An Improved Approach for Examination Timetabling Problem

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Abstract— **The examination timetabling problem depicts a major activity for academic institutions. An increasing number of students enroll in University, a wider variety of courses and increasing number of degree courses contribute to the growing examination timetabling problem to cater for major constraints required by universities. In this paper, we present a real-world examination timetabling dataset at Aligarh Muslim University that will be used as a future benchmark problem. In addition, new objective function that is used for attempts to spread exams throughout the examination period. This function involved in both timeslots and days assigned to each exam for different courses. It is different from the often used objective function from the literature that only considers for timeslot adjacency.**

Index Terms— **Examination, Examination Time Table, Scheduling, Exam Timetabling, Timetable Problem, Heuristic, Graph coloring**

I. INTRODUCTION

Examination timetabling is implied with an assignment of exams into a limited number of timeslots assign a subject for examination to a set of constraints (see Burke et al. [6]). Commonly accepted constraints for the examination timetabling problem are:

(i) number of student should not required to sit two exams at the same time or same time-slot (ii) in time table ,scheduled exams must not exceed the room capacity (iii) exam for each active subject in a particular course can assign a independent timeslot including backlog papers (iv) exam for two or more independent different courses can assign same timeslot. However, in the context of examination timetabling problem, there are many other constraints and these constraints vary among universities. Similar way in our dataset, we have some additional constraints.

A hard constraints are enforced the solutions to satisfying all the constraints are called *feasible*. Other way, we can say there might be some requirements that are not essential but should be satisfied, which are referred to as soft constraints. A common soft constraint refers to spreading exams as evenly as possible throughout the schedule. Due to the complexity of involve in the problem, it is not possible to have solutions that do not violate the soft constraints. In fact, the cost function is a function of violated soft constraints. Each weighted penalty value is associated with each violation of the soft constraint and main objective is to minimize the total penalty value.

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An approach for constructing examinations timetables have been discussed in the literature. According to Carter [7], divided these approaches into four broad categories: sequential methods,

cluster methods, constraint-based methods and meta-heuristics. According to Petrovic and Burke [8], following categories are: multi-criteria approaches, case-based reasoning approaches and hyper-heuristics/self adaptive approaches.

In sequential methods, the construction for remove the confliction in timetable problem is handle by graph coloring scheme. In Clustering methods, split exams into groups applied constraint-based approaches to maintain timetabling problems.

Meta-heuristic approaches (which includes simulated annealing, Tabu search, genetic algorithms and hybrid approaches such as mimetic algorithms) have also been investigated in the last 15 years. Thompson and Dowsland [9] investigated a two phase simulated annealing approach. Examples of Tabu search based approaches were depicted by Di Gaspero and Schaerf [15] and White and Xie [16]. Hybridization techniques perform well in examination timetabling .Multi-criteria approaches for timetabling offer a flexible way of handling different types of constraints simultaneously (see Petrovic and Bykov [19]). Case-based reasoning (see Burke et al. [20]) is an important approach that is used to motivated by the human process of learning effectively from previous experience and using that experience to solve new problems. Burke et al. [21] implemented a case-based reasoning method to select examination timetabling heuristics system.

Hyper-heuristics is new as powerful approaches which raising the level of generality of timetabling systems (see Burke and Petrovic [19], Petrovic and Burke [8], Kendall and Hussin [25]). Burke and Newall [26] have presented an adaptive heuristic approach which draws the squeaky wheel optimization methodology has developed by Joslin and Clements [27].

In this paper, we introduce a real-world examination timetabling dataset at Aligarh Muslim University (AMU). It has more practical constraints (see section 2) compared to existing benchmark examination datasets. We know that the dataset will be used as a future benchmark problem. The quality of the timetable is measured from the standard proximity cost function, where the closeness of the scheduled examination is not only measured based on the allocation of the timeslots, but also on the allocation of the days. This objective function can also be applied in the standard benchmark examination datasets (Carter et al. [5]) by adding a new variable *day* for each corresponding time-slot.

This paper is organized in this manner: The first section presents the statement of the problem. The formulation of the problem is described in Section 2. In Section 4 understanding a new objective function followed by some concluding remarks and future work for new research directions in Section 5.

