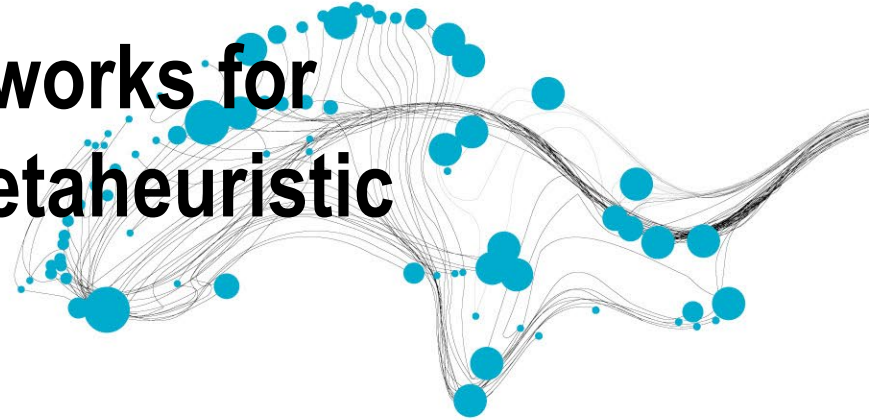


Hierarchical Distribution Networks for Vaccine Delivery: a SOAR metaheuristic



Dr. Giovanni Campuzano

Assistant Professor

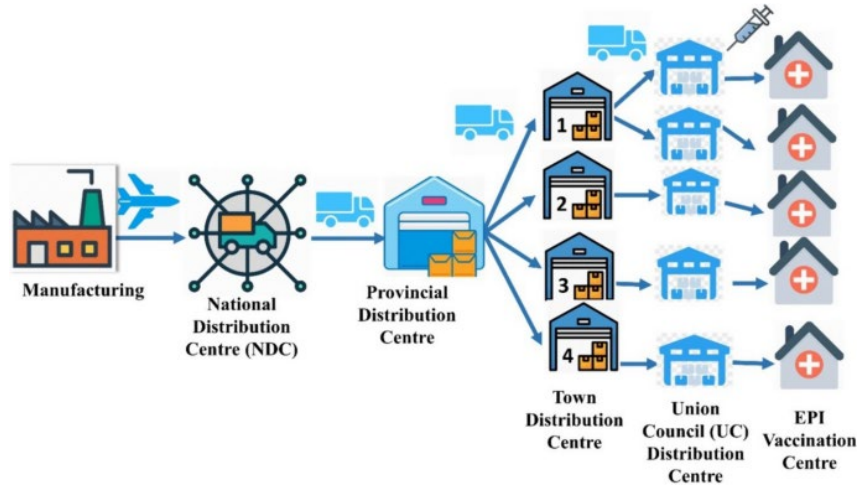
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MOTIVATION

- Vaccine Distribution in Chile Considering Geo-political subdivisions:



- The right vaccine to the right people at the right time.



MOTIVATION

- North of Chile:



- South of Chile:



MOTIVATION

- **Cities in the North of Chile:**
 - Higher temperatures.
 - Arid areas.
 - Isolated cities.



MOTIVATION

- **Cities in the Center of Chile:**
 - Several mountains around.
 - Cities located in valleys.
 - Rivers split the territory.



MOTIVATION

- **Cities in the South of Chile:**
 - Cities grouped in the coastline.
 - Sea levels might isolate areas.
 - Weather conditions might close highways.

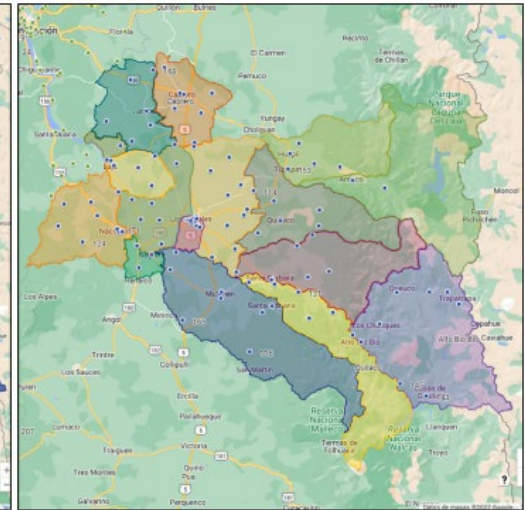


CLUSTERED GENERALIZED MEDIAN TOUR PROBLEM

- **Sub-division of the country:**
 - Regions, provinces, districts.
 - Geo-political administration.
 - Economic power of certain zones.
 - Natural barriers separate areas.



(a) Region of Biobío



(b) Province of Biobío and its districts

CLUSTERED GENERALIZED MEDIAN TOUR PROBLEM

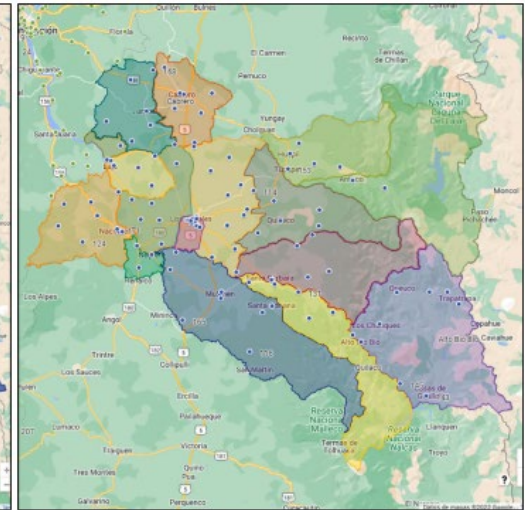
- **Sub-division of the country:**
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Governmental distribution systems must respect the administrative subdivision



