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An information visibility-based university timetabling for efficient use of learning spaces (IVUT)

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Information visibility

Abstract Academic institutions have limited resources that need judicious management. Building university timetables is a complex process that considers a big number of resources. Sometimes, allocating events takes place without seeing the full picture of the available resources. This leads to inefficiencies in utilization, especially with the absence of reevaluation techniques for timetables. Spaces could be underutilized or over-utilized but kept obscure due to lack of timely information. Providing updated information about spaces occupancy and utilization is important to construct resilient and adaptive timetables. Information visibility triggers re-scheduling and reallocation decisions. This paper introduces a new approach to construct resilient university timetables using genetic algorithms and data capturing technologies. The contributed approach adds a new dimension to solving the NP-hard timetabling and space allocation problems. It enables handling dynamic attendance patterns. By conducting periodical timetable assessments, appropriate spaces can be reallocated to suit the number of attendees in each event. This helps avoiding chaotic consequences resulting from space over-occupation as well as preventing the inability to use a space under the impression that is fully utilized. The developed solution relies on the use of RFID technology to enable information visibility. A case study was conducted at the Faculty of Commerce, Alexandria University, and the results are presented. Compared to current practices, the new concept proves to be an effective tool for managing timetables and resources in universities.

1. Introduction

Similar to the very popular traveling salesman problem (TSP), mathematicians agreed to classify timetabling problems as NP-hard [1,2]. The set of P and NP problems is very famous in complexity theory. The "P" class is the type of problems that can be solved in polynomial time. However, the "NP" class is

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Table 1 Description of the actual problem instance in 2012–2013.

Item	Data
No. of lecturers	131
No. of courses	150
No. of departments	7
No. of students	Between 10 and 2650
No. of groups	57
No. of rooms	32
No. of events	337
No. of days	7
No. of hours scheduled/day	12 (8.00 AM–8.00 PM)
Timeslot duration	2–3 h

the "Non-deterministic Polynomial" time class [3], in which the running time grows exponentially as the problem size increases. To solve the university course timetabling problem (UCTP), researchers made great efforts in developing search methods and algorithms that can produce good solutions. Space allocation problems are tightly related to the timetabling problems. They are also NP-Hard since there exist P^E ways of allocating E events to P places when searching for an optimal solution [4]. Accordingly, no efficient algorithm exists to solve large instances of these problems [5].

Educational institutions use timetables to schedule events by assigning them to timeslots and places in a way that makes optimal use of the available resources [6,7]. Inadequate timetables result in significantly poor space utilization levels; especially that the need for dynamic allocation of spaces inside university campuses is continuously increasing. Spaces inside universities are very diverse and may include the following: rooms, halls, amphitheatres, offices and parking lots, among others. To solve the space allocation problem in universities, spaces available need to be identified together with their different uses as well as their available time slots and all other constraints. The status of the resources over time also has to be tracked in order to make sure that they are efficiently used and that opportunities for building better timetables are not missed. This problem stimulates a deeper look and an investigation of new approaches for making the best use of available resources. A balance should be made between ensuring efficient resource utilization, on the one hand, and not causing disruption to the resources already allocated, on the other hand [8]. Consequently, in a highly dynamic environment, following static as well as manual approaches to solve resource allocation problems may result in misleading decisions. Accordingly, a large number of resources that need to be better managed and utilized may be wasted. The solution is not, then, in provisioning more resources, but in appropriately utilizing those available.

Some studies revealed that, in many academic institutions, teaching spaces are partially occupied, as rooms are not in use half of the time, and when they are in use they are often only half full [9,10]. In many cases, inflexibility in allocating spaces does not necessarily mean that the institution has insufficient resources, but that it might lack the sufficient information about these resources. This happens because of the absence of a mechanism that provides timely and accurate information about spaces inside universities.

