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Ant Colony Optimization & Multi-Criteria Decision Aid

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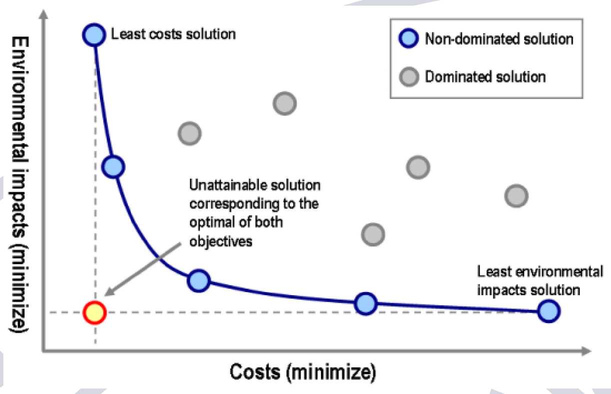
Ant Colony Optimization

Using the social insect metaphor has given raise to a great number of heuristics to solve **combinatorial optimization problems** (COP). Among these, the Ant Colony Optimization (ACO) heuristic has been one of the first heuristics of the kind, initiated by Marco Dorigo in the early 90's. ACO has proven to be a successful approach for various classical NP-hard problems encountered in combinatorial optimization, such as the traveling salesman problem (TSP), the quadratic assignment problem (QAP), graph coloring, job-shop scheduling, sequential ordering, vehicle routing, etc.
ACO is a population based algorithm, inspired by the collective foraging behaviour of ants. Pheromone trails are used for indirect communication (called *stigmergy*) between ants during the solution construction phase.

The basic steps of an ACO algorithm are :

- *Exploration* : The solution is constructed by each ant based on the pre-existing pheromone trails
- *Evaluation* : The objective function is evaluated for each solution built by an ant
- *Pheromone deposition* : Pheromone trails around best solutions are reinforced



In recent years, interest has raised for extending ACO algorithms to multi-objective optimization problems. Although several approaches have been considered, no general framework has established yet.

Advantages

1. Highly **robust** against local minima
2. **Fast convergence** to the optimal solution(s)
3. Search in solution space without an initial guess

Drawbacks

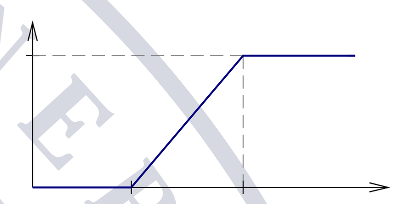
1. Most current versions of MOACO handle multi-objectives in a simplistic way (dominance relation)
2. Exploration of the whole pareto optimal front can reveal prohibitively costly
3. The number of non-dominated solutions returned can be too big to be usable in practice

Multi-criteria Decision Aid

Multi-criteria Analysis (MCA) is composed of a set of mathematical methods that take **several, sometimes contradictory criteria** into consideration and aggregate them in order to find **good compromises**, rather than an optimal solution that does not always exist.
Several families of problems are usually addressed by these methods :

- *Choice* : Choosing one or more "best" actions within a set of possible choices
- *Sorting* : Assignation of each action to the most appropriate of defined set of categories
- *Ranking* : Ranking of all considered actions from the best to the worst

MCDA methods extend the dominance relation between two actions which is based on the comparison of the value of the evaluation function on each criterion. A finer caracterisation of the relation can for example be achieved by introducing indifference and preference thresholds. These thresholds lead to define a richer preference relation, including indifference and incomparability between each pair of actions.



The value of the outranking relation between two actions, denoted π in the PROMETHEE methods, aggregates the outranking relation over each criteria by a weighted sum :

$$\pi(a, b) = \Sigma_j \, w_j F_j(a, b)$$

where w_j is the weight associated to criterion j.

Drawbacks

1. MCDA tools are often unable to efficently deal with very large sets of possible choices.

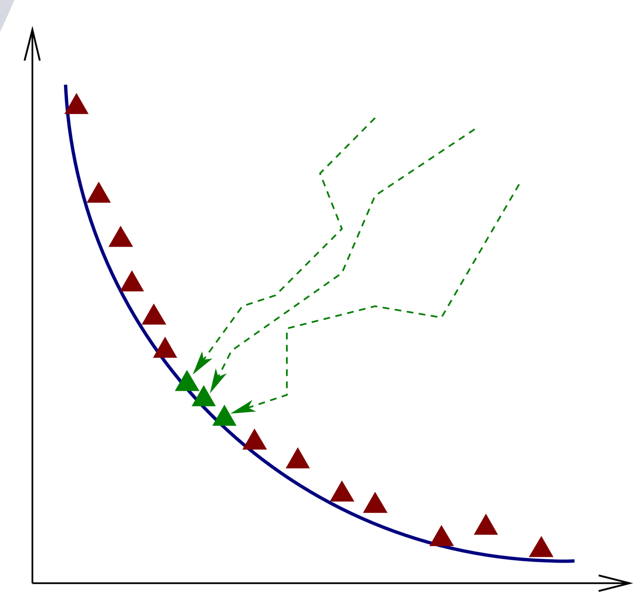
Advantages

1. The way a decision maker compares actions can be modeled with more subtelty than solely with the concept of dominance.
2. The formalism remains simple, thus easily understandable by the decision maker.

Taking the best of both approaches

Allying both approaches should **facilitate tackling complex decision problems** that are caracterized by a great number of possible choices. The aim being to provide the decision maker with a more concise yet stronlgy value added information.
The basic idea would be to perform the search through the solution space in a more directed manner, already taking the preference structure of the decision maker into account.
A non exhaustive series of potential benefits can be identified :

- Save computation time through oriented search as opposed to exploration of the whole pareto optimal frontier
- Provide the decision maker with a **restricted amount of information**, thus making handling of it easier
- Explore several **preference scenarios** in parallel by giving one or several ants specific preference structures



Potential Application Domains

Rational Drug Design 

The area of drug design is an example where this kind of approach could reveal to be highly efficient. Since each experiment in the drug development phase most often requires time and implies important financial resources, pharmaceutical companies are interested in optimizing the design phase and to carry out the actual experiments on a reduced set of preselected items. During this phase, the aim is to analyse the interactions between the drug and its receptor site and to design the molecules that give an optimal fit.

Telecommunication Network Migration

The appearance of new technologies regularly obliges telecommunication network managers to install new specific hardware. In such cases, they need to create a propagation strategy of this new techology over the existing network. Such a strategy not only has to follow technological requirements, but must also integrate marketing considerations, consumer habits and alike. With regard to the great number of possible combinations of how to perform the upgrade over the network and the multiple criteria that come into consideration, a mixed approach as the one proposed could give promising results.

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