A Hybrid Genetic Algorithm for Vehicle Routing Problem with Roaming Delivery Locations

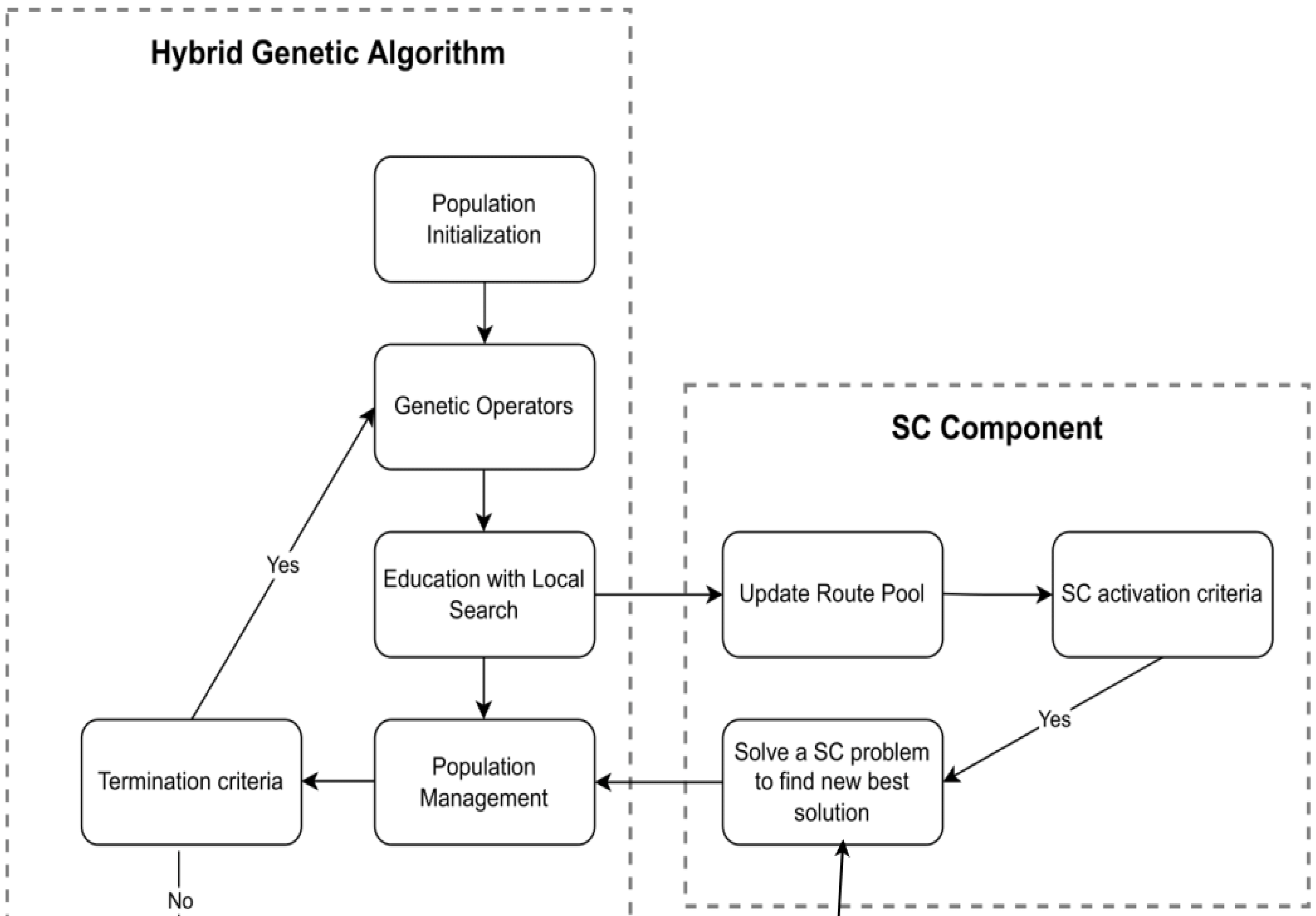
Quang Anh Pham, Minh Hoàng Hà, Duy Manh Vu, Huy Hoang Nguyen
ORLab, Faculty of Computer Science, Phenikaa University, Hanoi, Vietnam

Motivation

- In 2018, Amazon launched a new delivery service named "trunk delivery" that allows its couriers to **deliver goods to customers through accessing their trunks.**
- The Vehicle Routing Problem with Roaming Delivery Locations (VRPRDL) was introduced in [Reyes et al., 2017] for modeling this strategy. It also showed that the trunk delivery results in **reducing the total travel distance by 40-65% compared to the usual home delivery.**

Solution Method

- Our method named **HGA-SC** is a combination of a hybrid genetic algorithm (HGA) and a set-covering (SC) approach.
- HGA-SC was based on a *Hybrid Genetic Search with Adaptive Diversity Control* (HGSADC) which is one of the best algorithms for VRPs [Vidal, 2022].



$$\begin{aligned} \min \quad & \sum_{r \in \Omega} v_r \beta_r & \\ \text{s.t.} \quad & \sum_{r \in \Omega} \alpha_r^p \beta_r \geq 1 & \forall p \in P \\ & \beta_r \in \{0,1\} & \forall r \in \Omega \end{aligned}$$

Sensitivity Analysis of Algorithm Components

- Three versions of HGA-SC are tested for investigating the impact of new components.
- The results show that the mutation and SC components are complementary and important for the success of HGA-SC.

