Solving Bi-Objective Real-World Set-Covering Problems

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1 Motivation & Problem

Locating emergency resources (AEDs, cameras) in cities is a **bi-objective NP-hard Set Covering Problem (SCP)**: maximize probabilistic coverage while minimizing installation cost.

DRP
Defibrillator Relocation Problem

OCP
Optimal Camera Placement

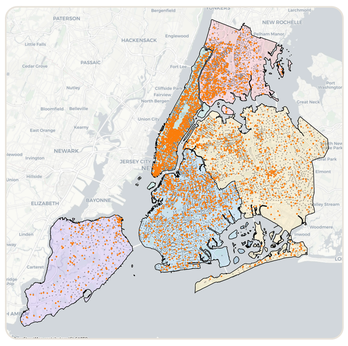
DRP considers both installation of new devices and relocation of existing ones. OCP considers new installation only.
Solution encoded as a binary vector $y \in \{0, 1\}^L$, compared against exact solver Ampl + Gurobi.

2 Real-World Instances

DRP

New York City — 5 boroughs

657 – 4,432 points
Sources: NYC Public AED Inventory + US Census 2010

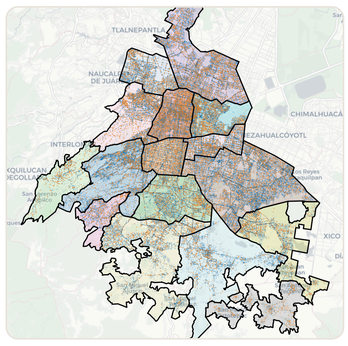


- Orange = existing AED locations
- Grey = candidate locations

OCP

Mexico City — 16 districts

1,390 – 40,264 points
Source: INAI public security data



- Orange = pre-installed cameras
- Blue = crime-event locations

3 Adapted MOEA/D

Decomposes the bi-objective problem into N scalar subproblems (Tchebycheff) solved cooperatively. Parameters automatically tuned with ParamILS, independently for each problem.

Initialization × 3
Random · Random + extremes · Structured (lin. / exp.)

Crossover × 5
Uniform mod. · Uniform · Intelligent · 1-point · 2-point

Mutation × 5
Random move · Prob. random · % swap · % delete · Bit-flip

4 Results on NYC Boroughs

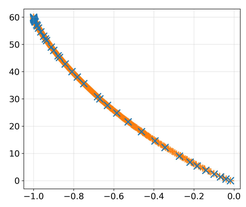
5	4 / 5	5 / 5	1 / 5
INSTANCES	BETTER HV	MORE NON-DOMINATED	BETTER TIME

Instance	#Pts	HV Ampl	HV MOEA/D	Gap
Staten Island	657	35.07	**36.06**	−2.81%
Bronx	2,151	830.78	**832.18**	−0.17%
Queens	2,885	1,394.00	**1,395.68**	−0.11%
Brooklyn	3,442	**1,628.48**	1,622.00	+0.39%
Manhattan	4,432	621.19	**622.34**	−0.18%

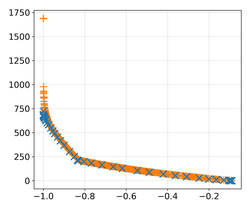
Negative gap ⇒ MOEA/D higher HV than Ampl. MOEA/D always finds more non-dominated solutions.

Pareto Fronts — DRP (4 instances)

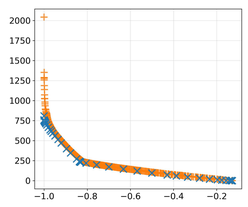
+ MOEA/D agg. front × Ampl front x: coverage y: cost



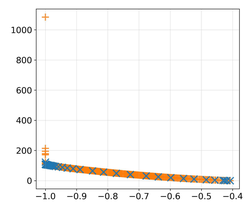
Staten Island



Queens



Brooklyn



Manhattan

5 Results on Mexico City Districts

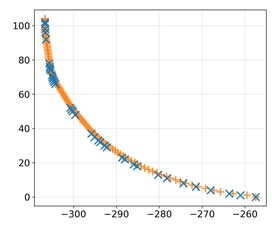
16	10 / 16	16 / 16	3 / 16
INSTANCES	BETTER HV	MORE NON-DOMINATED	BETTER TIME

