Spatial and temporal synchronization of truck platoons

RSM Erasmus University

Spatial and Transport Impacts of Automated Driving

Outline

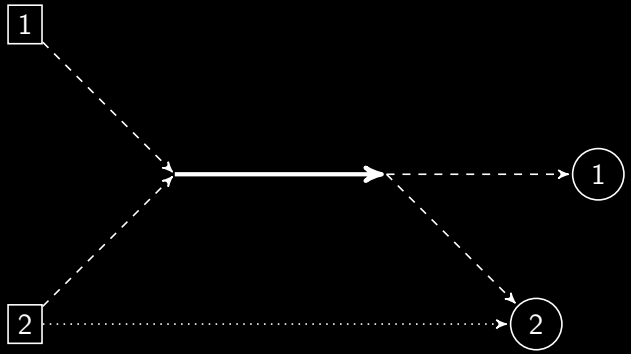
- Platoon planning - background
- Platoon planning - spatial and temporal synchronization
- Acceptance of platooning technology by truck drivers

Platoon planning - background

Goal - identify open issues in platoon planning

There is still some way to go....

Platoon planning problem



- Input - Origins, destinations, and time schedules of trucks
- Output - Platoon routes with meeting and split points

Platoon planning considerations

- Degree of centralization
- Level of automation
- Dynamics

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- **Level of automation**
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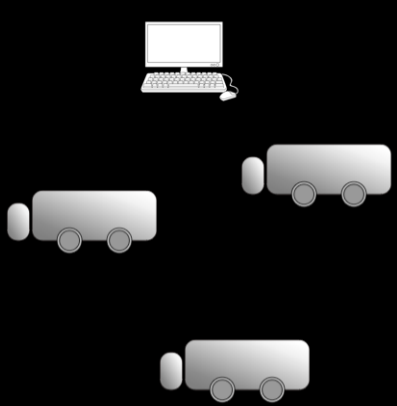
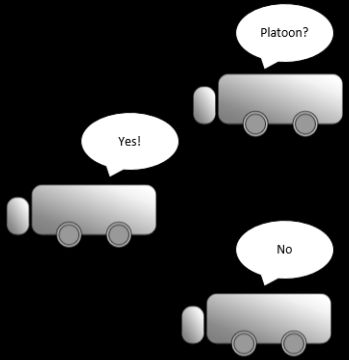
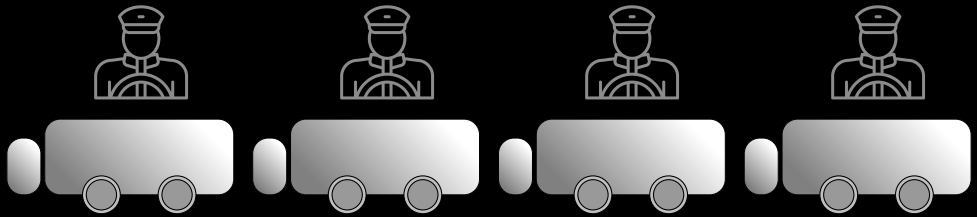
Degree of centralization

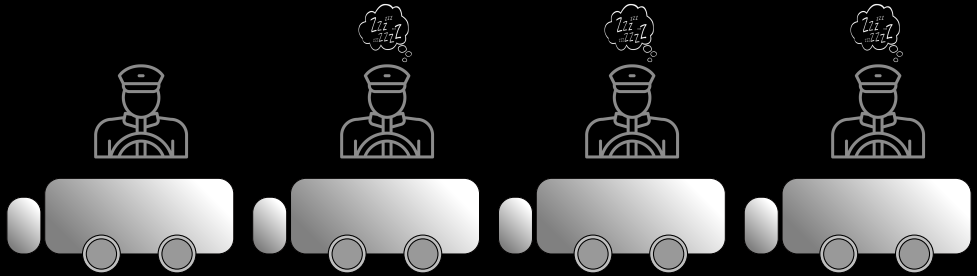




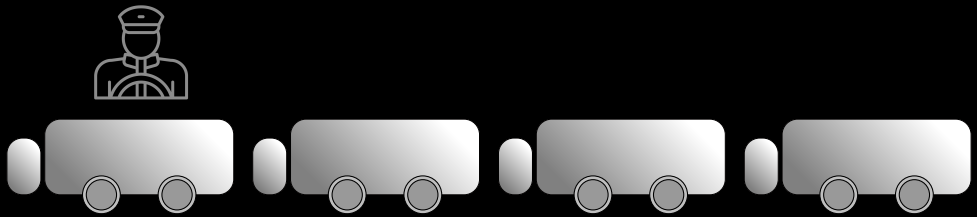
Levels of automation - Human driven platooning