- HGA-SC$_{base}$: removing both mutation and SC components.
- HGA-SC$_{noMut}$: removing only the mutation.
- HGA-SC$_{noSC}$: removing only the SC component.

Set	#Ins	Configuration	$\sum gap$	$\sum gap^*$	#BKS
$\mathcal{B}_1$	40	HGA-SC$_{base}$	1.34	1.18	37
		HGA-SC$_{noMut}$	1.72	1.11	36
		HGA-SC$_{noSC}$	1.51	1.41	36
		HGA-SC	**0.07**	**0.00**	**40**
$\mathcal{B}_2$	40	HGA-SC$_{base}$	8.39	5.94	35
		HGA-SC$_{noMut}$	6.28	5.86	36
		HGA-SC$_{noSC}$	5.73	3.48	36
		HGA-SC	**1.84**	**-0.44**	**40**
$\mathcal{B}_3$	20	HGA-SC$_{base}$	0.00	0.00	20
		HGA-SC$_{noMut}$	0.00	0.00	20
		HGA-SC$_{noSC}$	0.00	0.00	20
		HGA-SC	**0.00**	**0.00**	**20**
$\mathcal{B}_4$	20	HGA-SC$_{base}$	1.63	0.21	19
		HGA-SC$_{noMut}$	1.63	0.21	19
		HGA-SC$_{noSC}$	**0.18**	0.00	20
		HGA-SC	0.53	**0.00**	**20**

