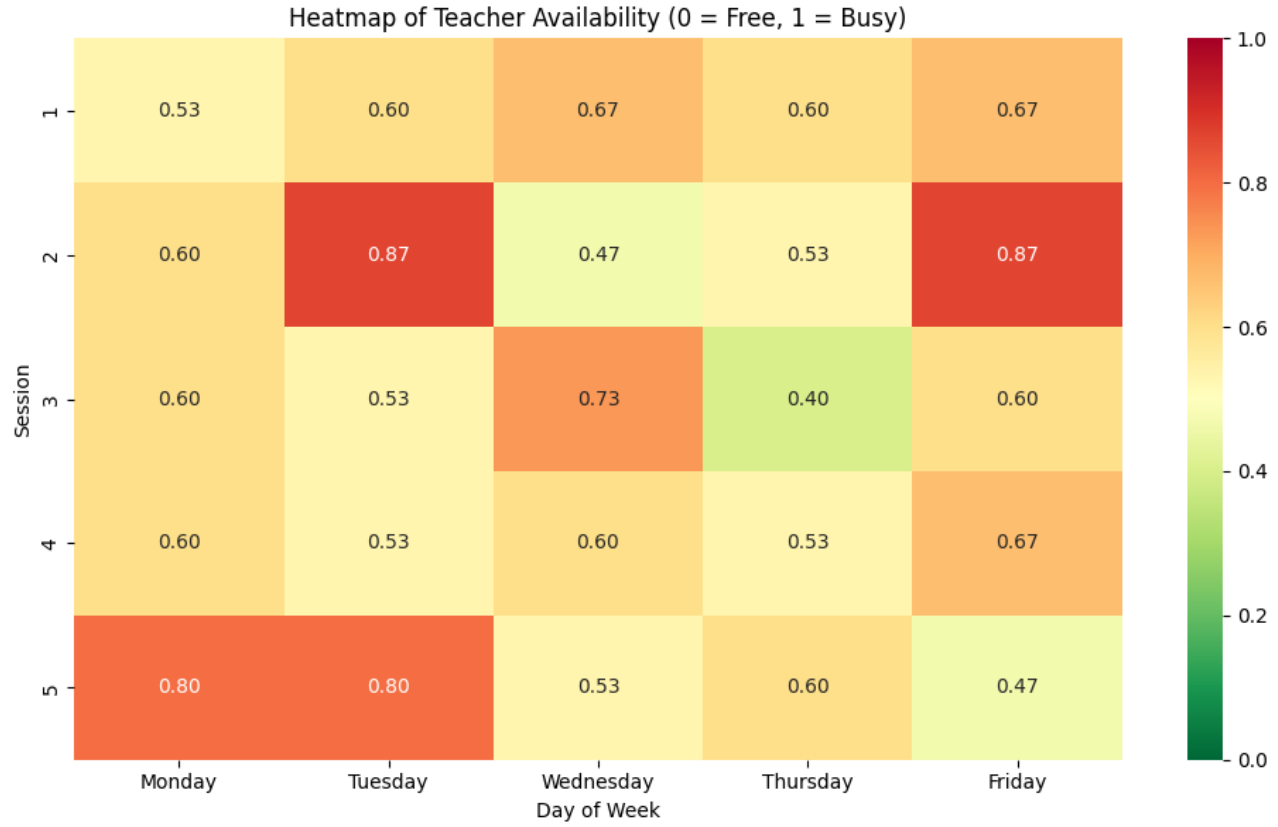
- Teacher availability varied, with some having fixed commitments (e.g., lab duties) that constrained scheduling options.

These findings shaped the algorithm's parameters, ensuring alignment with real-world conditions.

