A Novel Fuzzy Approach to Evaluate the Quality of Examination Timetabling

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Abstract. In this paper we introduce a new fuzzy evaluation function for examination timetabling. We describe how we employed fuzzy reasoning to evaluate the quality of a constructed timetable by considering two criteria: the average penalty per student and the highest penalty imposed on any of the students. A fuzzy system was created based on a series of easy to understand rules to combine the two criteria. A significant problem encountered was how to determine the lower and upper bounds of the decision criteria for any given problem instance, in order to allow the fuzzy system to be fixed and, hence, applicable to new problems without alteration. In this work, two different methods for determining boundary settings are proposed. Experimental results are presented and the implications analysed. These results demonstrate that fuzzy reasoning can be successfully applied to evaluate the quality of timetable solutions in which multiple decision criteria are involved.

1 Introduction

Timetabling refers to the process of allocating limited resources to a number of events subject to many constraints. Constraints are divided into two types: hard and soft. Hard constraints cannot be violated under any circumstances. Any timetable solution that satisfies all the specified hard constraints is considered to be a *feasible solution*, provided that all the events are assigned to a time slot. Soft constraints are highly desirable to satisfy, but it is acceptable to breach these types of constraint. However, it is very important to minimise the violation of the soft constraints, because, in many cases, the quality of the constructed timetable is evaluated by measuring the fulfillment of these constraints. In practice, the variety of constraints which are imposed by academic institutions are very different [6]. Such variations make the timetabling problem more challenging. Algorithms or approaches that have been successfully applied to one problem may not perform well when applied to different timetabling instances.

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Researchers have employed many different approaches over the years in an attempt to generate 'optimal' timetabling solutions subject to a list of constraints. Approaches such as Evolutionary Algorithms, e.g. [8, 16, 28], Tabu Search, e.g. [7, 17, 19, 29], Simulated Annealing, e.g. [27], Constraint Programming, e.g. [1, 4, 18], Case-Based Reasoning, e.g. [11, 30], and Fuzzy Methodologies, e.g. [2, 3, 23, 30] have been successfully applied to timetabling problems. Overviews of timetabling approaches are presented in [10, 12, 22, 24, 26].

In 1996, Carter et al. [13] introduced a set of examination timetabling benchmark data. The original benchmark data set consists of 13 problem instances. Since then certain difficulties have come to light with these benchmarks because different versions circulated under the same name (the situation is discussed and clarified in [24]. However, these benchmarks remain an important testbed. They consider the following constraints:

Hard constraint. The constructed timetable must be conflict free. The requirement is to avoid any student being scheduled for two different exams at the same time.

Soft constraint. The solution should attempt to minimise the number of exams assigned in adjacent time slots in such a way as to reduce the number of students sitting exams in close proximity.

In the context of these benchmark data sets, several different objective functions have been introduced in order to measure the quality of the timetable solution. In addition to the commonly used objective function that evaluates only the proximity cost (see next section for details), other objective functions have been derived based on the satisfaction of other soft constraints, such as minimising consecutive exams in one day or overnight, assigning large exams to early time slots, and others. This is discussed in more detail in the following section.

Previous studies such as [3] and [23], demonstrated that fuzzy reasoning is a promising technique that can be used both for modelling timetabling problems and for constructing solutions. These studies indicated that the utilisation of fuzzy methodologies in university timetabling is an encouraging research topic. In this paper, we introduce a new evaluation function that is based on fuzzy methodologies. The research presented in this paper will focus on evaluating the constructed timetable solutions by considering two decision criteria. Although the constructed timetable solutions were developed based on objectives specified earlier, the method is general in the sense that a user could, in principle, define additional criteria to be taken into account in evaluating any constructed timetables. This paper is motivated by the fact that, in practice, the quality of the timetable solution is usually assessed by a timetabling officer who considers several criteria/objectives.

In the next section, we present a brief description of existing evaluation methods, their drawbacks, and a detailed explanation of the proposed novel approach. Section 3 presents descriptions of the experiments carried out and the results obtained, followed by discussions in Section 4. Finally, some concluding comments and future research directions are given in Section 5.