Reinforcement Learning-Based Optimization of Logistical Hubs and Routing in the Context of the Physical Internet - A Case Study from Japan

Hisatoshi Naganawa[1] and Enna Hirata[2*]

1. Faculty of Ocean Science and Technology, Kobe University, Kobe, Japan.

2. Graduate School of Maritime Sciences, Kobe University, Kobe, Japan.

*Corresponding author: enna.hirata@platinum.kobe-u.ac.jp

Background of Research (1)

KOBE UNIVERSITY

Cost inflation

- Expansion of EC market
- Soaring fuel prices
- Small-lot

Working hours

- Working hour restrictions
- Decreased profits
- Intensifying Competition

Declining population

- Shortage of workers
- 36% of demand cannot be carried in 2030

What is Physical Internet ?

A new mechanism that applies the concept of Internet communications to logistics. Improved logistics efficiency by increasing utilization of logistics assets. Reduced GHG emissions due to fewer trucks required.

KOBE UNIVERSITY

To achieve Physical Internet,

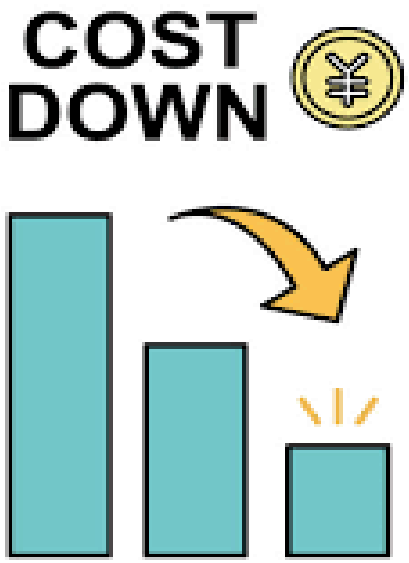
Determine optimal locations for distribution centers, taking into account factors such as the distribution of existing distribution centers

Optimization of truck transportation routes based on location of distribution centers

KOBE UNIVERSITY

Minimize the total cost of all trucks and distribution centers operated.

Since the total distance of trucks used and the number of distribution centers are inversely related, it ultimately comes down to the optimal total truck mileage and number of distribution centers.



Methodology (1)