II. Problem Statement Specification

In this paper, we study a real-world examination timetabling problem at the Educational Institution. In this Institution, many courses are running such B.Tech, M.Tech, B.Sc. B.A. etc. For conducting examination, examination Time table created for B.Tech and M.Tech Courses, for example 36 subjects studies during B.Tech and 16 subjects in M.Tech, but during examination period 12 subjects are active in B.Tech are allocate independent timeslot and 8 subjects are active in M.Tech are allocate independent timeslot but these exam may share the timeslot of B.Tech or M.Tech. The dataset presented for undergraduate and postgraduate examinations for Semester I, year 2016. It has processed in which excluded those courses which has no exam and modified the original dataset by replacing the appropriate examination. In this dataset, the total number of examinations is 322 with 29674 students, 35842 enrolled students and the number of days are 30 and available timeslots are 72.

In Institute, many courses which are enrolled by many students from different faculties and have shorter exam periods, allocate different timeslots and it has to be scheduled outside the examination weeks. These courses has to be excluded from dataset. There are many examinations as discuss above need to be scheduled together with other examinations.

In this problem, we have consider 4 week examination periods. Each week has 6 days (Monday to Saturday). Each day has 2 timeslots. In this model we consider real-world timeslots, we present the following vectors (Fig-1) which demonstrates the valuable idea:

(1, 1, 2, 2, 3, 3, 4, 4, 5, 5, 6, 6, 8, 8, 9, 9, 10, 10, 11, 11, 12, 12, 13, 13, 15, 15, 16, 16, 17, 17, 18, 18, 19, 19, 20, 20, 22, 22, 23, 23, 24, 24, 25,25, 26,26, 27,27)

Fig.1. Day Vector for a month

It can be seen that Sundays (day 7, 14 and 21) are missing because there are no examinations on Sunday.
The corresponding timeslot vector is presented in Fig-2.

(1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 43, 44, 45, 46, 47, 48, 49, 50, 51, 52, 53, 54)

Fig. 2. Timeslots Vector

In Figure 2, the timeslots are represented as indexes. Timeslots 1 and 2 are referring to day 1, timeslots 3 and 4 are referring to day 2, etc. Note that on Sunday, the first week (13, 14), are missing because there are no exam scheduled on Sunday. The same consideration is used for the second and third Sunday of weeks of exam period. The idea is to reflect the timeslot gap with practical time gap. In the real situation, we have 1 day (Sunday) break between the exam on Saturday evening (timeslot 12, 26 and 40) and Monday morning (timeslot 15, 29 and 43). Therefore, it is not appropriate to index in between Friday evening and Monday morning timeslot that predict there is no exam on Sunday. These indexing format (day vector and timeslot vector) can also be applied to other datasets, including the benchmark datasets by adding day vectors for each timeslot and also introducing missing timeslot (e.g. Sunday). The number of timeslots per day is assigned by the administration. Therefore, if the administrator has two timeslots per day, we should only have two day vectors for each day.

Each examination should be assigned to a single room. Room specifications are shown in Table-1. In any exceptional cases, i.e. no room available to fit the for conducting exam, then the exam can be assigned to multiple rooms but the room locations should be closed to each other, for example, in this case, it should be in ScienceBuilding (starting with the largest room in ScienceBuilding i.e. DPLecture DPMath, DPChem, DPComp and DPBio). This constraint is enforcing due to the location prospect. In case of large examinations, where the number of enrolments is greater than the largest room capacity (i.e. more than 850 seats in this case), then the examination can be assigned to any available room starting with DPLecture, DPMath, DPComp, DPChem, DPBio). The room can be shared with multiple exams depends on the availability of the seats. For assigning exams to rooms, priority should be given to assign an exam to a room which can accommodate the exam. In addition, wherever possible, students should be assigned to same room when they are sitting consecutive exams on same day.

Table 1: Available rooms for dataset

Department	Room	Capacity
DPLecture	LT-1 to LT-25	850
DPMath	LT-1 to LT-20	610
DPChem	LT-1 to LT-20	610
DPComp	LT-1 to LT-15	450
DPBio	LT-1 to LT-18	570

III. Problem Formulation

The examination timetabling problem can be stated as follows:

- NE is the number of examination;
- E_i is an exam where $i \in \{1,....,NE\}$;
- n_i is number of students sitting exam E_i where $i \in \{1,....,NE\}$;
- B is the set of all NE exams, $B=\{E_1,..., E_{NE}\}$;
- MS is the number of students;
- RN is the number of available rooms;
- DN is the number of days;
- TS is the given number of available timeslot;
- L_R is the capacity of room R where $f \in \{1,....,RN\}$;
- r_i specifies the assigned room for exam E_i, where $r_i \in \{1,....,RN\}$ and $i \in \{1,....,NE\}$;
- ts_i specifies the assigned time slot for exam E_i, where $ts_i \in \{1,..,T\}$ and $i \in \{1,..,NE\}$;
- d_i specifies the assigned day for exam E_i, where $d_i \in \{1,..,DN\}$ and $i \in \{1,..,NE\}$;