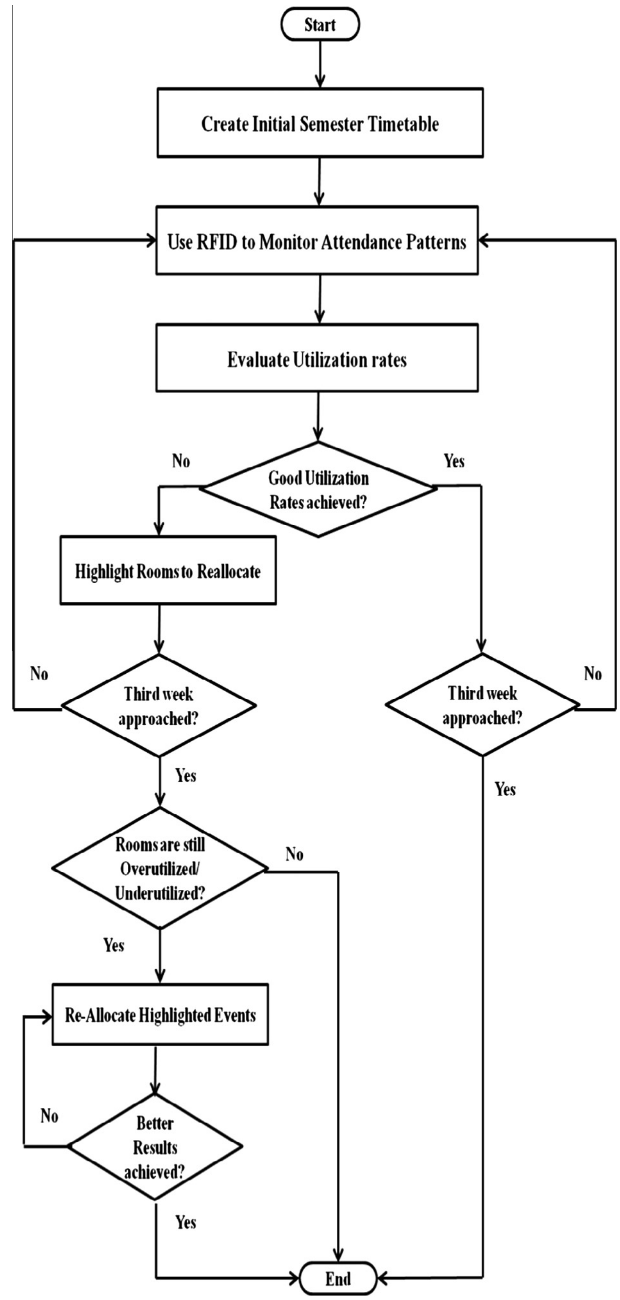

Figure 1 IVUT methodology chart.

This paper contributes an information visibility-based approach to dynamically solve the UCTP in the Faculty of Commerce, Alexandria University. There are four main divisions at the bachelor level inside the faculty: the Arabic (AR) division, the Affiliated Arabic division (AA), the English (E) division and the French (F) division. In 2012–2013, students in each division could study in one of seven specialties starting from the third academic year in a four-year based education system where the academic year consists of two semesters. In the first semester of year 2012–2013, the number of professors involved in teaching was 131 and the number of courses taught was 150 (considering courses taught in the three different languages). Thirty-two learning spaces were available and 337 events were considered to construct a timetable over a

Figure 2 UHF multi-channel RFID reader.

Figure 3 RFID antenna.

Figure 4 RFID passive tags.

seven-day week. The academic week starts on Saturday and the possible lecturing hours per day are 12, from 8:00a.m. to 8:00p.m. In this studied case, building semester timetables starts 6 weeks before the academic semester begins based on the semester course plan set by the academic departments. Professors' preferences are collected before the semester begins and the faculty builds the timetable centrally for the seven departments and all the student groups. The Faculty of Commerce is one with a very large number of students (between 10 and 2650 per group in year 2012–2013) and with 57 groups for the studied semester (see Table 1).

This case problem is solved considering that hard constraints include assigning professors to timeslots of their preferences, respecting room capacities, avoiding lectures' conflicts for professors and groups, excluding Fridays and end of day timeslots, and assigning all the lectures to the timetable. The set of soft constraints includes respecting a maximum number of lectures per professor and per group in one day, decreasing gaps between lectures for a professor and for a group and targeting either not less than 75% or 0% occupancy rate for each allocated event.

The increasing number of students enrolled in Egyptian public universities and their varying attendance patterns create the need for dynamically managing and utilizing spaces based on demand. The varying attendance patterns result in underutilization of spaces when students decide not to attend, and result in overutilization when students from other faculties or departments decide to attend the lecture. Underutilization and overutilization may also be the result of students transferring to or from other faculties or departments. The solution presented in this paper integrates genetic algorithms with RFID technology to achieve better space management. This paper is organized as follows. Section 2 reviews the related work on the timetabling and space allocation problems. Section 3 describes the contributed solution methodology. Testing and results are presented in Section 4. Section 5 includes the conclusion and future work.

2. Related work

UCTP is defined as a multi-dimensional problem, in which a number of students and professors are assigned to events [11]. An event is a pair of a suitable room and timeslot [12]. Rooms and spaces allocation decisions are problems associated with the timetabling procedures inside institutions. Space allocation, in universities and academic institutions, is the assignment of a set of lectures or meetings to a set of spaces and timeslots [8,13]. In this work, the authors define dynamic space allocation as "the ability of the involved decision makers inside universities to instantly find and dynamically allocate spaces to academic staff and students based on demand and depending on timely, accurate and visible information". Due to the high correlation between space allocation and timetabling, some approaches were successfully used to solve the two types of problems. Examples include the following: simulated annealing [14–16], tabu search [17–20] integer programming [21] and genetic algorithms [2,22,23].

