METAHEURISTICS

Most important terms

Single-Solution Based Metaheuristics

Repair Mechanisms

Parameter Tuning

Single-Solution Based Metaheuristic (SBH)

improve a single solution

"walks" through neighborhoods

Iteratively move from the current solution to another one

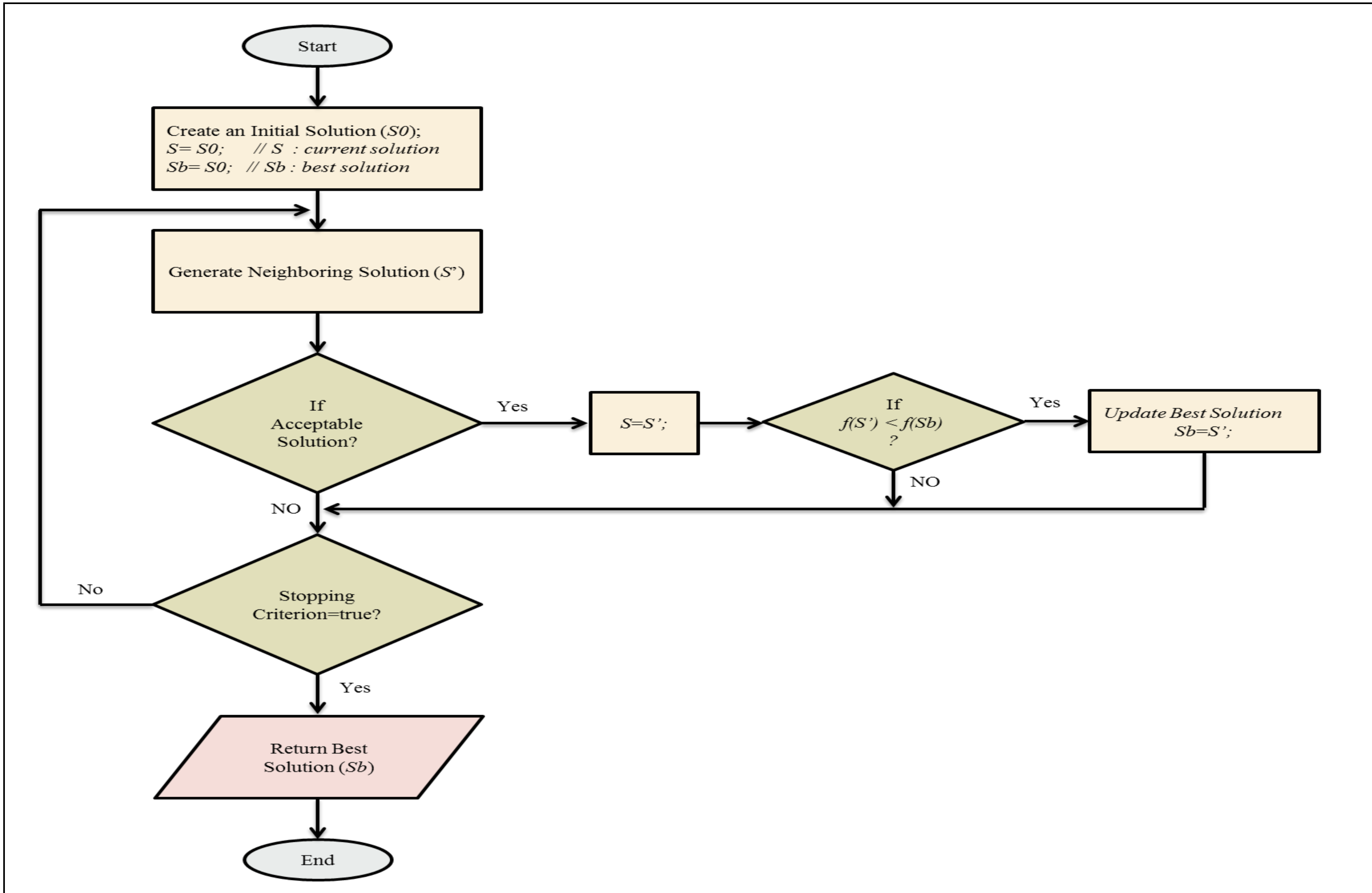
Generate an initial Sol. (***S***)

While Improvement is possible Do

modifying and improving (***S***)

Return (***S***)

Single-base Meta-heuristics



Single-base Meta-heuristics - Generate an Initial Solution

Two main strategies are used to generate the initial solution:

Greedy strategy

- makes the locally best choice at each step
- reduced polynomial-time complexity.
- often leads to better quality local optima.
- less iterations to converge toward a local optimum.

Random strategy

- Generating a random initial solution is a quick operation.
- take much larger number of iterations to converge.

To improve the robustness, a hybrid strategy may be used. It consists in combining both: random and greedy.

Note1

using better solutions as initial solutions does not always lead to better local optima.

Note2

There is always a trade-off between the use of random and greedy initial solutions in terms of the quality of solutions and the computational time

depend on the efficiency of the random and greedy algorithms and the SBH properties.