- $C=(C_{ij})_{NxN}$ is the conflict matrix where each element denoted by C_{ij}, (i,j Є{1,..,NE}) is the number of students taking exams E_i and E_j;
- $\Delta t=|t_i-t_j|$ is the timeslot different between exam E_i and E_j;
- $\Delta d=|d_i-d_j|$ is the day different between exam E_i and E_j;
- z_i is a lecturer for exam/courses E_i.

The constraints for our dataset are:

1) All exams must be scheduled and each exam must be scheduled only once.

(1) ,

$$\sum_{s=1} \lambda is = 1 \quad \text{for all } i \in \{1,....,NE\} \qquad (2)$$

Where

$$\lambda is = \begin{cases} 1 & \text{if exam } i \text{ is assigned} \\ 0 & \text{otherwise;} \end{cases} \qquad (2)$$

2) No student can sit in two exams concurrently. If examination k and l are scheduled in slot s, the number of students sitting both examination k and l must be equal to zero, i.e. $C_{kl} = 0$.

$$\sum_{k=1}^{NE-1} \sum_{l=k+1}^{NE} C_{kl} .x(t_k, t_l) = 0 \qquad (3)$$

where

$$x(t_k, t_l) = \begin{cases} 1 & \text{If } t_k = t_l; \\ 0 & \text{otherwise;} \end{cases} \qquad (4)$$

3) For each timeslot ts, the number of students sitting exams ($Students_s$) must not exceed the maximum seat number ($Seats$) i.e. 3090 seats per slot for this case.

$$Students_{ts} \le Seats \quad \text{for } ts \in \{1,..,TS\}; \qquad (5)$$

4) Student which has consecutive exams on the same day should be assigned to the same room.

$$\text{if } ts_k = x;\ ts_l = x+1;\ d_k = d_l \text{ and } c_{kl} \neq 0 \qquad (6)$$

$$\text{then } r_k = r_l \text{ for all } k, l \in \{1,....,NE\};$$

5) Special examination, $E_i \in S$ where $S \subset B$ should be isolated from other exams dataset, i.e. the special exam cannot share room with other exam at the same timeslot.

$$\sum_{i=1}^{NE} \alpha ir \le 1 \quad \text{for all } r \in \{1,....,RN\} \qquad (7)$$

Where

$$\alpha ir = \begin{cases} 1 & \text{if exam } Ei \in S \text{ is assigned to room } r; \\ 0 & \text{otherwise;} \end{cases} \qquad (8)$$

6) No students can seat 2 consecutive exams in a day.

$$\text{If } C_{ij} \neq 0;\ C_{ik} \neq 0;\ ts_i = x;\ [ts_j = x+1 \text{ OR } ts_j = x-1] \text{ and } d_i = d_j \qquad (9)$$

$$\text{then } d_k \neq d_i; \quad \text{for all } i,j \in \{1,...,NE\};$$

7) Wherever it is possible, each examination assigned to a single room.

$$\sum_{f=1}^{RN} \beta if = 1 \quad \text{for all } i \in \qquad (10)\ \&\ (11)$$

Where

$$\beta if = \begin{cases} 1 & \text{if exam } i \text{ is assigned to room } f; \\ 0 & \text{otherwise;} \end{cases}$$

8) Exam must be assigned to a room without exceed the room capacity.

$$\sum_{i=1}^{NE} e_i \cdot \beta if \le L_f \quad \text{for all } f \in \qquad (12)$$

Due to the complexity of the examination time table problem, constraints 6 and 10, could be relaxed if it assigning an examination to multiple rooms is unavoidable (constraint 10) and it is not possible to assign the same room for students sitting consecutive exams in a day (constraint 6). Therefore, the exam has relaxing constraint 10.

As benchmark dataset, wherever possible, examinations should be spread out over timeslots so that students have large gaps in between exams comes under soft constraint.