In 2012, the University of Wisconsin conducted a project to understand the main causes for the underutilization of its instructional spaces. Findings showed that the average utilization room rate was 39%, the average occupancy rate was 63% and the average frequency rate of a room was 24% for the university. The team members claimed that the reasons behind underutilization remain unclear. However, they agreed that one of the biggest reasons was the incomplete and the absence of enterprise data for the university spaces with an enterprise view, the thing that makes the decision making process more difficult. Also, an important factor discovered from analyzing the hourly instructional space utilization rates was that utilization of the instructional spaces depends, to a great extent, on the time of the day during which the space is being occupied. The team also concluded that the ultimate goal for space utilization should not only be to reduce costs, but also to improve the quality when utilizing spaces. The team had directly correlated this with the timetabling process and had disseminated surveys to the timetablers to understand the mechanism they

Table 2 Avg. occupancy room rates per day using UGA for Week-1.

Room	Sat (%)	Sun (%)	Mon (%)	Tue (%)	Wed (%)	Thu (%)	Fri (%)
201	0	0	0	0	0	0	0
202	0	0	71	76	0	0	0
203	0	0	0	0	0	0	0
301	0	0	83	83	0	0	0
302	0	0	0	58	0	0	0
303	0	0	0	0	0	0	0
401	0	0	0	0	0	0	0
403	0	0	0	0	0	0	0
405	0	0	0	0	0	0	0
407	91	0	89	91	93	89	0
501	0	0	0	0	0	0	0
503	0	0	0	0	0	0	0
506	0	0	0	0	0	0	0
507	50	0	0	0	67	0	0
601	92	83	76	86	83	0	0
603	0	0	100	79	0	0	0
605	83	75	80	79	75	70	0
705	0	0	0	0	0	0	0
707	0	0	0	0	0	0	0
91	91	93	96	93	93	93	0
92	0	0	0	0	0	0	0
93	100	88	93	96	85	90	0
94	0	0	0	0	0	0	0
95	100	80	100	80	100	0	0
1	88	61	80	66	0	73	0
2	50	0	100	56	0	0	0
3	0	0	0	56	0	0	0
4	0	0	0	80	0	0	0
5	89	98	100	98	97	100	0
6	83	83	83	83	83	83	0
7	97	96	97	100	100	100	0
8	72	53	56	46	59	90	0
No. of rooms with avg. occ. rates < 75% per day		No. of rooms with avg. occ. rates between 75% and 100%			No. of rooms with avg. occ. rates = 0%		No. of rooms with avg. occ. rates > 100%
16		60			148		0

follow when scheduling an instructional space. The team members provided some recommendations to be taken into account for improved space utilization and cost reduction. These recommendations include the following: constructing timetables that reevaluate and reconsider scheduling spaces, as well as, conducting a standard review process for monitoring and reporting the underutilized spaces [24].

Researchers conducted a study at the University of North Carolina to understand and analyze the important factors for efficient utilization of spaces [25]. They found that achieving efficient classroom utilization saves cost and is strongly tied with their budget and funding. This also positively affects space planning decisions for acquiring more spaces in the future. The team conducting the study regularly visited the university buildings and rooms in order to monitor and report any updates and changes in the utilization of spaces. The team later analyzed the data collected to resolve deficiencies and/or problems encountered. They neither mentioned the use of any technology to assist in monitoring space utilization rates nor related that to the timetabling process.

The ability to discover the factors that affect utilization of spaces is correlated with considering the changes that take place to at least one of the set of rooms or the set of events [9]. In their work, they also highlighted that current space planning practices are done with incomplete access to information about future events and enrollment patterns. They stated that the utilization of spaces is still measured by conventional, simple methods that get the average percentage of the seats occupied within the teaching space.

Many efforts have been made toward defining and discovering the different dimensions and requirements of the space allocation problem inside ninety-six universities and academic institutions in the United Kingdom [8]. Information was collected on three main aspects: the size and diversity of the space allocation process, the tools used to automate the space allocation process and constraints considered when allocating spaces. The main purpose of the survey was to discover whether a generic solution to the problem is possible or the variance among universities would not enable such approach. The survey results proved that a generic system for the space allocation must be able to satisfy all the requirements specified by a university. It was also discovered that efficient utilization of spaces inside academic institutions requires careful integration between timetabling and space allocation.

Table 3 Avg. occupancy room rates per day using IVUT for Week-2.

