Construction de solution : Ant colony optimization

Réalisé Par:

M. ELMALIKI Marouane
M. MAKKAS Zakaria
M. SAIF Mohammed Marouane

Encadré par :

Pr. Aziz OUAARAB

Université Cadi Ayyad de Marrakech
Faculté des Sciences et Techniques Marrakech
Département : Informatique
Filière : Intelligence Artificielle et Ingénierie Informatique

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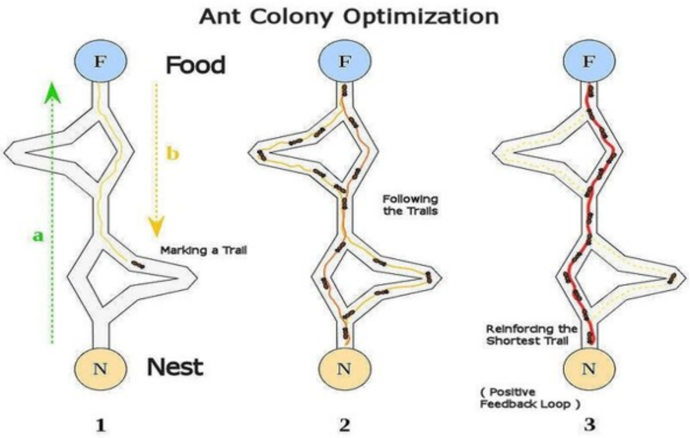
Plan:

Introduction

Context of Ant Colony Optimization

Ant Colony Optimization (ACO) is a recent method inspired by the behavior of real ants. ACO can be viewed as a branch of collective intelligence in artificial intelligence and as a metaheuristic in operations research. This review explores the origins of ACO, its methodology, applications, and theoretical significance, including its adaptation to continuous optimization and its hybridization with other methods in artificial intelligence and operations research.

Context of Ant Colony Optimization



Motivation for ACO in Solution Construction

- Behavior of Real Ants:

1. Ants aren't intimidated by the size of their workload
2. Ants value teamwork
3. Ants are organized
4. Ants save for rainy days
5. Ants get the job done

Motivation for ACO in Solution Construction

ACO is driven by its ability to efficiently and approximately solve optimization problems, particularly those classified as NP-hard. Instead of seeking optimal solutions, it prioritizes the rapid generation of good solutions, providing a valuable alternative for tackling complex problems. This approach draws inspiration from the behavior of ants, known for their skill in finding short paths, thereby enhancing the strength of ACO.

Fundamentals of ACO

Inspiration

Real ants solve complex problems by depositing pheromones on their paths, allowing other ants to quickly find food. In ACO, artificial pheromones are used to guide the search for solutions, reinforcing higher-quality solutions and exploring new possibilities.

Translation of Biological Concepts into Algorithms

Behaviors observed in real ants are translated into computer algorithms to solve optimization problems. Artificial pheromones are used to evaluate solution quality, favoring those leading to better solutions. This effectively explores the solution space for optimal or high-quality solutions.

Exploration and Exploitation in ACO

ACO balances exploration (search for new solutions) and exploitation (use of promising solutions) using artificial pheromones. Artificial agents follow pheromone trails to converge towards high-quality solutions while exploring new possibilities, preventing them from getting trapped in suboptimal solutions.

Solution Construction in ACO

Constructing Solutions in Ant Colony Optimization (ACO)

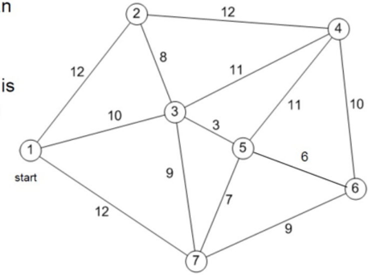
- Bullet points:
    - Create artificial ants.
    - Each ant represents a potential solution.

We kick off ACO by creating a team of artificial ants, each functioning as a potential problem solver.
These ants are ready to embark on the journey of constructing solutions to a given optimization problem.
The more ants we have, the more diverse strategies we can explore

Solution Representation

The Traveling Salesman Problem

- Starting from city 1, the salesman must travel to all cities once before returning home
- The distance between each city is given, and is assumed to be the same in both directions
- Only the links shown are to be used
- Objective - Minimize the total distance to be travelled



Solution Representation

- Bullet points:
  - Define how a solution is represented.
  - Example: In the Traveling Salesman Problem, a solution is an ordered sequence of cities.

