Technical University of Madrid,
September 3rd, 2015

Applications of Biased Randomized Algorithms in Rich Transportation & Logistics

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UOC Universitat Oberta de Catalunya

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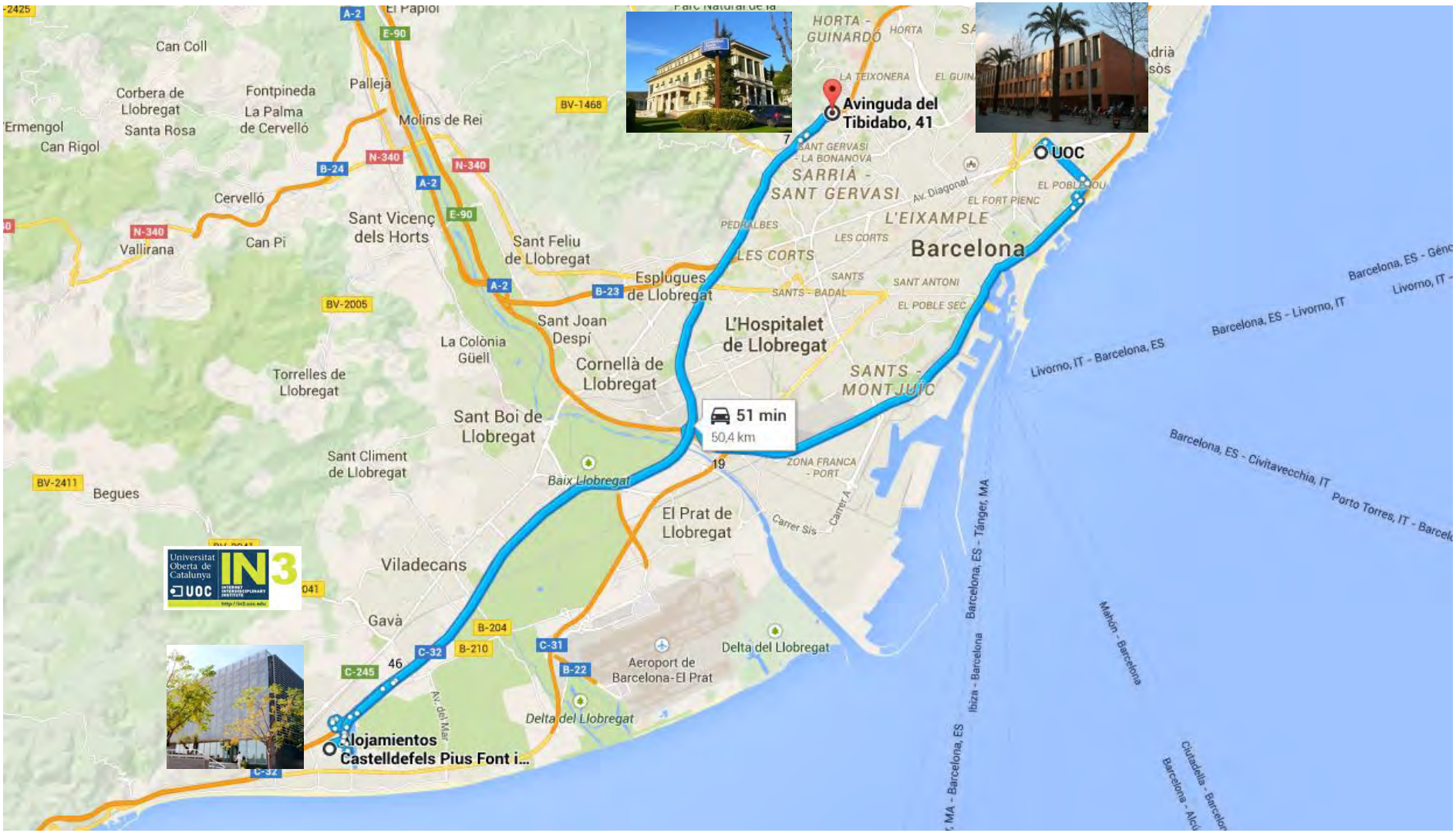
1. Introducing the IN3 @ Castelldefels (1/2)



1. Introducing the IN3 @ Castelldefels (2/2)

- *Internet Interdisciplinary Institute*
- **Parque Tecnológico del Mediterráneo**

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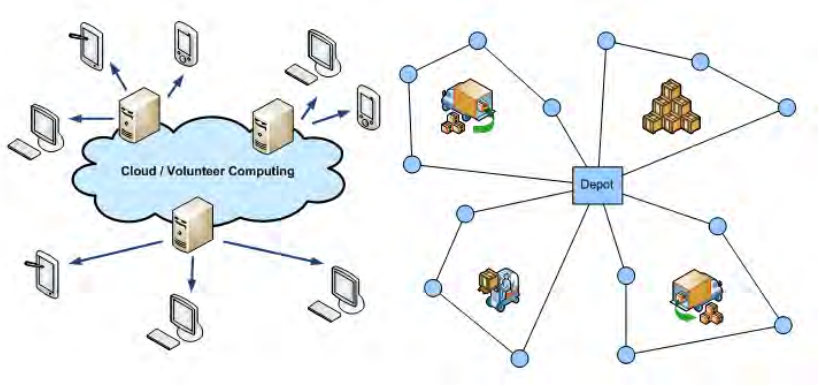
2. Introducing ICSO @ IN3 (1/2)

- What is ICSO? → Internet Computing & Systems Optimization.
- Goals? → To develop Hybrid Intelligent Algorithms for Smart Decision Making & Analytics.
- Applications fields? → Transportation & Logistics, Internet Computing, Smart Cities, Finance, etc.
- Coordination? → DPCS and SLP research groups at IN3 & UOC's Computer, Multimedia and Telecommunication Studies.



