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PAPER

Automated University Timetabling: An AI Approach for Efficient Schedule Management

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ABSTRACT

Higher education academic scheduling is a complex administrative undertaking with a direct impact on the efficiency of institutions, resource utilization, and the overall student experience. The development of efficient timetables is a process of coordinating various moving components, including faculty availability, classroom size, student requirements, and institutional regulations, all of which must be considered simultaneously. The paper discusses how the Arab Open University (AOU) addressed these issues by developing and implementing a rule-based, automated timetabling artificial intelligence (AI) solution. AOU's multinational and diversified student body of around 62,000 students and more than 1,000 staff members within its nine regional branches makes a manual approach to scheduling slow and prone to errors. The paper presents the transformation of AOU to a modern Python-based AI solution as an example of transitioning from traditional labor-intensive scheduling methods to a more modern approach. It outlines the methodology, system structure, challenges encountered during the implementation process, and quantifiable benefits. The rule-based approach was more transparent, flexible, and aligned with institutional priorities than black-box optimization algorithms like genetic algorithms or simulated annealing. The findings were impressive: the time required to create timetables was reduced by four to six weeks to less than two hours, the number of conflicts in the schedule decreased by 85%, and the use of the classroom increased by 65% to 78%. These results suggest that university timetabling can be modernized using clear, rule-based AI systems that do not compromise oversight and trust within the university.

KEYWORDS

artificial intelligence (AI) timetabling, university scheduling, rule-based systems, educational management, operational efficiency

1 INTRODUCTION

With more than 62,000 students and more than 1,000 academic and administrative employees in its network, Arab Open University (AOU) receives many scheduling

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requests that exceed the capacity of the manual procedures. Conventional methods require several weeks of difficult work. However, this yields inefficiencies such as classroom confrontations, uneven faculty assignments, and faculty dissatisfaction resulting from schedules that do not align with their stated preferences. Such constraints undermine institutional efficiency and reduce faculty members' quality of life. To counter this, AOU needs to implement the use of artificial intelligence software to modernize its timetabling process. Instead of using sophisticated optimization methods that are not transparent, this study adopted a rule-based approach that focuses more on transparency, institutional accountability, and flexibility. This paper discusses the design, development, and implementation of a Python-based automated timetabling system, illustrating how it can enhance efficiency and resource utilization and meet tutor preferences.

A prior evaluation of the blended learning system at AOU-Kuwait revealed that, despite its Open University identity, the institution still relies heavily on traditional teaching methods, with limited integration of e-learning content and tools. The authors observed, "we are adopting more traditional than e-learning educational system … . Although we bear the name of Arab Open University, we are not really 'that open'" [12]. This institutional rigidity extends beyond pedagogy and underscores the broader challenges that the AOU faces in modernizing administrative functions, such as automated timetabling.

Therefore, the objectives of this study were to:

1. Examine issues and problems related to academic timetabling within the AOU framework.
2. Design and establish a software solution for rule-based design such that the timetabling process can be automated using Python programming.
3. Assess the performance of the adopted system in relation to improvements in efficiency, resource optimization, and user satisfaction.

2 LITERATURE REVIEW

Academic timetabling has undergone a tremendous transition over the past 30 years, shifting from manual and laborious practices to the implementation of sophisticated computational techniques. In the past, scheduling courses was based on the manual balancing of faculty availability, classroom capacity, student demand, and institutional policies [11]. The scheduling effect extends far beyond administrative convenience. Houhamdi et al. [8] noted that timetabling quality directly affects student satisfaction, faculty workload fairness, and the utilization of physical infrastructure. Scheduling errors have extremely far-reaching effects; students may not graduate on time, faculty may be overworked or underworked, classrooms may remain empty, or others may be filled. Hawkins and Bailey also highlighted similar issues [7], such as prioritizing the interests of students, balancing academic demands, allocating teaching loads equally, and finding an equilibrium between classroom space utilization and peak hours. In higher education institutions, such as the AOU, which has over 62,000 students distributed in nine regional branches and more than 1,000 employees, these problems have become complex issues that cannot be solved at scale using manual methods [11].