(a) Region of Biobío

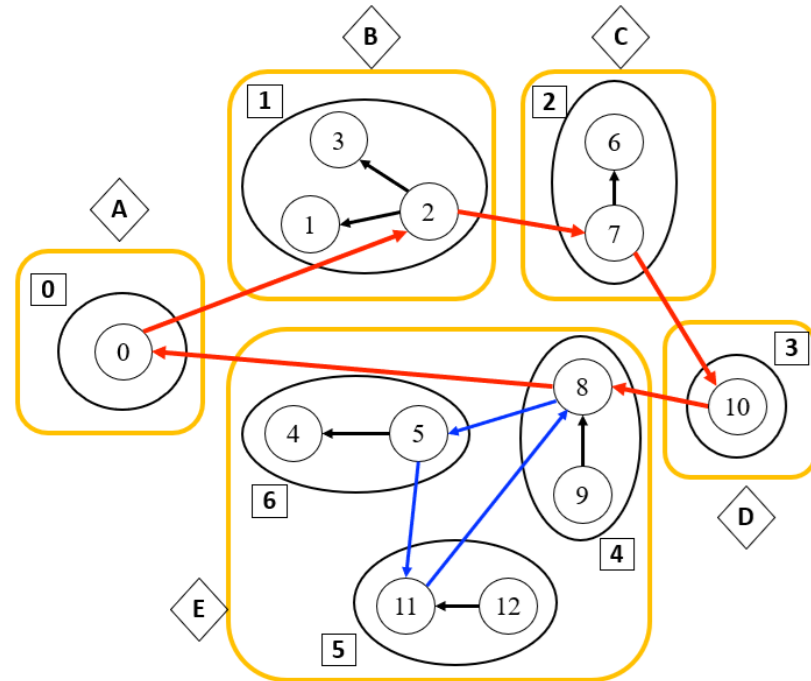


(b) Province of Biobío and its districts

CLUSTERED GENERALIZED MEDIAN TOUR PROBLEM

- **CGMTP:**

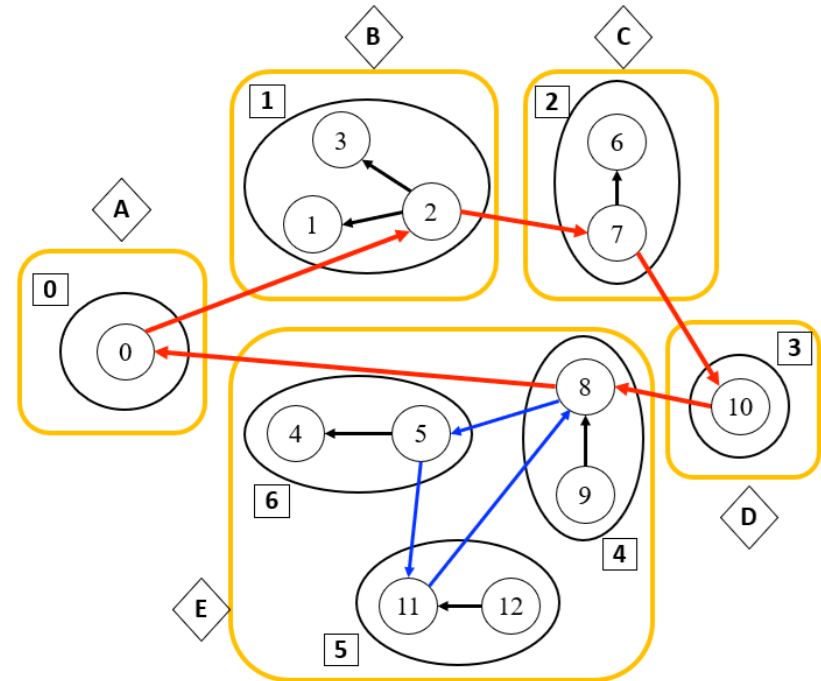
- ✓ Minimizes the transportation costs for the **vaccine distribution** system of the healthcare national authority, respecting the **geopolitical sub-divisions**.
- ✓ Develops a tactical-level optimization of the **vaccine distribution network** to health facilities.
- ✓ **Health facilities** are split into provinces (clusters) and districts (sub-clusters), considering hospitals, vaccination centers, etc.



CLUSTERED GENERALIZED MEDIAN TOUR PROBLEM

- **CGMTP:**

- ✓ First level (red arcs) uses a specialized vehicle to visit some clusters (not all of them), i.e., helicopter.
- ✓ Second level (blue arcs) uses road vehicles transporting vaccines to the non-visited sub-clusters, i.e., cold chain trucks.
- ✓ Third level arcs (black arcs) reach non-visited facilities from the closest visited node in the same cluster, i.e., cold chain ambulances.



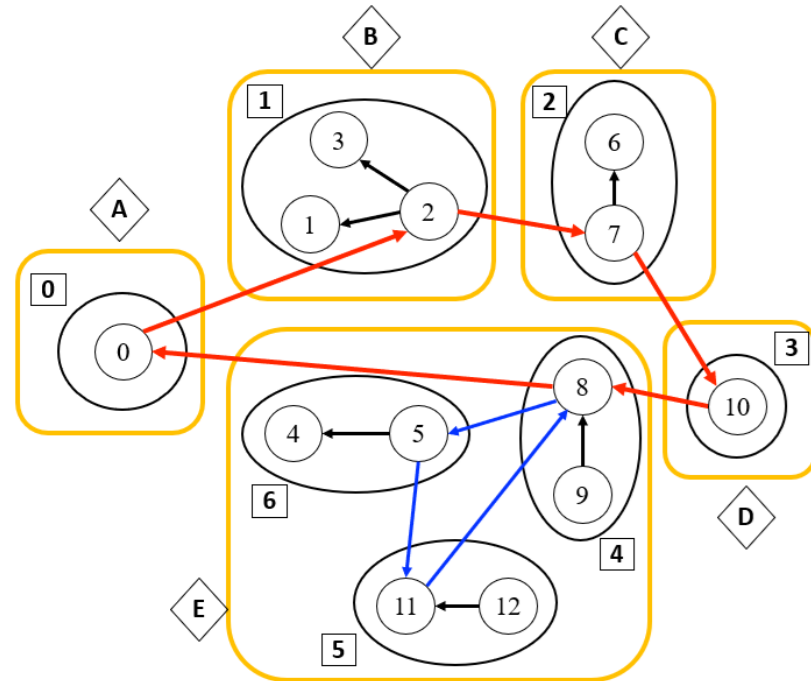
CLUSTERED GENERALIZED MEDIAN TOUR PROBLEM

- **CGMTP:**

- ✓ Time-temperature dependency limiting the maximum allowable **transport exposure**.
- ✓ Vehicles capacity for the **number of vaccines**.

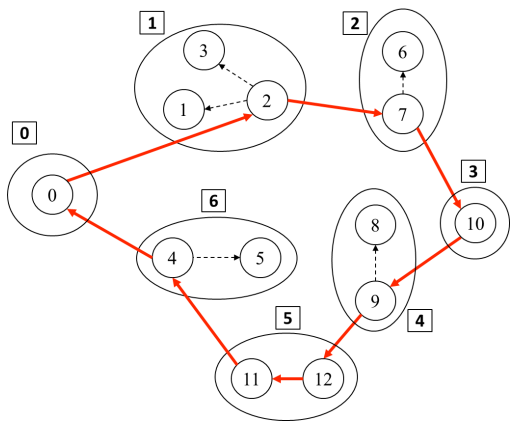


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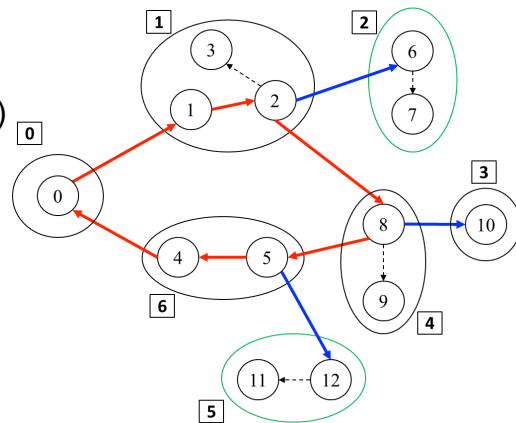


CLUSTERED GENERALIZED MEDIAN TOUR PROBLEM

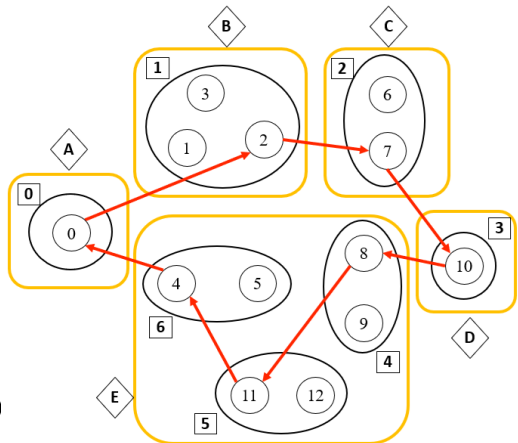
GMTP
(Obreque et al., 2020)



