Exploring Genetic Algorithms and Simulated Annealing for Immobile Location-Allocation Problem

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Motivation

UdG

Sport globalization → **Simultaneous sport events** → **Barman decision problem** → **Newronia & Porpra**

80 people wants match 1
20 people wants match 2

10 bars broadcast match 1	8 bars broadcast match 1 2 bars broadcast match 2
8 people/bar	10 people/ bar

Objectives

- Model the optimization problem
- Implement GA & SA
- Analyze GA & SA according our data
- Compare GA and SA solutions

The Data

- Coordinates from 15578 bars from Catalunya taken from *Páginas Amarillas* and a maps server
- Different clusters of bars due to the impossibility to tackle the whole problem at the same time
- Customers are randomly generated
  - Number of customers: around each bar are generated between 0 and 30 customers
  - Customers' coordinates: they are computed according a Gaussian distribution function centered to the corresponding bar
  - Customers' match: each customer chooses a match from a list. Each match has a certain probability to be chosen

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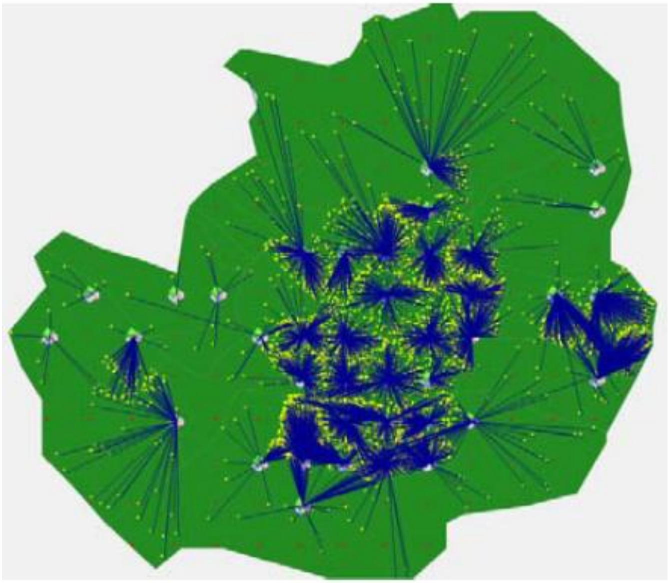
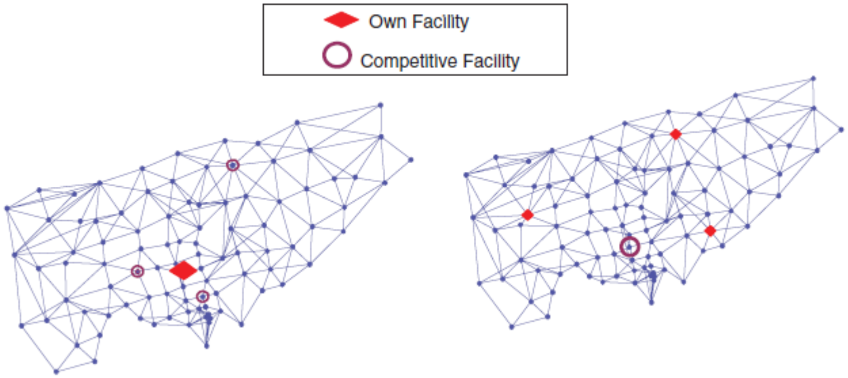
Location-allocation

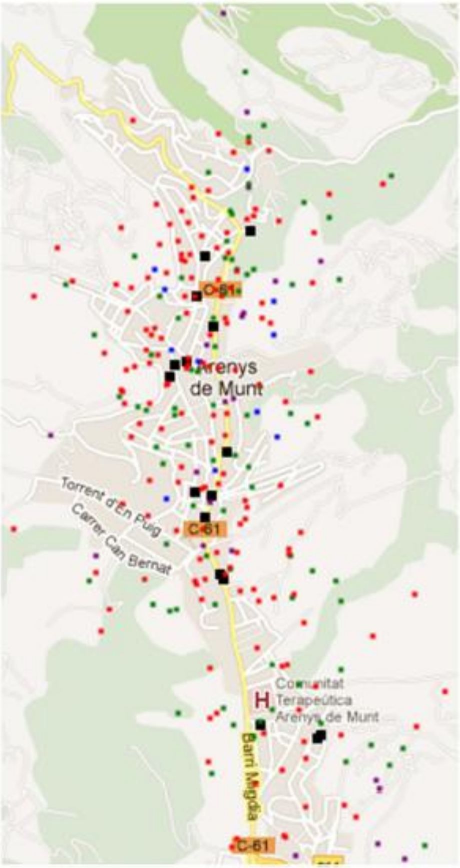
- Determine optimal location for one or more facilities that will service demand for a given set of points
- Every facility offers the same service
- Customers positions are known
- Complexity: $\binom{n}{k} = \frac{n!}{k!(n-k)!}$ where $\begin{cases} n \rightarrow & number\ of\ possible\ positions \\ k \rightarrow & number\ of\ facilities \end{cases}$