In the world of ACO, solutions need a common language. This is where solution representation comes in. Imagine it as a code that ants understand. For example, in the Traveling Salesman Problem, a solution might be represented as a sequence of cities to visit, forming a route.

Construction of Solutions

- Bullet points:
  - Ants pick components from the solution space.
  - Choices are influenced by pheromone levels and heuristic information.

The real magic starts when ants begin constructing solutions. Each ant navigates the solution space, selecting components like cities in the TSP. This process is not random; it's guided by a combination of pheromone levels and heuristic information, creating a balance between exploration and exploitation.

Pheromone and Heuristic Information

- Bullet points:
  - Pheromones guide ants and attract others.
  - Heuristic information provides extra guidance.

  Ants don't make decisions blindly. As they move, they leave behind a chemical trail called pheromones. Other ants can detect these pheromones and use them as cues for making decisions. Heuristic information is like additional advice for ants, guiding them based on their understanding of the problem.

Solution Evaluation

- Bullet points:
  - After completing a solution, ants check its quality.
  - Use an objective function to measure how good the solution is.

  Once an ant completes its journey (constructs a solution), it evaluates the quality of its work. This evaluation is done using an objective function, a tool that measures how well the solution satisfies the problem requirements. Ants aim to create solutions that score high on this evaluation

Pheromone Update

- Bullet points:
  - Stronger solutions result in stronger pheromone trails.
  - Pheromone evaporation simulates decay over time.

  Ants communicate through pheromones, and the strength of this communication depends on the quality of their solutions. Better solutions mean stronger pheromone trails. To keep things realistic, we introduce pheromone evaporation, simulating the natural decay of these chemical cues over time.

Iteration

- Bullet points:
  - The process repeats for several iterations.
  - Ants get better at finding optimal solutions over time.

  Ants get better at finding optimal solutions over time. Solving complex problems is rarely a one-shot deal. We iterate the entire process, allowing ants to improve their strategies over time. With each iteration, the artificial ant colony converges towards finding better and better solutions, learning from past experiences.

1. Definition of the solution components set
   $C = \{c_{ij}, i = 1, \ldots, n, j = 1, \ldots, |D_i|\}$
2. Probabilistic solution construction
   At each construction step, the current partial solution S_{p} extended by adding a feasible solution component from the set of feasible neighbors $N(\mathsf{sp}) \subseteq C$
3. Representation of construction as a graph
   GC(V,E) is the construction graph, where V represents vertices (partial solution states) and E represents edges (transitions between states). Paths in this graph are defined by the solution construction mechanism.
4. Probabilistic choice rule of a solution component (Ant System)

$$p(c_{ij} \mid \mathsf{sp}) = \frac{\tau_{ij}^{\alpha} \cdot \eta_{ij}^{\beta}}{\sum_{cil \in N(\mathsf{sp})} \tau_{il}^{\alpha} \cdot \eta_{il}^{\beta}} \qquad\qquad c_{ij} \in N(\mathsf{sp})$$

Search Space Exploration

Exploration locale et globale :

- Dans le contexte de l'ACO, les fourmis peuvent effectuer une exploration locale en se déplaçant dans les environs immédiats de leur position actuelle, tout en réalisant également une exploration globale en parcourant des zones plus étendues de l'espace de recherche.
- L'exploration locale est utile pour découvrir des solutions proches, tandis que l'exploration globale permet d'explorer davantage l'espace de recherche pour des solutions potentielles plus éloignées.

Mécanismes d'évaporation des phéromones

- Dans le contexte de l'ACO, les phéromones déposées sur les chemins par les fourmis jouent un rôle crucial. Cependant, pour éviter une convergence trop rapide vers une solution, il est souvent nécessaire d'introduire des mécanismes d'évaporation des phéromones .
- Cela permet de garantir que les pistes ne restent pas trop influencées par les choix antérieurs des fourmis, laissant ainsi de la place pour l'exploration de nouvelles alternatives.

Impact de la visibilité de la solution sur la construction pour ACO

- L'impact de la visibilité sur la construction de la solution se réfère à la manière dont cette perception influence les choix des fourmis lorsqu'elles construisent leurs solutions.
- Une visibilité accrue peut conduire à une exploration plus sélective de solutions potentielles, tandis qu'une visibilité réduite peut encourager une exploration plus large de l'espace de recherche.
- Ces considérations visent à équilibrer l'exploitation des solutions connues et l'exploration de nouvelles alternatives.

