Benders’ Decomposition for Curriculum-Based Course Timetabling
In this paper we applied Benders’ decomposition to the Curriculum-Based Course Timetabling (CBCT) problem. The objective of the CBCT problem is to assign a set of lectures to time slots and rooms. Our approach was based on segmenting the problem into time scheduling and room allocation problems. The Benders’ algorithm was then employed to generate cuts that connected the time schedule and room allocation. We generated only feasibility cuts, meaning that most of the solutions we obtained from a mixed integer programming solver were infeasible, therefore, we also provided a heuristic in order to regain feasibility.

We compared our algorithm with other approaches from the literature for a total of 32 data instances. We obtained a lower bound on 23 of the instances, which were at least as good as the lower bounds obtained by the state-of-the-art, and on eight of these, our lower bounds were higher. On two of the instances, our lower bound was an improvement of the currently best-known. Lastly, we compared our decomposition to the model without the decomposition on an additional six instances, which are much larger than the other 32. To our knowledge, this was the first time that lower bounds were calculated for these six instances.

General information
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Organisations: Department of Management Engineering, Management Science, Operations Research, Department of Applied Mathematics and Computer Science, MaCom A/S
Authors: Bagger, N. F. (Intern), Sørensen, M. (Ekstern), Stidsen, T. R. (Intern)
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Flow Formulations for Curriculum-based Course Timetabling

In this paper we present two mixed-integer programming formulations for the Curriculum based Course Timetabling Problem (CTT). We show that the formulations contain underlying network structures by dividing the CTT into two separate models and then connect the two models using flow formulation techniques. The first mixed-integer programming formulation is based on an underlying minimum cost flow problem, which decreases the number of integer variables significantly and improves the performance compared to an intuitive mixed-integer programming formulation. The second formulation is based on a multi-commodity flow problem which in general is NP-hard, however, we prove that it suffices to solve the linear programming relaxation of the model. The formulations show competitiveness with other approaches based on mixed-integer programming from the literature and improve the currently best known lower bound on one data instance in the benchmark data set from the second international timetabling competition. Regarding upper bounds, the formulation based on the minimum cost flow problem performs better on average than other mixed integer programming approaches for the CTT.

General information
State: Published
Organisations: Department of Management Engineering, Management Science, Operations Research, MaCom A/S, RHA Software Group
Authors: Bagger, N. F. (Intern), Kristiansen, S. (Ekstern), Sørensen, M. (Ekstern), Stidsen, T. J. R. (Intern)
Every semester universities are faced with the challenge of creating timetables for the courses. Creating these timetables is an important task to ensure that students can attend the courses they need for their education. Creating timetables that are feasible can be challenging, and when different preferences are taken into account, the problems become even more challenging. Therefore, automating the processes of generating these timetables is a great help for the planners and the universities. Scheduling and timetabling has been studied before in the literature, and two international conferences are dedicated to this research field. This thesis considers a University Timetabling problem, more specifically the Curriculumbased Course Timetabling (CTT) problem. The objective of the CTT problem is to assign a set of lectures to time slots and rooms. The literature has focused mainly on heuristic applications which are also apparent in the different surveys. The drawback of the heuristics is that they are problem specific and do not provide any information on the quality of the solutions they generate. The objective of this thesis is to minimize the gap between the best-known upper bounds and the best-known lower bounds for CTT by using Mixed Integer Programming (MIP) based approaches. We present a total of 15 different MIP based approaches that we have implemented, ranging from Cutting Plane techniques and Lagrangian Relaxation to Benders’ Decomposition and Dantzig-Wolfe Decomposition. Most of these implementations did not provide satisfying results. However, they provide valuable insights into the difficulties of the problem. We discuss all the approaches, the difficulties we have encountered, and suggestions on how to bring research further. Four of the implementations have led to articles submitted to international peer-reviewed journals. The first two articles focus on exact methods and extend each other. The last two focus on generating high-quality lower bounds by applying an extended formulation, which is then decomposed. The articles in this thesis have brought us closer to the goal of closing the gap between the best-known upper and lower bounds for CTT. Though CTT was the problem in focus, the methods implemented here are general enough to be applied for other scheduling problems as well.

Flow Formulation-based Model for the Curriculum-based Course Timetabling Problem
In this work we will present a new mixed integer programming formulation for the curriculum-based course timetabling problem. We show that the model contains an underlying network model by dividing the problem into two models and then connecting the two models back into one model using a maximum ow problem. This decreases the number of integer variables signicantly and improves the performance compared to the basic formulation. It also shows competitiveness with other approaches based on mixed integer programming from the literature and improves the currently best known lower bound on one data instance in the benchmark data set from the second international timetabling competition.
Room Allocation Optimisation at the Technical University of Denmark

As at many other universities the Technical University of Denmark (DTU) faces the challenge of solving a case of the curriculum based university course timetabling problem (CUCTT) multiple times a year. However, there are some slight modifications to the CUCTT problem usually described in the literature. One of the major differences is that the assignment of the courses to specific time slots are predetermined and cannot be subject to changes. This is a decision made by the administration, since this takes away the issue of course collisions, e.g. when two courses sharing a student are allocated at overlapping time slots, since the students are to ensure by themselves that their courses do not overlap. The problem was first considered in the masters' thesis [1] and the project here is an extension of the work done in that thesis.

