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

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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

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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

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<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 $V = \{0, 1, \dots, n\}$ 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 $q_0 = 0$).

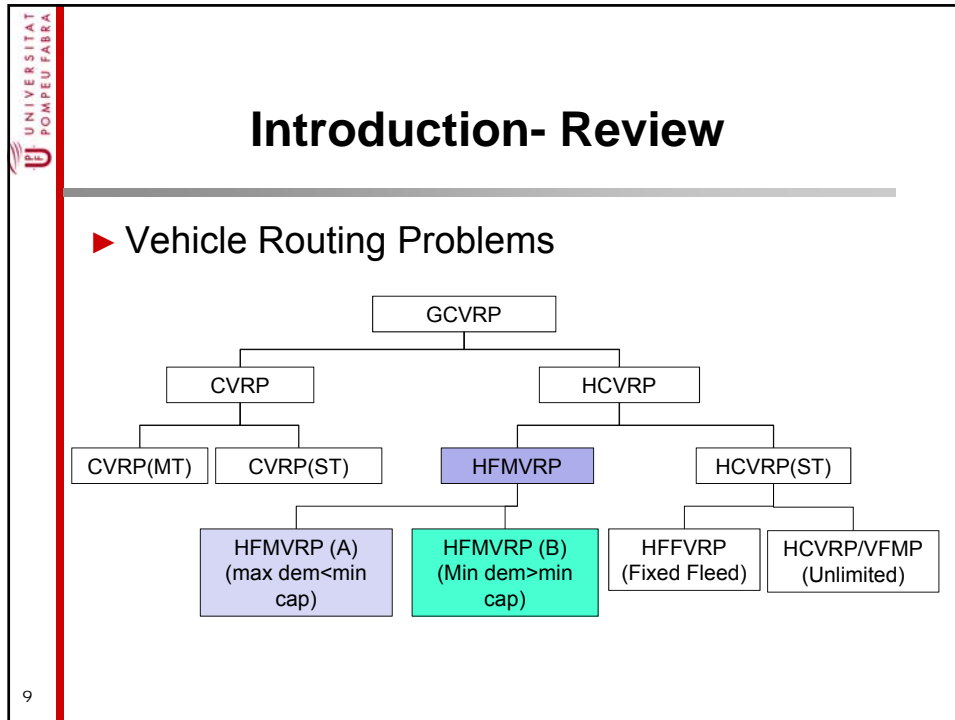
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Introduction- The Problem

- ▶ Heterogeneous Fleet Multitrip VRP (2/2)
 - The vehicle fleet is composed by m different vehicle types, with $M = \{1, \dots, m\}$.
 - 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
 - * (Min dem > min cap)
 - **Minimize the total distance**

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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 and 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

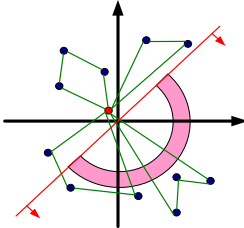
- ▶ CWS: the first edge (the one with the most savings) is the one selected.
- ▶ GCWS introduces randomness in this process by using a quasi-geometric statistical distribution
 - edges with more savings will be more likely to be selected at each step, but all edges in the list are potentially eligible.
- ▶ 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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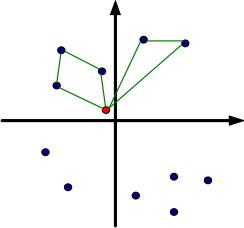
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Savings-Based Randomized Heuristic

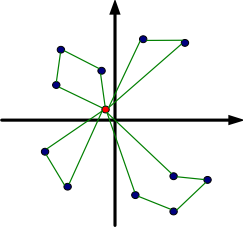
- ▶ Splitting (divide-and-conquer) method:
 - Given a global solution, the instance is subdivided in smaller instances and then the algorithm is applied on each of these smaller instances.



