The Design and Implementation of an Interactive Course-Timetabling System

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We describe the design and implementation of a multi-objective course-timetabling system for the Science Division at Rollins College. In the traditional vertex-coloring approach to timetabling, all conflicts are regarded as equally undesirable, but when all such conflicts are considered, including those that might involve only one or two students, a conflict-free timetable is rarely attainable. A more realizable objective is to minimize total conflict severity, where conflicts are assigned different levels of severity. This is a more natural model for an actual timetabling problem, where the undesirability of assigning various pairs of courses to overlapping timeslots varies significantly. Our second objective is to create timetables that result in relatively compact schedules for the professors and students.

We report on our progress toward building a robust decision-support system for course timetabling whose strategies are based on a weighted-graph model that the second author has been developing since the early 1990's [Kiaer and Yellen (1992)]. Starting from the exam-timetabling system developed in [Carrington, Pham, et al (2007)] and [Burke, Pham, et al (2008)], there were several major changes and complications we had to confront in adapting the exam-timetabling system and its weighted-graph model to our course-timetabling system.

The primary objective (*hard constraint*) for the Toronto timetabling benchmark problems on which the exam-timetabling system was applied is to produce conflict-free schedules, and the secondary objective (*soft constraint*) is to minimize the number of students taking back-to-back exams, or, more generally, taking exams in close proximity [Carter, Laporte, et al (1996)]. Those objectives are in sharp contrast to those described above for our course-timetabling system. Moreover, for the Toronto problems, a conflict occurs only when one or more students are taking two exams at the same time. For our Rollins course-timetabling problem, two courses offered at the same time can conflict for several reasons of varying severity. The conflict that occurs when two courses are taught by the same professor or require the same room or equipment is clearly more severe than one that occurs when a few students want to take both courses. Moreover, there are several gradations of conflict severity between these two extremes.

Our weighted-graph model has several attributes that take into account gradations in conflict severity and desirability for compact schedules, as well as other complications such as room and timeslot suitability/availability and shared resources. The vertex- and color-selection heuristics that drive our construction are derived from the additional information that our model carries.

For the Toronto problems, the *n* timeslots are represented by the integers 1 through *n*, whereas, at Rollins, as with most actual course-timetabling problems, the timeslots usually consist of multiple days of the week, e.g., MWF 9-9:50, TTh 9:30-10:45, etc. This makes conflict and proximity considerations more complicated. In particular, different timeslots (colors) can still overlap, and the proximity between two timeslots is no longer a simple function based on the difference between the corresponding integers. Also, when a course is assigned a timeslot, there must be a suitable and available room for that timeslot. Room assignments are not considered in the Toronto problems.

Our system includes a graphical user interface (GUI) that enables the user to participate in the input, construction, and modification of a timetable. In the input phase, course incompatibility, instructor and student preferences, and desire for compact schedules all require subjective judgments. The GUI allows the user to quantify and convert this information to the weighted-graph model. In the construction and modification phase, the GUI enables the user to directly assign or reassign courses to timeslots while guided by heuristics.

Our recent work also includes the design and testing of continuous analogues of certain heuristics that were used in [Carrington, Pham, et al (2007)] and new combinations of other heuristics previously used, and we report on those results. In addition, our construction now includes a *backtracking* component driven by many of those same heuristics. For example, if, during the initial construction, a vertex is selected for which there is no satisfactory color assignment (according to some pre-defined threshold), then one or more vertices are selected for uncoloring to free up a satisfactory color for the given vertex. Having implemented these changes, we compare the timetables our system generates to the actual Rollins timetable that was manually created.

Finally, we discuss how our current system lends itself to incorporating a learning mechanism and feedback loop that uses characteristics of the solution generated to adjust various weighted-graph parameters. This could lead naturally to a hyper-heuristics approach (see, e.g., [Qu and Burke (2009)]).

References

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