Room	Sat (%)	Sun (%)	Mon (%)	Tue (%)	Wed (%)	Thu (%)	Fri (%)
201	0	0	0	0	0	0	0
202	0	0	77	76	0	0	0
203	0	0	0	0	0	0	0
301	0	0	83	83	0	0	0
302	0	0	0	57	0	0	0
303	0	0	0	0	0	0	0
401	0	0	0	0	0	0	0
403	0	0	0	0	0	0	0
405	0	0	0	0	0	0	0
407	91	0	89	91	93	89	0
501	0	0	0	0	0	0	0
503	0	0	0	0	0	0	0
506	0	0	0	0	0	0	0
507	54	0	0	0	70	0	0
601	92	83	76	86	83	0	0
603	0	0	100	79	0	0	0
605	83	75	80	79	75	72	0
705	0	0	0	0	0	0	0
707	0	0	0	0	0	0	0
91	115	80	100	80	120	0	0
92	0	0	0	0	0	0	0
93	100	88	93	96	85	90	0
94	0	0	0	0	0	0	0
95	91	93	96	93	93	93	0
1	88	59	80	68	0	75	0
2	48	0	98	52	0	0	0
3	0	0	0	56	0	0	0
4	0	0	0	80	0	0	0
5	89	98	100	98	97	100	0
6	83	83	83	83	83	83	0
7	97	96	97	100	100	100	0
8	76	45	57	50	58	90	0

No. of rooms with avg. occ. rates < 75% per day	No. of rooms with avg. occ. rates between 75% and 100%	No. of rooms with avg. occ. rates = 0%	No. of rooms with avg. occ. rates > 100%
13	61	148	2

Table 4 Rooms with occupancy rate changes from week 1 to week 2 after RFID monitoring.

Room	Day	Occ_Rate (week 1) (%)	Occ_Rate (week 2) (%)
202	Mon	71	77
302	Tue	58	57
507	Sat	50	54
	Wed	67	70
605	Thu	70	72
91	Sat	100	115
	Wed	100	120
1	Sun	61	59
	Tue	66	68
	Thu	73	75
2	Sat	50	48
	Tue	56	52
3	Tue	56	56
8	Sat	72	76
	Sun	53	45
	Mon	56	57
	Tue	46	50
	Wed	59	58

Three approaches to automate space allocation in UK universities are as follows: hill-climbing, simulated annealing and genetic algorithms were discussed in [26]. The constraints addressed focused on space overuse and wastage, restrictions and requirements for sharing spaces, adjacency requirements and considering the unallocated/unoccupied resources. The approaches are mainly oriented toward efficient allocation of spaces without jointly addressing the timetabling constraints and requirements. Although the authors, in their work, have considered space allocation efficiency in the fitness function calculation, definition of efficient space allocation was not clear. Moreover, no technologies were incorporated to reevaluate the efficiency for the allocated spaces.

Different researchers tackled the space allocation problem in different contexts. However, these contributions mostly focused on the algorithms computational time, even for small problem instances. They also did not consider monitoring and reevaluation of the allocated spaces. Some examples follow. A hostel space allocation problem for university students was tackled using genetic algorithms while satisfying some domain specific constraints [27]. The approach aimed at optimizing the allocation of the bed spaces available to students in the hostel. The spaces allocated in the problem do not include any learning spaces. A mixed-integer goal programming model for office allocation was also contributed in [28]. The objective was to reassign a number of 144 offices to 289 faculty and staff members in six academic departments in the College of Administrative Science at The Ohio State University without taking into account the allocation of any events. A model for allocating spaces in an Australian educational institution focused on minimizing the vertical student pedestrian movements within the building without correlating this with timetable construction [29]. The authors indicated that the academic interaction should be maximized while the costs of relocation of occupants from the different building floors should be minimized.

Some authors used adaptive approaches to solve the timetabling problem. However, in these approaches the term "adaptive" refers to the algorithmic procedure used to find better solutions. It does not describe timetables. Once a timetable is published no modifications are envisaged. Some examples follow. An adaptive genetic algorithm for enhancing the search process was introduced in [30]. The authors introduced an approach to dynamically change the crossover and mutation rates during the solution generation process. Another approach that modifies the selection rate of solutions depending on the diversity in the population was introduced in [31]. Genetic algorithms, considering probabilistic mutation and crossover operators, were also used to solve the university course timetabling problem [32].

In order to better understand the problem dimensions and the approaches currently followed in building timetables and allocating spaces, a survey has been conducted in Alexandria University; a public Egyptian university, in faculties of

Table 5 Avg. occupancy room rates per day using IVUT for Week-3.

