University Timetabling Problems

Contents

1. Statement of Timetabling Problems
2. Approaches to Timetabling Problems
3. Some Innovations in Meta-Heuristic Methods for Timetabling

1

Literature

1. "Recent Research Directions in Automated Timetabling", Burke, E.K., Petrovic,S., accepted for publication in *European Journal of Operational Research - EJOR*, 2002.

2. "A Memetic Algorithm for University Exam Timetabling", Burke, E.K., Newall, J.P., Weare, R.F., 1996b. In: (Eds.) Burke, E., Ross, P. The Practice and Theory of Automated Timetabling: Selected Papers from the 1st Int'l Conf. on the Practice and Theory of Automated Timetabling, Napier University, August/September 1995, *Springer Lecture Notes in Computer Science Series*, Vol. 1153., pp. 241-250.

2

Highly recommended additional reading:

"A Survey of Practical Applications of Examination Timetabling Algorithms", Carter, M.W., *Operations Research* Vol.34, 1986, pages 193-202.

"A Multi-Stage Evolutionary Algorithm for the Timetable Problem, Burke, E.K., Newall, J.P., *IEEE Transactions on Evolutionary Computation* Vol.3 No.1, 1999, pages 63-74.

"Automated University Timetabling: The State of the Art", Burke, E., Kingston, J., Jackson, K., Weare, R., *The Computer Journal* Vol.40 No9, 1997, pages 565-571.

"Examination Timetabling: Algorithmic Strategies and Applications", Carter M.W., Laporte G., Lee, S.Y., *Journal of Operational Research Society* Vol. 74, 1996, pages 373-383

3

Statement of Timetabling Problems

Timetabling problem: assign a number of events into a limited number of time periods.

- **Course timetabling**
  Assign each lecture to some period of the week in such a way that no student is required to take more than one lecture at a time
- **Examination timetabling**
  Assign a number of exams into a limited number of time slots in such a way that no student is required to take more than one exam at a time

Graph representation
Vertices: courses / exams
Edges: if two courses/exams have at least one student in common

Hard constraints:

- no resource can be demanded to be in more than one place at any time
- the total resources at any time must not exceed the resources available

Soft constraints:

- time assignment
- time constraints between events
- spreading events out in time
- coherence
- resource assignment

5

Approaches to Timetabling problems

1. Sequential Methods

Graph Colouring Heuristics

- Largest degree first orders the events by their number of conflicts with other events.
- Largest weighted degree weights each conflict by the number of students involved in the conflict.
- Saturation degree selects an event which has the smallest number of valid periods available for scheduling.
- Colour degree prioritises those events that have the largest number of conflicts with the events that have already been scheduled.

6

How to select a valid period for each event?
- earliest valid period
- "best" valid period in the context of objective funstions

Example of a cost function for an exam timetabling:

cost(t) = 5000**unscheduled(t)* + 3 * *sameDay(t)* + *overNight(t)*

unscheduled(t)	holds the number of exams not scheduled in a valid period
sameDay(t)	present the number of conflicts where students have exams in adjacent periods on the same day
overNight(t)	present the number of conflicts where students have exams in overnight adjacent periods

7

☛ How to add random element in the search?

- Tournament selection
  1. Generates a subset of events randomly
  2. Selects the event that is ranked the first with respect to the heuristics.
- Bias selection
  An event is randomly selected from the list of the first *n* events.

8

2. Cluster Methods
1. The set of events is split into groups which satisfy hard constraints.
2. The groups are assigned to time periods to fulfil the soft constraints.

3. Constraint Based Approaches
A timetabling problem is modelled as a set of variables (i.e. events) to which values (i.e. resources such as rooms and time periods) have to be assigned to satisfy a number of constraints.

4. Meta-Heuristic Methods
Simulated annealing, Tabu search, Genetic algorithms

5. Multicriteria Approach
Criteria express the measures of the violations of the soft constraints.

6. Case-Based Reasoning in Timetabling
The previously solved timetabling problems are used in solving new timetabling problems.

