Creating Homogeneous Sectors

Criteria and Applications of Sectorization

Cristina Lopes, Maria Margarida Lima, Elif Göksu Öztürk, Ana Maria Rodrigues, Ana Catarina Nunes, Cristina Oliveira, José Soeiro Ferreira, Pedro Filipe Rocha

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Sectorization Problems

(also known as *districting* or *territory design*)

Sectorization...

... to group a set of previously defined
basic units
(points or small geographical areas)
into a fixed number of
sectors
(districts or responsibility areas),
according to criteria and constraints
regarding the geographic characteristics of
the territory and planning purposes.

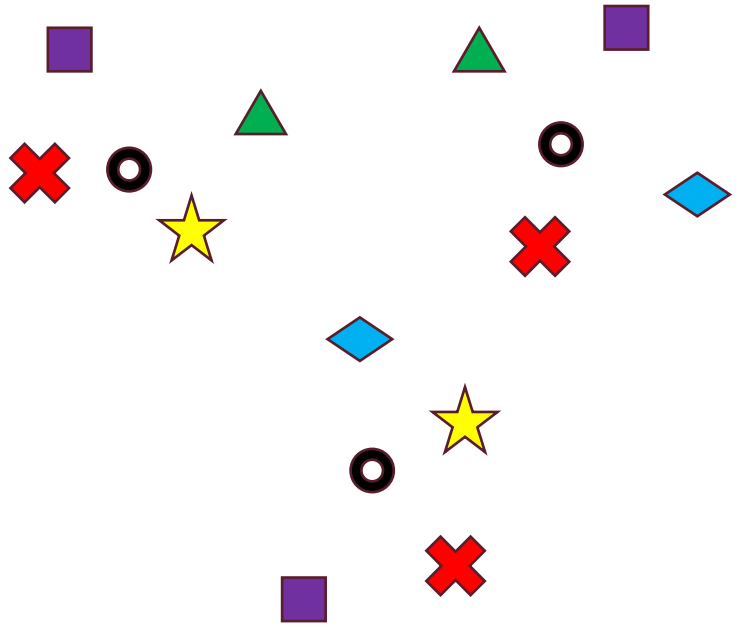
This process usually aims at
better organizing,
or simplifying a large problem into smaller
sub-problems.

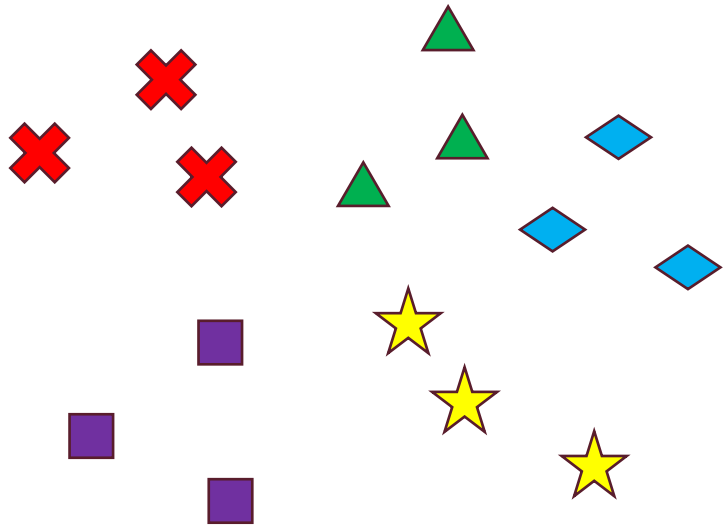

SECTORIZATION
IS RELATED TO
CLUSTERING,
BUT..
...with different motivation!