General information
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Organisations: Department of Management Engineering, Management Science
Authors: Bagger, N. F. (Intern), Larsen, J. (Intern), Stidsen, T. R. (Intern)
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Projects:

Manpower Planning at Danish Hospitals
Department of Management Engineering
Management Science
Operations Research
Region Sjælland, Produktion, Forskning og Innovation (PFI)
Period: 01/02/2017 → 31/12/2017
Number of participants: 1
Nurse Rostering, Integer Programming, Scheduling
Project participant:
Bagger, Niels-Christian Fink (Intern)

Mathematical Programming Approaches for Optimal University Timetabling
Department of Management Engineering
Period: 01/02/2014 → 18/05/2017
Number of participants: 7
Phd Student:
Bagger, Niels-Christian Fink (Intern)
Supervisor:
Sørensen, Matias (Intern)
Sørensen, Michael Malmros (Ekstern)
Main Supervisor:
Stidsen, Thomas Jacob Riis (Intern)
Examiner:
Pisinger, David (Intern)
Berghe, Greet Vanden (Ekstern)
Cacchiani, Valentina (Ekstern)

Financing sources
Source: Internal funding (public)
Name of research programme: Industrial PhD

Relations
Publications:
Mathematical Programming Approaches for Optimal University Timetabling
Project: PhD

Activities:

Applied nurse rostering at Danish hospitals in Region Zealand
Period: 15 Dec 2017
Niels-Christian Fink Bagger (Guest lecturer)
Department of Management Engineering
Management Science
Operations Research

Related event
Healthcare logistics: balancing between practice and theory*
13/12/2017 → 15/12/2017
Activity: Talks and presentations › Conference presentations

Daily Pattern Formulation and Valid Inequalities for the Curriculum-based Course Timetabling Problem
Period: 2016
Niels-Christian Fink Bagger (Guest lecturer)
Guy Desaulniers (Guest lecturer)
Jacques Desrosiers (Guest lecturer)
Department of Management Engineering
Management Science
Operations Research

Related event

11th International Conference on the Practice and Theory of Automated Timetabling
23/08/2016 → 26/08/2016
Italy
Activity: Talks and presentations › Conference presentations

Flow Formulation-based Model for the Curriculum-based Course Timetabling Problem
Period: 2015
Niels-Christian Fink Bagger (Guest lecturer)
Thomas Jacob Riis Stidsen (Guest lecturer)
Matias Sørensen (Guest lecturer)
Simon Kristiansen (Guest lecturer)
Department of Management Engineering
Management Science
Operations Research

Related event

7th Multidisciplinary International Conference on Scheduling: Theory and Applications
25/08/2015 → 28/08/2015
Prague, Czech Republic
Activity: Talks and presentations › Conference presentations

Danish Operations Research Society (DORS) (External organisation)
Period: Jun 2015 → …
Niels-Christian Fink Bagger (Secretary)
Department of Management Engineering
Management Science

Related external organisation

Danish Operations Research Society (DORS)
Activity: Membership › Membership of committees, commissions, boards, councils, associations, organisations, or similar

Université de Montreal
Period: 1 Mar 2015 → 12 Jul 2015
Niels-Christian Fink Bagger (Visiting researcher)
Department of Management Engineering
Management Science

Description

Study Abroad at École Polytechnique

Groupe d’Études et de Recherche en Analyse des Décisions, École Polytechnique, Université de Montréal
Activity: Visiting an external institution › Visiting another research institution

Discrete optimization support system for the collection grid in large offshore wind parks
Period: 2012
Niels-Christian Fink Bagger (Guest lecturer)
Michael Lindahl (Guest lecturer)
Department of Management Engineering
Management Science
Operations Research

Related event

5th Nordic Optimization Symposium
07/06/2012 → 09/12/2012
Trondheim, Norway
Activity: Talks and presentations › Conference presentations

Prizes:

Best Student Thesis 2013
Niels-Christian Fink Bagger (Recipient)
Department of Management Engineering, Management Science, Operations Research

Details
Awarded date: 2013
Degree of recognition: National
Granting Organisations: DONG Energy A/S
Prize: Prizes, scholarships, distinctions

Best Thesis in Operations Research 2013
Niels-Christian Fink Bagger (Recipient)
Department of Management Engineering, Management Science, Operations Research

Details
Awarded date: 29 Apr 2013
Degree of recognition: National
Granting Organisations: Danish Operations Research Society (DORS)
event: DORS - General Assembly
Prize: Prizes, scholarships, distinctions