- Topics of interest:
  - Applied Optimization & Simulation
  - Internet Computing
  - Biased Randomized Heuristics
  - Metaheuristics & Simheuristics
  - Logistics & Transportation
  - Finance & Risk Analytics
  - Manufacturing & Production
  - Etc.

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CYTED Ciencia y Tecnología para el Desarrollo

GOBIERNO DE ESPAÑA MINISTERIO DE CIENCIA E INNOVACIÓN

AGAUR Agència de Gestió d'Ajuts Universitaris i de Recerca

2. Introducing ICSO @ IN3 (2/2)

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ICSO
INTERNET COMPUTING & SYSTEMS OPTIMIZATION
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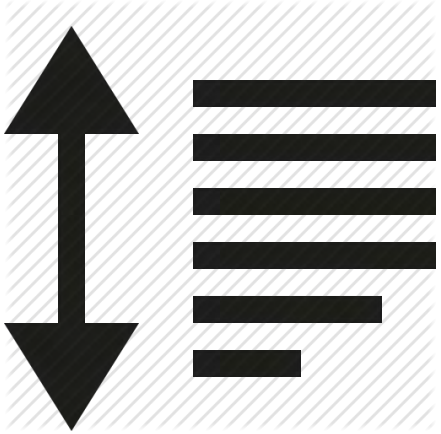
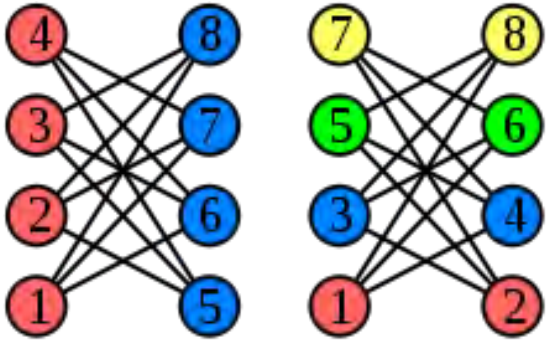
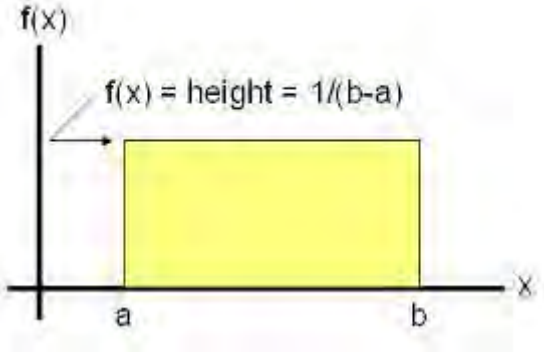
3. Biased-Randomization of Heuristics (1/4)

- Heuristics employ an iterative process. At each iteration, the next constructive movement is selected from a sorted list.
- Deterministic and iterative greedy procedures.



- if we randomize the order in which the elements of the list are selected, then a different output is likely to occur each time.
- However, a uniform randomization will basically destroy the logic behind the greedy behavior.

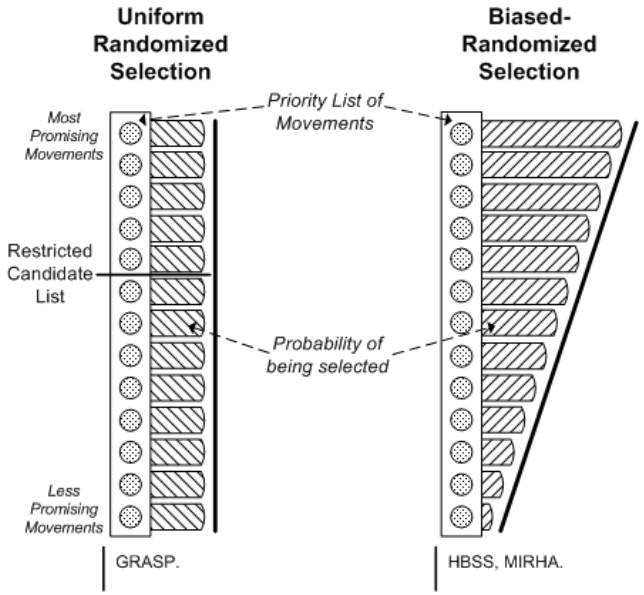




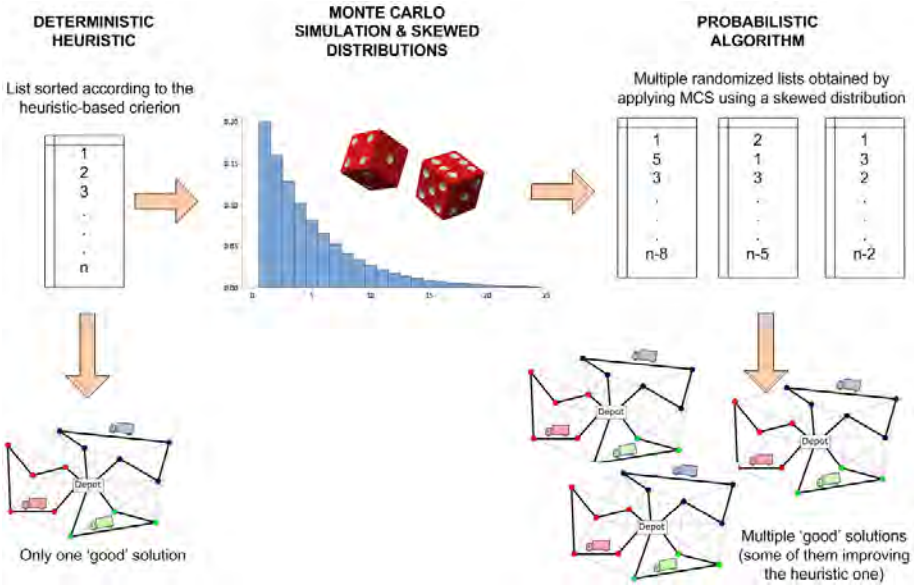
Juan, A.; Faulin, J.; Ferrer, A.; Lourenço, H.; Barrios, B. (2013): "MIRHA: multi-start biased randomization of heuristics with adaptive local search for solving non-smooth routing problems". TOP, 21: 109-132.