Environment Adaptation(Intensification and diversification strategies)

Update of pheromone levels

The update of pheromone levels in ACO is crucial for guiding the search for solutions. Pheromones signal the quality of solutions, and artificial ants strengthen paths to better solutions by depositing more pheromones. This attracts other artificial ants to higher-quality solutions and discourages suboptimal ones. This pheromone update adjusts the search over time.

$$\Delta T_{ij,k}(t) = \frac{Q}{L(t)}$$

$$T_{ij}(t+1) = (1-\rho)\cdot T_{ij}(t) + \Delta T_{ij}(t)$$

Intensification strategie

- **Role of Intensification in Focusing Search**
  Intensification involves concentrating the search on promising areas of the search space. This strategy aims to further exploit existing solutions to improve them. When a region of the search space shows signs of containing high-quality solutions, intensification directs efforts towards that area. This can be achieved by reinforcing the pheromone levels on the paths leading to these promising solutions.

Diversification strategie

- **Strategies for Diversification to Avoid Stagnation**
  Diversification is a strategy aimed at preventing the search from getting trapped in a specific region of the search space. When the search appears to stagnate or make little progress, diversification introduces elements of novelty. This can involve exploring new areas of the search or modifying the behaviors of the artificial ants to encourage the discovery of different solutions.

Practical Application of ACO

Exemple de problèmes résolus avec succès

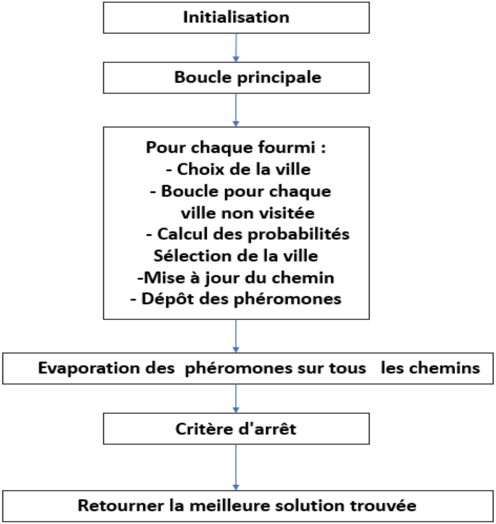
Dans le contexte du TSP, l'ACO a été utilisée avec succès pour trouver des solutions efficaces.

1. Modélisation du Problème
2. Dépôt de Phéromones
3. Exploitation et Exploration
4. Évaporation des Phéromones

Algorithme ACO pour TSP

1. Initialisation
2. Boucle principale (itérations)
3. Mise à jour des niveaux de phéromones
4. Critère d'arrêt
5. Retourner la meilleure solution trouvée

Architecture d'algoritme



Comparison with Other Solution Construction Approaches

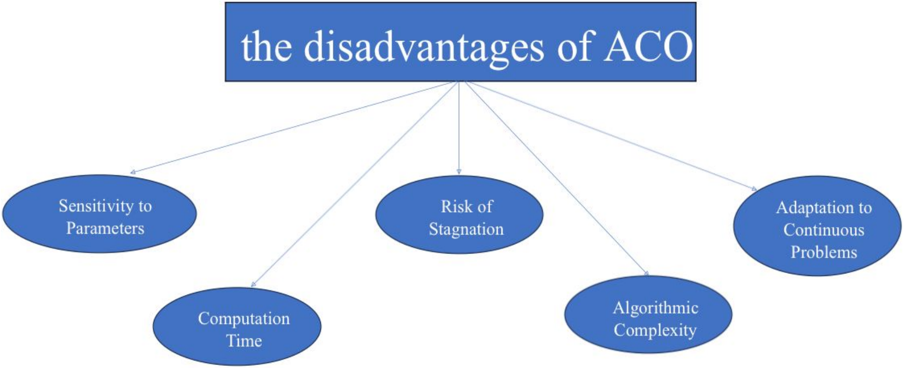
ACO vs Descente

Caractéristiques	**ACO**	**Descente**
Adaptabilité au Problème	Bonne	Moins adaptative
Complexité Temporelle	Dépend de la taille	Dépend de la rapidité
Sensibilité aux Paramètres	Sensible	Sensible
Taille d'espace de recherche	grands espaces	Limitté

ACO vs Recherche Tabou

Caractéristiques	**ACO**	**Recherche Tabou**
Adaptabilité au Problème	Bonne	Bonne
Complexité Temporelle	Dépend de la taille	Dépend de la rapidité
Sensibilité aux Paramètres	peut etre sensible	Sensible
Taille d'espace de recherche	grands espaces	espaces variés

Disadvantages of ACO



Conclusion

Références

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merci

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POUR VOTRE ATTENTION

ACO Implementation