SECTORIZATION VS. CLUSTERING

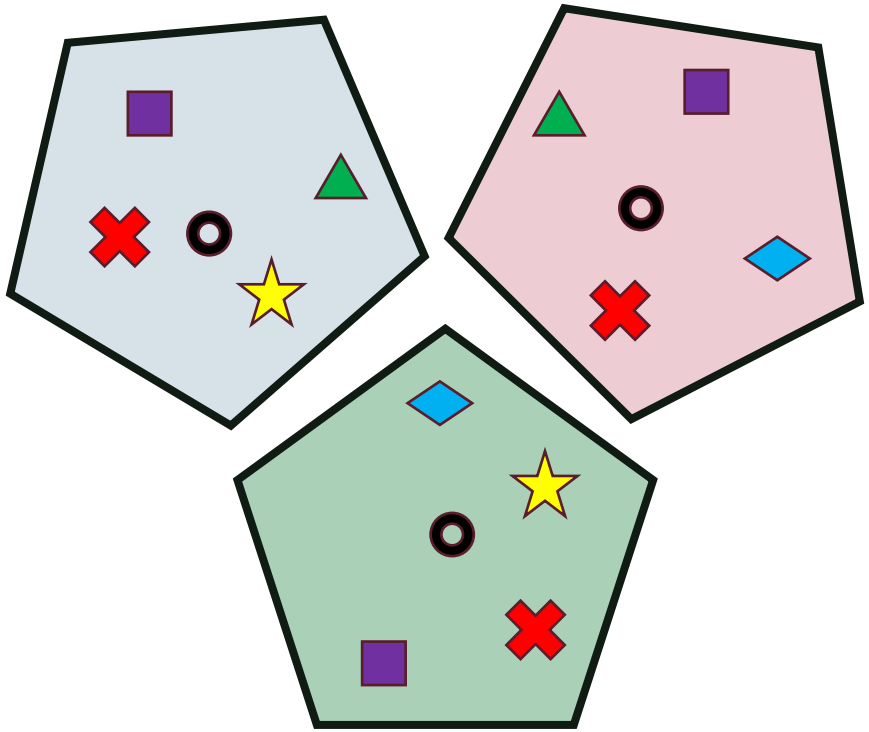
- ✓ Both aggregate smaller units into groups.
- ✓ Clustering strives for **inner similarity** of data, but sectorization aims at **outer homogeneity** (Kalcsics et al, 2005)
- ✓ In clustering, groups should be very **different** from each other, and similar points are classified in the same cluster.
- ✓ In sectorization, groups should be very **similar** to each other, and therefore very different points can be grouped in the same sector.

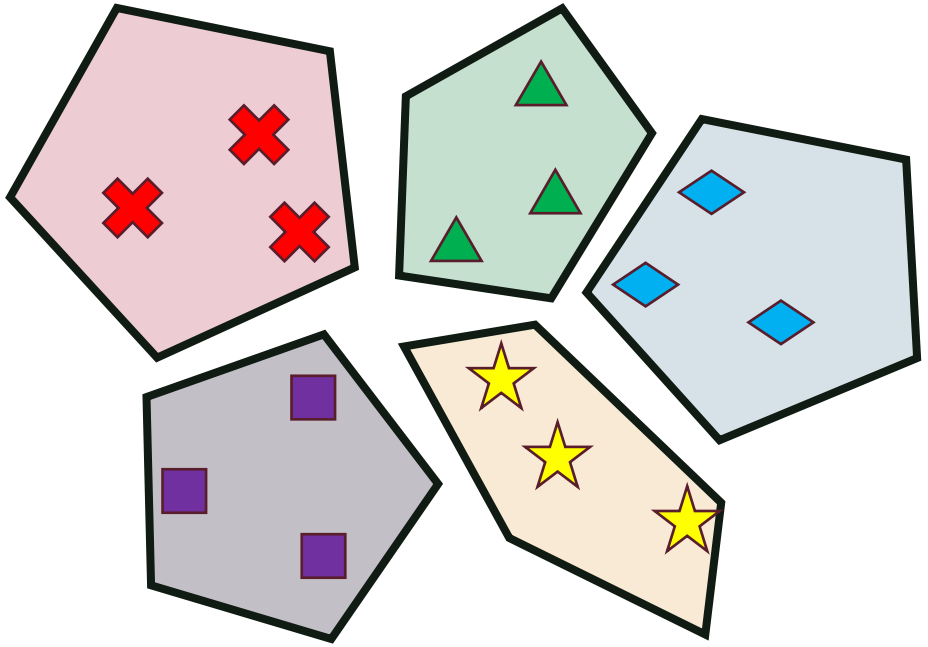
Sectorization vs. Clustering





Sectorization vs. Clustering

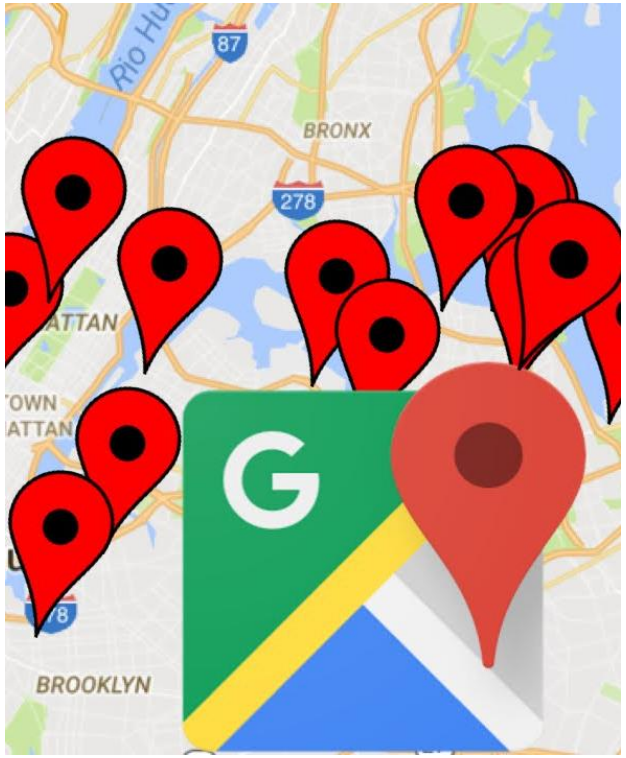




Equilibrium

Compactness

Contiguity



Common criteria in sectorization

Other criteria: capacity, desirability...

