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Optimization models and methods for tour planning in smart urban logistics

Introduction

- Parcel delivery demands are steadily increasing with the rapid development of e-commerce.
- Traffic congestion and air pollution caused by Large trucks have become one of the urgent problems that city managers need to solve.
- With the increase in labor costs and the restrictions on the working hours of the delivery staff, it is very difficult for delivery companies to provide customers with cheap, efficient and round-the-clock courier services.

From these perspectives, unmanned electric transportation becomes a good choice for city logistics.

Modelling

Objective

Primary objective : Minimize the use of the number of LV

$$\min\Big(\sum_{k\in F_T}\sum_{j\in V_{rd}} x_{0,j,k}\Big) \quad (1)$$

- $x_{i,j,k}$ equal to 1 if arc (i,j) in A_1 is traveled by LV-k, 0 otherwise

Secondary objective : Minimize the total travel cost

$$\min\Big(\sum_{k\in F_T}\sum_{(i,j)\in A_1} c_{i,j}x_{i,j,k} + \sum_{(k,l)\in F_D}\sum_{(i,j)\in A_2} c_{i,j}y_{i,j}^{k,l}\Big) \quad (2)$$

- $y_{i,j}^{k,l}$ equal to 1 if arc (i,j) in A_2 is traveled by the SAV-(k,l), 0 otherwise
- $c_{i,j}$ be the associated travel cost in arc (i,j)

Constraints:
Time window for customer node and depot
Travel distance for SAV
Capacity for LV and SAV
Priority visiting constraint at drop-off and pick-up rendezvous node
Synchronization for LV and SAV

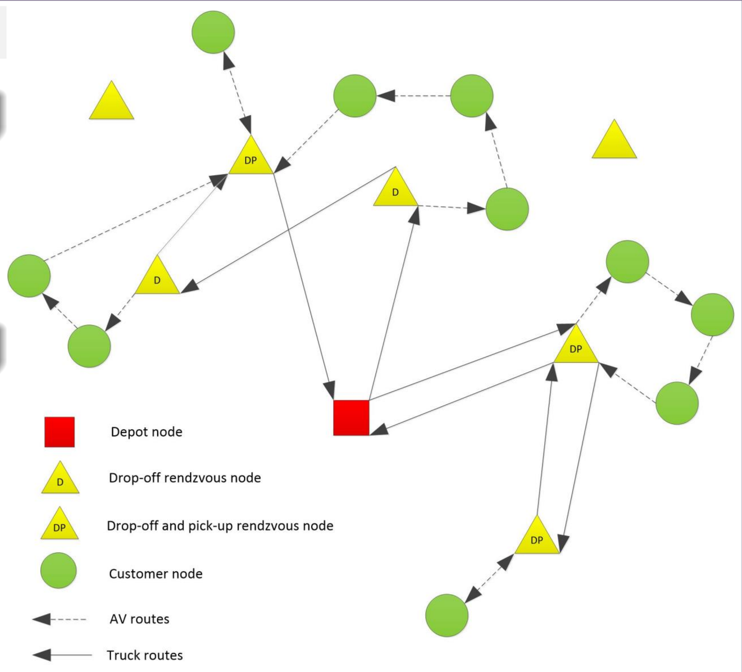

Fig. 1. The trucks plus automated vehicles delivery system. （Large Vehicle and Small Automated Vehicle: LV-SAV）

