Solving a real application of the Time-Constraint Open Vehicle Routing Problem

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Outline of the Presentation

- Introduction
  - Motivation: The Blood Sample Collection at a Clinical Laboratory
  - Problem description
  - Literature review
- Bias Random Key Genetic Algorithm
- Real application
- Conclusions and directions of future work.

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Introduction- Motivation

- The Blood Sample Collection at a Clinical Laboratory

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Introduction- Motivation

- The Blood Sample Collection at a Clinical Laboratory
  - * Health Care Management Problem
  - Redesign collection routes
    - * Daily Routes (5 days/week)
    - * Application Lab 1: 43 collection points
    - * Application Lab 2: 74 collection points
    - * The transport is subcontracted
    - * Constraints on travel time (2 hours) & capacity
    - * Minimize transportation costs

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Introduction- The Problem

- Time-Constraint Capacity Open VRP (1/2)
  - A direct graph $G = (V, A)$ is given, where $V = \{0, 1, \ldots, n\}$ is the set of $n + 1$ nodes and A is the set of arcs.
  - Node 0 represents the depot (laboratory), while the remaining nodes $V' = V \setminus \{0\}$ corresponds to the n collecting points.
  - Each collection point $i \in V'$ has q_i boxes to be transported to the depot (assume $q_0 = 0$).
  - Distance and travel times between each node.

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Introduction- The Problem

- Time-Constraint Capacity Open VRP (2/2)
  - Open routes (start at the first collecting point and finish at the laboratory)
  - The vehicle fleet is composed $M = \{1,\ldots, m\}$ identical vehicles with capacity Q_k.
  - The travel maximum time between the first collecting point to the laboratory is 2 hours.
  - **Minimize the total distance (or transportation costs)**

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Introduction- The Problem

- Applications of the Time-Constraint Capacity Open VRP
  - Blood Collection Sample at a Clinical Laboratory
  - Patients transportation to medical exams (1 hour)
  - School Bus (1 hour time constraint)
  - Retailing with subcontracted distribution transportation (8 hours working time)
  - Etc.

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Introduction- Review

- Main References

  - Guder, W. G., Narayanan, S., Wisser, H., & Zawta, B. (2003). *Samples: from the patient to the laboratory. The Impact of Preanalytical Variables on the Quality of Laboratory Results, 3rd ed*. Weinheim, Germany: Wiley-VCH Verlag GmbH & Co. KgaA.
  - Letchford, A. N., Lysgaard, J., & Eglese, R. W. (2007). A branch-and-cut algorithm for the capacitated open vehicle routing. *Journal of the Operational Research Society, 58*(12), 1642-1651.
  - Salari, M., Toth, P., & Tramontani, A. (2010). An ILP improvement procedure for the Open Vehicle Routing Problem. *Computers & Operations Research, 37*(12), 2106-2120.
  - Gonçalves, J. F., & Resende, M. G. C. (2011). Biased random-key genetic algorithms for combinatorial optimization. *Journal of Heuristics,17*, 487–525.

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Bias Random Key Genetic Algorithm

- GAs and random keys
  - Introduced by Bean (1994) for sequencing problems.
  - Individuals are strings of real-valued numbers (random keys) in the interval [0,1].

    S = (0.25, 0.19, 0.67, 0.05, 0.89)
    s(1) s(2) s(3) s(4) s(5)
  - Sorting random keys results in a sequencing order.