How to measure the criteria?

Rodrigues & Ferreira (2015)

Measures

- Equilibrium
- Compactness
- Contiguity

Equilibrium

sectors should be identical portions of the whole regarding some activity measure

- Evenly distribution of population, workload, or travel times among service staff
- Fairness of potential profit
- Bounds for size of sectors: max travel times, min number of customers

standard deviation of total activity q_i in sector

$$s'_q = \sqrt{\frac{1}{k-1}\sum_{i=1}^{k}(q_i - \bar{q})^2}$$

How to measure the criteria?

Rodrigues & Ferreira (2015)

Measures

- Equilibrium
- Compactness
- Contiguity

Compactness

Rounded shapes, avoiding *boomerangs*.

- Geographically concentrated activity: less travel, more sales or service time
- Higher concentration should avoid sparse sectors

Density d_i of each sector can be computed as the total activity in the sector weighted by the maximum distance between basic units and district centers

$$d_i = \frac{\sum_j q_{ij}}{dist(o_i, p_i)}$$

$$CV = \frac{s'_d}{\bar{d}}$$

q_{ij} = quantity assigned to the basic unit *j* in sector *i*
$dist(o_i,p_i)$ = distance between the centroid of sector *i* and the farthest point on the same sector.

How to measure the criteria?

Rodrigues & Ferreira (2015)

Measures

- Equilibrium
- Compactness
- Contiguity

Contiguity

If there is a walk between any pair of elements of the sector without leaving it

- Each sector is formed by one whole body and is geographically connected.

$$m_{wj}^{i} = \begin{cases} 1 & \text{if in sector i exists a walk between w and j} \\ 0 & \text{otherwise} \end{cases}$$

$$c_i = \frac{\sum_{j=1}^{n_i}\left(\sum_{w=1}^{n_i} m_{wj}^{i}\right)}{n_i\left(n_i - 1\right)}$$

contiguity can be measured by relative number of walks, and then weighted by number of vertices

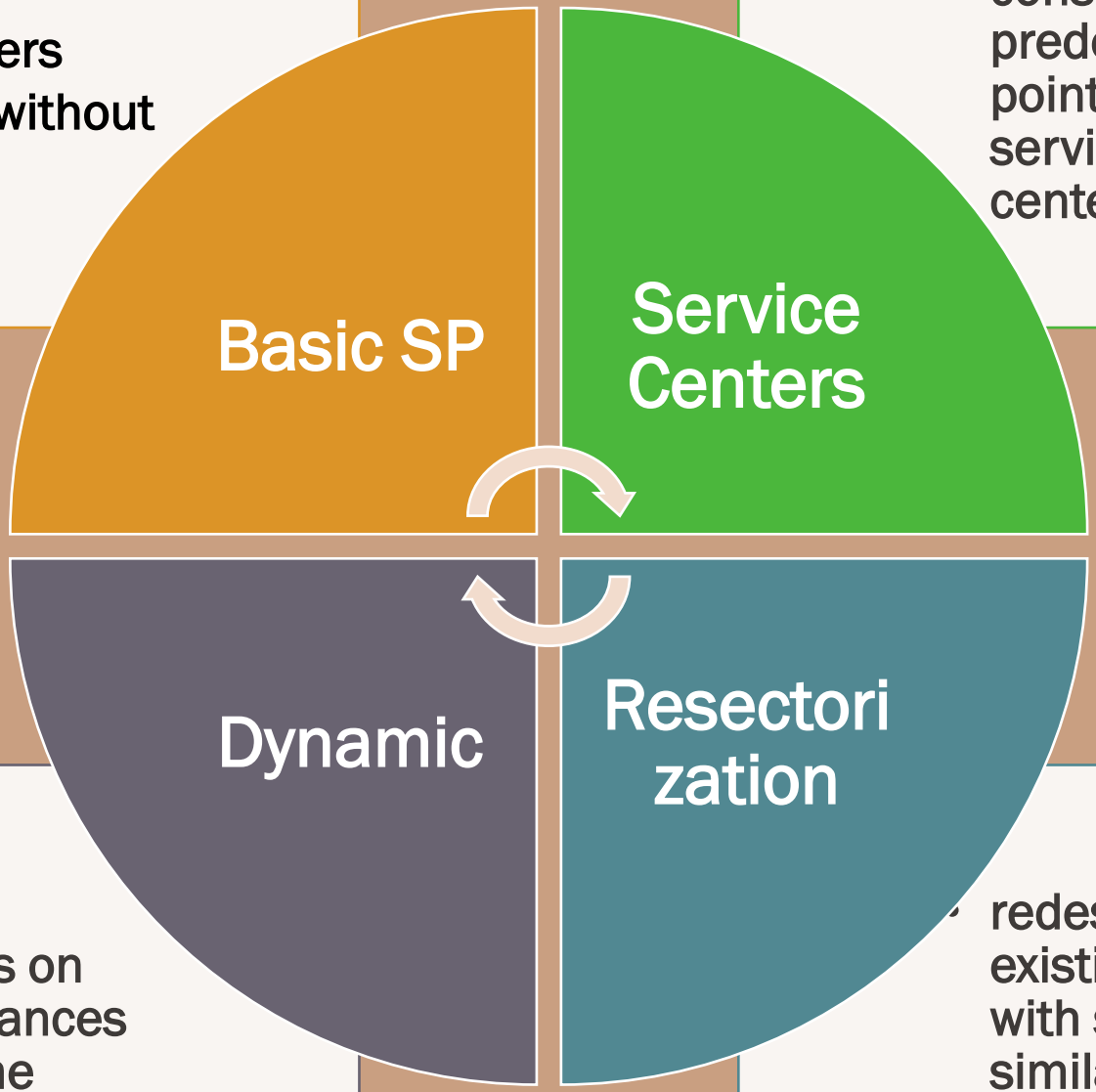
$$\overline{c} = \frac{\sum_{i=1}^{k} c_i n_i}{N}$$