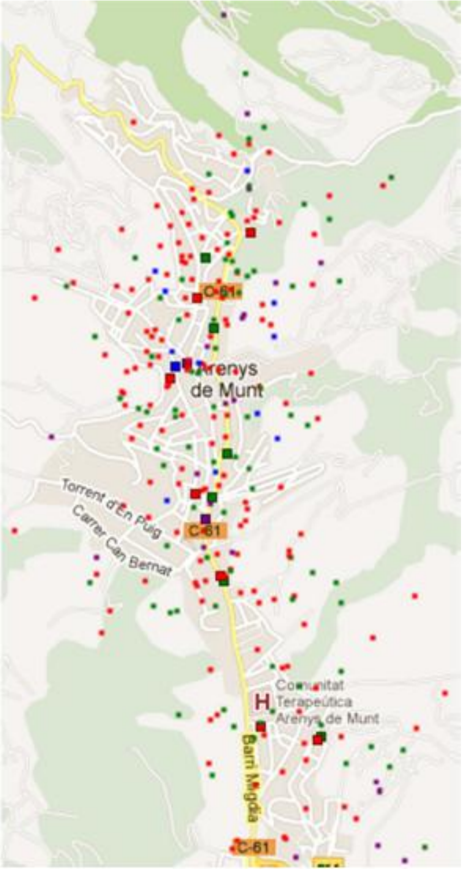




Immobile location-allocation

- Given a set of facilities with known positions and a demand with known positions, determine the optimal service each facility has to offer
- Facilities cannot be moved and their positions are known
- Customers' positions are known
- Complexity → $(N_{matches})^{N_{bars}}$





Immobile location-allocation

- Mathematical model

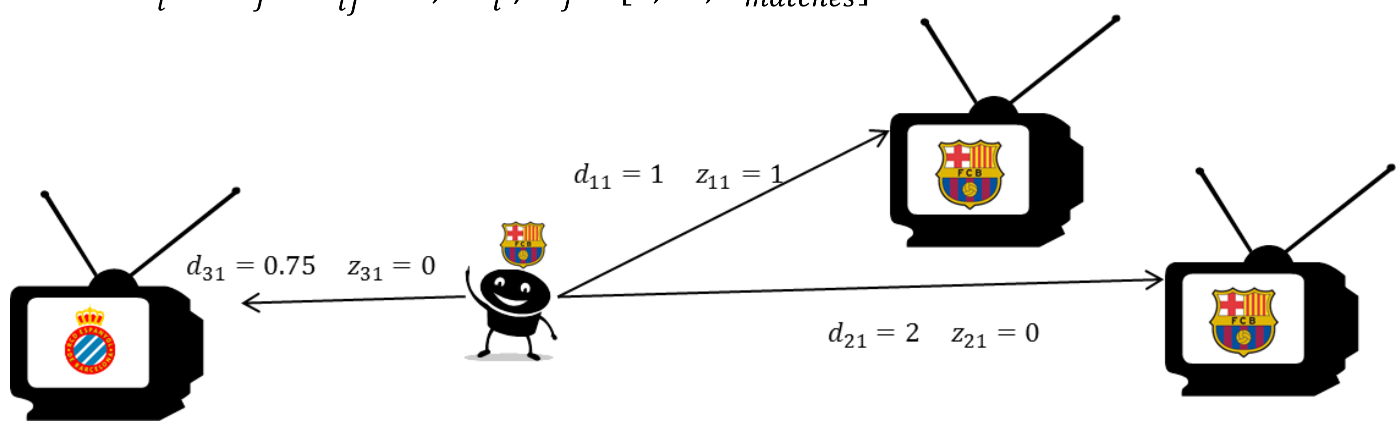
$$\max_{z_{ij}^q}\left\{\sum_{i=1}^{N_{bars}}\sum_{j=1}^{N_{customers}}\frac{z_{ij}^q}{1+d_{ij}^2}\right\}$$

