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Robust passenger assignment for line planning in public transport

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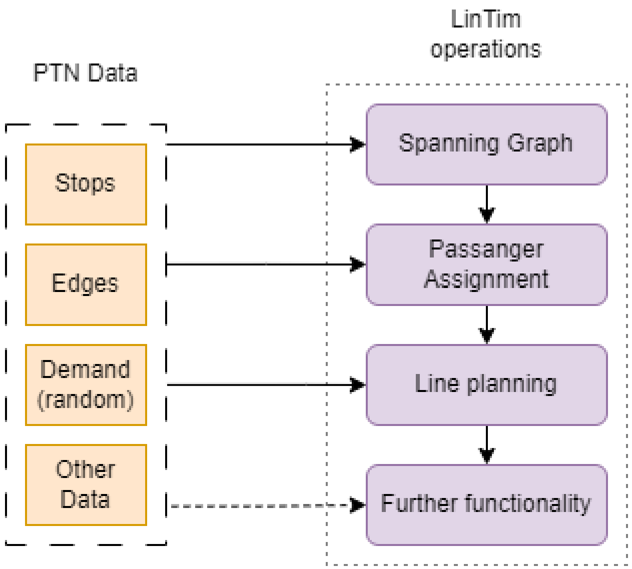
LINTIM

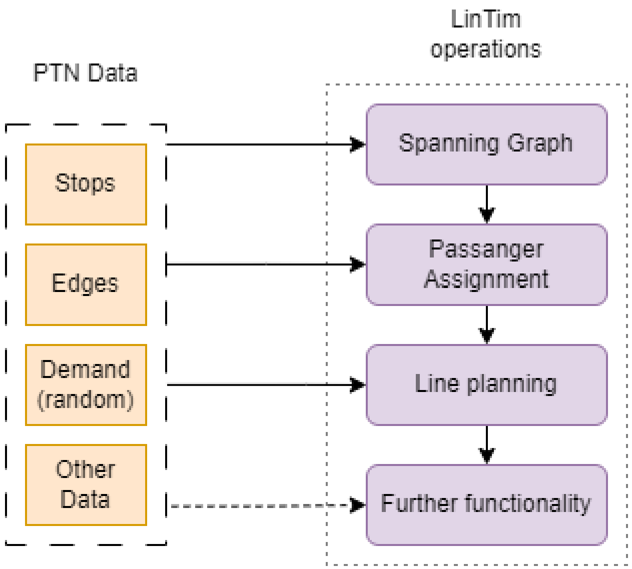
- LinTim is a tool for planning and analysing public transport supply
- Various functionality
  - Passenger assignment
  - Line planning
  - Timetabling
- Doesn’t currently have functionality for varying demand



Crude outline of LinTim operation

Varying demand

- Demand has effects on nearly all stages of planning
- Varying demand might cause current algorithms to find non-optimal line plans
- Simplest solution: use average demand
  - This is how random demand is currently dealt with



Crude outline of LinTim operation

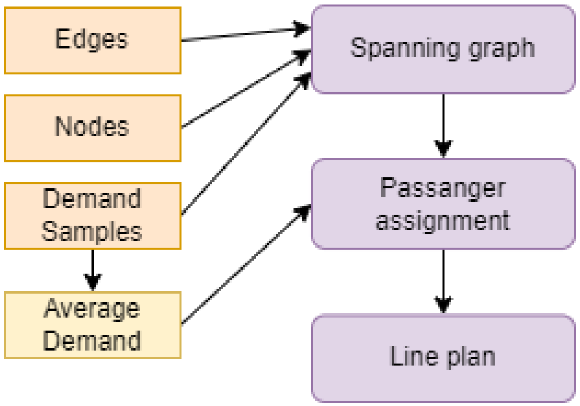
Statement of objectives

- We are given:
  - A graph representing all possible stops and edges
  - A method for sampling demand
  - Some evaluation metric