    S' = (0.05, 0.19, 0.25, 0.67, 0.89)
    s(4) s(2) s(1) s(3) s(5)
    Sequence: 4 – 2 – 1 – 3 – 5

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Bias Random Key Genetic Algorithm

- Random-keys vs biased random-keys
  - How do random-key GAs (Bean, 1994) and biased random-key GAs differ?
    - A random-key GA selects both parents at random from the entire population for crossover: some pairs may not have any elite solution
    - A biased random-key GA always has an elite parent during crossover
    - Parametrized uniform crossover makes it more likely that child inherits characteristics of elite parent in biased random-key GA while it does not in random key GA (survival of the fittest)

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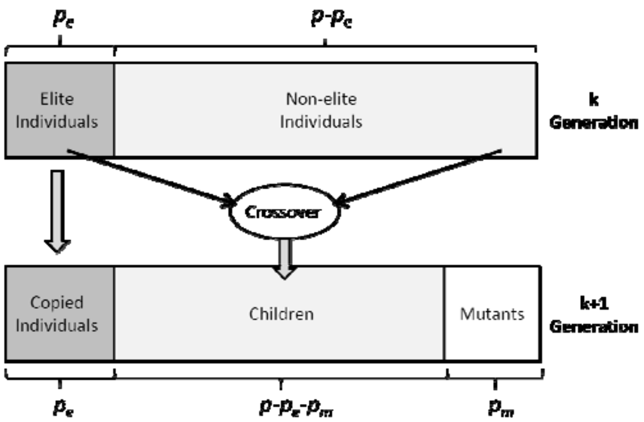
Bias Random Key Genetic Algorithm



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Bias Random Key Genetic Algorithm

Elite parent	0.27	**0.89**	**0.73**	**0.11**	0.55
Non-elite parent	**0.36**	0.98	0.21	0.08	**0.62**
CROSSOVER					
Random values < 0.67 (Probability = 0.6)	(0.86 ,	0.42 ,	0.33 ,	0.19 ,	0.66)
Child	0.36	0.89	0.73	0.11	0.62

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Bias Random Key Genetic Algorithm

- ► Framework for biased random-key genetic algorithms
  - * Gonçalves, J. F., & Resende, M. G. C. (2011)

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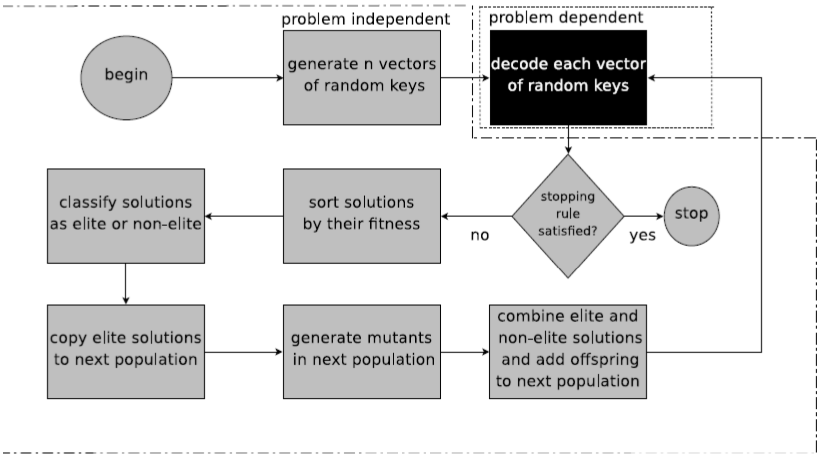
Bias Random Key Genetic Algorithm