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

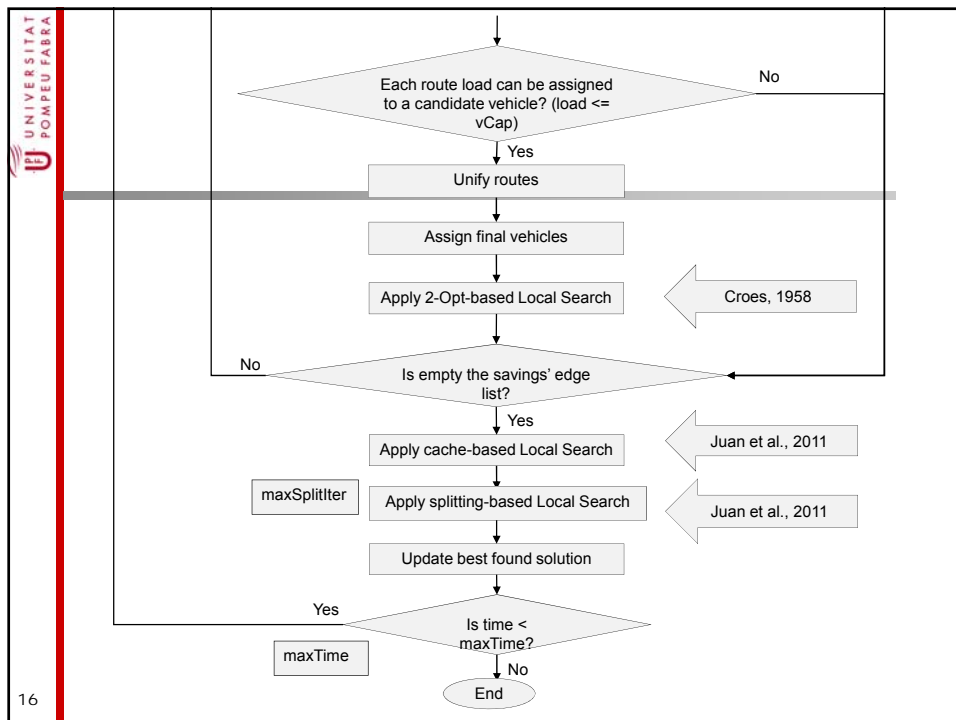
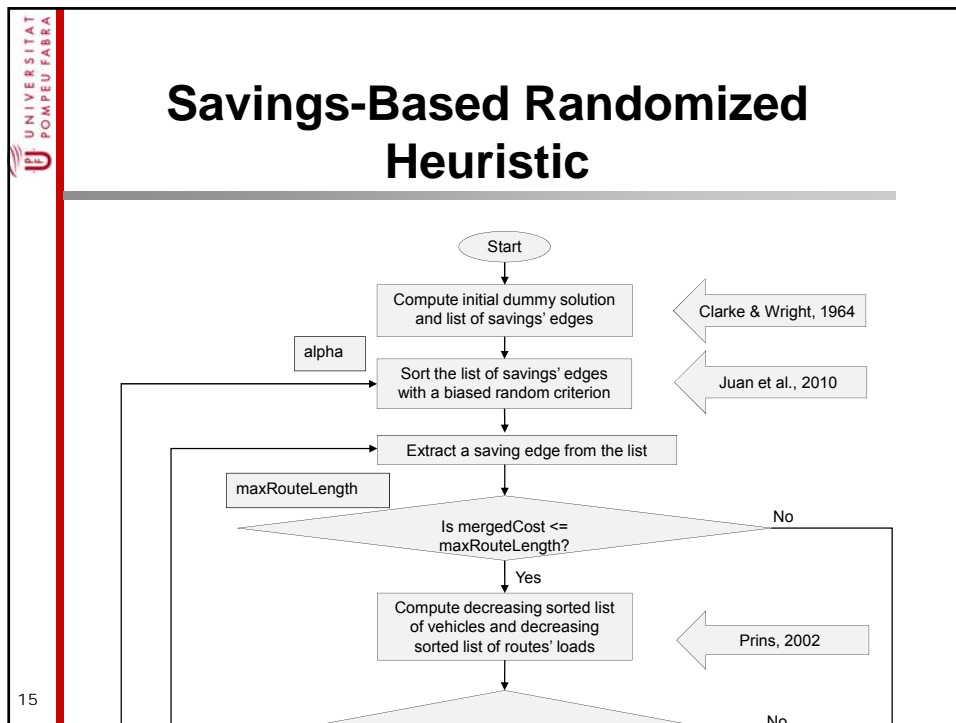
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Savings-Based Randomized Heuristic

- ▶ 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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Computational Results

▶ **Prins' instances**

- Proposed in **Prins (2002)**, these are twenty random instances, denoted as Prins_ i ($i = 1, 2, \dots, 20$).
- Each instance contains 100 customers uniformly distributed in a 200×200 km² 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

Instance	Customer s		CWS-Prins				Randomized CWS-Prins					
			Total	Cost	Routes	Time	Cost	Routes	Time	Gap	Average	Gap
			Delivered			(sec)			(sec)	(2-1)	10 Seeds	(3-1)
			Demand								(3)	
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**

- 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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Instance	Stores Total Visit Demand Delivered	Company Solution		CWS-Prins(*)			Randomized CWS-Prins					
		Cost (1)	Cost (2)	Time (sec)	Gap (2-1)	Best	Time	Gap	Gap	Average	Gap	Gap
						Cost (3)	(sec)	(3-1)	(3-2)	10 Seeds	(4-1)	(4-2)
A	372 77913	45302.4	40001.86	3.02	-11.70%	39534.11	63.22	-12.73%	-1.17%	39841.99	12.05%	-0.40%
B	366 79130	47184.35	41821.23	2.41	-11.37%	41072.46	55.2	-12.95%	-1.79%	41399.65	12.26%	-1.01%
C	371 91901	53941.43	50337.9	2.9	-6.68%	49669.31	66.48	-7.92%	-1.33%	50082.32	-7.15%	-0.51%
D	364 63078	36897.29	31697.62	1.73	-14.09%	31378.63	58.94	-14.96%	-1.01%	31543.09	14.51%	-0.49%
E	372 83571	50872.8	46372.77	2.7	-8.84%	45485.83	29.73	-10.59%	-1.91%	45836.63	-9.90%	-1.16%
F	373 85773	51315.4	46327.54	2.76	-9.72%	45275.62	7.67	-11.77%	-2.27%	45681.39	10.98%	-1.39%
G	372 84023	50492.74	45939.7	2.6	-9.02%	45165.12	28.53	-10.55%	-1.69%	45493.28	-9.90%	-0.97%
H	374 85539	51427.1	45070.87	2.76	-12.36%	44386.64	65.94	-13.69%	-1.52%	44909.39	12.67%	-0.36%
I	370 89596	54446.01	49613.35	2.88	-8.88%	49053.97	59.57	-9.90%	-1.13%	49354.83	-9.35%	-0.52%
J	372 76846	45056.4	39712.54	2.25	-11.86%	38973.19	29.33	-13.50%	-1.86%	39252.86	12.88%	-1.16%
Average		48693.59	43689.54	2.6	-10.45%	42999.49	46.46	-11.86%	-1.57%	43339.54	11.17%	-0.80%

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Real Application

▶ Grup Alimentari Guissona RESULTS 

- Savings 10% daily with respect to the actual solutions.
- Savings of 2% compared with Prins Algorithm.
- The average number of routes were similar, with a small reduction for our solutions.

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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-tuning 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
- ▶ 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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