Exact Results and Model Comparison

Industry solver results

Table 1: 3 SATELLITES AND 15/30 CUSTOMERS

3-15	Min K(s)	K	Min Cost(s)	UB	LB	GAP	3-30	Min K(s)	K	Min Cost(s)	UB	LB	GAP
CA1	2.75	2	143.547	383.858	383.82	0	CA1	10800	3	10800	756.631	678.174	0.104
CA2	2.563	2	1.297	378.539	378.539	0	CA2	142.421	3	10800	659.77	537.111	0.186
CA3	2.703	2	1.484	387.799	387.799	0	CA3	89.625	3	10800	690.872	579.589	0.161
CA4	1.953	2	46.047	400.919	400.882	0	CA4	52.313	3	10800	579.457	549.016	0.053
CA5	2.469	2	90.953	382.759	382.721	0	CA5	10800	3	10800	650.066	555.684	0.145
CB1	2.734	2	43	391.759	391.721	0	CB1	10800	3	10800	773.018	702.97	0.091
CB2	2.187	2	20.187	410.368	410.335	0	CB2	143.641	3	10800	642.184	554.506	0.137
CB3	3.141	2	201.031	448.449	448.405	0	CB3	45.406	3	10800	696.835	596.366	0.144
CB4	5.343	2	3.063	377.55	377.55	0	CB4	46.312	3	10800	612.975	546.36	0.109
CB5	7.453	1	213.813	408.05	408.011	0	CB5	82.562	2	10800	623.572	580.61	0.069
CC1	10800	2	10800	361.856	331.071	0.085	CC1	10800	3	10800	712.76	514.154	0.279
CC2	10800	2	3825	344.755	344.72	0	CC2	10800	3	10800	648.457	325.861	0.497
CC3	10800	2	10800	380.436	363.854	0.044	CC3	10800	3	10800	639.847	333.105	0.479
CC4	10800	2	10800	379.32	313.605	0.173	CC4	10800	3	10800	590.138	358.46	0.393
CC5	3.328	1	919.875	286.467	286.438	0	CC5	10800	3	10800	735.896	340.828	0.537
CD1	3.11	2	61.422	370.836	370.799	0	CD1	1881.64	2	10800	619.715	604.867	0.024
CD2	0.938	1	0.563	348.818	348.818	0	CD2	121.141	3	10800	635.046	553.516	0.128
CD3	1.891	1	0.609	382.097	382.097	0	CD3	10800	3	10800	650.32	562.087	0.136
CD4	3.157	2	28.734	381.555	381.519	0	CD4	94.094	3	10800	586.027	540.17	0.078
CD5	3.156	2	33.578	368.871	368.842	0	CD5	68.766	3	10800	651.964	561.11	0.139

We use CPLEX 12.6 to solve the formulation of the MILP model; it provides calculation benchmarks and estimates the scale of the problem that the solver can manage.
Meanwhile, The exact solution got by CPLEX is applied for model comparison.

Model comparison

We compare the LV-SAV model with the traditional model which the truck should wait for dispatcher's return at the same rendezvous node. It is apparent that the LV-SAV model possesses advantages over traditional models.

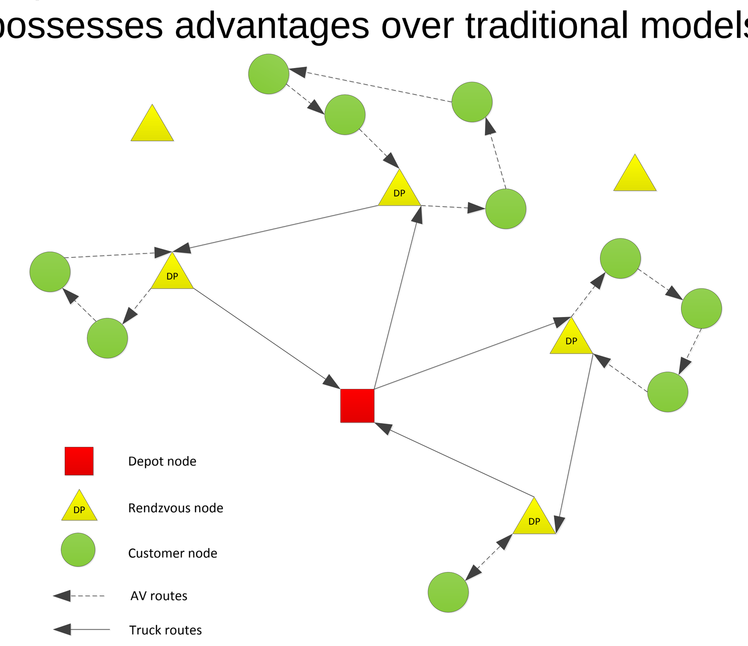

Fig. 2. Traditional model which the truck should wait for the return of the dispatcher at the same rendezvous node