Subject to

$$\forall_i \quad \sum_{j=1}^{N_{customers}} z_{ij}^q \le C_i$$

$$\forall_j \quad \sum_{i=1}^{N_{bars}} z_{ij}^q \le 1$$

$$x_i^q \ne M_j \rightarrow z_{ij}^q = 0; \quad x_i^q, M_j \in [1, \cdots, N_{matches}]$$



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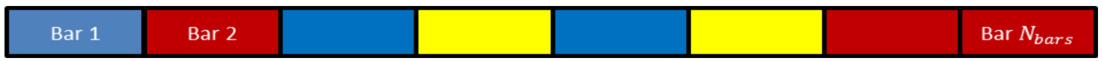
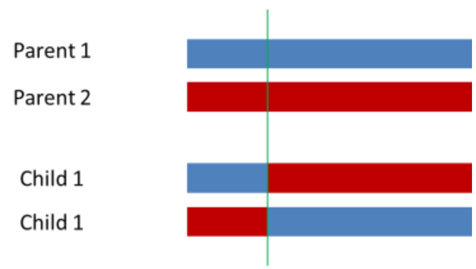
Genetic algorithms approach

- Chromosome



- Mutation
  - Probability μ_m to change the match
- Crossover
  - Single point crossover



- Fitness

$$Fitness(q) = \sum_{i=1}^{N_{bars}} \sum_{j=1}^{N_{customers}} \frac{z_{ij}^{q}}{1 + d_{ij}^{2}}$$

- Selection
  - Roulette rule

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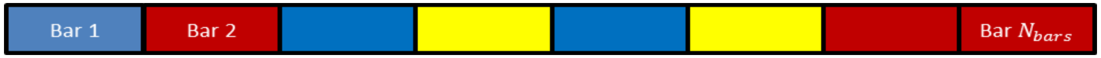
Simulated annealing approach

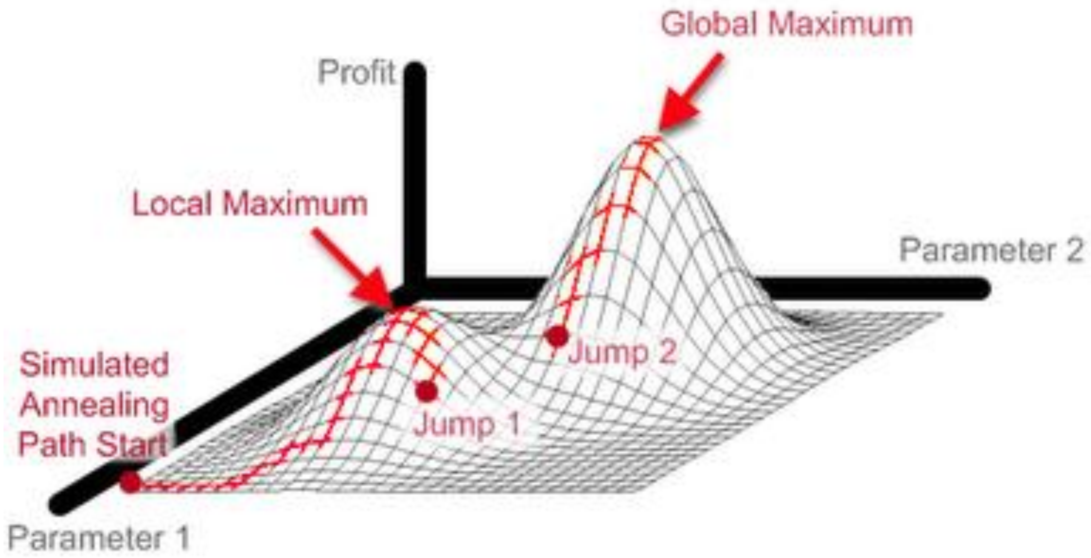
- Solution



- State selection

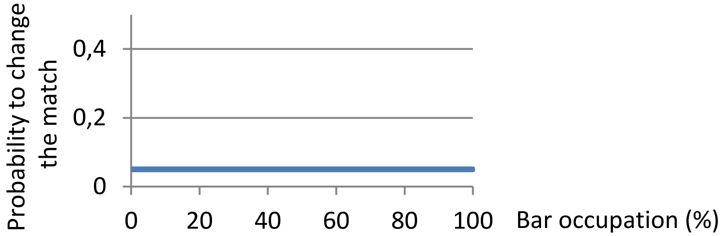
$$P\left(s' \mid E(s) < E(s')\right) = 1$$