3. Biased-Randomization of Heuristics (2/4)

- **GRASP** proposes to consider a restricted list of candidates, and then apply a uniform randomization.
- Thus, a deterministic procedure is transformed into a **randomized algorithm**.



- **BRAs:** instead of restricting the list of candidates, assign a **different probability** of being selected to each potential movement in the sorted list.
- Thus, elements at the top of the list receive **more probabilities** of being selected.
- **Idea:** use a **biased probability** distribution! (e.g. Geometric, Triangular, etc.)



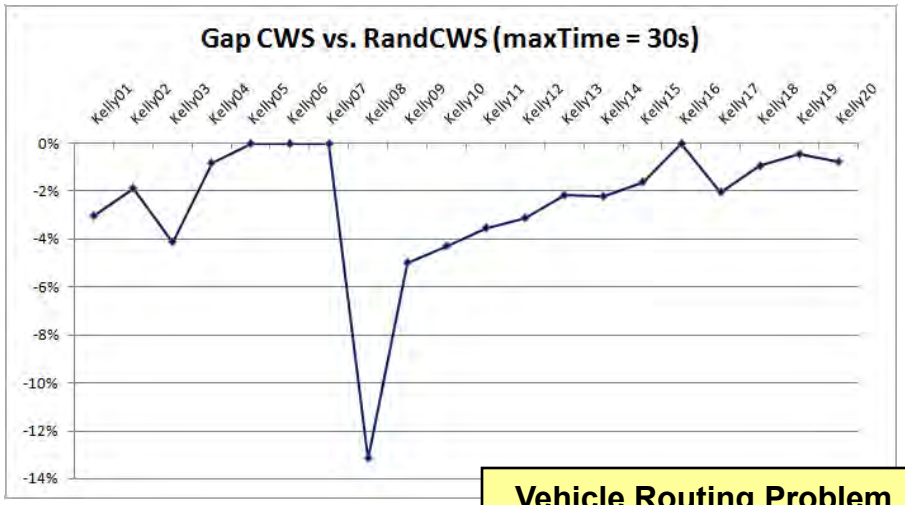
3. Biased-Randomization of Heuristics (3/4)

Biased Randomization

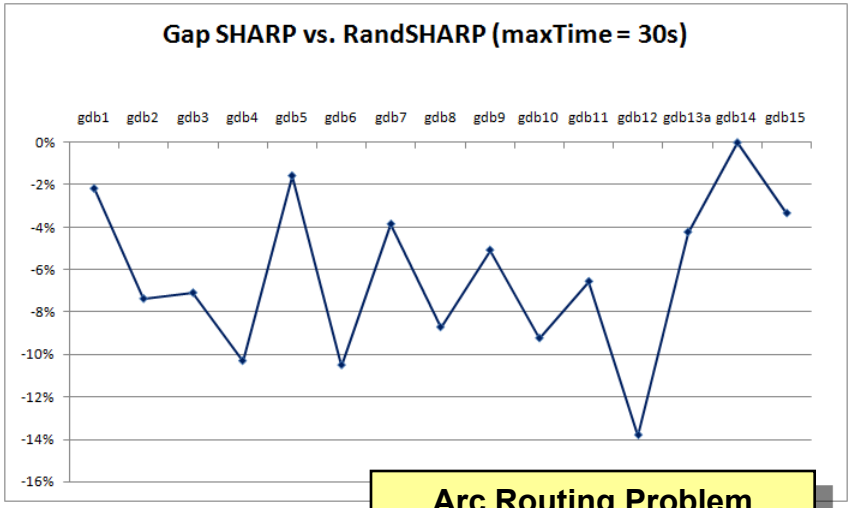
```
baseSol = RandNEH // Randomized NEH solution
baseSol = localSearch(baseSol) // Classical local search
bestSol = baseSol
while endCondition is false // e.g. elapsedTime < maxTime
   currentSol = enhancedSwap(baseSol) //perturbation
   currentSol = localSearch(baseSol)
   delta = currentSol - baseSol
   if delta < 0 // acceptance criterion
      baseSol = currentSol
      if currentSol < bestSol
         bestSol = currentSol
      end if
   else if delta > 0 and lastMovementWasAnImprovement and delta <= lastImprovement
      baseSol = currentSol
   end if
end while
return bestSol
```

Grasas, A.; Juan, A.; Faulin, J.; Ramalhinho, H. (s-150729): "A survey on Biased Randomization of Heuristics with applications to Logistics, Transportation, and Production". JORS.

3. Biased-Randomization of Heuristics (4/4)

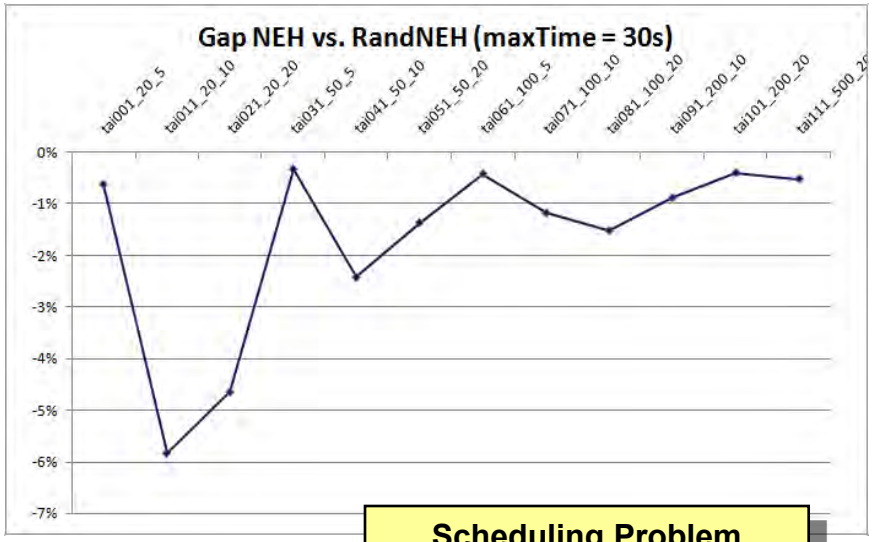


Vehicle Routing Problem



Arc Routing Problem

- If you have a heuristic for a complex decision-making problem (in any field), you can use BR to improve it in a **fast** and natural way.
- Also, you can use BR to generate a set of **alternative** solutions (Pareto frontier).