Room	Sat (%)	Sun (%)	Mon (%)	Tue (%)	Wed (%)	Thu (%)	Fri (%)
201	0	0	0	0	0	0	0
202	0	0	79	76	0	0	0
203	0	0	0	0	0	0	0
301	0	0	83	83	0	0	0
302	0	0	0	56	0	0	0
303	0	0	0	0	0	0	0
401	0	0	0	0	0	0	0
403	0	0	0	0	0	0	0
405	0	0	0	0	0	0	0
407	91	0	89	91	93	89	0
501	0	0	0	0	0	0	0
503	0	0	0	0	0	0	0
506	0	0	0	0	0	0	0
507	55	0	0	0	71	0	0
601	92	83	76	86	83	0	0
603	0	0	100	79	0	0	0
605	83	75	80	79	75	75	0
705	0	0	0	0	0	0	0
707	0	0	0	0	0	0	0
91	125	80	100	80	122	0	0
92	0	0	0	0	0	0	0
93	100	88	93	96	85	90	0
94	0	0	0	0	0	0	0
95	91	93	96	93	93	93	0
1	88	60	80	73	0	76	0
2	50	0	99	51	0	0	0
3	0	0	0	55	0	0	0
4	0	0	0	80	0	0	0
5	89	98	100	98	97	100	0
6	83	83	83	83	83	83	0
7	97	96	97	100	100	100	0
8	76	46	58	51	59	90	0

No. of rooms with avg. occ. rates < 75% per day	No. of rooms with avg. occ. rates between 75% and 100%	No. of rooms with avg. occ. rates = 0%	No. of rooms with avg. occ. rates > 100%
12	62	148	2

Table 6 Rooms with occupancy rate changes from week 1 through week 3 after RFID monitoring.

Room	Day	Occ_Rate (week 1) (%)	Occ_Rate (week 2) (%)	Occ_Rate (week 3) (%)
202	Mon	71	77	79
302	Tue	58	57	56
507	Sat	50	54	55
	Wed	67	70	71
605	Thu	70	72	75
91	Sat	100	115	125
	Wed	100	120	122
1	Sun	61	59	60
	Tue	66	68	73
	Thu	73	75	76
2	Sat	50	48	50
	Tue	56	52	51
3	Tue	56	56	55
8	Sat	72	76	77
	Sun	53	45	46
	Mon	56	57	58
	Tue	46	50	51
	Wed	59	58	59

Engineering, Commerce, Arts and Tourism. The data collected from the surveys confirmed that building timetables is a complex process and that none of the surveyed faculties used automated tools to build timetables and none used technology to monitor the actual number of attendees in order to reassess the initially published timetables.

Consequently, the authors developed a utilization-based genetic algorithm (UGA) that builds timetables considering space utilization rates for better resource management. The algorithm uses some heuristics to generate an initial population of feasible good quality timetables. It uses a simple weighted-sum formula to respect professors' preferences and to handle conflicts. In order to reduce waste in space resources, a new crossover type focusing on the utilization of learning spaces was proposed and a targeted mutation operator using a local search heuristic was also employed. The operator is applied to the under and/or the overutilized spaces. Refer to [33] for more details about the algorithm.

RFID stands for Radio Frequency Identification. It belongs to the broader class of Automatic Identification and Data Capture (AIDC) technologies. The number of publications related to using RFID technology has tripled from 1995 till 2004 [34]. RFID as a tracking technology was identified as one of the top ten technologies in the world in 2004 and 2005 [35]. This technology has grasped the attention of developed countries and its adoption resulted in great achievements in industry, business, supply chain [36–39], education [40], traffic [41], aviation and airports [42], healthcare [43,44] and many other domains.

Large companies such as Wal-Mart in the United States of America, Tesco in Europe, Toyota in Japan, and various government departments such as the Department of Defense in the United States of America use this tool increasingly. Wal-Mart has reduced out-of-stocks by 30% on the average after launching its RFID program [45]. RFID has many applications in universities and academic institutions. Some of which are as follows: personal automatic identification of students [42], managing students' attendances [40], lecture room and hall allocation, better asset tracking and resource utilization [46] and library management [47–49]. A review on these applications was presented in [50].

According to [51], RFID in job-shop scheduling was used to examine whether or not accurate information visibility can improve the performance of the shop-floor in manufacturing. The approach evaluated, among other objectives, the reduction in inventory waste, the waiting time, the assembly time, the cycle time and the number of backlog orders between an RFID and a non-RFID environment. The results of the study revealed that the information visibility provided by RFID had a great impact on operations, especially, when unforeseen disruptions in operations take place compared with a non-RFID scenario. Applying RFID in job-shop scheduling led to the reduction in many resource and time wastes and to the improvement in bottleneck operations.

Table 7 Avg. occupancy room rates per days after reallocation.

