Bus-Route Optimization

Jaan Tollander de Balsch

2017-11-20

Why should we care?

- Transportation accounts for 5% of the GDP of Europe ("Transport Sector Economic Analysis - European Commission")

Why should we care?

- Transportation accounts for 5% of the GDP of Europe ("Transport Sector Economic Analysis - European Commission")
- Estimated 30 percent of national greenhouse gases are generated by transportation

Why should we care?

- Transportation accounts for 5% of the GDP of Europe ("Transport Sector Economic Analysis - European Commission")
- Estimated 30 percent of national greenhouse gases are generated by transportation
- People spent significant amounts of time in public transportation. For example in France more than 60 minutes daily. ("Parisians Spend Total of 23 Days a Year on Transport - the Local")

How can bus-routes be optimized?

$$
\begin{aligned}
\underset{x}{\text{minimize}} \quad & f(x) \\
\text{subject to} \quad & g_i(x) \leq 0, \quad i = 1, \ldots, m \\
& h_i(x) = 0, \quad i = 1, \ldots, p
\end{aligned}
$$

- **Mathematical optimization methods** can be used for the creation of efficient bus networks

How can bus-routes be optimized?

$$
\begin{aligned}
\underset{x}{\text{minimize}} \quad & f(x) \\
\text{subject to} \quad & g_i(x) \leq 0, \quad i = 1, \ldots, m \\
& h_i(x) = 0, \quad i = 1, \ldots, p
\end{aligned}
$$

- **Mathematical optimization methods** can be used for the creation of efficient bus networks
- Requires formulating the bus routing problem mathematically

How can bus-routes be optimized?

$$
\begin{aligned}
\underset{x}{\text{minimize}} \quad & f(x) \\
\text{subject to} \quad & g_i(x) \leq 0, \quad i = 1, \ldots, m \\
& h_i(x) = 0, \quad i = 1, \ldots, p
\end{aligned}
$$

- **Mathematical optimization methods** can be used for the creation of efficient bus networks
- Requires formulating the bus routing problem mathematically
- Choose the best numerical method for optimization

Main Points of the Talk

1. How to formulate the bus-routing problem

Main Points of the Talk

1. How to formulate the bus-routing problem
2. How the optimization process works

Main Points of the Talk

1. How to formulate the bus-routing problem
2. How the optimization process works
3. The benefits of bus-route optimization

Formulation

1. **Objective**: Minimize the *cost function*, which can include

("Route Optimization Algorithm.."), ("Vehicle Routing Problem - Wikipedia"),

Formulation

1. **Objective**: Minimize the *cost function*, which can include
   - Monetary cost to operate the network

("Route Optimization Algorithm.."), ("Vehicle Routing Problem - Wikipedia"),

Formulation

1. **Objective**: Minimize the *cost function*, which can include
   - Monetary cost to operate the network
   - Total travel time

("Route Optimization Algorithm.."), ("Vehicle Routing Problem - Wikipedia"),

Formulation

1. **Objective**: Minimize the *cost function*, which can include
   - Monetary cost to operate the network
   - Total travel time
2. **Constraints**: What kinda of features we want to avoid in our network

("Route Optimization Algorithm.."), ("Vehicle Routing Problem - Wikipedia"),

Formulation

1. **Objective**: Minimize the *cost function*, which can include
   - Monetary cost to operate the network
   - Total travel time
2. **Constraints**: What kinda of features we want to avoid in our network
   - Avoid too long or inconvenient routes

("Route Optimization Algorithm.."), ("Vehicle Routing Problem - Wikipedia"),

Formulation

1. **Objective**: Minimize the *cost function*, which can include
   - Monetary cost to operate the network
   - Total travel time
2. **Constraints**: What kinda of features we want to avoid in our network
   - Avoid too long or inconvenient routes
3. Real life data to obtain numerical estimates for the parameters

("Route Optimization Algorithm.."), ("Vehicle Routing Problem - Wikipedia"),

Formulation

1. **Objective**: Minimize the *cost function*, which can include
   - Monetary cost to operate the network
   - Total travel time
2. **Constraints**: What kinda of features we want to avoid in our network
   - Avoid too long or inconvenient routes
3. Real life data to obtain numerical estimates for the parameters
   - Common travel routes