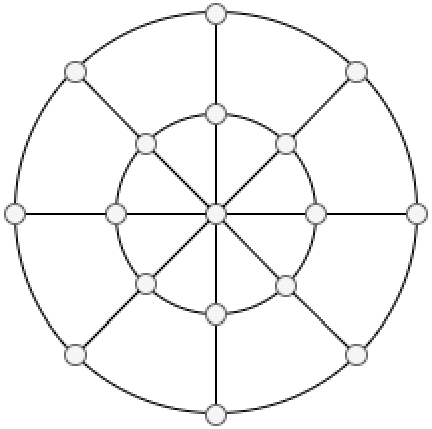
- We want:
  - The best (or at least a good) line concept according to an evaluation metric
    - This will naturally depend on the nature of demand. The best line concept for one set of demand samples will often not be the best for another.

Constraint: Spanning graphs, orb webs

- Spanning graphs determine, which edges must be used in a graph
- A spanning graph can be used to generate a passenger assignment, which can then be used to generate a line plan
- We'll create an algorithm, which finds a spanning graph
  - This spanning graph should on average generate the best line plan
- Now we need a line plan:
  - We could generate this with average demand
  - We could also create a similar algorithm for generating the line plan



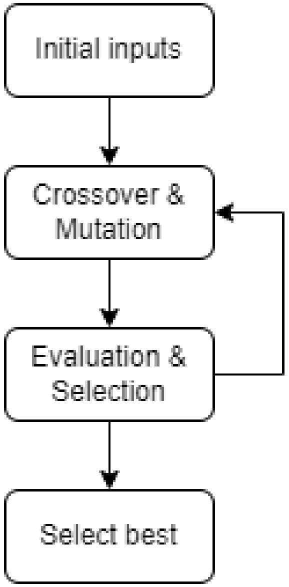
Idea of the algorithm for finding the end line plan



Orb webs, which will be used for testing the graph

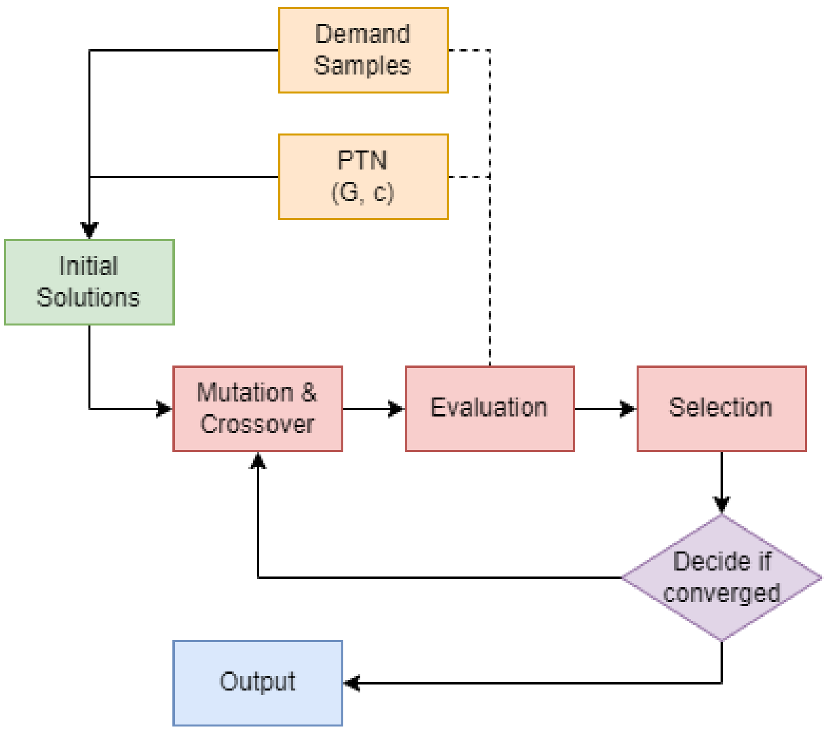
Genetic algorithms

- Genetic algorithms mimic natural selection
- Key components:
  - Fitness function
  - Mutation and crossover compatible genotype
- Advantages:
  - Mutation can prevent convergence in a local minimum
  - Very flexible
  - Fitness function has few requirements
    - Can be discontinuous for example
- Drawbacks:
  - Genetic drift
  - Random mutation