KOBE UNIVERSITY

Clustering of customers and suppliers by FCM

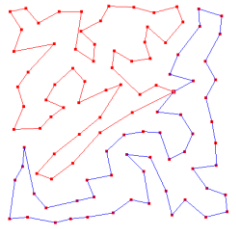
1

Determination of optimal location of π-hub by NEAT

2

Optimize of transportation routes by LKH-3

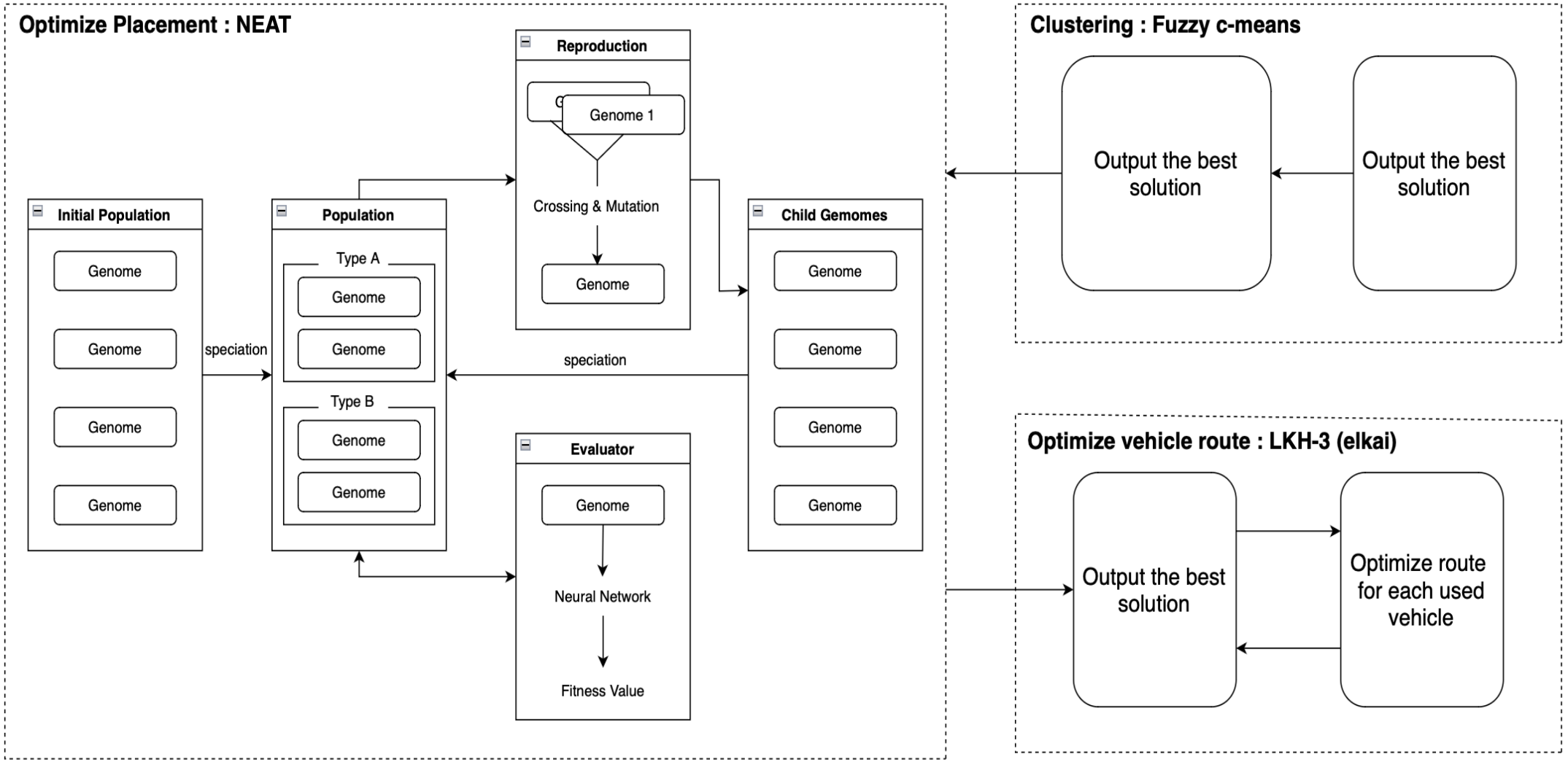
3



What is Neuroevolution of augmenting topologies(NEAT)?

NeuroEvolution of Augmenting Topologies (NEAT) was developed by Kenneth Stanley and Risto Miikkulainen in 2002 while at the University of Texas at Austin to generate evolving artificial neural networks (neuroevolutionary technology). It is a genetic algorithm (GA) for generating evolving artificial neural networks (neuroevolutionary technology). It attempts to find a balance between the fitness of the evolved solution and its diversity by modifying both the weighting parameters and the structure of the network.

Methodology (2)



Calculation of NEAT Adaptability

The genetic algorithm's bias is calculated by dividing the flow volume of each prefecture proportionally by the population of each municipality.