("Route Optimization Algorithm.."), ("Vehicle Routing Problem - Wikipedia"),

Formulation

1. **Objective**: Minimize the *cost function*, which can include
   - Monetary cost to operate the network
   - Total travel time
2. **Constraints**: What kinda of features we want to avoid in our network
   - Avoid too long or inconvenient routes
3. Real life data to obtain numerical estimates for the parameters
   - Common travel routes
   - Distribution of the population in the city

("Route Optimization Algorithm.."), ("Vehicle Routing Problem - Wikipedia"),

Example Network

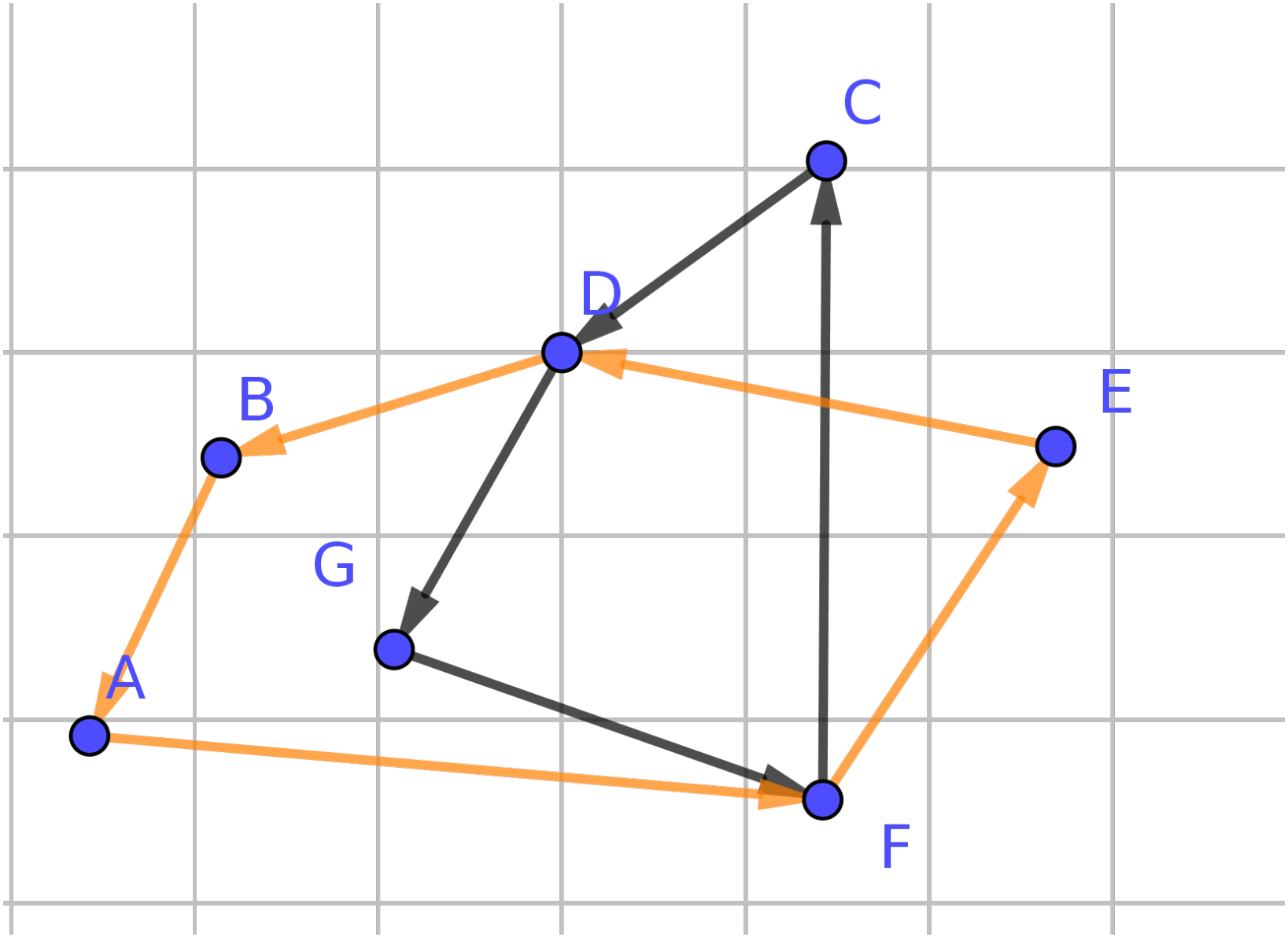

Figure 1: Letters are bus stops and connected arrows are bus-routes

Methods

Genetic optimization algorithm ("Genetic Algorithm - Wikipedia")