n_i =number of vertices of sector i

TYPES OF SECTORIZATION PROBLEMS

- static
- no centers
- with or without routing

- consider predetermined points as service centers



- allows changes on the instances over time

- redesigning an existing plan with some similarity

D3S

DECISION SUPPORT SYSTEM FOR SECTORIZATION

- ✓ deals with the four types of problems
- ✓ takes into account multicriteria identified by a decision maker
- ✓ suggests an appropriate sectorization

- ✓ Multi-objective genetic algorithms
- ✓ implemented in Python
- ✓ user-friendly web interface developed in Django
- ✓ Sectorization **instances** available at
  https://drive.inesctec.pt/s/NS47qnZEmYPwEQP

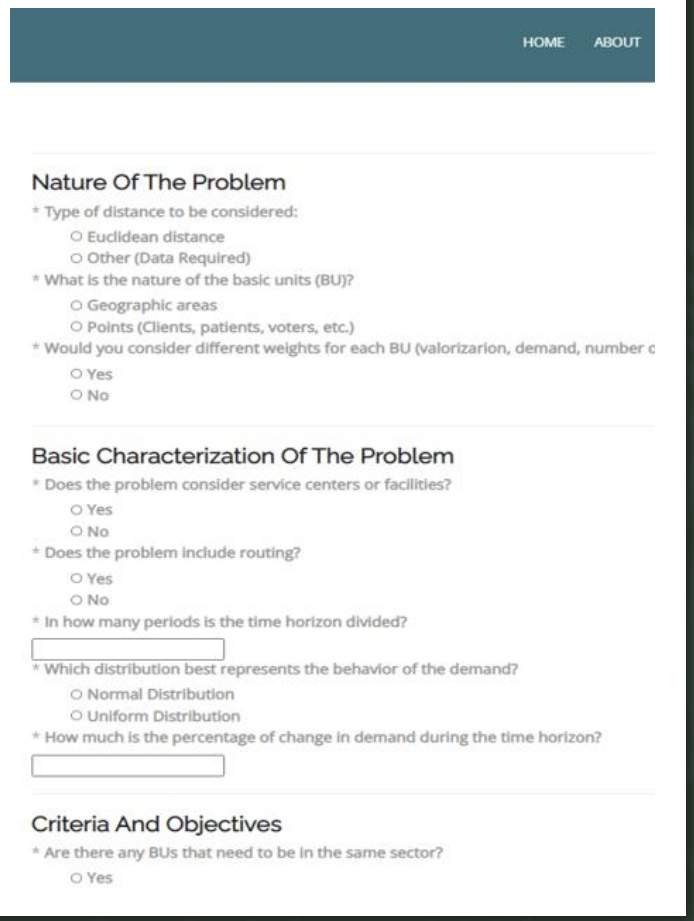
Instances link

D3S

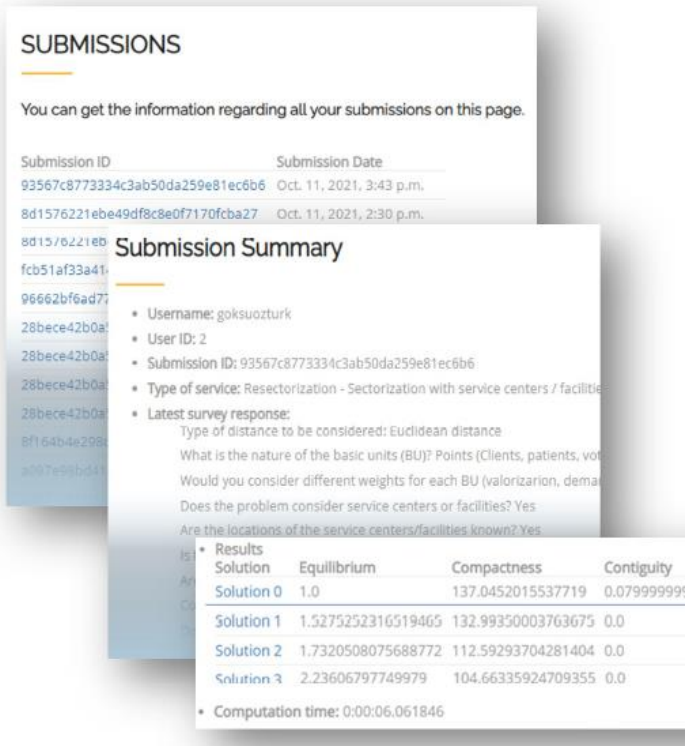
DECISION SUPPORT SYSTEM FOR SECTORIZATION

- ✓ **One objective:**
  Genetic algorithm (GA) provides one solution
- ✓ **More than one objective:**
  AHP – Analytic Hierarchy Process (Ozturk et al, 2021) pairwise comparison of objectives, to build a weighted composite fitness function for GA