IV. The New Objective Function

In order to influenced the practical issues, we approach a new objective function (named as *Penalty Cost*) which is pointed from a proximity cost (proposed by Carter et al. [5] and Burke et al. [36, 37]), as follows:

$$\textbf{Minimise } F = \frac{\sum_{i=1}^{NE-1} \sum_{j=i+1}^{NE} C_{ij} .Penalty(ts_i, ts_j)}{MS} \qquad 13)$$

where,

$$penalty\,(ts_i\,, ts_j\,) = \begin{cases} 2^{(5-\Delta t)(2-\Delta d)} & If\ |\Delta t|\leq 5\ and\ |\Delta d|\leq 2 \\ 0 & \text{otherwise}; \end{cases} \qquad (14)$$

Eqn 14 presents a weighted *penalty* value represent the cost of assigning exam E_i and E_j to timeslots. This value being 0, 1, 2, 4, 8, 16, 64 and 256. Cost is '0' if the gap of time slot for exam *Ei* and *Ej* is greater than 5 or the day gap is greater than 2. We only give a penalty up to a maximum of 5 timeslots in order to achieve well established proximity cost proposed by Carter et al. [5].

Whereas, we limit the penalty up to 2 days because 2 days gap between examinations gives ample free time for students. The main aim of objective function (eqns 13 and 14) to minimize the number of students having two exams in a row on the same day and try to spread out exams over timeslots. The penalty value for students having two consecutive exams on the same day (*penalty=256*) is higher than the penalty value for students having two consecutive exams on different days (*penalty=16*). This factor is not highlighted in the objective function proposed by Burke et al. [18, 22] and Carter et al. [5] and Carter et al. [5] totally ignores the day effect by assuming timeslot gap between each consecutive timeslot is the same, each day has exam, each day has the same number of time slots and the exams can be scheduled 24 hours a day without evening and weekend breaks. This can be observed by their objective function and their standard benchmark datasets.

V. Conclusions

In this paper, we have introduce a real-world examination timetabling problem at the academic institution with an objective to minimize student sitting consecutive exams on the same day and exam schedule should be conflict-free by using an objective function, *Penalty Cost* and each courses treat as independent each other. Subject of these courses can allocate same timeslot handle by organization depends on the room capacity and exam for subjects in same course must allocate different timeslot. The *Penalty Cost* attempts to spread out exams over timeslots so that students have large gaps between exams and we emphasize on minimizing consecutive exams on the same day. This function also implies the (hard constraint) no students sitting three consecutive exams on a day. This function can also be applied to the standard benchmark examination datasets (Carter et al. [5]) by adding a variable *day* for each corresponding timeslot. To influences with the examination timetabling problem, we have also recommended adding weekend breaks and room capacity for each room into the benchmark examination datasets specification (Carter et al. [5]). The maximum seat capacity for each timeslot has been applied by some researchers (see for example, Abdullah et al. [28] and Burke et al. [18]). Since the objective function for examination timetabling problems using standard benchmark datasets (proposed by Carter et al. [5]) was unable to cater for these features of examination timetabling problem, we hope that future research in this area will consider our proposed objective function in evaluating the quality of generated examination timetables with high accuracy. The current objective function can still be applied for theoretical/preliminary work, but for solving the practical examination timetabling problems, our objective function seem to be more appropriate.

Currently, we are design and implement a constructive heuristic which is adapted from a graph coloring heuristic to solve the institutional examination timetabling problem.

6. Future Scope

Our future work will concentrate on implementing the examinations scheduling for different courses sharing the common timeslot allocated by active subjects of same course independently depends on room seats available. This facility only has three slots per day (because the exam period is longer than other normal exams i.e. at 8:30am and 8:30pm) and exams have to be scheduled in a specific room only.

References

[1] E.K. Burke and Y. Bykov. (2006). Solving exam timetabling problems with the flex-deluge algorithm. Extended Abstract. Proceedings of the 6th International Conference on the Practice and Theory of Automated Timetabling. 30th August-1st September 2006, Brno, The Czech Republic, pp 370-372.

[2] M. Ayob, E.K. Burke and G. Kendall. (2006). An iterative re-start variable neighbourhood search for the examination timetabling problem. Extended Abstract. Proceedings of the 6th International Conference on the Practice and Theory of Automated Timetabling. 30th August-1st September 2006, Brno, The Czech Republic, pp 336-344.

[3] E.K. Burke, B. McCollum, P. McMullan and R. Qu. (2006). Examination timetabling: A new formulation. Extended Abstract. Proceedings of the 6th International Conference on the Practice and Theory of Automated Timetabling. 30th August-1st September 2006, Brno. The Czech Republic, pp 373-375.

[4] H. Asmuni, E.K. Burke, M. Garibaldi and B. McCollum. (2006). A novel fuzzy approach to evaluate the quality of examination timetabling. Proceedings of the 6th International Conference on the Practice and Theory of Automated Timetabling. 30th August-1st September 2006, Brno, The Czech Republic, pp 373-375.

