A Neural Network Based Construction Heuristic

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Many techniques for solving the Examination Timetabling Problem have been studied over the years. One such successful method is Heuristic Ordering. Examinations are assigned sequentially to the timetable in a predefined order established on the basis of some characteristic of the individual events. Typically events are scheduled by decreasing order of difficulty. This construction heuristic may be used to build an initial solution, often acceptable in its own right, or improved upon by use of an improvement heuristic. Although this technique has proven useful, its success is often determined by the nature of the particular problem and its constraints.

This research proposes a modification to the heuristic ordering approach in which the ordering of events is continuously adapted as the timetable is constructed. As the algorithm progresses, a neural network is used to adapt the difficulty associated with each event based on the characteristics of that event and the current state of the timetable. Events are then reordered before the next event is placed in the timetable.

By constructing a system to work at a higher level of generality, adapting as a solution unfolds, a greater range of timetabling problems can be considered. The completed system will be tested using benchmark data sets and the quality of the resulting timetables measured using existing cost functions based on optimising on soft constraints.

Introduction

Examination timetabling is a frequently recurring problem in schools and universities. In general, the problem is concerned with scheduling a number of examinations into a limited number of time-periods, subject to a set of constraints. Constraints may be generalised into two categories, namely hard constraints, and soft constraints. Normally, all hard constraints must be completely satisfied for a timetable to be considered feasible, while soft constraints are conditions of desirability, which may be violated if necessary. The types of constraints vary extensively between institutions [2]; though many are universal, such as 'prevent any student being scheduled for two exams in the same period' (conflict) or 'ensure room capacity is not exceeded in any period'. It is highly desirable to construct timetables to enable students to have adequate study time, by dispersing their exams throughout the exam session. Soft constraints, such as this are often used as a measure of quality for the final timetable [3].

Over the years, many methods have been studied for solving the Examination Timetabling problem. These methods have roughly been classified into four groups [6, 8], namely; Sequential Methods (Heuristic Ordering), Cluster Methods, Constraint Based Methods, and Meta-heuristic techniques. This research concentrates on Heuristic Ordering. This early approach, popular since the 1960's [11], uses heuristics to measure the difficulty of scheduling each exam, assigning exams to the timetable sequentially, most difficult first. This well-established approach has proved very effective [9], and offers a firm foundation for further development. Historically, initial timetable construction relied on a single heuristic, ordering events based upon a single characteristic. Common heuristics used are orderings by: Largest Degree, Weighted Degree, Colour Degree, Saturation Degree, Exam

size, or Randomly. These orderings used to build the initial timetable are known as Construction Heuristics [4, 6]. Often initial timetables may be enhanced using a meta-heuristic. These improvement heuristics search the neighbourhoods of initial solutions for a final high quality timetable. Therefore it is highly desirable (but not strictly necessary [4]) that solutions produced from the construction heuristic are of high quality.

Recent research has successfully improved upon the initial timetable produced. Burke and Newall added a random component to the process [5] and later they used adaptive heuristics [4]. The initial order was determined by a single heuristic, but could be updated, based upon the experience of previous trials. Most recent research has diversified from the single heuristic approach. Burke [1] and later Petrovic [17] use a multi-objective approach to optimising the timetable based on a number of specified criteria.

The work reported here proposes that a neural network be developed as a new construction heuristic. Our motivation is to provide a level of generality that will allow application to many problem domains. Neural networks have been successfully applied to timetabling and other areas of research. In one of the earliest reported usage, Gianoglio investigated how to translate variables and constraints imposed by the problem of school timetabling into a neural network [12]. He further integrates the output from the neural network with an expert system to suggest the best solutions to specific instances of school timetables. Kovacic also applies different neural network configurations to the problem of school timetabling [13]. Subsequently Pellerin and Herault investigated the use of neural networks in helping the planning and management of complex multiple task projects [16]. Some researchers have concentrated on the application of parallel algorithms to scheduling problems on specific neural network architectures [7, 14, 18].

Due to their internal representation of experiential knowledge and automated pattern recognition abilities, neural networks offer an attractive and novel means of updating event difficulty, and therefore event order, as the heuristic ordering algorithm directs the construction of a timetable. Recent work by McCollum and Corr [10,15], albeit in a different application area, has illustrated the benefits of neural networks in choosing an event order tailored to the changing nature of the underlying problem as the events are sequentially applied. Their technique has been used to choose the order in which transformations (events) should be applied to a piece of sequential code in order to modify the code making it amenable to parallel execution. On application of a chosen transformation the code is modified, thereby changing the nature of the underlying problem. The neural network, a Kohonen Network, taking characteristics of the problem (code) as input is used to choose which transformation should next be applied in order to move the code closer towards a satisfactory solution.

In choosing the order in which events should be scheduled in a timetable we propose an analogous approach to that outlined above. For each event, characteristics which affect the difficulty of scheduling that event are input to the neural network, as well as the current state of the timetable during the construction process. Example characteristics are Degree, Weighted Degree, Class-Size, and Specialised Constraints (with specific restrictions on rooms, periods, or event orderings). The Specialised Constraints are classified into two groups; Static Constraints (which remain constant as the timetable is constructed, e.g. Room and Period Allocations) and Dynamic Constraints (which change as the solution is developed, e.g. Scheduling events in a sequential order in the timetable).
When events affected by Dynamic Constraints are placed in the timetable, constraints on some other events must change immediately. Consequentially the scheduling difficulty of these particular events increase, and this is reflected by re-ordering before further scheduling is attempted. This iterative approach allows the algorithm to adapt as the timetable unfolds and offers a level of generality that will enable us to apply the same techniques across a range of scheduling problems

with different constraints and idiosyncrasies. When the scheduling of all events has been attempted, the quality of the final timetable is measured, based on constraint satisfaction.

The structure and training of the neural network will be crucial to the success of this technique. We have begun with a Kohonen Self Organising Neural Network, applied to the University of Nottingham 1994 data set. This complex data set contains many of the fore-mentioned specialised constraints, ideal for neural network application. The generalised approach of using a self organising neural network reduces the reliance of a training component, typical of supervised neural networks. This approach will allow us to investigate the effectiveness of our technique as a component in a generic scheduler and the extent to which the same system can deal with data from a number of institutions. Initial results using this method are encouraging. We will provide further details of our approach and present further initial findings at the conference.

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