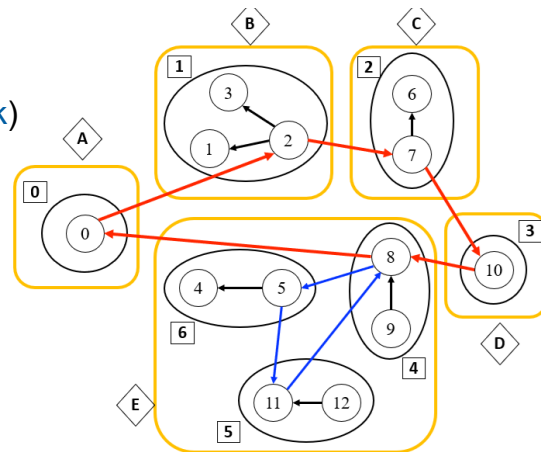
TLGMTP
(Obreque et al., 2024)



CGTSP
(Baniasadi et al., 2020)

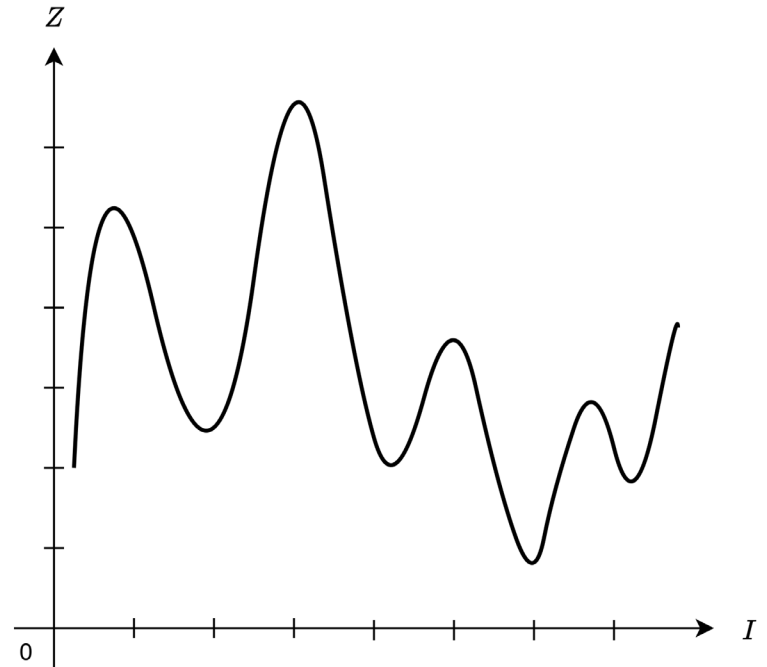


CGMTP
(This work)



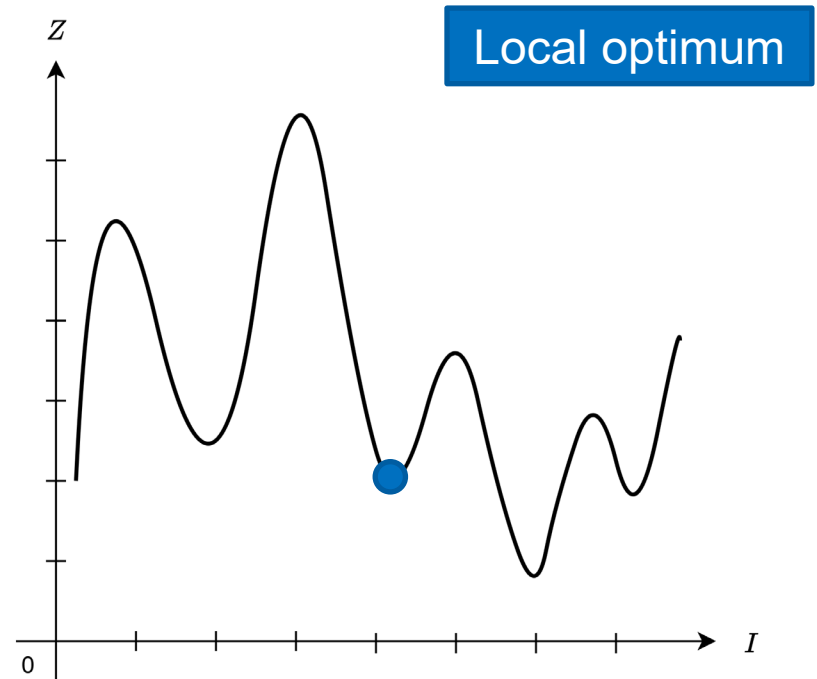
SOAR METAHEURISTIC ALGORITHM

- Adaptive Iterated Local Search:
 - Neighborhood Operators $N_l(\cdot)$
 - Perturbation Procedures $P_l(\cdot)$
 - Swapping
 - Insertion
 - 2-opt