- ✓ **Multiple solutions:**
  NSGA II – Non-dominated sorting genetic algorithm (Deb et al, 2002)
  Pareto fronts solutions are selected according to their performance
- ✓ **Routing:**
  Greedy algorithm, using Euclidian distances, or a distance matrix provided by the user

survey

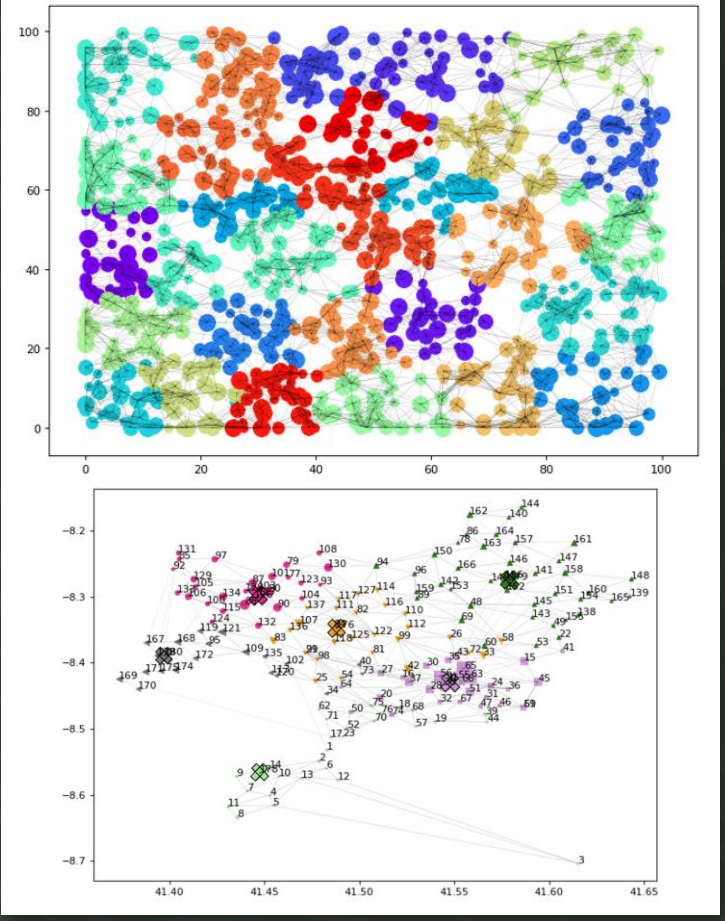


data



Genetic Algorithms
Multicriteria

results



D3S - Decision Support System for Sectorization

APPLICATIONS

Managing municipal waste collection

Assigning neighborhoods to schools

Defining sales territories

Locating health care services

Designing political districts

Electrical power distribution

Forestry and Harvesting

RESECTORIZATION OF FIRE BRIGADES IN THE NORTH OF PORTUGAL

- 6 fire brigades
- 175 basic units (regions:"*freguesias*")
- **compactness** criterion to reduce the rescue time
- **equilibrium** criterion to avoid overload situations
- **Similarity** used as a constraint, to facilitate the adaptation of firefighters to changes
- The similarity measure used is the percentage of regions that stay unchanged

