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Performance of Self Organizing Logistics: a Practical Comparison between Centralized and Decentralized Logistics

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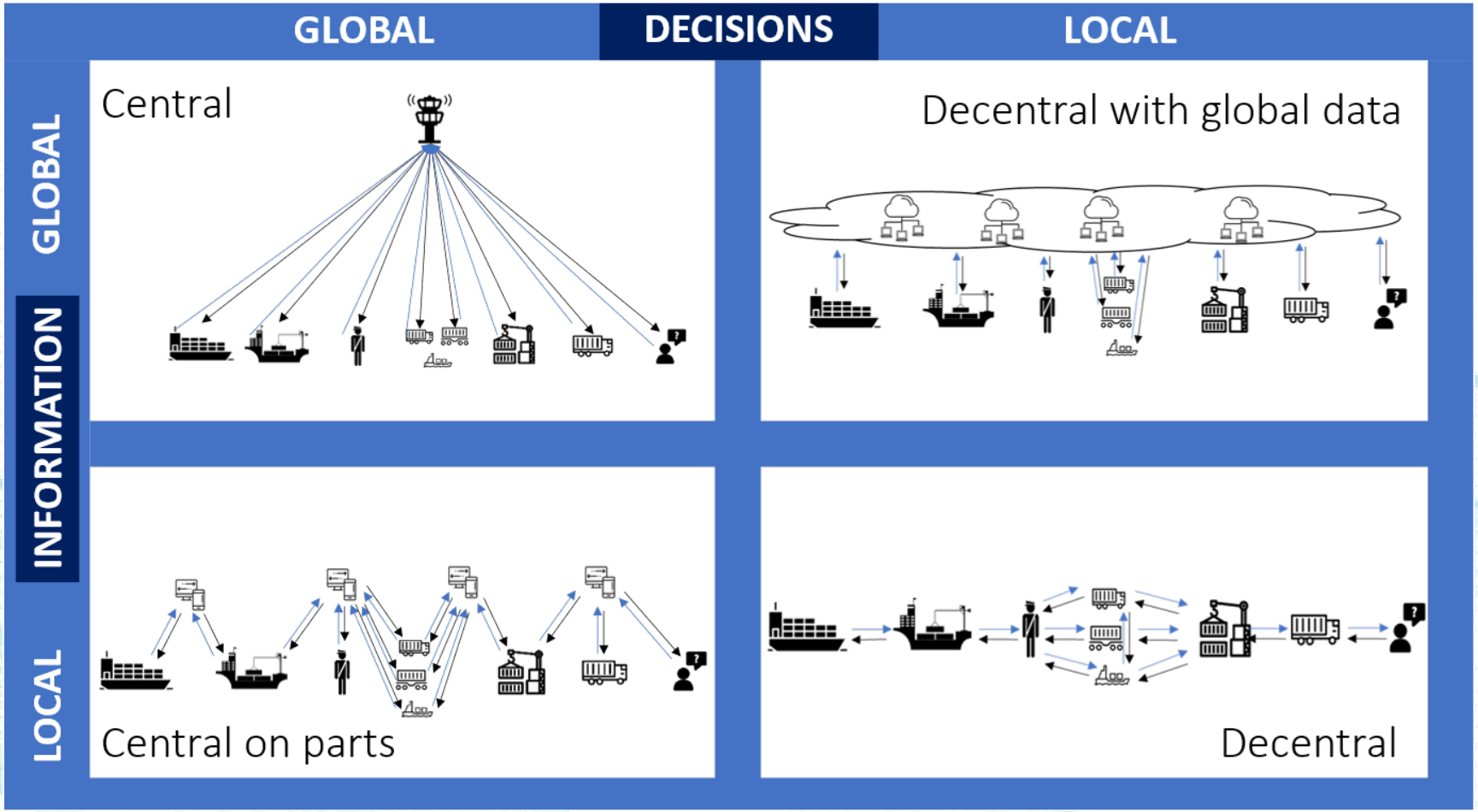
Agenda

- Self Organizing Logistics
- Problem statement
- Previous work
- Solving the problem
- Main results
- Considerations
- Future research

