A Savings-based Randomized Heuristic for the Heterogeneous Fleet Multitrip VRP

Angel A. Juan
José Cáceres

UOC
Universitat Oberta de Catalunya
Barcelona, Spain

ajuanp@uoc.edu
jcaceres@uoc.edu

Helena R. Lourenço
Àlex Grasas

UPF
Universitat Pompeu Fabra
Barcelona, Spain

helena.ramalhinho@upf.edu
alex.grasas@upf.edu

Mercè Roca

ESCI
Internacional Business School
Barcelona, Spain

merce.roca@esci.upf.edu

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Outline of the Presentation

- Introduction
  - Motivation
  - Problem description
  - Literature review
- Savings-Based Randomized Heuristic
  - The method
  - Computational results
- Real application
- Conclusions and directions of future work.

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Introduction- Motivation

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Introduction- Motivation

Grup Alimentari Guissona

- Actual Project - Grup Alimentari Guissona
  * Food Industry
  * Integrated logistics network
- Redesign the Vehicle Distribution Problem
  * 370 stores in Spain
  * Revenue 1,156 million euros
  * Three types of products (dry, fresh, frozen)
  * Centralized warehouse (La Closa, Guissona, Catalonia)
  * Daily distribution (Monday to Saturday)

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Introduction- Motivation

- Routing Problem
  - Heterogeneous fleet (7 different truck capacities)
  - Time windows in the stores
  - Constraints of assigning some trucks to some stores.
  - Maximum driving hours
  - Multitrip for some vehicles
  - Etc.
- Minimize operative costs

http://img.europapress.net/

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Introduction- Motivation

- Distribution System
  - Stores place orders
  - Order planning (adjust orders according inventory)
  - Route planning
    - Actually is planned manually, adjusting master routes according to the demand.
    - Order planning (adjust orders according truck capacity)
  - Load trucks
  - Start delivery
- The new algorithm should run in less than 20 minutes…

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Introduction- The Problem

- Heterogeneous Fleet Multitrip 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, while the remaining nodes $V' = V \setminus \{0\}$ corresponds to the n customers.
  - Each customer $i \in V'$ requires a supply of q_i units from the depot (assume $q_0 = 0$).

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Introduction- The Problem

- Heterogeneous Fleet Multitrip VRP (2/2)
  - The vehicle fleet is composed by m different vehicle types, with $M = \{1, \ldots, m\}$.
  - For each vehicle type $k \in M$, the capacity is Q_k.
  - There is a limited number of vehicles of each type (m_k)
  - It is allowed to do multitrip.
  - Some vehicles cannot go to some customers
    - * (max dem>min cap)
  - **Minimize the total distance**

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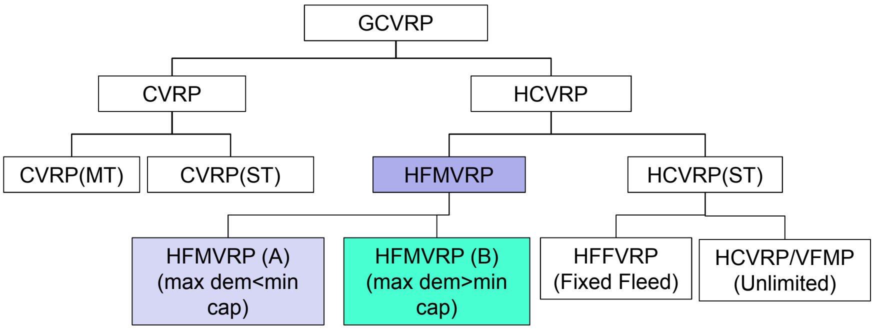
Introduction- Review