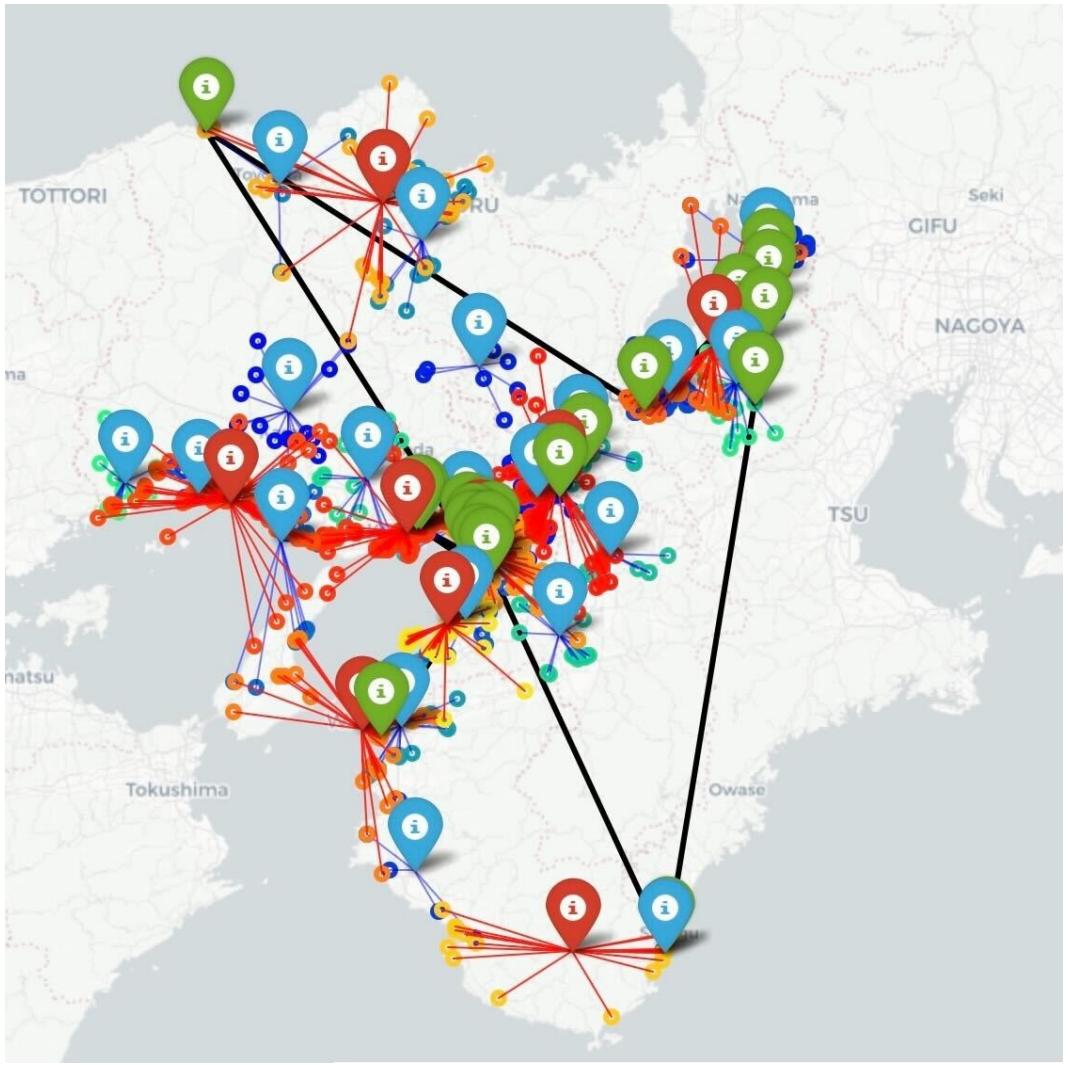
The probability that a logistics center will be located in a place with high flow volume (population) is high.

$$T_d = min \sum_{l_i, l_{i+1} \in L} \|l_i - l_{i+1}\| + min \sum_{l_i \in L} \sum_{s_{c_i} \in S_c} \|l_i - s_{c_i}\| + min \sum_{l_i \in L} \sum_{c_{c_i} \in C_c} \|l_i - c_{c_i}\| \quad (1)$$

$$p = \sum_{i=1}^{n} \sum_{v \in V} \sum_{s \in S} \mathrm{p} \times \alpha \times y_{sl}^{\alpha} - \varepsilon q_l + \sum_{s \in S} \sum_{\alpha \in A_s} \mathrm{p} \times \alpha \times y_{sv}^{\alpha} - q_l \quad (2)$$

$$f = \varepsilon \times (T_d - p * C_{penalty}) \quad (3)$$

Result (1)