Room	Sat (%)	Sun (%)	Mon (%)	Tue (%)	Wed (%)	Thu (%)	Fri (%)
201	0	0	0	0	0	0	0
202	0	0	79	76	0	0	0
203	0	0	0	0	0	0	0
301	0	56	83	83	0	0	0
302	0	0	0	0	0	0	0
303	0	0	0	0	0	0	0
401	0	0	0	0	0	0	0
403	0	0	0	0	0	0	0
405	0	0	0	0	0	0	0
407	91	0	89	91	93	89	0
501	0	0	0	0	0	0	0
503	0	0	0	0	0	0	0
506	0	0	0	0	0	0	0
507	55	0	0	0	71	0	0
601	92	83	76	86	83	0	0
603	0	0	100	79	0	0	0
605	83	75	80	79	75	75	0
705	0	0	0	0	0	0	0
707	0	0	0	0	0	0	0
91	91	93	96	93	93	93	0
92	0	0	0	0	0	0	0
93	100	88	93	96	85	90	0
94	0	0	0	0	0	0	0
95	90	80	100	80	98	0	0
1	88	60	80	73	55	76	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	63	0	99	80	61	0	0
5	89	98	100	98	97	100	0
6	83	83	83	83	83	83	0
7	97	96	97	100	100	100	0
8	76	46	58	51	59	90	0

No. of rooms with avg. occ. rates < 75% per day	No. of rooms with avg. occ. rates between 75% and 100%	No. of rooms with avg. occ. rates = 0%	No. of rooms with avg. occ. rates > 100%
12	63	149	0

The concept of information visibility for better resource management in universities was later introduced in [52]. The authors proposed the use of RFID technology to capture timely data about space utilization in universities. However, in spite of the fact that RFID is a powerful data capturing technology, data captured need to be processed using analytical tools to provide solutions to the timetabling and space allocation problems. A survey on analytical tools and approaches used with RFID-based applications can be found in [53,54]. In the solution methodology, proposed in the next section, the authors do not rely on the RFID technology alone but also on the UGA [33] to achieve better resource utilization in universities.

According to the previous related work, it is obvious that the space allocation problems handled in the education sector did not integrate the timetabling problem nor incorporate any monitoring/tracking technology. The former approaches focused on satisfying some requirements and constraints related only to the space allocation problem and not to timetabling. None of the previous research used RFID technology in monitoring university timetables. To the best of the researchers' knowledge, the previous related work does not include any approach that improves timetables based on the actual status of the allocated events. Contributions mostly focus on details related to the development of a timetable while neglecting the real full picture.

In fact, monitoring the performance of a timetable may show that the supposedly optimal solution for a timetabling problem would not prove optimal if utilization rates change. Some authors used agent systems to help make strategic decisions under dynamic, uncertain conditions when dealing with course timetabling [55]. These systems considered knowledge learnt by agents from historical data and knowledge bases, instead of making use of timely captured data. Other agent based approaches were implemented to assist only in the construction phase of the timetable [56–58]. Although these approaches produced feasible acceptable schedules, relying on timely captured data would certainly give better results.

3. Methodology

Research findings concerning the size and complexity of university timetabling led to the first international conference on the Practice and Theory of Automated Timetabling (PATAT) calling for the importance of developing more generic problem solving algorithms. The Practice and Theory of Automated Timetabling (PATAT) series of conferences sponsor the International Timetabling Competition (ITC) [59] where participants compete to solve real world timetabling problems. The contributed approach, in this paper, is novel and tackles a real world problem.

Due to the complexity of the timetabling problem, a wide range of heuristics was used to solve it [60–63]. However, heuristics only would not be enough to solve this type of problems. In the proposed methodology, the Utilization-Based Genetic Algorithm (UGA) [33] is integrated with the RFID technology to construct adaptive and resilient timetables. This UGA algorithm uses some heuristics together with the genetic algorithm and adopts a local search heuristic to further improve the produced solution. It focuses on maximizing the utilization rate of learning spaces inside academic institutions. The Information Visibility-based University Timetabling (IVUT) approach reallocates teaching events considering room capacities using timely captured data.

The data of the studied case of the Faculty of Commerce for the first semester in year 2012–2013 follow:

In allocating events in a timetable, UGA matches the number of attendees with the closest room capacity that can accommodate them. The algorithm calculates a utilization rate that is based on two other rates (see Eq. (1)): the frequency and the occupancy rates. Frequency rates measure how often a room is used relative to the total number of hours it is available [13,64] (see Eq. (2)). On the other hand, occupancy rates measure the extent to which a room is fully occupied relative to its total capacity [10] (see Eq. (3)).

$$\text{Utilization Rate/Room} = (\text{Freq Rate/Room}) * (\text{Occ. Rate/Room}) \qquad (1)$$

$$\text{Frequency Rate/Room} = \text{Total hours used/Total hours the room is available} \quad (2)$$

$$\text{Occupancy Rate/Room} = \text{No. of occupied seats/Total capacity of the room} \quad (3)$$

Table 8 Event reallocation decisions and impacts on occupancy rates and resource management.