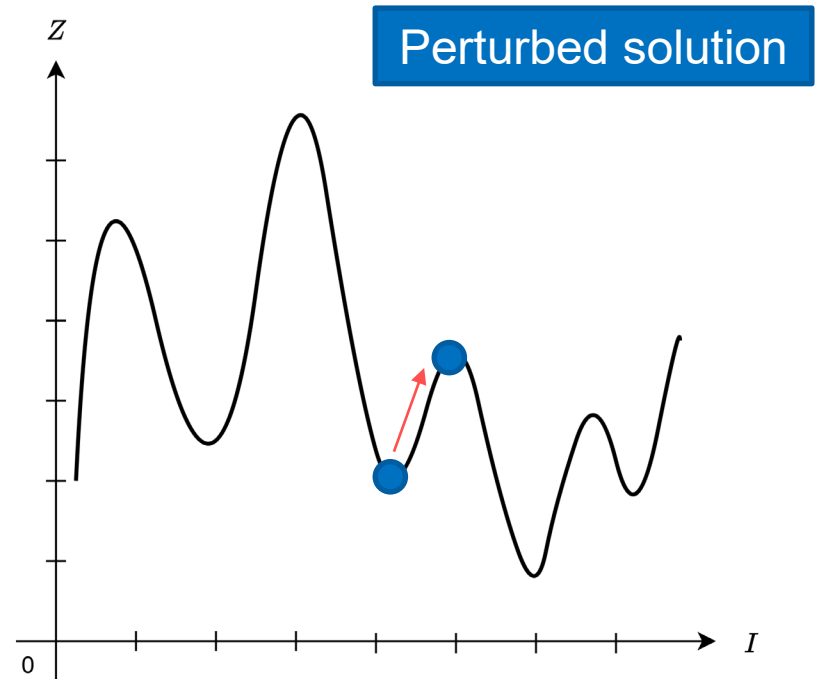
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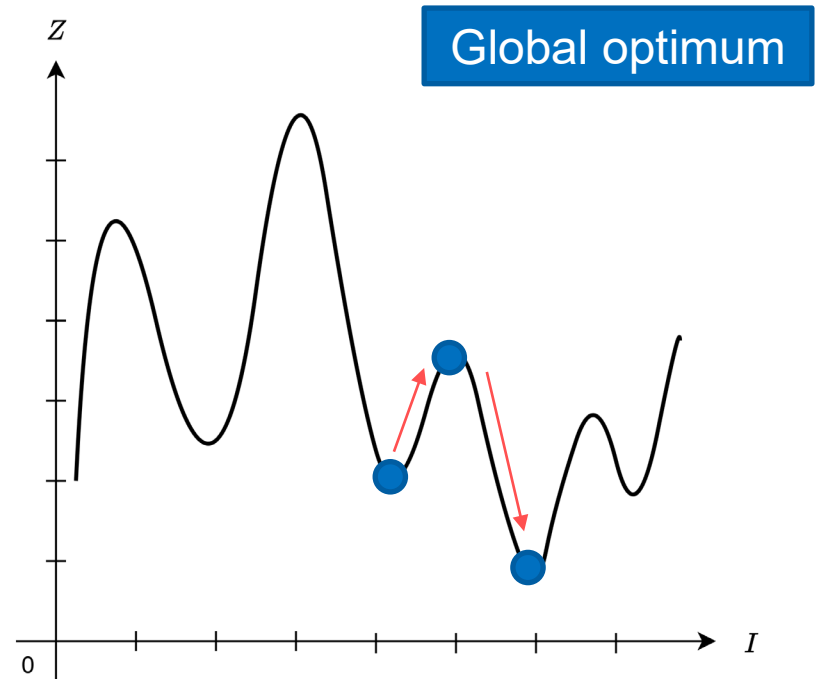
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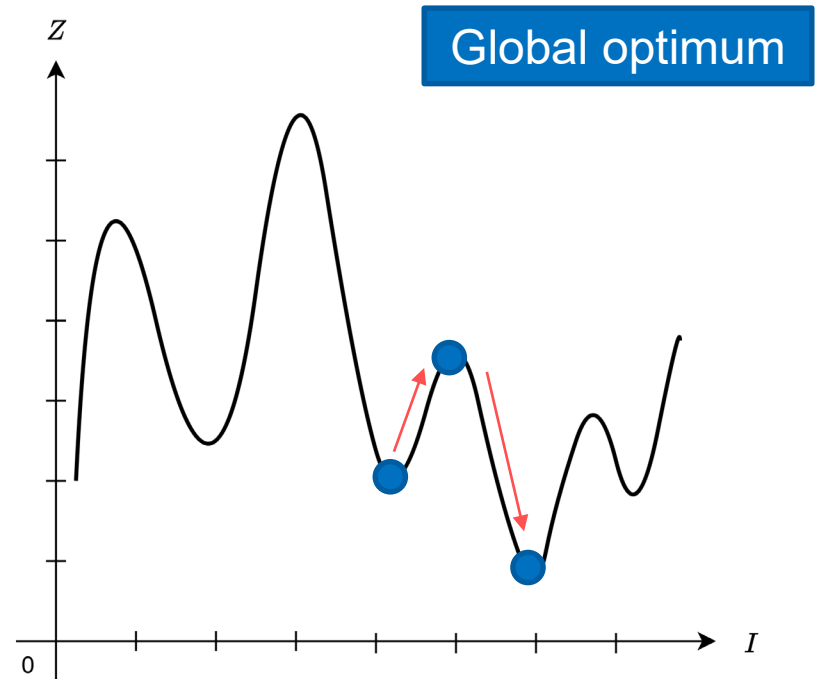
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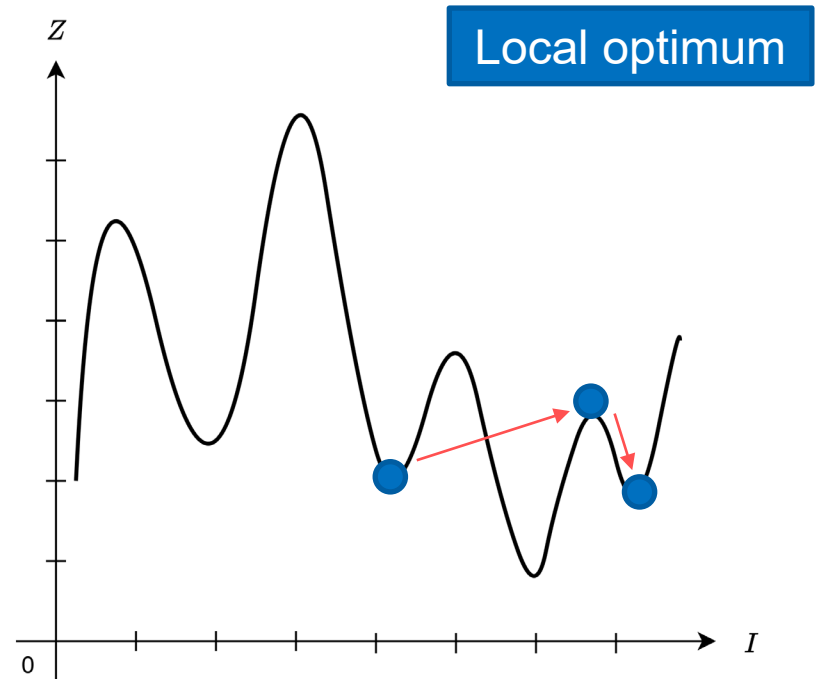
What is the main problem with this approach?



SOAR METAHEURISTIC ALGORITHM

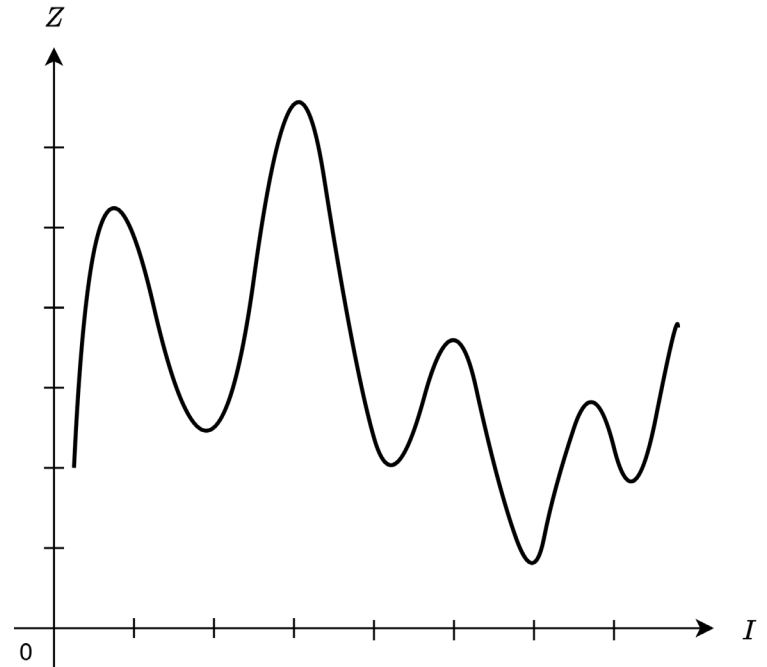
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Perturbation procedures can lead to the wrong regions