Instance	#Pts	HV Ampl	HV MOEA/D	Gap
Milpa Alta	1,390	5,023.18	**5,133.81**	-2.20%
Cuaj. de Morelos	1,800	4,197.42	**4,233.58**	-0.86%
La M. Contreras	3,205	2,178.27	**2,209.08**	-1.41%
Tlahuac	7,256	**15,898.14**	15,724.43	+1.09%
Xochimilco	7,408	**105,909.17**	102,851.65	+2.89%
Azcapotzalco	9,673	3,032.38	**3,079.79**	-1.56%
Iztacalco	11,096	494.19	**516.97**	-4.61%
Tlalpan	11,410	**142,153.40**	138,190.48	+2.79%
Benito Juarez	11,476	239.79	**244.45**	-1.94%
Coyoacan	12,319	**21,948.60**	21,777.45	+0.78%
Miguel Hidalgo	13,802	3,964.48	**4,008.24**	-1.10%
V. Carranza	14,468	1,508.67	**1,554.50**	-3.04%
Alvaro Obregon	15,743	**59,093.09**	58,624.53	+0.79%
Cuauhtemoc	22,238	223.03	**223.70**	-0.30%
G. A. Madero	24,363	**12,556.17**	12,549.78	+0.05%
Iztapalapa	40,264	—	**65,448.79**	—

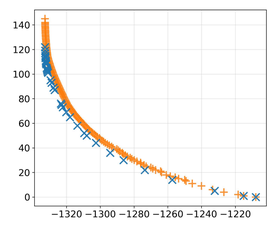
Negative gap ⇒ MOEA/D higher HV than Ampl. MOEA/D always finds more non-dominated solutions.

Pareto Fronts — OCP (8 instances)

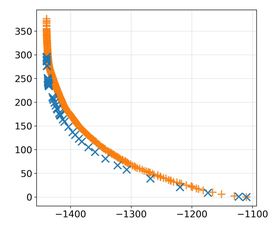
+ MOEA/D agg. front × Ampl front x: coverage y: cost



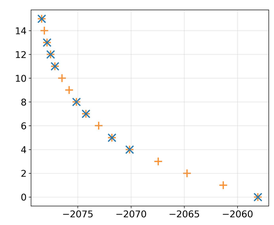
Cuaj. Morelos



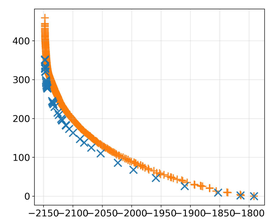
Tlahuac



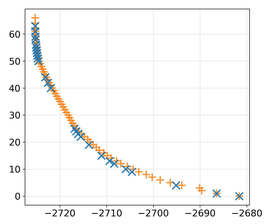
Xochimilco



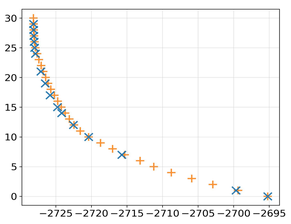
Iztacalco



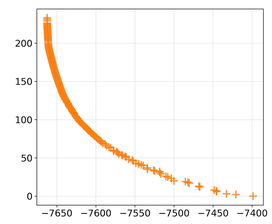
Tlalpan



Miguel Hidalgo



V. Carranza



Iztapalapa

6 Key Findings

Non-dominated solutions
MOEA/D consistently produces more non-dominated solutions across all instances.

Hypervolume
Better HV in 4/5 DRP and 10/16 OCP instances. Gaps stay within a competitive range.

Scalability
Scales up to 40,264 points — instances where Ampl + Gurobi fails to solve.

Diversity
Rich Pareto fronts: multiple trade-offs available simultaneously.

7 Conclusions

01 MOEA/D adapted for two bi-objective SCP variants with problem-specific operators.

02 Competitive with Ampl + Gurobi in HV — superior in solution diversity across all instances.

03 Scalable to large instances where exact solvers time out or fail entirely.

Project Repository

References

[1] Zhang & Li (2007). MOEA/D: A multiobjective evolutionary algorithm based on decomposition. IEEE Transactions on Evolutionary Computation, 712-731.

[2] Fonseca, Paquete & López-Ibáñez (2006). An improved Dimension Sweep Algorithm for the Hypervolume Indicator. In IEEE International Conference on Evolutionary Computation, 1157-1163.

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