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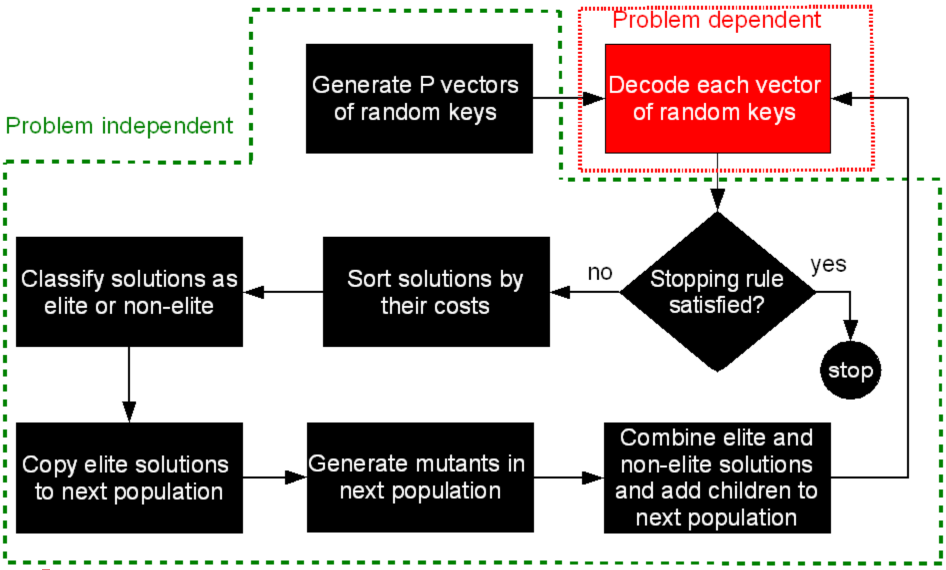
Framework for biased random-key genetic algorithms



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Bias Random Key Genetic Algorithm

- Decoders
  - A decoder is a deterministic algorithm that takes as input a random-key vector and returns a feasible solution of the optimization problem and its cost.
  - Bean (1994) proposed decoders based on sorting the random-key vector to produce a sequence.
  - A random-key GA searches the solution space indirectly by searching the space of random keys and using the decoder to evaluate fitness of the random key.

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Bias Random Key Genetic Algorithm

- Decoder for the Time-Constraint Capacity Open VRP
  - Suppose each collection points has one bag and the capacity of the vehicles is 2.
  - A solution: S= (0.05, 0.19, 0.25, 0.67, 0.89)
    s(4) s(2) s(1) s(3) s(5)
    Sequence: 4 – 2 – 1 – 3 – 5
  - Means that 3 routes are obtained:
    * 4-2-lab
    * 1-3-lab
    * 5-lab

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Real Application

- The Blood Sample Collection at a Clinical Laboratory
  - Application Lab 1: 43 collection points
  - Actually 10 routes
  - Data:
    * Laboratory
    * Distances and time matrix by google maps
      – vrp.upf.edu
  - Two scenarios & two different truck capacities

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Real Application

- The Blood Sample Collection at a Clinical Laboratory

Number of Routes using BRKGA for Lab 1

	Number of Routes	
	Vehicle Capacity = 16	Vehicle Capacity = 25
Scenario I	3 + 5	3 + 4
Scenario II	7	7

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Real Application

- The Blood Sample Collection at a Clinical Laboratory
  - Application Lab 2: 74 collection points
  - Actually 12 routes
  - Data:
    - * Laboratory
    - * Distances and time matrix by google maps
      - – vrp.upf.edu
  - Three different truck capacities

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Real Application

- The Blood Sample Collection at a Clinical Laboratory

Number of Routes using BRKGA for Lab 2

	Number of Routes	
Vehicle Capacity = 10	Vehicle Capacity = 16	Vehicle Capacity = 25
10	9	9

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Real Application

- The Blood Sample Collection at a Clinical Laboratory
  - Lab 1: saving 30% of total annual routing costs (around 45.000€)
  - Lab 2: saving around 20% of total annual routing costs.
  - Better management if there are new collection points or changes in the address.
  - Better service quality (2 hours transportation).
  - Better planning in the case of laboratory merging strategy.

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Conclusions

- Research should focus on solving real problems, with a great impact on Public Health Care System.
- The Bias Random Key Genetic Algorithm is easily adapted to new constraints or management issues.
- Also, it can be adapted to other routing problems.
- Companies require no fine-tunning or parameters to be set.

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Future Research

- Application to well-known instances in COVRP and compare results.
- Application of the CTCOVRP
  - School Bus at Barcelona
- More VRP real applications (fashion industry)
  - MANGO
  - DESIGUAL
- Improve the **vrp.upf.edu** web so the user can optimize the routes via internet.

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Thank you for your attention

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