[5] M.W. Carter, G. Laporte and S.Y. Lee. (1996) Examination timetabling: algorithmic strategies and applications. Journal of the Operational Research Society Volume 47 Issue 3, 373-383.

[6] E.K. Burke, D.G. Elliman, P.H. Ford and R.F. Weare. (1996). Examination timetabling in British universities - A survey. The Practice and Theory of Automated Timetabling I: Selected Papers from 1st International Conference on the Practice and Theory of Automated Timetabling (PATAT I), Edinburgh, UK, Lecture Notes in Computer Science 1153, Springer-Verlag. (Editors: E.K. Burke and P. Ross), pp76-92.

[7] M.W. Carter. (1986). A survey of practical applications of examination timetabling. Operations Research, 34, pp 193-202.

[8] Petrovic and E.K. Burke. (2004). University timetabling. Handbook of Scheduling: Algorithms, Models and Performance Analysis, Chapter 45, (Editor: J. Leung), CRC Press.

[9] J. Thompson and K. Dowsland. (1998). A robust simulated annealing based examination timetabling system. Computers Operations Research, 25, pp 637-648.

[10] N. Balakrishnan, A. Lucena and R.T. Wong. (1992). Scheduling examinations to reduce second order conflicts. Computers and Operations Research, 19, pp 353-361.

[11] P. Boizumault, Y. Delon and L. Peridy. (1996). Constraint logic programming for examination timetabling. The Journal of Logic Programming, 26, pp 217-233.

[12] L.T.G. Merlot, N. Boland, B.D. Hughes and P.J. Stuckey. (2003). A hybrid algorithm for the examination timetabling problem. The Practice and Theory of Automated Timetabling IV: Selected Papers from 4th International Conference on the Practice and Theory of Automated Timetabling (PATAT IV), Gent, Belgium, Lecture Notes in Computer Science 2740, Springer-Verlag. (Editors: E.K. Burke and P. De Causmaecker), pp 207-231.

[13] E.K. Burke and J.P Newall. (2003). Enhancing timetable solutions with local search methods. The Practice and Theory of Automated Timetabling IV: Selected Papers from 4th International Conference on the Practice and Theory of Automated Timetabling (PATAT IV), Gent, Belgium, Lecture Notes in Computer Science 2740, Springer-Verlag. (Editors: E.K. Burke and P. De Causmaecker), pp 195-206.
[14] P. David. (1998). A constraint-based approach for examination timetabling using local repair technique. The Practice and Theory of Automated Timetabling II: Selected Papers from 2nd International Conference on the Practice and Theory of Automated Timetabling (PATAT II), Toronto, Canada, Lecture Notes in Computer Science 1408, Springer-Verlag. (Editors: E.K. Burke and M. Carter), pp 169-186.
[15] L. Di Gaspero and A. Schaerf. (2001). Tabu search techniques for examination timetabling. The Practice and Theory of Automated Timetabling III: Selected Papers from 3rd International Conference on the Practice and Theory of Automated Timetabling (PATAT III), Konstanz, Germany, Lecture Notes in Computer Science 2079, Springer-Verlag. (Editors: E.K. Burke and W. Erben), pp 104-117.
[16] G.M White and B.S Xie. (2001). Examination timetables and tabu search with longer-term memory. The Practice and Theory of Automated Timetabling III: Selected Papers from 3rd International Conference on the Practice and Theory of Automated Timetabling (PATAT III), Konstanz, Germany, Lecture Notes in Computer Science 2079, Springer-Verlag. (Editors: E.K. Burke and W. Erben), pp 85-103.
[17] H. Asmuni, E.K. Burke and J.M. Garibaldi. (2004). A comparison of fuzzy and non-fuzzy ordering heuristics for examination timetabling. The Proceedings of the 5th International Conference on Recent Advances in Soft Computing 2004 (RASC2004), Nottingham, UK, pp 288-293.
[18] E.K. Burke, J.P. Newall and R.F. Weare (1996). A Memetic Algorithm for University Exam Timetabling. The Practice and Theory of Automated Timetabling I: Selected Papers from 1st International Conference on the Practice and Theory of Automated Timetabling (PATAT I), Edinburgh, UK, Lecture Notes in Computer Science 1153, Springer-Verlag. (Editors: E.K. Burke and P. Ross), pp 3-21
[19] S. Petrovic and Y. Bykov. (2003). A multi-objective optimisation technique for exam timetabling based on trajectories. The Practice and Theory of Automated Timetabling IV: Selected Papers from 4th International Conference on the Practice and Theory of Automated Timetabling (PATAT IV), Gent, Belgium, Lecture Notes in Computer Science 2740, Springer-Verlag. (Editors: E.K. Burke and P. De Causmaecker), pp 181-194
[20] E.K. Burke, B. MacCarthy, S. Petrovic and R. Qu. (2001). Case-based reasoning in course timetabling: an attribute graph approach. The Proceeding of the 4th International Conference on Case-based Reasoning (ICCBR-2001), Springer Lecture Notes in Artificial Intelligence 2080, pp 90-104
[21] E.K. Burke, S. Petrovic and R. Qu. (2006b). Case-based heuristic selection for timetabling problems. Journal of Scheduling, 9(2), pp 115-132
[22] E.K. Burke and J.P. Newall. (1999). A multistage evolutionary algorithm for the timetable problem. IEEE Trans. Evolutionary Computation. 3, 63-74.
[23] G. Kendall and N. Hussin. (2005a). An investigation of a tabu search based hyper-heuristic for examination timetabling. Multidisciplinary Scheduling: Theory and Applications, (Editors: G. Kendall, E.K. Burke, S. Petrovic and M. Gendreau), Springer, pp 309-328.