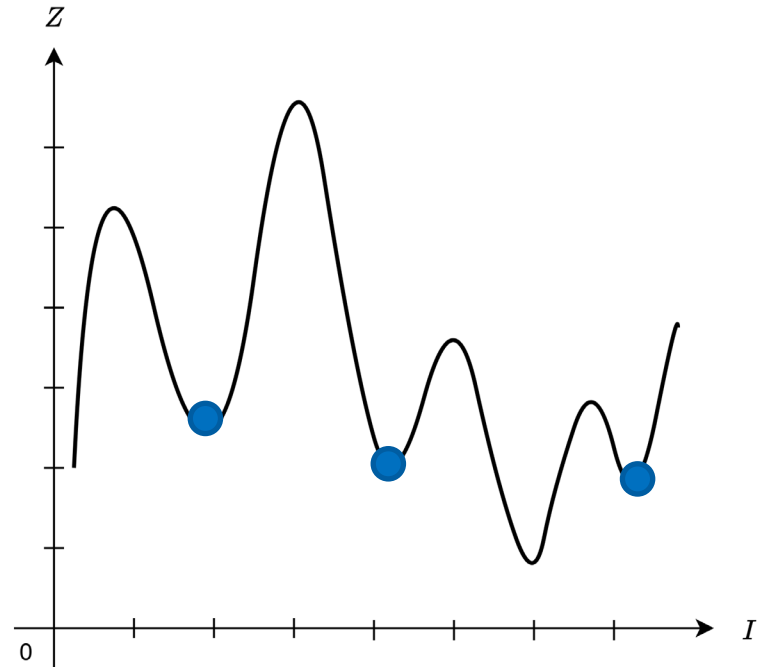
SOAR METAHEURISTIC ALGORITHM

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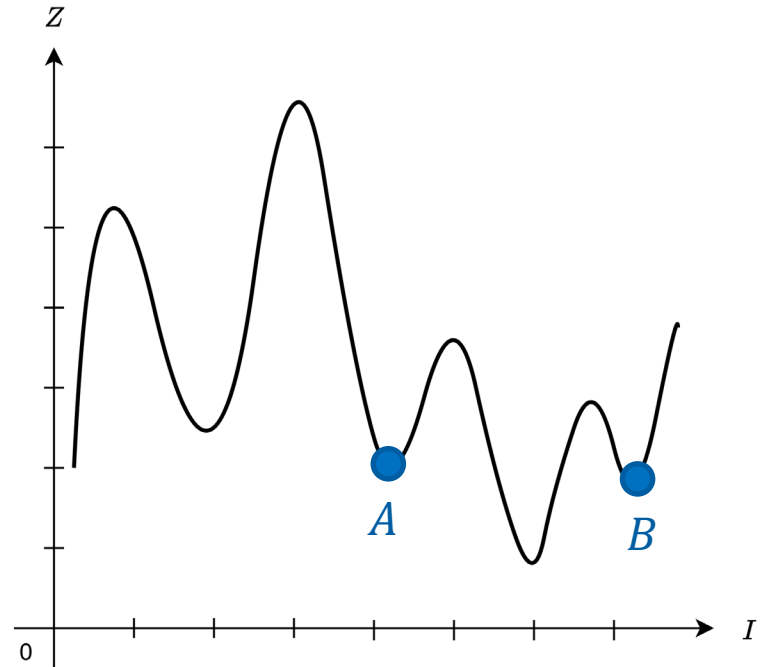
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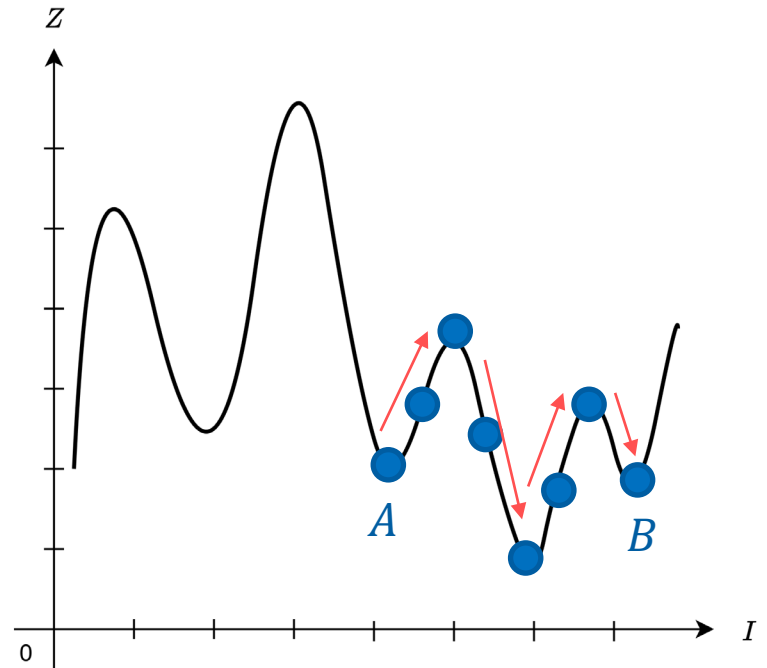
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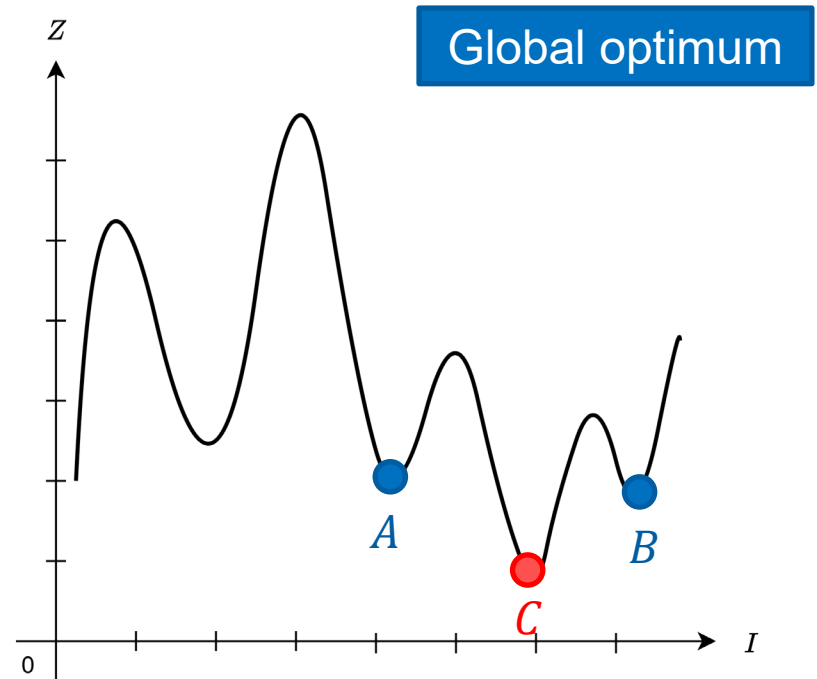