Scheduling Problem

4. Selected published applications (1/2)

Vehicle and Arc Routing Problems: CVRP, ARP, Heterogeneous, Green, Multi-Depot, Horizontal Collab. 2L-VRP, …

Juan, A.; Faulin, J.; Jorba, J.; Riera, D.; Masip; D.; Barrios, B. (2011): "On the Use of Monte Carlo Simulation, Cache and Spliting Techniques to Improve the Clarke and Wright Savings Heuristics". JORS, Vol. 62, pp. 1085-1097.

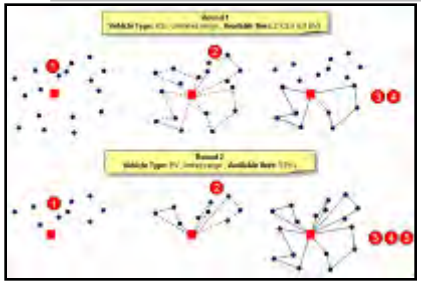
González, S.; Juan, A.; Riera, D.; Castellà, Q.; Muñoz, R.; Pérez, A. (2012): "Development and Assessment of the SHARP and RandSHARP Algorithms for the Arc Routing Problem". AI Communications, 25: 173-189

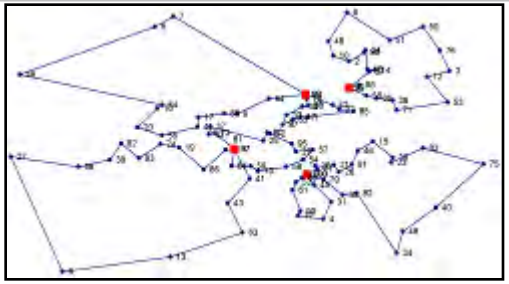
Juan, A.; Faulin, J.; Caceres, J.; Barrios, B.; Martinez, E. (2014): "A Successive Approximations Method for the Heterogeneous Vehicle Routing Problem: analyzing different fleet configurations". European J. of Industrial Engineering, 8(6): 762-788.

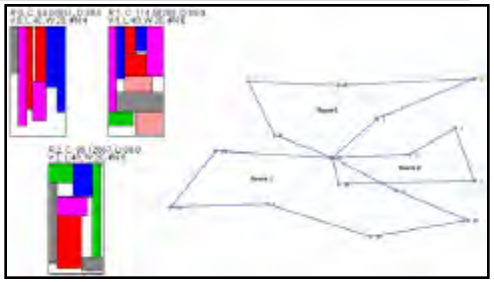
Juan, A.; Goentzel, J.; Bektas, T. (2014): "Routing Fleets with Multiple Driving Ranges: is it possible to use greener fleet configurations?". Applied Soft Computing, 21: 84-94.

Juan, A.; Pascual, I.; Guimarans, D.; Barrios, B. (2014): "Combining Biased Randomization with Iterated Local Search for solving the Multi-Depot Vehicle Routing Problem". ITOR, DOI: 10.1111/itor.12101.

Dominguez, O.; Juan, A.; Nuez, I.; Ouelhadj, D. (2015): "An ILS-Biased Randomization algorithm for the Two-dimensional Loading HFVRP with Sequential Loading and Items Rotation". Journal of the Operational Research Society, doi: 10.1057/jors.2015.48.





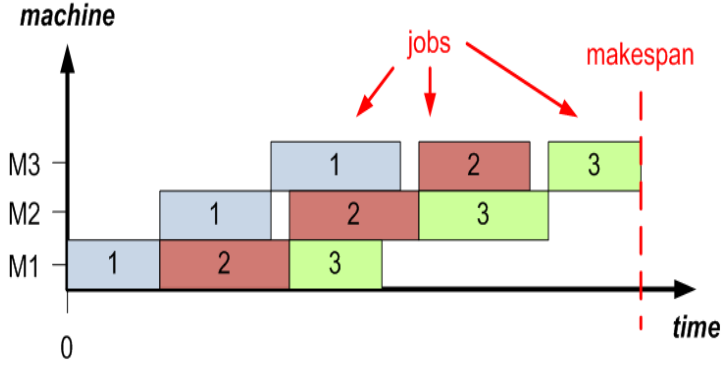


4. Selected published applications (2/2)

Networking & Scheduling Problems: Routing in sensor networks, PFSP, …

Vilajosana, X.; Llosa, J.; Pacho, C.; Vilajosana, I.; Juan, A.; Vicario, J.; Morell, A. (2010): "ZERO: Probabilistic Routing for Deploy and Forget Wireless Sensor Networks". Sensors, Vol. 10, Issue 10, pp. 8920-8937.

Juan, A.; Lourenço, H.; Mateo, M.; Luo, R.; Castella, Q. (2014): "Using Iterated Local Search for solving the Flow-Shop Problem: parametrization, randomization and parallelization issues". Int. Transactions in Operational Research, 21(1): 103-126.