Ex: The larger is the neighborhood, the less is the sensitivity of the initial solution to the S-metaheuristics performance .

Single-base Meta-heuristics

Neighborhood Structure	The types of movements applied in local searches are called neighborhood functions or neighborhood structures because they access to neighboring solutions and define the size of the neighborhood.

- The neighborhood structures have a prominent role in the performance of any SBH
- The existence of adequate neighborhood leads to enhance the ability of a SBH to generate good solutions.

Zapfel, G., R. Braune & M. Bogl. 2010. Metaheuristic search concepts Ed.: Springer.

Neighbors of a solution are obtained via making minor changes to the solution using neighborhood structures or move operators

Def.

Search space is a directed graph G = (S,E), where the set of **vertices S** corresponds to the solutions of the problem that are defined by the representation (encoding) used to solve the problem, and the set of **edges E** corresponds to the move operators used to generate new solutions (neighborhood in SBH).

There is an edge e_{ij} between solutions S_i and S_j if the solution S_j can be generated from the solution S_i using a move operator; that is, S_i and S_j are neighbors.

Single-base Meta-heuristics

Accepting Criteria

The acceptance criteria are one of the important components of the SBHs which determine the acceptance of the neighbor solution. **It has a significant role to escape from the local optima**.

A ***local optimum*** is a point in the search space where all neighboring solutions are worse than the current solution.

Burke, E. K. & G. Kendall. 2005. Search methodologies: introductory tutorials in optimization and decision support techniques Ed.: Springer.

Strategies can be applied in the selection of the Neighbor:

Best improvement	First improvement	Random selection	Accept all solutions
whole neighborhood of the current solution is generated and the best neighboring solution is accepted	neighboring solutions are generated one by one until the first neighboring solution that improves the current solution is accepted	The whole neighborhood of the current solution is generated. Among all improving neighbors, a neighbor is randomly accepted.	Any generated solution is accepted regardless of its quality. This kind is adopted to diversify the search

Single-base Meta-heuristics

Types of acceptance criteria:

Deterministic acceptance criteria	same decision is always returned no matter the initial and current solution.
Non-deterministic acceptance criteria	Different decisions are usually returned even if the initial solution is the same.
	Usually, in this kind of criteria, there are few parameters that have a significant impact on the acceptance or rejection the neighbor according to the acceptance probability.

Single-base Meta-heuristics

Stopping Criteria

The important issue that should be taken into consideration when designing SBH is how to determine the termination criterion.

inappropriate choice of stopping criterion leads either to stopping the search process before finding the optimum solution or to causing waste of time.

The stopping criterion may depend on:

- **the maximum number of non-improving iterations**.
- **the maximum number of iterations.**
- **the maximum amount of running time**.

Burke, E. K. & G. Kendall. 2005. Search methodologies: introductory tutorials in optimization and decision support techniques Ed.: Springer.

Single-base Meta-heuristics - Examples

LOCAL SEARCH/ HILL CLIMBING	By Holland
SIMULATED ANNEALING	By Kirkpatrick
TABU SEARCH	By Glover
ITERATED LOCAL SEARCH	By Martin
VARIABLE NEIGHBORHOOD SEARCH	By Hansen
GUIDED LOCAL SEARCH	By Voudouris
GRASP	By Feo

Single-base Meta-heuristics - Examples

LOCAL SEARCH/ HILL CLIMBING

Local search algorithm.
s = s_0 ; /∗Generate an initial solution s_0∗/
While not Termination Criterion **Do**
Generate (N(s)) ; /∗Generation of candidate neighbors∗/
If there is no better neighbor **Then** Stop;
s = s′; /∗Select a better neighbor s′∈ N(s)∗/
Endwhile
Output Final solution found (local optima).

Single-base Meta-heuristics - Examples

Advantages:

- Very easy method to design and implement
- Gives fairly good solutions very quickly
- widely used optimization method in practice

Disadvantages:

- very sensitive to the initial solution
- converges toward local optima

Works well if there are not too many local optima in the search space.

Single-base Meta-heuristics - Examples

In order to avoid becoming stuck at local optima, many alternatives algorithms have been proposed. Different families of approaches can be used to avoid local optima

- Iterating from different initial solutions
- GRASP
- Iterated local search
- Accepting nonimproving neighbors
- tabu search
- Simulated annealing
- Changing the neighborhood structure
- variable neighborhood search

Single-base Meta-heuristics - Examples

SIMULATED ANNEALING

Simulated annealing algorithm.

Input: Cooling schedule.

$s = s_0$; /∗Generation of the initial solution∗/

$T = T_{max}$; /∗Starting temperature∗/

Repeat

Randomly generate a random neighbor s′;

$\Delta f = f(s') - f(s)$; /*For minimization problem*/

If $\Delta f \leq 0$ Then s = s′/∗Accept the neighbor solution∗/

Else Accept s′ with a probability $e^{\frac{-\Delta f}{T}}$;

$T = g(T)$; /∗Temperature update∗/

Until Stopping criteria is satisfied /∗e.g. $T < T_{min}$∗/

Output: Best solution found.

THANK YOU

$$e^{\frac{-\Delta f}{T}}$$