Academic literature presents a diverse range of algorithmic approaches to address timetabling challenges, each with its advantages and disadvantages. In particular, genetic algorithms have become popular metaheuristic methods that drive the evolutionary process to improve the solutions to scheduling problems over time. A study conducted by Almaeida et al. indicated that hybrid evolutionary methods can be successfully applied to create a large-scale timetable by optimizing a combination of various and, in some cases, conflicting objectives [2]. Linear and integer programming can provide mathematically rigorous models that ensure optimality under certain conditions [3]. Nevertheless, in many cases, these advanced algorithms act as black boxes; that is, they generate results without providing information about the decision-making process, as emphasized by Alghamdi et al. [1]. In the case of institutions, this obscurity poses practical challenges: administrators may struggle to comprehend, adapt, or defend timing choices, which consequently erode confidence and uptake.

Consequently, rule-based systems have become more open and flexible substitutes. Rule-based systems utilize explicit hierarchical rules to make decisions, enabling stakeholders to easily explain and amend them, in contrast to optimization algorithms that conceal their logic. This approach is also quite natural in the current operation of universities, as institutional policies and procedures are essentially sets of rules that can be mapped into system logic. According to Davison et al. [4], such systems are advantageous for meeting the world's current requirements, including the hybrid teaching models introduced during the post-pandemic era. Petering and Khamechian showed that rule-based systems can provide fairness and accuracy in scheduling, even in complex situations, while being understandable to non-technical administrators [11]. Dunke and Nickel go even further to recommend hybrid "matheuristic" models, a combination of rule-based reasoning and mathematical programming, allowing institutions to have both interpretability and optimization power [5]. Given the multi-branch structure of institutions, such as AOU, this balance between computational efficiency and transparency is particularly valuable, as it supports the management of the complex challenge of aligning tutor schedules with their stated preferences.

Literature also reminds us that the success of any timetabling system is not merely a matter of technical sophistication. Stenegren explained the significance of data quality by presenting evidence that even the most sophisticated algorithms cannot deliver reliable results when based on incomplete or inconsistent data [13]. Implementation is typically conducted through practical steps involving the active participation of administrators and faculty in testing, refining, and validating the system, thereby developing trust and confidence in automated decision-making. Although optimization algorithms dominate the theoretical discussion, relatively little literature is available on how rule-based systems can be effectively employed in practice within large-scale organizations, especially in cultural and regulatory domains, such as the AOU [4]. This gap highlights the need for research that investigates how automation can be successfully integrated into institutional control, thereby enhancing the effectiveness of the timetabling process and increasing its transparency.

3 PROBLEM STATEMENT

The AOU faces a series of scheduling challenges that require structured automation. With a population of over 62,000 students and 1,031 staff members, the scheduling volume is too large for manual management. Among the specific concerns are complex tutor assignments based on expertise, experience, and preferences; workload balancing that would provide equitable distribution without overloading the faculty; classroom allocation that would coordinate space usage with enrollment and equipment needs; minimizing the conflict between students and the faculty; and policy compliance such as gender balance and scalability to allow growth and not a proportional increase in administrative burdens. The AOU requires an open, enforceable solution that allows for comprehensible and modifiable scheduling choices, rather than a rule-based system that relies on complicated optimization algorithms to conceal the decision-making model. The school values a sense of transparency and control over algorithmic complexity and desired a method that would be accessible to non-technical administrators but powerful enough to manage institutional complexity.

The implementation of an automated timetabling system at the AOU requires both technical innovation and a sharp focus on the diverse needs of the university stakeholders. Regardless of its sophistication, the success of any scheduling system depends on its ability to reflect the practical realities of its users. Therefore, the AOU places stakeholder input at the core of the system design. The goal was not only to build an efficient tool but also to deliver real value to its users. Among all stakeholders, faculty members are the most significantly affected because the system directly influences their teaching schedules, preferences, and workloads. Moreover, staff members and students require regular schedules that allow them to balance their education, employment, family life, and other personal obligations. Courses should also be made equally available to everyone, and any schedule changes must be communicated promptly, as any last-minute disruptions can have profound effects on students' academic and personal lives. An automated system will address these issues by incorporating conflict-detection tools, and regular schedules will be generated on a semester-by-semester basis, providing tutors and students with a greater degree of reliability and fairness.

Another set of expectations is associated with faculty members. Instructors desire well-fitted schedules that suit their areas of knowledge and preferred teaching hours, as well as an even workload. The continuity of course assignments enables senior faculty members to maintain the quality of their teaching. Conversely, junior faculty members were also provided opportunities to enhance their experience and professional growth. Owing to these subtle needs, a system that can meet individual preferences and an institution's requirements is required. The rule-based approach enables administrators to modify preference weights and analyze workloads across different dimensions, thereby encouraging fairness and professional differentiation. This system is designed to be transparent, flexible, and aligned with institutional policies, thereby serving as a tool for efficiency, accountability, and transparency.