Levels of automation - Human driven with in platoon resting



Levels of automation - Fully automatic platooning



Levels of automation - Hybrid platooning

Research gaps in platoon planning

Optimization

- Application of sophisticated meta-heuristics
- Planning methods for more automated platoons

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- Stochastic planning
- Effects of congestion

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System sustainability

- Ensuring greater participation - incentives?
- Dealing with strategic behaviour

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System sustainability

- Ensuring greater participation - incentives?
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Network design

- Additional infrastructure at certain locations
- Facility location decisions

Platoon planning - spatial and temporal synchronization

Goal - devise planning methods for platoons

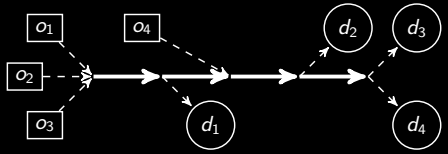
Simple two-truck platoons capture a large chunk of the benefits

Setting

- Minimization of costs
- Centralized human-driven platoon planning
- All trucks travel at the same speed
- All truck information is known prior to start of planning process

Problems

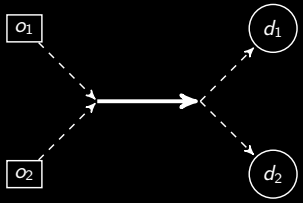
Truck platooning problem



Multiple trucks per platoon

Multiple platoons per trip

Truck pair routing problem

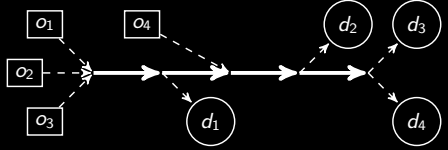


Two trucks per platoon

Single platoon per trip

Solution approaches

Truck platooning problem

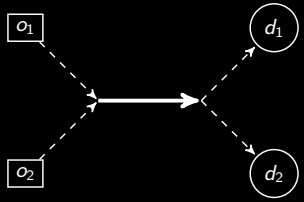


Two phase mixed integer program (MIP)

Based on a time expanded network

MIP_n - max of n trucks in a platoon (In our experiments $n = 2, 3$)

Truck pair routing problem

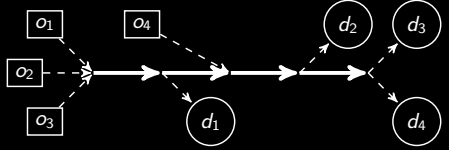


Reduction to shortest path problem

Optimal matching

Solution approaches

Truck platooning problem



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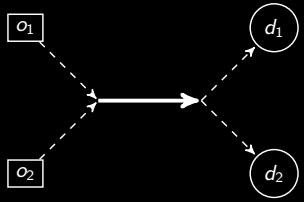
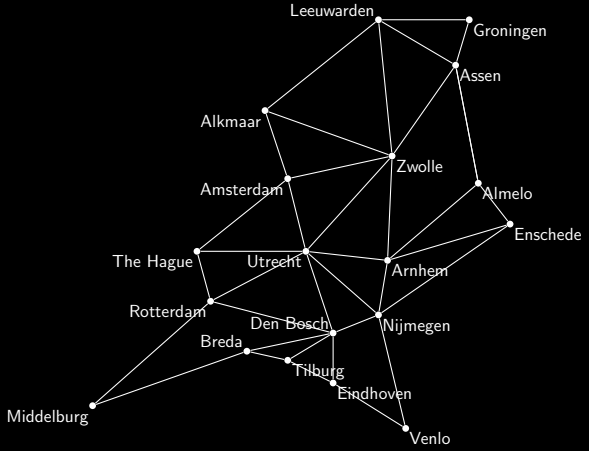


Reduction to shortest path problem

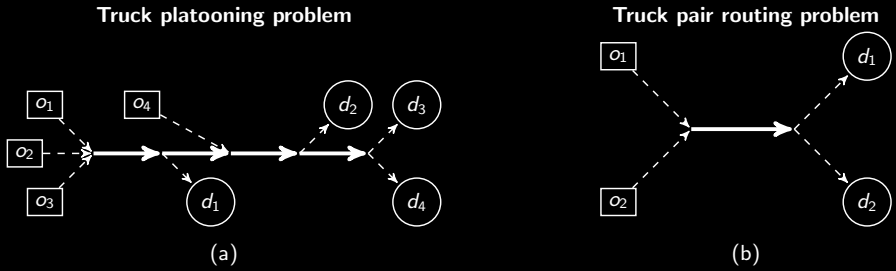
Optimal matching

Numerical experiments



Fuel savings factor - 10%
Flexibility - 30 min

Poll



What is the percentage gap in costs between the optimal truck platooning problem solution and the truck pair routing problem based heuristics? (How much worse is a (b) based solution worse than an (a) based solution?)