- Vehicle Routing Problems



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Introduction- Review

- Main References
  - Taillard, E. D. (1999). "A heuristic column generation method for the heterogeneous fleet VRP." Rairo-Recherche Operationnelle-Operations Research **33**(1): 1-14.
  - Prins C. (2002) Efficient heuristics for the heterogeneous fleet multitrip VRP with applications to a large-scale real case. Journal of Mathematical Modelling and Algorithms **1**:135-50.
  - Prins, C. (2009). "Two memetic algorithms for heterogeneous fleet vehicle routing problems." Engineering Applications of Artificial Intelligence **22**(6): 916-928.
  - Juan AA, Faulín J, Ruiz R, Barrios B, Caballero S. (2010) The SR-GCWS hybrid algorithm for solving the capacitated vehicle routing problem. Applied Soft Computing **10**: 215–24.
  - Juan A, Faulin J, Jorba J, Riera D, Masip D, Barrios B.(2011) On the use of monte carlo simulation, cache and splitting techniques to improve the clarke and wright savings heuristics. Journal of the Operational Research Society **62**:1085-97.

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Savings-Based Randomized Heuristic

- Our approach will be based on the Clarke and Wright's savings (CWS) algorithm (Clarke & Wright 1964).
  - SR-GCWS-CS: SimoRouting Clarke and Wright's Savings with Cache an Splitting
    - Reference: Juan, A., Faulin, J., Ruiz, R., Barrios, B., Caballe, S., 2009b. The SR-GCWS hybrid algorithm for solving the capacitated vehicle routing problem. Applied Soft Computing, 10, 215-224.

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Savings-Based Randomized Heuristic

- CWS: the first edge (the one with the most savings) is the one selected.
- GCWS introduces randomness in this process by using a quasi-geometric statistical distribution
  - edges with more savings will be more likely to be selected at each step, but all edges in the list are potentially eligible.
- Cache method:
  - A hash table is used to save, for each generated route, the best-known sequence of nodes (this will be used to improve new solutions)

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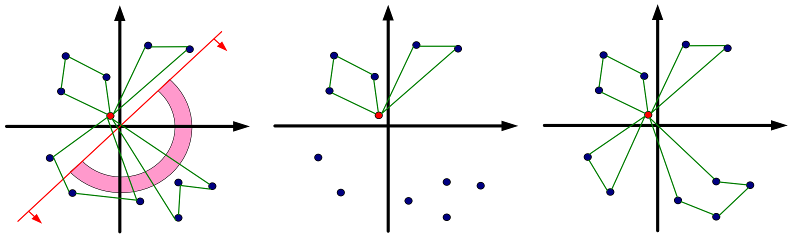
Savings-Based Randomized Heuristic

- Splitting (divide-and-conquer) method:
  - Given a global solution, the instance is sub-divided in smaller instances and then the algorithm is applied on each of these smaller instances.



1. Select routes on the SE area (area below the diagonal) — 2. Consider the new CVRP subproblem — 3. Solve the subproblem and re-construct the solution

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Savings-Based Randomized Heuristic

- Assign vehicles to routes
- Procedure TryToAssign to assign trips to trucks (Prins 2002)
  - When try to join to routes
  - Build a list of pair (route, capacity, vehicle) for the remaining routes;
  - Add the join route pair
  - Sort in decreasing order of vehicle load
  - Sort the vehicles in decreasing order of capacity
  - Assign vehicles to route
  - If no feasible assignment, the routes cannot be join.

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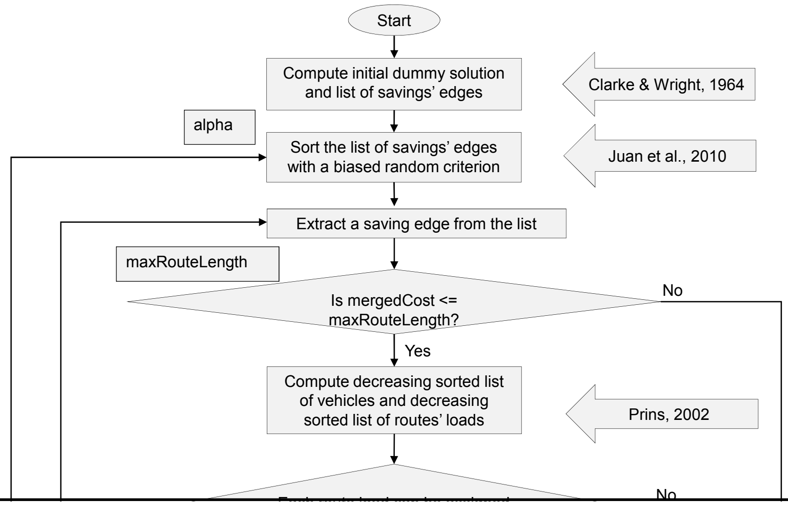
Savings-Based Randomized Heuristic



