Solving Exam Timetabling Problems with the Flex-Deluge Algorithm

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In this abstract we present a new exam timetabling algorithm together with a set of results on the university exam timetabling problems from the University of Toronto collection, available at `ftp://ftp.mie.utoronto.ca/pub/carter/testprob/`. A number of recent papers have studied these problems e.g. Carter et al. [7], Caramia et al. [6], Casey & Thompson [8], Abdullah et al. [1], Burke et al. [2],[4]. We will compare the results of our new algorithm against these results.

In [4] and [5], we investigated a Great Deluge algorithm for exam timetabling. The basic algorithm was introduced by Dueck [11] and accepts a candidate solution if it satisfies the following conditions:

$$P' \leq B \quad \text{when } P < B \qquad\qquad P' \leq P \quad \text{when } P \geq B \tag{1}$$

where P is the current penalty, P' is the penalty of the candidate solution and B is the current *upper limit* (called the "level"). At the beginning, B is equal to the initial penalty and with each step it is lowered by a decay rate (denoted by ΔB), which corresponds to the *search speed*. In [4], it was shown that the right choice of ΔB helps to fit the search procedure into an available time limit and that (unsurprisingly) longer searches generally produce better results.

In this paper, we propose an extension of the Great Deluge algorithm (which we call "Flex-Deluge"), where the acceptance of uphill moves depends on a "flexibility" coefficient k_f ($0 \leq k_f \leq 1$). The acceptance rules are outlined in Expression (2):

$$P' \leq P + k_f\,(B - P) \quad \text{when } P < B \qquad\qquad P' \leq P \quad \text{when } P \geq B\,. \tag{2}$$

By varying k_f, it is possible to obtain an algorithm with characteristics of both the original Great Deluge ($k_f = 1$) and greedy Hill-Climbing ($k_f = 0$). This property is similar to that of the Peckish strategy (an intermediate between Hill-Climbing and Random Ordering) proposed by Corne and Ross in [9].

The proposed mechanism enables the search procedure to develop with an adaptive level of *strictness of acceptance* for each particular move. The method draws upon an idea of White & Xie [13], who suspended the *movement* of exams with low degree in order to leave more room for the movement of higher degree exams. The *degree* of an exam here is defined in terms of graph colouring (see [3]). Thus, when moving an

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exam into a different timeslot we calculate the flexibility coefficient as a ratio of the exam's degree to the maximum degree.

A series of experiments has been carried out. The following three new features were added to the algorithm of Burke et al. [4]:

- Employing the flexible acceptance condition as described above.
- When a move causes an infeasible solution, the algorithm uses Kempe chains to repair infeasibility. The advantages of this technique for exam timetabling are highlighted by Thomson and Dowsland in [12].
- In addition, we also follow suggestions that are derived from the work of Di Gaspero [10]. The normal procedure is to re-allocate a randomly chosen exam to a new (also randomly chosen) timeslot. However, in this approach, in approximately 20% of the cases, we instead perform just the swapping of all the exams in two randomly chosen timeslots. The flexibility for this second type of move was chosen to be 0.5 (after a series of experiments).

The software was written in Delphi 7 and run on a PC Pentium 4 3.2 MHz. Each run lasted 5-10 hours while performing up to 2×10^9 moves. In [4] it was stated that this time is quite acceptable for exam timetabling (because in real world situations exam timetables are produced months before they are required) and there is no reason to reduce the time taken at the expense of the quality of solution.

We present the results of our algorithm on the eleven most commonly studied problems from the Toronto benchmark set. The identifiers and characteristics of the problems are presented in Table 1. Also, this table contains the comparison of our best results with a range of published ones, including the first results of Carter et al. [7], the original Great Deluge results [4] and the most successful results from other author's work.

Table 1. Published and our best results on benchmark problems

Dataset	Exams	Periods	Carter et al. (1996)	Caramia et al. (2001)	Burke & Newall (2003)	Casey & Thompson (2003)	Abdullah et al. (2004)	Burke et al. (2004)	Flex-Deluge
Car-s-91	682	35	7.1	6.6	4.6	5.4	5.21	4.8	**4.42**
Car-f-92	543	32	6.2	6.0	4.0	4.4	4.36	4.2	**3.74**
Ear-f-83	190	24	36.4	**29.3**	37.05	34.8	34.87	35.4	32.76
Hec-s-92	81	18	10.8	**9.2**	11.54	10.8	10.28	10.8	10.15
Kfu-s-93	461	20	14.0	13.8	13.9	14.1	13.46	13.7	**12.96**
Lse-f-91	381	18	10.5	**9.6**	10.82	14.7	10.24	10.4	9.83
Sta-f-83	139	13	161.5	150.2	168.73	**134.7**	150.28	159.1	157.03
Tre-s-92	261	23	9.6	9.4	8.35	8.7	8.13	8.3	**7.75**
Uta-s-92	622	35	3.5	3.5	3.2	-	3.63	3.4	**3.06**
Ute-s-92	184	10	25.8	24.3	25.83	25.4	**24.21**	25.7	24.82
Yor-f-83	181	21	41.7	36.2	36.8	37.5	36.11	36.7	**34.84**

The results produced by our method support the strength of the suggested approach. Also, they suggest that the effectiveness of the method is relatively higher for the large-scale problems. This also holds for the original Great Deluge exam timetabling method (see [4]).

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