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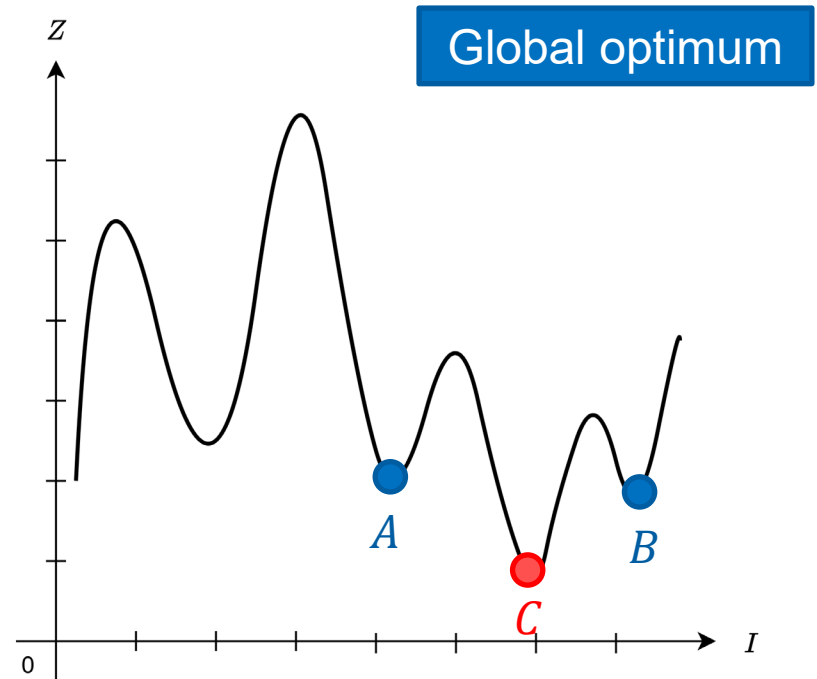
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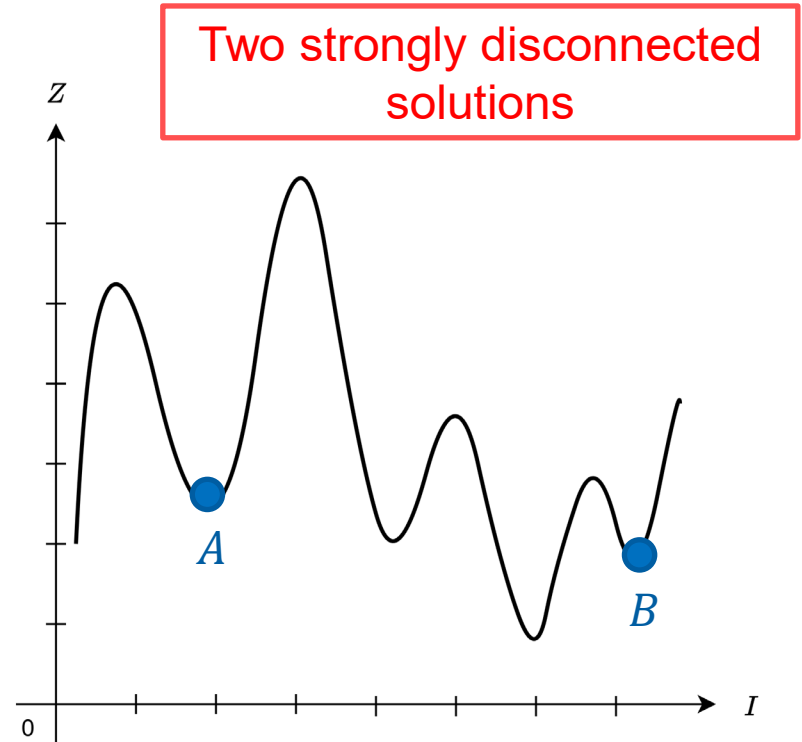
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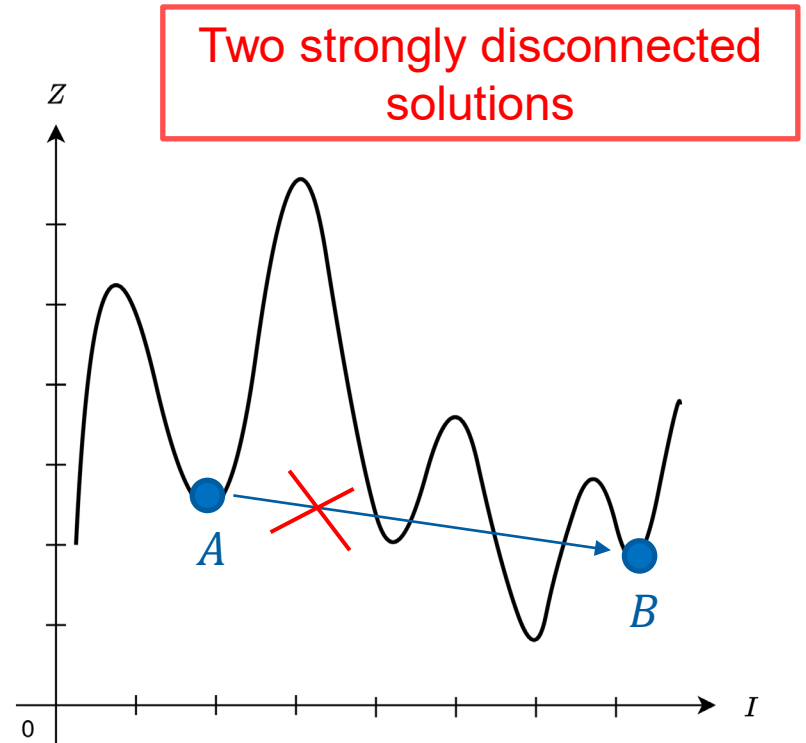
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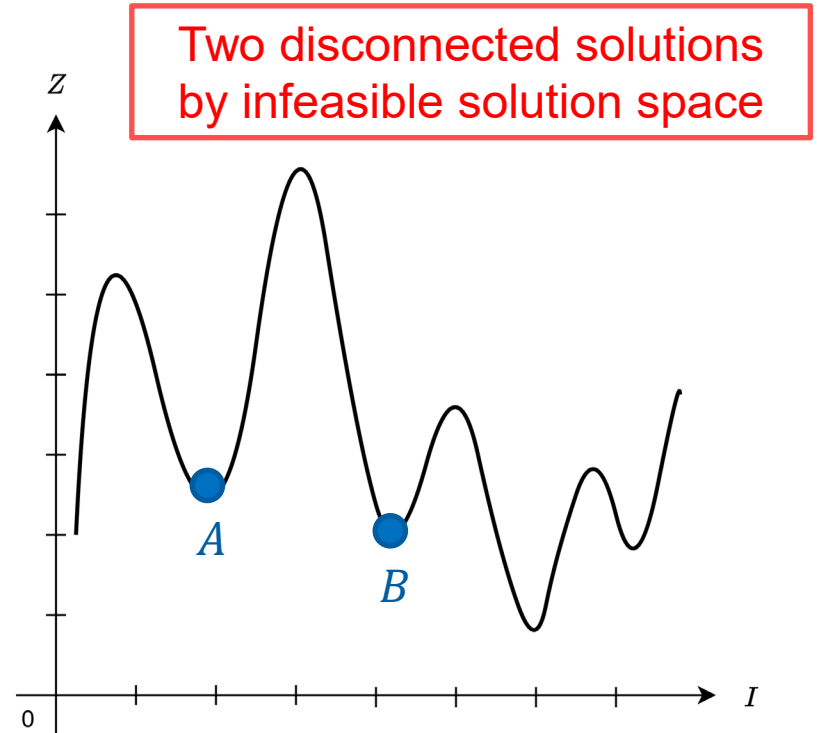