Route Selection: LKH-3

Determination of logistics base: NEAT

==========

Blue points: Supplier

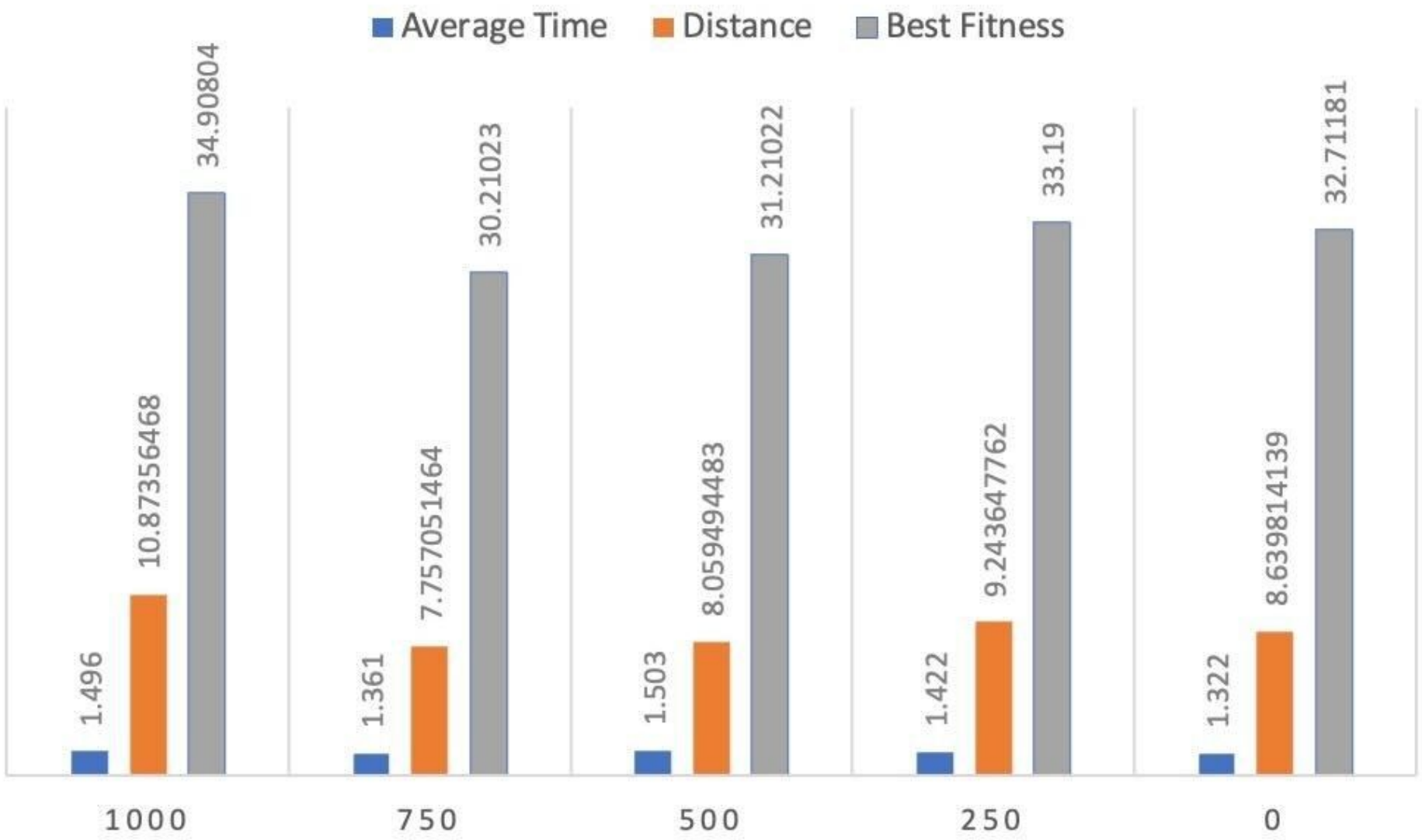
Blue pins: Supplier's accumulation points

Red points: Customer

Red pins: Customer's accumulation points

Green pins: π-hubs

Result (2)


Average Time
Distance
Best Fitness
1.496
10.87356468
34.90804
1.361
7.757051464
30.21023
1.503
8.059494483
31.21022
1.422
9.243647762
33.19
1.322
8.639814139
32.71181
1000
750
500
250
0

Conclusion

KOBE UNIVERSITY

- The hybrid method proposed by Pan et al. (2019)[1)] with the addition of region-specific flow bias and changing the algorithm from GA to NEAT allows for a more realistic simulation of optimal placement of logistics hubs and delivery route search, introducing the concept of PI.
- Derivation of the optimal number of clusters by the hybrid method using LKH-3, clustering, and genetic algorithm can be applied to other real data sets such as factory sites, logistics hubs, and important logistics roads, and can be applied to solve real problems in society
- Advancement of PI through this research will contribute to reducing greenhouse gas emissions in the logistics industry, alleviating truck driver shortages, and improving profit margins in transportation revenues.

1) https://www.tandfonline.com/doi/full/10.1080/00207543.2020.1856440

Future Issues

KOBE UNIVERSITY

- Although this study is limited to truck transportation, the challenge is to optimize the appropriate combination between different transportation modes and transportation planning based on the concept of the Physical Internet.
- Comparison and validation with other optimization algorithms is also needed.

Thank You.

KOBE UNIVERSITY