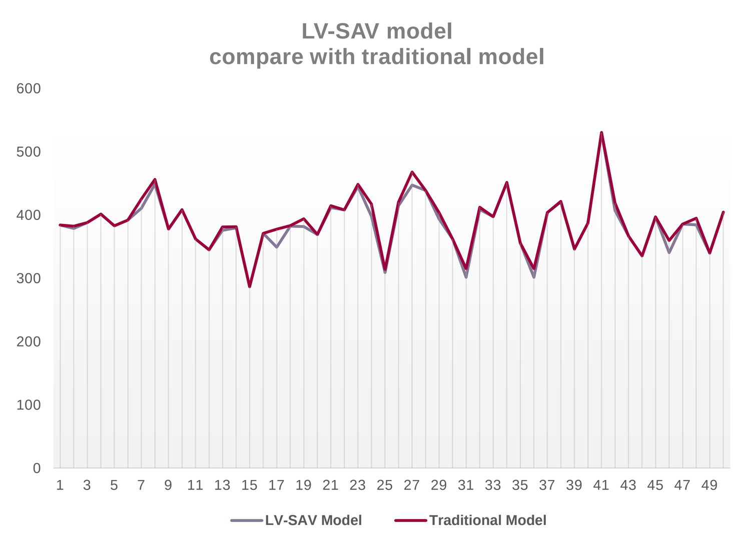

Fig. 3. Comparison of cost between LV-SAV model and traditional model

Matheuristic

We propose simple heuristics to acquire a workable solution fleetly. Feasible solutions obtained from simple heuristics are improved by a destroy and repair approach for the optimization of the primary objective, then the local search is applied to optimize the primary and secondary objective simultaneously.
Insertion, swap, traditional 2-opt and change-satellite moves are used in the multi-start variable neighborhood descent algorithm in local search phase. Moreover, the granular neighbor technology, which contains the move elements that are likely to belong to good feasible solutions, is also involved in the local search approach. In addition, the backtracking technology is applied to connect LV route with SAV routes exactly and quickly.