RESECTORIZATION OF FIRE BRIGADES IN THE NORTH OF PORTUGAL

- **compactness** criterion to reduce the rescue time
- minimizing the distance between fire departments and regions, weighted by the demand of each region (more frequent visits)

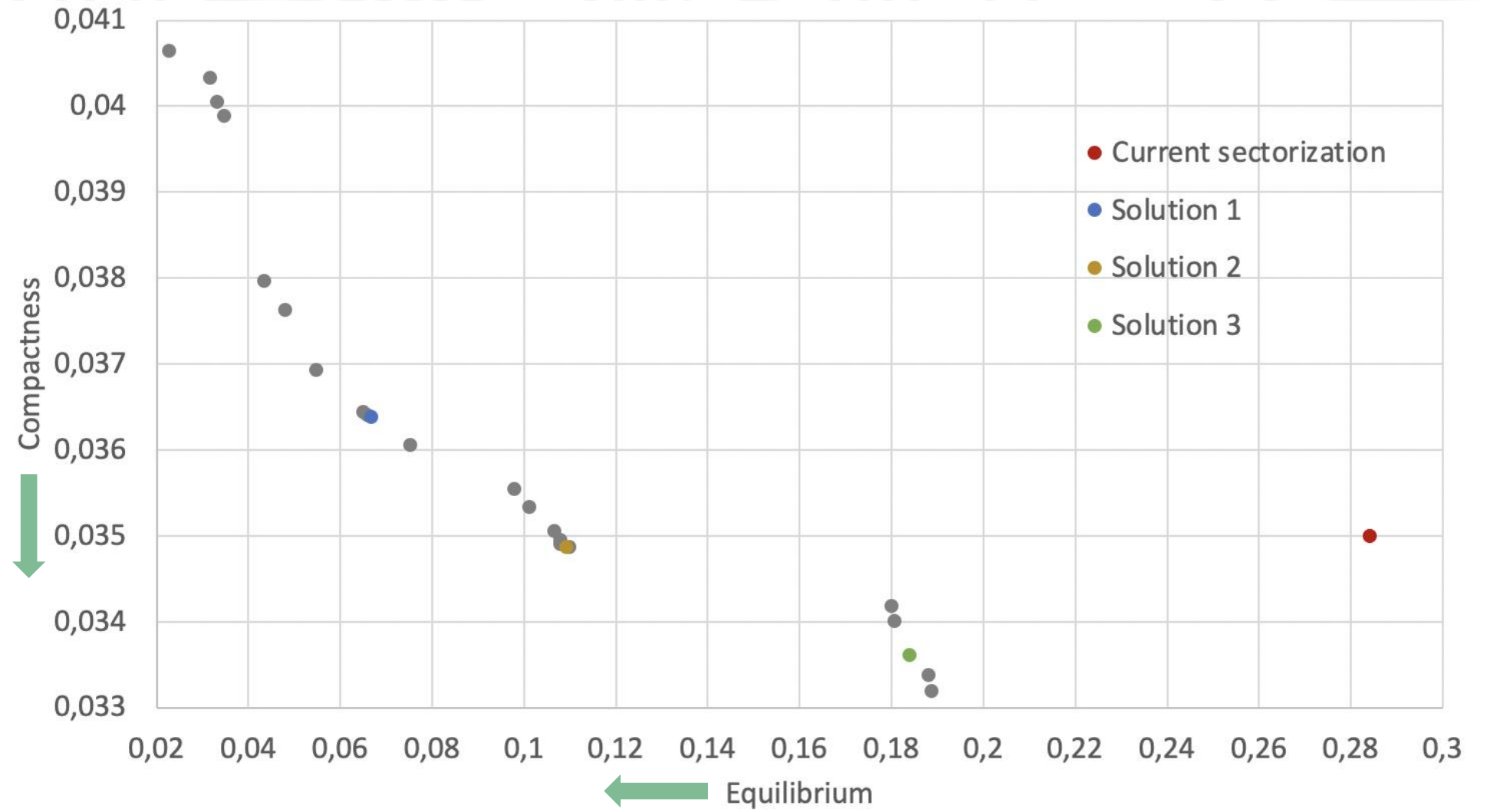
- **equilibrium** criterion to avoid overload situations
- distribute the regions equitably among the fire brigades, assuming the capacity of each fire brigade and the demand of each region
- minimize the standard deviation of the occupancy percentage of fire brigades