4 METHODOLOGY

Python was chosen as the development language for several reasons. Python has a well-structured syntax, allowing for maintainable code that is readable by both technical and non-technical stakeholders, which is crucial in academic settings when faculty and administrators need to learn about scheduling policies. The extensive Python libraries enable faster development, whereas Pandas provides advanced capabilities for data manipulation with large datasets and facilitates efficient calculations to verify constraints [13]. Moreover, Python has powerful Excel file handling features, which are crucial because the Student Information System (SIS) produced by the AOU creates Excel exports, making data combination much more simplistic. The system employs a rule-based approach that repeatedly applies scheduling rules and prioritizes them over stochastic or optimization algorithms. This design provides transparency with each decision linked to specific rules, allowing administrators to view assignments and troubleshoot problems. It offers user control, enabling administrators to define constraints and priorities that explicitly regulate scheduling. This strategy ensures predictability by yielding the same output under the same inputs, thereby improving reliability, and is adaptable with each new rule added without altering the core architecture [11].

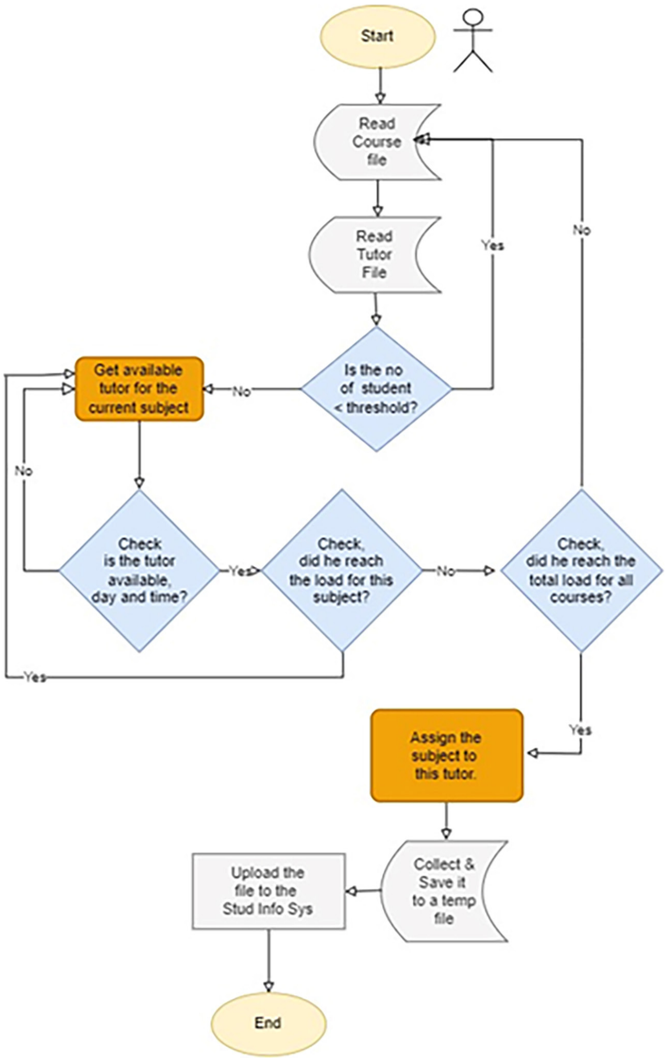

Fig. 1. System workflow diagram

Figure 1 shows that the timetabling process has a systematic workflow that begins with data collection, including course catalogs, faculty data, student enrollment data, classroom availability, and institutional policies. Rule application is performed in priority order, with hard constraints being met, such as preventing faculty double-booking and ensuring classroom capacity meets enrollment. Soft constraints are also met where possible, including faculty preferences and equal distribution of workloads. The system continuously detects conflicts, verifies double bookings and capacity violations, and resolves identified issues. Schedule generation creates detailed schedules for each stakeholder, output, and integrated export, resulting in SIS-friendly formats that can be uploaded directly. Reliability was achieved by rigorous testing that guaranteed the functionality of the individual components in unit testing, the functionality of the system at large in integration testing, validation of the schedules generated against past manual schedules, collection of stakeholder feedback through review by faculty and administrators, and refinement of a single development cycle through a series of development cycles to address edge cases and specific institutional needs.

