The space of phylogenetic trees consists of all weighted trees with a fixed set of labeled leaves. It was introduced as a metric space by Billera, Holmes and Vogtmann (BHV) in 2001 and has some interesting properties. This space is investigated because of its applications in biology: The task is to determine a 'center point' for a given set of trees in this space. Those trees are, e.g., derived by samplings of different genes of humans and ape species. Each gene sampling results in a tree proposing a possible evolutionary tree for those species, where the tree may vary for different genes. The goal is to find one tree which represents the set of sampled gene trees.

We model the problem as a location problem: The sampled gene trees are the existing facilities and we search a new facility (the evolutionary tree) which is as close as possible to them. The challenge of the location problems is the complexity of the space, which consists of an exponential amount of different tree structures amongst other tricky features.

In the talk the BHV - tree space will be introduced, followed by some approaches to location theory within it. Those are either to work in a low dimension or to assume some structure on the existing facilities. Afterwards, first results for these location problems are presented. Thereby the methodology is shown, using existing knowledge of problems by carrying over some specifics of the tree space to a well-known environment.

2 - Application of tropical optimization techniques to the solution of location problems
Nikolai Krivulin

We consider minimax single-facility location problems in multidimensional spaces with Chebyshev and rectilinear distances. Both unconstrained problems and problems with constraints imposed on the feasible location area are under examination. We start with the description of the location problems in a standard form, and then represent them in the framework of tropical (idempotent) algebra as constrained tropical optimization problems. These problems involve the minimization of non-linear objective functions defined on vectors over an idempotent semifield, subject to vector inequality and equality constraints. We apply methods and results of tropical optimization to obtain direct, explicit solutions to the problems. To solve the problem, we introduce a variable to represent the minimum value of the objective function, and then reduce the optimization problem to an inequality with the new variable in the role of a parameter. The existence conditions for the solution of the inequality serve to evaluate the parameter, whereas the solutions of the inequality are taken as a complete solution to the problem. We use the results obtained to derive solutions of the location problems of interest in a closed form, which is ready for immediate computation. Extensions of the approach to solve other problems, including minimax multi-facility location problems, are discussed. Numerical solutions of example problems are given, and graphical illustrations are presented.

3 - A comparison of algorithms for solving the capacitated facility location problem with convex production costs
Andreas Klose

We consider the capacitated facility location problem with differentiable convex production cost functions. The problem arises in numerous real-world applications as queues in call-centres, server queueing or when production is pushed beyond normal capacity limits. For finding proven optimal solutions, we suggest a branch-and-bound method based on Lagrangian relaxation and subgradient optimization. This method is compared on a large number of test instances to three other exact solution methods: A cutting plane approach that uses supporting hyperplanes of the convex cost functions for generating lazy constraints as well as fractional cuts; in case of quadratic cost functions, the use of a commercial solver for quadratically constrained MIPs based on a perspective formulation of the problem as suggested in the literature; and, finally, a Benders decomposition approach.

■ MB-21

Monday, 10:30-12:00 - Building CW, ground floor, Room 025

Robustness in public transport

Stream: Public Transportation
Chair: *Pieter Vansteenwegen*

1 - Integrating robust timetabling in railway line planning
Sofie Burggraeve, Simon Bull, Richard Lusby, Pieter Vansteenwegen

We propose an algorithm to build from scratch a railway line plan that minimizes passenger travel time and operator cost and for which a feasible and robust timetable exists. A line planning module and a timetabling module work iteratively and interactively. The line planning module creates an initial line plan. The timetabling module evaluates the line plan and identifies a critical line based on minimum buffer times between train pairs. The line planning module proposes a new line plan in which the time length of the critical line is modified in order to provide more flexibility in the schedule. This flexibility is used to improve the robustness of the railway system. The algorithm is validated on a high frequency railway system with little shunt capacity. While the operator and passenger cost remain close to the initially built line plan, the timetable corresponding to the final line plan has the potential to significantly improve the minimal buffer time, and thus the robustness, in 8 out of 10 studied cases.

2 - Robust control strategy for minimising energy consumption of electric buses using cooperative ITS technology
Giulio Giorgione, Francesco Viti, Marcin Seredynski

The introduction of high capacity electric buses to public transport substantially reduces transportation externalities. One of the main drawbacks of electric buses is the limited range. It can be extended thanks to on-route opportunity charging. We propose a complementary approach based on Driving Assistance Systems (DASs). Specifically, we combine Green Light Optimal Speed Advisory (GLOSA) and Green Light Optimal Dwell Time Advisory (GLODTA) to reduce energy consumption of an electric bus. The former optimises the velocity of the bus, while the latter optimises battery-charging time at a bus stop so that the use of charging infrastructure is optimised without affecting service level of the bus. The proposed algorithm is robust to changes of traffic signal settings and the PT traffic thanks to continuous access to Signal Phase and Timing (SPaT) from signal controllers as well as to information about charging requests from other buses, the algorithm adapts its approach to the difficulty of the underlying optimisation problem. We also identify the best positions to place recharging stations. The heuristic rules developed in this study are applied to a Bus Rapid Transit (BRT) system. We assume that bus dwell times at bus stops as well as traffic signal timings are known by our system. Provided example shows how adopting speed and dwell time strategies help achieving efficient BRT operations, i.e., energy consumption is reduced and scheduling constraints are satisfied.

3 - An efficient heuristic for real-time train rescheduling and local rerouting
Sofie Van Thielen, Francesco Corman, Pieter Vansteenwegen

In practice, unexpected events frequently cause delays, often leading to conflicts, since multiple trains simultaneously require the same infrastructure. Currently, such conflicts are manually resolved by dispatchers, although it is impossible for them to anticipate the impact of their actions on the entire network. Conflict detection and resolution tools can help dispatchers make informed decisions. This research introduces a new heuristic that uses rescheduling and rerouting in station areas and is innovative due to strong similarities with real-life situations. The algorithm for rescheduling is based on limiting the total delay caused by conflicts, through analyzing the predicted progress over the following hour. If the conflict arises in a station area, an optimization procedure checks first whether rerouting leads to a solution with (almost) no delays. Because some trains have a needless amount of