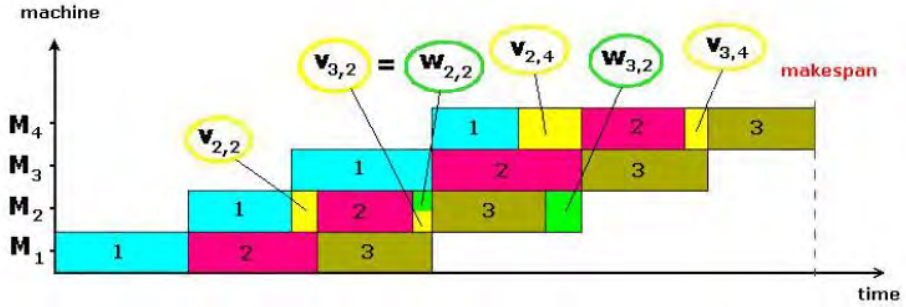


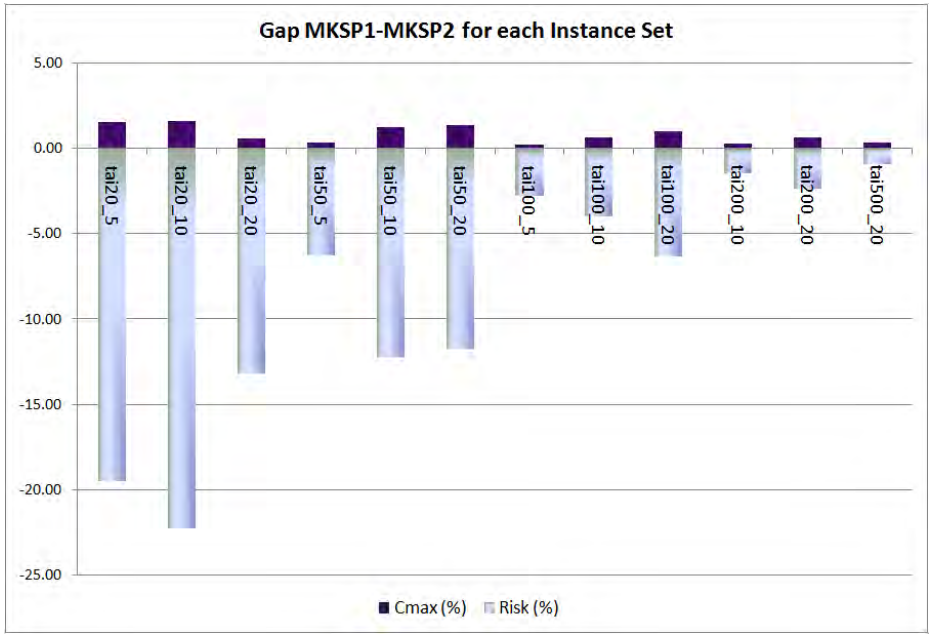
5. COPs with non-smooth objective functions

Scheduling problems with non-smooth objective functions

Ferrer, A.; Guimarans, D.; Lourenço, H.; Juan, A. (rs-150915): "Solving non-smooth flow-shop problems with failure-risk penalties using a biased-randomized iterated local search". Expert Systems with Applications.

$$\mathrm{TCost} := C_{\mathrm{mksp}} + \sum_{k \in \mathcal{M}} \Psi^k(v_{1,k}, \ldots, v_{n,k}),$$

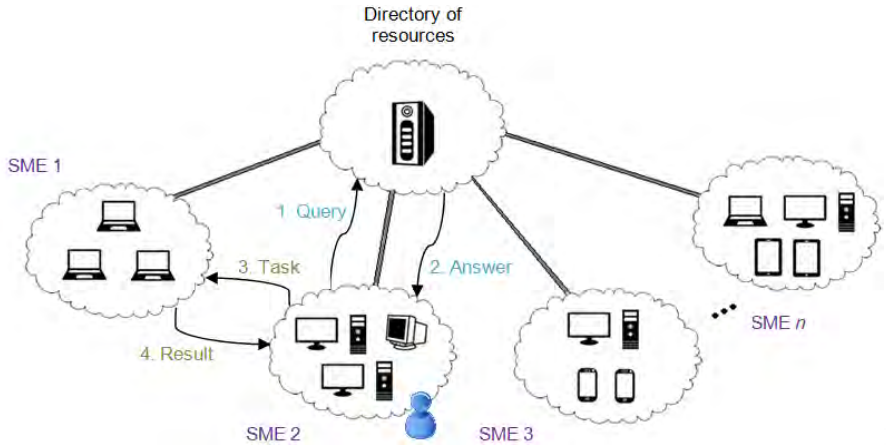




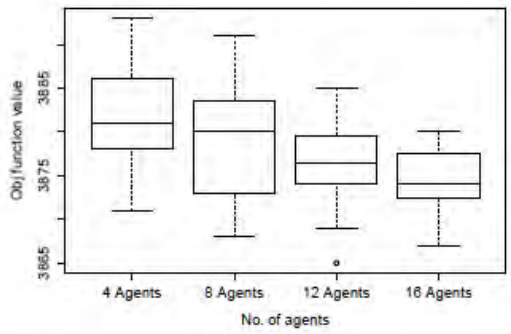
6. Multi-agent & web-based solving approaches

Multi-agent solving approaches to COPs

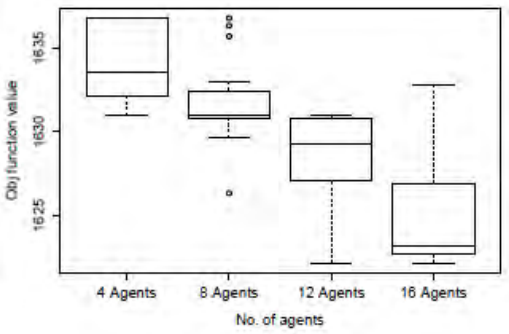
Martin, S.; Ouelhadj, D.; Beullens, P.; Ozcan, E.; Juan, A. (2nd review): "Multi-agent based Cooperative Search in Combinatorial Optimisation". European Journal of Operational Research.