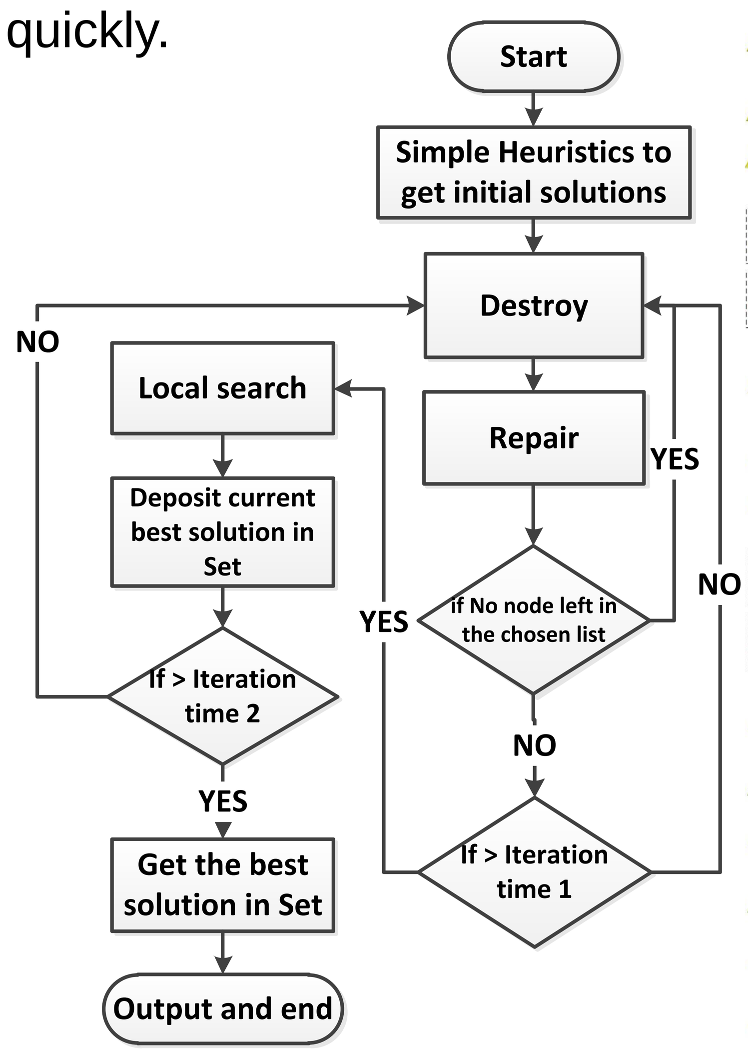

Fig. 4. Flow chart of the mathheuristic

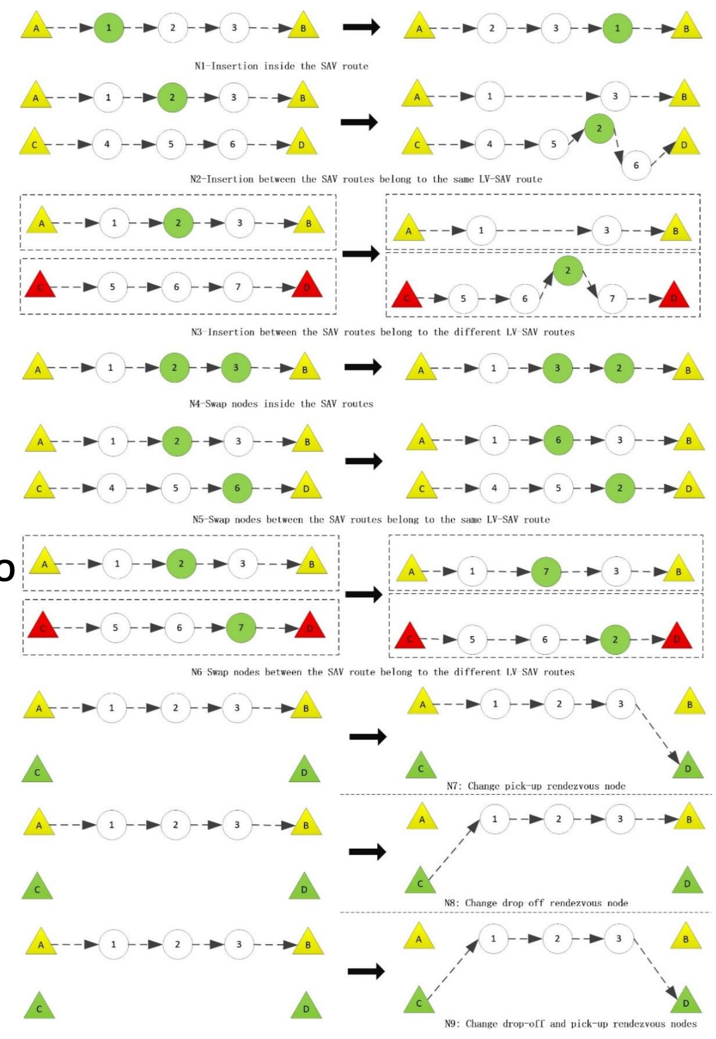

Fig 5: Moves

```
procedure EXPLORE(node n)
    if REJECT(n) then return
    if COMPLETE(n) then
        OUTPUT(n)
    for n_i : CHILDREN(n) do EXPLORE(n_i)
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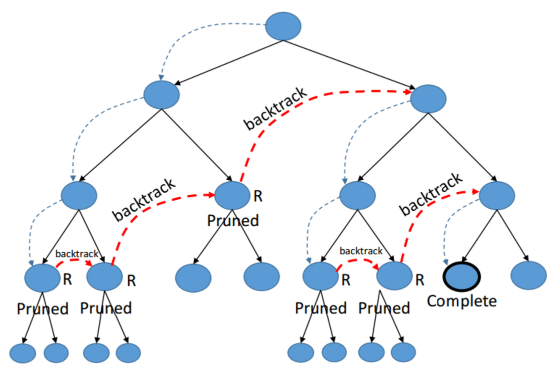

Fig 6: Backtracking technology

$$\vartheta = \beta \cdot \frac{z'}{(n+K)},$$

Fig 7: Granular neighbor technology

Results and Future Work

Matheuristic performance

We use simulation experiments to detect the efficiency of the algorithm, for the simplest instance(3 satellites and 15 customers), the algorithm equip with fast running speed and little error with the exact solution. Furthermore, the matheuristic could solve the hardest instance (5 satellites and 100 customers) within 1000s.

