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SimILS

A Simulation-based extension of the Iterated Local Search metaheuristic for Stochastic Combinatorial Optimization

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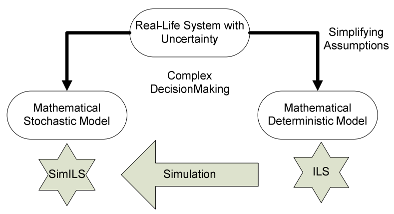
Outline of the Presentation

- Introduction
- Iterated Local Search Method
- SimHeuristics
- SimILS
- Conclusions
- Directions of future work.



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Search...

*Levantou-se, e, fiel à regra de que em todas as operações de busca o melhor é começar sempre por uma ponta e avançar com **<u>método e disciplina</u>**, atacou o trabalho pelo extremo de uma fileira de estantes, resolvido a não deixar papel sobre papel sem verificar se, entre o de baixo e o de cima, outro papel não estaria escondido.*

Todos os nomes, José Saramago, Editoral Caminho, 1999

"He stands up and, following the law that in all search operations the best thing is always to start from one point and **<u>advance methodically and with discipline</u>**, he attacks the job from one end of the bookshelf, resolved not to leave any page unturned without checking whether, between the lower and upper one, there is another paper hidden."

All the names, José Saramago

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Local optimization algorithms

- Given a solution, attempts to improve this solution by making local modifications at each iteration.
  - Local search
    - 1. Get an initial solution *x* (current solution). Use a constructive heuristic.
    - 2. Search the neighborhood. While there is an untested neighbor of *x*:
      - 2.1 Let *x'* be an untested neighbor of *x*;
      - 2.2 If *c(x')<c(x)* set *x=x'*; (*x'* is the new current solution)
    - 3. Return *x* (local optimal solution).

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Iterated Local Search

- A Local Search Method.
- Combines local optimization with a big transition/perturbation.
  - Diversification strategy based on the structure of the problem.
  - ***Optimization techniques***
- Local optimal solutions.
- Able to make large changes at any stage of the algorithm.

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Iterated Local Search

- Get an **initial solution** x;
  - * Heuristic method or a random solution.
  - * **local optimization** method
- For a certain number of iterations:
  - **Perturbation Step**
    - * method that makes a large modification based in optimization and on the structure of the solution x, resulting in x’.
  - Small-steps
    - * **local optimization** method, initial solution x’; final solution x’’.
  - Perform an accept/reject test
    - * accept all solutions, accept with a certain probability or accept only if it is a better solution.
    - * If x’’ is accepted, then x = x’’.
- Return the best solution found.

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Iterated Local Search

▸ Main References

* **Lourenço H.R.**, Martin O. and Stützle T. (2010), Iterated Local Search: Framework and Applications. In *Handbook of Metaheuristics, 2nd. Edition*. Vol.146. M. Gendreau and J.Y. Potvin (eds.), Kluwer Academic Publishers, International Series in Operations Research & Management Science, pp. 363-397.
* **Lourenço H.R.,** Martin O. and Stützle T. (2003), Iterated Local Search. In Handbook of Metaheuristics, F. Glover and G. Kochenberger, (eds.), Kluwer Academic Publishers, pp. 321-353.
  – More than 980 citations in Google Scholar

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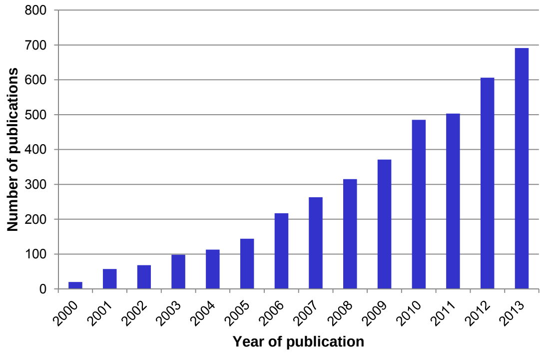
Iterated Local Search

▸ Google Scholar's number of publications for "Iterated Local Search"



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Stochastic Combinatorial Optimization Problems

- Stochastic Combinatorial Optimization Problems
  - Uncertainty is present – Random Data
  - Example: Stochastic Demand in Vehicle Routing Problems
  - Strategic Problems
- SimILS: Simulation + Iterated Local Search
- Extends ILS to solve Stochastic Models.

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SimHeuristics

- Four approaches to simulation optimization:
  - gradient-based and random search algorithms
  - evolutionary algorithms and metaheuristics
  - mathematical programming-based approaches
  - statistical search techniques.
    - * Fu M C, Andradóttir S, et.al (2000).
- (TB-41) Simheuristics: Hybridizing Simulation with Metaheuristics for Decision-Making under Uncertainty
  - Angel A. Juan, Scott Grasman, Javier Faulin, Markus Rabe,Tolga Bektas

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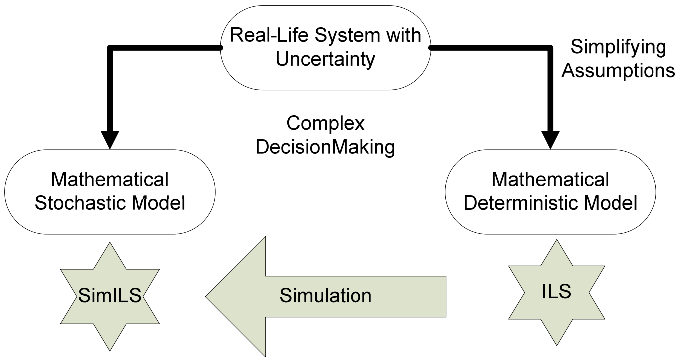
Stochastic Combinatorial Optimization Problems