$$P\left(s' \mid E(s) \geq E(s')\right) = e^{\frac{E(s') - E(s)}{T}}$$

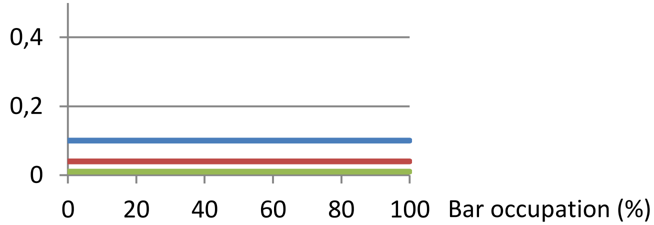


Neighborhood function

- Non-coordinate search space → **Need of a new neighborhood function**
  - Each bar has a probability to change its match

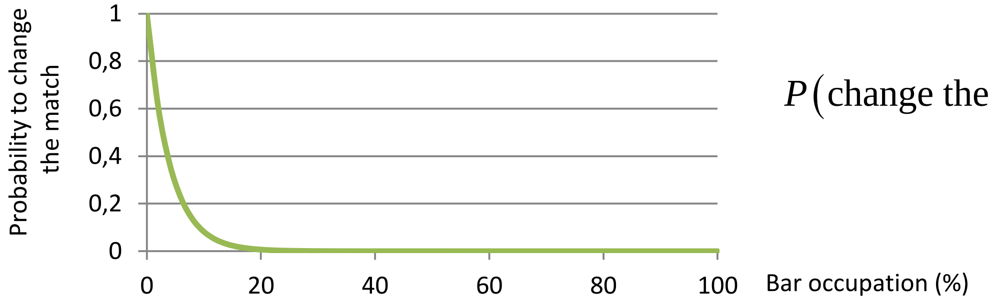


  - The probability varies depending the problem the algorithm's phase



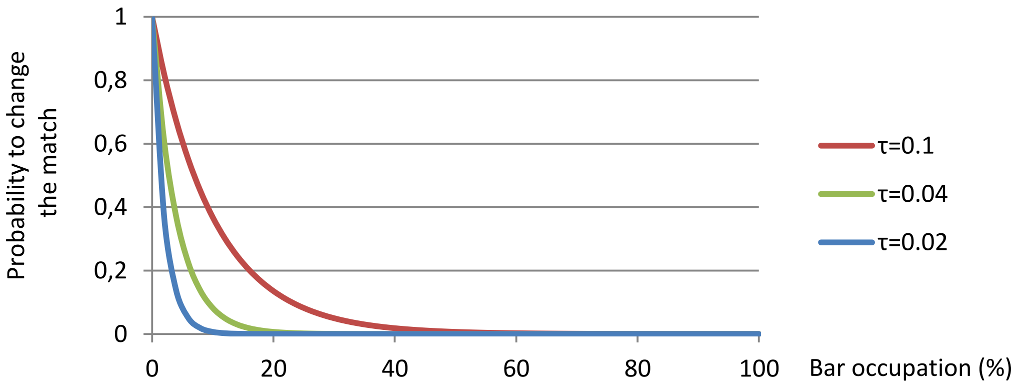
Neighborhood function

- Non-coordinate search space → **Need of a new neighborhood function**
  - The probability changes depending on the occupation



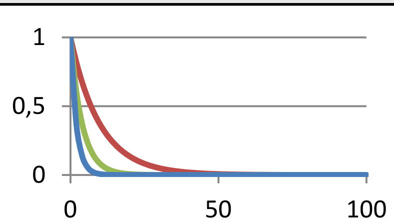
$$P\left(\text{change the match of the ith bar}\right) = e^{-\frac{o_i}{\tau}}$$

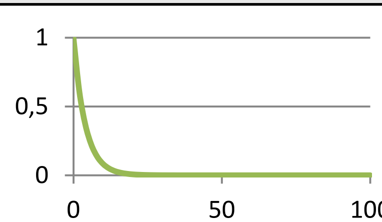
  - Different exponential curves depending on the features of the problem