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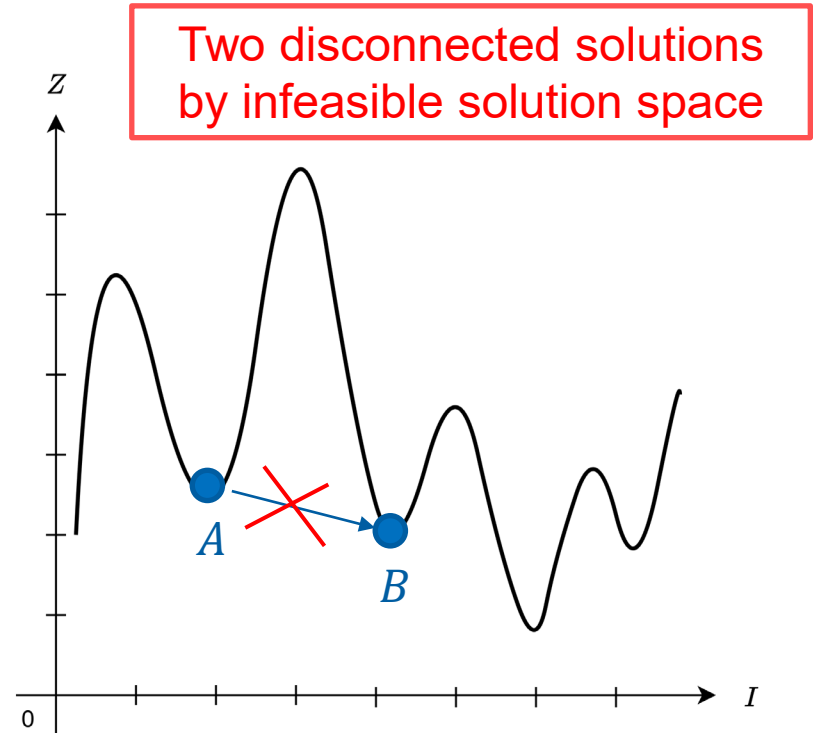
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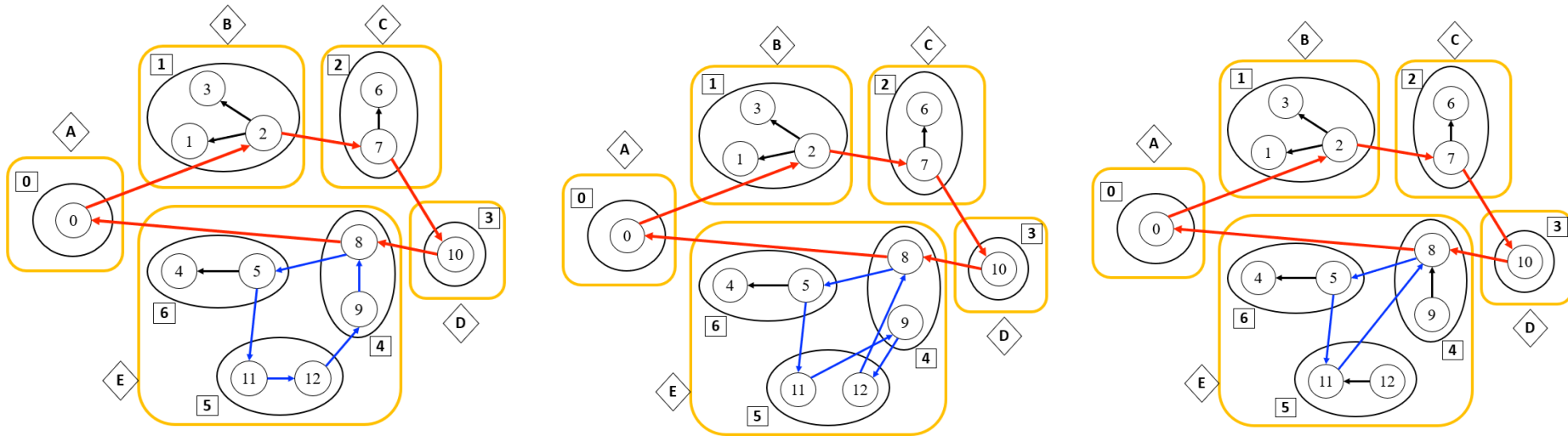
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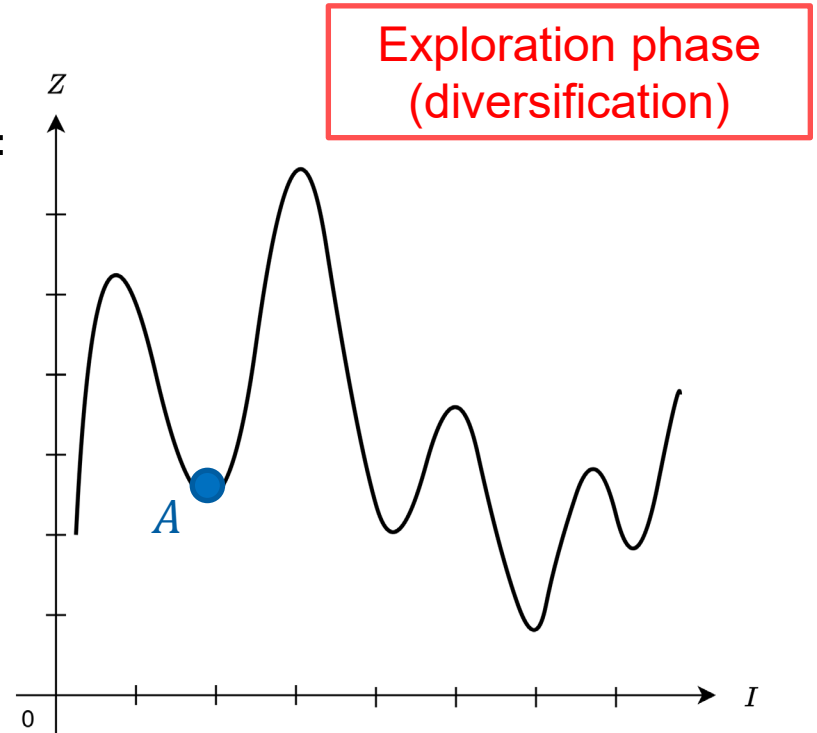
SOAR METAHEURISTIC ALGORITHM