- SimILS



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SimILS

Procedure *SimILS*

$s_0 = GenerateInitialSolution$

$s^* = LocalSearch(s_0)$

$(s^*, sf(s^*), statistics) = Simulation(s^*, \text{long})$

Repeat

$s' = Perturbation(s^*, \text{history})$

$s'^* = LocalSearch(s')$

$(s'^*, sf(s'^*), statistics) = Simulation(s'^*, \text{short})$

$s^* = AcceptanceCriterion(s^*, s'^*, \text{history})$

Until termination condition met

$(s^*, sf(s^*), statistics) = Simulation(s^*, \text{long})$

Return $s^*, sf(s^*)$

End

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SimILS

Stochastic Objective Function

Procedure *SimILS*

s_0 = *GenerateInitialSolution*

s^* = *LocalSearch*(s_0)

$ss^* = s^*$

$(ss^*, sf(ss^*), statistics)$ = *Simulation*(ss^* ,long)

$bsf^* = sf(ss^*)$

Repeat

s' = *Perturbation*(s^* ,history)

s'^* = *LocalSearch*(s')

s^* = *AcceptanceCriterion*(s^* , s'^* ,history)

$(s^*, sf(s^*), statistics)$ = *Simulation*(s^* ,short)

If $sf(s^*) < bsf^*$

$bsf^* = sf(s^*)$;

$ss^* = s^*$

Until termination condition met

$(ss^*, sf(ss^*), statistics)$ = *Simulation*(ss^* ,long)

$(s^*, sf(s^*), statistics)$ = *Simulation*(s^* ,long)

Return $(ss^*; sf(ss^*))$ and $(s^*; sf(s^*))$

End

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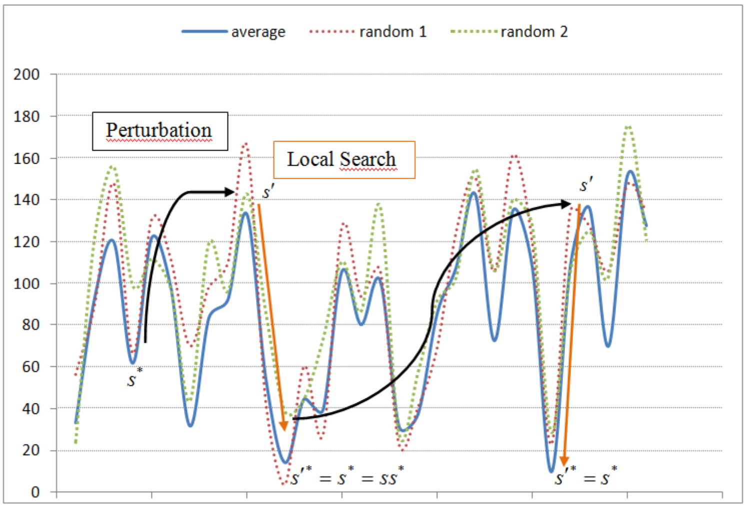
Exemplification of the SimILS for a COP with stochastic objective function



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SimILS
Stochastic Constraints

```
Procedure SimILS
     s0 =GenerateInitialSolution (input data: average values)
     s* =LocalSearch( s0 )
     (s*, sf(s*), service level)=Simulation( s* ,long)
     Repeat
       s' = Perturbation( s* ,history)
       s* = LocalSearch( s' )
       (s*, sf(s*), service level)=Simulation( s* ,short)
     Until verifying service level threshold
     Repeat
           s' = Perturbation( s* ,history)
           s'* =LocalSearch( s' )
           (s'*, sf(s'*), service level)=Simulation( s'* ,short)
           s* =AcceptanceCriterion( s* , s'* ,service level, history)
     Until termination condition met
     (s*, sf(s*), service level)=Simulation( s* ,long)
Return (s*; sf(s*))
End
```

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Aplications

- Permutation Flow-Shop Problem with Stochastic Processing Times
  - Stochastic Objective Function
  - Initial Solution: NEH heuristic by Nawaz et al. (1983).
  - Monte Carlo Simulation
  - ILS method
  - Expected Makespan

  - Juan AA, Barrios BB, Vallada E, Riera D, Jorba J (2014)

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Aplications

- Inventory Routing Problem with Stochastic Demands and Stock-outs
  - * The problem consists in defining a routing distribution plan that includes the product quantities to deliver to a set of retailers.
  - * Stochastic objective function (that is, with inventory holding or stockout costs)
  - * stochastic constraints
  - * The service level is given by a refill policy that goes from no refill to 100% refill of the estimated demand
  - Juan AA, Grasman SE, Caceres-Cruz J, Bektaş T (2014)

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Final Comments

- ILS represents one of the most efficient yet easy-to-implement frameworks for solving combinatorial optimization problems.
- Most real-life problems are filled with uncertainty.
- By integrating simulation inside the local search process, SimILS framework extends the virtues of ILS to stochastic COPs as well.

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Future Research

- Applications
  - Stochastic Location Problem
    - * Demand at the retailers is stochastic
    - * Adela Pagés, Angel A. Juan, Helena Ramalhinho
  - Recourse Allocation in Cloud Computing
    - * Jorge Lobo, Helena Ramalhinho
    - * Network Function Center Management System
  - VRP and IRP with stochastic data
    - * Adela Pagés, Alex Grasas, Angel A. Juan, Helena Ramalhinho, etc.…

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Questions…

- Comments, questions etc…

- http://www.econ.upf.edu/~ramalhin/

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