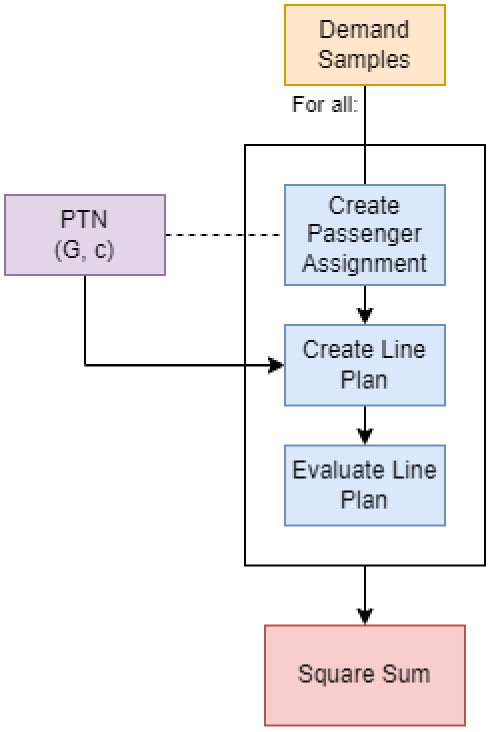


Abstract implementation of genetic algorithms

Implementation



Specific implementation of the algorithm



Idea behind evaluation

Preliminaries

- Demand generation
  - We'll vary p_s and p_r from 0.035 to 1 in 10 steps each
  - We get 100 demand samples
- Passenger assignment: SP Method
  - Find the shortest path
  - Distribute all demand on this path
- Evaluation
  - Each spanning graph is evaluated for each demand sample

$$d(u,v) = \left\lceil 10 \cdot \left(\frac{p_s}{s_{u,v}+1} + \frac{p_r}{r_{u,v}+1}\right) + \frac{1}{2} \right\rceil$$