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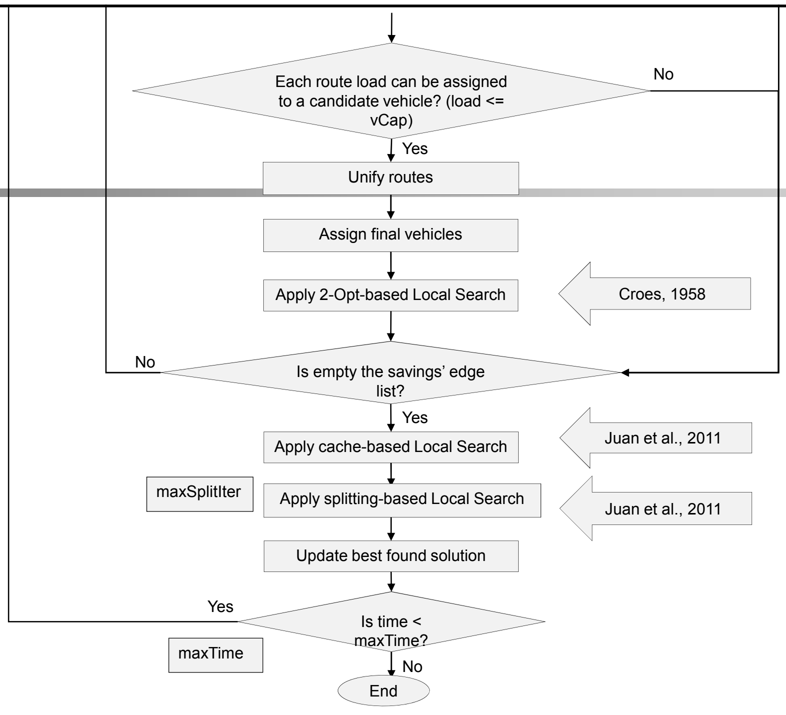

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Computational Results

► *Prins' instances*

- Proposed in **Prins (2002)**, these are twenty random instances, denoted as Prins_*i* (*i = 1, 2,…, 20*).
- Each instance contains 100 customers uniformly distributed in a *200 x 200* km^2 grid.
- Each customer's demand is uniformly distributed in *[1, 100]*.
- The depot is placed at the center of the grid, and the maximum time allowed per route is *300* minutes (or *350* km at a speed of *70* km/h).
- The fleet is composed by $k = 9$ types of vehicles with $m_k = 2$ for all $k = 1, 2,\dots, 9$.
- Each type of vehicle has a capacity given by $Q_k = 600 - 50(k - 1)$.

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Computational Results

► Golden et al. (1984)

- proposed 20 instances for the Fleet Size and Mix vehicle Routing Problem of different sizes
- Taillard (1999) defined the number of available vehicles of each type.
- the number of customers is in the range of 50 and 100.