RESECTORIZATION OF FIRE BRIGADES IN THE NORTH OF PORTUGAL

- The **capacity of each fire brigade** derives from its number of ambulances, its number of fire fighting vehicles and its number of firefighters
- The **demand of each region** depends on its number of inhabitants and its area

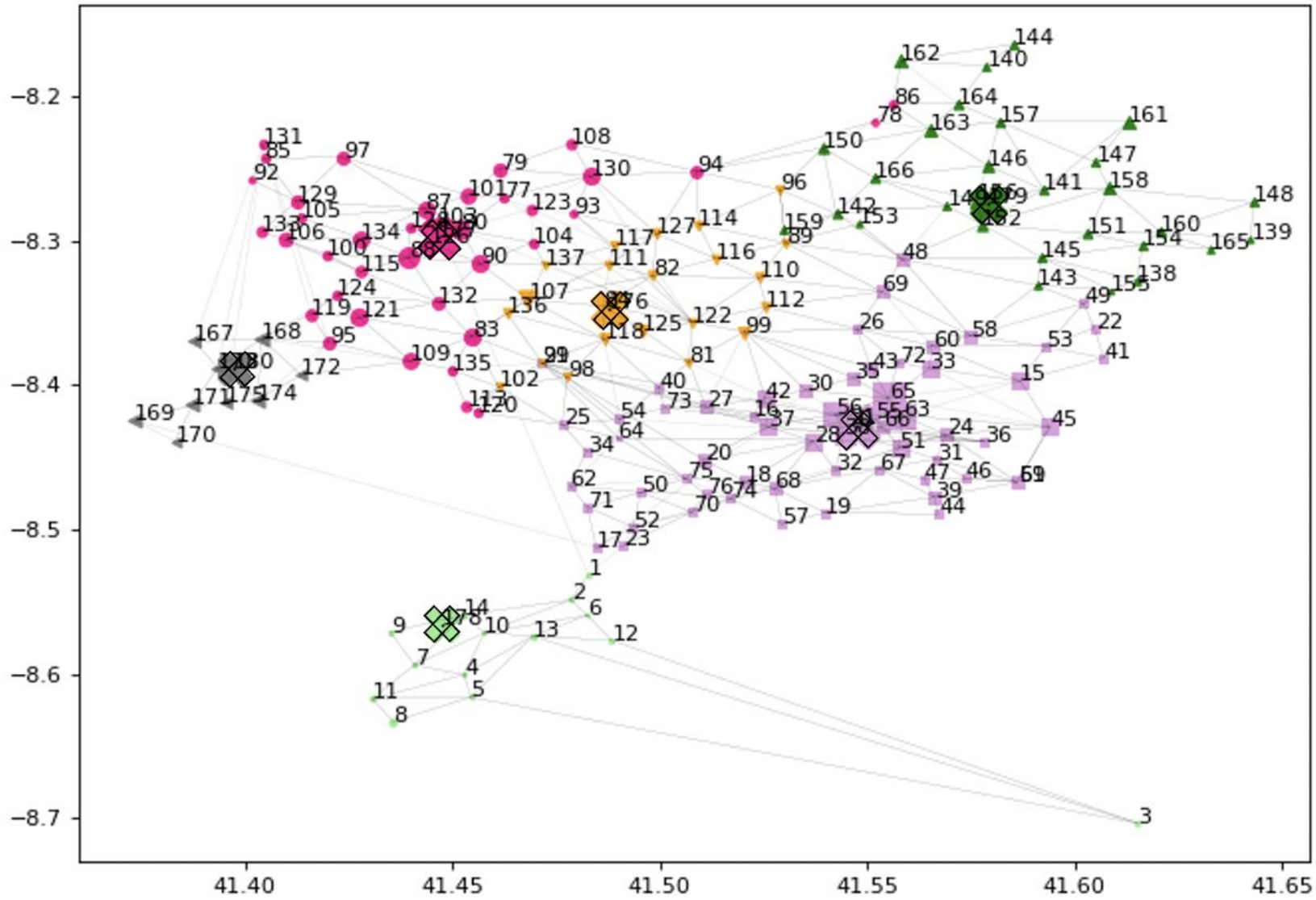
- **Population** growth will increase the need for pre-hospital emergencies, being necessary ambulances and firefighters.
- Growth in the **area** of the region may increase the number of forest fires, accidents, etc., requiring more vehicles and firefighters

Comparing solutions



- the current sectorization of the fire brigades: sectors are compact but not balanced.
- maintaining good compactness, the equilibrium between corporations can be improved, minimizing overload.

