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Fairness in Academic Course Timetabling

 Springer

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Abstract

Creating timetables is a complex and recurring task at a university. In this thesis, we will deal with formal problems related to course timetabling, issues concerning the formalization, and solution approaches.

First, we study the University Course Timetabling Problem (UCTP), a very general formalization of the course timetabling task in terms of a search problem. The task is to find a feasible timetable, i.e., an assignment of lectures to rooms and timeslots such that no room is occupied by two lectures at the same time and no two lectures are taught simultaneously if they are attended by the same students. This problem captures the essence of various more specific course timetabling problems. We investigate the structure of the UCTP search space and establish sufficient conditions for the connectedness of clash-free timetables under the Kempe-exchange operation. Furthermore, we propose and evaluate the Kempe Insertion Heuristic (KIH), a heuristic algorithm for solving the UCTP.

Second, we consider fairness aspects of course timetabling with a particular focus on how fairness can be formalized and measured. We introduce fairness objectives based on Jain's fairness index and max-min fairness to a popular benchmarking problem model. We show that a problem decomposition which isolates room and timeslot assignment has similar computational properties to an analogous decomposition of the standard benchmarking problem. Additionally, we present several approaches to measuring fairness differences, and we propose and evaluate heuristic approaches to solving the benchmarking problems with fairness objectives.

Finally, we present a comprehensive case study on our implementation of a course timetabling system at the Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU) school of engineering. The system has been used in practice since 2011. We report on our problem model the organization of the course timetabling process, as well as the reception by students and lecturers.

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List of Symbols

| | |
|---------------|-------------------------------------|
| \preceq | Max–min fairness relation |
| \prec | Strict max–min fairness relation |
| \preceq_P | Weak Pareto dominance relation |
| \prec_P | Strict Pareto dominance relation |
| α | Resource availability function |
| β | Period preference function |
| γ | Room preference function |
| δ | Minimum vertex degree of a graph |
| Δ | Maximum vertex degree of a graph |
| κ | Kempe-exchange |
| \mathbb{N} | Natural numbers |
| ρ | Assignment of events to rooms |
| σ | Vertex ordering |
| τ | Timetable |
| φ | Boolean formula |
| χ | Chromatic number of a graph |
| C | Set of classes |
| \mathcal{A} | Variables of a boolean formula |
| C | Set of courses |
| L | Course conflicts |
| F | Room conflicts |
| deg | Degeneracy of a graph |
| diam | Diameter of a graph |
| d | Degree of a vertex |
| \mathcal{D} | Problem domain |
| E | Set of events |
| girth | Girth of a graph |
| h | Period restriction number |
| \mathcal{I} | Instance of a combinatorial problem |
| NP | Complexity class NPTIME |

| | |
|----------|--------------------------------------|
| N | Neighborhood of a vertex |
| $PSPACE$ | Complexity class $PSPACE$ |
| P | The complexity class $PTIME$ |
| P | A set of timeslots |
| R | Set of rooms |
| S | Set of solutions |
| size | Size of a CNF formula |
| T | Set of teachers |
| U | Set of curricula |
| var | Number of variables in a CNF formula |
| wp | Welsh-Powell number of a graph |

Acronyms

| | |
|------------|---|
| ACO | Ant Colony Optimization |
| ACP | Algorithm Configuration Problem |
| AMOSa | Archived Multi-Objective Simulated Annealing |
| BACP | Balanced Academic Curriculum Problem |
| BFS | Breadth-first Search |
| BSSP | Basic Student Sectioning Problem |
| CB-CTT | Curriculum-based Course Timetabling |
| CNF | Conjunctive Normal Form |
| DPLL | Davis–Putnam–Logemann–Loveland |
| EA | Evolutionary Algorithm |
| EIP | Event Insertion Problem |
| ETP | Examination Timetabling Problem |
| ETT | Examination Timetabling |
| FAU | Friedrich-Alexander-Universität Erlangen-Nürnberg |
| GA | Genetic Algorithms |
| GBACP | Generalized Balanced Academic Curriculum Problem |
| GD | Great Deluge |
| GGA | Grouping Genetic Algorithm |
| GLBOP | Generalized Lexicographic Bottleneck Optimization Problem |
| HC | Hill Climbing |
| HGHH | Hybrid Graph-based Hyper Heuristic |
| ILP | Integer Linear Programming |
| ILS | Iterated Local Search |
| ITC2007 | International Timetabling Competition 2007 |
| JFI-CB-CTT | Jain’s Fairness Index Curriculum-based Course Timetabling |
| KIH | Kempe Insertion Heuristic |
| KX | Kempe-exchange Neighborhood |
| LBAP | Lexicographic Bottleneck Assignment Problem |
| LBFS | Lexicographic Breadth-first Search |
| LBOP | Lexicographic Bottleneck Optimization Problem |
| LCD | Largest Color Degree |

| | |
|------------|--|
| LD | Largest Degree |
| LSAP | Linear Sum Assignment Problem |
| LSD | Least Saturation Degree |
| LS | Local Search |
| SLS | Stochastic Local Search |
| LVOP | Lexicographic Vector Optimization Problem |
| LWD | Largest Weighted Degree |
| ME | Move Event Neighborhood |
| MMF-CB-CTT | Max–min Fair Curriculum-based Course Timetabling |
| NOLH | Nearly Orthogonal Latin Hypercubes |
| PE-CTT | Post-enrollment Course Timetabling |
| PKC | Pair-wise Kempe Chain |
| PSO | Particle Swarm Optimization |
| RO | Random Ordering |
| SA | Simulated Annealing |
| SAT | Boolean satisfiability |
| SE | Swap Event Neighborhood |
| SOP | Min-sum Optimization Problem |
| SO | Saturation Ordering |
| SSP | Student Sectioning Problem |
| STP | School Timetabling Problem |
| TF-CB-CTT | TechFak Curriculum-based Course Timetabling |
| TS | Tabu Search |
| uar | uniformly at random |
| UCTP | University Course Timetabling Problem |
| VNS | Variable Neighborhood Search |
| WEO | Weak Elimination Ordering |
| WMW | Wilcoxon-Mann-Whitney |