Event ID	Old room		No. of students monitored			New room		Timeslot		Rate		Effect
	ID	Capacity	w1	w2	w3	ID	Capacity	Old	New	Before reallocation (%)	After reallocation (%)	
496	302	60	35	34	33	301	60	12	22	56	56	Free-up room 302
646	91	200	200	230	250	1	400	52	52	125	63	Over-utilization
649			200	240	244		400	44	44	122	61	handled
465;508	3	400	225	197	196	95	200	32	33	51	98	– Improved Occ. Rate – Free-up room 3
163;169	2		160	192	180			42	62	50	90	– Improved Occ. Rate – Free-up room2
479;516	1		225	224	220	1	400	33	33	55	55	Merging possibility
308			250	236	240			43	43	60	60	No change
629;636			250	272	292			42	42	73	73	No change
321	8	30	18	16	16	8	30	53	53	55	55	No change
319			20	20	21			63	63	71	71	No change
512			25	14	13			43	43	46	46	Merging possibility
483			10	17	17			24	24	58	58	No change
486			10	15	15			44	44	51	51	Merging possibility
305	507		20	18	17	507		34	34	59	59	No change

Table 9 The resources saved after reallocation and applying IVUT.

Item	UGA without RFID monitoring	UGA with RFID monitoring (IVUT)
Total no. of rooms used out of 32 rooms	19	16
Total no. of rooms saved out of 32 rooms	13	16

Table 10 Event IDs with improved occupancy rates.

Event ID	Old room	New room	Old rate (%)	New rate (%)
646	91	1	125	63
649			122	61
163	2	95	50	90
169			50	90

According to the University of Wisconsin study [24], the benchmark used as a good utilization rate of a space is 56% or higher, and a percentage of 75% or higher is considered for good frequency and occupancy rates of spaces. In UGA, the same standards were followed. The average utilization rate of a room in a day is the multiplication of the averages of both the frequency and the occupancy rates of that day. The same formula is used to calculate the utilization rate of a room in a week.

In 2009, the UK Higher Education Space Management Project [65] revealed that one of the wrong practices in building timetables is to request rooms more than needed without considering the size and capacity of the room in relation to the number of attendees assigned. The calculation of occupancy rates made in previous space utilization projects was not based on actual data obtained to calculate an accurate rate, but on forecasted numbers or assumptions taken from historical scenarios [65,24]. As a result, these utilization rates may be far from the actual rates thus misleading the decision making process. In this research, occupancy rates are calculated based on actual timely data captured using RFID technology to be able to instantly identify real numbers about students attending classes and to keep timetablers updated with any change. The logic behind IVUT methodology is better clarified through the flowchart in Fig. 1.

4. Testing and results

This section investigates testing the IVUT methodology in the case study of the Faculty of Commerce-Alexandria University to reassess the initially constructed timetables using the RFID technology.

The IVUT methodology is constructed based on the UGA algorithm developed in [33]. The testing is based on the real data collected from the Faculty of Commerce in year 2012–2013. In semester one in year 2012–2013, average occupancy rates per room per day for the faculty after applying UGA and before the RFID monitoring are presented below. Note that there is no significance in ordering the room numbers in the tables.

It is obvious that the number of events with poor occupancy rates (less than 75%) is 16 events and the number of events with good occupancy rates (between 75% and 100%) is 60 events. There are zero events with occupancy rates that exceeded 100% and 148 unoccupied events. The UGA algorithm saved up to 41% of the available rooms in the faculty instead of only 19% when following the old manual approach. Also, 29% of the total working hours available weekly to build the schedule were saved [33].

4.1. RFID experiment components

The undergone experiment uses a "UHF Multi-Channel RFID Reader" connected to an antenna inside each teaching space to detect tags within the read range of readers. RFID readers are pre-identified, so that each reader has an ID labeled by the name of a certain room. This helps detecting which reader transmits data to the database and, hence, knowing which room is being examined.

The tags used in the experiment are passive tags (see Fig. 4). The tags are pre-identified in the database with the data needed to be maintained. In our case, the student ID number, his/her name, the group, the department and the academic year of the student are stored on the tag (Figs. 2 and 3).

4.2. Experiment implementation

The seating capacity of every room is known and stored in the database. Students are not authorized to enter the faculty without having their faculty IDs where the RFID tags are embedded.

Readers and antennas in each room are supposed to detect the tags of the students attending the lecture and to update the database with the actual number of attendees. Comparing the room capacity with the actual number of attendees, occupancy and utilization rates are calculated and investigated for further assessment. In fact, not all rooms were equipped with readers but this was tested in a restricted number of rooms for a proof of concept. The rest of the data was simulated only over three weeks. This number of weeks was judged sufficient because the Faculty of Commerce does not have a credit hour system for the undergraduates. Thus, from day one students know the list of courses they should attend and accordingly it is appropriate to monitor attendance patterns over three weeks for reallocation decisions purposes (see Tables 2 and 3).

