Development of a Genetic Algorithm for Personal Rapid Transit Network Design under Demand Uncertainty

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Summary

The global urban population is steadily growing, making efficient and sustainable urban transportation critical for striving economic activity and quality of life. A potential solution to these challenges is Personal Rapid Transit (PRT), an autonomous on-demand transit system. This network comprises small, autonomous vehicles operating on a dedicated infrastructure and offering on-demand transport between stations, combining elements of both individual and public transport.

Before such a PRT system can be realized, a holistic model showcasing the benefits of this transport mode is required. Such a model must encompass all aspects that are relevant to the real world construction and operation of a PRT network. It must consider the layout and construction process of the infrastructure, the operation strategy of the network and the dynamic effects on demand within a multimodal transit environment. The goal of this thesis is to answer how to optimally design PRT network infrastructure, including guideways, intersections, and stations, based on a given location and expected demand.

Existing PRT network design approaches have limitations, such as oversimplifications and lack of scalability for larger networks. In the course of this work, a mathematical model that allows macroscopic simulation of station locations, passenger demand, travel time, and even considering empty vehicle flows is developed. In order to determine the optimal topology and sizing of the guideways, a multivariate genetic algorithm (NSGA-II) is employed, as it allows to consider competing objectives of different stakeholders.

The resulting pipeline's aptitude is validated through a sensitivity analysis, including variations in hyperparameters and comparisons with actual PRT microsimulation data for the networks proposed by the algorithm. The strong correlation between predicted and actual vehicle flows for passengers and empty vehicles demonstrates the model's accuracy.

The PRTNDP is then applied successfully in the context of a case study in Garching near Munich, delivering valid infrastructure proposals quickly for realistic-sized networks. Notably, the pipeline can process readily available OpenStreetMap (OSM) networks at any location, enhancing its real-world applicability. Furthermore, the adaptable meta-heuristic is technology-agnostic, making the procedure suitable for various transport modes. The developed infrastructure proposal pipeline is thus a valuable tool for shaping a future with efficient and sustainable urban transit.