Ruiz, X.; Calvet, L.; Ferrarons, J.; Juan, A. (2015): "SmartMonkey: a web browser tool for solving combinatorial optimization problems in real time". Proceedings of the 2015 Int. Conf. of the Forum for Interdisciplinary Mathematics (FIM2015). November 18-20. Barcelona, Spain.



(a) tai50_20

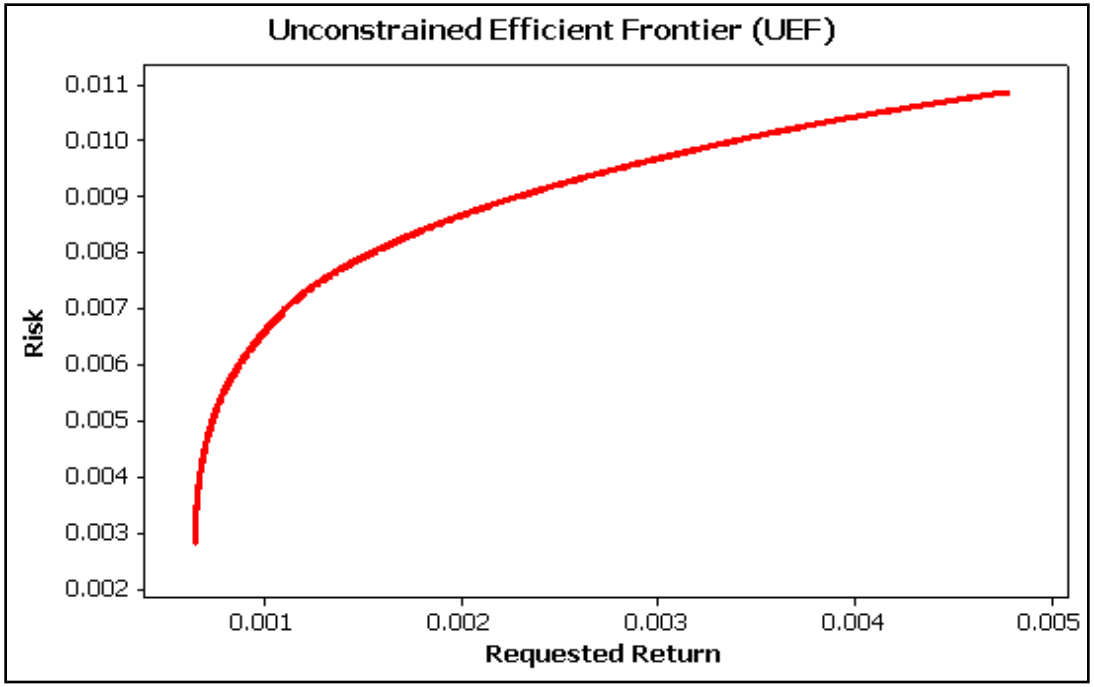


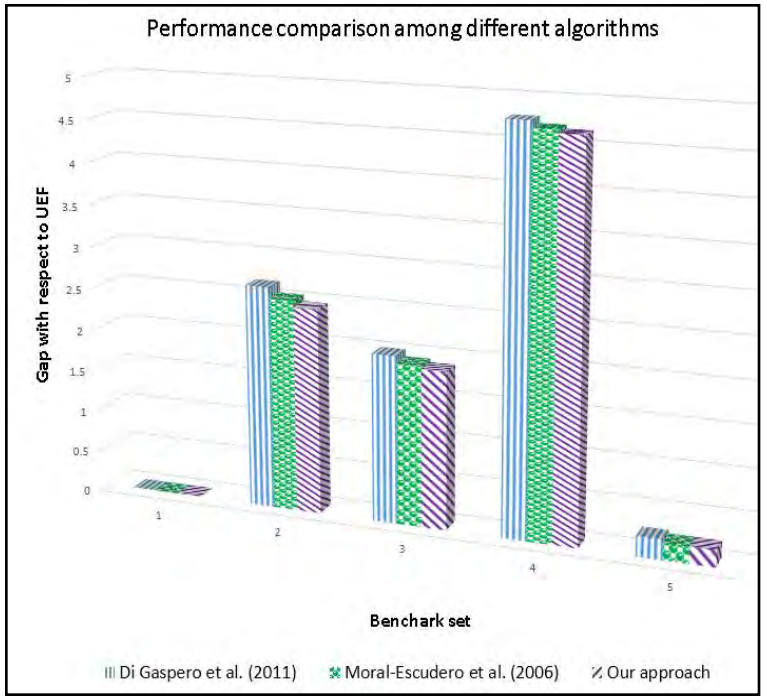
(b) A-n63-k9

7. Financial models

Financial Models: Rich Portfolio Optimization Problems

Kizys, R.; Juan, A.; Sawik, B. (s-150322): "ARPO: An Iterated Local Search Algorithm for Portfolio Optimization under Realistic Constraints". Quantitative Finance.