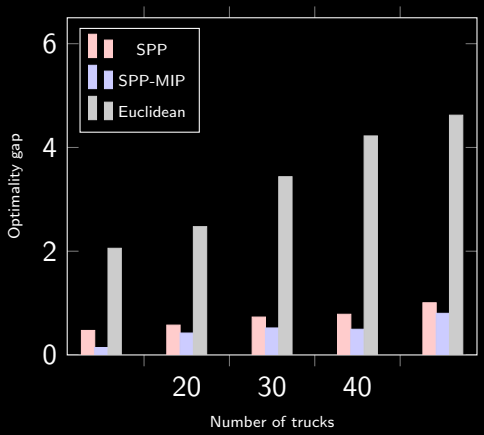
A. $< 5\%$

B. $5\% - 10\%$

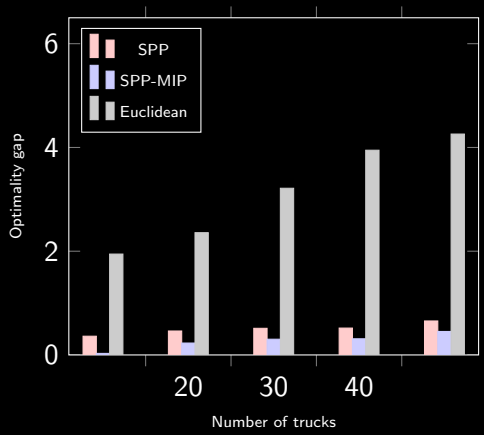
C. $10\% - 20\%$

D. $> 20\%$

How well do the heuristics perform?



(a) MIP_3



(b) MIP_2

- Two of the heuristics get to within 1% of the optimal solution
- The poorly performing one gets to within 2-4%.

How quick are these heuristics?

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Table: Run times of the MIP and different heuristics (in seconds)

Trucks	MIP_3		MIP_2		SPP	SPP-MIP	Euclidean
	Phase 1	Phase 2	Phase 1	Phase 2			
10	75.000	3.510	53.640	3.507	0.174	41.082	6.50E-07
20	215.768	28.313	146.985	27.171	0.645	173.104	5.90E-07
30	391.208	152.940	284.039	141.694	1.403	420.070	8.70E-07
40	605.050	709.328	342.605	456.584	2.458	678.593	6.40E-07
50	873.838	1897.613	497.229	1033.237	3.949	1116.737	6.20E-07

- SPP heuristic is considerably quicker than MIP and gets to within 1% of the optimal result

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- SPP heuristic is considerably quicker than MIP and gets to within 1% of the optimal result
- Simple two-truck platoon arrangements with one platoon per trip provide a lot of the benefits of more complicated arrangements
- Simple two-truck platoon arrangements are much easier to coordinate and more robust in practice

Some (other) key takeaways

- Heuristics perform well and provide practically more robust solutions

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- An improvement procedure on the heuristic solutions reduces the gap even further in a matter of seconds
- Most trucks form platoons with an adjustment in their time schedule rather than by making detours from their shortest paths (average detours are under 1km)

Acceptance of platooning technology by truck drivers

Goal - extract possibly existing driver views on platooning and how they think it will affect their jobs

Drivers are not very enthusastic

This study

- Focus groups - exploratory - open-ended
- Visit truck stops in the country
  - Conduct focus groups with willing drivers

Focus group structure

- Revolves around the three forms of platooning
  - Human driven platooning
  - Human driven platooning with in-platoon resting
  - Hybrid platooning

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- Typical focus group - 4-7 people and approximately an hour
- Language of focus group - Dutch
- Getting truck drivers to participate was a challenge

Some quotes (very roughly translated)

"Truck driving is a like a paid hobby..."

"If platooning becomes a reality, I will quit my job....."

"Platooning can become a reality within 5 years..."

"It will take 20 years for platooning to become a reality.."

"Everyone needs to have the technology for us to see its benefits....."

Overarching results

- Drivers differ in their views on already implemented technology
  - They make work easier and safer
  - They take away autonomy - full freedom to continuous tracking
- Most drivers agree platooning will become a reality but views on when differ
  - Jobs may become meaningless
  - Loss of autonomy
  - Their jobs may become obsolete
  - Their wages may go down
- Drivers are not very enthusiastic about platooning
- Doubts in capabilities of system

Thank you