On a weekly basis, occupancy rate changes for occupied rooms are captured by RFID. During the first week, after publishing the initial timetable, occupancy rates are observed and low attendance rate rooms are identified. In the second week, assignments are reevaluated in light of the list of highlighted rooms from the first week. Final observations will be made during the third week, where reallocation decisions may be necessary. Average occupancy rates in the second and third weeks follow:

From Table 4, updated data sent by RFID regarding the actual number of attendees during the second week show improvements in rooms: 202 on Monday, 507 on Saturday and Wednesday, 605 on Thursday, 1 on Tuesday and Thursday and room 8 on Saturday, Monday and Tuesday.

From Table 5, it is observed that room 202 on Monday, room 507 on Saturday and Wednesday, room 605 on Thursday, room 1 on Tuesday and Thursday and room 8 on Saturday, Monday and Tuesday will not be reallocated because of the improved pattern in their occupancy rates. On the other hand, it is clear that rooms 302, 3 and 4 have only one day in which they are used and that room 91 on Saturday and Wednesday has overutilized events that need reallocation.

This means that investigations, of whether these rooms could be completely freed-up and reallocated in other rooms within the same timeslot or other acceptable timeslots should take place. Accordingly, events of these rooms need to be further examined in terms of the following: the time availability and preferences of professors, the number of students attending and alternate room capacities. This is described in the following section (see Table 6).

4.3. Re-allocation decisions

Reallocation decisions are made in order to achieve one of the following objectives:

1. Freeing-up a space throughout the whole week or day.
2. Improving underutilized rooms.
3. Handling overutilized rooms.

According to the case on hand, the new rates are presented in Table 7 and the reallocation decisions are described in Table 8. Some decisions were made to achieve one of three objectives: reallocate an event in a bigger or smaller room for better occupancy rate, and reallocate an event in a similar size room to free-up a room for the whole week, or to leave events unchanged because no other better placement is available. However, a compromise between the costs incurred and the benefits achieved from a reallocation decision should take place before reallocating. This is because changing the place of a lecture might:

1. Cause disturbance in other lectures.
2. Affect timeslot availability of a certain professor if no room was available in the same timeslot.
3. Increase the number of occupied rooms and/or days that were better kept unoccupied for urgency cases.
4. Negatively affect occupancy rates.

In room 302, moving event (496) to room 301 was for the sake of completely freeing up room 302, as this was the only event held in this room. In rooms, 2 & 3 events (465 & 508 and 163 & 169) were moved to room 95 in order to free up room 2 and 3 and improve occupancy rates. However, events (646 and 649) were reallocated from room 91 to room 1 in order to handle the overutilization problem (see Tables 9 and 10).

Sometimes after making all the possible reallocation decisions, some underutilized or over-utilized events remain. In the case of the underutilized events, a proposed solution might be to search for the possibility of merging two underutilized events together in one room, only if, they share the same professor and course and that the groups involved do not have any other scheduled events at the same time. Moreover, in the case of the overutilized events, splitting groups, in these particular events only, into subgroups might result in a better situation by coordinating this with professors.

Table 8 illustrates the positive impact RFID monitoring can have on improving timetables and space allocations. From the one hand, by taking some rooms as examples with simulated rate changes, up to three rooms were saved instead of being occupied. This means that around 54 extra timeslots (because all rooms are available three timeslots six days a week) became available for any emergency need. However, actual (and not simulated) rate changes after monitoring could free more than three rooms.

On the other hand, not only more rooms were saved, but also occupancy rates per rooms were improved. IVUT was able to handle overutilization, which directly influences students' learning levels as well as handling underutilization that addresses space allocation efficiency. These over/underutilizations are presented in the following table:

From the previous tables it is obvious that the weekly RFID monitoring adds a new dimension to the NP-hard timetabling and space allocation problems. A number of spaces could be saved in addition to increasing the efficiency in allocating and utilizing spaces. This could never be achieved without a proper visibility of information that RFID technology made possible. Paying more attention to the details of building the timetable without seeing the full picture and considering all the dimensions when constructing a timetable, leads to making wrong decisions that will have negative impacts throughout the semester.

5. Conclusion and future avenues

This work investigated the important role information visibility can play in solving the university timetabling problem using RFID technology. It focused on the large Egyptian public universities, where large numbers of human, space and financial resources need to be efficiently managed. These large Egyptian public universities are characterized by changes in attendance patterns which legitimize the reallocation of space resources. The IVUT proposed methodology enabled better use of resources and addressed the university dynamic timetabling problem in a very practical manner considering joint space reallocation decisions. Accordingly, occupancy rates per rooms were improved. This enabled freeing-up a space throughout the whole week or day, improving underutilized rooms and handling overutilized rooms. Overutilization directly influences students' learning levels and must not be overlooked.

Future research will focus on larger scale implementations as well as conducting further studies and analysis to define the standards of good space utilization for the Egyptian universities rather than following the University of Wisconsin standards. The research can also be extended to quantify more parameters such as which courses and timeslots have higher attendance patterns to help in future timetable construction and space allocations.

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