Instance	Q_A	m_A	Q_B	m_B	Q_C	m_C	Q_D	m_D	Q_E	m_E	Q_F	m_F	%
GT_13	20	4	30	2	40	4	70	4	120	2	200	1	95.39
GT_14	120	4	160	2	300	1							88.48
GT_15	50	4	100	3	160	2							94.76
GT_16	40	2	80	4	140	3							94.76
GT_17	50	4	120	4	200	2	350	1					95.38
GT_18	20	4	50	4	100	2	150	2	250	1	400	1	95.38
GT_19	100	4	200	3	300	3							76.74
GT_20	60	6	140	4	200	3							95.92

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Computational Results

- Li *et al*. (2007): five large-scale HVRP instances, inspired by Golden et al., and denoted as Li_*i*, with *i* = 1,…, 5. Number of customers is between 200 and 360, and each case has a geometric symmetry with nodes located in concentric circles around the depot.

Instance	Q_A	m_A	Q_B	m_B	Q_C	m_C	Q_D	m_D	Q_E	m_E	Q_F	m_F	%
H1	50	8	100	6	200	4	500	3	1000	1			93.02
H2	50	10	100	5	200	5	500	4	1000	1			96.00
H3	50	10	100	5	200	5	500	4	1000	2			94.76
H4	50	10	100	8	200	5	500	2	1000	2	1500	1	94.12
H5	50	10	100	8	200	5	500	1	1000	2	1500	1	92.31

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Computational Results

- Summary

			CWS-Prins			Randomized CWS-Prins					
Instance	Customers	Total Delivered Demand	Cost	Routes	Time (sec)	Cost	Routes	Time (sec)	*Gap (2-1)*	Average 10 Seeds *(3)*	*Gap (3-1)*
Prins	*100*	*Average*	2692.57	10.9	0.08	2562.97	10.65	*16.93*	***-4.78%***	2584.6	***-3.97%***
GT	*50-100*	*Average*	*767.73*	*9.17*	*0.05*	*741.9*	*10.25*	*24.5*	***-6.12%***	*749.33*	***-5.34%***
H	*200-360*	*Average*	*9765.44*	*20.8*	*58.61*	*9431.48*	*20*	*68.43*	***-3.31%***	*9601.32*	***-1.75%***

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Real Application

- Grup Alimentari Guissona RESULTS
  - 25 daily instances
  - Fleet Composition of the Distribution Company

Vehicle Type	Q_k	m_k	MQ_k	AM_k	MQM_k
A	222	8	1.776	1	1.776
B	414	5	2.070	1	2.070
C	482	139	66.998	2	133.996
D	550	3	1.650	1	1.650
E	616	6	3.696	1	3.696
F	676	3	2.028	1	2.028
G	752	4	3.008	1	3.008
H	1.210	1	1.210	1	1.210
TOTAL		*169*	*75.691*		*149.434*

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Real Application

- Grup Alimentari Guissona RESULTS
  - Less 6551 Km in average a day!

		Company Solution		Prins Adaptation*** (CWS + 2-opt)				Randomized Prins Adaptation*** + 10 seeds + 60 sec + 2-opt + Cache				
Instance*	AVE # Customers	Cost (1)	Routes	Cost (2)	Routes	Time (sec)	Gap (2-1)	Best Cost (3)	Routes	Time (sec)	Gap (3-1)	Gap (3-2)
25	362	42006	159	35860	157	2.45	-16.38%	35455	156	34.27	**-17.34%**	**-1.15%**

Real Application

- Grup Alimentari Guissona RESULTS
  - Savings more than 17% daily with respect to the actual solutions.
  - Savings of 1% compared with Prins Algorithm.
  - The average number of routes were similar, with a small reduction for our solutions.
  - Important saving in €!

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Conclusions

- After 50 years research, VRP is still a relevant and interesting problem…
- Research should focus on solving real problems, they are more difficult than the classic well-known VRP.
- Heuristics and Metaheuristics are an excellent tool to solve real VRP.
- Companies require no fine-tunning or parameters to be set.

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Future Research

- Heterogeneous Fleet Multitrip VRP
  - Improve the algorithm, in particular the truck assignment
  - Include time windows and cost function.
- Blood sample collection VRP
  - Interesting and relevant applications in **Health Sector**
- More VRP real applications (fashion industry)
  - MANGO
  - DESIGUAL
- vrp.upf edu (VRP in Google maps)

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