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].

Heuristic Ordering

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.

Neural Networks

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 thereby modifying the code and making it amenable to parallel execution. On application of a chosen transformation the code is modified; in so doing the nature of the underlying problem is changed. The neural 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.

A New Construction Heuristic

In choosing the order in which events should be scheduled in a timetable we propose an analogous approach to that outlined above. The neural network will take characteristics of an event and information about the quality of the current solution as input and produce a modified difficulty rating for each event. Events are then reordered and one chosen to be placed in the timetable. When placed, the quality of the solution, as measure by the extent to which soft constraints are satisfied, is modified. This quality measure is fed back to the network. The characteristics of each event including its current difficulty value, degree of conflict, ordering constraints, etc are input in turn to the network and a new difficulty rating determined for each event. 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.

The structure and training of the neural network will be crucial to the success of this technique. We have begun with a multilayer perceptron structure trained on data gathered from expert timetablers scheduling events from a particular data set. This approach will result in a system tailored to the particular environment that produced the data on which the network was trained, typically a particular institution, and as such has limited application. In order to generalise our approach we intend to investigate the use of a self-organising architecture as a means of removing the reliance on a training component. 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. We will provide further details of our approach and present initial findings at the conference.

References

[1] E.K.Burke, Y.Bykov, S.Petrovic
A Multicriteria Approach to Examination Timetabling
The Practice and Theory of Automated Timetabling: Selected Papers from the third International Conference, Lecture Notes in Computer Science 2079 p118-131. Springer-Verlag, Berlin, 2001.

[2] E.K.Burke, D.G Elliman, P.Ford, R.F.Weare
Examination Timetabling in British Universities: A survey
The Practice and Theory of Automated Timetabling: Selected Papers from the first International Conference, Lecture Notes in Computer Science 1153 p76-90. Springer-Verlag, Berlin, 1996.

[3] E.K.Burke, J.P.Newall
A multi-stage evolutionary algorithm for the timetable problem
IEEE Transactions on Evolutionary Computation.3(1) p63-74, 1999

[4] E.K.Burke, J.P.Newall
Solving Examination Timetabling Problems through the Adaption of Heuristic Orderings
Accepted for publication in Annals of Operational Research 2003/2004

[5] E.K.Burke, J.P.Newall, R.F.Weare
A simple heuristically guided search for the timetable problem
In *International ICSC Symposium on Engineering of Intelligent Systems (EIS'98) p574-579 ICSC Academic Press, Canada/Switzerland, 1998.*

[6] E.K.Burke, S.Petrovic
Recent research directions in automated timetabling
European Journal of Operational Research 140 p266-280 (2002)

[7] M.Carrasco, M.Pato
A Potts Neural Network Heuristic for the Class/Teacher Timetabling problem
Proceedings of the Fourth Metaheuristics International Conference. Porto, Portugal, July, 2001

[8] M.W.Carter, G.Leporte
Recent developments in practical examination timetabling
The Practice and Theory of Automated Timetabling: Selected Papers from the first International Conference, Lecture Notes in Computer Science 1153 p3-21. Springer-Verlag, Berlin, 1996.

[9] M.W.Carter, G.Leporte, and J.W.Chinneck
A general examination scheduling system
Interfaces 11, p109-120,1994

[10] P.Corr, P.Milligan, and V.Purnell
A neural network based tool for semi automatic code transformation

In VECPAR 2000. Selected papers and invited talks from the fourth international conference on vector and parallel processing 2000, Porto, Portugal. Lecture Notes in Computer Science v1981, p142-153, 2000

[11] E.Foxley and K.Lockyer
The construction of examination timetables by computer
The computer journal 11 p264-268, 1968

[12] P.Gianoglio
Application of neural networks to timetable construction
Proceedings if the 3rd international workshop on neural networks and their applications. Nimes, France p53-67 1990

[13] M.Kovacic
Timetable construction with a Markovian neural network
European Journal of Operational Research, Volume 69, No. 1, pages 92-96, 1993

[14] J.H.Lim, K.F.Loe
Timetable scheduling using neural networks with parallel implementation on transputers
Proceedings of the IEEE International Joint Conference on Neural Networks, Vol 1, p122-127, 1991

[15] B.McCollum, P.H.Corr, P.Milligan
A Meta-heuristic Approach to Parallel Code Generation
In VECPAR 2002. Selected papers and invited talks from the fifth International Conference on *vector and parallel processing 2002, Porto, Portugal. Lecture Notes in Computer Science v2565, p693-702, 2003.*

[16] D.Pellerin, J.Herault
Scheduling with neural networks: application to timetable construction
Neurocomputing, Volume 6, No. 4, p419-442, 1994

[17] S. Petrovic, Y.Bykov
A Multiobjective Optimisation Technique for Exam Timetabling Based on Trajectories
The Practice and Theory of Automated Timetabling: Selected Papers from the fourth International Conference, Lecture Notes in Computer Science 2740 p181-194. Springer-Verlag, Berlin, 2003

[18] K, Tsuchiya, Y.Takefuji
A neural network parallel algorithm for meeting scheduling problems
Applied Intelligence, Volume 7 No. 3, pp 205-213, 1997