Self Organizing Logistics



Problem statement

- Truck scheduling: vehicle routing problem with time windows
- General objective:
  - Minimize vehicle use
- Subject to:
  - Deliver all orders on time

Objectives applied in research

1. Minimize arrival time end of day at depot
2. (a) Maximize utility rate vehicles and (b) minimize travel time in between orders

Previous work

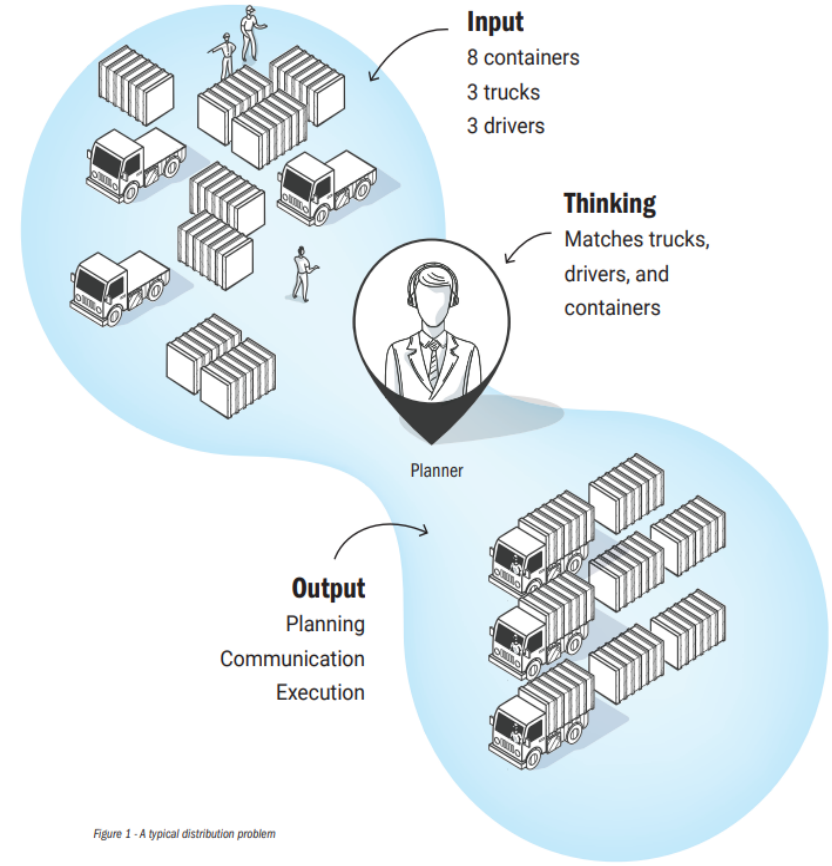
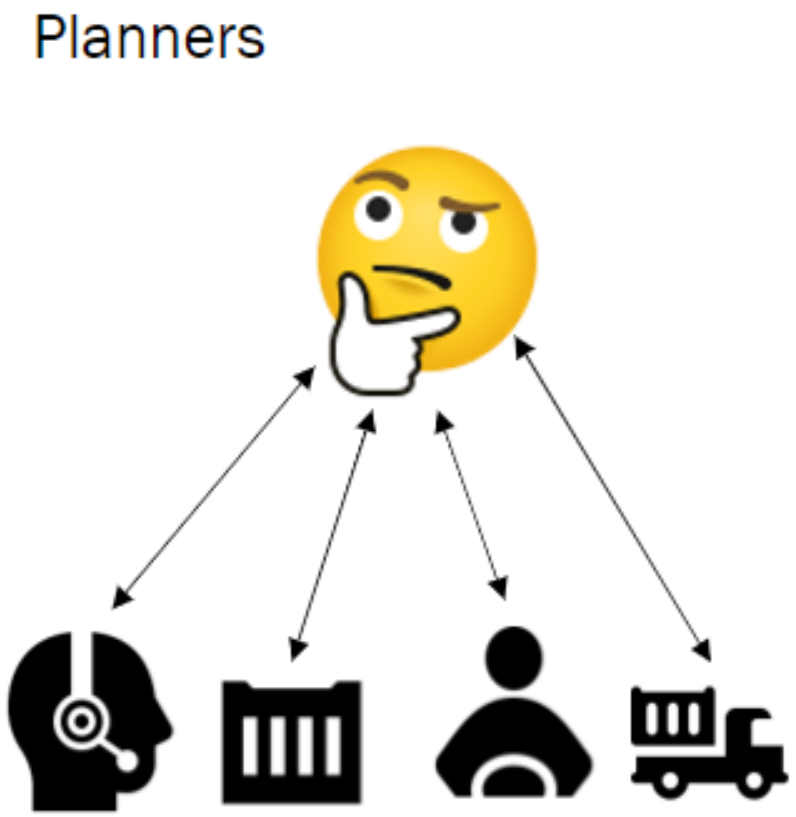