Demand between nodes u and v

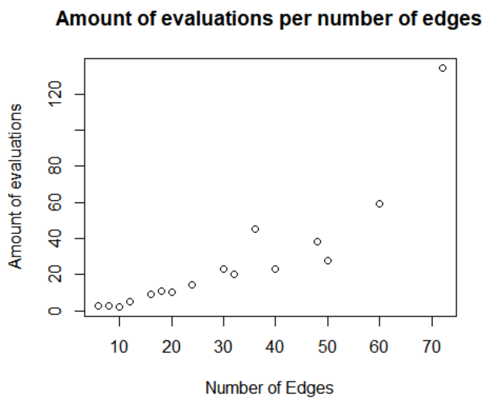
$$e(S,d) = 2^a + c$$

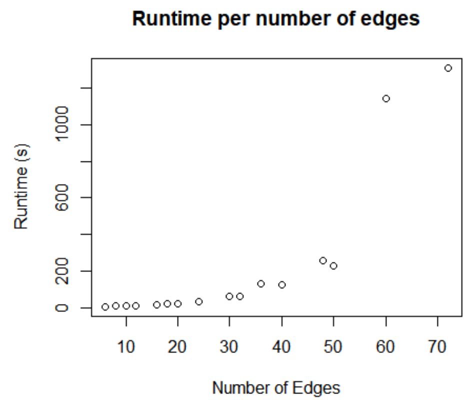
$$e(S) = \sum_{d \in D} e(H,d)^2$$

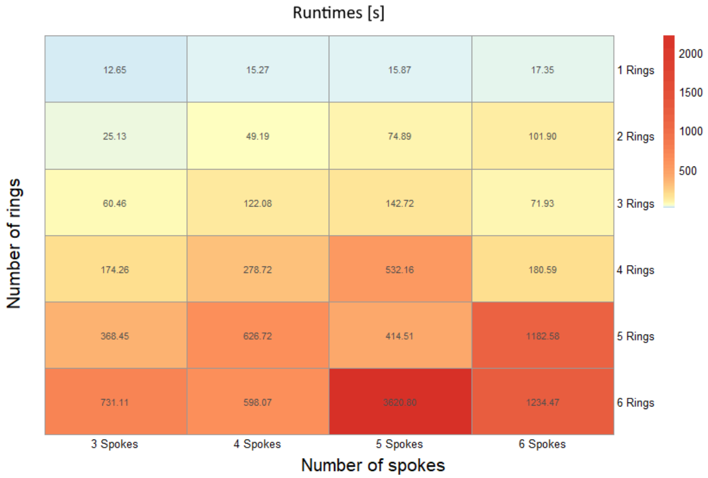
Evaluation of a spanning graph H

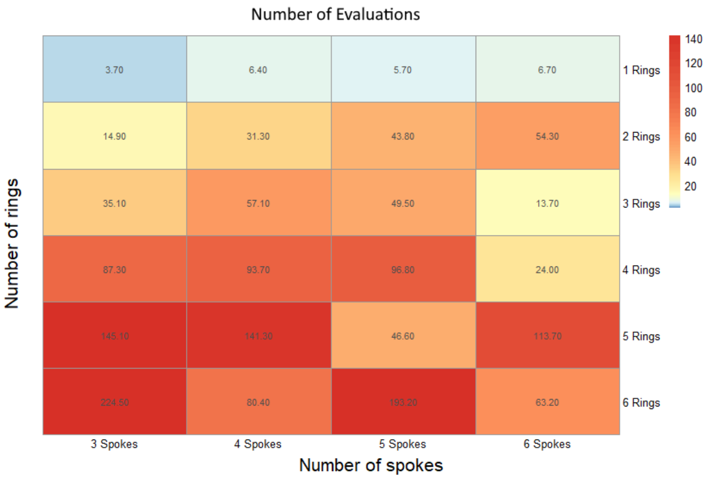
Runtime

- Hardware:
  - 16GB RAM
  - AMD Ryzen 5600
- No parallel processing



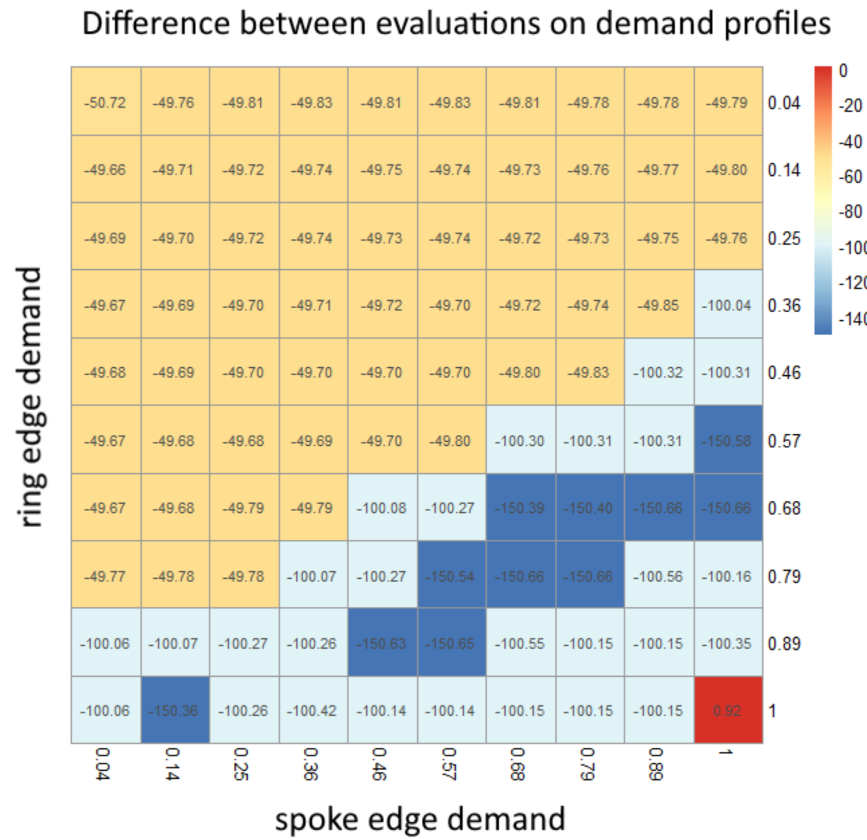






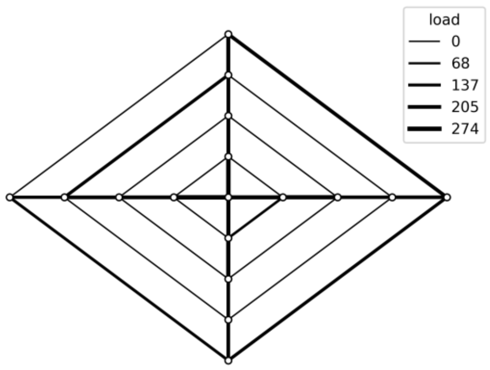
Results

- There are cases, where mean demand profiles do not sufficiently capture the nature of demands
- In this case, the mean demand is very close to the demand profile, where spoke edge demand and ring edge demand are 1

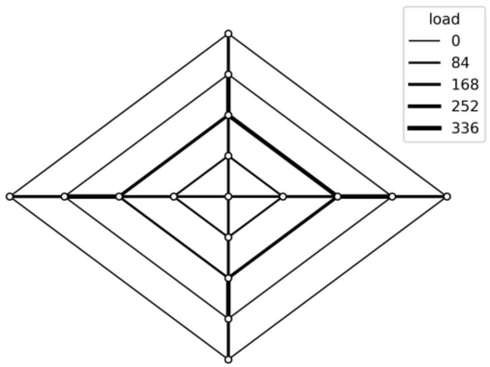


Heatmap of differences between evaluations between graphs generated with mean demand and variant demand profiles, when analyzed with variant demand profiles

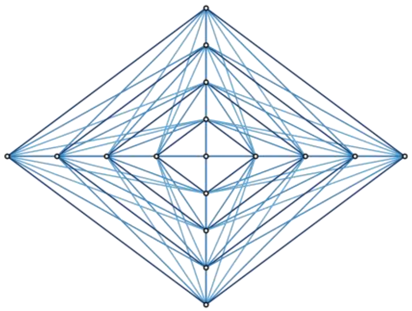