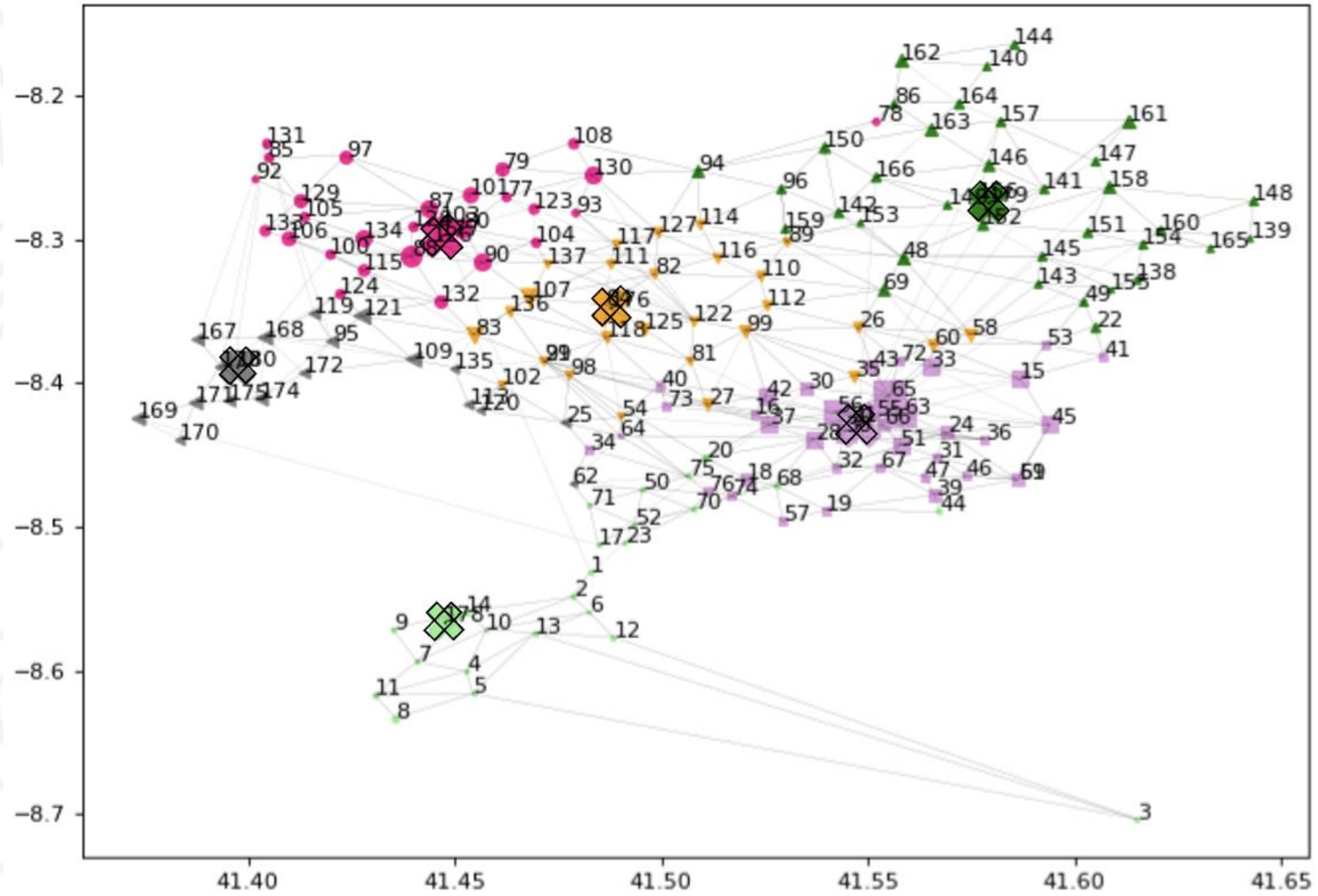
Current Setorization



Compactness: 0.035

Equilibrium: 0.284

Proposed solution



Compactness: 0.035
Equilibrium: 0.109
Similarity: 80.6%

CONCLUSIONS

- Sectorization problems can be classified into 4 types:
  - Basic Sectorization Problems,
  - Sectorization problems with Service Centers,
  - Resectorization, and
  - Dynamic Sectorization problems.

- The Decision Support System for Sectorization D3S can solve multi-objective sectorization problems, in a user-friendly environment, and can contribute to a well-informed decision making in management and logistics.
- An application of resectorization of fire brigades in the north of Portugal was analysed and optimized solutions were proposed to reduce rescue time with a better use of the available resources.

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