[24] E.K. Burke and J.P. Newall. (2004). Solving examination timetabling problems through adaptation of heuristic orderings. Annals of Operations Research, 129, pp 107-134.
[25] D.E. Joslin and D.P. Clements. (1999). Squeaky wheel optimisation. Journal of Artificial Intelligence Research, 10, pp 353-373.
[26] A. Schaerf. (1999a). A survey of automated timetabling. Artificial Intelligence Review, 13(2), pp 87-127.
[27] E.K. Burke and S. Petrovic. (2002). Recent research directions in automated timetabling. European Journal of Operational Research, 140(2), pp 266-280.
[28] E.K. Burke, K. Jackson, J.H. Kingston and R.F. Weare. (1997). Automated university timetabling: the state of the art. The Computer Journal, 40(9), pp 565-571.
[29] V.A. Bardadym. (1996). Computer-aided school and university timetabling: a new wave. The Practice and Theory of Automated Timetabling I: Selected Papers from 1st International Conference on the Practice and Theory of Automated Timetabling (PATAT I), Edinburgh, UK, Lecture Notes in Computer Science 1153, Springer-Verlag. (Editors: E.K. Burke and P. Ross), pp 22-45.
[30] E.K. Burke and S. Petrovic. (2002). Recent research directions in automated timetabling. European Journal of Operational Research, 140(2), pp 266-280.
[31] S. Abdullah, S. Ahmadi, E.K. Burke and M. Dror. (to appear 2006a). Investigating Ahuja-Orlin's large neighbourhood search approach for examination timetabling. Accepted for publication in OR Spectrum.
[32] S. Abdullah , S. Ahmadi, E.K. Burke, M. Dror and B. McCollum. (to appear 2006b). A tabu-based large neighbourhood search approach for the capacitated examination timetabling problem. Accepted for publication in the Journal of the Operational Research Society.
[33] E.K. Burke, J. Kingston and D. de Werra. (2004). Applications to timetabling. Handbook of Graph Theory, (Editors: J. Gross and J. Yellen), Chapman Hall/CRC Press, pp 445-474.
[34] G.M. White and P.W. Chan. (1979). Towards the construction of optimal examination schedules. INFOR, 17(3), pp 219-229
[35] H. Asmuni, E.K. Burke, J.M. Garibaldi and B. McCollum. (2005a). Fuzzy multiple ordering criteria for examination timetabling. The Practice and Theory of Automated Timetabling V: Selected Papers from 5th International Conference on the Practice and Theory of Automated Timetabling (PATAT V), Pittsburg, USA, Lecture Notes in Computer Science 3616, Springer-Verlag, (Editors: E.K. Burke and M. Trick), pp 334-353.
[36] M.W. Carter and G. Laporte. (1996). Recent developments in practical examination timetabling. The Practice and Theory of Automated Timetabling I: Selected Papers from 1st International Conference on the Practice and Theory of Automated Timetabling (PATAT I), Edinburgh, UK, Lecture Notes in Computer Science 1153, Springer-Verlag. (Editors: E.K. Burke and P. Ross), pp 3-21.
[37] D. de Werra. (1985). An introduction to timetabling. European Journal of Operational Research, 19, pp 151-162.

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