Resulting graphs



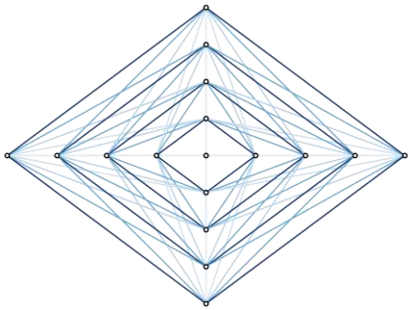
A graph generated by variant demand



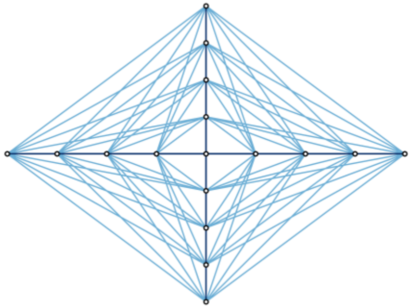
A graph generated by mean demand



Demands with p_s=1, p_r=1



Demands with p_s=1, p_r=0



Demands with p_s=0, p_r=1

Future research questions

- How do mean generated and variate generated graphs differ when different demand distributions are presented?
- How would different, perhaps less symmetric, graphs behave?

References and literature

- Heinrich, I., Herrala, O., Schiewe, P., Terho T., (2023). Using Light Spanning Graphs for Passenger Assignment in Public Transport. In 23rd Symposium on Algorithmic Approaches for Transportation Modelling, Optimization, and Systems (ATMOS 2023). Open Access Series in Informatics (OASIcs), Volume 115, pp. 2:1-2:16, Schloss Dagstuhl - Leibniz-Zentrum für Informatik
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