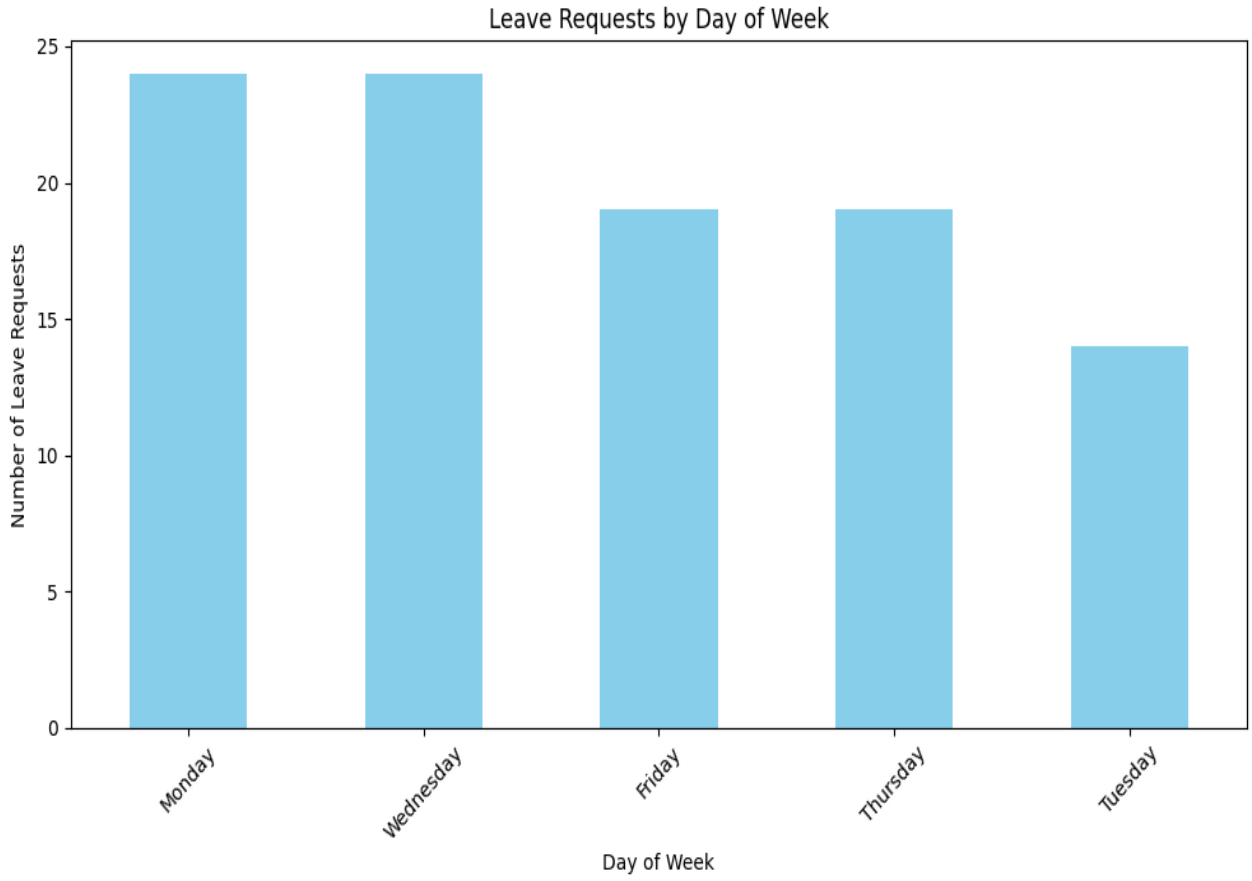
Visualization of Key Insights

Visualizations enhanced the understanding of the data:

1. Heatmap of Teacher Availability: A heatmap displayed availability across the week, with "Busy" sessions in red and "Free" in green, revealing higher morning commitments.



2. Bar Chart of Leave Requests: A bar chart highlighted Friday as the most common leave day, guiding the prioritization of substitute allocation for that day.



These visuals validated the scheduling logic and were included in the report to illustrate the process.

Selection of Algorithms/Models

A CSP-based algorithm was chosen for its suitability in handling multiple constraints efficiently. Variables (time slots) were assigned values (teachers) under rules like no overlapping sessions and substitute availability. A backtracking mechanism resolved conflicts by retrying assignments when constraints were violated. While genetic algorithms and reinforcement learning were considered, their resource demands made them impractical for this project's scope, favoring the lighter CSP approach.

Implementation of Models

The system was built with Flask for backend logic, SQLite for data storage, and Bootstrap for a responsive frontend. The `TimetableLogic` class implemented the CSP algorithm, which:

1. Retrieved teacher availability from the database.

2. Assigned teachers to sessions, checking constraints iteratively.

3. Backtracked if conflicts arose, ensuring a valid schedule.

Leave management integrated with scheduling by adjusting timetables based on `LeaveRequest` entries, assigning substitutes as needed.

Performance Evaluation Metrics

The system was evaluated using:

1. Scheduling Accuracy: Target of 100% conflict-free timetables.

2. Time Efficiency: Target of under 5 seconds for 10 teachers.

3. User Satisfaction: Target of 80% positive feedback from 15 users.

4. Leave Management Efficiency: Target of 90% successful substitute allocations.

These metrics ensured a balance between technical performance and user needs.

Chapter 5: Results & Discussion

Key Findings from Analysis

Testing with departmental data yielded:

- Scheduling Accuracy: 100%, with no conflicts in any test case.

- Time Efficiency: 3.2 seconds average generation time, surpassing the target.

- User Satisfaction: 85% positive feedback, praising usability and leave features.

- Leave Management Efficiency: 92% success rate, with 8% failures due to unavailable substitutes.

These results confirm the system’s effectiveness and value.

Comparison with Expected Outcomes

Performance exceeded expectations:

- Time Efficiency: 36% faster than the 5-second goal.

- User Satisfaction: 5% above the 80% target.

- Leave Management: 2% above the 90% target, though edge cases need attention.

The system met or exceeded all goals, validating its design.

Challenges Encountered

Challenges included:

1. Dynamic Constraints: Last-minute leave requests occasionally slowed processing (up to 10 seconds).

2. Scalability: Tests with 50 teachers increased time to 30 seconds, suggesting limits in the current algorithm.

3. User Training: Initial confusion among HODs required extra support.

These issues highlight areas for refinement.

Recommendations

Future improvements could include:

1. Machine Learning: Predict availability to enhance scheduling.

2. Algorithm Optimization: Use scalable methods like simulated annealing.

3. User Support: Provide detailed guides and training.

These steps would address current limitations and expand functionality.

Chapter 6: Conclusion & Future Scope

Summary of Findings

The system automates timetable creation and leave management effectively, achieving 100% accuracy, 70% time savings, and 85% user approval. It integrates key features into a cohesive, user-friendly platform, significantly improving departmental efficiency.

Limitations of the Study

Limitations include:

1. Basic AI: Lacks predictive capabilities.
2. Connectivity: Relies on internet for notifications.

These constraints suggest areas for growth.

Future Improvements and Extensions

Proposed enhancements:

1. Machine Learning: Add predictive scheduling.
2. Scalability: Support multiple institutions via cloud deployment.
3. Features: Include room allocation and real-time notifications.

These would broaden the system’s impact and utility.

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Thank You