Figure 1 - A typical distribution problem



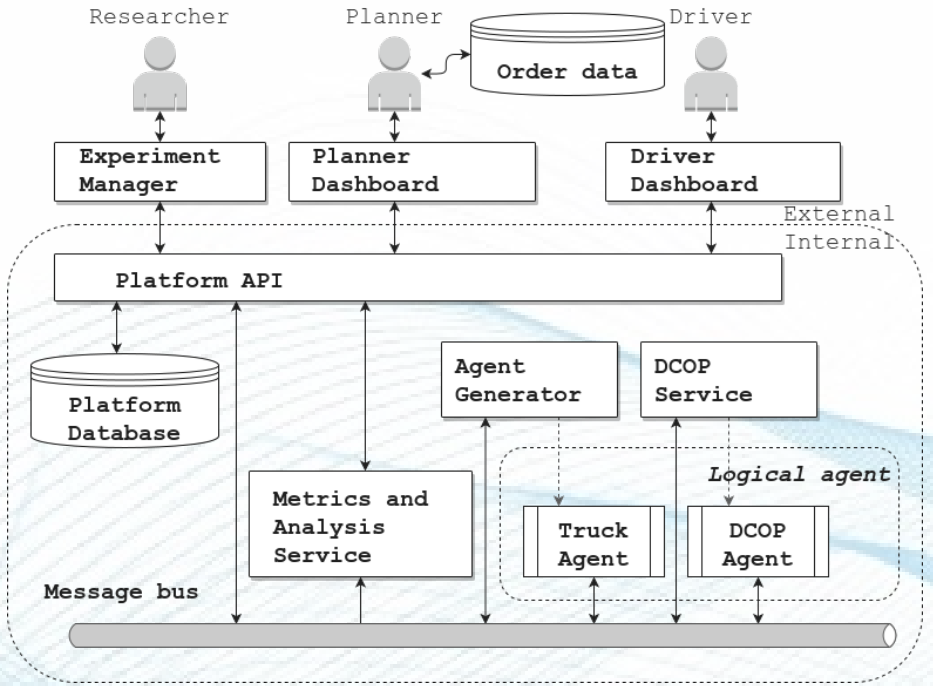
Previous work

Talking Trucks (Pingen e.a., 2020)

- How to achieve self organisation?

→Formulate the problem as a Distributed Constraint Optimization Problem (DCOP)

→Appy CoCoA (Van Leeuwen e.a., 2017)



Pingen, G. L. J., van Ommeren, C. R., van Leeuwen, C. J., Fransen, R. W., Elfrink, T., de Vries, Y. C., Karunakaran, J., Demirović, E., & Yorke-Smith, N. (2022). Talking Trucks: Decentralized Collaborative Multi-Agent Order Scheduling for Self-Organizing Logistics. *Proceedings of the International Conference on Automated Planning and Scheduling*, *32*(1), 480-489. https://doi.org/10.1609/icaps.v32i1.19834

C. J. van Leeuwen and P. Pawełczak, **CoCoA: A non-iterative approach to a local search (A)DCOP solver,** in *Proc. AAAI Conference on Artificial Intelligence,* San Francisco, CA, USA, Feb. 4—11 2017.