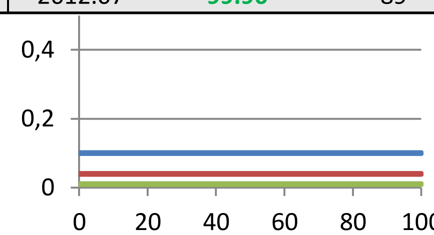


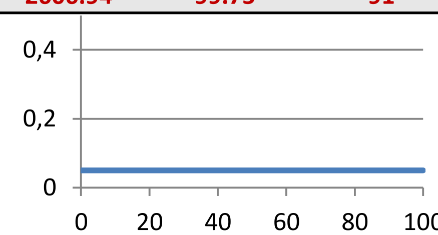
Neighborhood function comparison

Exponential probability with variable τ			Exponential probability with $\tau = 0.05$			Variable uniform probability			Constant uniform probability		
E	% of allocated customers	% of bars with occupation < 4%	E	% of allocated customers	% of bars with occupation < 4%	E	% of allocated customers	% of bars with occupation < 4%	E	% of allocated customers	% of bars with occupation < 4%
217.04	95.33	0	211.34	94.00	0	214.45	95.00	0	216.15	93.00	0
104.43	97.82	1	103.85	98.55	3	103.04	98.55	2	104.01	96.38	3
1223.49	99.43	0	1218.94	98.93	0	1221.93	98.93	0	1218.18	98.93	2
616.49	99.86	3	616.55	100	3	614.95	99.86	5	613.67	99.86	6
2010.62	100	0	2013.74	100	1	2005.71	100	8	2007.23	100	13
996.03	100	12	994.11	100	11	993.98	100	19	991.81	100	23
5579.03	99.83	1	5571.28	99.71	3	5535.93	99.73	48	5531.09	99.68	41
2622.78	99.86	20	2622.36	99.89	28	2612.07	99.96	89	2606.94	99.75	91









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Experimental results

- Individual LA finds the worst solutions
- SA achieves the best solutions
- SA is faster than GA

Number of facilities	Fitness			% of allocated customers			% of facil. with occupation < 4%			Elapsed time (s)		
	Individual	GA	SA	Individual	GA	SA	Individual	GA	SA	Individual	GA	SA
8	**81.39**	**109.56**	108.27	**56.73**	**79.30**	78.13	**0.00**	**4.29**	**0.00**	**0.000**	**0.467**	0.129
18	**170.38**	279.91	**281.86**	**51.39**	94.16	95.72	**0.00**	**1.11**	**0.00**	**0.001**	**3.103**	0.662
42	**438.26**	707.69	**723.27**	**56.94**	**99.88**	99.83	**0.00**	**12.61**	**0.00**	**0.009**	**17.164**	4.140
46	**427.11**	681.92	**706.08**	**55.50**	98.17	**99.68**	**2.17**	**13.06**	2.61	**0.009**	**11.741**	2.440
48	**479.4**	824.50	**838.18**	**53.85**	99.50	**99.58**	**0.00**	**4.58**	**0.00**	**0.011**	**22.155**	5.660
50	**484.39**	754.45	**776.96**	**57.10**	97.58	**97.97**	2.00	**12.40**	**0.00**	**0.004**	**16.409**	4.067
72	**622.92**	1057.11	**1079.42**	**54.89**	98.89	**98.97**	**0.00**	**4.58**	3.06	**0.021**	**34.486**	11.088
127	**1389.85**	2374.754	**2421.44**	**55.58**	**100.00**	**100.00**	0.79	**14.80**	**0.16**	**0.028**	**159.720**	50.617
313	**3019.05**	5144.42	**5258.10**	**55.75**	99.58	**99.75**	**0.32**	**21.15**	0.58	**0.136**	**712.152**	293.865
1495	14660.55	**-**	**25826.85**	55.91	**-**	99.97	**0.07**	**-**	0.54	**3.571**	**-**	5285.298

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Conclusions

- Formalization of the immobile location-allocation problem
- Implementation of GA and SA approaches
- The new neighborhood function improves the performance of SA
- SA outperforms GA
- A global optimization strategy outperforms an individual strategy

Future work

- Develop an estimator of the customers’ position just before the match
- Use the true distance between bars (considering streets) or even the temporal distance (considering different means of transport)
- Study problem partition strategies in order to simplify the given problem
  - Study the use of clustering algorithms to divide the initial problem: 2nd International Conference on Applied and Theoretical Information Systems Research (2nd ATISR)

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