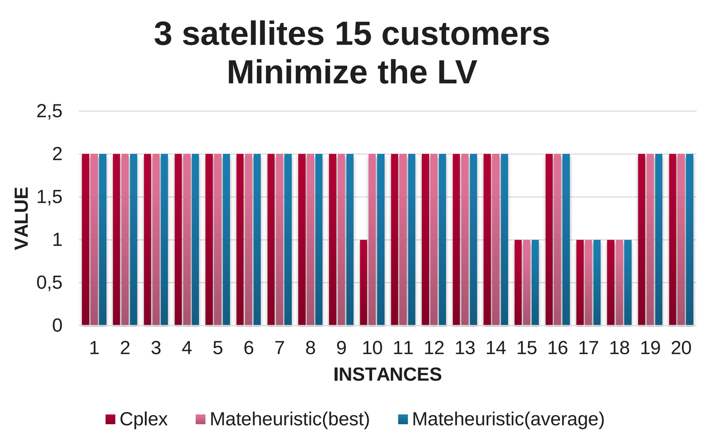

Fig 8: Primary objective comparison.

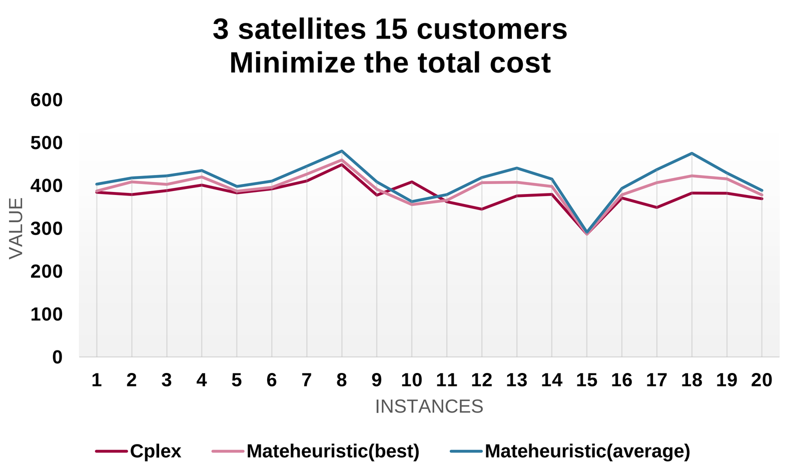

Fig 9: Secondary objective comparison

Performance of algorithm runs 10 times

Cplex runtime: 4 instances > 10800s; 16 instances average:116.130s
Matheruistic runtime：20 instances average: 1.829s
Primary objective GAP: 0
Secondary objective GAP: 0.049(best); 0.089 (average)

Sensitivity Analysis for moves

Sensitivity Analysis and contribution of individual components

	Base	No swap	No insert	No 2-opt	No change satellites
Cost Best	398.261	7.150%	7.385%	0.122%	1.760%
Cost Average	415.512	8.802%	9.187%	0.380%	3.318%
Time(s)	1.820	-51.858%	-50.903%	-4.324%	-56.926%

Future work: From level 1 to level 2

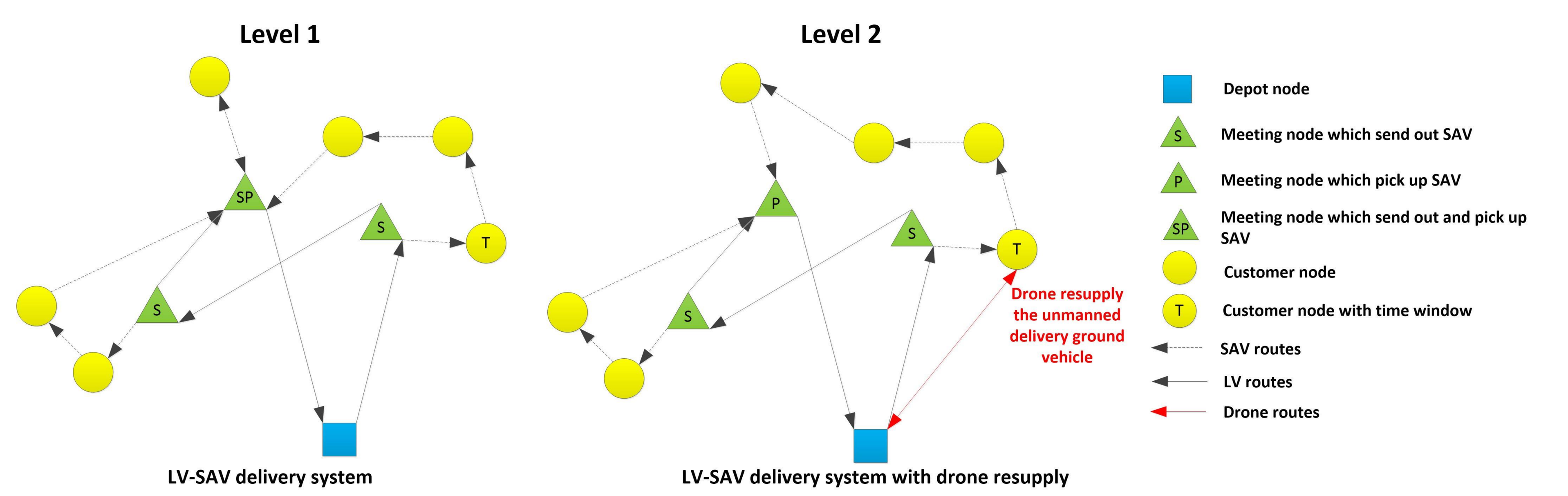

Fig 10: From LV-SAV delivery system to LV-SAV-DRONE delivery system

References

- [1] N. Boysen, S. Schwerdfeger, F. Weidinger, Scheduling last-mile deliveries with truck-based autonomous robots, European Journal of Operational Research (2018).
- [2] C. C. Murray, A. G. Chu, The flying sidekick traveling salesman problem: Optimization of drone-assisted parcel delivery, Transportation Research Part C: Emerging Technologies 54 (2015) 86–109.
- [3] U. Breunig, V. Schmid, R. F. Hartl, T. Vidal, A large neighbourhood based heuristic for two-echelon routing problems, Computers & Operations Research 76 (2016) 208–225.
- [4] Dellaert, N.P., Dashty Saridarq F.,T. Van Woensel, T.G.Crainic, Branch & Price Based Algorithms for the Two-Echelon Vehicle Routing Problem with Time Windows, Transportation Science (2018).

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