Solving the problem

Decentral method

- Problem defined as Distributed Constraint Optimization Problem
- Solved using CoCoA (Van Leeuwen e.a., 2017)

Central method (current research)

- Problem defined as Mixed Integer Linear Program
- Solved using exact solver in Python

Problem definition

Solution methods

- DECENTR: results from Pingen e.a., 2021
- CENTR1: objective 1
- CENTR2: objective 2
- HUMAN: results from human planner

Problem instances

- 3 experiments (days): increasing window length

Table 4: Problem size and computation time per scenario in minutes on a regular notebook (i7-8650U 1.90GHz). In comparison the human planner required 1 day of work.

Exp.	# orders	# trucks	DEC.	CEN.1	CEN.2
0	38	8	< 1	1	3
1	37	9	< 1	3	5
2	41	9	< 1	6	8

Main results: driven kilometers per experiment

- km. with load: same for decentral and central methods
- km. without load: lowest for central methods
- human planner can deviate from constraints > less km. with load

Table 2: Total number of driven kilometers per experiment

	With load				Without load			
Exp.	DEC.	CEN.1	CEN.2	HUM.	DEC.	CEN.1	CEN.2	HUM.
0	280.45	280.45	280.45	263.27	93.82	61.68	61.68	110.64
1	910.18	910.18	910.18	900.76	389.31	326.83	324.52	432.30
3	873.61	873.61	873.61	858.01	93.63	93.63	93.63	93.63

Main results: waiting time per vehicle

- Start of day: central performs best
- During day: decentral performs best
- End of day: central performs slightly better

Table 3: Average time of waiting per vehicle (in hours).

	Start of day				During the day				End of the day			
Exp.	DEC.	CEN.1	CEN.2	HUM.	DEC.	CEN.1	CEN.2	HUM.	DEC.	CEN.1	CEN.2	HUM.
0	2.31	0.36	0.74	1.49	0.23	1.83	0.50	0.45	7.37	6.91	7.78	7.17
1	2.44	0.12	0.34	1.24	0.35	1.30	1.15	-0.20*	2.37	4.13	4.09	4.40
3	2.27	0.5	0.5	1.06	0.08	0.0	0.0	0.0	3.62	4.58	4.58	3.68

Lower => better

Lower => better

Higher => better

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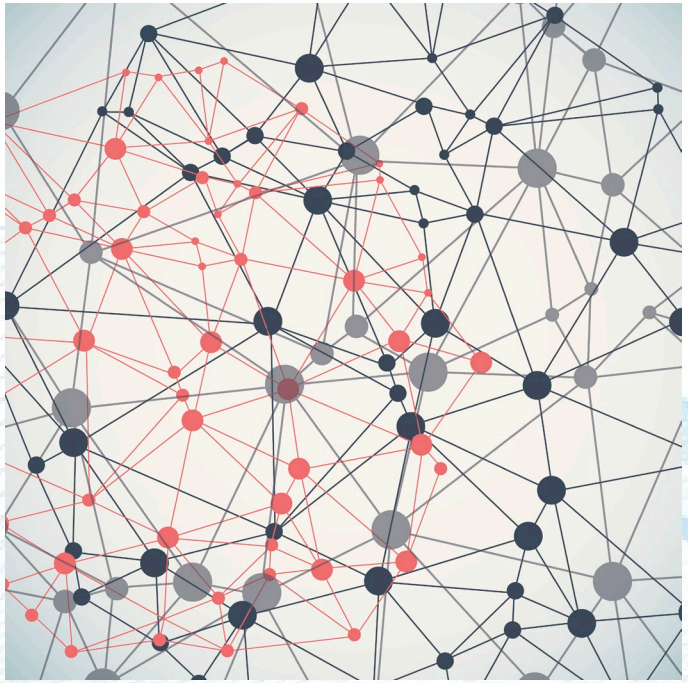
Considerations

- Hypothesis: given enough runtime, central method should find optimum
  - Results to be used to assess performance decentral method
  - Central method: disadvantaged by runtime
- Findings:
  - Central slightly outperforms decentral methods
  - Running time of decentral better than central
  - Both methods outperform human planner on runtime and KPIs
- Physical internet: logistics problems are often larger than current research > runtime huge advantage for decentral method



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Future research

- Increase problem size
- Increase problem difficulty

- Dynamic scheduling
- Multi-fleet
- Multi-modal

Thank you for your attention!

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