1. Initializing a *population* which is set of possible *routing candidates* (individual bus network)

Existing solvers, such as Gurobi, can be to perform the optimization. ("Gurobi Optimization - the State-of-the-Art Mathematical Programming Solver")

Methods

Genetic optimization algorithm ("Genetic Algorithm - Wikipedia")

1. Initializing a *population* which is set of possible *routing candidates* (individual bus network)
2. Computing the *fitness* of each of the individual routings in the population which measure how good each routing is

Existing solvers, such as Gurobi, can be to perform the optimization. ("Gurobi Optimization - the State-of-the-Art Mathematical Programming Solver")

Methods

Genetic optimization algorithm ("Genetic Algorithm - Wikipedia")

1. Initializing a *population* which is set of possible *routing candidates* (individual bus network)
2. Computing the *fitness* of each of the individual routings in the population which measure how good each routing is
3. Selecting a percentage of the best performing individuals and using them to *reproduce* new individuals

Existing solvers, such as Gurobi, can be to perform the optimization. ("Gurobi Optimization - the State-of-the-Art Mathematical Programming Solver")

Methods

Genetic optimization algorithm ("Genetic Algorithm - Wikipedia")

1. Initializing a *population* which is set of possible *routing candidates* (individual bus network)
2. Computing the *fitness* of each of the individual routings in the population which measure how good each routing is
3. Selecting a percentage of the best performing individuals and using them to *reproduce* new individuals
4. We also apply a random mutation on randomly selected individuals to avoid getting stuck in the local optimum

Existing solvers, such as Gurobi, can be to perform the optimization. ("Gurobi Optimization - the State-of-the-Art Mathematical Programming Solver")

Methods

Genetic optimization algorithm ("Genetic Algorithm - Wikipedia")

1. Initializing a *population* which is set of possible *routing candidates* (individual bus network)
2. Computing the *fitness* of each of the individual routings in the population which measure how good each routing is
3. Selecting a percentage of the best performing individuals and using them to *reproduce* new individuals
4. We also apply a random mutation on randomly selected individuals to avoid getting stuck in the local optimum
5. Use process recursively

Existing solvers, such as Gurobi, can be to perform the optimization. ("Gurobi Optimization - the State-of-the-Art Mathematical Programming Solver")

Benefits

- Savings in transportation time

Benefits

- Savings in transportation time
- Economical impact, saving money

Benefits

- Savings in transportation time
- Economical impact, saving money
- Positive environmental impact, less greenhouse gases

Conclusion

- We learned

Conclusion

- We learned
  - What bus-routing probelm consists of

Conclusion

- We learned
  - What bus-routing probelm consists of
  - How it is solved

Conclusion

- We learned
  - What bus-routing probelm consists of
  - How it is solved
  - About the positive effects of good bus-routing

Conclusion

- We learned
  - What bus-routing probelm consists of
  - How it is solved
  - About the positive effects of good bus-routing
- Proper bus-routing is important for functioning public transportation

Conclusion

- We learned
  - What bus-routing probelm consists of
  - How it is solved
  - About the positive effects of good bus-routing
- Proper bus-routing is important for functioning public transportation
- Well designed bus network can impact your daily life by saving time!

References

"Genetic Algorithm - Wikipedia." https://en.wikipedia.org/wiki/Genetic_algorithm.

"Gurobi Optimization - the State-of-the-Art Mathematical Programming Solver." http://www.gurobi.com/.

"Parisians Spend Total of 23 Days a Year on Transport - the Local." https://www.thelocal.fr/20160418/parisians-spend-23-days-a-year-on-public-transport.

"Route Optimization Algorithm.." https://www.slideshare.net/Mazhar_Nazik/route-optimization-algorithm-57634160.

"Transport Sector Economic Analysis - European Commission." https://ec.europa.eu/jrc/en/research-topic/transport-sector-economic-analysis.

"Vehicle Routing Problem - Wikipedia." https://en.wikipedia.org/wiki/Vehicle_routing_problem.