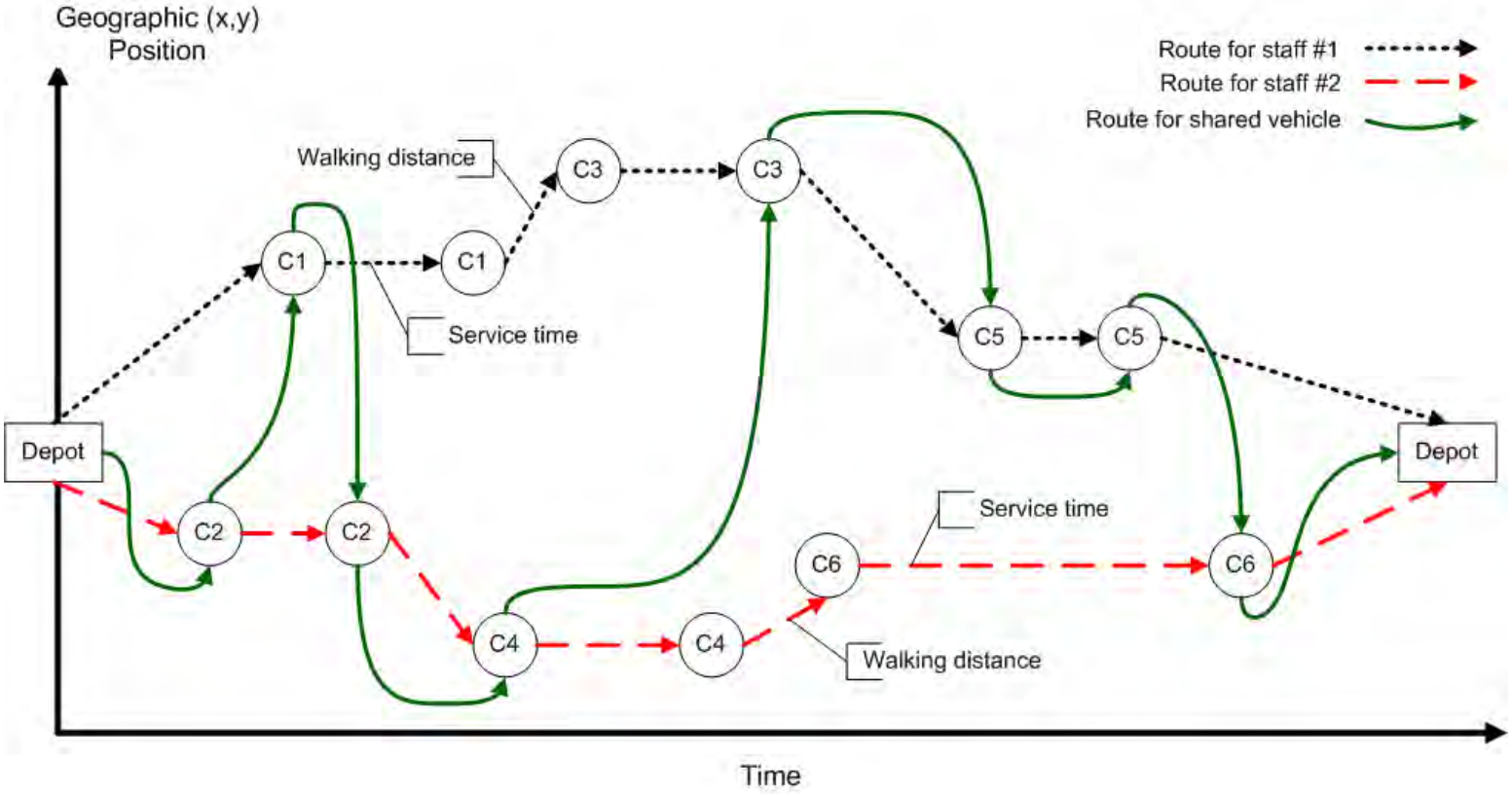


8. Synchronized VRPs

Rich VRPs with dynamic behavior.

Fikar, C.; Juan, A.; Martinez, E.; Hirsch, P. (s-150518): "A discrete-event metaheuristic for dynamic home-service routing with synchronized ride-sharing". European Journal of Industrial Engineering.

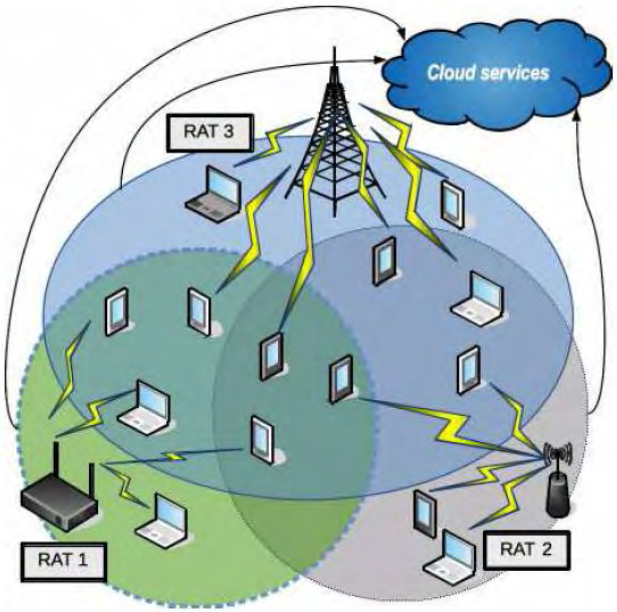
$$\text{Min} \sum_{i=1}^{n} \left(\sum_{l=1}^{m} a_i^l + \sum_{h=1}^{k} d_i^h \right) + \sum_{e \in E} \left(\sum_{l=1}^{m} (c_e x_e^l + w_e y_e^l) + \sum_{h=1}^{k} c_e z_e^h \right)$$

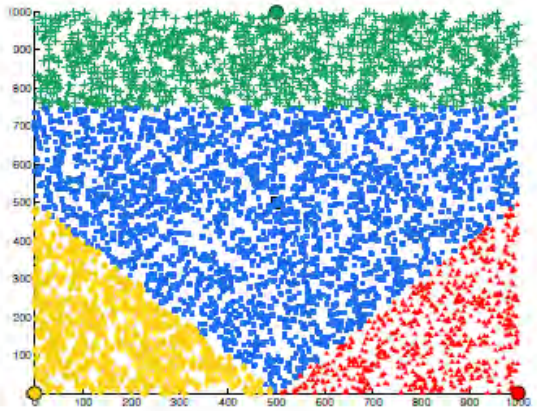


9. Smart Cities

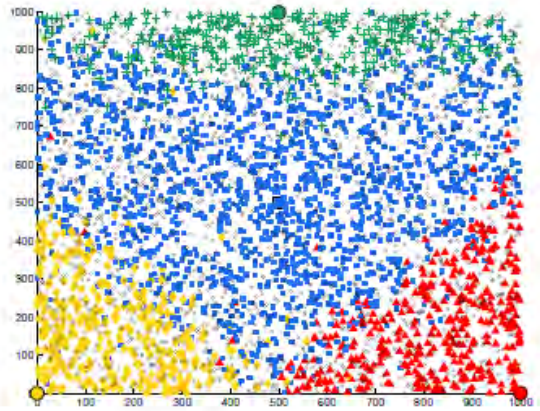
Cloud computing

Mazza, D.; Pages, A.; Tarchi, D.; Juan, A.; Corazza, G. (u.d.): "A social-aware biased-randomized algorithm for mobile cloud computing in smart cities".