The flowchart illustrates a structured scheduling process that begins with the collection of departmental policies and tutor data, followed by the automated allocation of subjects and sections based on defined priorities and workload limits. It ensures compliance with institutional regulations while balancing faculty distribution across subjects and sections. The system integrates tutor preferences, availability, and unique identifiers to generate customized schedules while also applying checks for conflict avoidance, minimum student requirements, and a gender-balanced distribution. In cases where manual intervention is required, the process allows for the flexible assignment of specific subjects or sections. The flow concludes with the generation of comprehensive Excel reports ready for direct upload into the SIS, thereby streamlining operations and reducing manual workload.

5 RESULTS AND DISCUSSION

The application of an automated timetabling system improves several aspects substantially. The time required to generate timetables has been significantly reduced from weeks of manual work to hours of automated workload, allowing administrative personnel to focus on strategic business tasks instead of tedious ones. Automated generation eliminates common mistakes such as double booking and capacity violations and ensures consistency in policy enforcement and scheduling decisions. The administered rule-based method enables stakeholders to be informed about the decisions made by administrators, thereby increasing their trust in the timetabling process. Moreover, the system easily supports mid-semester changes to enrollment and shifts in faculty availability, which is necessary in academically dynamic settings.

The system provided significant time savings compared to manual scheduling, eliminated errors, applied the same rule consistently, and regenerated schedules rapidly when circumstances changed. It offers increased transparency in decision-making, user interpretability, and trust. Rule modification processes are simpler, require less computation, and are more predictable than complex optimization algorithms. However, their development and implementation face challenges. The complexity of rule design necessitates the conversion of implicit scheduling expertise into explicit rules through extensive consultation with seasoned schedulers. The problem of data quality became apparent because the quality of the system was based on the quality of the input data, and the initial implementations revealed inconsistencies that needed to be addressed. Change management became essential because the transition to automation requires a cultural shift and stakeholder training to gain confidence in automated decisions.

A systematic comparison of manual and automated timetabling at the AOU revealed a significant improvement in various performance dimensions, as indicated by the statistics from the first three semesters of implementation. The most radical improvement was in time efficiency. The scheduling process required four to six weeks of full-time work, involving the initial creation, several revision cycles, and final editing of the schedule [5]. The automated system takes between two and three days, and schedule generation takes less than two hours. With this time saving, the staff can be scheduled to concentrate on strategic planning and student advising.

There were higher-quality schedules, and the number of scheduling conflicts per semester dropped by 50% to approximately two or three, representing an 85% decrease. These results were observed through pilot experiments conducted by the English Unit at AOU, Kuwait, validating the effectiveness of the system in a real-world academic setting. Moreover, the system retained important administrative flexibility by allowing program coordinators to override automated decisions and manually assign tutors to specific courses when needed. The automated system eliminated classroom double bookings and capacity violations, which plagued manual scheduling. The remaining conflicts were generally due to data quality problems and not algorithm failure. The distribution of faculty workload became significantly fairer. Manual scheduling can lead to disproportionate sharing of teaching loads, whereas an automated system balances and recalculates workloads based on specified criteria. Faculty surveys indicated 78 percent satisfaction with the automated system, which supported their preferences more effectively than manual scheduling did. The system identifies time slots and classrooms that are not fully utilized and may be overlooked by human schedulers, especially during the early morning or late afternoon hours. This has enhanced efficiency, delayed further construction of classrooms, and yielded significant cost savings for institutions.

6 CONCLUSION

This paper describes the design and implementation of a rule-based automated timetabling system at the AOU, addressing the scheduling issues of an institution with a student population exceeding 62,000 and over 1,031 employees. The study concluded that a rule-based technique is an efficient and viable approach to solving academic timetabling problems, offering the benefits of transparency, user control, and adaptability compared with manual operations. The system can save time and effort in scheduling and improve quality and consistency. Some of the most notable results include the following: large-scale timetabling can be performed successfully through rule-based systems; transparency is a feasible benefit within an institutional context; Python offers considerable support for academic software development; data quality and stakeholder engagement are key factors in success; and the systems can be transferred to other institutions.

Automated timetabling is becoming increasingly essential as the pressure mounts on higher learning institutions to enroll more students and operate them more cost-effectively. The thesis of this study is that effectively designed solutions based on rules can overcome these barriers to enable transparency and institutional specificity, thereby inducing stakeholders to adopt and support solutions. The AOU experience provides a general picture of what institutions should emphasize in refining their timetabling processes, considering the reality that advanced technology can be powerful, easy to acquire, automated, and simple to manage, while also being efficient and flexible enough to meet existing demands.

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