- Strategic Oscillation:



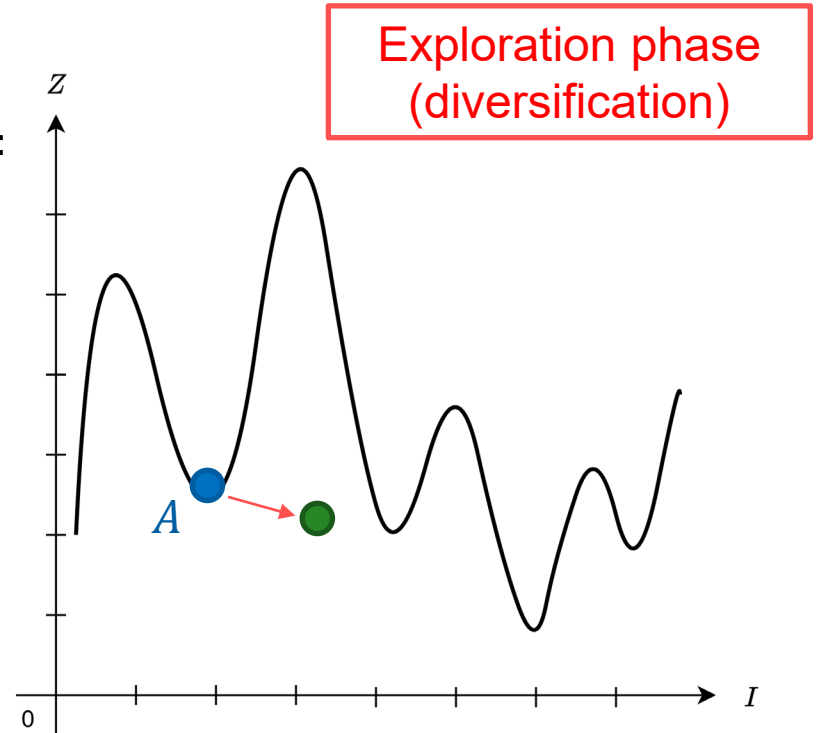
SOAR METAHEURISTIC ALGORITHM

- **Strategic Oscillation:**
 - Evaluation function (feasible and infeasible):
 - $F(x; \lambda) = f(x) + \lambda \cdot \phi(x)$
 - $\phi(x)$: *cost of violated arcs*
- **Procedure:**
 - **Diversification:** decrease penalty $\lambda \downarrow$
 - **Intensification:** increase penalty $\lambda \uparrow$



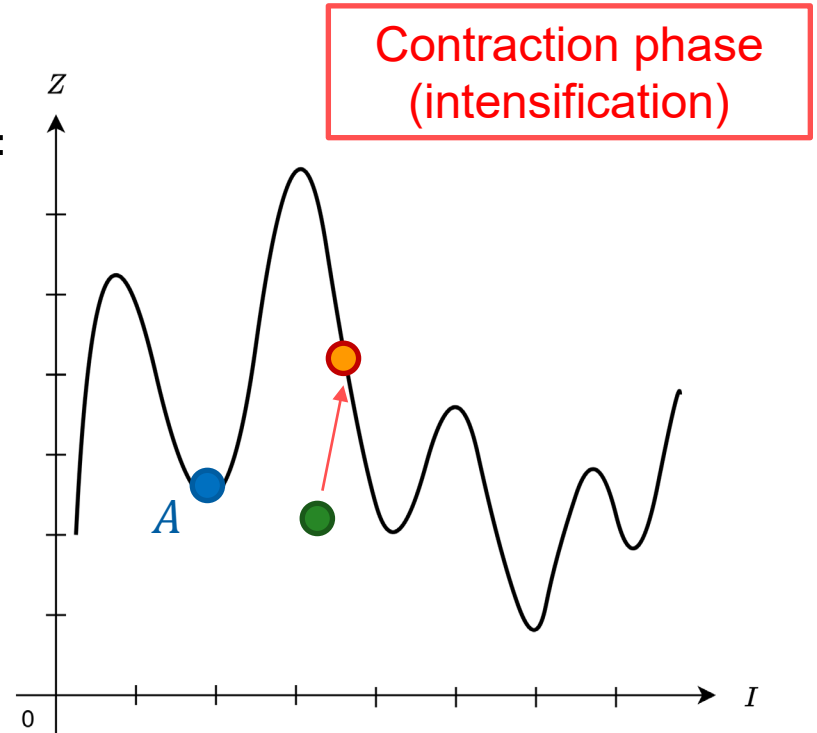
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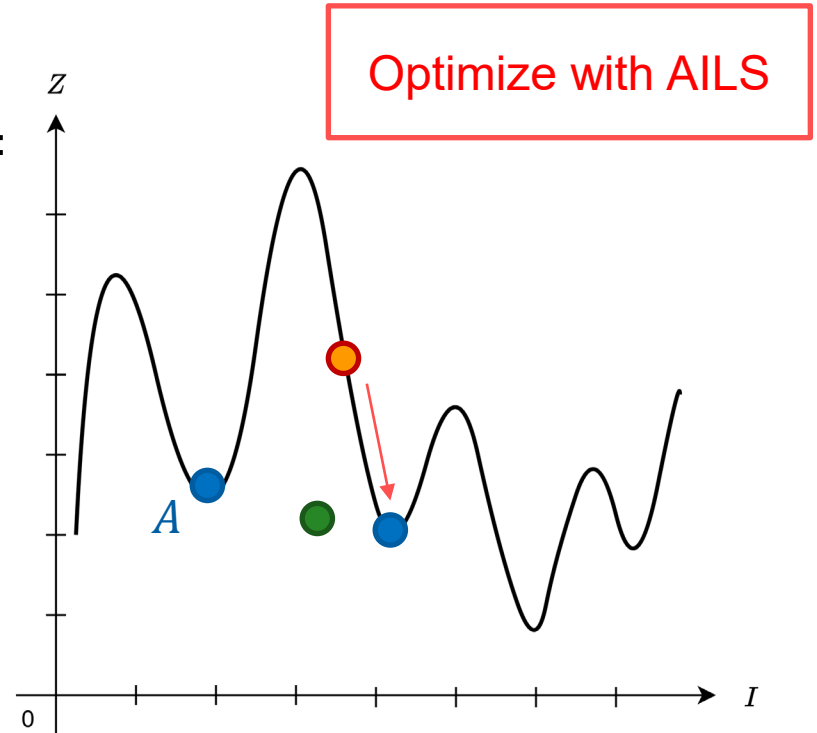
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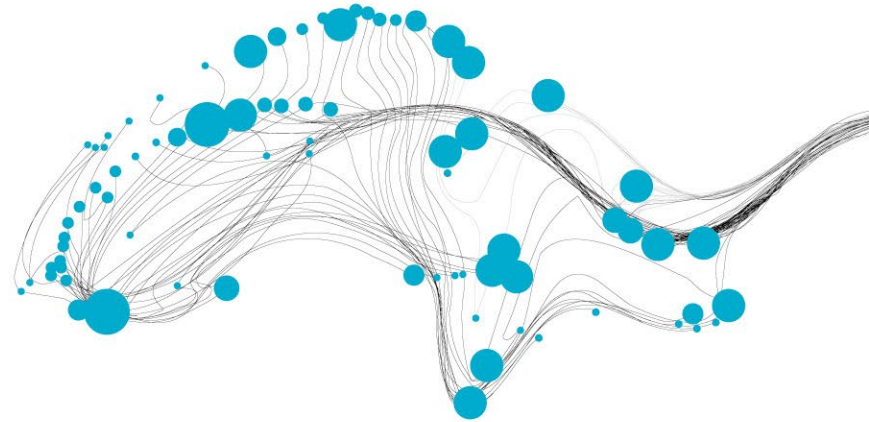


CONCLUSION AND FUTURE WORKS

- **To-Do List:**
 - Conduct a significance test to compare the performance of the metaheuristics.
 - Analysis of SOAR components.
 - Experiments for the applied case of Chile.
 - Comparison to TL-GMTP.

- **Future Works:**
 - Develop a Bender Decomposition algorithm.
 - Enhance SOAR with machine learning / reinforcement learning.

Questions ?



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