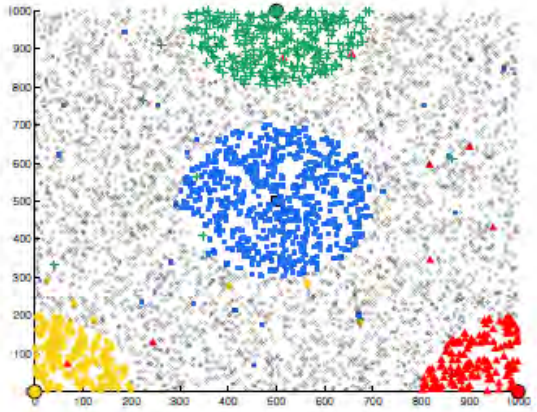




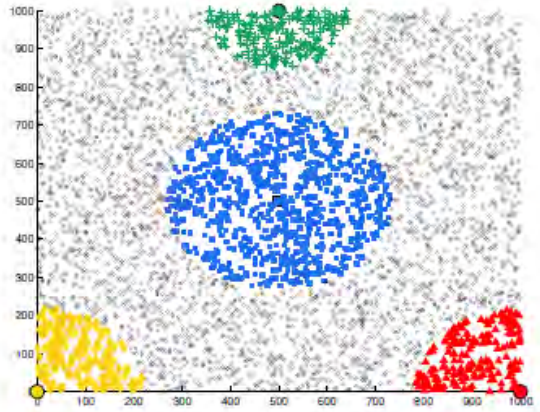
(a) Nearest Node Configuration



(b) Greedy Heuristic Configuration



(c) Biased-randomized Configuration



(d) Ex-post Optimal Configuration

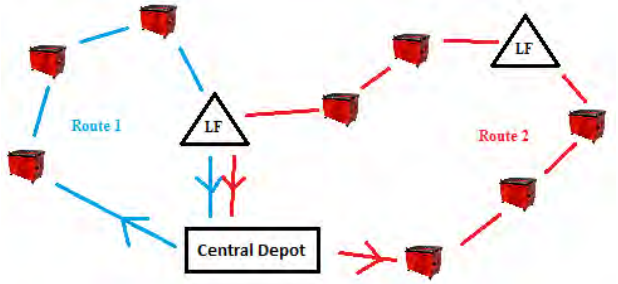
10. Other L&T problems

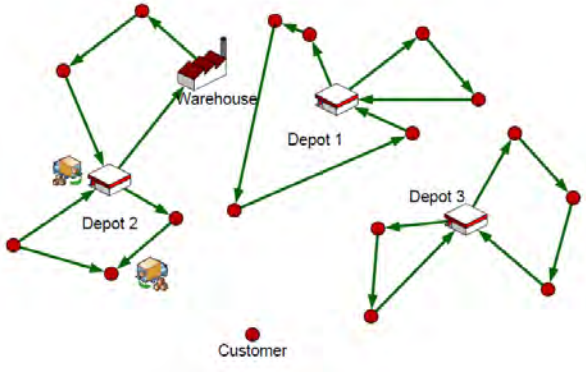
Waste collection management, rich IRPs, FLPs, …

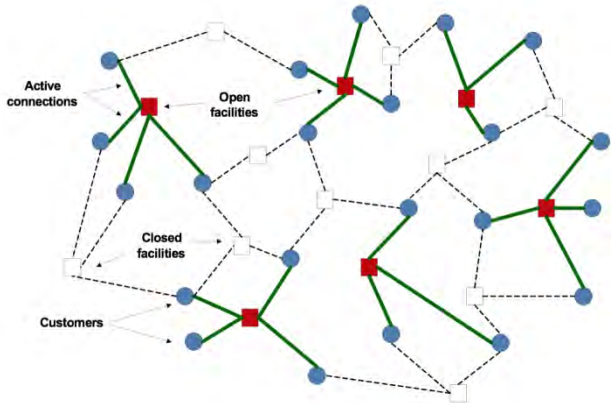
Gruler, A.; Fikar, C.; Juan, A.; Hirsch, P.; Contreras, C. (2015): "A Simheuristic for the Waste Collection Problem with Stochastic Demands in Smart Cities". Proceedings of the 16 ASIM Dedicated Conference on Simulation. Dortmund, Germany. September 23-25.

Pfeilsticker, L.; Juan, A.; Rabe, M. (2015): "Development of a Simheuristic Approach for Solving Realistic Inventory Routing Problems". Proceedings of the 16 ASIM Dedicated Conference on Simulation. Dortmund, Germany. September 23-25.

De Armas, J.; Juan, A.; Marques, J. (2015): "A Biased-Randomized Algorithm for the Uncapacitated Facility Location Problem". Proceedings of the 2015 Int. Conf. of the Forum for Interdisciplinary Mathematics (FIM2015). November 18-20. Barcelona, Spain.







11. Conclusions

- **Biased randomization**: by combining **skewed probability distributions** with direct Monte Carlo simulation, the logic behind the heuristic can be slightly randomized without losing it.
- BR allows to transform the deterministic heuristic procedure into a probabilistic algorithm that can be run several times.
- **Advantages**: easy-to-implement, few parameters, quiet **flexible** and efficient approach, real-time, …
- Some applications to L&T, Production, Internet Computing, and Finances. The number of **potential applications** to these and other fields is really (really) large.

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THANK YOU!

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