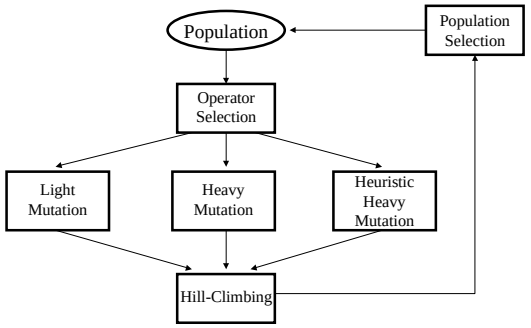
9

Some Innovations in Meta-Heuristic Methods for Timetabling

Genetic algorithm + Local search + Heuristics

Memetic algorithm

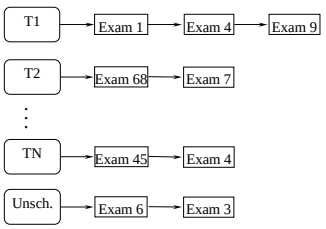
10



11

Representation of the solution

Member of the population



12

Evaluation function

cost(t) = 5000**unscheduled(t)* + 3 * *sameDay(t)* + *overNight(t)*

unscheduled(t) holds the number of exams not scheduled in a valid period

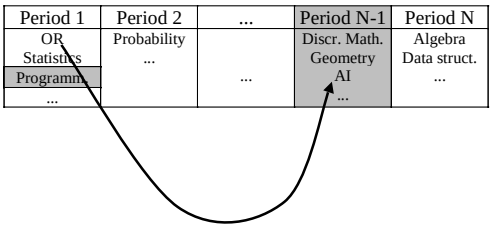
sameDay(t) presents the number of conflicts where students have exams in adjacent periods on the same day and, respectively.

overNight(t) presents the number of conflicts where students have exams in overnight adjacent periods

13

Evolutionary Operators

- Light mutation operator



14

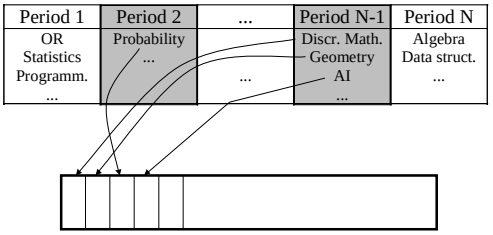
- Heavy mutation operator

Period 1	Period 2	...	Period N-1	Period N
OR Statistics Programm. ...	Probability ...	...	Discr. Math. Geometry AI ...	Algebra Data struct ...

rescheduling of time periods

15

- Heuristic Heavy Mutation



heuristic rescheduling of events

16

Hill-climbing

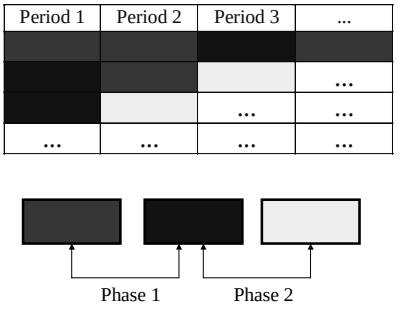
- Direct the search toward the local optima.
- The hill-climbing operator takes exams sequentially from periods that are randomly ordered, and reschedules them in valid periods that cause the least penalties.

Selection phase

- Members of the population are ordered by the values of their evaluation functions.
- According to a certain probability it is decided whether to leave the solution for the next generation or not.

17

Decomposition



18

Heuristic Initialisation

- Gives initial solutions of higher quality than randomly generated initial solutions.
- Diversity is desirable in evolutionary algorithms.
- Measures of diversity of the initial solutions are defined.

19

Summary

- Various operators that utilise heuristics are used to improve and accelerate the search process within the evolutionary method.
- Algorithms for timetabling might be more efficient if they consider subsets of events, rather then the whole set of events.
- Employment of heuristic initialisation strategies can provide significant benefits in terms of the quality and diversity of the members of the population.

20