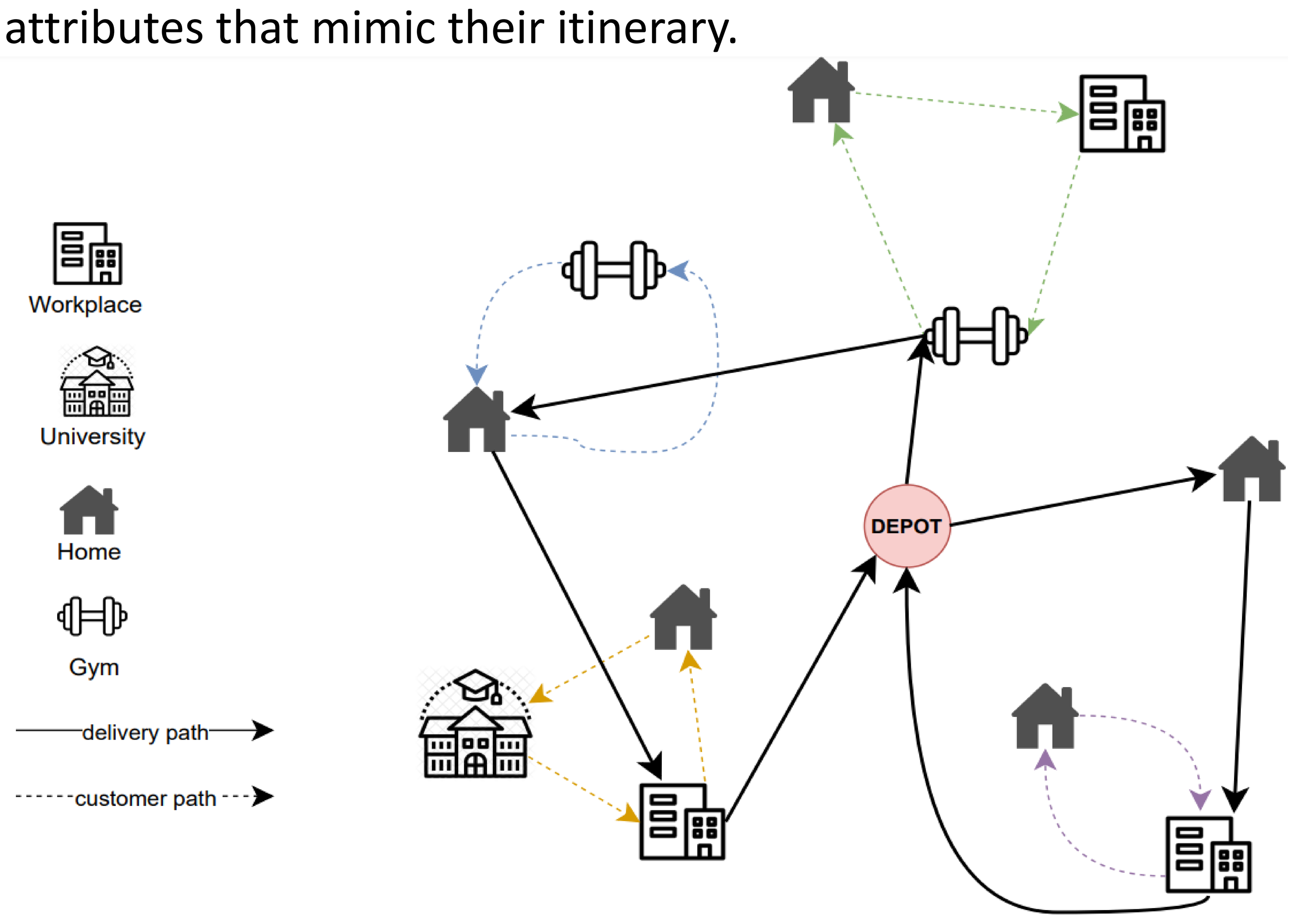
Contribution

- We propose a novel hybrid genetic algorithm to deal with the VRPRDL. It relies on a well-known solution framework for VRPs, and integrates two new features: **a mutation operator for diversification and a set-covering component for intensification.**
- Empirically, the new method **outperforms other existing approaches and improves 49 best-known results.**

Problem Description

VRPRDL is a vehicle routing problem (VRP) minimizing the total traveling cost in which:

- Each customer is represented by a set of locations where they can be served only once during planning horizon.
- Each location has a time window (TW).
- TWs associated with locations of a customer satisfy special attributes that mimic their itinerary.



Comparison Results

Set	n	Method	$\overline{gap_1}$	$\overline{gap_5}$	*nbRou*	*time*	*time$_{ori}$*
$\mathcal{B}_1$-var	15-60	HGA-SC	**-0.18**	**-0.22**	**2.97**	290.39	177.08
		CGBH	0.00	-	3.03	62.29	1.91
$\mathcal{B}_1$-var	120	HGA-SC	**-1.76**	**-2.27**	**6.00**	3089.36	1688.71
		CGBH	0.00	-	7.80	1258.60	62.12
$\mathcal{B}_2$-var	15-60	HGA-SC	**-0.47**	**-0.47**	**2.37**	342.57	209.35
		CGBH	0.00	-	2.63	135.36	6.28
$\mathcal{B}_2$-var	120	HGA-SC	**-2.10**	**-2.75**	**5.00**	3678.24	2086.79
		CGBH	0.00	-	6.20	2577.19	241.00

Set	#Ins	n	Method	$\overline{gap}$	$\overline{gap^*}$	*max*	*max**	*time*
$\mathcal{B}_1$	30	15-60	CGBH	–	0.00	–	0.00	1.91
			LNS*	0.00	0.00	0.01	0.00	60.00
			HGA-SC	**0.00**	**0.00**	**0.00**	**0.00**	142.00
$\mathcal{B}_1$	10	120	CGBH	–	0.06	–	0.22	62.12
			LNS*	0.05	0.00	0.25	0.00	360.00
			HGA-SC	**0.01**	**0.00**	**0.03**	**0.00**	1696.56
$\mathcal{B}_2$	30	15-60	CGBH	–	0.00	–	0.05	6.28
			LNS*	0.02	0.00	0.55	0.00	60.00
			HGA-SC	**0.00**	**0.00**	**0.00**	**0.00**	158.08
$\mathcal{B}_2$	10	120	CGBH	–	0.37	–	1.39	241.00
			LNS*	0.48	0.20	2.43	1.47	360.00
			HGA-SC	**0.18**	**-0.04**	**0.98**	**0.00**	1799.55
$\mathcal{B}_3$	20	40	CGBH	–	0.01	–	0.15	3.27
			LNS*	0.01	0.00	0.12	0.00	60.00
			HGA-SC	**0.00**	**0.00**	**0.00**	**0.00**	168.08
$\mathcal{B}_4$	20	40	CGBH	–	–	–	–	–
			LNS*	0.14	0.01	1.21	0.21	60.00
			HGA-SC	**0.03**	**0.00**	**0.00**	**0.00**	170.29

- We compare HGA-SC with 2 methods:
  - LNS* [Dumez et al., 2021]
  - CGBH [Yuan et al., 2021]

- HGA-SC always find or even improve the Best Known Solution (BKS) of every instance in four sets.
- The max gap between the objective values of HGA-SC and BKS is **0.98%**, while these figures for LNS* and CGBH are **2.43%** and **1.39%**, respectively. **(more stable)**
- When increasing the route length, the increase in the average running time of HGA-SC **(2 times in the worst case)** is small compared to CGBH **(10-32 times)**.

References

[1]: Reyes, D., Savelsbergh, M. and Toriello, A., 2017. Vehicle routing with roaming delivery locations. *Transportation Research Part C: Emerging Technologies*, 80, pp.71-91.
[2]: Vidal, T., 2022. Hybrid genetic search for the CVRP: Open-source implementation and SWAP* neighborhood. *Computers & Operations Research*, 140, p.105643.
[3]: Dumez, D., Tilk, C., Irnich, S., Lehuédé, F. and Péton, O., 2021. Hybridizing large neighborhood search and exact methods for generalized vehicle routing problems with time windows. *EURO Journal on Transportation and Logistics*, 10, p.100040.
[4]: Yuan, Y., Cattaruzza, D., Ogier, M., Semet, F. and Vigo, D., 2021. A column generation based heuristic for the generalized vehicle routing problem with time windows. *Transportation Research Part E: Logistics and Transportation Review*, 152, p.102391.