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Fairness in Academic Course Timetabling

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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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Contents

List of Symbols

$\preceq$	Max–min fairness relation
$\prec$	Strict max–min fairness relation
$\preceq_{\mathrm{P}}$	Weak Pareto dominance relation
$\prec_{\mathrm{P}}$	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
$\mathcal{S}$	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